Groundwater phosphorus concentrations: global trends and links with agricultural and oil and gas activities

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Introduction

Why Phosphorus?

- Main limiting nutrient in most freshwater ecosystems
- Historically assumed phosphorus concentrations in groundwater were negligible due to adsorption onto soil matrix, but new research shows elevated P concentrations in groundwater and impacts on surface waters [1]
- Past focus was on point sources such as septic tank leakage
- No research to date examining oil and gas wells as a potential pathway for anthropogenic contamination at the surface to reach groundwater

Objectives

- Compile available groundwater P data to analyze the extent of enhanced P concentrations in groundwater globally and identify spatial relationships between anthropogenic sources (agriculture) and anthropogenic pathways (oil and gas wells) and enhanced P concentrations in groundwater

Contamination Pathways

Municipal

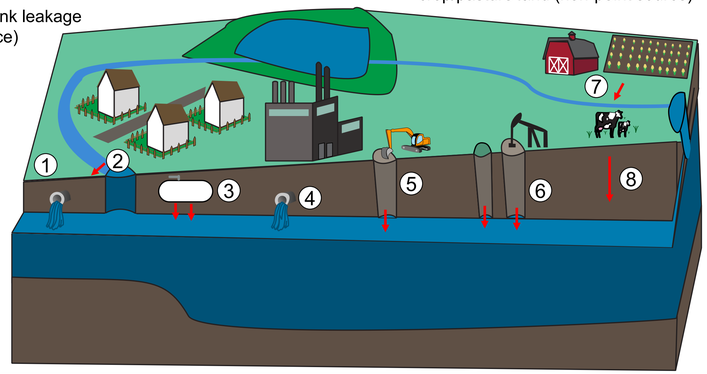
1. Municipal water treatment release (point source)
2. Runoff from domestic fertilizer use (non-point source)
3. Septic tank leakage (point source)

Industrial

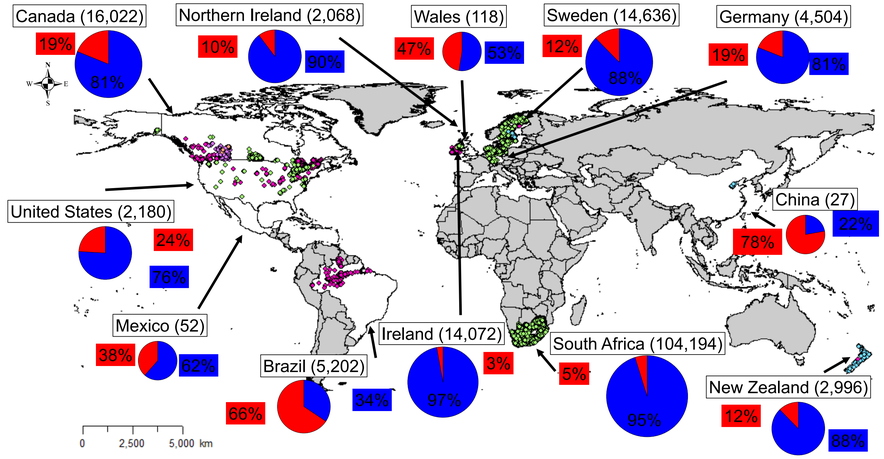
4. Wastewater treatment (point source)
5. Contamination of groundwater supplies from mining and production activities (point source)

Agricultural

6. Direct addition to groundwater from active or abandoned wells (point source)
7. Runoff from crop/pasture land (non-point source)
8. Infiltration from fertilizer use on crop/pasture land (non-point source)



