MANURE AND OTHER ORGANIC WASTES – THE BASICS

THIS CHAPTER EXPLORES:

- the physical properties of solid and liquid manure
- manure's odour and gaseous properties
- manure's chemical or nutrient properties
- the processes by which different chemicals or nutrients in manure will cycle through, and possibly be lost to, the environment
- manure's biological properties
- environmental risks
- nutrient management planning.

Best management practices for manure and other organic wastes are based on scientific principles and real-world experience. Understanding the physical, chemical and biological properties of manure and other organic materials will help you manage these products safely and more effectively.

PHYSICAL PROPERTIES

Livestock manure has a variable composition. In other words, it has solid and liquid portions as well as organic and inorganic components. Manure's composition will vary with livestock type, age, size, nutrition, housing and bedding, as well as the nature and amount of materials (such as bedding and wastewaters) added to it.

Manure = fecal material + undigested feed + urine + bedding + uncontaminated water + wastewater + other wastes.

The key principle to manure management is to account for all materials – especially liquids.

MANURE COMPONENT	COMPOSITION	
FECES	• undigested feed • other bodily wastes	• organic forms of nutrients and organic acids • inorganic forms of nutrients and salts
URINE	• water • acids and salts	• nutrients (e.g., nitrates)
BEDDING	• straw, wood fibre	• wasted solid feed
UNCONTAMINATED WATER	• drinking water • leaking or spilled water	• eavestroughs, precipitation, snowmelt
WASHWATER AND RUNOFF	• facilities washwater • milking centre washwater	• runoff from yards, stored feed, and solid manure

Moisture content and total solids affect handling characteristics. When it's more liquid and less solid, it's easier to handle with pumps and gravity systems designed for liquids.

A typical 20,000-bird facility needs about 9 tonnes (9.25 tons) of wood shavings to provide a 10-cm (4-in.) depth on the floor.

SOLID MANURE

Worth noting: solid manure is typically 40–80% liquid by composition.

composition

▶ consists mostly of bedding and fecal material

▶ varies with livestock type, age, nutrition and bedding

▶ also changes with time and degree of decomposition

dry matter content

▶ usually ranges from <18% (e.g., solid dairy) to 60% dry matter (e.g., poultry manure with wood shavings)

▶ contains moisture primarily from animal urine and spillage from waterers

MANURE CHARACTERISTICS (SOLID MANURE SYSTEMS)					
ANIMAL TYPE	AVERAGE WEIGHT (lbs)	ADDITIONAL BEDDING (average ft³/day)	DENSITY (lbs/ft³)	TOTAL VOLUME/ DAY (ft³)	% DRY MATTER (average)
SOWS AND LITTERS	400	0.58	60	0.624	14.6
FEEDER HOGS – solid scrape	117	0.013	60	0.158	13.2
WEANER HOGS SEW	26.7	.0076	60	0.066	13.5
HOLSTEIN MILKING-AGE COWS – freestall solid	1400	0.598	52	2.135	21.2
MATURE BEEF COWS (with calf)	1300	0.156	50	1.258	30
MATURE BEEF COWS (with calf) – deep bedded	1300	0.578	40	1.690	45
BEEF FEEDERS	683	0.082	52	0.661	21.9
BEEF FINISHERS	800	0.096	52	0.774	21.9
SHEEP – meat	175	0.060	45	0.156	30
GOATS – meat (including unweaned offspring)	160	0.012	50	0.096	30
GOATS – meat feeder kids (>45 lbs)	40	0.0029	50	0.024	30
GOATS – dairy does	170	0.016	50	0.123	30
GOATS – dairy kids	36.7	0.0033	50	0.027	30

All figures in this table are averages.

Liquid manure materials with low solid content (i.e., <8% dry matter) are easier to collect, transfer and handle.

LIQUID MANURE

composition

- consists mostly of facility washwater + milking centre washwaters (dairy) + added runoff + snow and rain + bedding + feces + urine bedding and fecal material

dry matter content

- usually ranges from <8% (e.g., dairy manure and milking centre) total solids to 12% (e.g., dairy manure with medium bedding)

Knowing species- and system-specific manure characteristics such as volume and dry matter is important when designing manure management systems.

