How to Interpret a Manure Analysis Report

By Keith Reid

INTRODUCTION: WHY MANURE?

Manure is an inevitable part of livestock farming since livestock excrete roughly 80% of the nutrients they consume in feed. This can be treated as a waste or a valuable resource that can be used to recycle these nutrients back to the land. Using manure as a resource on your farm has several advantages:

- Nutrients in manure can replace mineral fertilizer and reduce input costs for crop production
- Applying manure to the soil will provide organic matter that will build soil carbon stocks and improve soil health
- Managing manure to retain nutrients will reduce the odours associated with manure application, making your neighbours happier
- Managing manure to maximize nutrient use will reduce the environmental losses, protecting the water resources we depend on

To realize these advantages, it is critical to know what is in the manure you are planning to apply. The nutrients in manure will vary between species and management systems. Having a manure analysis report, and knowing what it means, is the best way to maximize the value of your manure applications.

Figure 1: Solid manure pile

COMMON CONVERSION FACTORS:

1. %DM/100 X dry basis % = as applied %
2. ppm/10,000 = %
3. % P X 2.29 = % P_2O_5
4. % K X 1.2 = % K_2O
5. % X 10 = kg/T (metric tonne)
6. % X 10 = kg/m^3 (cubic meter)
7. % X 20 = lb/ton (US ton)
8. % X 83 = lb/1000 US gallons
9. 1 mS/cm = 1 dS/m = 1 mmhos/cm

MANURE ANALYSIS

To optimize fertility management, it is recommended that prior to field application, a manure analysis is conducted. There are many labs that analyze manure; here are some things to look for and be aware of when reading a lab report.

Most labs will provide numerical values for nutrients and organic matter, percent dry matter and/or percent moisture and pH. It is always important to pay attention to units, as different labs will provide measurements using different units, and sometimes a conversion must be performed to assist with understanding the parameters.

Dry Matter

A lab report will typically tell you the percent dry matter. The inverse of this is percent moisture (100% – % dry matter = % moisture). The higher the percent dry matter, the dryer the product is. The percent dry matter often comes into play when determining the amount of nutrients in the manure. Typically, nutrient values will be reported on a dry weight basis, but if the report does not say, it is worth inquiring. This is an important distinction when calculating fertilizer value.

If a manure is 15% dry matter and the sample is 2% nitrogen (dry weight basis), it is only 0.3% nitrogen as-applied (Dry matter * dry-weight basis measurement = as-applied measurement). Applying 10 metric tonnes of manure as it comes off the pile will give you 30 kgs of nitrogen, not 200 kgs of nitrogen.

C:N ratio

The carbon to nitrogen ratio (C:N) of manure will affect nutrient cycling and if and how quickly some of the nutrients in the manure will become available to the crop. Depending on the livestock species and the amount and type of bedding material, the C:N ratio can vary in manure but typically ranges from 8:1 to 40:1. Applying materials that have a C:N ratio of greater than ~40:1 will result in "tying up nitrogen" – where microorganisms, as they break down that carbonaceous material, will need more nitrogen than what is found in the manure and will "rob" the surrounding soil (and your crop) of nitrogen in order to decompose the manure. This can result in nitrogen deficiencies in your crop. A C:N ratio in the teens or low twenties usually means that there is more nitrogen in the manure than the microorganisms need, and so it will become plant-available more readily. Soil-applied manure with a C:N in the mid-20s to low 30s will slowly become plant-available over subsequent years.

The C:N ratio is not a standard measure in all manure analyses, but it can be inferred by the N content of the manure since the C concentration does not vary as much as N. In general, samples with an N content greater than 2.5% (dry matter basis) will have a C:N ratio <10, while any sample with an N concentration less than 1.5% will have a C:N >20.

Nutrients

Nutrient contents of manure will vary with the livestock species, the feeding programs, and the amount of dilution of urine and feces by bedding materials or precipitation. Typically, nutrient concentrations are higher in poultry and swine manure than in manure from ruminants because their rations are not diluted with the fibre in forage-based diets. Nitrogen transformations will occur in storage, with the organic fraction increasing in solid manure systems, while the NH_4-N fraction tends to increase in liquid systems. Phosphorous, potassium, and most micronutrients in manure should be readily available. However, with high application rates, caution must be taken that you are not applying some nutrients in excess. A balance of nutrient sources that target crop needs is always advised.