Global Distribution of Data



Concentration Range

<0.1 mg P/L >0.1 mg P/L

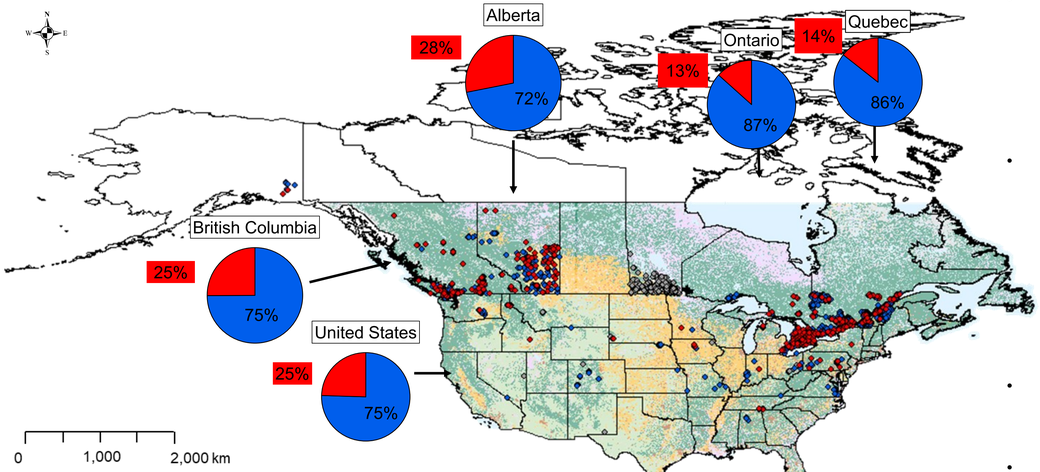
Concentration Type

Particulate P Dissolved P
Total Dissolved P Total P (ICP-MS) Total P

Country with data Country with no data

- All 12 countries with available groundwater P data have samples with concentrations >0.1 mg P/L, which can pose a eutrophication risk to surface waters
  - Max concentration: a dissolved phosphorus sample in Sweden with a concentration of 793 mg P/L
- 0.8% of sites use more than 1 analysis method to determine P concentration of groundwater samples

Land Use and Total Phosphorus (TP) Concentrations



Land Use

Unclassified Roads Grassland (managed)
Other Settlements Grassland (unmanaged)
Water Cropland Trees
Wetland

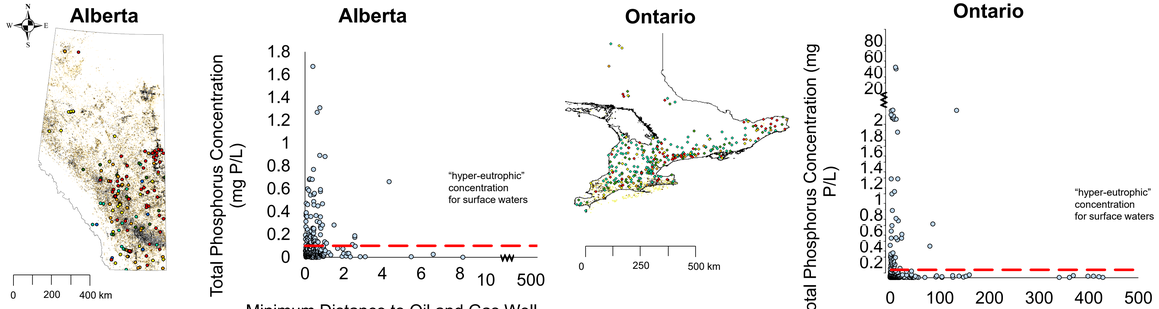
Phosphorus Concentrations

<0.1 mg TP/L >0.1 mg TP/L
Analysis method other than TP

- For samples with TP concentrations >0.1 mg TP/L:
  - 93% are taken within 50 km of crop/pastureland
  - 91% are taken within 10 km of crop/pastureland
  - 74% are taken within 1 km of crop/pastureland
- There are spatial gaps in current placement of TP monitoring sites. Within a 30 km by 30 km search area we find:
  - 0.8% of land area in the United States has at least 1 TP monitoring site
  - 4% of land area in Canada has at least 1 TP monitoring site
    - British Columbia: 6.1%
    - Alberta: 15.2%
    - Ontario: 8.4%
    - Quebec: 8.4%
- Land use surrounding current TP monitoring sites is biased towards crop/pastureland and not representative of overall land use distribution across Canada
- Land use surrounding current TP monitoring sites is similar to overall land use distribution across United States

Oil and Gas Wells and Total Phosphorus (TP) Concentrations

- We find elevated TP concentrations at TP monitoring sites located closer to oil and gas wells in Alberta and Ontario



Well Density (oil and gas wells per km²)

0 1.5-2 4-5
0-1 2-3 5-10
1-1.5 3-4 >10

Total Phosphorus Concentration

<0.004 mg P/L 0.02-0.035 mg P/L
0.004-0.01 mg P/L 0.035-0.1 mg P/L
0.01-0.02 mg P/L >0.1 mg P/L

Conclusions

- Global groundwater P concentrations pose a eutrophication risk to surface waters
- In Canada and the United States, there is a correlation between crop/pastureland and elevated TP concentrations
- In Alberta and Ontario, Canada, it is possible that oil and gas wells are acting as a pathway for anthropogenic P from the surface to reach groundwater

References: [1] Holman, I. P., et al. (2008). "Phosphorus in groundwater—an overlooked contributor to eutrophication?" Hydrological Processes **22**(26): 5121-5127.
[2] Canadian Council of Ministers of the Environment (2004). Canadian Water Quality Guidelines for the Protection of Aquatic Life. Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems.