NCDOT Stormwater BMP Monitoring to Evaluate Metals Sampling Methodologies

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Background

- 2015: NC adopted new water quality standards for metals
- Criteria now expressed as dissolved fraction
- NCDOT Highway Stormwater Program (HSP) investigating how new standards might impact compliance activities
- HSP has metals sampling data from years of research projects, but limited data on dissolved metals
Purpose of Study

1) Evaluate different techniques for sampling dissolved metals in the highway environment

2) Develop Quality Assurance Project Plan (QAPP) for future dissolved metals monitoring efforts

3) Work with NC Division of Water Resources (DWR) to adopt an acceptable method for dissolved metals sampling from roadway runoff
Study Conception

• 2015: NC released new water quality standards for metals

> >>> Shift in criteria from total recoverable to dissolved

• NCDOT HSP already conducting joint research with North Carolina State University (NCSU) on bioswale performance

*Idea*: leverage existing research to develop a field study

*Goal*: evaluate potential impact of sampling technique on dissolved metals concentration
Field Study Design

• Joint study with NCSU to support development of NCDOT’s *programmatic strategy* for metals

  Tetra Tech conducted *grab sampling* in parallel with NCSU automatic sampling

• “Paired” samples collected at inlet and outlet of each bioswale

  First pair filtered immediately in field; second pair filtered 12-24 hours after collection

• Samples analyzed for *copper, lead, and zinc* (total & dissolved)
Dissolved Metals Sampling Protocols

• Current NCDOT/NCSU dissolved metals protocol:
  *Automatic sampling*
  Samples filtered upon receipt by analytical laboratory (~12-24 hour delay)

• Industry protocols for **ambient** dissolved metals sampling:
  *Manual (grab) sampling*
  “Clean hands/dirty hands” method\(^1\)
  Samples filtered within 15 minutes of collection\(^2\)

\(^1\)USEPA Method 1669 (USEPA 1996)
\(^2\)40 CFR Part 136 (USEPA 2007)
Key Study Question

Is there a statistical difference in dissolved metals concentration when samples are filtered immediately in the field versus 12-24 hours later?
Study Implications

• What are best practices for conducting dissolved metals monitoring for stormwater?

• Potential for modification of NCDOT sampling protocols for research and compliance activities moving forward
Expected Products

• Develop Quality Assurance Project Plan (QAPP) for metals to be added to HSP’s Programmatic QAPP

• Incorporate research data into NCDOT HSP’s research database - STORMDATA

Quality Assurance Project Plan

...
Study Sites

1) NCSU Sediment and Erosion Control Research and Education Facility (SECREF), Raleigh, NC
   ***controlled field site***

2) NC-50/NC-98 Interchange (“50/98”), near Bartons Creek, NC

3) I-40/I-95 Interchange (“40/95”), Benson, NC

Sampling conducted at 2 bioswales at each location.
What is a Bioswale?

A bioswale is an enhanced vegetated conveyance channel that features a specialized media to increase water quality treatment and infiltration.
SECREF Bioswales

“Bioswale 3”

forebay

HDPE inflow pipe

Simulated runoff (via surface pond)
SECREF Bioswales

“Bioswale 6”

forebay
SECREF Bioswales

Grab sampling procedure

- weir box
- sampling rod and collection bottle
40/95 Bioswales

“Bioswale N”

“Bioswale S”

rain gages

grate outlet
(underdrain)

forebay

inflow weir box
40/95 Bioswales

“Bioswale S”

“Bioswale N”

conditions during sampling event
40/95 Bioswales

“Bioswale S”

grate at outlet with weir box for underdrain sampling

“Bioswale S”
50/98 Bioswales

“Bioswale 2”

“Bioswale 4”

inlet weir

outlet (underdrain)

forebay
50/98 Bioswales

“Bioswale 2”

- Outlet (underdrain)
- Inlet weir
- Enclosure for autosamplers (NCSU)
50/98 Bioswales

“Bioswale 2”

“Bioswale 4”

conditions during sampling event

submerged inlet weir

forebay
Grab Sampling Methods

• Active flow must be occurring at inlet and outlet

• Grab samples collected at inlet first
  – Collection bottles placed in nappe of flow across weir

• For dissolved metals:
  – First sample ("IMM") filtered immediately (within 15 minutes)
  – Second sample ("DEL") filtered after 12-24 hour delay

• Samples handled using “clean hands/dirty hands” (USEPA 1996)
Sample Filtration in the Field
Data Analysis & Results
Initial Data Analysis

- Four storm events sampled at each bioswale site

- For each study site:
  - Combined data for both bioswales into a single dataset
  - Analyzed inlet and outlet data separately and together

- Used Hypothesis Testing (Student’s t-test) approach to answer the question:

  *Is there a statistical difference in dissolved metals concentration when samples are filtered immediately in the field versus 12-24 hours later?*
Initial Results

1) Significant difference in dissolved copper concentration between IMM and DEL samples for:
   - SECREF: inlet samples only (N=8), inlet and outlet samples combined (N=16)
   - 40/95: inlet samples only (N=8)
   - Field sites (40/95 and 50/98): inlet samples only (N=16)
   - All sites: inlet samples only (N=24), inlet and outlet samples combined (N=48)
Initial Results (continued)

2) No significant difference in dissolved copper concentration in outlet samples

3) No significant difference in dissolved lead or dissolved zinc concentrations at any sites
Additional Analysis

• Initial analysis suggests there is a statistical difference in dissolved copper concentration when samples are filtered immediately versus after a 12-24 hour delay.

