Nitrate

Nitrate is Wisconsin's most widespread groundwater contaminant (data from DNR, DATCP and UW-Extension's Central Wisconsin Groundwater Center) and is increasing in extent and severity (Kraft et al. 2008, Kraft 2003, Kraft 2004, Saad 2008). Nitrate (NO_3) is a water-soluble molecule that forms when ammonia or other nitrogen rich sources combine with oxygenated water. Nitrate levels (as nitrate-N) in groundwater are below 2 milligram per liter (mg/L) where pollution sources are absent. Higher levels indicate a source of contamination such as agricultural or turf fertilizers, animal waste, septic systems, and wastewater. At least 90% of nitrate inputs into our groundwater originate from manure spreading, agricultural fertilizers, and legume cropping systems (Shaw, 1994).

Human health concerns, both acute and chronic, are the primary reason high levels of nitrate in drinking water are of concern. Nitrate can cause a condition called methemoglobenemia or "blue-baby syndrome" in infants under six months of age. This condition deprives the infant of oxygen and in extreme cases can cause death. DHS has investigated several cases of suspected blue-baby syndrome and associated at least three with nitrate contaminated drinking water. Some studies raise concern regarding the effect of nitrate on the developing fetus in early stages of pregnancy, thyroid function, diabetes and cancer. While more research is needed in this area, to ensure protection of health, people of all ages are encouraged to drink water that meets the safe drinking water standard for nitrate of 10 mg/L.

Nitrate converts to nitrite in the human body and can then convert into N-nitroso compounds (NOC's). NOC's are some of the strongest known carcinogens and have been found to induce cancer in a variety of organs. As a result, additional human health concerns linked to nitrate contaminated drinking water include increased risk of: non-Hodgkin's lymphoma (Ward et al., 1996); gastric cancer (Xu et al., 1992; Yang et al., 1998); and bladder and ovarian cancer in older women (Weyer et al., 2001). There is also growing evidence of a correlation between nitrate and diabetes in children (Parslow et al., 1997; Moltchanova et al., 2004).

Nitrate exposure has also been linked to birth defects. A recent report (Brender et al.,2013), is one of several epidemiological studies over the past decade examining statistical links between nitrate exposure and neural tube birth defects. Some, but not all, of these studies have concluded there is a statistical correlation between maternal ingestion of nitrates in drinking water and birth defects. At this time, there is no clear animal model demonstrating this effect. Further work would be needed to conclusively demonstrate that exposure to nitrates and nitrites during pregnancy increase the risk of birth defects. Nonetheless, these studies collectively indicate an ongoing need for caution in addressing consumption of nitrates, and support the continuation of private well testing programs for pregnant females. Given the need for more knowledge in this area, and the pervasiveness of nitrate contamination in groundwater, we expect that this will continue to be a subject of investigation. DHS will continue to monitor and review the literature on this topic.

In addition to the effects of elevated nitrate concentration on human health, a number of studies have shown that nitrate can have lethal and sublethal effects on a variety of species of fishes, amphibians, and aquatic invertebrates (Crunkilton et al. 2000, Camargo et al. 1995, Marco et al. 1999, Smith et al. 2005, McGurk et al. 2006, Stelzer et al. 2010). This is significant in that many baseflow-dominated streams in agricultural watersheds can exhibit elevated nitrate concentrations, with levels in some Wisconsin streams at times exceeding 30 mg/L NO_3-N. In Wisconsin, exposure of animals to potentially lethal nitrate concentrations would be most likely to occur in springs and in groundwater-fed low-order streams in agricultural or urban areas, and in nitrate-rich water bodies on farms such as ditches and ponds. Stream nitrate concentrations and nitrogen exports are expected to increase on average as older water within the aquifer is replaced by modern water that is reflective of current land-use (Masarik, et.al, 2007).

Due to human health concerns, community water supplies that exceed the 10 mg/L ES are required to treat drinking water to the federal drinking water standard of 10 mg/L. Common solutions include drilling of a new non-contaminated well or the removal of excess nitrate through water treatment processes. A 2012 survey of Wisconsin municipal systems found that 47 systems have had raw water samples that exceeded the nitrate ES (up from just 14 systems in 1999). This survey also showed that respondents had collectively spent over $32.5 million on remedies, up from $24 million as of 2004 and that 74 systems are experiencing increasing nitrate levels. Excessive nitrate levels have also forced the installation of treatment systems or the replacement of wells at hundreds of other smaller public drinking water systems.

