Manure Nitrogen Mineralization

Nitrogen in manure occurs mainly in organic forms (e.g., proteins) and as ammonium (NH_4). Some composted manures contain small amounts of nitrate. Ammonium and nitrate are plant-available forms of N, while organic N is not immediately plant-available. Organic forms may account for nearly all of the N in some types of manure (e.g., weathered cattle manure from corrals). In dairy lagoon water (from which some of the coarse solids usually have been removed in settling ponds or by screening), organic N may constitute less than half of total N, with the remainder in the NH_4 form.

Key Points

- *Mineralization is the microbial conversion of organic N to ammonium, a plant-available form of N*
- *In the first year following manure application, net mineralization of organic N can range from zero for mature composts to more than 50% for poultry manure.*
- *To protect groundwater quality while providing manure N at agronomic rates, the crop and irrigation system must be managed to maximize recovery of residual manure N as it is mineralized over a period of years.*

When manure is applied to land, a portion of the organic N is converted by soil microbes to NH_4. This is the process of ***mineralization***. (NH_4 is then nitrified by different soil microbes to nitrate.) To calculate the N fertilizer value of manure and to construct crop N budgets, an estimate of the rate of mineralization is useful. This rate is usually expressed as a fraction or percentage of the initial organic N that will be mineralized during the season or year following application.

Table 1 provides approximate values of N mineralization that can be used to estimate the N value of manure to crops.

Variability of Manure N Mineralization

The actual rate of mineralization is determined by several factors not reflected in the Table 1 values, including animal diet, age of manure, and soil temperature and moisture content. Mineralization is more rapid in warm, moist soils and slower in soils that are cold or dry. Even under uniform soil and environmental conditions, manures from the same animal species can display a wide range of N mineralization rates. In an 8-week laboratory study of 107 solid and liquid dairy manure samples, N mineralization for most samples fell between 10 and 20% of initial organic N. However, mineralization for some samples exceeded 50% of organic N while for others was less than zero, indicating N immobilization (Van Kessel and Reeves, 2002). Manure carbon to nitrogen ratio (C:N), which in some other research has been related to rate of N mineralization, was not helpful in explaining variability in this study.

Other researchers (Gale et al., 2006; Heinrich, 2009) have found that manures and other organic materials can be grouped into categories displaying similar N mineralization rates based on how the materials were produced, treated, and stored. In laboratory incubations at UC Davis, Heinrich (2009) observed some consistency in N mineralization rate within types of dairy manure – fresh manure, corral manure, separated solids, windrow compost, lagoon water, and lagoon sludge. The Year 1 values for dairy solid and liquid manures in Table 1 are based in part on the results of that study. These values are in approximate agreement with Oregon State University manure N mineralization guidelines (Sullivan, 2008). The values for dairy lagoon water are also supported by the findings of a multi-year field study in California (Harter et al., 2002).

Table 1. Guidelines for animal manure N mineralization in California.

	Year 1	Year 2
	- % applied organic N mineralized-	
Dairy lagoon water	**40-50**	**15**
Dairy lagoon sludge and slurry; corral manure	**20-30**	**15**
Dairy mechanical screen solids	**10-20**	**5**
Aerobically composted cattle or horse manure (finished or mature)	**0-10**	**5**
Solid poultry manure	**50**	**15**

1. 40-70% of mineralization value will occur within the first 4-8 weeks following application (Andrews & Foster, 2007; Gale et al., 2006). It is suggested that the lower value (40%) be used for late fall or winter applications.
2. Dairy lagoon water N mineralization may be delayed if a significant proportion of solid particles remains on the surface of the soil, as may occur when lagoon water is applied without sufficient dilution with fresh water.

Prediction of Manure N Mineralization for Time Intervals <1 Year

Annual mineralization factors, such as shown in Table 1, are useful where only one crop per year is grown and where only short time periods are available each year for manure application. Annual factors are less satisfactory in regions with mild winters and year-round crop production where manure can be applied at almost any time of the year. This is particularly a problem for dairy lagoon water in the Central Valley, which can be applied in irrigation water to forage crops throughout much of the year.

