Potential Data Analysis and Performance Evaluation of Manufactured BMPs

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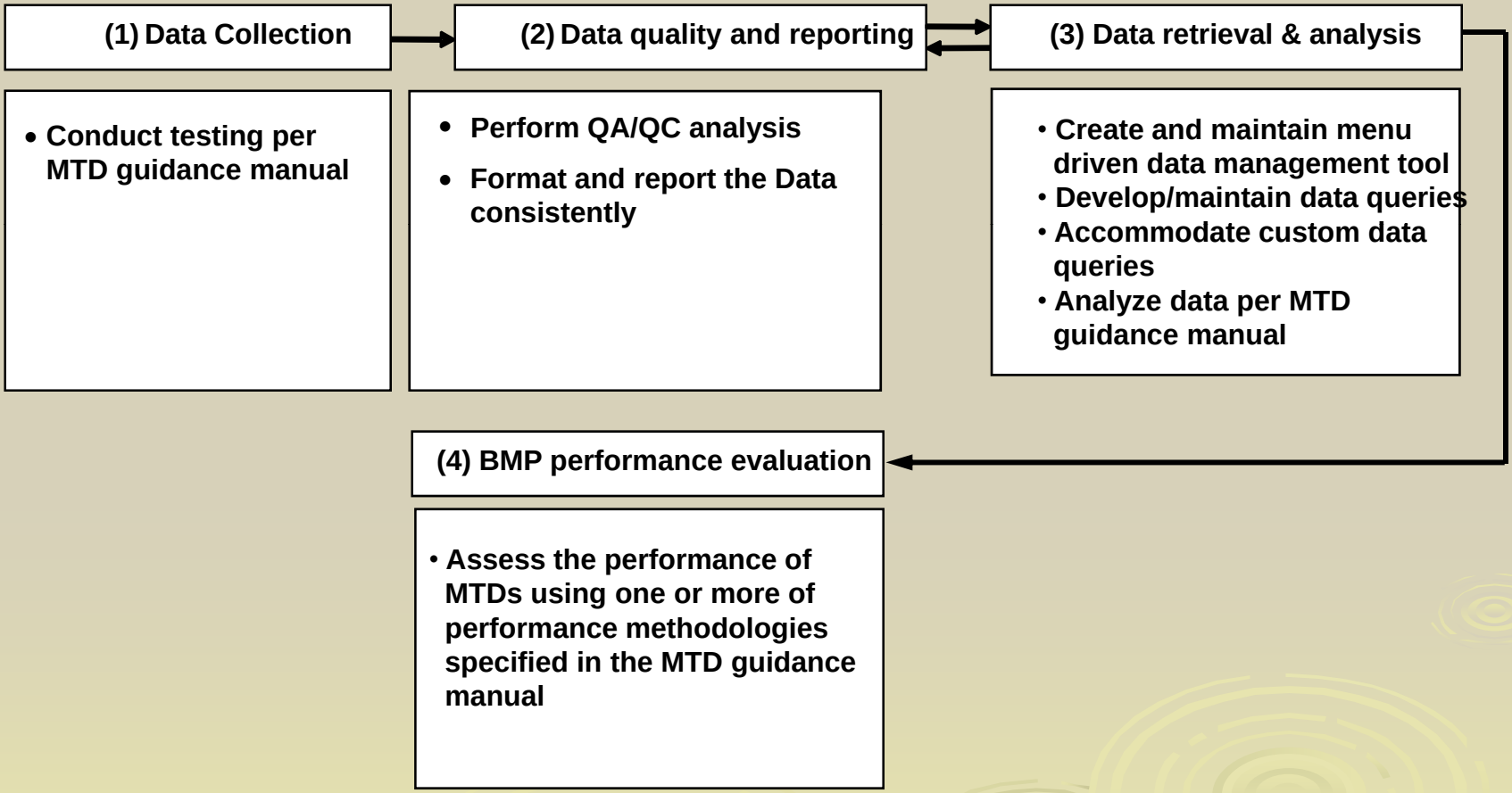
Focus of the Paper

