

Complex Controls on Groundwater Quality in Growing Mid-Sized Cities: A Case Study Focused on Nitrate and Emerging Contaminants

Courtney Richards¹(richcou2@isu.edu), Sarah Godsey¹, Danelle Larson¹, John Welhan², Kathleen Lohse¹, Dewayne Derryberry¹, Shannon Kobs-Nawotniak¹, Bruce Finney¹
1 Idaho State University, 2 Idaho Geological Survey



Overview

- The mid-sized city of Pocatello, ID is supported by an aquifer system susceptible to contamination.
- Nitrate-N concentrations have not changed over time, however concentrations exhibit spatial patterns, including hot spots at exurban boundaries.
- Pharmaceutical and personal care products (PPCPs) were detected at sites with increased nitrate-N concentrations suggesting similar sources for PPCPs and nitrate.

Why is groundwater contamination important in mid-sized cities?

The process of growth in mid-sized cities is often an outward expansion of residential living creating expanding exurban boundaries. Planning codes and city service plans are not typically established for exurban fringe, and as a result, there is an increased use of on-site sewage treatment (Wilhelm, 1994). Growth of exurban areas can lead to long-term contamination from septic systems (LaGro, 1996). Contaminants produced by septic systems include nitrate and emerging contaminants of concern, such as personal care products and pharmaceuticals (PPCPs). Nitrate has been well studied as a public health concern, especially for vulnerable populations, however PPCPs and their possible health risks are a new field of study. The Lower Portneuf River Valley aquifer in Pocatello, ID supports both an urban and exurban environment where understanding nitrate and PPCP contamination patterns may identify sources and mitigate health risks.

Nitrate-N concentration have no detectable change over time

The nonparametric Wilcoxon test showed no change in median concentrations. Therefore we used all available data for spatial interpolation hot spot analysis.

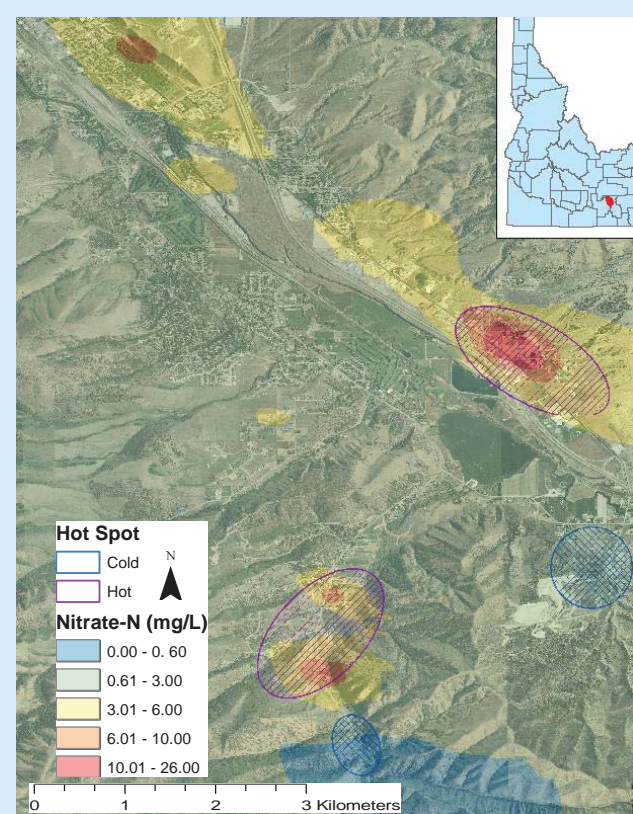
- Inputs: Paired wells tested at multiple time periods (1990s-2004, 1990s-2015, 2004-2015)

Null Hypothesis	Test	Significance	Conclusion
The median nitrate concentrations are the same in the 1990s and 2004.	Wilcoxon Signed Rank Test	0.365	Any differences too small to detect

