APPENDIX B ASSESSMENT OF APPROACHES TO EVALUATING BMP PERFORMANCE

Overview of Approaches to Evaluate BMP Performance

A variety of pollutant removal methods have been utilized in BMP monitoring studies to evaluate efficiency. This section describes and gives examples of methods employed by different investigators. Historically, one of six methods has been used by investigators to calculate BMP efficiency:

- Efficiency ratio
- Summation of loads
- Regression of loads
- Mean concentration
- Efficiency of individual storm loads
- Reference watersheds and before/after studies

Although use of each of these methods provides a single number that summarizes efficiency of the BMP in removing a particular pollutant, they are not designed to look at removal statistically, and thus, do not provide enough information to determine if the differences in inflow and outflow water quality measures are statistically significant.

Efficiency Ratio

Definition

The efficiency ratio is defined in terms of the average event mean concentration (EMC) of pollutants over some time period:

$$ER = 1 - \frac{\text{average outlet EMC}}{\text{average inlet EMC}} = \frac{\text{average inlet EMC - average outlet EMC}}{\text{average inlet EMC}}$$

EMCs can be either collected as flow weighted composite samples in the field or calculated from discrete measurements. The EMC for an individual event or set of field measurements, where discrete samples have been collected, is defined as:

$$EMC = \frac{\sum_{i=1}^{n} V_i C_i}{\sum_{i=1}^{n} V_i}$$

where,

V: volume of flow during period i
C: average concentration associated with period i
n: total number of measurements taken during event

The arithmetic average EMC is defined as:

$$\text{average EMC} = \frac{\sum_{j=1}^{m} EMC_j}{m}$$

where,

m: number of events measured

In addition, the log mean EMC can be calculated using the logarithmic transformation of each EMC. This transformation allows for normalization of the data for statistical purposes.

$$\text{Mean of the Log EMCs} = \frac{\sum_{j=1}^{m} Log\left(EMC_j\right)}{m}$$

Estimates of the arithmetic summary statistics of the population (mean, median, standard deviation, and coefficient of variation) should be based on their theoretical relationships (Appendix A) with the mean and standard deviation of the transformed data. Computing the mean and standard deviation of log transforms of the sample EMC data and then converting them to an arithmetic estimate often obtains a better estimate of the mean of the population due to the more typical distributional characteristics of water quality data. This value will not match that produced by the simple arithmetic average of the data. Both provide an estimate of the population mean, but the approach utilizing the log-transformed data tends to provide a better estimator, as it has been shown in various investigations that pollutant, contaminant, and constituent concentration levels tend to be well described by a log-normal distribution (EPA 1983). As the sample size increases, the two values converge.

Assumptions

This method:

- Weights EMCs from all storms equally regardless of relative magnitude of storm. For example, a high concentration/high volume event has equal weight in the average EMC as a low concentration/low volume event. The logarithmic data transformation approach tends to minimize the difference between the EMC and mass balance calculations.

- Is most useful when loads are directly proportional to storm volume. For work conducted on nonpoint pollution (i.e., inflows), the EMC has been shown to not vary significantly with storm volume. Accuracy of this method will vary based on the BMP type.

- Minimizes the potential impacts of smaller/"cleaner" storm events on actual performance calculations. For example, in a storm by storm efficiency approach, a low removal value for such an event is weighted equally to a larger value.

- Allows for the use of data where portions of the inflow or outflow data are missing, based on the assumption that the inclusion of the missing data points would not significantly impact the calculated average EMC.

Comments

- This method is taken directly from non-point pollution studies and does a good job characterizing inflows to BMPs but fails to take into account some of the complexities of BMP design. For example, some BMPs may not have outflow EMCs that are normally distributed (e.g., media filters and other BMPs that treat to a relatively constant level that is independent of inflow concentrations).

- This method also assumes that if all storms at the site had been monitored, the average inlet and outlet EMCs would be similar to those that were monitored.

- Under all circumstances this method should be supplemented with an appropriate non-parametric (or if applicable parametric) statistical test indicating if the differences in mean EMCs are statistically significant (it is better to show the actual level of significance found, than just noting if the result was significant, assuming a 0.05 level).