- To provide potential guidance and methodologies to:
  - Analyze data collected from MTDs, and
  - Assess the performance of MTDs

Background

- Some guidance are provided by existing MTDs protocols, but they are not consistent:
  - TARP
  - TAPE
  - ETV
  - Wisconsin
  - New jersey
- The most comprehensive guidance is provided by the US EPA/ASCE urban stormwater BMP performance monitoring

Prerequisite of a successful data management and data analysis



Data Collection

ACTIVITIES

- Test/monitor the MTDs
- In-line data collection
- Collect samples and analyze them in analytical lab

SUPPORT TOOLS

- MTD Testing Protocol
- Data Reporting Protocol
- Database and data retrieval guidance?

Data Collection Quality

- The MTD guidance manual and data protocol ensure:
  - *consistency* and
  - *high quality*

  in data collection activities by all testing facilities regardless of location and test conductor.

Data Reporting

- ACTIVITIES
- Data QA/QC
- Electronic data delivery

SUPPORT TOOLS

- Data Reporting Protocol
- Database and data retrieval guidance?

MTDs Data Management Tool

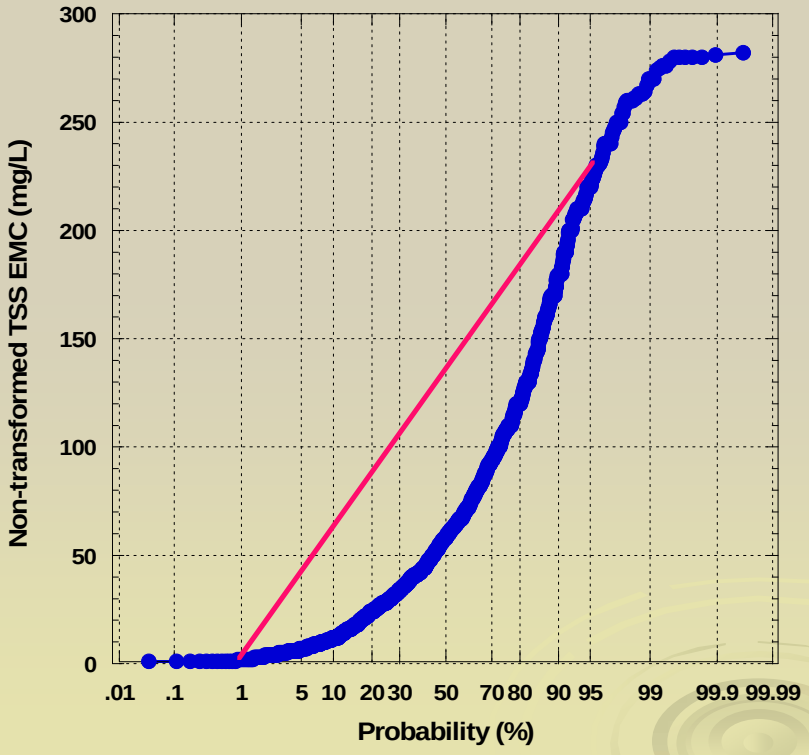
- Database constructed in MS Access or similar software with user-friendly querying interface and Data Analysis Tool (DAT)
- User-friendly interface allows users to access data easily, through:
  - GIS-based map interface for test results in geographic testing facilities
  - Menu-driven query screen