Application rates of manure should be based on a soil test report received after soil sampling. Knowing the nutrient content of your soil will help reduce the risk of over-applying nutrients and causing environmental damage and potentially reduce input costs.

Nitrogen

Nitrogen can take many forms in manure. "Organic nitrogen" refers to nitrogen that is part of microbial bodies or plant or animal tissue. The organic form of nitrogen is typically not readily plant-available. Organic nitrogen needs to be "mineralized" to become plant-available. This means that the microbes need to process the organic nitrogen, and then when the microbes excrete or die, that organic nitrogen is turned into its mineral form. The mineral forms of nitrogen that are plant-available are ammonium-nitrogen (NH_4) and nitrate-nitrogen (NO_3). The rate of mineralization will vary with the C:N ratio of the manure (faster with low C:N ratios, slower with high), as well as the weather (fastest under warm, moist conditions, but delayed by cold or dry soils). One of the challenges with using manure as the only source of N for the crop is that the release of N may not match the time when the crop needs it. Slow, steady mineralization of the organic N may not provide enough available N during the rapid growth phase of the crop when N uptake is greatest, but then keep releasing N later in the season after the crop has been harvested. Implementing the 4R principles into your nutrient management plan will help narrow the margin of error that may occur in approximating how much N will be needed.

The nitrogen content of your manure can be presented in several different ways in a manure analysis.

Figure 2: Spreading of manure onto a field

Total Nitrogen (N)

The total nitrogen analysis will include the organic N in the manure plus the NH_4-N in the sample. Some labs will digest the sample in strong acids to release the amino-N plus ammonium-N (total Kjeldahl N, or TKN), while other labs use a combustion analyzer; for manure analyses, these methods can be considered to be equivalent. The organic N concentration is calculated by subtracting the NH_4-N in the manure sample from the total N. Unlike compost, the nitrate concentration in manure is negligible, and is ignored.

A reminder: organic nitrogen needs to be broken down (mineralized) to release NH_4-N before it is available to crops.

Ammonium Nitrogen (NH_4-N)

Ammonium is a mineral form of N that is rapidly available to plants, either by direct uptake or by conversion to nitrate-N, which will move easily with soil water. Ammonium is the dominant form of mineral N in livestock manure, but the proportion will vary widely depending on the species and handling system. Typical proportions of NH_4-N in different manure types are shown in Table 1.

Table 1: Proportion of total nitrogen present as ammonium* (Typical values expressed as % of total N, as applied to land)	
Nutrient type	**Ammonium-N**
liquid hog	66%
liquid dairy	42%
liquid beef	43%
liquid poultry	67%
solid hog	26%
solid dairy	21%
solid beef (high bedding)	12%
solid horse	15%
solid poultry (broilers)	6%
solid poultry (layers)	46%
composted cattle manure	0.6%
*As the liquid concentration of the material increases, the ammonium content also increases. (Ontario Ministry of Agriculture Food and Rural Affairs, 2018)	

Ammonium will volatilize into the air if the manure is applied to the soil surface and left there. This process is particularly rapid under warm, windy conditions. Application method and timing will greatly impact the availability of N from manure, particularly with liquid manure.

Calculating Nitrogen Availability from Manure Analyses

The nitrogen that gets to the crop from a manure application comes from two different pools: the mineral N (NH_4-N) and the mineralization of the organic N. The mineral N is immediately available, the same as fertilizer (NH_4-N and NO_3-N are the same compounds as found in conventional fertilizer). However, mineral N is also lost from the soil if not taken up by plants soon after application. Some of the NH_4-N will be retained over the winter if manure is applied in the fall, as it will bind to the soil. However, it is safe to assume that all the mineral N in manure applied in early fall when conditions are still warm will have converted to NO_3-N and has been lost through either leaching or denitrification. For manure applied immediately before planting in the spring, all the NH_4-N that is not lost to the air through volatilization will be available to the crop. Where possible, manures with high N contents should be applied in the spring before planting.

Manure applied in the late summer or fall will undergo many transformations before spring, so it is difficult to predict the amount of N that will be available to the crop with a high level of precision. It is most common to assume that a certain proportion of the total N in the applied manure will be available to the following crop and that the proportion of available N will increase as manure is applied later in the season. Because the NH_4-N is subject to loss from the soil as well as to the air, manure incorporation is not assumed to increase N availability unless there is a cover crop grown to retain the N. Table 2 shows the approximate availability of fall-applied manure N as a proportion of the total N applied.

