Manure Management Facts

Manure Nutrients and their Behaviour in Soil

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Manure is both a natural by-product of livestock production and an excellent source of nutrients for crop production. The use of manure as a fertilizer is a beneficial way to recycle manure nutrients within an agricultural system. Most livestock operations are on, or surrounded by, large areas of productive agricultural land where manure can be applied in a sustainable manner. In many instances, manure can be a substitute for commercial, inorganic fertilizers. Manure not only acts as a source of plant nutrients but, through the addition of organic matter, it also helps to improve soil tilth, structure, aeration and water holding capacity.

Manure as a Fertilizer

Manure contains both macro- and micro-nutrients needed for crop production in organic and inorganic forms. Inorganic nutrients are readily available to the growing crop, while the organic nutrients become available gradually over time. A crop responds to inorganic nutrients in soil, whether they originate from manure or commercial fertilizer. The manure nutrients of primary interest for crop production are nitrogen (N) and phosphorus (P).

There are many factors that affect the nutrient composition of manure including the type of housing system, whether or not bedding is used, the type of bedding, the age of the animals, the feeds and feed supplements that are being used and the type of manure storage and handling system.

Nitrogen in Manure

The nitrogen (N) content of manure is highly variable (Table 1). A manure analysis is required to determine how much N is in the manure and in what forms. A proper manure analysis contains three N measurements:

- total nitrogen
- ammonia (or ammonium) nitrogen
- organic nitrogen

As the term suggests, total nitrogen is an estimate of all the N contained in the manure. It includes ammonium N, organic N and any nitrate N that may be present. Not all of this N will be available to the crop following application.

Ammonium N (NH_4-N) is the predominant inorganic form of N in manure and it is immediately available to the crop following application. It may be expressed as either ammonium or ammonia on the manure analysis and it is the same form of N as is in ammonium-based commercial fertilizers.

Nitrate N (NO_3-N) is another inorganic form of N. Although soil can contain significant quantities of nitrate N, it is typically present in manure in very low or insignificant amounts.

Manitoba

Organic nitrogen is determined indirectly by calculating the difference between total N and ammonium N. Organic N is slowly released to the crop and can have a significant impact on the N-supplying power of the soil if it is allowed to build up after several years of manure applications.

Organic N = Total N – Ammonium N

Phosphorus in Manure

The phosphorus (P) content of the manure is also highly variable (Table 1). Although manure is a mixture of organic and inorganic P, manure analyses routinely measure only total P.

Manure Application to Soil

When manure is applied to soil, the nutrients can undergo a number of transformations that may accelerate or delay their availability for crop uptake. The availability of the N in manure is highly variable and is influenced by the forms of N in the manure, application techniques and timing, along with weather conditions. The availability of the P in manure depends on the forms of the P and its placement relative to the plant root system.

Table 1. Nitrogen, Phosphorus and Moisture Contents of Various Manures[1]

Manure Type		Total Nitrogen	Ammonium Nitrogen	Organic Nitrogen	Total Phosphorus	Dry Matter
		-------------- lb/1000 gal --------------				%
Liquid Pig[2] n=70	Ave	36	22	14	12	4.3
	Max	68	52	37	32	8.0
	Min	6.0	4.4	1.6	1.0	2.0
Liquid Dairy n=208	Ave	31	15	16	8.2	7.1
	Max	76	72	56	85	15
	Min	7.0	0.7	0.5	1.0	1.0
Liquid Chicken n=65	Ave	79	58	21	25	8.3
	Max	115	99	92	51	14
	Min	30	1.1	1.3	6.0	2.6
Manure Type		**Total Nitrogen**	**Ammonium Nitrogen**	**Organic Nitrogen**	**Total Phosphorus**	**Dry Matter**
		----------------- lb/ton -----------------				%
Solid Dairy n=75	Ave	11	2.6	8.2	3.0	20
	Max	16	6.4	15	17	38
	Min	6.6	0.0	1.6	1.0	15
Solid Beef n=147	Ave	11	1.2	9.6	2.3	28
	Max	40	8.5	40	13	67
	Min	2.8	0.0	1.4	0.6	15
Solid Chicken n=54	Ave	45	14	30	20	48
	Max	94	34	82	56	84
	Min	6.0	4.1	0.3	1.2	16

[1] MARC 2008. Manure Application Rate Calculator software for Manitoba, Manitoba Agriculture, Food and Rural Initiatives

[2] For pig manure data by operation type with and without phytase use, see the Farm Practices Guidelines for Pig Producers in Manitoba, Manitoba Agriculture, Food and Rural Initiatives, April 2007.

