Chemical and Biological Contamination of Stormwater Detention Ponds in Coastal South Carolina

John E. Weinstein
Kevin D. Crawford
Thomas R. Garner

1Department of Biology, The Citadel
2Department of Chemistry, University of Wisconsin-Oshkosh
Stormwater Detention Ponds

- **Common BMP**
  - enhance aesthetics and property values, open space

- **Protect natural receiving waters by controlling the quantity and quality of runoff**

- **Trap suspended sediment**
  - many contaminants are sediment-bound

- **Sediments slowly fill ponds**
Stormwater Detention Ponds

- Reduction in efficiency
- Periodic sediment removal recommended
- No requirement of testing for chemical or biological sediment contaminants
- >8,000 stormwater ponds
Critical Gaps

- How contaminated are bottom sediments in typical coastal stormwater ponds?
- Do these contaminants pose ecological and human health risks?
1. Collect and analyze sediments for chemical and biological contamination

2. Model relationships between contaminant levels and physical characteristics of pond

3. Identify stormwater ponds with contaminant levels that may pose risk.
Stormwater Pond Sediment Project - Methodology

• Sampled 18 Ponds
  – June 2007
  – Classified based on land use

• Analyzed Sediments
  – TOC, Grain size, and % Moisture
  – PAH
  – Metals
  – Pesticides
  – PBDEs
  – Fecal Coliform
Field Methods

- Surveyed 16 stormwater ponds and 2 reference
  - Collection Locations
    - Pond Inlet (A)
    - Pond Center (B)
  - Ekman Grab
  - Homogenized using a Stainless Steel Bucket and Spoon
Stormwater Ponds

**Reference**
- Willow Swamp Road (FMNF) (R1)
- Dill Plantation (R2)

**Golf Course**
- Indigo Run (80)
- Arrow Head C.C. (62)
- Traditions G.C. (57)

**Residential-LD**
- Daniel Island (89)
- Pawleys Place (31)
- Whitehall Plantation (109)
- Ashton Glenn (24)
- Ricefields (38)

**Residential-HD**
- Sable Palm Apts. (7)
- Canterbury (44)

**Commercial**
- Wal-Mart, J.I. (70)
- Tanger Outlets, H.H. (48)
- M.B. Chevrolet (26)
- Riverland Woods (68)
- Toys R Us, M.B. (83)
- Nascar Speed Track (87)
Analytical Methods

PAHs
- 16 priority pollutants
  - HPLC-FD

Metals
- Al, Cd, Cu, Fe and Zn
  - flame atomic absorption
- Cr and Pb
  - graphite furnace atomic absorption
Analytical Methods

Pesticides
  – 30 analytes
    • GC-MS

PBDEs
  – 6 isomers
    • GC-MS

Fecal coliform
  – multiple tube technique
Polycyclic Aromatic Hydrocarbons
Polycyclic Aromatic Hydrocarbons (PAHs)
\[ \sum \text{PAH}_{\text{LMW}} \]

Inlet

\[ \text{REF} \] \[ \text{GC} \] \[ \text{RLD} \] \[ \text{RHD} \] \[ \text{COM} \]

Inlet

\[ \text{Cente} \]

\[ \text{REF} \] \[ \text{GC} \] \[ \text{RLD} \] \[ \text{RHD} \] \[ \text{COM} \]
<table>
<thead>
<tr>
<th>Location</th>
<th>Pond type/Age</th>
<th>Land Use</th>
<th>ΣPAH$_{16}$ (ng/g d.w.)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ontario, Canada</td>
<td>Wet Detention/10 yrs</td>
<td>Commercial</td>
<td>16,370</td>
<td>Marsalek et al., 2002</td>
</tr>
<tr>
<td>Minneapolis, MN</td>
<td>Variety</td>
<td>Variety</td>
<td>227-26,230</td>
<td>Polta et al., 2006</td>
</tr>
<tr>
<td>Clearwater, FL</td>
<td>Wet Detention/20 yrs</td>
<td>Residential</td>
<td>592,000</td>
<td>Fernandez &amp; Hutchinson, 1992</td>
</tr>
<tr>
<td>Largo, FL</td>
<td>Wet Detention/30 yrs</td>
<td>Commercial</td>
<td>7,161,000</td>
<td>Fernandez &amp; Hutchinson, 1992</td>
</tr>
<tr>
<td>Coastal SC</td>
<td>Wet Detention/4-12 yrs</td>
<td>Commercial</td>
<td>mean=24,371 (high=159,041)</td>
<td>This study</td>
</tr>
</tbody>
</table>
Metals
Copper

Inlet

Cente

REF  GC  RLD  RHD  COM

Cu (mg/kg dry weight)
Other findings…

• Cu, Pb and Zn levels were higher in clay-rich pond centers
• Al and Cd levels were higher near the sand-rich pond inlets
# Metals Perspective