Example

The example calculations given below are for the Tampa Office Pond using arithmetic average EMCs in the efficiency ratio method.

Table B.1: Example of ER Method results for TSS in the Tampa Office Pond

Period of Record	Average EMC In	Average EMC Out	Efficiency Ratio
1990	27.60	11.18	59%
1993-1994	34.48	12.24	64%
1994-1995	131.43	6.79	95%
ER is rounded, but the other numbers were not (to prevent introduction of any rounding errors in the calculations)			

Summation of Loads

Definition

The summation of loads method defines the efficiency based on the ratio of the summation of all incoming loads to the summation of all outlet loads, or:

$$\text{SOL} = 1 - \frac{\text{sum of outlet loads}}{\text{sum of inlet loads}}$$

The sum of outlet loads are calculated as follows:

$$\text{sum of loads} = \sum_{j=1}^{m}\left(\sum_{i=1}^{n} C_i V_i\right) = \sum_{j=1}^{m} EMC_j \cdot V_j$$

Assumptions

- Removal of material is most relevant over entire period of analysis.
- Monitoring data accurately represents the actual entire total loads in and out of the BMP for a period long enough to overshadow any temporary storage or export of pollutants.
- Any significant storms that were not monitored had a ratio of inlet to outlet loads similar to the storms that were monitored.
- No materials were exported during dry periods, or if they were, the ratio of inlet to outlet loads during these periods was similar to the ratio of the loads during the monitored storms.

Comments

- A small number of large storms typically dominate efficiency.

- If toxics are a concern then this method does not account for day-to-day releases, unless dry weather loads in and out are also accounted for. In many cases long-term dry weather loads can exceed those resulting from wet weather flows.

- Under all circumstances this method should be supplemented with an appropriate non-parametric (or if applicable parametric) statistical test indicating if the differences in loads are statistically significant (it would be better to show the actual level of significance found, rather than just noting if the result was significant, assuming a 0.05 level).

Example

The example calculations given in Table B.2 are for the Tampa Office Pond using a mass balance based on the summation of loads.

Table B.2: Example of SOL Method results for TSS in the Tampa Office Pond

Period of Record	Sum of Loads In (kg)	Sum of Loads Out (kg)	SOL Efficiency
1990	134.60	39.67	71%
1993-1994	404.19	138.44	66%
1994-1995	2060.51	130.20	94%
SOL Efficiency is rounded, but the other numbers were not (to prevent introduction of any rounding errors in the calculations)			

Regression of Loads (ROL)

Definition

The regression of loads method as described by Martin and Smoot (1986) defines the regression efficiency as the slope (β) of a least squares linear regression of inlet loads and outlet loads of pollutants, with the intercept constrained to zero. The zero intercept is specified as an "engineering approximation that allows calculation of an overall efficiency and meets the general physical condition of zero loads-in (zero rainfall) yield zero loads-out". The equation for the ROL efficiency is:

$$\text{Loads out} = \beta \bullet \text{Loads in} = \beta - \frac{\text{Loads out}}{\text{Loads in}}$$

The percent reduction in loads across the BMP is estimated as:

$$\text{Percent Removal} = 1 - \beta = 1 - \frac{\text{Loads out}}{\text{Loads in}}$$

Due to the nature of stormwater event monitoring, it is rare that all of the assumptions for this method are valid, particularly requirements for regression analysis. The example calculations and plots provided in this section are from one of the better studies available at the time this manual was written, and as can be seen from the ROL plots, the data does not meet the requirements for proper simple linear regression analysis.

Assumptions

- Any significant storms that were not monitored had a ratio of inlet to outlet loads similar to the storms that were monitored. The slope of the regression line would not significantly change with additional data.

- No materials were exported during dry periods, or if they were, the ratio of inlet to outlet loads during these periods was similar to the ratio of the loads during the monitored storms.

- The data is well represented by a least squares linear regression, that is:

    - The data is "evenly" spaced along the x-axis.

    - Using an analysis of variance on the regression, the slope coefficient is significantly different from zero (the p value for the coefficient should typically be less than 0.05, for example).

