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Memorandum

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Subject Defining enhanced treatment for the Technology Assessment Protocol – Ecology (TAPE)

Introduction

Enhanced treatment in the Stormwater Management Manual for Western Washington (Ecology 2005) is currently defined as "providing a higher rate of removal of dissolved metals than basic treatment facilities." The terminology used in the Stormwater Management Manual for Eastern Washington (Ecology 2004) is metals treatment instead of enhanced treatment; however, the definition of the performance goal is the same. Due to limited data available for dissolved metals removal in stormwater treatment facilities, the Washington State Department of Ecology (Ecology) did not specify a numeric removal efficiency goal in either manual.

However, Ecology did provide guidance for evaluating the enhanced treatment performance of emerging stormwater treatment technologies in the Technology Assessment Protocol – Ecology (TAPE; Ecology 2008). The TAPE guidelines indicate that data collected for enhanced treatment facilities should "demonstrate significantly higher removal rates than basic treatment facilities" and "provide a higher rate of removal of dissolved metals than most basic treatment facilities." (Ecology 2008). Further, the TAPE guidelines indicate that data from vendors and/or the International Stormwater Best Management Practice (ISBMP) database for basic treatment facilities can be used to "determine if the device [being tested for enhanced treatment] demonstrates significantly higher removal rates" than basic treatment. Ecology (2005, 2008) also states that the enhanced treatment performance goal applies for influent dissolved copper concentrations ranging from 0.003 to 0.02 milligrams per liter (mg/L) and influent dissolved zinc concentrations ranging from 0.02 to 0.3 mg/L.

The purpose of this memorandum is to recommend numeric performance goals that will facilitate a more direct evaluation of enhanced treatment performance in emerging stormwater technologies. To maintain consistency with the definition for enhanced treatment in the Stormwater Management Manual for Western Washington, the recommended numeric performance goals were developed based on an extensive review of data obtained from the ISBMP database and a subsequent analysis of these data to quantify removal efficiencies for dissolved metals in basic treatment facilities. If approved by Ecology, these numeric performance goals will be incorporated into a revised version of the TAPE guidelines that will be released prior to June 2011.

Methodology

The analysis involved the following steps:

1. Selection of appropriate basic treatment best management practices (BMPs).

2. Review and screening of datasets from the ISBMP database.

3. Statistical analysis of data obtained from the ISBMP database to define typical levels of treatment for dissolved metals that can be achieved by basic treatment facilities

The following subsections describe these steps in more detail.

Determining the Basic Treatment BMP List

Data from the ISBMP database can be used to determine typical levels of treatment for dissolved metals with basic treatment BMPs. As a first step, the basic treatment BMPs that are currently approved in Washington were compared to corresponding BMPs in the ISBMP database and representative BMPs for basic treatment in the ISBMP database were identified. Monitoring data from these BMPs were subsequently obtained through queries of the ISBMP database.

Basic treatment BMPs in the Stormwater Management Manual for Western Washington (Ecology 2005) include the following:

- Biofiltration swales
- Filter strips
- Basic wetpond
- Wetvault
- Treatment wetlands

- Combined detention/wetpool
- Sand filters
- Bioretention
- Ecology embankments (now media filter drains)
- Storm Filter – zeolite/perlite/granular activated carbon (ZPG)

Wetlands, bioretention, and ecology embankments (media filter drains) are also considered enhanced treatment BMPs in the Stormwater Management Manual for Western Washington (Ecology 2005) and were removed from the basic treatment BMP list. Large sand filters (treating 95 percent of the average annual runoff volume compared to 91 percent for basic sand filters) and amended sand filters (i.e., processed steel fiber or crushed calcitic limestone mixed with sand) are also considered enhanced treatment facilities. Removing these BMPs and clarifying the types of sand filters to be included in the analysis resulted in the following list of basic treatment BMPs:

- Biofiltration swales
- Filter strips
- Basic wetpond
- Wetvault
- Combined detention/wetpool
- Sand filters (sand filter vaults and linear sand filters)
- Storm Filter – ZPG

The Storm Filter – ZPG performance data was obtained directly from the Technical Evaluation Engineering Report (TEER) prepared by Stormwater Management Inc. (2004). Data for the other basic treatment BMPs was obtained from the ISBMP database. The corresponding categories in the ISBMP database include the following:

- Biofilter – grass swales
- Biofilter – grass strips
- Retention pond (wet) surface pond with a permanent pool
- Retention underground vault or pipe (wet)
- Filter – sand

Quality Assurance Review

The ISBMP database includes many datasets that can be used to evaluate the performance of stormwater BMPs. To identify a subset of datasets that are representative and suitable for determining BMP performance, the datasets were reviewed and screened based on the following general criteria:

- Influent concentrations
- Geographic location
- Data quality
- BMP design
- Miscellaneous monitoring problems

The specific steps that were performed during this review and the associated screening criteria are as follows:

1. A query was performed on the ISBMP database to identify basic treatment BMPs identified in the previous subsection with datasets that included influent dissolved copper concentrations ranging from 0.003 to 0.02 mg/L and influent dissolved zinc concentrations ranging from 0.02 to 0.3 mg/L (ASCE 2009).

