How Many Events Do You Need? A Statistical Approach to Developing a GSI/BMP Monitoring Program

Elizabeth Fassman-Beck, Ph.D.[1], Emily Darin[1], Bridget Wadzuk, Ph.D. [2]

1. Southern California Coastal Water Research Project, Costa Mesa, CA
2. Villanova University, Villanova, PA

Highlights

- GSI inflow and outflow EMC distributions are reasonably consistent when at least 15 events are monitored for GSI/BMPs located in the USA Mid-Atlantic region (EPA rain zone 2).
- Using the International Stormwater BMP database and an R Shiny application, an automated workflow was developed to analyze many different datasets across different EPA rain zones.
- The workflow can be used with other data sets to establish reasonable expectations for future monitoring programs that should accurately capture GSI/BMP performance.

Introduction

Compliance monitoring programs are being increasingly developed as a tool to evaluate Green Stormwater Infrastructure (GSI) [aka stormwater Best Management Practices (BMPs)] and are becoming common practice in municipal watershed management plans. There are currently very few compliance programs with scientifically derived requirements for the number of events that must be sampled to determine the effectiveness of a GSI facility. Knowing the number of events that would effectively represent the distribution of all the events that occur could effectively reduce costs for facilities participating in such a program.

Location and climate are hypothesized as important factors influencing runoff pollutant concentrations. Likewise, determining the appropriate number of events to sample which may be considered representative may also be location and climate specific. For example, temperate climates such as the USA east coast offer reasonably frequent, year-round rainfall. It is not uncommon to see the capture of 10-15 storm events per year set as a goal for monitoring in academic research proposals. Conversely, rainfall is much less frequent in the arid south-west, with a maximum of 10 events occurring per year. Some programs in California only require 1 monitored event to demonstrate compliance due to the challenges of feasibly sampling with such infrequent rainfall. The majority of GSI monitoring to date occurs through grant funding over a relatively brief period, such as 1-2 years. It is rare to find multi-year monitoring programs that generate data from greater than 20-30 total events, even in rainy climates.

This work begins to explore the number of storms that are required to be sampled to accurately represent the performance of a GSI. In other words, what is the minimum number of events that should be sampled to reflect the distribution of untreated (inflow) and treated (outflow) EMCs expected to occur at a GSI site? Using this data-informed approach will enable compliance programs to set realistic sampling goals and understand the confidence and uncertainty around the data from sampled events.

Methodology

GSI/BMP sites with at least 20 monitored events for total suspended solids (TSS), dissolved copper and total phosphorus data were extracted from the International Stormwater BMP Database

(www.bmpdatabase.org) for a range of BMP types and facility locations. The parameters were arbitrarily chosen; TSS is ubiquitous in regulatory objectives for stormwater management across the USA while phosphorus and copper were selected as representative nutrients and dissolved heavy metals, respectively. Only flow-weighted event mean concentration (EMC) data are considered herein.

Datasets were organized by EPA rain zone to distinguish climates. Two datasets were arbitrarily selected from among the five largest datasets for each of the nine rain zones. TSS, phosphorus and copper data were exported from these datasets and imported into R studio. GSI inflow and outflow EMC data distributions were analyzed separately. The data were not found to follow a consistent distribution among analytes, and a unique data transformation was not identified.

The parent distribution is considered the "true" distribution describing water quality EMCs for each BMP's inflow and outflow. Using the untransformed parent data sets of each analyte, an R studio shiny web application was made to derive subsets of data using a determined sample size. The number of events chosen for the subsets of data were created arbitrarily based on likely effort and number of sampled events (n) for the average BMP. If the BMP sampling effort was minimal, n would most likely equal a number as small as five. A more realistic number of sampled events would be ten or fifteen events, and ambitious sampling programs would monitor greater than fifteen events. Some of the data subsets sizes are unique to each dataset, because dataset reduction was dependent on parent dataset size.

Subsampling with replacement was done one hundred times for each analyte dataset, i.e., 100 data sets with n=5 were created from the parent data set, 100 data sets with n= 10 were created, and so on. The 10th, 25th, 50th, 75th and 90th quartiles of each analyte's EMC were calculated for each of the 100 subsampled datasets. The distribution of each quartile in comparison to the quartile value for the parent distribution was explored using R studio for data visualization.

Results and discussion

The inflow and outflow TSS EMC quartiles for one GSI site in EPA Rain Zone 2 is shown as an example of the results of the analysis. The data visualization suggests that the distribution of EMCs in each percentile show median values that approach the quartile value of the parent data set when at least 15 events are monitored (Figure 1). This was consistent throughout each analyte, inflow or outflow, and EPA rain zone investigated to date. The analysis suggests that sampling at least fifteen events could give you a reasonable representation of the EMC distribution of the parent data set.

Inflow EMC quartile distributions demonstrate greater variability amongst data subsets compared to outflow EMC quartile distributions. Untreated runoff is known to vary substantially from storm to storm, and site to site. Tighter distributions for the outflow EMCs suggest the GSI consistently treats runoff, regardless of the variation in inflow conditions.

