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Nitrogen Behavior
In the Environment

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Manure and commercial fertilizers contain nutrients essential for plant growth. Nitrogen, phosphorus and potassium are the most critical of these nutrients. This publication outlines some basic information about nitrogen and its interaction in the environment.

Nitrogen (N) is a vital element found in all living things. Crops require nitrogen in relatively large amounts, making it the nutrient most often deficient in crop production.

Managing nitrogen inputs to achieve a balance between profitable crop production and minimizing nitrogen loss to the environment should be every producer's goal. The behavior of nitrogen in the soil system is complex, yet understanding the basic processes can lead to a more efficient nitrogen management program.

Nitrogen is changing its chemical form continually and moving from plants through animals, soil, water and the atmosphere. This movement and transformation of nitrogen in the environment is known as the "nitrogen cycle" (Figure 1). Critical processes in the nitrogen cycle affecting manure handling and plant growth include the following:

- **Mineralization** — the conversion of organic nitrogen in soil organic matter, crop residues and manure to inorganic nitrogen (ammonia and ammonium). In this process, soil microorganisms break down organic material and release ammonium (NH_4^+) nitrogen. Formation of NH_4^+ increases as microbial activity increases, and microbial growth is directly related to soil temperature and water content.

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- **Nitrification** — the conversion of ammonium through nitrite (NO_2^-) to nitrate (NO_3^-). Nitrification is a biological process that specific species of bacteria mediate. It proceeds rapidly in warm, moist, well-aerated soils. Nitrification slows when soil temperatures drop below 50 F. Ammonium-forming fertilizers should not be fall-applied until soil temperatures are below 50 F.
- **Immobilization** — the conversion of inorganic nitrogen to organic nitrogen. Microorganisms that decompose high-carbon, low-nitrogen residues, such as corn stalks or small-grain straw, need more nitrogen to break down the material than is present in the residue. Immobilization occurs when the growing microbes use nitrate and/or ammonium present in the soil to build proteins. A temporary reduction in the amount of plant-available nitrogen occurs following immobilization (tie-up) of soil nitrogen.
- **Volatilization** — the release of ammonia into the atmosphere. Significant losses from some surface-applied nitrogen sources can occur through the process of volatilization. In this process, nitrogen is lost as ammonia (NH_3^+) gas. Ammonia is an intermediate form of nitrogen during the process in which urea is transformed to NH_4^+. Volatilization rates are greatest when the soil pH is higher than 7.3 and the air temperature is high.