MANURE CHARACTERISTICS (LIQUID MANURE SYSTEMS)

ANIMAL TYPE	AVERAGE WEIGHT (lbs)	TOTAL (ft^3/day)	% DRY MATTER (average)	ADDITIONAL BEDDING/WATER
SOWS AND LITTERS	400	0.722	2.9	–
FEEDER HOGS	117	0.245	5.0	–
WEANER HOGS	35	0.100	2.7	–
MILKING-AGE COWS	1400	2.613	9.1	0.017 ft^3/cow/day
DAIRY HEIFERS	650	0.744	11.0	0.016 ft^3/cow/day
DAIRY CALVES	200	0.240	11.0	0.005 ft^3/cow/day
WASHWATER – free-stall	–	–	–	0.6 ft^3/cow/day
WASHWATER – tie-stall – pipeline	–	–	–	0.5 ft^3/cow/day
WASHWATER – tie-stall – no pipeline	–	–	–	0.25 ft^3/cow/day
BEEF COW (with calf)	1300	1.508	9.0	–
BEEF FEEDERS	683	0.793	9.0	–
BEEF FINISHERS	800	0.928	9.0	–

SEMI-SOLID MANURE

Liquid manure can be pumped. However, if your system generates manure with a dry matter content in the 14–18% range, it becomes difficult to manage: too dry to pump and too wet to manage easily as a solid.

This material – often referred to as semi-solid manure – should be diluted with washwaters and runoff or mixed with additional bedding to be managed as a solid or liquid.

MANURE TYPES AND MANURE MANAGEMENT SYSTEM

MANURE TYPE AND SYSTEM	DRY MATTER CONTENT	FORM	STORAGE TYPE
SWINE – liquid manure DAIRY – minimal bedding, high dilution with milking centre washwater	• <8%	• liquid	• tank – concrete, steel, glass-lined • earthen – no tractor access
DAIRY – moderate bedding, medium dilution	• 8–12%	• liquid	• tank – concrete, steel, glass-lined • earthen – no tractor access
DAIRY – high bedding, medium dilution	• 21%	• solid portion	• concrete pad with managed runoff (e.g., separate runoff storage)
DAIRY – high bedding, no dilution BEEF – high bedding, no dilution	• >21%	• solid	• covered concrete storage with access • concrete pad with managed runoff (e.g., separate runoff storage)
SHEEP – high bedding, no dilution	• 35%	• solid	• in-barn (solid pack)
POULTRY – high bedding, no dilution, air-dried	• 60%	• solid	• covered concrete storage with tractor access • solid pack (in-situ)

ODOUR AND GASEOUS PROPERTIES

The human nose is capable of detecting a broad range of odorous compounds – many at extremely low concentrations. Researchers have identified more than 160 odourless and odour-producing compounds that can originate from manure. It's this wide range and mix of compounds combined with our keen ability to detect odours that result in the variety of manure smells we experience.

Some of the more common compounds in manure are described in the following chart.

PRIMARY MANURE GASES

COMPOUND	DESCRIPTION
CARBON DIOXIDE	• odourless • generated by microbial activity (anaerobic* and aerobic)
METHANE	• odourless • generated by anaerobic activity
AMMONIA	• sharp, pungent, irritating odour, only mildly toxic • generated by anaerobic and aerobic activity • water-soluble and less dense than air • readily disperses in open environment, resulting in it being more of an odour concern within barns than during land application
HYDROGEN SULPHIDE and RELATED SULPHUR-CONTAINING COMPOUNDS	• hydrogen sulphide gas has a powerful rotten-egg fragrance • produced during anaerobic decomposition of manure • water-soluble and heavier than air • humans can readily detect very low concentrations of such compounds • hydrogen sulphide can be very toxic if allowed to accumulate in enclosed spaces
VOLATILE ORGANIC ACIDS	• wide variety of types and characteristics • mostly produced under anaerobic conditions • important contributors to manure odour
PHENOLICS	• highly odorous compounds • found in raw manure and increase under anaerobic conditions

* "anaerobic" means oxygen-deficient
Chart adapted from: Koelsch, Rick, *FFPPA Reference Manual*

The amount and type of gases produced will depend on the type of manure and the way it's handled. Aerobic conditions will generate gases such as carbon dioxide and nitrous oxide. Anaerobic conditions (liquid manure, centre of solid piles) can generate hydrogen sulphide, ammonia and methane.

Some gases are often trapped within the bulk of the manure until the storage is disturbed for spreading. That's why the smell is much worse at spreading time.

Manure odour is strongest during application. For the most part, odour-causing gases are trapped in stored manure.

Manure odour is strongest during application. For the most part, odour-causing gases are trapped in stored manure.

