Minnesota Pollution Control Agency

Estimating Ground Water Sensitivity to Nitrate Contamination

Environmental Outcomes Division

Ground Water Monitoring & Assessment Program

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Water resource managers often view ground water pollution sensitivity maps as an important tool for ground water protection. Methods for mapping sensitivity consider factors such as soil permeability, aquifer conductivity, depth to water, and recharge. Sensitivity ratings are based on the time it takes for water to travel from a point of origin (for example, a septic system or a farm field) to the water table or an aquifer.

Sensitivity methods based strictly on time of travel provide little information about the potential fate of contaminants in ground water. For example, nitrate can be transformed in ground water through a process called "denitrification." Denitrification reduces potential negative effects of nitrate on drinking water or surface water receptors.

The Ground Water Monitoring and Assessment Program (GWMAP) of the Minnesota Pollution Control Agency (MPCA) has collected data that suggest denitrification is an important process in ground water. Denitrification occurs within well-defined conditions in ground water. Assessing these conditions is an important tool for water managers, and is more useful in aquifer management than simple estimates of hydrologic sensitivity. "Geochemical sensitivity" is the term we use to describe sensitivity of ground water to nitrate contamination.

Under what conditions is an aquifer sensitive to nitrate contamination?

In Minnesota, surficial aquifers are recharged annually. This means the time it takes water to move from a point of origin to the water table is less than one year. By traditional mapping techniques, these surficial aquifers are considered sensitive to nitrate contamination. Resource managers, in turn, may use these sensitivity estimates for water planning, even though deeper portions of these aquifers may not be sensitive because nitrate will be denitrified.

Recharge and infiltration certainly affect the fate of nitrate in the environment, but we emphasize the importance of characterizing the aquifer chemistry to predict the fate of nitrate. These concepts are explained in greater detail in a report (MPCA, 1998a). The following table can be used as a rough guide to identify ground water that is sensitive to nitrate contamination.

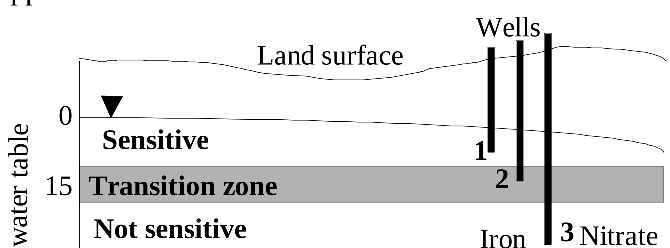
When using this table, all three criteria must apply for a ground water sample to be classified as sensitive or not sensitive. This is important, because we have observed mixed results for many samples. Dissolved oxygen and oxidation-reduction potential

Characteristic	Sensitive	Not sensitive
Filtered iron concentration	Less than 0.1 part per million	More than 1 part per million
Eh	More than 250 millivolts	Less than 225 millivolts
Dissolved oxygen	More than 1 part per million	Less than 1 part per million

(ORP) are measured in the field[1]. Iron samples are filtered in the field using a 0.45-micron filter and sent to a lab for analysis. A value of 0.7 part per million for total (unfiltered) iron may be used in place of filtered iron. The criteria shown in the table can be modified if technical staff have a sufficient basis for modifying the values.

How does the geochemical sensitivity concept work?

We advocate taking ground water samples vertically within the aquifer of concern. For example, consider the figure below. The data for it come from our St. Cloud land use study (MPCA, 1998b, 1999). In the figure, there are three wells sampled at different depths and data for each well are included. The data indicate that the upper portion of the aquifer is sensitive to nitrate contamination but the lower portion is not. A transition zone, where nitrate is denitrified, occurs between the upper and lower zones.



Well	Oxygen (ppm)	Eh (mV)	Iron (ppm)	Nitrate (ppm)
1	6.3	308	0.03	5.60
2	4.6	300	0.07	0.50
3	1.7	287	0.30	0.05

How does this affect aquifer management?

In the example above, the surficial sand and gravel aquifer is mapped as being sensitive to contamination (DNR, 1999). Age dating indicates that water throughout the aquifer is less than 50 years old. Nitrate, however, is denitrified between five and 15 feet. Some important recommendations can be made based on these results:

1. Different land uses are compatible (for example, irrigated agriculture and residential development).
2. Drinking water wells should be completed at depths of more than 30 feet below the top of the aquifer, preferably deeper.
3. Large water supply wells, such as those used for irrigation and municipal supply, should draw from deeper, confined aquifers to prevent drawdown of the surficial system. Drawdown in the surficial system would pull nitrate-rich water deeper into the aquifer, contaminating much of the aquifer.

How does one map geochemical sensitivity for nitrate?

- Sample several wells at various depths in the aquifer of concern;
- measure dissolved oxygen and ORP in the field;
- collect nitrate and filtered iron samples for laboratory analysis;
- develop a three-dimensional sensitivity map using the guidelines stated above; and
- develop appropriate aquifer management strategies.

For more information

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References

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Minnesota Pollution Control Agency. 1998b. *Water Quality in the Upper Fifteen Feet of a Shallow Sand Aquifer.* 38 pp.

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[1] The ORP measurement is not the same as Eh. ORP measurements must be corrected for temperature and for the particular probe being used. Call the manufacturer of the probe to obtain the correction factor.