In 2012 DNR began working with other stakeholders on the "Wisconsin Safer Drinking Water Nitrate Initiative. The initiative is targeted at reducing nitrate levels in groundwater by making the most efficient use of nitrogen in agricultural production. Activities in project areas include measuring all current nitrogen inputs and baseline groundwater nitrate levels, calculate agricultural input and production costs, determine and implement best nitrogen management practices that optimize groundwater conditions and agricultural production efficiency, and measure whether predicted results are achieved. Project areas have been selected in Rock and Sauk Counties within subwatersheds with large numbers of public drinking water systems approaching unsafe levels of nitrate contamination. DNR is currently working with stakeholders to determine an optimal nitrogen management system. In the next phase of the project the nitrogen management system will be applied in one of the project areas. Monitoring of nitrogen inputs, groundwater nitrate levels, production costs will continue and costs of nitrogen management will be compared to water treatment costs.

About one third of Wisconsin's families obtain their water from privately owned wells and hence are at risk of excessive nitrate exposure. A 2008-9 DHS survey determined that one-third of private well owners have never had their water tested for nitrate. The most common reasons cited by well owners who had not tested their water was that their water "tasted and looked fine." Thirteen percent listed cost as a reason for not testing their water.

DATCP (2007) and DNR (2005, 2007) surveys and meta-analysis of state databases indicate 9 to 11% of private wells statewide exceeded the nitrate enforcement standard (ES) of 10 mg/L. Exceedence rates are greater in agricultural districts, with rates in highly cultivated areas in south-central Wisconsin estimated at 21% of wells. As seen in Figure 1, 20-30% of the privately owned wells in Calumet, Columbia, Dane, La Crosse and Trempealeau counties exceed the 10 mg/L nitrate standard. A nationwide USGS study compared nitrate concentrations in 495 wells between 1992 and 2004 and showed that the proportion of wells with concentrations of greater than 10 mg/L increased from 16 to 21 percent (Dubrovsky et al. 2010).

Owners of nitrate-contaminated private wells do not qualify for well compensation funding unless the nitrate-N level in their well exceeds 40 mg/L and the water is used for livestock. In order to establish a safe water supply, they may opt to replace an existing well with a deeper, better cased well or to connect to a nearby public water supply. Alternatively, they may choose to install a water treatment system or use bottled water. A study published by DHS examined this issue (Schubert et al., 1999). Their survey of 1,500 families found that few took any action to reduce nitrate exposure. Of those who did, most purchased bottled water for use by an infant or pregnant woman.