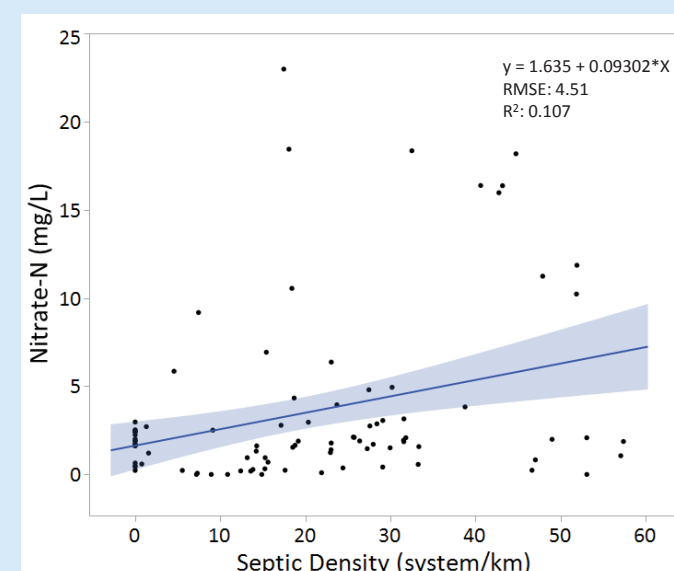
Null Hypothesis	Test	Significance	Conclusion
The median nitrate concentrations are the same in the 1990s and 2015.	Wilcoxon Signed Rank Test	0.173	Any differences too small to detect

Null Hypothesis	Test	Significance	Conclusion
The median nitrate concentrations are the same in 2004 and 2015.	Wilcoxon Signed Rank Test	0.678	Any differences too small to detect

Nitrate hotspots occur at boundaries of urban development, but do not correlate with septic density



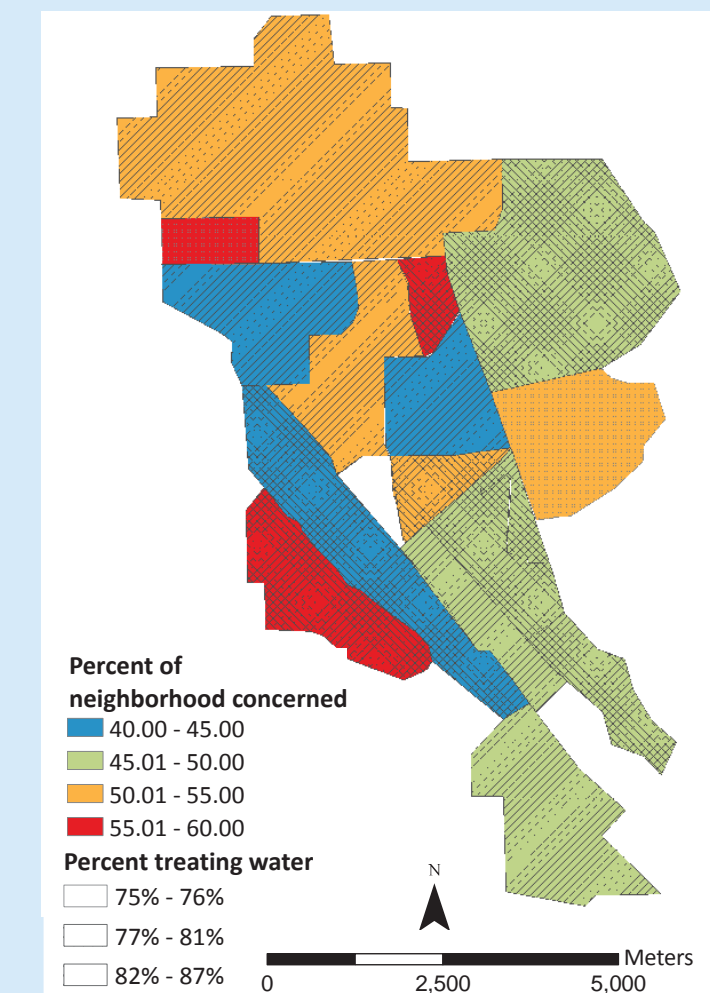
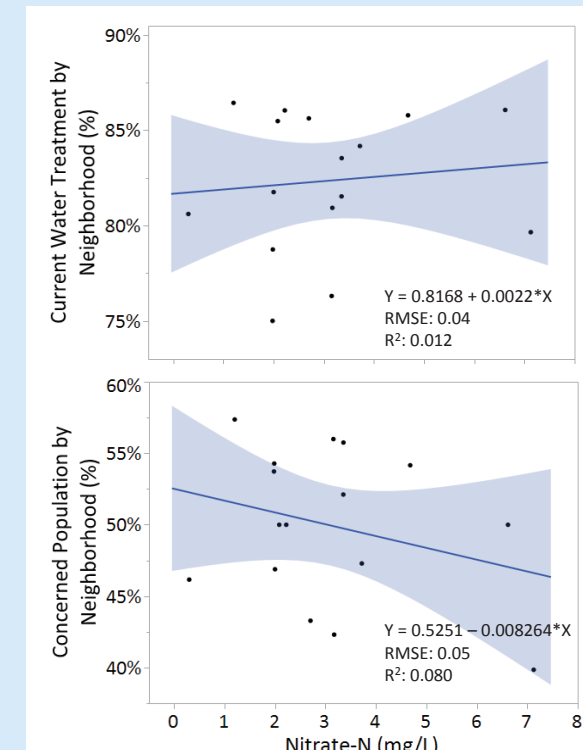
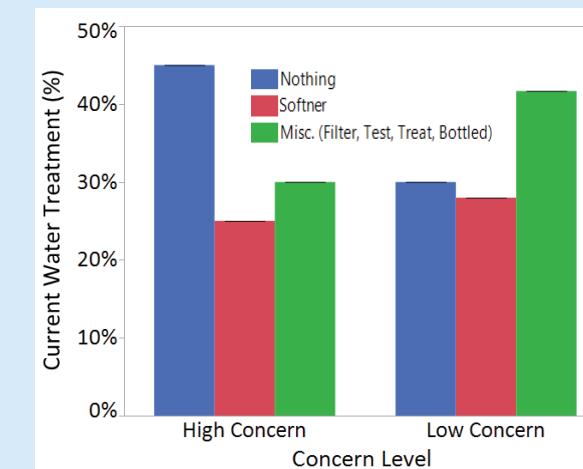
- Predicted nitrate-N across the LPRV using ordinary kriging (left figure).
- Hot spot analysis using Getis-Ord Gi* resulted in two hot spots (in purple) and two cold spots (in blue).
- Initial analysis shows septic density is a poor predictor of nitrate-N concentration (right figure).
- Septic density was determined for each sampling location based off a 1km radius neighborhood around the well location.
- In the future, nitrate concentration will be compared to septic density upslope of the sampling point.