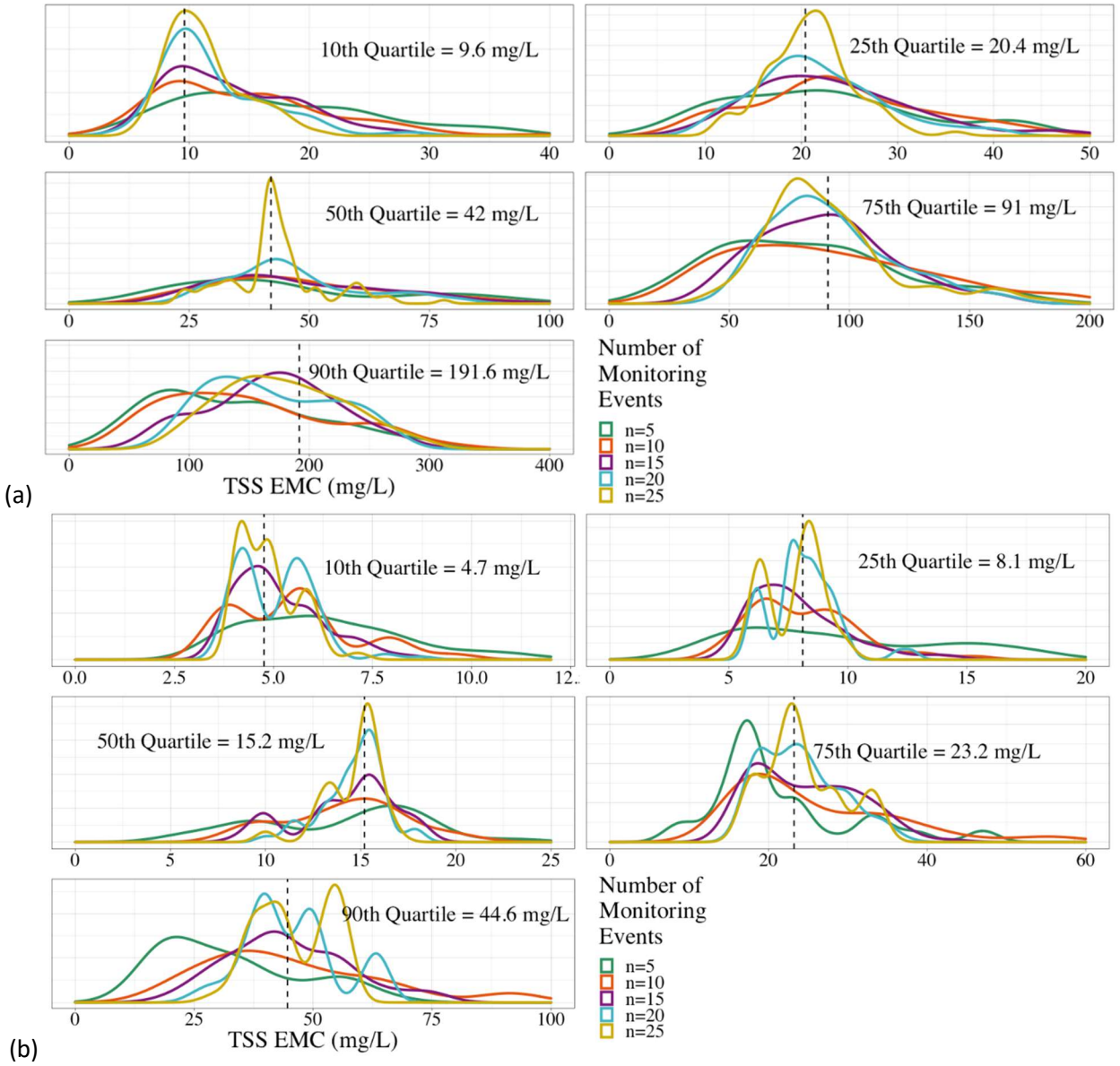

Figure 1: Distribution of dissolved TSS EMCs (mg/L) measured at a bioretention cell in EPA rain zone 2 (mid-Atlantic) for 10th ,20th ,50th ,75th and 90th quartiles of subsampled datasets. Dashed line indicates quartile of parent dataset (a) inflow EMCs (n=145), (b) outflow EMCs (n=34).

Conclusions and future work

Establishing a data-driven, standardized approach to determine minimum sampling effort allows performance to be evaluated robustly among various locations and climates, likely preventing GSI programs from over or under sampling while ensuring confidence in representative data. This study found the minimum number of monitoring events to be between 15-20 events for Copper, TSS and Total Phosphorus to reasonably represent the "true" distribution of water quality EMCs. We are now analyzing more data with different BMPs in different EPA rain zones to expand the results. Future work will also incorporate quantitative analysis of the differences in quartile results.