    - A check of the residuals shows that the data meets regression requirements. The residuals should be random (a straight line on probability paper) and the residuals should not form any trend with predicted value or with time (i.e., they form a band of random scatter when plotted).

Comments

- A few data points often control the slope of the line due to clustering of loads about the mean storm size. Regressions are best used where data is equally populous through the range to be examined. This is readily observed in the examples that follow (See Figures B.1 through B.3).

- The process of constraining the intercept of the regression line to the origin is questionable and in some cases could significantly misrepresent the data. It may be more useful to apply the *Regression of Loads* method over some subset of the data without requiring that the intercept be constrained to the origin. The problem with this alternative approach is that a large number of data points are required in order to get a good fit of the data. Often a meaningful regression cannot be made using the data that was collected. This is well illustrated by the very low R^2 values in the table below. Forcing the line through the origin, in these cases, provides a regression line even where no useful trend is present.

- There is sufficient evidence that this first order polynomial (straight line) fit is not appropriate over a large range of loadings. Very small events are much more likely to demonstrate low efficiency where larger events may demonstrate better overall efficiency depending on the design of the BMP.

Table B.3: Example of ROL Method results for TSS in the Tampa Office Pond

Period of Record	Slope of Regression Line	R^2	Percent Removal
1990	0.21	0.06	79%
1993-1994	0.18	-0.06	82%
1994-1995	0.05	0.46	95%
Percent Removal is rounded, but the other numbers were not (to prevent introduction of any rounding errors in the calculations)			

The regressions used to arrive at the above slopes are given in Figures B.1-B.3.

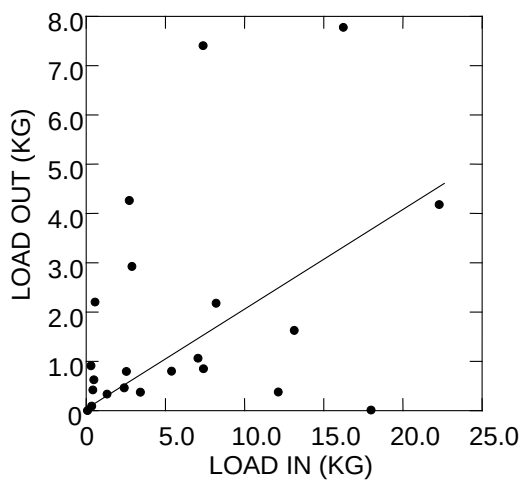

Figure B.1: ROL Plot for use in Calculating Efficiency for TSS using the Tampa Office Pond (1990) (Slope = 0.2135, R^2 = 0.0563, Standard Error in Estimate = 2.176, one point is considered an outlier with a Studentized Residual of 3.304). All points were used for regression. Method is not valid due to failure of simple linear regression assumptions.

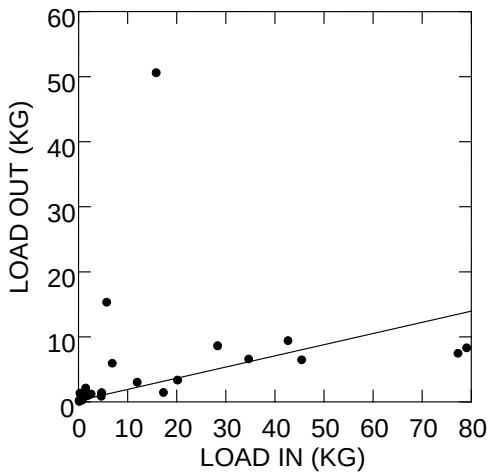

Figure B.2: ROL Plot for use in Calculating Efficiency for TSS using the Tampa Office Pond (1993-1994) (Slope = 0.1801, R^2 = -0.0562, Standard Error in Estimate = 10.440, one point is considered an outlier with a Studentized Residual of 13.206 and one point has a high Leverage of 0.323). All points were used for regression. Method is not valid due to failure of simple linear regression assumptions.