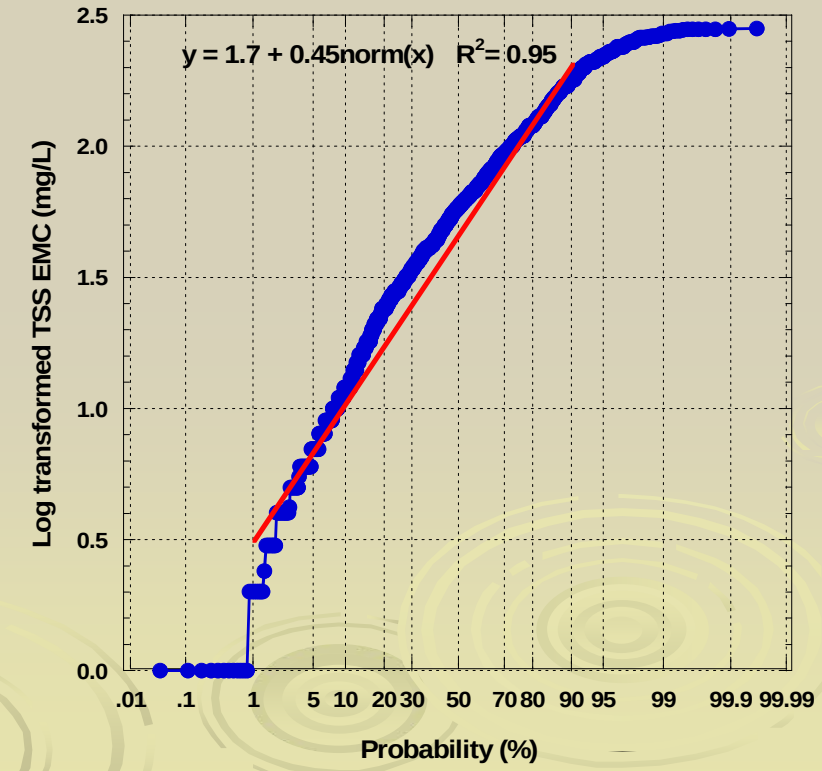
Data Retrieval & Analysis:

- Querying: Well-designed, user-friendly interface allows users to:
  - Efficiently access data from database
  - Effectively use data in reports or subsequent analysis
- Data Analysis Tool Gide:
  - Provides guidance to perform summary statistics
  - Perform scientifically-sound statistical analysis
  - Evaluate performance evaluation of MTDs

Statistical methods for data analysis

- Data distribution—assume MTDs data are log-normality distributed and testing for data distribution may not be necessary. If testing needed, recommend using probability plot or Shapiro-Wilk W test to verify or reject the normal distribution.





Major questions to be address statistically

- Probability of meeting water quality requirements
- MTD effectiveness for specific pollutant removal
- Comparing effectiveness of two or more MTDs
- Developing a linear regression equation
- Effectiveness of MTDs over time

Statistical methods to address questions

Topic	Question	Statistical method
Probability of meeting water quality requirements	How do we estimate how often the MTD effluent concentration would meet a water quality standard or regulatory discharge limit? How do we estimate the MTD percentage removal of a pollutant with a specified confidence level?	This should be available directly from the effluent probability plot of laboratory or field testing data, assuming the field data sample is large enough to be representative.

Statistical methods (Cont.)

Topic	Question	Statistical method
MTD effectiveness for specific pollutant removal	In an influent-effluent approach or before-after approach, how do we decide whether a given MTD is effective in removing a pollutant?	Hypothesis testing through null hypothesis (H_0) or alternative hypothesis (H_A). Statistical test that can be performed include student's t-test with equal variance and t-test with unequal variance. Both tests assume a particular probability distribution.

Statistical methods (Cont.)

Topic	Question	Statistical method
Comparing effectiveness of two or more MTDs	How do we compare the effectiveness of two or more MTDs under similar test condition or under a given geographic location?	Paired t-test comparing the mean of effluent concentration for normal or log-normally distributed data. Comparing three or more BMPs use the analysis of variance (ANOVA). Specific analysis include: parametric ANOVA (equal variances), Welch ANOVA (unequal variance).

Statistical methods (Cont.)

Topic	Question	Statistical method
Developing a linear regression equation	How does MTD effectiveness vary as a function of factors such as storm event characteristics, MTD design variables, operational, maintenance practices?	Multiple linear regression using the following form: $y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots \beta_m x_m + \varepsilon$ where, y=response variable, x=model variable, β = model parameters, and ε random error

Statistical methods (Cont.)

