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Transport of contaminants in an agricultural catchment during snowmelt: buffer strips vs. preferential flow paths

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Objective

- The primary objective was to better understand the flow paths that affect the fluxes of dissolved compounds from a small agricultural catchment during snowmelt.

- We focused on spring snowmelt, because this is the dominant hydrological event in many moderate and high latitude catchments and, thus, is a prominent factor influencing the quality of surface waters.
• Catchment area 187 ha
• Elevation range 26 m - between 118 and 142 m a.s.l.
• Slope 2-6%

6 snowmelts between 2009 and 2011

Sample Collection
• Stream water - 2-4 times a day
• Snowmelt - snow lysimeter
• Soil water – vacuum soil moisture samplers
• groundwater

Water samples: EC, pH, Ca$^{2+}$, Mg$^{2+}$, NH$_4^+$, SO$_4^{2-}$, NO$_3^-$, Cl$^-$, SiO$_3^{2-}$, PO$_4^{3-}$.
Identification of Conservative Tracers & Number of End-Members - Bivariate plots for Cl and Ca; PCA for the event of January 21–27

S – snowpack
OF- overland flow
SS – soil solution beneath cropland adjacent to the stream
SGW – shallow groundwater beneath cropland adjacent to the stream
SGS – an average chemistry of saturated mineral soils, situates in the near-stream location (virtual end-member)
WGW – groundwater of near stream wetlands
BASE – deeper groundwater contributing to stream base flow
3 end-members – their share?

Overland flow

Shallow soil/groundwater

Deeper groundwater

hydrograph separation
only a small percentage (5-7%) of the landscape generated subsurface water flow that contributed to the stream discharge.
Observed and EMMA model-predicted loads of solutes in stream outflow during 7 days high flow event

<table>
<thead>
<tr>
<th></th>
<th>NO$_3^-$</th>
<th>NH$_4^+$</th>
<th>PO$_4^{3-}$</th>
<th>Ca$^{2+}$</th>
<th>Mg$^{2+}$</th>
<th>Cl$^-$</th>
<th>SO$_4^{2-}$</th>
<th>SiO$_3^{2-}$</th>
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<tbody>
<tr>
<td></td>
<td>[m$^3$]</td>
<td>[kg]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>observed</td>
<td>5695.7</td>
<td>88</td>
<td>3.3</td>
<td>3.1</td>
<td>391</td>
<td>86</td>
<td>123</td>
<td>285</td>
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<tr>
<td>predicted</td>
<td>5784.4</td>
<td>93</td>
<td>4.1</td>
<td>2.9</td>
<td>415</td>
<td>85</td>
<td>126</td>
<td>270</td>
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<tr>
<td>percentage share [%]</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Overland flow</td>
<td>41</td>
<td>27</td>
<td>40</td>
<td>93</td>
<td>11</td>
<td>19</td>
<td>22</td>
<td>7</td>
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<tr>
<td>Shallow groundwater</td>
<td>13</td>
<td>61</td>
<td>42</td>
<td>5</td>
<td>18</td>
<td>15</td>
<td>30</td>
<td>20</td>
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<tr>
<td>Base flow</td>
<td>46</td>
<td>11</td>
<td>17</td>
<td>2</td>
<td>71</td>
<td>66</td>
<td>48</td>
<td>73</td>
</tr>
</tbody>
</table>
Larger Narew River, spring 2002

60 m$^3$s$^{-1}$

9 m$^3$s$^{-1}$
In the space of a few weeks, the Narew River (2002) transports more than 90% of its annual load of $\text{NO}_3^-$, ca. 70% of $\text{SO}_4^{2-}$ and 50-60% of P.
Conclusion: „buffer” strips in early spring

- fluxes of contaminants bypass potential structures or buffers that could constrain their impact on the freshwater ecosystems

or

- existing buffers are ineffective in removing contaminants moving along shallow hydrological pathways

Short period of snowmelt in early spring - critical for the riverine ecosystems.

Export of solutes may be little affected by the vegetation of the buffer strips because the vegetation is in a dormant phase. Tree and grassland strips - barrier for sediment-bound nutrients.
through which substances bypass retention zones and are conveyed directly and quickly to the aquatic system (Haag and Kaupenjohann, 2001, changed)
landscape-scale preferential flow.
tile drain network

http://www.extension.umn.edu/DrainageOutlet/QandA.html

http://www.omafra.gov.on.ca/english/engineer/facts/10-091.htm
Soil fauna

Mole *Talpa europaea* – build up the tunnel system (6 cm in diameter) at the depth of 20–50 cm. Total length of the tunnel network is 100–200 m (up to 1 km) /2000–6000 m²
Conclusion cont.

• buffer strips proposed in the European Codes of Good Agricultural Practices cannot be regarded as a panacea.

• Concept of buffer strips in control of diffuse contaminants needs to be refined, developed and formalized through combination of rigorously defined field experiments and realistic mathematical models.
technical solutions

Controlled drainage, also known as drainage water management,

Two-Stage Ditches with Constructed Floodplains
but enhanced emission of N$_2$O