CHEMICAL (NUTRIENT) PROPERTIES

Nutrients are found in all components of manure, be they organic or inorganic. For more information about their functions in growing crops, please see the textbox on the facing page. Their environmental implications are explored toward the end of this section.

MACRONUTRIENTS

Nitrogen (N)

In fresh feces, most of the nitrogen is in organic form, either as undigested feed or in a biological form within the bodies of bacteria and other microbes that make up the normal population of the digestive tract. In urine, a large part of the nitrogen is present as uric acid or urea, with a lesser amount as ammonium or organic salts. These compounds are transformed in storage and handling, so that what's applied to the field is much different from what comes from the animal.

Phosphorous (P)

Most of the phosphorous is excreted in the feces, primarily in organic compounds like phytin (from undigested feed), and also as ortho-phosphate. The organic compounds are readily degraded in storage or in soil, so that much of the P in manure becomes available to crops eventually.

Only 40% of the manure P is considered to be available to crops in the year of application, but this is primarily because of uneven application or placement where crop roots cannot easily reach the P in the manure. Note: 80% of the total applied P will eventually contribute to an increase in soil test P. Some manure treatments such as anaerobic digestion will increase available P in the year of application.

Potassium (K)

Most of the potassium is excreted in the urine as soluble potassium salts. A small amount will be contained within the bacteria in the feces. Potassium doesn't get bound up in organic compounds in either animal or plant cells, so it's readily available for crop uptake. It's also subject to loss with any manure runoff.

AVAILABLE MANURE NUTRIENTS FROM VARIOUS LIVESTOCK TYPES – LIQUID MANURE														
Animal Type	Ave DM	# Samples	Total N	NH_4-N	Usable N[1]	P_2O_5	K_2O	Year 1 Value[2,3]	Year 2-4 Value[2,3]	Total N	NH_4-N	NH_4-N	P	K
	%	lbs/1000 gal						$/1000 gal		%	ppm	%	%	%
HOG	3.8	924	40	26.5	26.5	12.0	18.4	22.35	6.00	0.40	2648	0.26	0.13	0.17
DAIRY	8.5	860	36	15.3	17.9	8.3	25.9	18.60	5.10	0.36	1527	0.15	0.09	0.24
BEEF	7.1	61	31	13.4	15.6	7.4	21.6	16.00	4.45	0.31	1337	0.13	0.08	0.20
POULTRY	10.6	137	83	55.8	58.4	27.6	32.4	47.65	13.50	0.83	5581	0.56	0.30	0.30
RUNOFF	0.6	41	5.2	3.2	3.5	1.5	9.6	4.60	0.75	0.052	321	0.03	0.02	0.09
MILK-FED VEAL	7.2	5	33	5.4	13.2	6.4	18.4	12.35	4.90	0.33	543	0.05	0.07	0.17
BIOSOLIDS AEROBIC	2.0	10	12	1.1	4.3	5.5	0.0	3.77	2.86	0.12	109	0.01	0.06	
BIOSOLIDS ANAEROBIC	4.4	39	28	7.8	13.1	12.9	0.0	11.55	6.90	0.28	776	0.08	0.14	0.00

1 Usable N = amount of nitrogen available in the year of application assuming spring application is incorporated within 24 hours.
2 Value of manure is based on purchase price of an equivalent amount of mineral fertilizer ($N-P_2O_5-K_2O$ = 0.48-0.21-0.26 $/lb).
3 The actual immediate value for crop production will be less if all the nutrients applied are not required for growing the crop.
Source: Data from manure analysis provided by A&L Lab, Guelph Agri-Food Lab, Stratford Agri-Analysis and University of Guelph Analytical Services from 1991 to 2003

Nitrogen deficiency in corn shows up as yellowing in leaves.

Potassium deficiency will impede water uptake in alfalfa.

