2 Understanding Manure

In order to properly use manure as a fertilizer, producers need to understand moisture content, nutrient forms, nutrient transformations and nutrient availability.

2.1 Moisture Content

The moisture content of manure is influenced by livestock production practices and the manure handling and storage technology used on the farm. In liquid systems, bedding is not added to the manure but water, from a variety of sources, may be added to the manure. Within the barn, the choice of feeding equipment (such as wet-dry feeders) can significantly reduce the amount of water that enters the manure storage. Wash water will also enter the manure storage. The design of the liquid manure storage structure will also affect the quantity of rainwater that is added to the manure.

In solid systems, the type and amount of bedding and the amount of precipitation entering the manure pack or pile is exposed to (such as in open-lot situations) greatly affect the moisture content of the manure. The way in which manure is stored will also affect the moisture content. Diverting rainwater from the manure pile, with roof and eaves will reduce the moisture content. Covering the manure pile will also reduce the moisture content.

In general, livestock manure can be classified as solid, semi-solid or liquid. Solid and semi-solid manures have a higher organic matter content than liquid manure because of the added bedding. Manure types can be differentiated on the following basis:

- Solid <80% moisture content
- Semi-solid 80% to 90% moisture content
- Liquid >90% moisture content

2.2 Nutrients in Manure and Soil

Livestock manure contains most of the nutrients that crops require, including nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca), magnesium (Mg), copper (Cu), manganese (Mn), zinc (Zn), boron (B) and iron (Fe). Nitrogen, P and K are macronutrients because they are required in large amounts for optimal plant growth. They are also called primary nutrients because they are typically the nutrients limiting crop production and the most commonly applied as fertilizer. Sulphur, Ca and Mg are also macronutrients but are considered secondary nutrients because they are normally present in soil in sufficient amounts for crop growth. Copper, Mn, Zn, B and Fe are all called micronutrients because they are required in very small quantities by plants.

The nutrient content of manure is highly variable. The actual nutrient content of a manure will depend on the type of operation, moisture content of the manure, 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. The manure nutrient analysis results can also be greatly affected by how the manure sample is taken. Table 2.1 illustrates the wide range in manure nutrient concentrations from manure samples analyzed at commercial laboratories (data from the Manure Application Rate Calculator software for Manitoba).

Table 2.1: Manure Nutrient Analysis Ranges for Total Nitrogen, Ammonium, Phosphorus and Potassium for Swine, Dairy, Beef and Poultry Manures

	Nutrient Concentrations								
	Lab Units [2]			Metric			Imperial		
Liquid Swine n=133 [1]	% for all except ppm for NH_4^+-N			kg/1,000 L			lb/1,000 gal		
	avg	min	max	avg	min	max	avg	min	max
Total N	0.31	0.04	0.68	3.1	0.4	6.8	31	4	68
NH_4^+-N	1,946	230	5,150	1.9	0.2	5.2	19	2	52
Total P	0.10	0.00	0.51	1.0	0.0	5.1	10	0	51
Total K	0.14	0.03	0.37	1.4	0.3	3.7	14	3	37
Dry Matter (1 - 10%) [3]	3.4	1.0	9.0						
Liquid Dairy n=252	% for all except ppm for NH_4^+-N			kg/1,000 L			lb/1,000 gal		
	avg	min	max	avg	min	max	avg	min	max
Total N	0.34	0.07	0.76	3.4	0.7	7.6	34	7	76
NH_4^+-N	1,463	21	7,168	1.5	0.0	7.2	15	0	72
Total P	0.09	0.01	0.85	0.9	0.1	8.5	9	1	85
Total K	0.32	0.02	0.98	3.2	0.2	9.8	32	2	98
Dry Matter (1 - 20%)	8.9	1.0	19.9						
Solid Beef n=45	% for all except ppm for NH_4^+-N			kg/tonne			lb/ton		
	avg	min	max	avg	min	max	avg	min	max
Total N	0.60	0.14	2.02	6.0	1.4	20.2	12	2.8	40.4
NH_4^+-N	564	11	2,656	0.6	0.0	2.7	1.1	0.0	5.3
Total P	0.14	0.03	0.64	1.4	0.3	6.4	2.8	0.6	12.8
Total K	0.59	0.16	2.54	5.9	1.6	25.4	11.8	3.2	50.8
Dry Matter (20 - 40%)	26.4	20.1	38.4						
Liquid Poultry n=35	% for all except ppm for NH_4^+-N			kg/1,000 L			lb/1,000 gal		
	avg	min	max	avg	min	max	avg	min	max
Total N	0.80	0.30	1.42	8.0	3.0	14.2	80	30	142
NH_4^+-N	5,751	107	1,051	5.8	0.11	10.5	58	1	105
Total P	0.28	0.06	0.51	2.8	0.6	5.1	28	6	51
Total K	0.33	0.16	0.53	3.3	1.6	5.3	33	16	53
Dry Matter (1 - 20%)	9.10	2.60	18.70						

[1] number of samples in the dataset for each manure type
[2] all analyses in this column are in % except for NH_4^+-N
[3] dry matter ranges for typical manure analyses (dry matter contents < 1.0% not included as these manures are considered to be highly dilute)

Reference: Manure Application Rate Calculator (MARC98) for Manitoba

In Alberta, Schedule 3, Table 5 of the Standards and Administration Regulation under the *Agricultural Operation Practices Act* contains specific manure nutrient values of typical agricultural livestock manures for the purpose of calculating land-base requirements for livestock operations. *Agricultural Operation Practices Act.* Regulation 267/2001. Queens Printer for the Province of Alberta.

Table 2.2: Boron, Sulphur, Copper, Zinc and Manganese Manure Analysis Results for Various Swine Operations with Liquid Manure and Beef Feedlots with Solid Manure

			Nutrient Concentrations [1]								
Manure/Operation Type			**Lab Units (ppm)**			**Metric (kg/1,000 L)**			**Imperial (lb/1,000 gal)**		
Liquid Swine Manure [2]		**n**	**avg**	**min**	**max**	**avg**	**min**	**max**	**avg**	**min**	**max**
B	Nursery	11	4.27	3.15	7.34	0.004	0.003	0.007	0.04	0.03	0.07
	Feeder	92	1.98	0.32	11.20	0.002	0.000	0.011	0.02	0.00	0.11
	Sow	37	1.57	0.36	5.63	0.002	0.000	0.006	0.02	0.00	0.06
	Farrow-Finish	5	1.87	0.52	2.75	0.002	0.001	0.003	0.02	0.01	0.03
S	Nursery	11	266.0	34.1	727	0.266	0.034	0.727	2.66	0.34	7.27
	Feeder	92	271.3	42.8	1,220	0.271	0.043	1.220	2.71	0.43	12.20
	Sow	37	143.1	23.2	606	0.143	0.023	0.606	1.43	0.23	6.06
	Farrow-Finish	5	162.0	39.2	313	0.162	0.039	0.313	1.62	0.39	3.13
Cu	Nursery	11	57.9	1.2	169.0	0.058	0.001	0.169	0.58	0.01	1.69
	Feeder	92	37.2	1.6	177.0	0.037	0.002	0.177	0.37	0.02	1.77
	Sow	37	13.4	0.6	152.0	0.013	0.001	0.152	0.13	0.01	1.52
	Farrow-Finish	5	20.4	2.5	45.2	0.020	0.003	0.045	0.20	0.03	0.45
Zn	Nursery	11	131.0	1.58	541.0	0.131	0.002	0.541	1.31	0.02	5.41
	Feeder	92	53.98	1.18	239.0	0.054	0.001	0.239	0.54	0.01	2.39
	Sow	37	50.34	1.27	338.0	0.050	0.001	0.338	0.50	0.01	3.38
	Farrow-Finish	5	35.95	5.77	95.8	0.036	0.006	0.096	0.36	0.06	0.96
Manure/Operation Type			**Lab Units (ppm)**			**Metric (kg/tonne)**			**Imperial (lb/ton)**		
Solid Beef Manure [3]		**n**	**avg**	**min**	**max**	**avg**	**min**	**max**	**avg**	**min**	**max**
B	Feedlot	173	6.9	1.7	16.5	0.007	0.002	0.017	0.014	0.003	0.033
S	Feedlot	173	2,458	679	6,042	2.46	0.68	6.04	4.92	1.36	12.08
Cu	Feedlot	173	22.6	0.84	49.9	0.023	0.001	0.050	0.045	0.002	0.100
Zn	Feedlot	173	152	21.6	589	0.152	0.022	0.589	0.304	0.043	1.178
Mn	Feedlot	173	157	28.4	372	0.157	0.028	0.372	0.314	0.057	0.744

