Groundwater nitrate in western Wisconsin—an update on a study of factors influencing nitrate leaching from fields

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ABSTRACT

Nitrate is a common contaminant of concern in groundwater throughout western Wisconsin. An ongoing well testing program in collaboration with the Western Wisconsin Conservation Council, a farmer-led watershed council in the area, found that mean nitrate concentrations in 42% of sampled wells were above the 10mg L^{-1} health standard. In addition to developing a long-term record of nitrate concentrations in regional wells, lysimeter nests were installed in 4 fields around the region to generate additional information about both the factors that contribute to elevated nitrate in regional groundwater systems and the efficacy of strategies to mitigate nitrate sources including nitrate leaching from agricultural soils.

INTRODUCTION

Nitrate is a common contaminant across the state of Wisconsin (Figure 1). It is a contaminant of concern because it can cause methemoglobinemia (known as blue baby syndrome) in young children (Ward et al., 2018), and is linked to elevated levels of colorectal cancers in adults (Schullehner et al. 2018). Rural communities that rely solely on private wells for their drinking water are most at risk from elevated levels of nitrate in groundwater.

Although there are multiple anthropogenic sources of nitrate to groundwater, including residential septic systems, the most widespread source is the application of commercial and manure fertilizers to agricultural lands (Burow et al., 2010; WI-GCC, 2019). There are numerous best management practices that can limit nitrate loss and leaching (Hess, 2020), however the variability of soils, changing precipitation patterns, and myriad other factors may mean that what works on one field won't have the same beneficial impacts on the next field (Rittenberg et al., 2015). A mismatch between best management practice recommendations and outcomes can lead to disenfranchisement of producers who invest in ineffective practices. This project is working alongside producers to develop a long-term record of nitrate levels in farm wells and, at the same time, provide more targeted information at the field scale about nitrate movement in soils in relation to soil character, nutrient management, cropping practices, and climate.

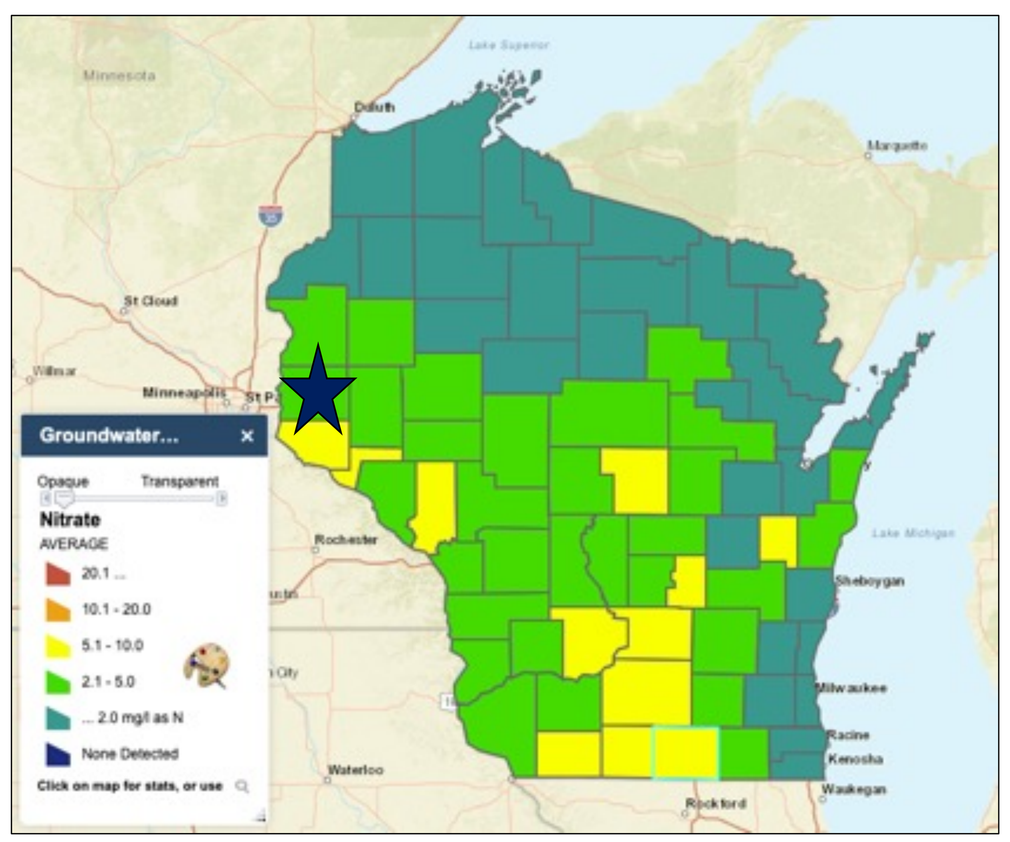


Figure 1. Project location (star) and nitrate concentrations in counties across Wisconsin from the Well Water Quality Viewer maintained by UW Stevens Point (Mechenich, 2021).

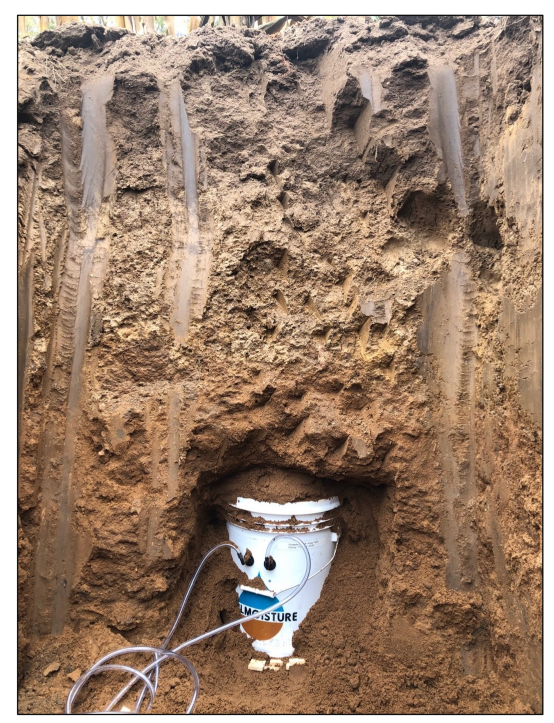
METHODS

- 100 wells were sampled between May 2018 and August 2021.
- Samples were collected 4 times from each well in its first year of sampling.
- Samples were collected from the spigot closest to the well pump and before any treatment.
- Wells were flushed for 10 minutes or until specific conductivity (SC) readings stabilized prior to sample collection, then dissolved oxygen, temperature, SC, and pH were measured at the time of sample collection.
- Chloride was measured in well samples by ISE and nitrate was analyzed colorimetrically following cadmium reduction on a Lachat Quikchem 8500 series 2.
- One sample was collected annually from those wells with stable nitrate concentrations below 10 mg L^{-1}.
- Four samples were collected annually from those wells where nitrate concentrations exceeded 20 mg L^{-1} and/or experienced variability >5 mg L^{-1} over the course of a year.
- Well logs were acquired from Wisconsin Geological and Natural History Survey and Wisconsin DNR Well Construction Information System.
- Suction cup lysimeters were installed in July 2021 at 2' and between 4 and 8' in 4 different fields.
- Wick lysimeters were installed in October 2021 at the suction cup lysimeter sites.