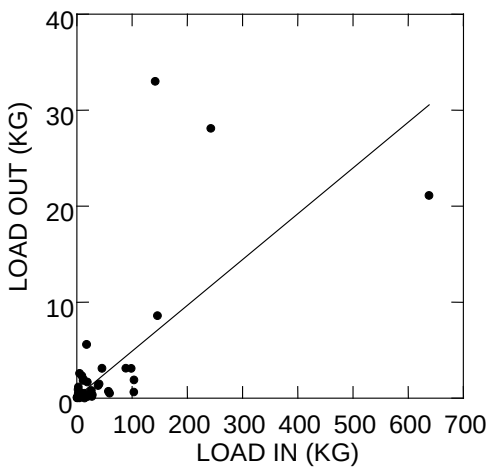

Figure B.3: ROL Plot for use in Calculating Efficiency for TSS using the Tampa Office Pond (1994-1995) (Slope = 0.0492, R^2 = 0.4581, Standard Error in Estimate = 5.260, three points are considered outliers (Studentized Residuals of 3.724, 8.074, and –4.505, the point to the far right on the graph has large Leverage (0.724) and Influence, Cook Distance = 36.144). All points were used for regression. Method is not valid due to failure of simple linear regression assumptions.

Mean Concentration

Definition

The mean concentration method defines the efficiency as unity minus the ratio of the average outlet to average inlet concentrations. The equation using this method is:

$$\text{Mean Concentration} = 1 - \frac{\text{average outlet concentration}}{\text{average inlet concentration}}$$

This method does not require that concentrations be flow weighted. This method might have some value for evaluating grab samples where no flow weighted data is available or where the period of record does not include the storm volume.

Assumptions

- The flows from which the samples were taken are indicative of the overall event.

Comments

- This method might be useful for calculating BMP's effectiveness in reducing acute toxicity immediately downstream of the BMP. This is due to the fact that acute toxicity is measured as a threshold concentration value of a specific constituent in the effluent at or near the point of discharge.

- This methods weights individual samples equally. Biases could occur due to variations in sampling protocols or sporadic sampling (i.e., collecting many samples close in time and others less frequently). The sample collection program specifics are not accounted for in the method and estimated efficiencies are often not comparable between studies.

- There is appreciable lag time for most BMPs between when a slug of water enters a BMP and when the slug leaves the BMP. Unless this lag time is estimated (e.g., through tracer studies) results from this approach can be quite inaccurate. Results of this method may be particularly difficult to interpret where lag time is ignored or not aggressively documented.

- This method does not account for storage capacity. Typically BMPs will have an equal or lesser volume of outflow than of inflow. On a mass basis this affects removal, since volume (or flow) is used with concentration to determine mass for a storm event:

$$1 - \frac{C_{out} V_{out}}{C_{in} V_{in}} \geq 1 - \frac{\text{average outlet concentration}}{\text{average inlet concentration}}$$

where,

C_{in}: Concentration In
C_{out}: Concentration Out
V_{in}: Volume In
V_{out}: Volume Out

In this respect, it is often more conservative (i.e., lower removal efficiency stated) to use a concentration rather than mass-based removal approach.

Efficiency of Individual Storm Loads

Definition

The Efficiency of Individual Storm Loads (ISL) method calculates a BMP's efficiency for each storm event based on the loads in and the loads out. The mean value of these individual efficiencies can be taken as the overall efficiency of the BMP. The efficiency of the BMP for a single storm is given by:

$$\text{Storm Efficiency} = 1 - \frac{Load_{out}}{Load_{in}}$$

The average efficiency for all monitored storms is:

$$\text{Average Efficiency} = \frac{\sum_{j=1}^{m} \text{Storm Efficiency}_j}{m}$$

where,

m: number of storms

Assumptions

- Storm size or other storm factors do not play central roles in the computation of average efficiency of a BMP.
- Storage and later release of constituents from one storm to the next is negligible.
- The selection of storms monitored does not significantly skew the performance calculation.

Comments

- The weight of all storms is equal. Large storms do not dominate the efficiency in this scenario. The efficiency is viewed as an average performance regardless of storm size.