[1] All nutrient values expressed on a wet-weight basis.
[2] Data adapted from: Fitzgerald, M.M. and G.J. Racz. 2001. Long-term effects of hog manure on soil quality and productivity. Final Report presented to the Agri-Food Research and Development Initiative.
[3] Unpublished Data (B. Olson, Alberta Agriculture, Food and Rural Development, 2002).

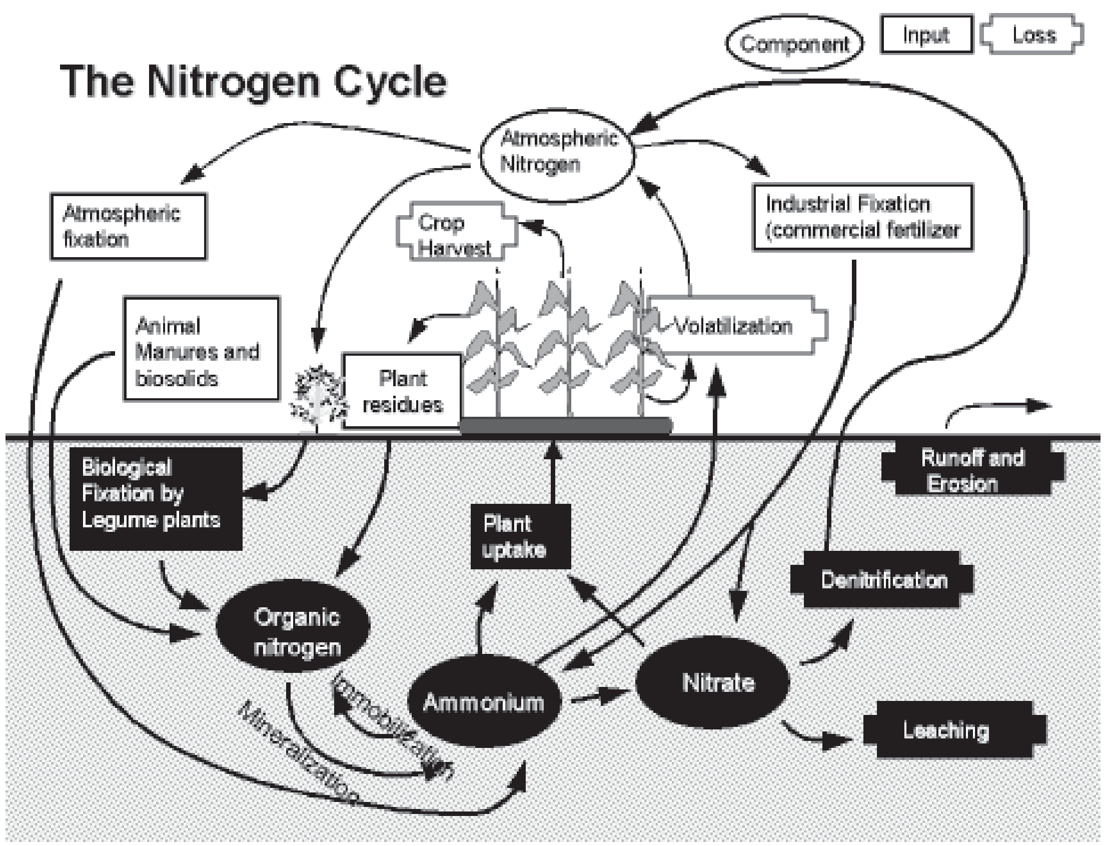
2.2.1 Nitrogen Forms in Manure

Manure is an excellent source of N. The N found in manure is primarily made up of two forms: ammonium N and organic N. Manure contains very little nitrate N.