Application Timing Matters…A Lot!

When you apply manure will affect how much N is available, depending on the split between organic and NH_4-N in the manure. Ammonium (NH_4+) is rapidly available to plants, either taken up directly or converted to nitrate (NO_3-), but this also means it is subject to loss if there aren't growing plants to take it up. Organic N, in contrast, needs to be mineralized before it is available – a process that takes time in cool soils.

This means that the N availability from a manure that has mostly organic N (e.g. solid bedded pack from a beef farm) can be greater from a fall application. Nitrogen availability from manure high in NH_4-N (e.g. liquid swine manure) will be greatest from a spring application with immediate incorporation. Poultry manure also falls in this category, as most of the organic N is in the form of uric acid that rapidly breaks down to release NH_4-N.

Table 2: Estimated N availability from fall-applied manure as a proportion of total N

Manure Type	Application Time	Late Summer	Early Fall	Late Fall
	Species			
Solid Manure	Solid Cattle / Sheep / Horse	0.20	0.30	0.35
	Solid Swine	0.30	0.40	0.45
	Solid Poultry / Mink	0.40	0.50	0.60
Liquid Manure	Liquid Cattle	0.30	0.35	0.40
	Liquid Swine / Poultry	0.25	0.35	0.45

(Ontario Ministry of Agriculture Food and Rural Affairs, 2017)

Table 3: Proportion of NH_4-N from spring-applied manure retained in the soil

Incorporation	Injected (covered)	Incorporated			Not Incorporated
		1 day	3 days	5 days	
Proportion retained	1.00	0.75	0.50	0.40	0.35
These estimates are for average weather conditions. For any non-injected manure, increase the retained N by 0.10 for application in cool conditions (<10°C) and decrease by 0.10 for application in warm conditions (>20°C).					

Adapted from (Ontario Ministry of Agriculture Food and Rural Affairs, 2017)

Nitrogen availability from spring-applied manure can be predicted with greater precision by accounting for the availability of the organic-N and NH_4-N as separate pools. The first step is to determine how much of the applied NH_4-N is retained in the soil. This will vary with the weather conditions as well as how rapidly the manure is incorporated, as shown in Table 3.

The NH_4-N available to the crop is calculated as the concentration of NH_4-N in the manure (from the lab report) multiplied by the proportion that is retained in the soil.

The next step is to estimate the mineralization of the organic-N fraction of the manure. Organic N is calculated by subtracting the NH_4-N from the Total N in the sample. The availability of the organic-N to crops can be predicted using the C:N ratio of the manure, along with the time of application as shown in Table 4:

Table 4: Estimated organic N availability from manures

Manure Type	Application Time	Year 1	Year 2	Year 3
Poultry	Before June 15	0.30	0.15	0.05
	June 15 to Sept 15	0.15	0.20	0.05
	After Sept 15	0	0.30	0.05
Other livestock C:N < 15	Before June 15	0.20	0.10	0.05
	June 15 to Sept 15	0.10	0.20	0.05
	After Sept 15	0	0.30	0.05
C:N 15 to 25 (high in bedding)	Before June 15	0.10[2.]	0.20	0.10
	June 15 to Sept 15	0	0.20	0.10
	After Sept 15	0	0.10	0.10
C:N > 25 (very high in bedding)	Before June 15 incorporated	0-0.20[3.]	0.20	0.10
	Before June 15 surface	0	0.10	0.10
	After June 15	0	0.10	0.10

[1.] Estimates are based on a number of studies in the Northeastern US, Eastern Canada, and Europe, including Magdoff, 1978, Anderson et al., 1993, Klausner et al., 1994, Goss et al., 1995, Beauchamp et al., 1997, and Jensen et al., 1994. N availability for applications later in the season are not well studied, but it is assumed that mineralization is reduced in the application year and studies for spring-applied manures vary from about ½ to 2x the listed numbers.

[2.] There may be temporary N immobilization if manure is incorporated, but N will begin to mineralize later in the season.

[3.] This represents a net immobilization of nitrogen for the duration of the season.