AVAILABLE NUTRIENTS FOR MANURE FROM VARIOUS LIVESTOCK TYPES – SOLID MANURE

Animal Type	Ave DM	# Samples	Total N	NH_4-N	Usable N[1]	P_2O_5	K_2O	Year 1 Value[2]	Year 2-4 Value[3]	Total N	NH_4-N	NH_4-N	P	K
	%	lbs/ton						$/ton		%	ppm	%	%	%
HOG	28.2	40	17.8	4.7	7.5	8.5	11.0	9.90	4.50	0.89	2324	0.23	0.46	0.51
DAIRY	24.2	150	12.2	2.6	3.7	3.1	10.8	5.85	2.05	0.61	1278	0.13	0.17	0.5
BEEF	28.6	155	14.6	1.6	3.4	4.2	12.3	6.50	2.80	0.73	812	0.08	0.23	0.57
SHEEP	31.3	35	14.4	3.4	4.7	4.8	14.5	7.95	2.85	0.72	1716	0.17	0.26	0.67
DAIRY GOATS	35.5	39	21.6	5.8	7.6	5.2	11.50	11.50	3.40	1.08	2878	0.29	0.28	1.04
COMPOSTED, CATTLE	38.3	29	17.2	1.1	5.8	5.2	23.8	11.00	3.40	0.86	543	0.05	0.28	1.1
GRAIN-FED VEAL	28.8	18	15.8	2.7	4.4	3.3	10.2	6.05	2.40	0.79	1328	0.13	0.18	0.47
HORSES	36.5	20	10.8	1.6	2.8	2.9	10.6	5.25	1.95	0.54	784	0.08	0.16	0.49
RABBIT	45.5	20	24.4	2.6	5.6	15.8	13.8	13.24	8.25	1.22	1281	0.13	0.86	0.64
POULTRY	52.6	623	47.4	11.0	20.8	20.4	25.3	24.85	11.30	2.37	5495	0.55	1.11	1.17
LAYERS	32.7	149	34.5	15.4	19.6	15.6	17.0	20.15	7.95	1.72	7719	0.77	0.85	0.79
PULLETS	36.2	47	42.0	12.4	20.0	16.6	19.4	21.40	9.20	2.1	6200	0.62	0.90	0.90
BROILERS	73.0	22	62.2	3.8	20.9	23.6	34.6	28.55	14.40	3.11	1881	0.19	1.28	1.6
BROILER BREEDERS	58.2	37	39.0	6.6	15.7	26.8	30.3	26.30	13.60	1.95	3300	0.33	1.46	1.40
TURKEYS	39.2	27	46.1	16.48	23.7	23.2	24.4	27.15	11.90	2.31	8239	.82	1.26	1.13

1 Usable N = amount of nitrogen available in the year of application assuming spring application is incorporated within 24 hours.

2 Value of manure is based on purchase price of an equivalent amount of mineral fertilizer ($N-P_2O_5-K_2O$ = 0.48-0.41-0.26 $/lb)

3 The actual immediate value for crop production will be less if all the nutrients applied are not required for growing the crop.

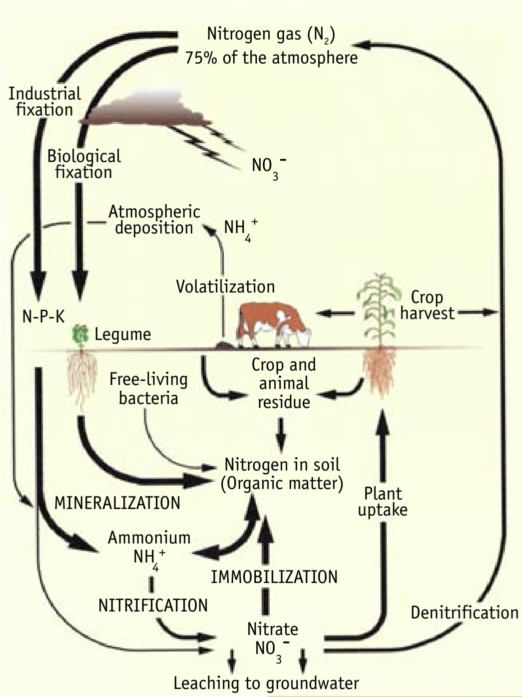
PHYSIOLOGICAL FUNCTION OF MAJOR NUTRIENTS IN AGRICULTURE

Whether they involve livestock or crops, most production systems depend on ample supplies of available nutrients. **Macronutrients (nitrogen, phosphorous** and **potassium)** plus **secondary nutrients (calcium, magnesium** and **sulphur)** are considered essential for plant and animal life.

