Evaluation of Leaf Collection as a Means to Reduce Nutrient Loads from Urban Basins

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Background

• Strong public interest to keep lakes fishable and swimmable
  – Beach closures (algal blooms)
  – Invasives
• Federal/State pollutant restrictions
  – Rock River TMDL for Total P
Adaptive Management Approach To Reduce Phosphorus to Area Lakes

- Approximately 30 partners
- Addresses municipal/industrial wastewater plants, municipal stormwater, and agricultural runoff
- Evaluates wide range of practices, both agricultural and urban
Pilot Study: Urban Phosphorus Reduction through Leaf Collection

- **Leaf collection** identified as reasonable measure to reduce total phosphorus delivered to lakes
- What percent phosphorus reduction can MS4s expect by collecting leaves?
- Are some leaf collection practices better than others?

Photo credit: City of Woodstock, IL

[Image of leaf collection truck and workers]
Four Study Basins in Madison, WI

<table>
<thead>
<tr>
<th>Study Basin</th>
<th>Source Area</th>
<th>Yellowstone</th>
<th>East Kenosha</th>
<th>West Kenosha</th>
<th>Gray Fox</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (ac.)</td>
<td>15.9</td>
<td>3.0</td>
<td>2.5</td>
<td>9.1</td>
<td></td>
</tr>
<tr>
<td>Streets</td>
<td>17%</td>
<td>19%</td>
<td>17%</td>
<td>14%</td>
<td></td>
</tr>
<tr>
<td>Driveways</td>
<td>6%</td>
<td>4%</td>
<td>5%</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>Roofs</td>
<td>17%</td>
<td>19%</td>
<td>16%</td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td>Sidewalks</td>
<td>5%</td>
<td>3%</td>
<td>4%</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Lawns/Open</td>
<td>55%</td>
<td>54%</td>
<td>58%</td>
<td>63%</td>
<td></td>
</tr>
<tr>
<td>Other Impervious</td>
<td>&lt;1%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Tree Cover</td>
<td>45%</td>
<td>68%</td>
<td>57%</td>
<td>26%</td>
<td></td>
</tr>
</tbody>
</table>
Measurement of Phosphorus in Water

Photo credit: USGS

Photo credit: USGS
Measurement of Phosphorus in Gross Solids (leaves)

Photo credit: USGS
Mean Monthly Total Phosphorus Concentration, in mg/l

- E. Kenosha (2013-2014)

No Leaf Collection or Street Cleaning

April - May - June - Aug - Sept - Oct - Nov
Municipal efforts included weekly collection of leaf piles followed by high-efficiency street cleaning October – November 2015
In addition to municipal efforts, USGS field crews would clear all organic debris from street surface prior to rain event.
Before Leaf Blowing

After Leaf Blowing

Photo credit: USGS
2015 Mean Monthly Phosphorus Yield

- **Yellowstone (Control)**
- **E. Kenosha (Test)**

**Graph Details**
- **Axes:**
  - **Y-axis:** Mean Phosphorus Yield (lbs./acre)
  - **X-axis:** Months of the year
- **Colors:**
  - Orange: Yellowstone (Control)
  - Dark Blue: E. Kenosha (Test)

**Data Points**
- April, May, June, July, August: Lower values
- September, October, November: Higher values, particularly October with a significant peak

**Photographs**
- Control – 11/10/15
- Test – 11/11/15

**Photo Credit:** USGS

**Preliminary Information:**
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Seasonal Total Phosphorus Load as a Percent of the 2015 Annual Load (winter excluded)

Yellowstone (Control)
- Spring: 14%
- Summer: 26%
- Fall: 60%

E. Kenosha (Test)
- Fall: 16%
- Spring: 22%
- Summer: 62%

[3] = Number of events
Most of the phosphorus measured in the fall is dissolved.

Leaf collection may be one of the only options to reduce dissolved phosphorus since structural controls will not address the dissolved fraction.
Paired Basin Status
Total Phosphorus Concentration (Log), in mg/L

Spring/Summer 2015

Fall 2015

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## Percent Reduction in Nutrient Concentrations 2015

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Spring/Summer</th>
<th>Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Suspended Solids</td>
<td>--(1)</td>
<td>--</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>--</td>
<td>-80(^{(2)})</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>--</td>
<td>-31</td>
</tr>
<tr>
<td>Total Organic Carbon</td>
<td>--</td>
<td>-76</td>
</tr>
<tr>
<td>Dissolved Phosphorus</td>
<td>--</td>
<td>-84</td>
</tr>
<tr>
<td>Dissolved Nitrogen</td>
<td>--</td>
<td>-39</td>
</tr>
<tr>
<td>Dissolved Organic Carbon</td>
<td>--</td>
<td>-77</td>
</tr>
</tbody>
</table>

(1), no statistical change  
(2), A negative value indicates percent reduction
Cumulative Mass of Leaves on Streets

Leaf Collection Dates

Rainfall
Landfall 2015
Gray Fox 2015
Kenosha 2015

Preliminary Information – Subject to Revision. Not for Citation or Distribution
Estimating Phosphorus Load in Runoff from Leaf Mass on Streets

$y = a(1-\exp(-bt))$

Red Maple:

$a = 0.40$

$b = 1.44$

Solid and dashed lines represent leaching at 20° and 4° Celsius, respectively.

Duan et al. (2014)

Preliminary Information – Subject to Revision. Not for Citation or Distribution
What we know...

- Up to 60% of the annual phosphorus load can occur from leaf litter in the fall
- Phosphorus is primarily dissolved in Fall. Leaf collection may be one of only a few management options
- Removal of leaves from streets can reduce nutrient concentrations by 80%, BUT....
  - Timing of leaf collection is critical to significant phosphorus reduction

Photo credit: USGS
What we’re still learning...

- What factors control phosphorus leaching from leaves over time?
- Will municipal leaf collection strategies have any measurable benefit?
  - Vacuum mulching
  - Bagging
  - Transfer
  - Other
- Are certain geographic areas in a city more prone to high phosphorus loading?
  - Tree density
  - Species
  - Land use

Photo credit: USGS