BMP Performance Expectation Functions - A Simple Method for Evaluating Stormwater Treatment BMP Performance Data

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Many agencies are struggling with processes on reviewing and approving BMPs.

Treatment guidelines are simplistic and create confusion as to how to evaluate BMP performance.

The end result can be misuse (or no use) of BMPs.
Typical Guidelines

- Percent Removal
- Load Reduction
- Effluent based guidelines

80% TSS  60% TP  40% TN
Percent Removal

- High percent removals do not guarantee good performance
  - 90% oil removal

- Low percent removals do not necessarily mean poor performance
  - 20 mg/l in and 20 mg/l out is a zero percent removal yet does not mean bad performance
Effluent Based Guidelines

- It is reasonable to expect passive BMP’s to meet strict standards?
  - Wastewater Treatment Plants
- Do effluent based guidelines imply higher levels of monitoring and compliance?
Annual Load Reduction

- A high annual load reduction does not necessarily mean clean water
  - One storm transports a massive load while EMC’s remain high
- A low annual load reduction does not necessarily mean poor performance
  - Clean Sites
Baseline Concentrations

- Many water quality professionals recognize that there are irreducible concentrations
  - 20 mg/l is frequently recognized
- Should this be considered a baseline concentration?
Performance Expectation Functions

- Allows for a regulatory definition of how a BMP should perform for a pollutant parameter.
- Recognizes baseline concentrations.
- Allows for both percent removal and load based review of BMP performance.
- Unlike regression, this method tests how well the data fit the line vs. how the line fits the data.
Example Using TSS

- Use a baseline concentration of 20 mg/l
- For concentrations less than or equal to 100 mg/l the effluent guideline is 20 mg/l
- For concentrations greater than 100 mg/l the expected effluent is 80% of the influent.
Performance Expectation Function
20 mg/l Baseline @ 80%
Performance Expectation Curve - Influent vs. Effluent

- Influent (mg/l) vs. Effluent (mg/l)
## Data Set

### Example Data Only

<table>
<thead>
<tr>
<th>Influent</th>
<th>Expected Effluent</th>
<th>Expected Percent removal</th>
<th>Observed Effluent</th>
<th>Observed Percent Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>20</td>
<td>0.00%</td>
<td>5</td>
<td>16.67%</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>0.00%</td>
<td>12</td>
<td>-20.00%</td>
</tr>
<tr>
<td>12</td>
<td>20</td>
<td>0.00%</td>
<td>16</td>
<td>-33.33%</td>
</tr>
<tr>
<td>14</td>
<td>20</td>
<td>0.00%</td>
<td>6</td>
<td>57.14%</td>
</tr>
<tr>
<td>16</td>
<td>20</td>
<td>0.00%</td>
<td>8</td>
<td>50.00%</td>
</tr>
<tr>
<td>17</td>
<td>20</td>
<td>0.00%</td>
<td>15</td>
<td>11.76%</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
<td>0.00%</td>
<td>21</td>
<td>-5.00%</td>
</tr>
<tr>
<td>24</td>
<td>20</td>
<td>16.67%</td>
<td>17</td>
<td>29.17%</td>
</tr>
<tr>
<td>25</td>
<td>20</td>
<td>20.00%</td>
<td>3</td>
<td>88.00%</td>
</tr>
<tr>
<td>28</td>
<td>20</td>
<td>28.57%</td>
<td>30</td>
<td>-7.14%</td>
</tr>
<tr>
<td>34</td>
<td>20</td>
<td>41.18%</td>
<td>17</td>
<td>50.00%</td>
</tr>
</tbody>
</table>
Data Set

Performance Expectation Curve - Influent vs. Percent Removal

Percent Removal vs. Influent Conc (mg/l)
Performance Expectation Curve - Influent vs. Effluent

- Influent (mg/l)
- Effluent (mg/l)
Sign Test

- Use a simple binomial test to establish the probability of the data being:
  - On the line
  - Above the line
  - Below the line

- Assume 50% of the points above and 50% below

\[
P(X) = \frac{n!}{(n-X)!X!} \cdot p^X \cdot q^{n-X}
\]
Sign Test Applied to Example

