Methods of Measuring Nutrient Spiraling in Urban Streams

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Introduction:
Rapid urban development is occurring in many areas of the USA, and is accompanied by dramatic changes in stream ecosystems. Urban development results in alteration of natural waterways by channelization, diversion, or impoundment to meet competing needs of flood protection and water delivery. Furthermore, urban streams are subject to increased nutrient loading via runoff from fertilized areas and impervious surfaces. Given these changes, there is a need to study how urban streams transport and transform nutrients that are delivered to them, and how the efficiency of nutrient retention differs from better-studied, non-urban streams.

Urbanization is especially rapid in warm desert regions of the Southwest. The Phoenix (AZ) metropolitan area is now the 5th largest in the country and consistently reports high rates of population growth. Albuquerque, NM, also is experiencing intense urbanization. Both cities developed along large, desert rivers that have been highly altered over the past century.

Objectives:
- Examine nitrate uptake in five urban streams of Phoenix, AZ and Albuquerque, NM.
- Determine NO₃⁻ uptake lengths using 3 different methods.
- Evaluate the three methods to determine which provides the best measure of nutrient uptake in urban streams from the CAP-LTER region.

Nutrient Spiraling Theory:
- Spirals are used to describe the cycling and downstream transport of nutrients in streams.

Uptake length (Sₚ) is defined as the average distance (in meters) that a nutrient molecule travels downstream before it is taken up, or assimilated by the biota of the stream. Sw can be determined graphically by plotting the concentration against downstream distance for a given stream.

Uptake lengths can be determined from:
- background changes in nutrient concentration
- short-term nutrient enrichment injections
- injections using stable isotopes.

Natural changes in background NO₃⁻:
- Natural declines reflect net result of release and uptake processes.
- Ten streams sampled for longitudinal NO₃⁻ profiles (data only shown for 5).
- Plot of NO₃⁻ corrected for dilution versus distance.
- Sw from natural declines usually higher than with nutrient additions.

Short-term NO₃⁻ enrichment:
- Short-term enrichment experiments reflect gross uptake.
- Five streams sampled longitudinally for NO₃⁻ before and after a 2-4 hr injection of KNO₃.
- Plot of NO₃⁻ corrected for background and dilution versus distance.

Injections with ¹⁵NO₃⁻:
- ¹⁵NO₃⁻ injections represent 'actual' uptake because background NO₃⁻ is only slightly elevated.
- Three streams sampled for ¹⁵NO₃⁻ before and after a 2-4 hr injection of KNO₃.
- Plot of ¹⁵NO₃⁻ corrected for background and dilution versus distance.

Sw ranged from 294m to 1274m
Sw in concrete channels was higher than in earthen channels.
Sw from nutrient additions was shorter than those from natural declines.
Due to increased NO₃⁻ levels during additions, ambient uptake conditions may be altered.

Conclusions:
- Sw may be influenced by channel type in urban streams.
- Using natural declines to determine Sw is not reliable when used over multiple sites.
- Isotope method gives closest 'actual' Sw, but is too costly to use for multiple sites.
- High NO₃⁻ levels and channel modifications may lead to a condition of saturated uptake kinetics with respect to NO₃⁻ in urban streams.
- As a result, Sw from nutrient additions may reflect the 'actual' Sw value in urban systems.

Summary of Results:

<table>
<thead>
<tr>
<th>Site</th>
<th>Channel type</th>
<th>NO₃⁻ (µg-N/L)</th>
<th>Sₓ (m)</th>
<th>Sᵧ (m)</th>
<th>Sᵧ (m%)</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR</td>
<td>Earthen</td>
<td>18</td>
<td>759</td>
<td>294</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>IBW</td>
<td>Earthen</td>
<td>100</td>
<td>357</td>
<td>555</td>
<td>357</td>
<td></td>
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<tr>
<td>HL</td>
<td>Concrete</td>
<td>6100</td>
<td>3164</td>
<td>1274</td>
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<td></td>
</tr>
<tr>
<td>GB</td>
<td>Earthen</td>
<td>1200</td>
<td>3333</td>
<td>526</td>
<td>526</td>
<td>N/A</td>
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<tr>
<td>PB</td>
<td>Concrete</td>
<td>5200</td>
<td>1000</td>
<td>833</td>
<td>833</td>
<td>N/A</td>
</tr>
</tbody>
</table>

ND = natural decline; NA = nutrient addition; % = isotope injection

Nutrient addition or ¹⁵N?

<table>
<thead>
<tr>
<th>Site</th>
<th>NO₃⁻ (µg-N/L)</th>
<th>Sw (m)</th>
<th>Sw (m%)</th>
<th>Sw (m%)</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR</td>
<td>18</td>
<td>91</td>
<td>357</td>
<td>292%</td>
<td></td>
</tr>
<tr>
<td>IBW</td>
<td>100</td>
<td>357</td>
<td>555</td>
<td>55%</td>
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</tr>
<tr>
<td>HL</td>
<td>6100</td>
<td>1274</td>
<td>1274</td>
<td>0.8%</td>
<td></td>
</tr>
</tbody>
</table>

As background NO₃⁻ increases, agreement of Sw between Nutrient Additions and ¹⁵N decreases.
Na = nutrient addition; N = isotope injection

Implications:
- Sw may be measured using stable isotopes.
- Using natural declines to determine Sw is not reliable when used over multiple sites.
- Isotope method gives closest 'actual' Sw, but is too costly to use for multiple sites.
- High NO₃⁻ levels and channel modifications may lead to a condition of saturated uptake kinetics with respect to NO₃⁻ in urban streams.
- As a result, Sw from nutrient additions may reflect the 'actual' Sw value in urban systems.