Nitrogen Behaviour in Soil

Mineralization

The organic N in manure must go through a decomposition process known as mineralization – the conversion of organic N to ammonium N. In Manitoba, it is estimated that about 25% of the organic N in manure is mineralized and available to the next crop. The remainder becomes available during subsequent years at significantly decreased rates.

Nitrification

Although nitrate is present at low concentrations in manure, manured soils can contain significant amounts. This is because the ammonium from the manure is converted to nitrate by soil microorganisms through the nitrification process.

Volatilization

The ammonium N in manure can be lost to the atmosphere as ammonia gas through the chemical process of volatilization. The amount of N lost through volatilization during application of manure depends on the amount of ammonium in the manure, exposure of the manure to the atmosphere and weather conditions (Table 2). The actual amount of ammonium available to the crop is calculated by subtracting the amount of ammonia estimated to be lost by volatilization during application from the amount of ammonium in the manure.

Available Ammonium N = Total Ammonium N x (100% - % Volatilization loss)

Management practices that minimize N losses due to volatilization include:

- injection of manure
- surface application of manure with immediate incorporation;
- cool conditions;
- humid conditions (note: manure should not be applied in wet or rainy conditions that increase the risk of surface runoff).

Immobilization

Immobilization is the conversion of inorganic N to organic N (i.e. the opposite of mineralization).

Table 2. Volatilization losses (%) associated with different application methods and weather conditions

Method of Application	Weather Conditions				
	Average	Cool Wet	Cool Dry	Warm Wet	Warm Dry
Injected	0	0	0	0	0
Incorporated 1 day	25	10	15	25	50
Incorporated 2 day	30	13	19	31	57
Incorporated 3 day	35	15	22	38	65
Incorporated 4 day	40	17	26	44	72
Incorporated 5 day	45	20	30	50	80
Not Incorporated	66	40	50	75	100
Irrigated	Above +10%	Above +10%	Above +10%	Above +10%	Above +10%
Standing/Cover Crop/Stubble	35	25	25	40	50

Denitrification

Nitrogen can be lost to the atmosphere as N_2 and N_2O through a microbial process called denitrification. N_2O is a potent greenhouse gas.

Management practices that minimize N losses due to denitrification include:

- avoiding nutrient applications to areas of the field that are wet such as poorly drained soils and depressional areas
- late fall (when soil temperatures are below 4C), spring or in-season applications of N containing fertilizers including manure, whenever possible.

Nitrate Leaching

Nitrate is highly soluble in water. As water moves down through the soil, such as after snowmelt or heavy rainfall, it can carry nitrate with it. Nitrate contamination of groundwater is a concern, particularly if the groundwater is a source of drinking water. The guideline maximum acceptable concentration of nitrate in drinking water, set by Health Canada, is 10 milligrams per litre (mg/L) nitrate N (or 45 mg/L nitrate).

Management practices and conditions that minimize the risk of nitrate leaching and nitrate contamination of groundwater include:

- N applications that target crop N requirements
- annual soil testing for residual N at a depth of 0-24 inches
    - residual soil nitrate N is the concentration of nitrate in the soil after harvest when the crop is not actively growing
- adjustment of N application rates to maintain low concentrations of residual soil nitrate N
- medium to fine textured soils
    - coarse textured soils such as sands are at the highest risk of nitrate leaching
- crops with dense or deep rooting systems such as grass and alfalfa that are efficient at intercepting and withdrawing soil nitrate N
- judicious irrigation to avoid excess moisture levels
- deep groundwater that is protected by fine textured materials such as clay.

Runoff and Soil Erosion

Nitrogen can be transported to surface water in runoff water and through soil erosion. Nitrogen in the form of ammonia is particularly toxic to fish.

Management practices that minimize N losses to surface water include:

- soil conservation practices to minimize soil erosion
- injection and incorporation of manure, particularly fall-applied manure
- maintaining appropriate application setbacks.

Phosphorus Behaviour in Soil

Although P is less dynamic in soil than N, its management in manure is challenging. Most Manitoba soils are naturally deficient in plant-available P. Crops growing on low P soils require fertilization to reach optimal yields and will benefit from a build up in soil P until agronomic requirements are met. However, repeated applications of manure can result in soil P levels well above agronomic requirements. In addition to being a valuable crop nutrient, P is a serious contaminant at elevated levels in surface water. For this reason, loss of P from agricultural lands is of particular concern to surface water quality.

Mineralization

As with N, mineralization of organic P to inorganic P takes place in the soil and contributes to the supply of plant available P.