NUTRIENT	FUNCTION IN LIVESTOCK	FUNCTION IN PLANTS
NITROGEN (N)	• proteins for muscle, skin, internal organs • enzymes for metabolic processes	• proteins for tissue growth • enzymes for metabolic processes • photosynthesis and respiration
PHOSPHOROUS (P)	• bone growth • energy transfer • milk, meat or egg production	• photosynthesis and respiration • energy transfer • cell division
POTASSIUM (K)	• muscular activity • blood pressure regulation • pH buffering	• plant structure • photosynthesis and respiration • water uptake by roots
CALCIUM (Ca)	• bone growth and repair • milk or egg production • reproductive functions	• cell wall strength • cell formation • enzyme activation
MAGNESIUM (Mg)	• enzymes • muscle relaxant	• photosynthesis • protein and enzyme activation
SULPHUR (S)	• component of several amino acids in proteins and enzymes	• component of several amino acids in proteins and enzymes

HOW KEY NUTRIENTS CYCLE THROUGH THE ENVIRONMENT

Nitrogen



In manure, nitrogen has two forms: inorganic and organic. The chief, inorganic form, **ammonium (NH_4^+)**, is available for plant growth, and also highly volatile as it can convert to ammonia gas under the right conditions. Ammonium can be a problem if raw manure runs off into surface water, where some of it converts to dissolved ammonia, which is very toxic to fish.

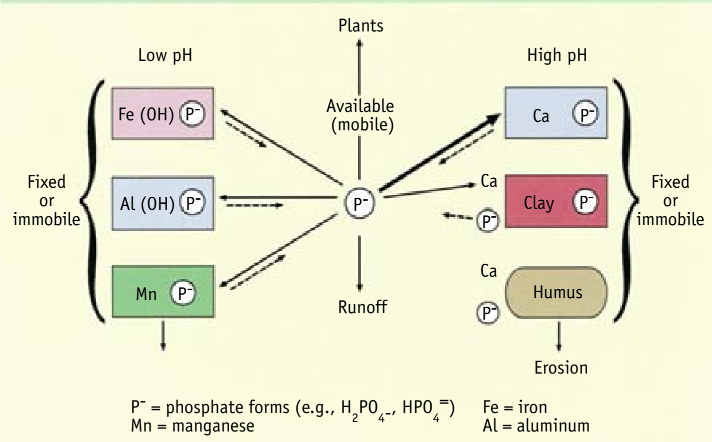
The organic N component in manure is quite stable and will eventually become converted to ammonium through a process known as mineralization. In soil, ammonium will stick to soil surfaces (clay and organic matter). It's available to plants and is subject to a process called nitrification, whereby soil microbes change ammonium to nitrite or nitrate NO_3^-.

Nitrate (NO_3^-) in soil is subject to several fates. It can be taken up by plants or absorbed by soil microbes (i.e., immobilized). It may leach through the soil beyond the root zone. It may be found in cropland runoff. In wet soils, nitrates can be transformed by soil microbes through denitrification to N gases such as N_2 and N_2O. N_2O is a greenhouse gas.

Phosphorous

Phosphorous has two forms in manure: organic P and inorganic P. Manure P is only 40% available as fertilizer phosphate in the first year following application. There are inorganic phosphates as minerals in soil (see illustration) and in solution – plus small amounts of organic P. In soils with low pH, P is bound in immobile forms as iron, manganese and aluminum compounds. In soils with a high pH, P can be found attached to clay and humus particles or tied up with calcium compounds. In solution, phosphates can be taken up by plants, lost in soil runoff or leached out of the root zone through soil cracks. Phosphate in surface water can promote algal blooms. As these aquatic plants die and decompose, and oxygen levels in the water drop, fish and other aquatic life are killed.

SOIL PHOSPHOROUS – FORMS, FATE & AVAILABILITY



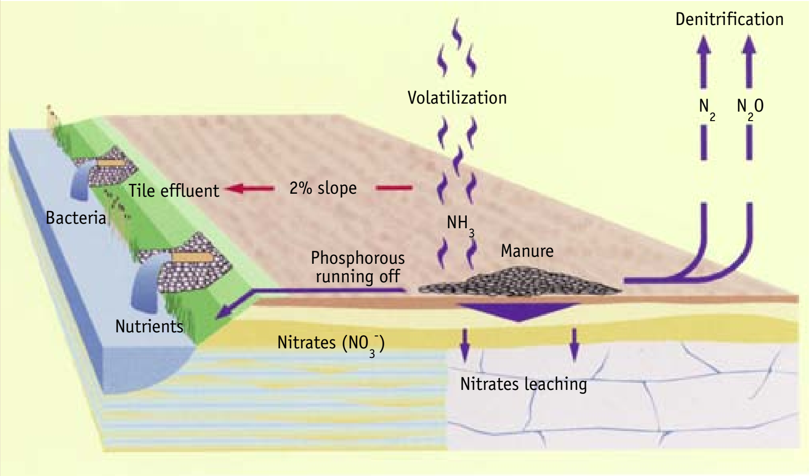
Potassium

Potassium does not form part of complex compounds within plants or animals, but remains almost exclusively as K ions in solution, either within cells or in the intra-cellular fluid. This means that most of the K in manure is in a readily available form – up to 90% as available as fertilizer K.