• But… what is the magnitude of the difference?
Procedure

1) Combined dissolved copper data for all sites (N=48)

2) Analyzed data using two different linear regression models:
   – Ordinary Least Squares (OLS) regression
   – Deming regression

3) Estimated mean percent difference between IMM and DEL dissolved copper samples from slope of trendline
Example Results: Deming Regression

Dissolved Copper: Deming Regression
(All Sites; Inlet & Outlet Data (N = 48))

DEL = 0.943*IMM + 0.840
DEL = 0.971*IMM

1:1 line (IMM = DEL)
## Results

<table>
<thead>
<tr>
<th>Regression Model</th>
<th>Independent Variable (x)</th>
<th>Dependent Variable (y)</th>
<th>Slope</th>
<th>Intercept</th>
<th>Mean % Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLS</td>
<td>DEL</td>
<td>IMM</td>
<td>1.023</td>
<td>-0.634</td>
<td>2.3%</td>
</tr>
<tr>
<td>OLS</td>
<td>DEL</td>
<td>IMM</td>
<td>0.958</td>
<td>0</td>
<td>4.2%</td>
</tr>
<tr>
<td>OLS</td>
<td>IMM</td>
<td>DEL</td>
<td>0.913</td>
<td>1.029</td>
<td>8.7%</td>
</tr>
<tr>
<td>OLS</td>
<td>IMM</td>
<td>DEL</td>
<td>1.015</td>
<td>0</td>
<td>1.5%</td>
</tr>
<tr>
<td>Deming</td>
<td>neither</td>
<td>neither</td>
<td>0.943</td>
<td>0.840</td>
<td>5.7%</td>
</tr>
<tr>
<td>Deming</td>
<td>neither</td>
<td>neither</td>
<td>0.971</td>
<td>0</td>
<td>2.9%</td>
</tr>
</tbody>
</table>

Mean percent difference between IMM and DEL for dissolved copper is between **1.5 percent and 8.7 percent**.
Summary & Path Forward

• All regression models suggest a mean percent difference less than 9 percent between IMM and DEL dissolved copper concentrations.

• Findings of study suggest the additional cost and logistical complexity of grab sampling and field filtering are not warranted at this time, or at least until further information becomes available to suggest otherwise.

• After conclusion of field study, developed QAPP which prescribes automated sampling for future dissolved metals monitoring efforts by NCDOT and partners.
Quality Assurance Project Plan for Stormwater Metals Monitoring (DRAFT)

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8.0 MONITORING EXPERIMENTAL DESIGN

8.1 SAMPLING SITE SELECTION

Field monitoring locations shall be in areas where traffic load and right-of-way width do not present significant risk exposure to researchers and equipment. Additionally, field sites selected for monitoring must allow sufficient space for sampling instrumentation and equipment installation and for safe sample collection.

Refer to Section 9.2 (Sampling Site Selection) of the NCDOT Highway Stormwater Program GARP (NCDOT, 2015) for additional site selection considerations.

8.2 PARAMETERS OF CONCERN

Typical parameters of concern (POCs) for stormwater metals monitoring, accepted analytical methods (per USEPA), and sampling charters are summarized in Table 6.1. Proposed specific POCs should be determined at project initiation and be agreed upon by NCDOT and the project team.

Table 6-1. Typical parameters of concern for stormwater metals monitoring.

<table>
<thead>
<tr>
<th>Parameter of Concern</th>
<th>Analytical Method</th>
<th>Reporting Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cadmium</td>
<td>EPA Method 300.001</td>
<td>0.5 μg/L</td>
</tr>
<tr>
<td>Copper</td>
<td>EPA Method 300.001</td>
<td>0.5 μg/L</td>
</tr>
<tr>
<td>Lead</td>
<td>EPA Method 300.001</td>
<td>2 μg/L</td>
</tr>
<tr>
<td>Zinc</td>
<td>EPA Method 300.001</td>
<td>10 μg/L</td>
</tr>
</tbody>
</table>

8.3 REPRESENTATIVE STORMS

For the NCDOT Highway Stormwater Program GARP (NCDOT, 2013), "It is highly recommended that NCDOT has a representative storm much past at least 2.5 inch of precipitation, and, preferably, the total precipitation and duration be within 5% of the average or median storm event for the area (USEPA, 1999, NCDOT, 2005). Where the scale of work identifies a certain number of storms that need to be monitored, only representative storms shall count towards this number."

It is essential a storm event when sampling will occur, a minimum of two independent weather forecasting services should be consulted. First, the National Centers for Environmental Information (NCEI) National...
Thank You!!

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