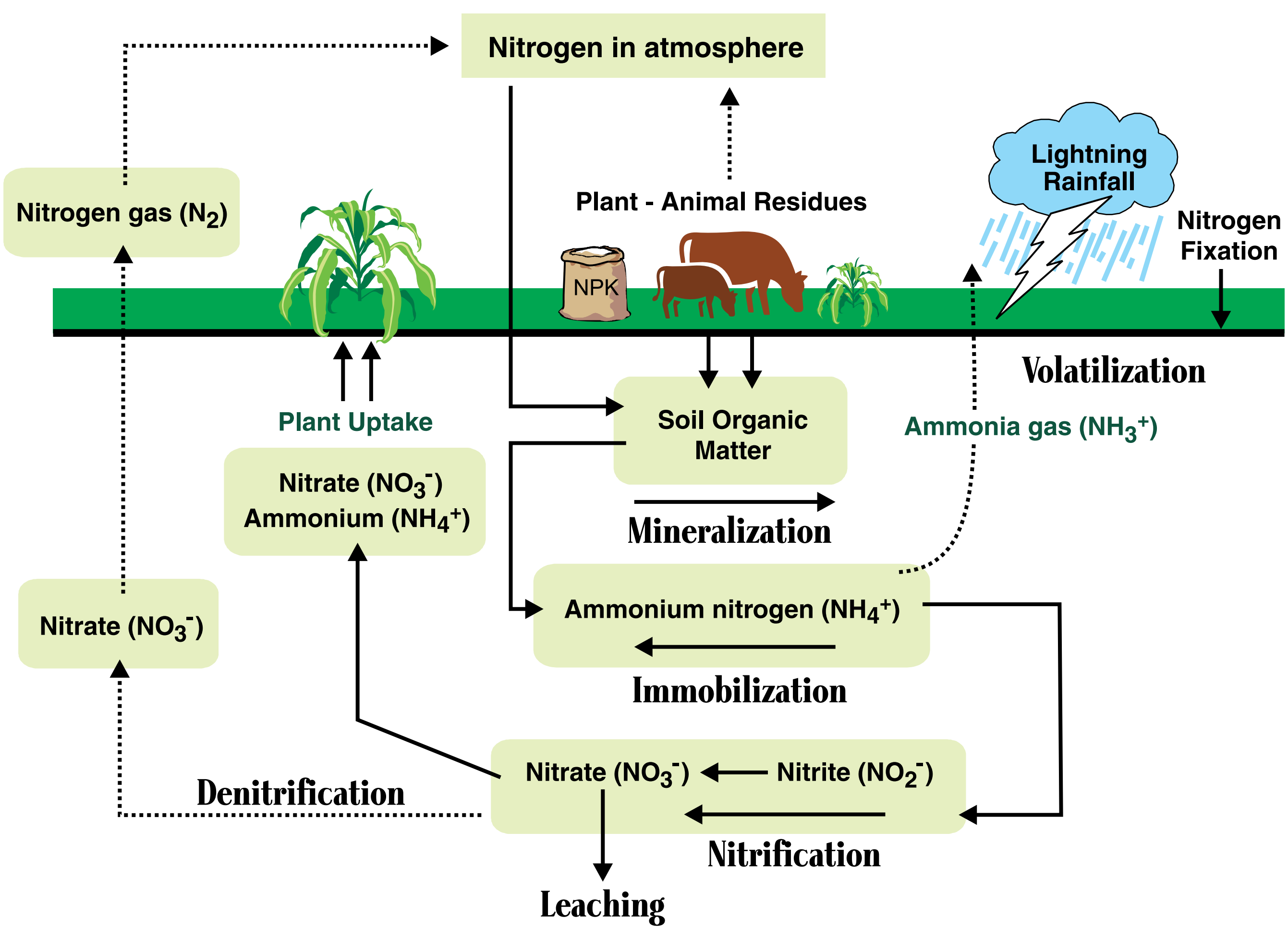

Figure 1. The nitrogen cycle. (Source: Livestock and Poultry Environmental Stewardship Curriculum)

- **Denitrification** — the process by which bacteria convert nitrate (NO_3^-) to nitrogen gas (N_2), which is lost to the atmosphere. Denitrifying bacteria use NO_3^- instead of oxygen in their metabolic processes when the soil atmosphere lacks oxygen. Denitrification occurs in waterlogged soil with ample organic matter to provide energy for bacteria. For these reasons, denitrification generally is limited to topsoil. Denitrification can proceed rapidly when soils are warm and saturated for two or three days.
- **Leaching** — the downward movement of nitrate through the soil profile with soil water. In contrast to the biological transformations previously described, loss of nitrate by leaching is a physical event due to water percolation through the soil. Nitrate is soluble and moves with excess soil water below the root zone. Nitrate that moves below the root zone has the potential to enter groundwater or surface water through tile drainage systems. The federal standard for the amount of nitrate-nitrogen allowed in drinking water is 10 parts per million.

To summarize these processes, keep in mind that nitrogen is lost from the plant/soil environment through the processes of volatilization, denitrification and leaching. Of course, harvesting crop products also removes nitrogen.

Plants' Nitrogen Uptake

Animal manures and other organic wastes can be important sources of nitrogen for plant growth. Although nitrogen can be added to soil in organic or inorganic forms, plants take up only inorganic nitrogen (that is, NO_3^- and NH_4^+). The organic nitrogen components of any fertilizer, including manure, must be mineralized to inorganic forms before they are available to plants. Commercial N fertilizers, legumes, manures and crop nitrification can result in less nitrogen loss and more plant uptake.

Nitrogen Interaction With Soil

Soil consists of many negatively charged mineral and organic particles. A measure of the total negative charge in soil is called its cation exchange capacity, or CEC. Most soils have enough exchange capacity to absorb and hold all positively charged particles or nutrients in soils. While the soils exchange capacity can hold ammonium ions, nitrate is a negatively charged nutrient and the negatively charged soil particles generally repel it, causing it to remain in the soil solution.

Water moving through soil will leave most nutrients "stuck" on the soil cation exchange sites. Nitrate is extremely soluble in water, so water picks it up and carries it along while moving through the soil.

Coarse-textured soils have large pore space, resulting in lower water holding capacity. Therefore, these soils have a higher potential to lose nitrate via leaching, when compared with fine-textured soils. Some sandy soils, for instance, may retain only ½ inch of water per foot of soil, while some silt loam or clay loam soils may retain up to 2 inches of water per foot. However, nitrate can be leached from any soil if excess rainfall or irrigation saturates the soil and causes water to move through the root zone.

Ammonium nitrogen has properties that are of practical importance for nitrogen management. Ammonium has a positive charge, and the negatively charged soil and soil organic matter attract or hold it. This means that NH_4^+ does not move downward in soils. However, NH_4^+ that plants do not take up is subject to change (conversion to NO_3^-) by the biological transformation occurring within days of NH_4^+ application to the soil system.

Inhibiting the conversion of NH_4^+ to NO_3^-, or nitrification, can result in less nitrogen loss and more plant uptake. However, preventing nitrification totally is not possible. Nitrification inhibitors are available commercially. These inhibitors are added to nitrogen fertilizers, including manure, and they work by inhibiting the growth of the bacteria that cause nitrification.

No way is available to totally prevent the loss of nitrogen to the atmosphere via volatilization or by the movement of some NO_3^- to water supplies, but sound management practices can keep losses within acceptable limits. These practices can include proper application timing, placement and incorporation, as well as appropriate storage and handling of manure or commercial fertilizers.

For additional information on water quality, see these other NDSU Extension Service publications and resources:

- “Environmental Implications of Excess Fertilizer and Manure on Water Quality”
- “Phosphorus Behavior in the Environment”
- “North Dakota Fertilizer Recommendation Tables and Equations”
- North Dakota Corn Nitrogen Calculator — www.ndsu.edu/pubweb/soils/corn/

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For more information on this and other topics, see **www.ag.ndsu.edu**