Installing suction cup lysimeters in July 2021

Using an excavator to install wick lysimeters October, 2021

Installed suction cup lysimeter in October, 2021



Wick lysimeter installed 4' below ground surface October, 2021

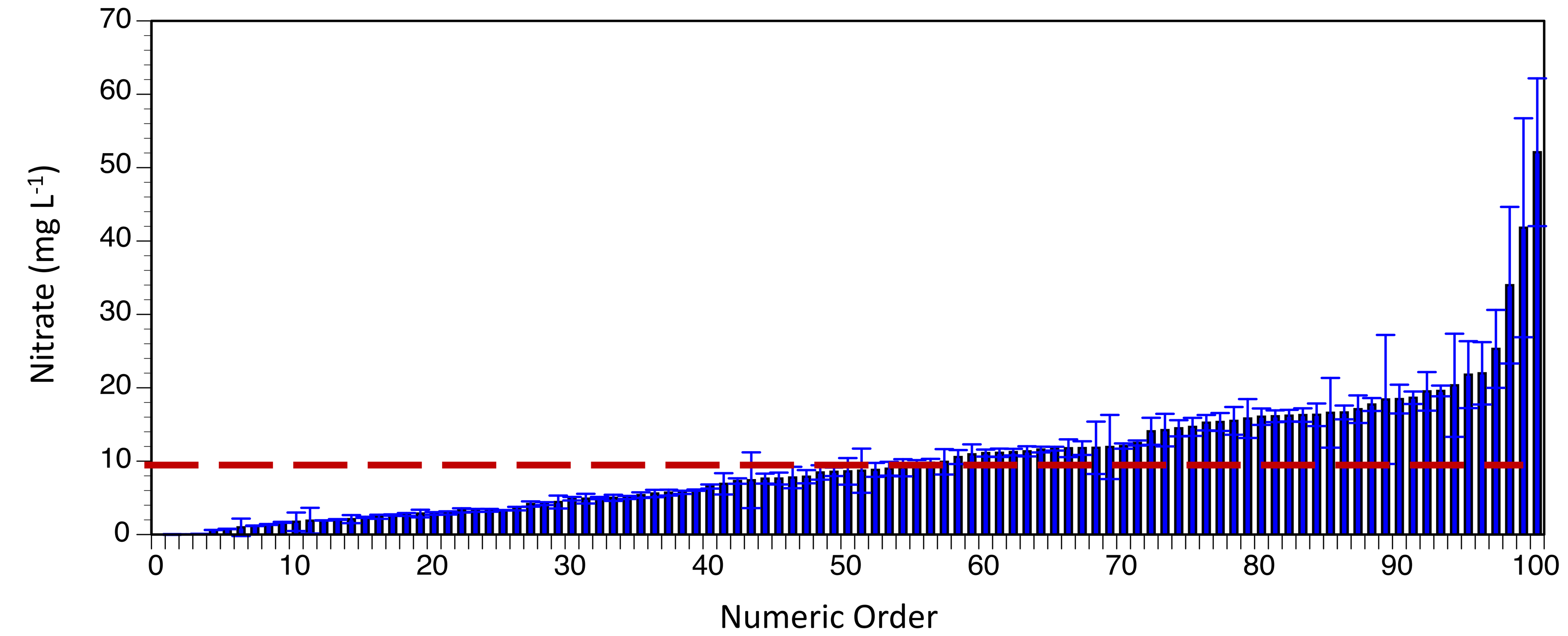


Figure 2 Mean nitrate for each well. Mean values are arranged in numeric order from lowest to highest concentration. Whiskers represent 1 standard deviation around the mean. Dashed line is at the 10 mg L^{-1} health standard for nitrate

RESULTS

- Mean nitrate concentrations in 42% of the wells sampled in this study exceeded the 10 mg L^{-1} health standard, and 6% exceeded 2X the health standard (Figure 2).
- Mean nitrate concentrations in all wells were strongly, positively correlated with specific conductivity (R^2=0.65; Figure 3).
- Annual precipitation was highest in 2019 and lowest in 2021 (Figure 3).
- Mean nitrate concentrations were generally higher and more variable in wells drawing water from limestone aquifers (Figure 4).
- Mean nitrate concentrations in winter sampled limestone wells were 2X higher in January 2020 than in January 2021 (Figure 4).
- Many wells in this data set had no known well logs and are drawing from "unknown" aquifers.
- More data are needed to make statistical comparisons between mean nitrate concentrations in limestone and sandstone aquifers.
- Drought conditions in 2021 did not allow for sample collection from lysimeter nests.

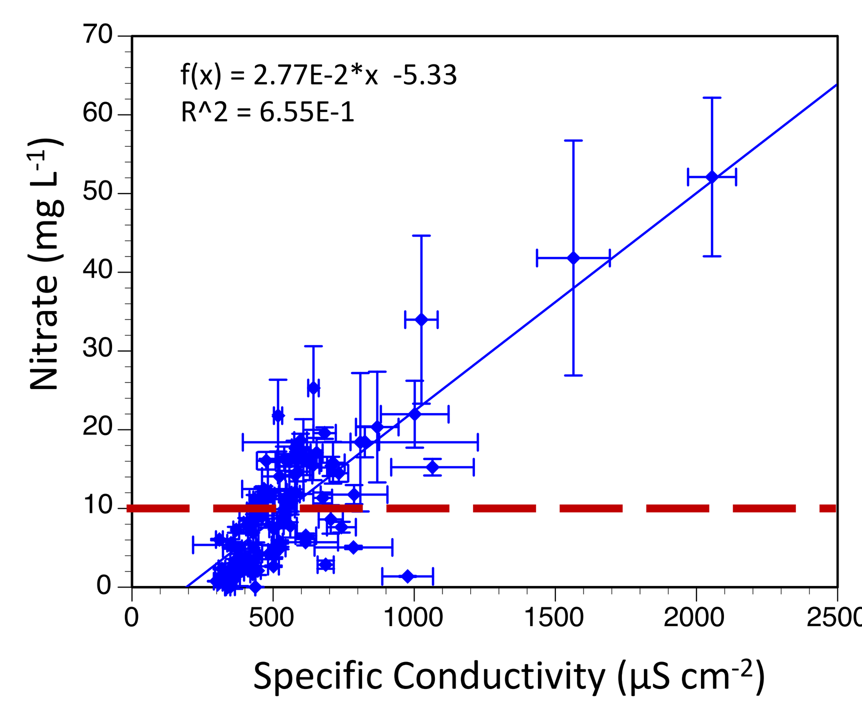


Figure 3. Specific conductivity and nitrate for each well. Whiskers represent 1 standard deviation around the mean. Dashed line is at the 10 mg L^{-1} health standard for nitrate

