Swine Manure and Nitrate Leaching

What It Means for Your Fields, Water Quality, and Long-Term Nutrient Management

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Swine manure has long been a reliable nutrient source for corn and other crops across South Dakota and the Northern Great Plains. When managed well, it supplies nitrogen, improves soil structure, and reduces fertilizer costs. When managed poorly, it can become a major source of nitrate loss to groundwater and surface waters.

Nitrate nitrogen moves easily with water. Unlike phosphorus, it does not bind strongly to soil. Once nitrate moves below the crop rooting zone, it is no longer available to the crop and can contaminate tile drainage, shallow groundwater, and drinking water supplies.

This fact sheet explains how nitrate leaching occurs, why swine manure increases risk under certain conditions, and what producers can do to keep nitrogen where crops can use it.

What Is Nitrate Leaching

Nitrate leaching is the downward movement of dissolved nitrate with percolating water through the soil profile. It is a natural process that occurs even in native grasslands and forests. However, agricultural systems greatly increase the amount of nitrate available for movement.

In humid and subhumid regions, precipitation often exceeds crop water use during fall, winter, and early spring. Excess water moves downward through the soil, carrying nitrate with it. Figure 1 illustrates how nitrate moves from manure-amended soils into groundwater.

Leached nitrate may reenter plant roots later if roots grow deeper, but much of it is lost to groundwater or subsurface drainage before crops can recover it.

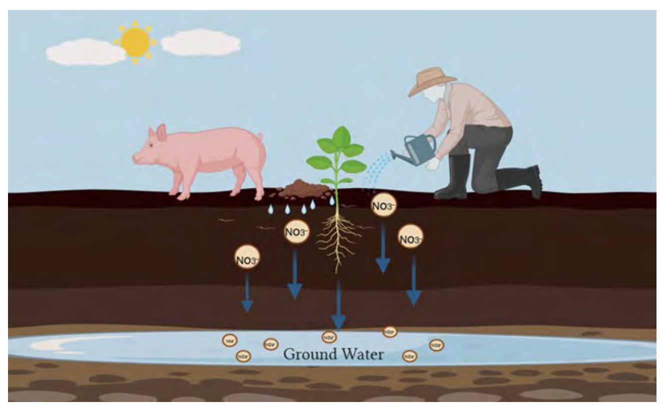

Figure 1. Nitrate Leaching from Swine Manure–Amended Soils to Groundwater.

Why Nitrate Is a Special Concern

Nitrate is highly soluble and weakly held by soil particles. This makes it more vulnerable to leaching than most other nutrients.

Groundwater supplies drinking water to nearly half of the population in the United States. The drinking water standard for nitrate nitrogen is 10 mg ppm (parts per million).. Concentrations above this level increase health risks and require costly treatment or alternative water sources.

From a producer's perspective, nitrate leaching is also an economic loss. Nitrogen that leaches is nitrogen that was paid for but not used by the crop.

Where Leached Nitrate Comes From

In agricultural soils, nitrate in drainage water comes from several sources:

- Fertilizers and manure
- Decomposition of soil organic matter
- Weathering of soil minerals
- Atmospheric deposition

In cropped systems, fertilizers and manure account for the largest share. Swine manure is especially important because much of its nitrogen is converted to nitrate within weeks of application.

Nitrogen Availability From Swine Manure

Liquid swine manure typically contains about half of its nitrogen as ammonium and half as organic nitrogen. After application:

- Ammonium is rapidly converted to nitrate through nitrification.
- Organic nitrogen mineralizes gradually over time.

Research shows that only about half of the total nitrogen applied in swine manure is available to the crop in the first year. The rest is lost through volatilization, leaching, denitrification, or remains in the soil. This means that timing and placement of manure for optimum nitrogen use efficiency are critical.

Factors That Increase Nitrate Leaching Risk

Nitrate leaching does not have a single cause. It results from interactions among soil, climate, management, and cropping systems.

Soil and Landscape

- Sandy and well-drained soils allow rapid water movement and higher leaching risk.
- Fine-textured soils slow water movement but may lose nitrogen through denitrification, especially under saturated conditions
- Lower landscape positions often receive more drainage water.

Climate

- High rainfall years greatly increase nitrate losses.
- Snowmelt and spring rains are especially risky periods.
- Freeze thaw cycles can accelerate nitrate movement.

Management

- High manure application rates increase residual soil nitrate.
- Repeated manure applications to the same fields compound risk.
- Fall applications leave nitrogen exposed during months with no crop uptake.

