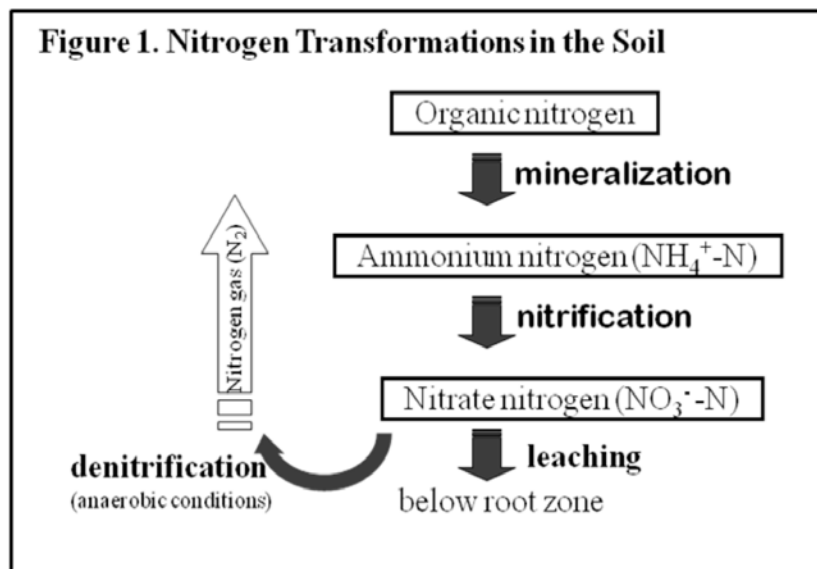


Nitrogen Transformations in Soil

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Manure contains many nutrients needed for crop production. Of these nutrients, nitrogen is one of the most important and is the most common added to soil for high yields. Nitrogen undergoes many transformations in soil as it is used, re-used, and made available by soil microbes.

It is critical to understand what happens to manure nitrogen after soil application in order to use it efficiently for crop production. The fate of nitrogen in soil addresses the different forms of nitrogen that occur, how they are used by plants, and how they move with water. Illustrated in figure 1 is just a portion of a nitrogen cycle that includes many interactions and forms of nitrogen in the atmosphere, water, soils, and living organisms.

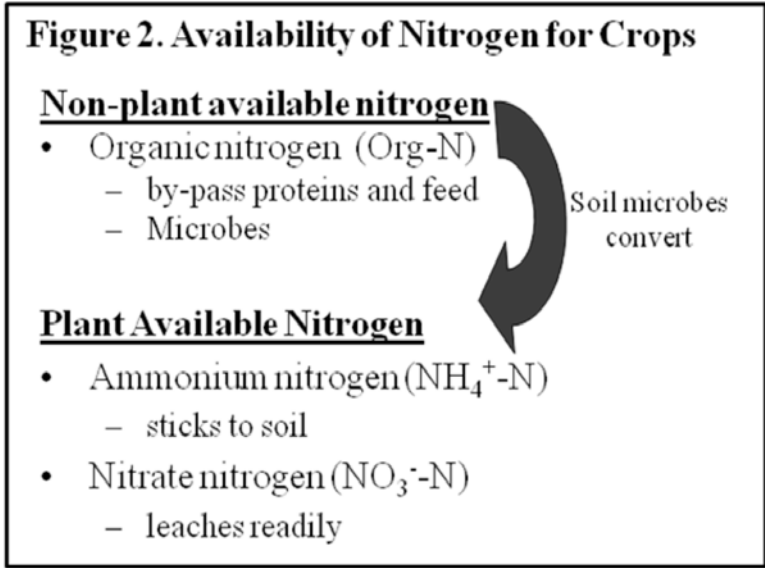


Forms and Fate of Nitrogen in Soil

There are three major forms or states of nitrogen in soil: organic nitrogen (Org-N), ammonium nitrogen ($\text{NH}_4^+\text{-N}$), and nitrate nitrogen ($\text{NO}_3^-\text{-N}$). Plants cannot use the nitrogen in the organic form. Plants can only use ammonium and nitrate forms of nitrogen. Microbes are constantly metabolizing and recycling nitrogen as they breakdown organic matter. **Mineralization** occurs when organic nitrogen is broken down to form ammonium nitrogen, which is available for plant use. **Nitrification** occurs as ammonium is further changed by microorganisms to the nitrate form, also available to plants. The rate at which nitrogen becomes available is determined by the complexity and stability of the organic matter and by microbial activity. It may occur in days or, if the nitrogen is in a very stable form, it may take years.

Organic Nitrogen is nitrogen contained in organic matter. For example it includes proteins, organic acids, and DNA as well as more complex organic molecules. Organic nitrogen is found in both feces and urine. In feces it is in partially digested forage and feed and in excreted microbes. In urine, most of the organic nitrogen is in the form of urea. Organic matter does not move easily through soil so these materials tend to remain near the soil surface when applied in liquid manure.