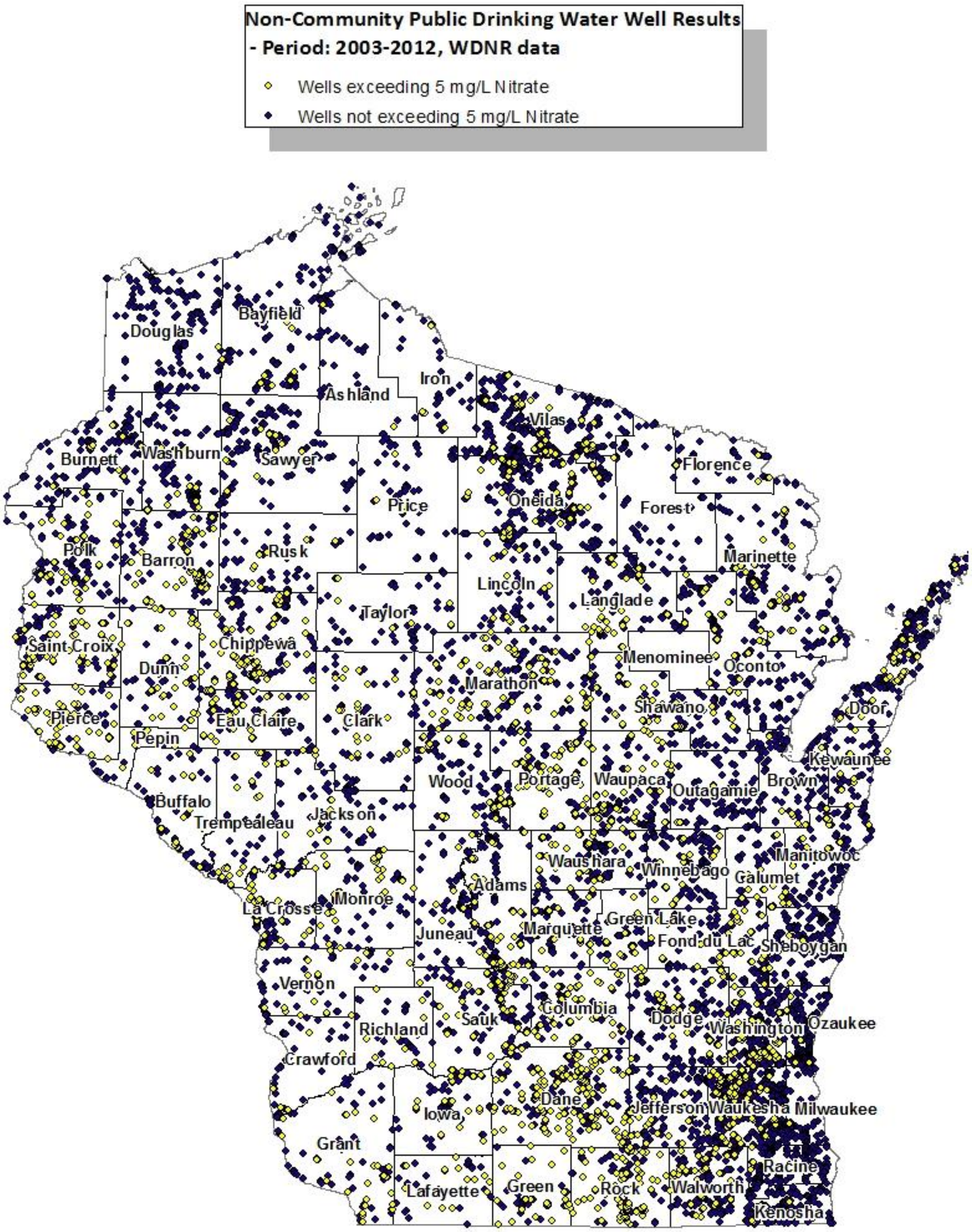

Figure 1:Non-community public wells with raw water samples exceeding 5 mg/L Data source: DNR Drinking Water System, 2013.

Various studies indicate nitrate in drinking water systems is increasing and that current management activities to limit nitrate pollution have questionable effectiveness (Mechenich and Kraft 1997, Kraft 2003, Saad 2008). For instance, nitrate concentrations in Central Wisconsin groundwater will continue to increase even using University recommendations for fertilizer application. Nitrate concentrations will increase as nitrate pollution penetrates deeper into thick aquifers (Kraft et al. 2008).

According to Tesoriero (2013) long travel times of groundwater discharge is the reason nitrate trends in streams and rivers do not match expectations based on reduced regional use of nitrogen-based fertilizer. In this same study, the USGS hydrologic researchers found that the movement of nitrate through groundwater to streams can take decades to occur, which means that changes in the use of nitrogen-based fertilizer may take decades to be fully observed in streams: “This is an important finding because long travel times will delay direct observation of the full effect of nutrient management strategies on stream quality." Dubrovsky (2010) states that “Nitrate concentrations are likely to increase in aquifers used for drinking-water supplies during the next decade, or longer, as shallow groundwater with high concentrations moves downward into the groundwater system. In some geologic settings improvements in nutrient management practices on the land surface can take years to decades to result in lower nutrient concentrations in groundwater because of the slow rate of groundwater flow. Similar time delays also are expected for streams that receive considerable groundwater discharge.”

Several studies funded through the joint solicitation and done at the UW Arlington Agricultural Research Station have looked at nitrogen inputs on fields in continuous corn (Brye, 2001; Masarik, 2003; and Norman, 2003). Important findings include:

- Nitrate concentrations are highly variable throughout the year, and from year to year. Highest concentrations are measured in wet years, particularly when wet years follow dry years. Highest concentration measured in leachate (for two week period) on optimally fertilized fields – around 45 mg/L. Highest annual flow-weighted mean concentration – 24 mg/L. During the dry years the nitrate concentrations were actually quite low.