One useful approach to this problem is shown in the Oregon fertilizer calculator (Andrews and Foster, 2007), which recommends both <u>full season</u> and <u>28-day</u> mineralization percentages for a range of organic products, including animal manures. Because mineralization usually proceeds faster in the first few weeks after application, then more slowly for the remainder of the year, the 28-day factors are usually half or more of the full season factor. Based on these guidelines, we suggest that N mineralization in the 4- to 8-week period following manure application will equal <u>40 to 70% of the full year factors</u> shown in Table 1 (also see footnote 1 of Table 1).

Accounting for Long-term Mineralization of Manure N

Organic manure N not mineralized becomes integrated into the soil organic matter and is an important residual nutrient source for future crops (Seiter and Horwath, 2004). This is a "good news-bad news" situation. The mineralization of residual organic manure N from continuously manured soil is potentially well synchronized with the N demand of agronomic crops such as grains and forages. Also the increase in soil microbial activity due to repeated manure applications keeps N to some degree in "active organic" (and non-leachable) forms.

The problem in temperate climates is that production of nitrate following mineralization of residual organic N may occur at times when crops are not present or are small, e.g., during spring pre-irrigations or in the fall and early winter after the summer crop is harvested but before the winter crop has begun to take up N. Also, the rate of mineralization of the accumulated residual manure N will be influenced by manuring history, soil texture, tillage intensity, and other factors, and therefore is difficult to gauge.

The following strategies are recommended for managing N crops in fields having a history of regular manure applications:

1. In fields with a history (at least 3-7 years in most of California) of regular manure additions, reduce manure application rates to the point that total manure N applied is approximately equal to projected crop demand (Chang et al., 2007; Crohn, 2006). During periods of high crop N demand, apply carefully targeted doses of N using fertilizers or manures having high NH_4 and low organic N, e.g., poultry manure or dairy lagoon water that has gone through a solids separation treatment.
2. Use soil nitrate testing before applying fertilizer or manure, e.g., in spring.
3. Use plant tissue N sampling.
4. Use post-harvest soil nitrate testing with deep (3-4 ft) samples.
5. Establish check strips from which manure and N fertilizer applications are excluded, and use these check strips for soil and plant sampling and yield measurement.
6. Re-examine ways to reduce leaching of nitrate past the root zone.
    - Do not apply available N immediately before or during pre-irrigation
    - Avoid long, slow furrow or border check irrigations, which result in non-uniform water applications and potentially high nitrate leaching losses from some parts of the field.
    - Modify crop rotations to keep soil nitrate levels low. Some dairy producers plant a late summer-fall sudangrass crop following the silage corn crop. The sudangrass takes up residual nitrate that would otherwise be susceptible to loss during the winter. The practice of no-till farming may allow the sudangrass to be planted sooner after the summer crop is harvested.

Calculating Plant-Available Nitrogen (PAN) for Animal Manure

Plant-available N (PAN) of manure is defined as inorganic N plus the portion of the organic N that will be mineralized during the season or year following application. In Example 1, PAN is estimated for the summer crop planted immediately after manure is applied and for a second crop grown later in the same year. In Example 2 using dairy lagoon water, PAN is calculated only for the crop to which the manure is applied.

EXAMPLE 1.

An analytical laboratory report indicates that a sample of dairy corral manure contains 25 lb of total N/ton and 3 lb ammonium N (NH_4-N) per ton. (These values are reported on an "as received" moisture content basis.) Nitrate content of the sample was assumed to be negligible and was not determined. The sample has been collected in the spring shortly before the manure is to be applied and immediately incorporated. What is the PAN (plant-available N) from this application to be credited to the summer crop and to a following fall-planted crop?