Organic matter must be broken down by soil microbes to release nitrogen in forms that plants can use (Figure 2). In general, conditions that are good for microbial activity, such as warm and moist soil, will promote more rapid breakdown of organic nitrogen. However, some organic nitrogen is in forms that are difficult for microbes to digest and release under any circumstances. For this reason it is hard to predict how much and when plant-available nitrogen will be released from organic matter. The majority of manure nitrogen is usually released in the first year of application but additional nitrogen will become available in subsequent years.



Ammonium nitrogen is the first plant usable form released when organic nitrogen is broken down by microbes. This process, called **mineralization**, occurs at a faster rate in the late spring, summer, and early fall than in colder months because warm, moist soils promote microbial activity. Ammonium nitrogen (NH₄⁺-N) has a positive charge which is important because it explains its behavior in soil. Because soil particles have a negative charge, there is an attraction between ammonium and soil particles which prevents ammonium from moving with water flowing through the root zone. In a sense, ammonium “sticks” to soil. For this reason, there is little concern about ammonium nitrogen moving past the root zone and ending up in groundwater.

Organic and ammonium nitrogen are the two common forms of nitrogen in liquid manure. When liquid manure is applied at agronomic rates, neither the organic nor ammonium form will penetrate more than a short depth into the soil and there is little chance of either of them moving through the soil profile to groundwater. However, ammonium nitrogen will not remain in soil for long. It will be converted to nitrate nitrogen.

Nitrification is the process by which a specialized group of soil microorganisms changes ammonium nitrogen to nitrate nitrogen. Like ammonium nitrogen, nitrate nitrogen can be used by plants. Unlike ammonium, nitrate (NO₃⁻) has a negative charge, which causes it to be repelled by negatively charged soil particles. As a consequence, nitrate nitrogen doesn’t “stick” to soil and

travels readily through the soil profile with water. When water goes below the plant root zone, nitrate nitrogen will go with it, a process called **leaching**.

The rate of nitrification, or how quickly ammonium nitrogen is changed to nitrate nitrogen, determines how quickly ammonium nitrogen applied in an irrigation containing liquid manure (or a commercial fertilizer) will be converted to nitrate nitrogen. Once nitrate nitrogen is present it can be leached in subsequent irrigations. Soil temperature is the main factor influencing the rate of nitrification in our agricultural soils. The warmer the soil, the faster ammonium nitrogen will be converted to nitrate nitrogen. Winters in California generally do not get cold enough to stop the nitrification process entirely. However the process is slowed down during cooler months and typically occurs in the range of several weeks to months. Under hot conditions, the transformation can occur within a few days to weeks. During summer, if more ammonium nitrogen is applied than the crop will use before the next irrigation, the excess ammonium will be converted to nitrate. When the next irrigation is applied, any excess water that moves below the root zone will carry nitrate nitrogen with it.

An additional potential fate for nitrate nitrogen under specific field conditions is its conversion to nitrogen gas (N₂) through a process called **denitrification**. This occurs when soil is totally saturated by flooding and no oxygen is present. When these conditions occur, specialized microbes convert nitrate, through a series of steps, into nitrogen gas. The nitrogen gas can then move up through soil and into the atmosphere, which is composed mostly of nitrogen.

Summary

Nitrogen in organic materials must first be decomposed by microorganisms before it can be used by plants. Mineralization is the process by which microbes break down organic matter and release ammonium nitrogen. Ammonium nitrogen, which can be used by plants, does not leach because it has a positive charge so it “sticks” to negatively charged soil particles. If not taken up by plants, ammonium nitrogen will be further degraded by organisms to produce nitrate nitrogen, also available to plants, through the process called nitrification. Nitrate molecules are negatively charged. They will be repelled by negatively charged soil particles, and if not taken up by plants, will move easily with water through soil, potentially resulting in nitrates reaching groundwater.

Understanding the forms of nitrogen and how they change within the soil will help you to maximize the nutrient potential of your liquid manure for crop production and will help minimize the possibility of nitrogen leaching out of the root zone and into the groundwater.

Information in this document was compiled by CDQAP to assist dairy producers in understanding and complying with the General Order Waste Discharge Requirements for Existing Milk Cow Dairies (Central Valley Regional Water Quality Control Board Order R5-2007-0035). Effort has been made to ensure accuracy, but these summaries are not official regulatory guidance and are not legal advice. Producers are advised that these summaries are not intended to be a substitute for producers reading the complete order and consulting their own legal counsel to ensure compliance with the waste discharge requirements. Should any information here conflict with the General Order and/or official information provided by the Regional Board, Board-provided information takes precedence.