Once the manure is applied to the soil, the positively charged potassium ions are attracted to the negatively charged clay and humus particles. This adds to the pool of potassium that forms part of the soil minerals. From 90–98% of the total potassium in soil is bound in unavailable forms within the mineral structure, with up to 10% held in exchangeable form on clay minerals, and 1–2% in the soil solution. This dissolved K can leach from very sandy soils under heavy rainfall.

HOW NUTRIENTS IN MANURE ARE LOST

Some of the same macronutrients that are essential for sustaining animal, crop and soil life are, in excessive quantities, harmful to water and air quality. The processes by which nutrients are lost during manure storage, handling and application are summarized in the table on page 21.



It can be challenging to manage manure nutrients effectively and minimize loss. Manure nutrients, especially forms of manure nitrogen, are prone to manure loss as a gas – by volatilization of ammonia or through denitrification. Organic and inorganic forms of manure nitrogen can be lost from cropland with surface runoff or through cracks in the soil into tile drains. Inorganic nutrients can be immobilized by soil microbes or leached into shallow aquifers.

NUTRIENT LOSS DURING STORAGE, HANDLING AND APPLICATION	
PROCESS	**DETAILS**
VOLATILIZATION	• is the loss of free ammonia (NH_3) to the atmosphere • manure-based ammonium (NH_4^+) will readily convert to ammonia if left on the surface • manure with higher levels of NH_4^+ will more readily produce NH_3 • rate of loss depends on temperature, wind speed, soil moisture, pH, vegetative cover, rainfall and infiltration – loss is greatest in warm, sunny dry weather • loss is almost eliminated by incorporating manure into the soil
DENITRIFICATION	• manure-based nitrogen (ammonium) will convert to nitrate and nitrite (nitrification) • in saturated soils, nitrates will be converted by microbes to nitrogen gas (N_2) • in semi-saturated soils and storages, nitrates will be converted by microbes to N_2O
RUNOFF	• surface-applied manure is at risk of runoff • runoff increases with slope, low infiltration rates, compacted or frozen soils, low vegetative or crop cover, intense rainfall or rate of application and snowmelt
LEACHING	• leaching is the movement of soil solutions and their solutes out of the soil profile/rooting zone • for this to happen, there must be a high concentration of nitrates (and/or bacteria) in the rooting zone and a net movement of water through the soil profile • sandy and gravelly soils with high water tables are at the greatest risk • prime sources of nitrate are: ○ improperly stored manure (e.g., uncovered solid or composted manure on bare soil) ○ nitrogen fertilizers applied above crop requirements, and ○ manure and legumes with high ammonium concentrations
PREFERENTIAL FLOW	• preferential flow is mass flow of applied liquids directly into tile, where it's carried to tile outlets • all manure-based nutrients and bacteria can end up in surface waters, as effluent flows through cracks and continuous earthworm holes
IMMOBILIZATION	• immobilization occurs when nutrients are tied up by soil microbes in soil • soil microbial populations are large and diverse enough to trap available nitrates and phosphates from soil solutions before plants can use them • the rate of immobilization depends on the ratio of carbon:nitrogen of crop residues or manure added to the soil ○ if the high carbon: low nitrogen material such as straw or sawdust bedding is added to soil, the microbes will tie up any available nitrates ○ in time the microbes will run out of food and release the nitrogen following mineralization ○ see chart on page 25 for the C:N ratio of common soil management materials

Losses of manure nitrogen in the ammonia form can be minimized if manure is applied during cooler conditions and incorporated soon after.

AMMONIA NITROGEN LOSS* (percentage)

SEASON DETAILS	AVERAGE	COOL, WET	WEATHER CONDITIONS COOL,DRY	WARM,WET	WARM,DRY
SPRING/SUMMER					
Incorporated within 1 day	25	<1	15	25	<5
Incorporated within 5 days	45	20	30	50	80
Not incorporated	66	40	50	75	100
Injected in season	5	5	5	5	5
FALL					
Early	66	40	50	75	100
Late	25	25	25	25	25**
Cover crop if grown after manure application	35	25	25	40	50

* An additional 10% ammonium loss should be calculated for manure irrigation systems.