- 13 points above the line, 12 below
- Probability of occurrence is 50%, therefore accept that BMP meets the PEF
- If 17 below and 8 above there is only a 5% chance of occurrence, therefore reject that the BMP meets the line
Mass Load Balance Calculations

<table>
<thead>
<tr>
<th>Influent (mg/l)</th>
<th>Expected Effluent (mg/l)</th>
<th>Expected Percent removal</th>
<th>Observed Effluent (mg/l)</th>
<th>Observed Percent Removal</th>
<th>Volume (liters)</th>
<th>Mass IN (mg)</th>
<th>Effluent Mass Observed</th>
<th>Effluent Mass Expected</th>
<th>Mass Removed Observed - Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>20</td>
<td>0.0%</td>
<td>5</td>
<td>17%</td>
<td>2000</td>
<td>1.20E+04</td>
<td>1.00E+04</td>
<td>4.00E+04</td>
<td>-3.00E+04</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>0.0%</td>
<td>12</td>
<td>-20%</td>
<td>500</td>
<td>5.00E+03</td>
<td>6.00E+03</td>
<td>1.00E+04</td>
<td>-4.00E+03</td>
</tr>
<tr>
<td>12</td>
<td>20</td>
<td>0.0%</td>
<td>16</td>
<td>-33%</td>
<td>300</td>
<td>3.60E+03</td>
<td>4.80E+03</td>
<td>6.00E+03</td>
<td>-1.20E+03</td>
</tr>
<tr>
<td>14</td>
<td>20</td>
<td>0.0%</td>
<td>6</td>
<td>57%</td>
<td>500</td>
<td>7.00E+03</td>
<td>3.00E+03</td>
<td>1.00E+04</td>
<td>-7.00E+03</td>
</tr>
<tr>
<td>16</td>
<td>20</td>
<td>0.0%</td>
<td>8</td>
<td>50%</td>
<td>1500</td>
<td>2.40E+04</td>
<td>1.20E+04</td>
<td>3.00E+04</td>
<td>-1.80E+04</td>
</tr>
<tr>
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<td>20</td>
<td>0.0%</td>
<td>15</td>
<td>12%</td>
<td>150</td>
<td>2.55E+03</td>
<td>2.25E+03</td>
<td>3.00E+03</td>
<td>-7.50E+02</td>
</tr>
<tr>
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<td>20</td>
<td>0.0%</td>
<td>21</td>
<td>-5%</td>
<td>2000</td>
<td>4.00E+04</td>
<td>4.20E+04</td>
<td>4.00E+04</td>
<td>2.00E+03</td>
</tr>
<tr>
<td>24</td>
<td>20</td>
<td>16.7%</td>
<td>17</td>
<td>29%</td>
<td>800</td>
<td>1.92E+04</td>
<td>1.36E+04</td>
<td>1.60E+04</td>
<td>-2.40E+03</td>
</tr>
<tr>
<td>25</td>
<td>20</td>
<td>20.0%</td>
<td>3</td>
<td>88%</td>
<td>1900</td>
<td>4.75E+04</td>
<td>5.70E+03</td>
<td>3.80E+04</td>
<td>-3.23E+04</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Mass In (Kg)</th>
<th>Total Mass Out (Kg)</th>
<th>Total Mass Out Expected (Kg)</th>
<th>Observed – Expected (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.83</td>
<td>2.93</td>
<td>3.04</td>
<td>-.011</td>
</tr>
</tbody>
</table>

Therefore, the BMP meets the load reduction expectation
More work is needed

- Tie storm frequency to storms collected
  - Too many small or big storms
- Analysis of outliers
  - Residuals are normally distributed
- Other Pollutants
  - Soluble vs. particulate
- Tie the PEF to particle size distribution?
Conclusion

- Use of the PEF allows for a regulatory defined function that can be coupled with water quality goals
- Dispenses with the problematic simple percent removal
- Avoids issues associated with low influent and effluent concentrations and loads by using both
- Used in conjunction with a rigorous review program can lead to the successful use of many BMPs