- Some data points cannot be used due to the fact that there is not a corresponding measurement at either the inflow or the outflow for a particular storm, and thus efficiency cannot always be calculated on a storm-by-storm basis. This is not true for the ER method, however it is a limitation of the Summation of Load Method.

- Storm by storm analysis neglects the fact that the outflow being measured may have a limited relationship to inflow in BMPs that have a permanent pool. For example, if a permanent pool is sized to store a volume equal to the average storm, about 60 to 70 percent of storms would be less than this volume [from studies conducted using SYNOP (EPA 1989)].

Table B.4: Example of Individual Storm Loads Method results for TSS in the Tampa Office Pond

Period of Record	Efficiency
1990	29%
1993-1994	-2%
1994-1995	89%

Summary and Comparison of Historical Methods

The table below shows the results of the various historical methods shown above for calculating efficiency for the Tampa Office Pond. The four methods demonstrated (mean concentration method was not applicable to data available from the Tampa Office Pond study) vary widely in their estimates of percent removal depending on the assumptions of each method as discussed above.

Table B.5: Comparison of BMP efficiency methods.

	Method			
Design	**Efficiency Ratio (ER)**	**Summation of Loads (SOL)**	**Regression of Loads (ROL)**	**Efficiency of Individual Storms**
1990	59%	71%	79%	29%
1993-1994	64%	66%	82%	-2%
1994-1995	95%	94%	95%	89%

Other Methods and Techniques

"Irreducible Concentration" and "Achievable Efficiency"

As treatment occurs and pollutants in stormwater become less concentrated, they become increasingly hard to remove. There appears to be a practical limit to the effluent quality that any BMP can be observed to achieve for the stormwater it treats. This limit is dictated by the chemical and physical nature of the pollutant of concern, the treatment mechanisms and processes within the BMP, and the sensitivity of laboratory analysis techniques to measure the pollutant. This concept of "irreducible concentration" has significant implications for how BMP efficiency estimates are interpreted. However, it is possible to get concentrations as low as desired, but in most cases achieving extremely low effluent concentrations may not be practical (i.e., would require treatment trains or exotic methods). For example, colloids are typically viewed as "never" being able to be removed in a pond (settling is the primary mechanism for treatment in ponds), despite the fact that they could be further removed through chemical addition.

The term "irreducible concentration" (C*) has been used in stormwater literature (Schueler 2000) to represent the lowest effluent concentration for a given parameter that can be achieved by a specific type of stormwater management practice. Schueler examined the effluent concentrations achieved by stormwater management practices from published studies for several parameters. From this research, the following estimates of "irreducible concentrations" for TSS, Total Phosphorous, Total Nitrogen, Nitrate-Nitrogen, and TKN for all stormwater management practices were proposed:

Table B.6: "Irreducible concentrations" as reported by Schueler, 2000

Contaminant	Irreducible Concentration
TSS	20 to 40 mg/L
Total Phosphorous	0.15 to 0.2 mg/L
Total Nitrogen	1.9 mg/L
Nitrate-Nitrogen	0.7 mg/L
TKN	1.2 mg/L

Recent research (ASCE 2000) indicates that achievable effluent concentrations vary appreciably between BMP types. For example, in many cases, well-designed sand filters can achieve lower effluent concentrations of TSS than well-designed detention facilities or grassed swales. However, sand filters have issues with long-term maintenance of flow treatment volumes.

The typical approach to reporting the ability of a BMP to remove pollutants from stormwater entails comparing the amount of pollutant removed by the BMP to the total quantity of that pollutant. The concept of irreducible concentration, however, suggests that in some cases it may be more useful to report the efficiency of the BMP relative to some achievable level of treatment (i.e. express efficiency as the ability of the BMP to remove the fraction of pollutant which is able to be removed by a particular practice.)