Total Nitrogen (N) is a measure of all of the N contained in the manure. In general, it includes the ammonium N, the organic N and any nitrate N that may be present. Not all of the nitrogen in manure is available for crop production. As well, the concentrations of total N in manures are highly variable both between and within all livestock types. Table 2.1 demonstrates the broad range of total N contents of manure.

Ammonium N (NH_4^+-N) is an inorganic form of N in manure. The quantity of ammonium N in manure is of particular importance because it is immediately available for crop uptake. The amount of ammonium N in manure varies widely, even within livestock types (Table 2.1). Despite the existence of exceptions, there are observed trends in the relative ammonium N contents of solid versus liquid manure. For example, although liquid swine manure analyses have shown that the ammonium N content can be anywhere from 30 to 90 % of the total N, typically, liquid swine manure has more than half of the total N in the plant-available ammonium form. As well, although some solid beef manure analyses have shown the ammonium N content to be up to 60% of the total N, solid beef manure often contains most of the N in the organic form, with only 5 to 10% of the total N in the ammonium form.

Nitrate N (NO_3^--N) is another inorganic form of N. Although soil can contain significant quantities of nitrate N, most manures contain low amounts.



Potash and Phosphate Institute, 2002.

Organic N is not measured directly but is calculated from the total N and ammonium N measures, as follows:

Organic N = Total N – ammonium N

The organic N must be decomposed (mineralized) to inorganic N to be made plant available.

2.2.2 Nitrogen Processes in Soil

Differences in the forms of N present in manure, application techniques, and soil and weather conditions all influence the availability of the manure N to plants. For example, manure with a high ammonium N content will provide more plant-available N than manure with low ammonium N content. However, if manure is not applied using techniques that conserve N, it may be lost to air or water and rendered unavailable to plants.

Mineralization: When using manure as a fertilizer, it is important to understand that only a portion of the total manure N is immediately available. Some of the N in manure is in the organic form and must go through a decomposition process known as mineralization. Specifically, mineralization is the conversion of organic N to ammonium N. Mineralization can be slow and, as a result, the N is released throughout the growing season rather than at the time of application, as is the case with commercial inorganic fertilizer.

Nitrification: Although manure contains low amounts of nitrate, nitrate can be found in manured soils in significant quantities. This is because ammonium is converted to nitrate by microorganisms in the soil through a process called nitrification.

Immobilization: Many solid manure systems use large amounts of bedding materials that are high in carbon (C). This can raise the C:N ratio of the manure significantly. A high C:N ratio in manure can delay the availability of N to the crop in the year of application. Soil organisms use the added C as a source of food. As they consume C, they also consume N, thereby making it temporarily unavailable to plants. This process is called immobilization

Canola Field

(conversion of inorganic N to organic N). When the organisms die, N and other nutrients are released back into the soil.

Volatilization: Nitrogen can be lost to the atmosphere by the conversion of ammonium to ammonia gas through a process called volatilization. Nitrogen losses through this process can occur during storage as well as during field application. The amount of N lost through volatilization during land application of manure is a function of the amount of ammonium in the manure, exposure of the manure to the atmosphere and weather conditions.