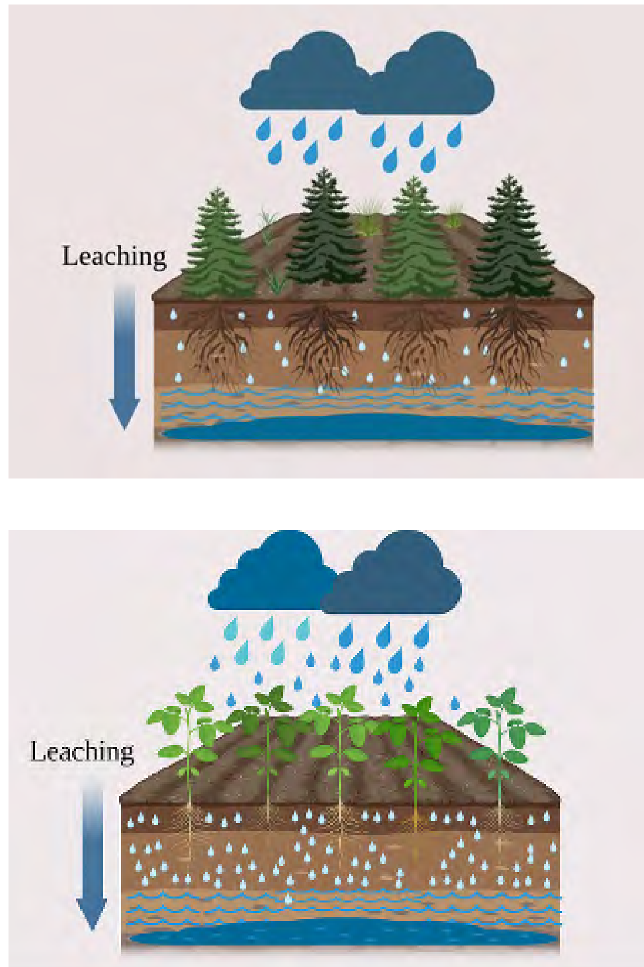

Figure 2. Water Saturation and Leaching in Natural and Agricultural Soils.

Why Timing Matters

Manure application timing is one of the most important decisions producers can control.

Fall Application: Fall-applied swine manure consistently results in higher nitrate leaching. During winter and early spring, nitrogen is converted to nitrate without crop uptake. Studies show that only 14 to 18 percent of fall-applied manure nitrogen is recovered by corn.

Spring Pre-Plant Application: Spring application reduces the time between nitrogen availability and crop uptake. Nitrogen recovery by corn improves to 30 to 38 percent, and nitrate losses decline.

Soil Type	Application Timing	% of Applied N Lost via Leaching	Corn N Uptake (% of applied N)	Notes
Fine sandy loam (well-drained)	Fall	15%	14–18%	Highest leaching losses; vulnerable to nitrate movement.
	Spring pre-plant	8–10%	30–38%	Lower losses compared to fall; better crop uptake.
	Side-dress	8–10%	30–38%	Similar to spring; efficient timing for minimizing losses.
Silt loam (imperfectly drained)	Fall	3–5%	14–18%	Leaching relatively small; losses dominated by denitrification.
	Spring pre-plant	3–5%	30–38%	Timing had little effect; soil drainage limited leaching.
	Side-dress	3–5%	30–38%	Same as spring; denitrification more important than leaching.

Table 1: Nitrogen Loss and Corn Uptake Across Soil Types and Application Timings

Side-Dress Application: Applying manure closer to peak crop nitrogen demand provides the greatest efficiency. Side-dress timing minimizes nitrate buildup during wet periods and maximizes crop uptake.

In a two year study (2005–2007) in southwestern Ontario, Canada, Jayasundara et al., (2010) examined the impact of liquid swine manure application timing (late fall, spring pre plant, and side dress) on nitrogen uptake by corn and nitrate leaching losses in two contrasting soil types (well drained fine sandy loam and imperfectly drained silt loam). The results indicated that corn recovered significantly less manure N with fall application (14–18% of applied N) compared to spring or side dress applications (30–38%), and nitrate leaching was highest with fall application, especially in the sandy loam (15% of applied N vs. 8–10% with spring applications). In the silt loam, gaseous losses through denitrification were dominant, with fall application resulting in 29% of applied N lost in gaseous form. Nitrogen losses were reduced when manure was applied in the spring prior to planting or as a side-dress during the growing season because manure nitrogen was either rapidly immobilized by soil microbes or taken up by actively growing crops, minimizing leaching and denitrification risks. This means that fall manure application increases environmental nitrogen losses and reduces crop uptake efficiency, while spring or side dress applications maximize manure N use by corn and minimize leaching and denitrification risks, particularly in well-drained soils (Table 1).