The following example illustrates this approach. Suppose that two similar BMPs have been monitored and generated the following results for TSS:

Table B.7: Example TSS results for typical ER Method

Percent TSS Removal Using Absolute Scale		
	BMP A	**BMP B**
Influent Concentration	200 mg/L	60 mg/L
Effluent Concentration	100 mg/L	30 mg/L
Efficiency Ratio	50%	50 %

Clearly, the effluent from BMP B is higher quality than that from BMP A, however comparing percent removals between BMPs alone would indicate that both BMPs have an equal efficiency. Methods have been suggested for quantifying the dependence of BMP efficiency on influent concentration. The following section presents one such method advanced by Minton (1998).

In order to account for the dependence of BMP efficiency on influent concentration, Minton (1998) suggests a method of evaluating BMP efficiency that would recognize the relationship between influent concentration and efficiency. The relationship is summarized as follows:

$$\text{Achievable Efficiency} = (C_{influent} - C_{limit}) / C_{influent}$$

where,

$C_{influent}$: Influent Concentration of Pollutant; and
C_{limit} : The lower attainable limit concentration of the BMP (e.g., "irreducible concentration" or value obtained from previous monitoring of effluent quality)

For example, if a BMP had a lower treatment limit of TSS at 20mg/L concentration, then at an influent TSS concentration of 100 mg/L, it would be assigned an equivalent performance of 80%, while at an influent TSS concentration of 50 mg/L the equivalent performance would be 60%.

This method relies on the ability to determine the lower attainable limit concentration, which is analogous to the "irreducible concentration" for a specific BMP, however effluent quality is best described not as a single value, but from a statistical point of view (See the Effluent Probability Method).

The Achievable Efficiency may be useful in better understanding the results of the ER method in cases where the influent concentration is lower than is typically observed.

Alternately, a single factor (dubbed the Relative Efficiency here) can be used to report how well a BMP is functioning during some period relative to what that BMP is theoretically or empirically able to achieve (as defined by the Achievable Efficiency).

As shown below, the Relative Efficiency can be found by dividing the Efficiency Ratio by the Achievable Efficiency, thus yielding an estimate of how well the BMP performed relative to what is "achievable".

$$\text{Relative Efficiency} = \frac{\text{Efficiency Ratio}}{\text{Achievable Efficiency}} = \frac{[(C_{influent} - C_{effluent})/C_{influent}]}{[(C_{influent} - C_{limit})/C_{influent}]}$$

Or simplifying:

$$\text{Relative Efficiency} = (C_{influent} - C_{effluent})/(C_{influent} - C_{limit})$$

If applied to the example presented earlier in this section, the following results are obtained:

Table B.8: Example TSS results for demonstration of Relative Efficiency approach

	BMP A	**BMP B**
Influent Concentration	200 mg/L	60 mg/L
C_{limit}	20 mg/L	20 mg/L
Effluent Concentration	100 mg/L	30 mg/L
Relative Efficiency	56%	75 %

For this example, the results indicate that BMP B is achieving a higher level of treatment than BMP A and this approach may be more useful as a comparative tool than the Efficiency Ratio for some data sets. The Relative Efficiency for a BMP's effectiveness is still influenced by influent concentration but less so than is the Efficiency Ratio.

As $C_{influent}$ approaches C_{limit} the Relative Efficiency goes to infinity, which is not a very meaningful descriptor. However, if the influent concentration is near the "irreducible concentration" for a particular pollutant, very little treatment should occur and $C_{influent} - C_{effluent}$ should approach zero. $C_{effluent}$, at least theoretically, should always be higher than C_{limit} and the numerator of the equation should approach zero faster than the denominator. If $C_{influent}$ is less than C_{limit}, the Relative Efficiency approach should not be used. As is always the case, any of the percent removal efficiency approaches (including the Efficiency Ratio Method) should not be employed if there is not a statistically significant difference between the average influent and effluent concentrations.

If this method is used to represent data from more than one event (i.e., mean EMCs are calculated) it should be supplemented with an appropriate non-parametric (or if applicable parametric) statistical test indicating if the differences are statistically significant (it would be preferred to show the actual level of significance found, instead of just noting if the result was significant, assuming a 0.05 level).