The values provided in Table 4 relate to the influence of the C:N ratio on the percentage of nitrogen mineralized following land application. Different values are given depending on the time of application, where early season applications provide a longer period for the processes of decomposition and mineralization to occur and therefore have greater N mineralization values. Negative numbers will occur in situations where the organic-N concentration is low and dry matter is high, indicating that the C:N ratio of the organic fraction is high enough that it will be immobilizing N from the soil, including some of the NH_4-N applied with the manure. However, nitrogen will be released in subsequent years as the organic components decompose.

The total N available to the crop from the manure is the sum of the NH_4-N that has been retained in the soil and the available organic-N. The % available N is multiplied by the application rate of manure to calculate the reduction in N fertilizer.

Phosphorus

The phosphorus nutrient value on a manure lab analysis may be presented as % P, % P_2O_5, ppm P, or ppm P_2O_5. The fertilizer value of phosphorous is represented as P_2O_5. If the results are presented as P only, you must multiply that value by 2.29. For example, an analysis that presents 400 ppm P is really 916 ppm (or ~0.09%) P_2O_5.

There is a maxim among crop advisers that "manure is great for building soil P, but terrible for feeding the crop." It is bulky enough that it cannot produce the same concentration of P in a band near the seed as is possible with mineral fertilizer, and some of the P compounds in manure are slow to break down into available forms. Reducing the P fertilizer rate by approximately half the amount added as manure is a reasonable target. With any manure application, regular soil tests will help to monitor the impact on the availability of P to crops.

Watch the total P application rates with the manure, particularly if it is being applied primarily to supply nitrogen to crops. In the dairy manure example, if the manure was applied at 25 tons/acre, it would supply about 260 lb/ac of P_2O_5. If all of the N requirements are met through manure, the P application can be much greater than what is removed by the crop resulting in a significant build-up of P soil test values and the risk of elevated P in runoff.

Sample Calculation of P fertilizer adjustment After Manure Application:

Siobhan is growing a field of silage corn, and her soil test calls for applying 90 kg/ha (81 lb/ac) of P_2O_5. Her dairy manure has a total P concentration of 0.2% P (as applied), which she plans to apply at 15 tons/acre (30,000 lbs/acre).

Total P in Manure = 0.2%

P_2O_5 in Manure = 0.2 X 2.29 = 0.46%

P_2O_5 applied = 30,000 lbs/acre X 0.46% = 138 lb/ac

Fertilizer reduction = 138/2 = 69 lb/ac

Siobhan should plan to apply (81-69 =) 12 lb/ac of P_2O_5 fertilizer, or about 26 lb/ac of DAP.

Potassium

The potassium nutrient value on a lab analysis may present results as % K, % K_2O, ppm K, or ppm K_2O. The fertilizer value of potassium is represented as K_2O. If the results are presented as K only, you must multiply that value by 1.2. For example, an analysis that presents 400 ppm K is 480 ppm (or ~0.05%) K_2O.

Potassium in manure will be in soluble forms, so it is as available to plants as mineral fertilizer.

Manure for Increasing Soil Organic Matter

In addition to providing nutrients to your crop, manure application can improve soil health by increasing soil organic matter, enhancing soil tilth, improving soil structure, and increasing water retention (Magdoff and Van Es 2021). Building soil organic matter means increasing the amount of carbon in the soil. Soil organic matter is roughly 50% carbon, which means for every 1% organic matter in your soil, you have 0.5% organic carbon. In a changing climate, using soil as a carbon sink ultimately reduces greenhouse gases, helping to mitigate climate change. Building soil carbon is also a climate change adaption strategy – healthy soils with good levels of organic matter are more drought tolerant, have better drainage, and are more resilient in the face of disturbances such as extreme weather events (Favoino and Hogg, 2008; Martínez-Blanco et al., 2013)

The top six inches of soil in a field is referred to as an acre furrow slice, which weighs approximately 2,000,000 lbs. If your soil test shows 3% soil organic matter, that means that you have 60,000 lbs of soil organic matter per acre, which is approximately 30,000 lbs of soil carbon per acre. That's the same as two school buses!

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SUMMARY

Manure is an excellent material for supporting soil health and providing nutrients to crops, but the material is variable and having a lab analysis can help maximize the value of your farming system. The availability of nitrogen in the manure will vary depending on the C:N ratio, with lower availability from materials with higher C:N. The phosphorus, potassium, and micronutrients in the manure will add to the store of plant-available nutrients in the soil and could be an environmental concern if high rates of manure are added.

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