2. The datasets from Step 1 were refined by location. The TAPE guidelines indicate that BMPs should be located at sites within, or representative of, the Pacific Northwest (Ecology 2008). This was interpreted to include sites located in Washington and Oregon. Since the data in the ISBMP database from these two states was considered insufficient for characterizing the treatment performance of basic treatment BMPs, the analysis was expanded to include monitoring data collected in California as well. BMPs located in other states were not included for further analysis.

3. The datasets from Step 2 were refined by determining whether monitoring was conducted according to a quality assurance project plan (QAPP) or monitoring plan or a sampling and analysis plan (SAP), and if that QAPP or SAP was equivalent to that required under the TAPE guidelines. Studies of sites that did not include a QAPP or a SAP were not included for further evaluation.

4. The datasets from Step 3 were refined by BMP design. The Stormwater Management Manual for Western Washington includes both general and specific design guidelines for the BMPs, including factors such as residence times, basin sizing, and soil depth (Ecology 2005). The BMPs that did not meet the design guidelines were not included.

5. The final criteria consisted of a review of project reports or narratives, where possible. In a few instances, the project reports revealed problems with the BMPs which clearly affected system performance (e.g., extensive gopher damage, no plant growth). These BMPs were not included in the final dataset.

The 23 sites summarized in Table 1 were carried forward for further analysis.

Table 1. Basic treatment facilities evaluated from the International Stormwater Best Management Practice database and technical evaluation engineering reports.

BMP Type	Test Site Name	Location	Number of Samples	
			Dissolved Copper	Dissolved Zinc
Biofilter - Grass Strip	Cottonwood RVTS	CA	14	15
Biofilter - Grass Strip	Irvine B RVTS	CA	0	1
Biofilter - Grass Strip	Irvine C RVTS	CA	1	4
Biofilter - Grass Strip	Redding C RVTS	CA	5	3
Biofilter - Grass Strip	Sacramento D RVTS	CA	7	2
Biofilter - Grass Strip	San Rafael RVTS	CA	17	20
Biofilter - Grass Strip	Yorba Linda C RVTS	CA	5	6
Biofilter - Grass Strip	Yorba Linda D RVTS	CA	3	4
Biofilter - Grass Swale	Bioswale Native East	OR	5	6
Biofilter - Grass Swale	Bioswale Non-Native West	OR	5	6
Biofilter - Grass Swale	Del Amo	CA	4	6
Biofilter - Grass Swale	I-5/I-605 swale	CA	6	11
Biofilter - Grass Swale	Melrose	CA	5	4
Biofilter - Grass Swale	Palomar Swale	CA	8	9
Filter - Sand	Eastern SF	CA	9	10
Filter - Sand	Escondido	CA	11	14
Filter - Sand	Foothill SF	CA	11	11
Filter - Sand	I-5/I-78 P&R	CA	15	17
Filter - Sand	La Costa P&R	CA	13	14
Filter - Sand	Termination	CA	8	8
Retention Pond (Wet) - Surface Pond With a Permanent Pool	La Costa WB	CA	8	13
Storm Filter – ZPG	Heritage	WA	8	8
Storm Filter – ZPG	Lake Stevens	WA	9	10
Total			**177**	**202**

BMP = best management practice
P&R = park and ride
RVTS = roadside vegetated buffer strip
SF = sand filter
WB = wet basin
ZPG = zeolite/perlite/granular activated carbon

Statistical Analysis

A statistical analysis was performed on the data obtained from the quality assurance review to define typical levels of treatment for dissolved metals by basic treatment facilities. This specifically involved the use of a bootstrapping technique to compute 95 percentile confidence intervals around the average pollutant removal efficiency of the basic treatment BMPs for dissolved copper and dissolved zinc. Bootstrapping offers a distribution-free method for computing confidence intervals around a measure of central tendency (Efron and Tibshirani 1993). The generality of bootstrapped confidence intervals means they are well-suited to non-normally distributed data or datasets not numerous enough for a powerful test of normality (Porter et al. 1997).

In its simplest form, bootstrapping consists of randomly selecting a subset of values from a dataset, calculating a summary statistic (e.g., average or median) of the subset, and repeating many times. Repetition generates a distribution of possible values for the statistic of interest. Confidence intervals of the statistic can be calculated from the distribution by sorting the results and locating the value, which corresponds to the desired upper and lower percentile value. For example, to determine the upper and lower values for a 95 percentile confidence interval:

1. Calculate the average for 1,000 synthetic datasets
2. Sort the results
3. Identify the values ranked 25th and 975th in the sorted set, corresponding to 2.5% and 97.5% of the distribution; these values represent the upper and lower 95 percentile confidence limits, respectively.