Percent Removal Relative to Water Quality Standards

From a practical or programmatic perspective, it may be more useful to substitute the water quality limit for the "irreducible concentration" as a measure of how well the BMP is meeting specific water quality objectives. A measure of efficiency can be calculated to quantify the degree to which stormwater BMPs employed are meeting or exceeding state or federal water quality criteria or standards for the runoff they treat.

Standards are enforceable regulations established within the context of an NPDES permit or a TMDL and are usually specific to the receiving water. Water quality criteria are more general guidelines expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular beneficial use.

By showing that stormwater is being treated to a level that is higher than standards require or criteria recommend, a permitee may be able to demonstrate to regulators or stakeholders that their current stormwater management practices are adequate for a particular constituent of concern. The equation to calculate the Percent Removal Relative to Receiving Water Quality Limits is as follows:

Percent Removal Relative to Receiving Water Quality Limits =

$$(C_{influent} - C_{effluent})/(C_{influent} - C_{standard/criterion})$$

The following example illustrates the application of this approach for reporting efficiency:

Table B.9: Example of percent removal relative to receiving water quality limits approach

	BMP A
Influent Concentration (EMC)	1.65 ug/l
$C_{standard/criterion}$	0.889 ug/l
Effluent Concentration (EMC)	0.635 ug/l
Percent Removed Relative to Established WQ Limits	133 %

The results indicate that the BMP for the given event is meeting the water quality standard or criterion for dissolved lead. In fact the BMP is functioning to remove in excess of the amount needed to bring the influent concentration below the water quality limit (as indicated in the example by a value greater than 100%). Use of this method is only recommended for specific event analysis. As mentioned for previous analyses, if this approach is taken for a series of events it should be supplemented with an appropriate non-parametric (or if applicable parametric) statistical test indicating if the differences are statistically significant (it would be better to show the actual level of significance found, than just noting if the result was significant, assuming a 0.05 level)

"Lines of Comparative Performance©"

For many stormwater treatment BMPs, the efficiency of the BMP decreases as a function of the influent concentration. Methods have been recommended that integrate this concept into efficiency evaluations. The "Lines of Comparative Performance©" (Minton 1998) is one such method.

In this method, plots of percent removal as a function of the influent concentration for each storm are generated for each pollutant monitored. The results of these plots are overlaid on plots of data collected from studies of similar BMPs within a region.

"Lines of Comparative Performance©" are generated for the data from similar BMPs based on best professional judgment by examining the likely "irreducible concentration" for a particular pollutant, the detection limit for that pollutant, and knowledge of expected maximum achievable efficiency for a BMP type.

This method has primarily been suggested as an approach to evaluate the efficiency of innovative and "unapproved" stormwater technologies. "To be accepted, the performance data points of an unapproved treatment technology must fall above and to the left of the 'Line of Comparative Performance©." This approach has several limitations, the most significant of which is self-correlation.

An alternate method which does not include some of the significant problems associated with the "Lines of Comparative Performance©", but presents relatively the same information can be generated using a simple plot of effluent concentration as a function of influent concentration with "rays" (or curves on a log plot) originating from the plot origin for several levels of control (e.g., 0, 25, 50, 75, and 90%). The plot may need to be a log-log plot for data with a large range of values typical of stormwater monitoring data.

Multi-Variate and Non-Linear Models

Reporting efficiency as a percent removal that is calculated based on the difference between influent and effluent concentrations will always make a BMP that treats higher strength influents appear to be more efficient than one treating weaker influents if both are achieving the same effluent quality. A more useful descriptor of efficiency would take into consideration that weaker influents are more difficult to treat than concentrated ones. A multi-variate equation that includes corrections to compensate for this phenomena or a non-linear model may be worth considering for reporting efficiency.

A model that approaches pollutant removal in a manner similar to the reaction rates for complex physical and chemical batch and plug-flow processes may be useful. To date calibration of such a model for all but the most elementary situations (e.g., settling of solids in relatively simplistic flow regimes) is difficult given the complexity of the real-world

problem. As more high quality data becomes available, other approaches to evaluating BMP efficiency may become apparent.

Effluent Probability Method (Recommended Analysis Approach)

The Effluent Probability Method is the recommended analysis approach that is described in Chapter 7 of this manual.

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