Fate of Industrial Nitrogen in an Alluvial Aquifer

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Plant Location
HISTORIC SITE PLAN
Blue Squares = residual N  Pink Squares = residual metals  Green Square = residual N and metals
STUDY PURPOSE

♦ Investigate groundwater contamination and geochemistry in an alluvial aquifer

♦ Evaluate monitored natural attenuation (MNA)
  • Demonstrate that natural processes are removing contaminants from groundwater
  • Demonstrate it is taking place at a rate that is protective of human health and environment

♦ Direct assessment of Bow River impacts by the contaminated groundwater
METHODS

- Historical data review
- Water sampling (flood period)
- River and groundwater N mass flux estimates
- Hyporheic zone sampling
♦ Silt overlying fluvial sands and gravels overlying bedrock (Paskapoo Formation)
  • Bedrock depth varies from 4 to 14 m bgs

♦ Groundwater hydraulically connected with surface water as evident in:
  • Piper plots
  • Water table fluctuations associated with river stage

♦ Water depth varies from 1.5 to 5.5 m bgs

♦ Hydraulic Conductivity on order of $10^{-3}$ m/s
RESULTS

♦ NH₃ & NO₃⁻ concentration & mass decreasing over time

♦ 11 of 22 wells above NH₃ chronic FAL criteria and 17 of 22 wells above NO₃⁻ FAL criteria (April 2006)

♦ Maximum estimated time to reach criteria is 24 years for NH₃ and 16 years for NO₃⁻ (in MW29)
CONCENTRATION DECREASE – MW11

Graph showing the concentration of NH₃ and NO₃ over time from Jan-97 to Jan-06, with sampling dates indicated. The graph includes lines for NH₃, NH₃ chronic criteria, Expon. (NH₃), NO₃, NO₃ dw criteria, and Expon. (NO₃).
Spring flooding causes periods of high river discharge and high water table in wells

- Initiates nitrification (MW25, MW26, MW28 & MW29)
  - Nitrification is biological oxidation of ammonia to nitrate
  - Aerobic reaction
- Source area continuing to release residual nitrogen (MW7, MW8, MW9, MW11, MW17 & 5-9)
NITRIFICATION

NH$_3$

NO$_3^-$

Sampling Date

MW25

MW29

Discharge
SOURCE AREA

- NH₃
- NO₃⁻

Sampling Date

Q (m³/s)

Discharge

MW11

04-5-9
HYPODERMIC SAMPLING LOCATIONS
GROUNDWATER IMPACTS ON RIVER

- Elevated NH$_3$ & NO$_3^-$ concentrations in hyporheic groundwater
  - up to 21 and 45 mg-N/L, respectively,
  - spatially variable
  - evidence of paleochannels

- NH$_3$ & NO$_3^-$ concentrations in Bow River consistently below criteria
  - During hyporheic sampling
  - Long term monthly sampling program
BOW RIVER SAMPLING LOCATIONS
RIVER MASS FLUX ESTIMATES

- Significant increase in mass fluxes of Cl⁻, NH₃ and NO₃⁻ from background to WWTP

- Not significant difference observed from the site
  - suggests discharge of nitrogen-rich groundwater does not have as measurable an effect as wastewater effluent

<table>
<thead>
<tr>
<th>Bridge</th>
<th>Km from WWTP outfall</th>
<th>Q</th>
<th>NH₃</th>
<th>NO₃⁻</th>
<th>Cl⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odgen</td>
<td>-1.0</td>
<td>122 - 145</td>
<td>0.039 - 0.043</td>
<td>1.5 - 1.8</td>
<td>36 - 43</td>
</tr>
<tr>
<td>Glenmore</td>
<td>2.6</td>
<td>137 - 162</td>
<td>0.74 - 0.88</td>
<td>6.5 - 7.6</td>
<td>64 - 75</td>
</tr>
<tr>
<td>Southland</td>
<td>5.3</td>
<td>130 - 154</td>
<td>0.51 - 0.60</td>
<td>7.4 - 8.7</td>
<td>70 - 82</td>
</tr>
<tr>
<td>Douglasdale</td>
<td>8.9</td>
<td>116 - 138</td>
<td>0.34 - 0.39</td>
<td>4.3 - 5.1</td>
<td>53 - 61</td>
</tr>
</tbody>
</table>
GROUNDWATER MASS FLUX ESTIMATES

<table>
<thead>
<tr>
<th>Ammonia (kg/d)</th>
<th>Nitrate (kg/d)</th>
<th>Chloride (kg/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>2005</td>
<td>Δ(%)</td>
</tr>
<tr>
<td>1998</td>
<td>2005</td>
<td>Δ(%)</td>
</tr>
<tr>
<td>1998</td>
<td>2005</td>
<td>Δ(%)</td>
</tr>
</tbody>
</table>

Transect 1

| Transect 1 | 13.3  | 2.5  | 81   | 2.9  | 1.5  | 48   | 11.8 | 8.8  | 25   |

Transect 2

| Transect 2 | 41.8  | 26.1 | 38   | 15.6 | 9.5  | 39   | 74.0 | 77.7 | -5   |

♦ <1% of WWTP effluent nitrogen (~4,000 and 8,160 kg/d) in the Bow River
CONCLUSIONS

- MNA could be an acceptable alternative for GW remediation
  - Decreasing mass and concentration due to non-destructive (i.e. dilution) and destructive processes (i.e. nitrification)
  - Demonstrated little effect on main receptor (Bow River) as compared to WWTP effluent
RECOMMENDATIONS

♦ Allow natural attenuation to remediate site

♦ Continued research
  • Improve river mass flux estimations
    → add Deerfoot bridge
    → improve velocity-area methodology
    → integrate diurnal fluctuations in river concentrations
  • Evaluate nitrification and potentially denitrification via
    weekly/monthly sampling of multi-level piezometers
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