** Spreading on forages, cover crops and residues will increase ammonia loss.

Use average weather conditions to estimate N loss value when projecting a future nutrient management plan.
(D. Hilborn, C. Brown, E. Beauchamp [1995])

BIOLOGICAL PROPERTIES

Manure is made up of animal wastes, bedding and wastewaters. It is a kind of ecosystem with all the necessities for biological habitat – namely space, cover, food and water. This can be a good thing, as healthy manure environments rapidly convert manure to soil organic matter and available nutrients. But this same environment can house pathogenic bacteria and unwanted pests such as rodents.

SOLID MANURE AND ITS DECOMPOSITION

Stacked solid manure provides:

- ▸ a protected environment for soil life
- ▸ food materials in the form of bedding and feces and inorganic nutrients
- ▸ water from moisture content of manure.

LIFE FORMS IN MANURE THAT PROMOTE DECOMPOSITION

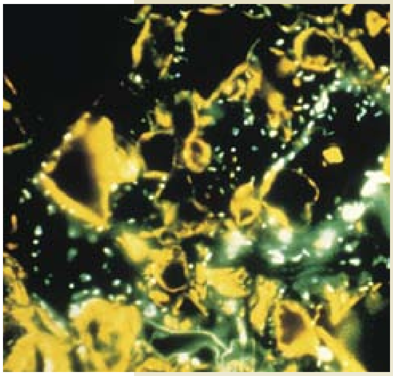
SOIL ORGANISM GROUP	TYPE OF ORGANISM	FUNCTION
DECOMPOSERS	• bacteria • fungi	• transform manure into materials that can be used by other life forms (e.g., shredded straw into humus) • retain (immobilize) nutrients in their tissue – some are pathogens
BACTERIA-FEEDERS	• protozoa • nematodes	• release inorganic nutrients (NH_4^+) • destroy some pathogens
FUNGUS-FEEDERS	• nematodes • insects	• release inorganic nutrients (NH_4^+) • destroy some pathogens
SHREDDERS	• earthworms • insects (springtails, dung beetles) • arthropods (centipedes, millipedes, pillbugs)	• shred bedding and waste feed into finer-sized materials • provide habitat and food for decomposers • accelerate decomposition rate when present
LARGER PREDATORS	• large insects, rodents, birds	• control populations of other manure life • aerate manure by burrowing

The rate at which solid manure decomposes is determined largely by:

- ▸ its composition – livestock type, bedding, feed, moisture content
- ▸ the method of storage and handling
- ▸ age (or state of decomposition)
- ▸ temperature, and
- ▸ method of application.

Solid manure with high N levels, such as poultry manure, will decompose thoroughly and quickly if kept moist and well-aerated. Conversely, semi-solid manure and solid manure at the bottom of an uncovered stack – where the manure can be saturated – will decompose more slowly. Most of the decomposers and shredders require aerobic conditions producing CO_2 gas, more microbial biomass and more stable carbon compounds in the remaining organic materials.

Solid manure will be subjected to aerobic and anaerobic decomposition.



Soil bacteria transform manure nutrients, making them usable by other soil life forms, such as protozoa, which in turn release inorganic N forms such as ammonium.

Fresh manure may be a better soil amendment than composted manure because it stimulates a more diverse soil ecosystem.

LIQUID MANURE AND ITS DECOMPOSITION

Stored liquid manure is mostly subjected to anaerobic decomposition, which produces methane (CH_4) and less stable compounds (e.g., volatile fatty acids). This process also leads to more odorous gases.

The number and diversity of life forms are lower in liquid manure than in solid manure.

MANURE AS A SOIL AMENDMENT

Organic matter from manure is an important soil amendment. Consistently manured soils have higher levels of soil organic matter.

Fresh manure may be a better amendment than composted manure because it's in a form that's readily used by soil fauna and, due to its complex nature, stimulates a more diverse soil ecosystem. When manure is composted before application, many of the processes that stabilize soil structure have occurred in the compost pile, not the soil.