References and Acknowledgements

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Does concern with health from water pollution predict treatment of water for households?



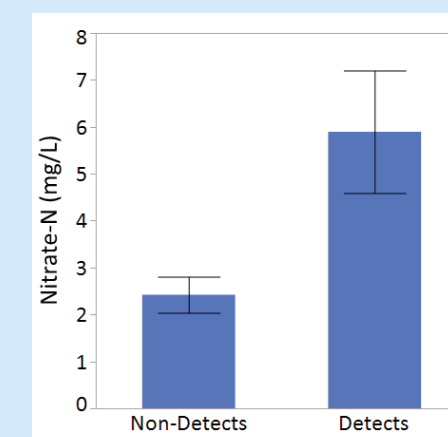
- These figures represent hypothetical survey data.
- Updated figures will be produced once public survey data is available.
- There were ~1500 surveys mailed and ~400 responses received which are currently being processed.

Survey Questions:

- Which of the following do you do for your household water needs? (Nothing, Softener, Filter, Treatment, Test, Buy Bottled Water)
- Thinking about the Portneuf River and groundwater, on a scale of 1 to 5, how concerned are you with health issued due to pollution? (1= low, 5 = high)

PPCPs detected in groundwater significantly correlate with NO₃-N concentrations

Higher nitrate-N concentrations were found where PPCPs were detected (figure below).



- This correlation suggests that PPCPs and nitrate may both derive from anthropogenic sources.
- Sulfadimethoxine, an animal antibiotic, and other PPCPs used by humans were found together in some wells. This suggests that contamination may come from multiple sources.

PPCP Detected	# of Detects	Type of substance
Carbamazepine	2	Anticonvulsant and mood stabilizer
DEET	3	Insect repellent
Diphenhydramine	1	Antihistamine
Codeine	1	Analgesic and cough reliever
Ibuprofen	5	Nonsteroidal anti-inflammatory
Fluoxetine	1	Depression
Sucralose	18	Non-nutritive sweetener
Sulfadimethoxine	2	Antibiotic used by domesticated animals
Sulfamethoxazole	14	Antibiotic used by humans

Future work

- Fingerprint nitrate-N sources through $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$ isotopic signatures.
- Study the variability of $\delta^{18}\text{O}$ and δD in groundwater to better understand flow dynamics.
- Continue to put groundwater data in risk perception frameworks.

Null Hypothesis	Test	Significance	Conclusion
The distribution of NO ₃ -N concentrations are the same between PPCP detects vs. non-detects.	Mann-Whitney Test	.029	Moderate evidence medians differ

*No spatial information provided due to confidentiality and the small number of detections.