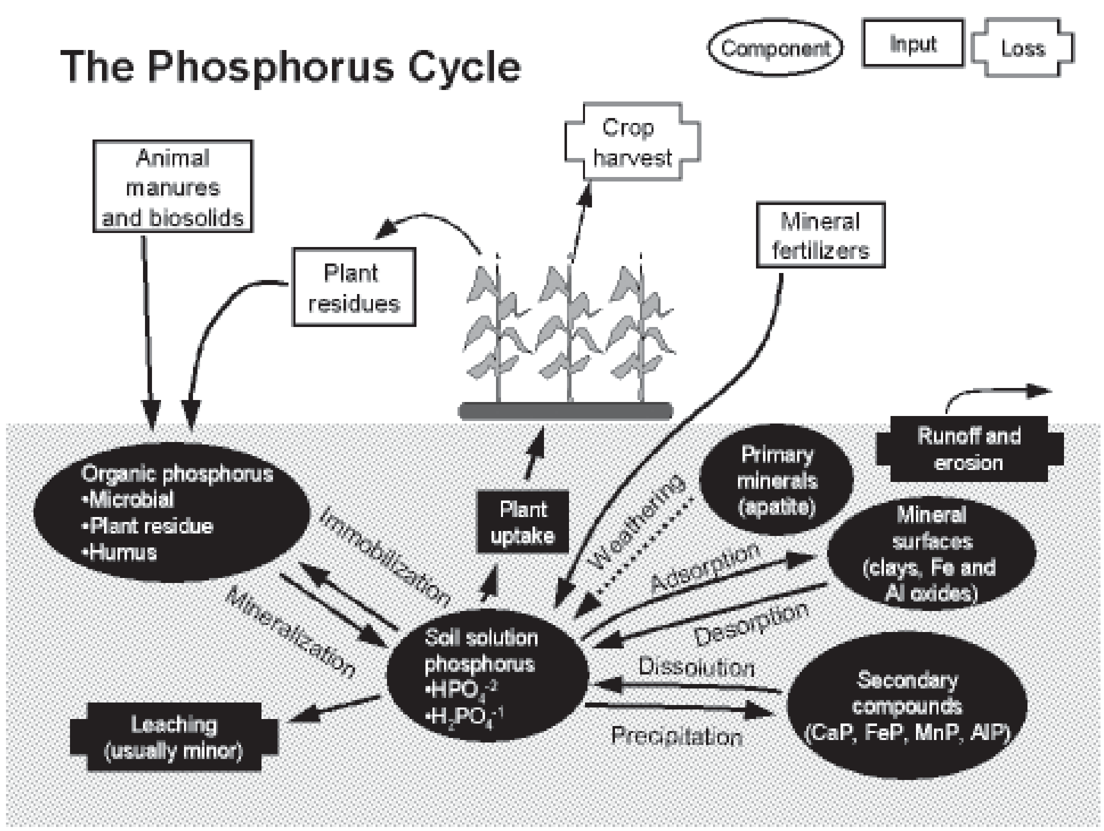
Nitrate Leaching: Nitrate is highly soluble in water. As excess water moves down through the soil profile, such as after snowmelt or heavy rainfall, it can carry any nitrate present with it. Nitrate is more prone to leaching from coarse textured soils and at times of the year when the crop is not actively growing (pre-seeding and post harvest).

Denitrification: Soils become anaerobic (lack oxygen) when saturated or during periods of high microbial activity. When soils are anaerobic, the soil bacteria can continue to breathe using nitrate instead of oxygen. During this process, nitrate is consumed and N gases (such as N_2 and N_2O) are released to the atmosphere. This process is called denitrification.

2.2.3 Phosphorus Forms in Manure

Manure contains significant amounts of P in both inorganic and organic forms. When excreted, manure contains primarily organic P within the solid portion of the manure. Over time, some of the organic P is converted to soluble inorganic P.

Total Phosphorus: As with N, the total P content of manure is highly variable for all livestock types. Table 2.1 illustrates the range in P contents for various manure types. In addition to the variability between operations



Potash and Phosphate Institute, 2002.

and livestock types, there can be significant variability in total P concentrations within a given liquid manure storage. Most of the P is contained within the solids, which tend to settle to the bottom of the liquid manure storage resulting in an increasing concentration of P with depth.

Organic and Inorganic P: Research in Saskatchewan found that from 10% to 50% of the total P in liquid swine manure could be present as soluble inorganic phosphate, which is considered to be immediately available to plants. However, because inorganic P in manure is not routinely measured, the availability of P in manure in the year of application is estimated to be 50% of the total P measured in manure.

