Nitrate Occurrence in Groundwater in Southern Ontario: A Review

Shoaib Saleem, Jana Levison, Beth Parker, and Ralph Martin

School of Engineering, University of Guelph, Guelph, Ontario, Canada
Plant Agriculture, University of Guelph, Guelph, Ontario, Canada

Introduction

- Groundwater is the essential source of water for about 30% of the population in Ontario and most rural communities entirely depend on groundwater for their water supply.
- Farm productivity and profitability have increased over the last few decades due to advancements in agricultural technologies and improved farming practices. However, high nutrient application rates to keep up with the production goals have also increased the risk of groundwater contamination.
- Excess nutrients, especially nitrogen, can leach down in the form of nitrate and adversely impact groundwater quality.
- Many studies have been conducted in southern Ontario to evaluate the impact of nitrate on groundwater quality in different hydrogeological settings.

Objectives

- The objective of this study is to provide a complete comparison of previous nitrate contamination studies in southern Ontario with various studies in Canada and internationally.
- The review is coupled with GIS analysis to investigate geospatial conditions in southern Ontario related to groundwater nitrate occurrence.
- Directions for future research to investigate the most vulnerable hydrogeologic settings related to nutrient applications, cropping systems and climate change scenarios for nitrate transport in groundwater are presented.

Groundwater Nitrate Studies in Southern Ontario

- Various studies have been conducted across southern Ontario to highlight the widespread presence of nitrate in groundwater wells (Table 1). Table 1. Descriptive statistics of nitrate-N (mg L⁻¹) for different studies in southern Ontario (spatial coordinates available).

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of Sites</th>
<th>&lt;0.5</th>
<th>0.5-1</th>
<th>1-10</th>
<th>&gt;10</th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
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<tr>
<td>Tecumseh, 2002</td>
<td>25</td>
<td>12</td>
<td>1</td>
<td>0</td>
<td></td>
<td>1.86</td>
<td>0.07</td>
<td>8.26</td>
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<tr>
<td>Levison and Novakowski, 2004</td>
<td>47</td>
<td>1</td>
<td>3</td>
<td>39</td>
<td></td>
<td>6.35</td>
<td>0.1</td>
<td>37.5</td>
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<tr>
<td>Levison, 2007</td>
<td>33</td>
<td>1</td>
<td>6</td>
<td>26</td>
<td></td>
<td>2.05</td>
<td>0.6</td>
<td>5.0</td>
</tr>
<tr>
<td>Levison, 2009</td>
<td>34</td>
<td>2</td>
<td>5</td>
<td>27</td>
<td></td>
<td>2.28</td>
<td>0.2</td>
<td>3.5</td>
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<tr>
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<td>27</td>
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<td>0.2</td>
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<tr>
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<td>1</td>
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<td></td>
<td>2.58</td>
<td>0.1</td>
<td>4.0</td>
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<td>2.58</td>
<td>0.1</td>
<td>4.0</td>
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<tr>
<td>Hamilton, ON, 2015</td>
<td>252</td>
<td>62</td>
<td>136</td>
<td>39</td>
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<td>4.73</td>
<td>0.0</td>
<td>14.0</td>
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<td>62</td>
<td>136</td>
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<td>Hamilton, ON, 2015</td>
<td>252</td>
<td>62</td>
<td>136</td>
<td>39</td>
<td></td>
<td>4.73</td>
<td>0.0</td>
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<tr>
<td>Total</td>
<td>1560</td>
<td>412</td>
<td>1125</td>
<td>206</td>
<td>154</td>
<td>75</td>
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</tbody>
</table>

† Multiple samples taken at each site are averaged for the analysis. Hamilton_OB = Overburden well samples in Hamilton (2015).

- Most of the regions in southern Ontario have lower (less than 3 mg L⁻¹ nitrate-N) nitrate concentrations and higher nitrate concentrations are in southwestern Ontario (Fig. 1) in regions under intensive agricultural operations (Murray, 1997).

Focused Investigation

- Two counties (Norfolk and Oxford) were selected in southern Ontario to focus on specifically sandy and loam soils and agricultural land use (Fig. 2 a, b).
- Weighted overlay was used in ArcGIS to delineate vulnerable areas and these vulnerable areas were compared with the values of nitrate-N in groundwater above 3 mg L⁻¹ (Fig. 3).

Conclusions

- Results of ArcGIS analysis showed that groundwater samples with more than 3 mg L⁻¹ nitrate-N were primarily within the previously delineated vulnerable areas based on developed criteria.
- These results provide useful insights in nitrate dynamics in different crop and soil types and identified nitrate trends with depth in groundwater across southern Ontario.

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Contact

Shoaib Saleem
Tel: (902) 305-0321
Email: saleems@uoguelph.ca

Fig. 1: (a) Areal distribution of nitrate-N concentrations in groundwater in southern Ontario. This map is generated from the data collected from all Ontario groundwater based studies with known spatial coordinate information. (b) Wells in Norfolk County.

Fig. 2: Distribution of nitrate-N concentrations greater than 3 mg L⁻¹ in Norfolk and Oxford Counties related to (a) agricultural land use (AAFC, 2013) and (b) soil type (Ontario Geological Survey, 2015).

Fig. 3: Weighted Overlay map showing vulnerable areas with low, medium, and high index.