Retention

Inorganic P tends to bind readily in both alkaline and acidic soils to organic matter, calcium (Ca), magnesium (Mg), iron (Fe) and aluminum (Al). Fine textured soils (i.e. clays) are able to bind considerably more P than coarse textured soils (i.e. sands).

Solubilization

Soil does not have an unlimited capacity to bind P. Rising soil test P levels are often accompanied by an increase in soluble P (P dissolved in water).

Runoff and Soil Erosion

Phosphorus can be transported to surface water as particulate P through soil erosion and as soluble P in runoff water. The loss of soluble P in runoff water is more difficult to control than P transported by soil erosion.

Management practices that minimize P losses to surface water include:

- soil conservation practices that minimize soil erosion
- injection and incorporation of manure, particularly fall-applied manure
- maintaining appropriate application setbacks
- managing soil test P levels to remain below 60 ppm, whenever possible.

Manure Analysis

Testing manure for each livestock operation and each application event is the best way to estimate the nutrient content of manure. A manure analysis should be based on a well-mixed, representative sample. Manure is very heterogeneous and obtaining a representative sample can be very difficult. Sometimes, more than one sample is required to estimate the nutrient concentration because the characteristics of the manure change (for example, during pump-out of a liquid manure storage structure).

It is ideal to know the nutrient content of the manure before application so that application rates can be set to meet crop nutrient requirements or removals. Receiving test results prior to manure application can be challenging, particularly for liquid manure. This is because the manure in storage is not typically agitated until just before and during pump-out for application. One way to address this concern is to have a database of historical manure test results for a given operation to use until recent test results can confirm nutrient contents.

Manure samples should be analyzed by an accredited laboratory on at least an annual basis. More frequent manure analyses may be required if the manure is applied at multiple times during the year (such as spring and fall) or if management practices are likely to create a change in the nutrient content of the manure. Rapid field test kits for liquid manure exist for estimating the readily available portion of N, however, the result of a field test should be verified by comparing it to a laboratory analysis of the same manure sample. Historical laboratory test results for a given operation can be used to assess the accuracy of recent laboratory and field test results.

A basic manure analysis package should include total nitrogen, ammonium N, total P, total K and dry matter content. The cost of a basic manure analysis package will vary depending on the laboratory and the type of analyses conducted. Field test kits allow for immediate estimation of the ammonium N content of liquid manure. The results should always be checked against a laboratory analysis.

Manure Sample Handling Instructions

1. Consult the laboratory regarding any specific requirements it may have regarding sample size and shipping, turn-around times, analytical options and costs. The lab will provide a submission form and may also provide containers (usually plastic jars) and labels.
2. For liquid manure, fill the plastic jar with manure to approximately the ¾ mark, to allow space for gases to accumulate, and close the lid tightly. For solid manure, a zip-loc bag may suffice.
3. Double bag the sample (whether liquid or solid) and seal the bags to prevent leakage.
4. Store the sample in a cool place (preferably a refrigerator or freezer) until shipped.
5. Place manure in a sturdy shipping box along with a completed copy of the lab's submission form (include all required information including name, address, sample description and parameters for analysis). Label the shipping box according to the courier's instructions.
6. Ship to the laboratory as quickly as possible (by courier, prepaid). Be certain that the sample spends no more than two days in transit. A courier service can provide delivery in less than two days. Regular mail service frequently does not. If a sample must be stored before shipping, refrigerate or freeze it.

Manure contains nitrogen (N), phosphorus (P), potassium (K) and micro-nutrients and can be a substitute for synthetic fertilizers. The nutrient content of manure is highly variable and can be difficult to establish. The concentration of each nutrient depends on the livestock type, feed and manure handling system.

The availability of N and P for crop uptake depends on their form, the method of manure application as well as soil and weather conditions. When applied to soil, manure nutrients enter the soil nutrient cycle where they undergo a number of transformations.

Although valuable in crop production, manure nutrients can be lost from the agricultural system and become environmental contaminants if managed poorly. There are a number of soil conservation and manure management practices that can be used to minimize the risk of nutrient loss to the environment.

Analyzing a well-mixed, representative manure sample is the best way to estimate the nutrient content of manure. Used in conjunction with estimates of manure nutrient availability, a manure application rate can then be calculated to meet crop nutrient requirements or removals.

For information on how to calculate a manure application rate, refer to the factsheet titled "Calculating Manure Application Rates".

For More Information

- Your local Manitoba Agriculture, Food and Rural Initiatives Growing Opportunities (GO) Centre or Office.
- Manitoba Agriculture, Food and Rural Initiatives website: **manitoba.ca/agriculture**