Topic	Question	Statistical method
Effectiveness of MTDs over time	How can we tell if the effectiveness of a MTD is changing over time within a year or multiple years?	Graphic representation using time-series plot or Mann-Kendall test.

Methods to Evaluate MTDs Performance

- Pollutant EMC reduction for single test or storm event
- Pollutant load reduction for single test or storm event
- Pollutant load reduction for multiple tests of storm events
- Mean pollutant concentration removal efficiency
- Performance based on regression of loads (ROL)
- Performance relative to achievable
- Performance relative to water quality standard
- Performance based on effluent probability method

MTDs Performance Evaluation (Cont.)

Method	**Approach/Formula**	**Applicable certification program**
Pollutant EMC reduction for single test or storm event	$\text{Efficiency} = 100 \times (1 - \frac{\text{Effluent EMC}}{\text{Influent EMC}})$	ETV, TARP, TAPE, EPA/ASCE
Pollutant load reduction for single test or storm event	$\text{Efficiency} = 100 \times (1 - \frac{\text{Effluent load}}{\text{Influent load}})$	ETV, TARP, TAPE, EPA/ASCE
Pollutant load reduction for multiple tests or storm events	$\text{Efficiency} = 100 \times (1 - \frac{B}{A})$	ETV, TARP, TAPE, EPA/ASCE

$$B = \left[\sum (\text{effluent EMC}_1 \times \text{flow } V_1) + (\text{effluent EMC}_2 \times \text{flow } V_2) + \ldots\ldots\ldots (\text{effluent EMC}_n \times \text{flow } V_n)\right]$$

$$A = \left[\sum (\text{influent EMC}_1 \times \text{flow } V_1) + (\text{influent EMC}_2 \times \text{flow } V_2) + \ldots\ldots\ldots (\text{influent EMC}_n \times \text{flow } V_n)\right]$$

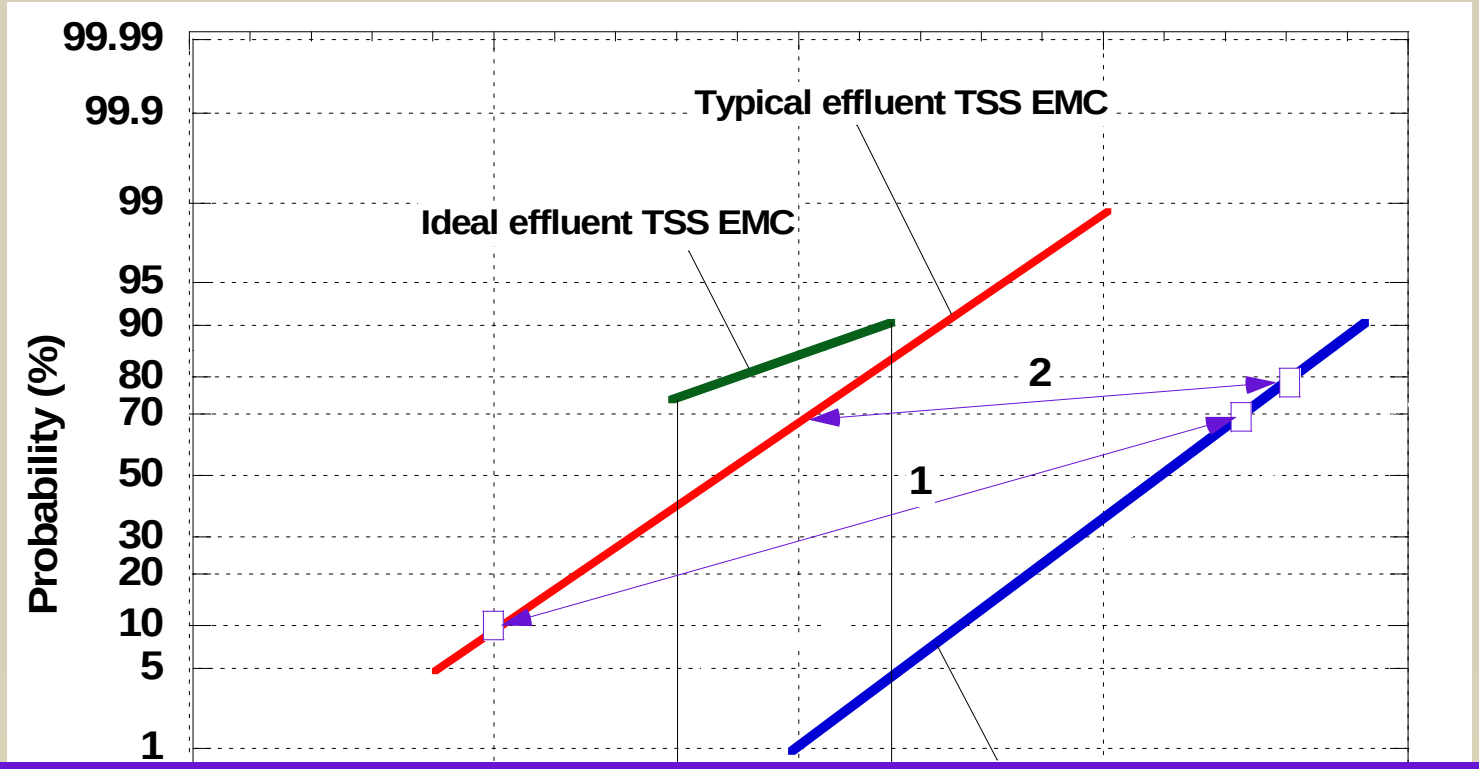
MTDs Performance Evaluation (Cont.)