- Over the long-term (7 years), flow-weighted mean nitrate leaching values on continuous corn rotations fertilized at economic optimum rates were around 10 mg/L. Nearly 20% of nitrogen fertilizer applied at economic optimum rates is lost to leaching over the long-term. These studies show that even in the best managed agricultural systems, groundwater concentrations at or above the health standard for nitrate-nitrogen are likely.

- When manure was applied to a field in addition to the optimal rate of nitrogen fertilizer, the flow-weighted mean concentration was two to three times greater than the flow-weighted mean concentration from fields that just received the optimum amount of fertilizer. This finding suggests that when applications of nutrients exceed the crop need, the nitrate losses to groundwater increase significantly.

It is important to recognize that not all farms can be required to have a nutrient management plan (NMP). As of 2008, all farms can be required to implement nutrient management with a $28/ac cost share offer or if the farm: 1) is required by local manure storage or livestock siting ordinances; 2) participates in the Farmland Preservation Program/Working Lands programs; 3) is regulated by a WPDES permit; 4) accepts cost share for manure storage; or 5) causes a discharge. In 2012 about 22% of the state’s land was covered by a NMP. It is difficult to assess the impact and effectiveness of nutrient management planning on groundwater nitrate levels without full coverage and implementation of NM is achieved across the state. Figure 2 shows each county's percentage of cropland covered by a NMP. A comparison of Figure 1 and Figure 2 shows where the greatest needs are for NMPs.

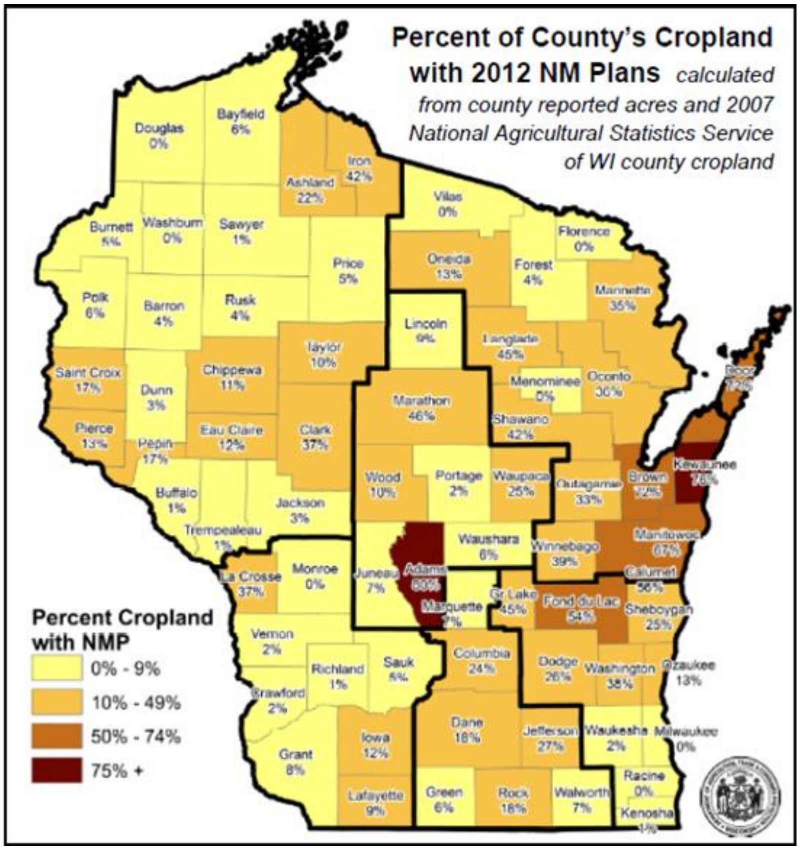

Figure 2. The percent of cropland with nutrient management plans in 2012 as reported to DATCP.

For more information on DATCP's efforts to reduce nitrate levels in groundwater, as well as efforts to reduce nonpoint source pollution in general, please refer to DATCP's Activities in this report:
http://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/DATCPactivities.pdf

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