For this application, the average pollutant removal efficiency was calculated for each of the 23 sites included in the evaluation. This was performed to prevent sites with a relatively high number of individual samples from having a disproportionate influence on the results. Bootstrapping was then used to compute the 95 percentile confidence interval around the average removal efficiency for the basic treatment facilities shown in Table 1.

Finally, it is possible that low influent contaminant concentrations may bias percent removal calculations (Schueler 1996; Strecker et al. 2001). In order to determine whether this was occurring, particularly with dissolved copper, the analysis was repeated using a slightly modified influent range of 0.005 to 0.02 mg/L.

Results

The results from the analysis described in the previous section are presented in Table 2. These data indicate the upper limit of the 95 percentile confidence intervals for the average dissolved copper and dissolved zinc removal efficiency in basic treatment BMPs were 27.0 percent and 61.8 percent, respectively. Theses values did not significantly change with the modified dissolved copper influent range. Based on this analysis, and for simplicity, the recommended performance goal for dissolved copper was increased slightly to 30 percent while the recommended performance goal for dissolved zinc was decreased slightly to 60 percent.

If approved by Ecology, a revised version of the TAPE guideline manual would be prepared to identify the following steps for evaluating the performance of enhanced treatment BMPs based on these performance goals:

Table 2. Average dissolved metals treatment from basic treatment facilities evaluated from the International Stormwater Best Management Practice database.

BMP Type	Test Site Name	Average Removal (%) Dissolved Copper	Dissolved Zinc
Biofilter - Grass Strip	Cottonwood RVTS	40.2%	69.3%
Biofilter - Grass Strip	Irvine B RVTS	NA	70.0%
Biofilter - Grass Strip	Irvine C RVTS	43.3%	70.0%
Biofilter - Grass Strip	Redding C RVTS	6.0%	17.6%
Biofilter - Grass Strip	Sacramento D RVTS	25.2%	79.7%
Biofilter - Grass Strip	San Rafael RVTS	70.0%	74.9%
Biofilter - Grass Strip	Yorba Linda C RVTS	14.8%	77.2%
Biofilter - Grass Strip	Yorba Linda D RVTS	44.0%	76.2%
Biofilter - Grass Swale	Bioswale Native East	19.1%	40.2%
Biofilter - Grass Swale	Bioswale Non-Native West	17.2%	30.0%
Biofilter - Grass Swale	Del Amo	5.9%	22.3%
Biofilter - Grass Swale	I-5/I-605 swale	12.1%	55.3%
Biofilter - Grass Swale	Melrose	53.9%	77.5%
Biofilter - Grass Swale	Palomar Swale	11.7%	18.4%
Filter - Sand	Eastern SF	5.6%	47.5%
Filter - Sand	Escondido	32.8%	89.3%
Filter - Sand	Foothill SF	-18.9%	62.7%
Filter - Sand	I-5/I-78 P&R	-4.9%	56.0%
Filter - Sand	La Costa P&R	15.0%	86.8%
Filter - Sand	Termination	-20.4%	10.4%
Retention Pond (Wet) - Surface Pond With a Permanent Pool	La Costa WB	8.6%	22.8%
Storm Filter – ZPG	Heritage	8.7%	7.6%
Storm Filter – ZPG	Lake Stevens	3.9%	1.9%
	Bootstrapped Lower CI Average	9.3%	39.2%
	Average	17.9%	50.6%
	Bootstrapped Upper CI Average	**27.0%**	**61.8%**

BMP = best management practice
CI = confidence interval
NA = not applicable
P&R = park and ride
RVTS = roadside vegetated buffer strip
SF = sand filter
WB = wet basin
ZPG = zeolite/perlite/granular activated carbon

1. Using the compiled monitoring data for the BMP that is being evaluated, compute the 95 percentile confidence limits for the average removal efficiencies of dissolved copper and dissolved zinc using the bootstrapping technique described in the previous section.

2. Compare the lower limit of the 95 percentile confidence interval from Step 1 to the performance goals for enhanced treatment (i.e., 30 percent for dissolved copper and 60 percent for dissolved zinc).

3. If the lower limit of the 95 percentile confidence interval is greater than 30 percent for dissolved copper and 60 percent for dissolved zinc, it can be concluded that the BMP met the goals with the required 95 percent confidence and could be approved for enhanced treatment.

Recommendations

The recommended performance goals for enhanced treatment are 30 percent removal of dissolved copper and 60 percent removal of dissolved zinc

Ecology may want to include additional considerations (i.e., influent constituent concentrations) when evaluating treatment facility performance against these goals. Consistently high or low influent concentrations may bias systems performance evaluated on a percent removal basis (Strecker et al. 2001).

The recommended performance standards in this memorandum are not intended to be retroactive for stormwater treatment facilities that have already received a general use level designation (GULD) for enhanced treatment.

These enhanced treatment performance goals are interim goals that will remain in place until the next revision of the TAPE guidance manual. They should be reevaluated as additional monitoring data from basic treatment facilities (i.e., results of the National Pollutant Discharge Elimination System [NPDES] Phase I Stormwater permit monitoring) become available.

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