Step 1. Calculate the organic N content of the manure

Manure organic N = Total N minus NH_4-N

= 25 lb N/wet ton – 3 lb N/wet ton = **22 lb organic N/wet ton**

Step 2. Determine short-term mineralization factors, i.e., partition the annual mineralization factor shown in Table 1 between a silage corn (summer) crop and a fall-planted forage crop.

Corral manure annual Year 1 factor = 20-30%. Use mid-point of range = **25%**

For the summer crop, take 70% of this value, which is the upper end of the partitioning range (40-70%) suggested in footnote 1 of Table 1. Credit the remaining 30% of the mineralized N to the fall-planted crop.

Mineralization percentage for summer crop = 70% X 25% = **17.5%**

Mineralization percentage for fall-planted crop = 30% X 25% = **7.5%**

Step 3. Calculate Plant-Available N (PAN), including the reported NH_4-N, for the summer crop.

PAN for the summer crop = 3 lb NH_4-N + (17.5% X 22 lb organic N)

= **6.9 lb N/ton wet manure**

Step 4. Calculate PAN credit to the fall-planted crop.

PAN for the fall-planted crop = 7.5% X 22 lb organic N

= **1.7 lb N/ton wet manure**

Summary example: A 10 ton/acre (wet basis) spring application of this manure would provide an estimated PAN of 69 lb N/acre to the summer crop, PAN of 17 lb N/acre to the fall-planted crop, and a total N application of 250 lb N/acre.

EXAMPLE 2.

Dairy lagoon water with a total N content of 500 milligrams per liter (mg/L or ppm) and ammonium N (NH_4-N) content of 260 milligrams per liter is applied by furrow irrigation to 24-inch tall corn. What is the plant-available N (PAN) content of this lagoon water, expressed in pounds per acre-inch and pounds per 1000 gallons? Assume that none of the lagoon water NH_4-N will be lost by volatilization during the application.

Step 1. Calculate the organic N content of the lagoon water in mg/L

Lagoon water organic N = total N minus NH_4-N

= 500 mg/L - 260 mg/L = **240 mg/L**

Step 2. Determine the short-term mineralization percentage, i.e., partition the full-year percentage shown in Table 1.

In Table 1, the mid-point of the mineralization percentage range for dairy lagoon water is **45%**

The suggested partitioning percentage is 40-70% (footnote 1, Table 1). With summer temperatures and considering the small particle size of lagoon water organics, use the upper end of the range, 70%.

Mineralization percentage for summer crop = 70% X 45% = **31.5%**

Step 3. Calculate PAN (NH_4-N plus mineralized organic N) in mg/L for the summer crop

PAN = 260 mg/L NH_4-N + (31.5% X 240 mg/L organic N) = **336 mg/L**

Step 4. Convert PAN from units of mg/L to lb N/acre-inch and lb N/1000 gal

Use the following conversions:

lb/acre-inch = mg per liter/4.41

lb/1000 gal = mg per liter/120

PAN = (336 mg/L)/4.41 = **76.0 lb N/acre-inch lagoon water**

PAN = (336 mg/L)/120 = **2.80 lb N/1000 gal lagoon water**

Summary calculations: The dairy lagoon water described in this example is applied uniformly to a 3-acre area. The lagoon pump operates at 700 gpm, and the application takes 90 minutes. What is the estimated amount of PAN and total N applied in lb N/acre?

Volume lagoon water applied = (700 gal/min X 90 min)/3 acres = 21,000 gal/acre

PAN applied = 2.8 lb N/1000 gal X 21,000 gal = 59 lb N/acre

Lagoon water total N content = (500 mg/L)/120 = 4.17 lb N/1000 gal lagoon water

Total N applied = 4.17 lb N/1000 gal X 21,000 gal = 88 lb N/acre

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Authors: G.S. Pettygrove, Cooperative Extension Soils Specialist, Department of Land, Air & Water Resources, University of California, Davis; A.L. Heinrich, UC Cooperative Extension, Salinas CA; D.M. Crohn, Associate Professor of Environmental Science and Extension Biological Systems Engineer, Department of Environmental Sciences, University of California, Riverside

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