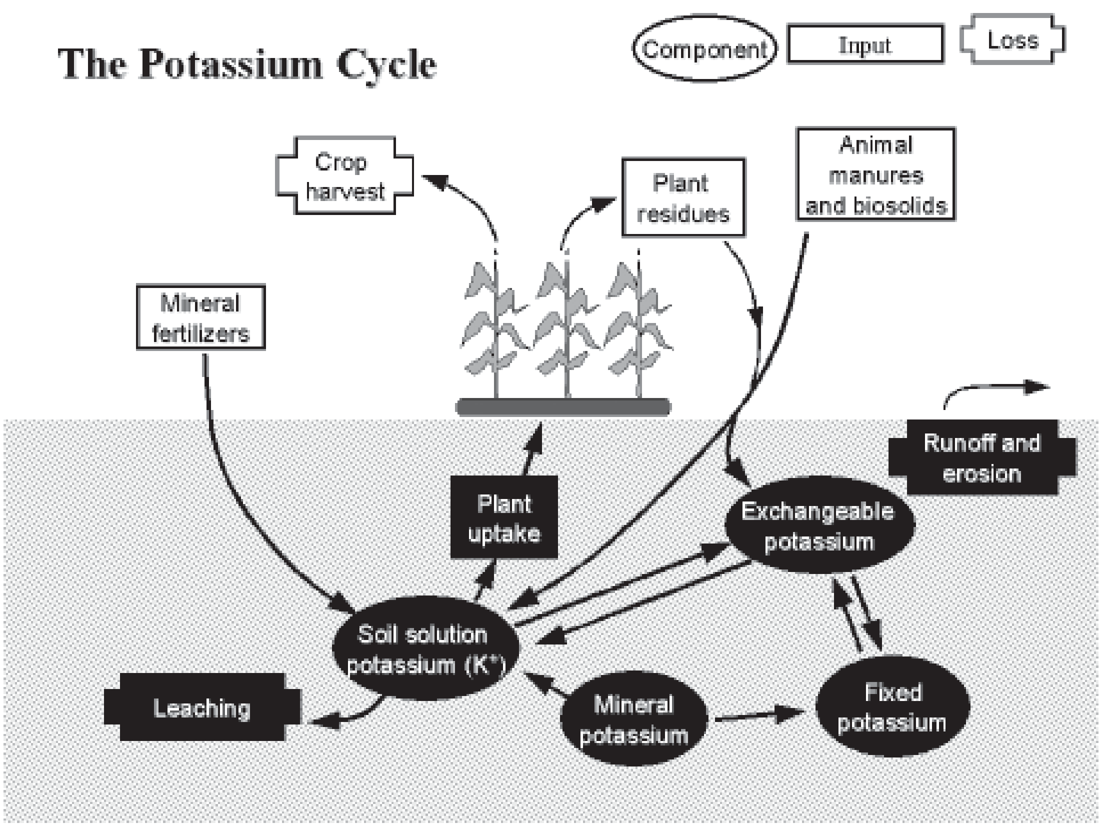
2.2.4 Phosphorus Processes in Soil

Differences in the concentrations and forms of P in manure will influence P availability. For example, manure with a high inorganic P content will provide more plant-available P immediately after application than manure with a low inorganic P content. Soil properties will also influence the availability of P.

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 soil through sorption and precipitation reactions. It can be bound to soil organic matter or to Fe, Al, Mg and Ca through the development of mineral complexes. Fine textured (clayey) soils are able to bind considerably more P than coarse textured (sandy) soils.

In general, inorganic P that is retained in neutral to alkaline (high pH) soils will be predominantly associated with Ca and Mg while P that is retained in neutral to acidic (low pH) soils will be primarily associated with iron (Fe) and aluminum (Al). A large amount of P can be retained by a soil that is rich in



Potash and Phosphate Institute, 2002.

Solubilization: Soil has a large, but not infinite, capacity to bind P. As soil test P levels increase, there is often a concurrent increase in soluble P. Soluble P can occur in both organic and inorganic forms.