<table>
<thead>
<tr>
<th>Metal</th>
<th>Previous studies (mg/kg)</th>
<th>Current Study (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>4,542-15,799</td>
<td>927-26,977</td>
</tr>
<tr>
<td>Cd</td>
<td>0.45-4.1</td>
<td>&lt;1.5-4.2</td>
</tr>
<tr>
<td>Cr</td>
<td>10.5-83.1</td>
<td>&lt;8-56.1</td>
</tr>
<tr>
<td>Cu</td>
<td>2.5-355.7</td>
<td>&lt;5-589.6</td>
</tr>
<tr>
<td>Fe</td>
<td>8,934-38,406</td>
<td>520-15,050</td>
</tr>
<tr>
<td>Pb</td>
<td>4.8-930</td>
<td>&lt;1-13.8</td>
</tr>
<tr>
<td>Zn</td>
<td>17.3-2,605</td>
<td>&lt;1-572.7</td>
</tr>
</tbody>
</table>
Pesticides

- Organochlorides
  - 15 analytes
- Organophosphates
  - 15 analytes
Chlorpyrifos (Dursban®)

Chlorpyrifos (ng/g dry weight)

REF  GC  RLD  RHD  COM

Inlet  Cente
PBDEs

- Polybrominated diphenyl ethers
- Flame retardants
  - furniture, clothes, TV, computers, toasters, etc.
- Ubiquitous
Fecal Coliforms
Sediment Fecal Coliform

Inlet vs. Center

Fecal Coliform (MPN/g)

- REF
- GC
- RLD
- RHD
- COM
Sediment Fecal Coliform

![Graph showing Fecal Coliform levels in different settings]

- **Reference**: Low Density Golf Course, Commercial
- **Res. Low Density**: Various labels (80A, 80B, 82A, etc.)
- **Res. High Density**: Various labels (82B, 82A, 80B, etc.)
- **Commercial**: Various labels (87A, 87B, 88A, etc.)

**Fecal Coliform (MPN/g dry weight)**

- Maximum value: 19,400
## Sediment Fecal Coliform Perspective

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Location</th>
<th>Fecal Coliform Levels</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estuarine sediments</td>
<td>New Orleans, LA</td>
<td>16.8-87.5 MPN/g</td>
<td>Jeng <em>et al.</em>, 2005</td>
</tr>
<tr>
<td>Recreational beaches</td>
<td>Lake Huron, MI</td>
<td>1-10 CFU/g</td>
<td>Alm <em>et al.</em>, 2002</td>
</tr>
<tr>
<td>River/Cattle grazing</td>
<td>Flagstaff, AZ</td>
<td>0-11,000 CFU/g</td>
<td>Crahill <em>et al.</em>, 1999</td>
</tr>
<tr>
<td>Dredge material</td>
<td>Upper Mississippi River</td>
<td>82-4,200 MPN/g</td>
<td>Grimes, 1980</td>
</tr>
<tr>
<td>Marinas</td>
<td>Lake Texoma, TX</td>
<td>35,000-500,000 CFU/g</td>
<td>An <em>et al.</em>, 2002</td>
</tr>
<tr>
<td>Sludge</td>
<td>Winnipeg, Canada</td>
<td>6,600,000-21,000,000 MPN/g</td>
<td>Bujoczek <em>et al.</em>, 2001</td>
</tr>
<tr>
<td>Stormwater detention ponds</td>
<td>coastal SC</td>
<td>254-19,400 MPN/g</td>
<td>This study</td>
</tr>
</tbody>
</table>
Screening Assessments

• Ecological
  – ARCS (EPA 1996)
    • Threshold Effect Concentration (TEC)
    • Probable Effect Concentration (PEC)
  – EPA Region 4
    • Sediment screening values (SSV)

• Human Health
  – EPA Region 9
    • Preliminary Remediation Goal (PRG)

*In situ vs. post-removal fill assessments*
Summary – Metals PEC

PEC Exceedances (%)

Reference | Golf Course | Res. Low Density | Res. High Density | Commercial

R1A | R2A | R1B | R2B | 80A | 80B | 82A | 82B | 57A | 57B | 89A | 89B | 31A | 31B | 109A | 109B | 24A | 24B | 38A | 38B | 7A | 7B | 44A | 44B | 70A | 70B | 48A | 48B | 26A | 26B | 68A | 68B | 83A | 83B | 87A | 87B
Results

• Commercial ponds had higher levels of PAH, Cu, Pb and Zn than various other land use classes

• Residential and golf course ponds generally had levels of contaminants similar to reference ponds

• Contaminants associated with vehicular use
Results

• Pesticides were detected in pond sediments, but independent of current land use

• Fecal coliform levels were generally similar to reference pond sediments
Results

- PAHs in stormwater pond sediments are the contaminant of greatest concern.
- Sediment from contaminated ponds exceeded several toxicological benchmarks for both ecological and human health.
Recommendations

1. Commercial ponds, and residential ponds with large watershed sizes, should be tested for sediment contaminants prior to removal to determine the appropriate method for sediment disposal.
Recommendations

2. During sediment removal, stormwater ponds should be cut off from their receiving body in order to protect downstream biota from exposure to resuspended, contaminated materials.
Recommendations

3. Enforcement of maintaining pond efficiencies, including periodic sediment removal, may be necessary to prevent stormwater ponds from achieving the contaminants levels observed in older Florida ponds.
Acknowledgements

• SCDHEC-OCRM
  – Sadie Drescher
  – Mark Messersmith
• SC Sea Grant Consortium
  – Denise Sanger
• The Citadel Foundation
• Students
  – Gavin Globensky, Colby Swank, Leigh Thackston, and Kyle Williams

For more information: john.weinstein@citadel.edu