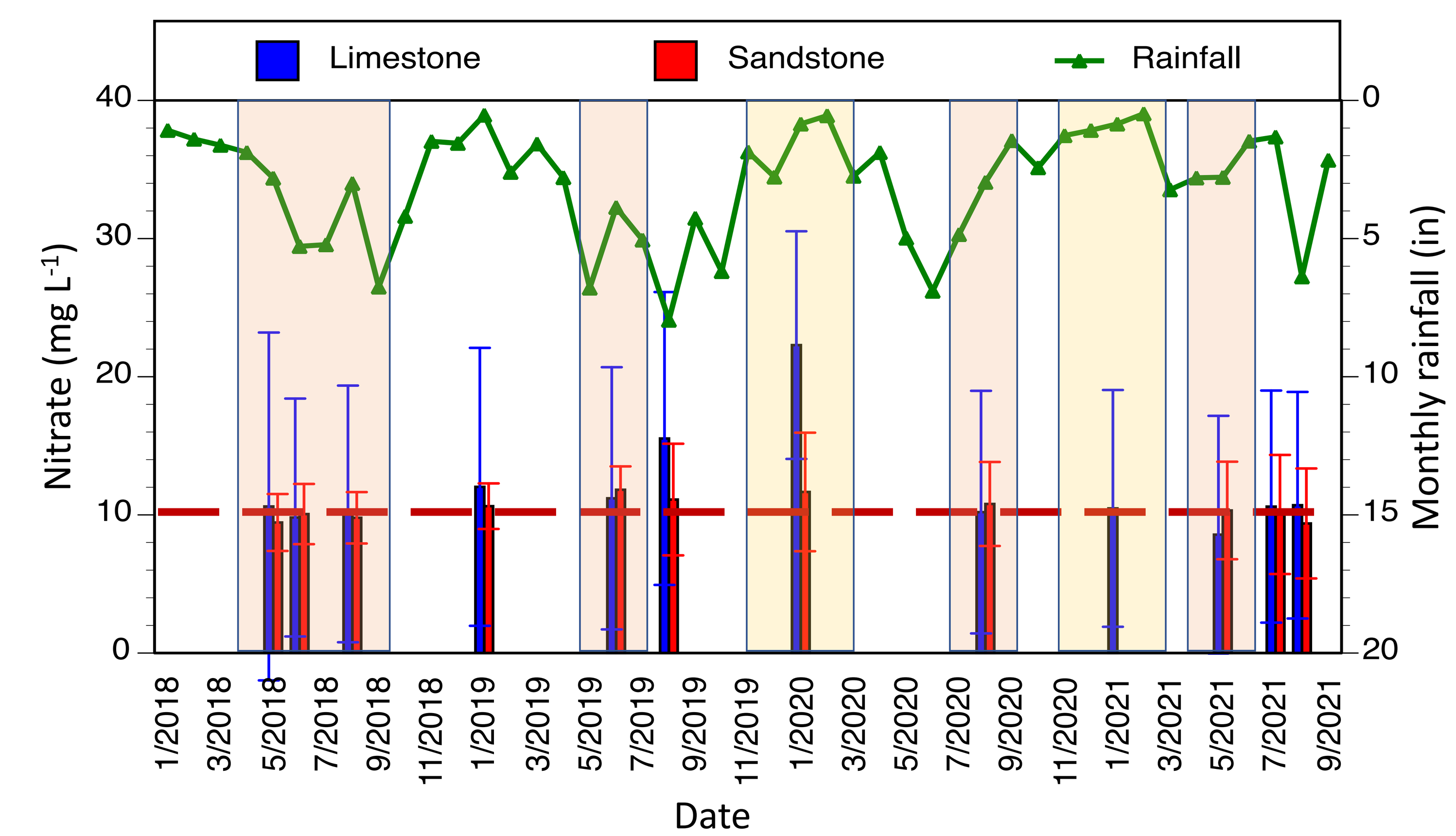


Figure 4. Mean nitrate concentrations in all wells that draw from limestone aquifers (blue bar) and all wells that draw from sandstone aquifers (red bar). Monthly rainfall values (green line) are presented on an inverted axis. Whiskers represent 1 standard deviation around the mean. Dashed line is at the 10 mg L^{-1} health standard for nitrate. Shading denotes comparable well sets.

CONCLUSIONS SO FAR…

- Mean nitrate concentrations in wells in this study are higher than in wells from larger, publicly available data sets (Mechenich, 2021).
- Climate may influence nitrate concentrations in western Wisconsin wells drawing from limestone aquifers more than those in sandstone.
- In mild to moderate drought conditions very little water, and accompanying nitrate, moves downward through the soil profile despite differences in soils and nutrient management practices.

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DAIRY INNOVATION HUB

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