Application Rate and Frequency: Higher manure rates increase nitrate concentrations throughout the soil profile. Research shows nitrate detected at depths greater than four feet following high or repeated manure applications.

Applying manure to both corn and soybeans in a rotation increases nitrate loss without meaningful yield benefits. Soybean can fix its own nitrogen, so manure nitrogen applied ahead of soybean often remains unused and vulnerable to leaching. More nitrogen does not mean more yield, but it does mean more loss.

Application Method Tradeoffs

Manure injection reduces odor and surface runoff losses but can increase nitrate movement deeper in the soil by placing nitrogen closer to drainage pathways. Surface application reduces leaching risk in some cases but increases nitrogen losses to the air and runoff risk if not incorporated.

No single method is best for all fields. The right choice depends on soil type, drainage, timing, and weather conditions.

Role of Soil Organic Matter

Organic matter influences nitrate leaching in complex ways. Manure solids and crop residues improve soil structure and water holding capacity. Liquid manure can stimulate decomposition of existing soil organic matter. Higher soil organic matter and higher soil pH can increase nitrate mobility if nitrogen rates are not adjusted. Figure 3 illustrates how organic matter and soil conditions affect nitrate movement.

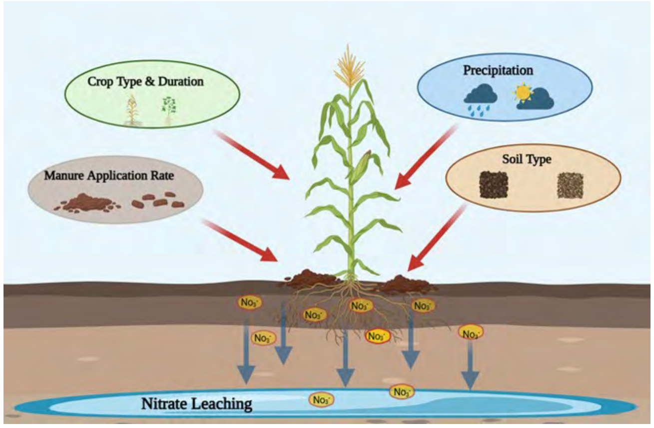

Figure 3. Factors Influencing Nitrate Leaching from Swine Manure–Amended Soils.

Crop Type and Rotation Effects

Crop choice strongly influences nitrate leaching. Perennial grasses and forages reduce leaching by maintaining year-round nitrogen uptake. Deep-rooted cereals reduce residual nitrate more effectively than shallow-rooted crops. Corn soybean rotations generally lose less nitrate than continuous corn, but management still matters.

Applying manure only before corn in a corn soybean rotation reduces nitrate loss compared to applying manure to both crops.

Cover Crops as a Tool

Winter cover crops, especially cereal rye, capture residual soil nitrate after harvest.

Research shows:

- Rye can take up 10 to more than 70 pounds of nitrogen per acre.
- Nitrate losses through drainage can be reduced by 10 to over 60 percent.
- Yield impacts are variable and depend on termination timing and weather.
- Cover crops are most effective on sandy or tile-drained soils receiving manure.

What This Means for Producers

- Nitrate leaching is driven by water movement and nitrogen rate.
- Fall-applied manure carries the highest risk of nitrate leaching.
- Sandy and well-drained soils require extra caution.
- Applying manure to soybean rarely pays off.
- Wet years amplify losses regardless of management.

Practical Actions to Consider

- Shift manure application from fall to spring or side-dress where possible.
- Match manure nitrogen rates to realistic crop yield goals and demand.
- Avoid applying manure to soybean when nitrogen is not needed.
- Use cover crops on high-risk fields.
- Monitor soil nitrate trends over time.
- Adjust plans during wet years.

Swine manure is a valuable fertilizer, but nitrate nitrogen does not stay put. Once it moves with water, it is gone from the field and becomes a water quality issue.

Keeping nitrogen in the crop rooting zone requires aligning rate, timing, placement, and crop demand. Small adjustments in manure management can protect groundwater, improve nitrogen efficiency, and preserve long-term flexibility for South Dakota farms.

References

Jayasundara, S., Wagner Riddle, C., Parkin, G., Lauzon, J., & Fan, M. Z. (2010). Transformations and losses of swine manure ^{15}N as affected by application timing at two contrasting sites. Canadian Journal of Soil Science, 90(1), 55–73.

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