2.2.5 Potassium in Manure

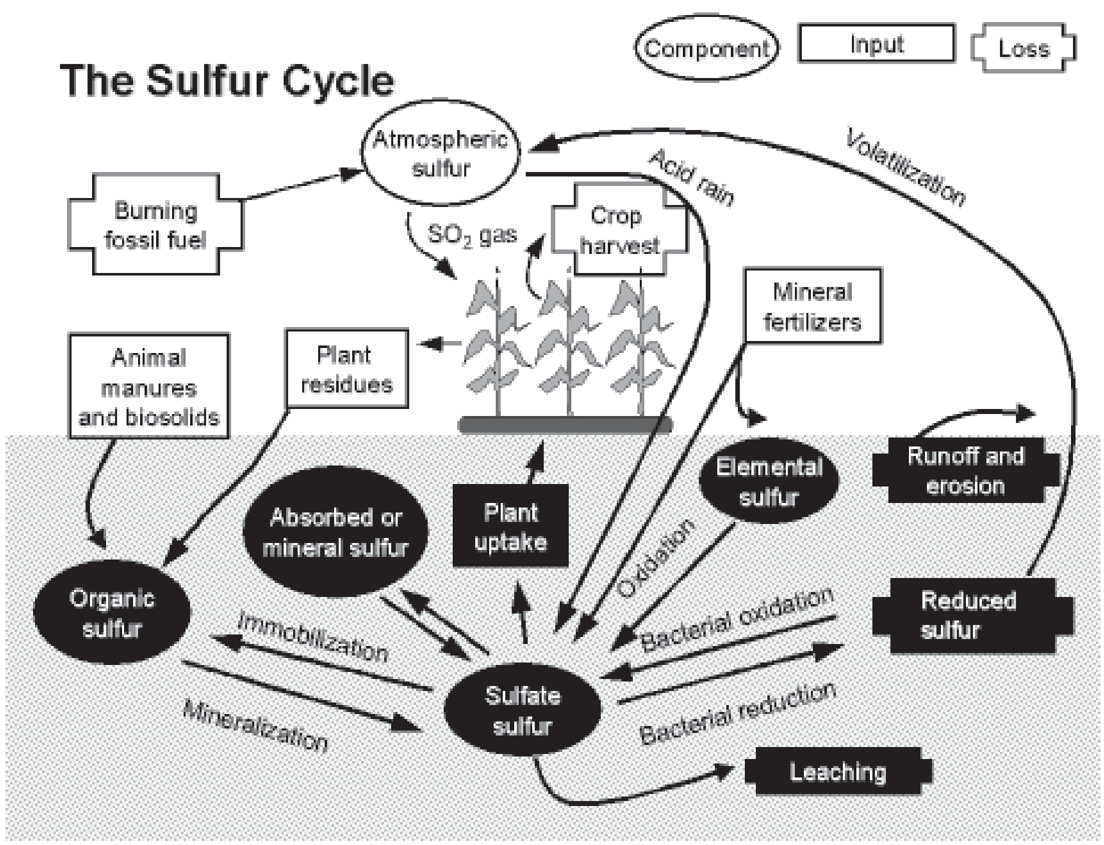
Manure is a good source of potassium (K) for plant growth. The K in manure is inorganic. Unlike some of the other manure nutrients, there are no transformations required by soil microorganisms to make potassium readily available for plant uptake. K is relatively mobile in sandy or organic soils and less mobile in heavier textured soils. As with the other macronutrients, there is a broad range of K contents in manure (Table 2.1).

2.2.6 Sulphur in Manure

Manure contains sulphur in both organic and inorganic forms. A portion of the sulphur in manure will be readily available as sulphate (SO_4^{2-}). That portion of the manure that exists as organic sulphur cannot be used directly by plants, it must first be converted (mineralized) to sulphate-S by soil microorganisms. The sulphur in the form of sulfide must be oxidized to sulphate.

Some animal manure, such as liquid swine manure, can be low in S relative to N. This is a management consideration when fertilizing high-S-demanding crops like canola.

Table 2.1 shows the ranges of S found in liquid swine manure and solid cattle-pen manure.



Potash and Phosphate Institute, 2002.

2.2.7 Micronutrients in Manure and Soil

Manure contains micronutrients such as (Cu), manganese (Mn), zinc (Zn), cobalt (Co), molybdenum (Mo) and boron (B). Table 2.2 contains liquid swine and solid beef manure analysis results for B, Cu and Zn from research conducted in Manitoba and Alberta.

Crops require relatively small quantities of micronutrients. Manured soils often provide sufficient quantities of micronutrients for crop production. Crops that are grown on soils that are deficient in micronutrients normally exhibit physiological symptoms. Micronutrient deficiencies can be verified through plant tissue testing.