Method	**Approach/Formula**	**Applicable certification program**
Mean pollutant concentration removal efficiency	$\text{Efficiency} = 100 \times (1 - \frac{\text{Average effluent Conc.}}{\text{Average influent Conc.}})$ This technique does not require flow measurement and it might be useful for pollutants with grab sampling where no flow weighted data is available.	EPA/ASCE urban stormwater BMP performance monitoring
Regression of loads (ROL)	Compute effluent and influent load; perform linear regression based on outflow and inflow load and determine the R^2 and slope of regression line. Under special circumstance, the regression lines may be forced through (0,0) as it may produce a more realistic lead removal.	EPA/ASCE urban stormwater BMP performance monitoring

MTDs Performance Evaluation (Cont.)

Method	**Approach/Formula**	**Applicable certification program**
Relative to achievable	$\text{Efficiency} = 100 \times (1 - \frac{\text{Attainable limit Conc.}}{\text{Average influent Conc.}})$	EPA/ASCE urban stormwater BMP performance monitoring
Relative to water quality standard	$\text{Efficiency} = 100 \times (\frac{\text{avg. infl. conc.} - \text{avg. effl. conc.}}{\text{avg. infl. conc.} - \text{WQ standard conc.}})$	EPA/ASCE urban stormwater BMP performance monitoring
Effluent probability method	This method provides comprehensive MTD performance evaluation by presenting the standard parallel probability plot of both influent and effluent EMCs for all storm events or performance tests.	EPA/ASCE urban stormwater BMP performance monitoring

Example effluent probability plots



Summary

- Data analysis and performance evaluation of MTDs must be consistent and scientifically sound
- Statistical methods that can be used to address specific question related to the performance evaluation of MDTs may include:
  - Summary statistics—range, mean, median, SD, COV
  - Shapiro Wilk W test
  - Probability distribution plot
  - Time series plot
  - t-test and equal variance t-test
  - Paired t-test
  - ANOVA or Welch ANOVA
  - Multiple linear regression
  - Mann-Kendall test
  - Regression on order statistics (ROS)

Thank you for your participation

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