MICROBIAL PROCESSES

Microbial processes are determined by the manure materials available, moisture content, exposure to air, and temperature. The decomposition process is more rapid when conditions are moist, warm, and aerobic, and when the manure materials have sufficient nitrogen content. There are several key microbial processes.

decomposition

- manure and soil microbes use available organic materials as a food source
- complex materials are broken down into simpler materials (e.g., proteins into amino acids)
- if the manure is solid and stored so that it's mostly aerobic (i.e., oxygen present), energy is released and the temperature of the stored manure increases – the products of decomposition are then available to further changes

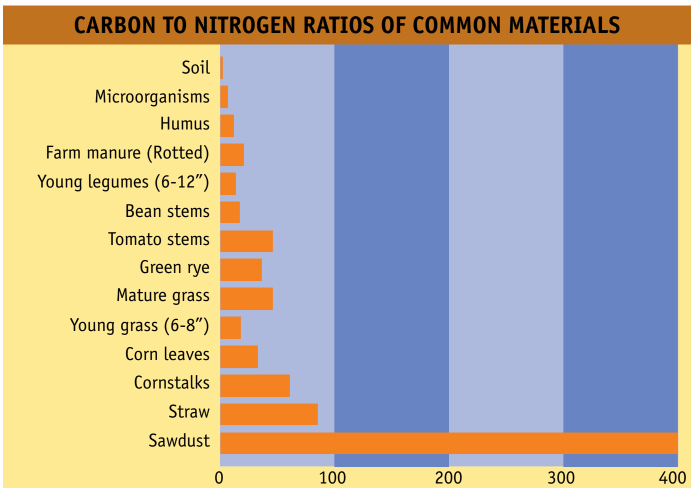
transformation

- manure and soil microbes can change the chemical nature of manure decomposition products
  - e.g., simple carbon compounds like sugars can be oxidized to release CO_2 + water + energy (for the microbes)
  - in liquid manure, carbon compounds are transformed to fatty acids and methane (CH_4) gas
  - nitrogen compounds can be transformed to ammonia (NH_3) gas, ammonium (NH_4^+) salts and nitrate (NO_3^-) nitrogen
- pathogens found in manure can be transformed into organic materials by high temperatures and a process known as denaturation (where protein compounds are broken down into components)

assimilation

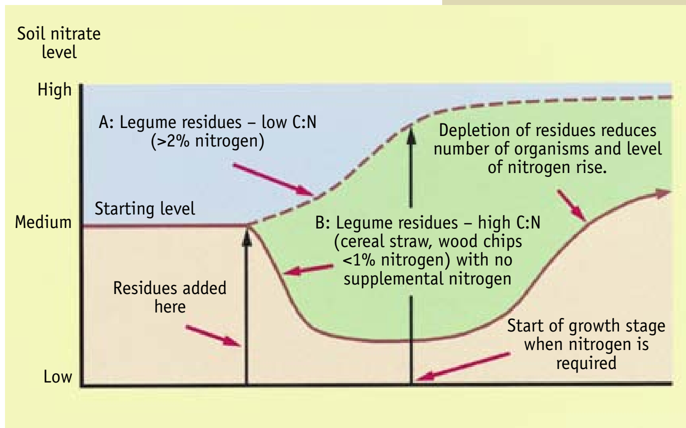
- just as simple carbon compounds are needed by microbes for energy, nitrogen compounds are required to build tissue
- if the N content of manure is limited, as in manure with a very high bedding content, decomposition will be rapid at first – then this N will be assimilated into the organisms themselves
- when this happens, the manure's N content can be immobilized and remain unavailable for plant growth when used as fertilizer
- manures with less bedding or higher N contents have a better balance between carbon and nitrogen compounds (C:N ratio) and will release more available nutrients when applied as fertilizer

Organic material with a chemical composition that's high in carbon relative to nitrogen content (C:N ratio) carries an increased risk. Much of the N content released during decomposition could be tied up (immobilized) by soil microbes, and therefore not readily available for crop growth.



Livestock diseases such as Johne's disease can be spread by contact with manure from infected cattle. Keeping livestock away from stored manure is a best management practice.

Much of the nitrogen released during manure decomposition will be tied up and later released by soil microbes – and not always when the crop requires it. The challenge is to account for this effect when determining nutrient application rates.



Livestock and poultry manure may harbour infectious diseases that can affect livestock and people. Their presence presents another good reason to manage manure with care.

PUT YOUR MANURE TO THE TEST

Having your operation's manure analyzed by a laboratory is the most accurate way of knowing what nutrients it contains. Livestock operations should sample and analyze manure for nitrogen, phosphorous, potassium and total solids during development of their nutrient management strategy and nutrient management plan. For more information on sampling and analysis procedures, see the Nutrient Management Act protocol or *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land*, available through the Ontario Ministry of Agriculture, Food and Rural Affairs.

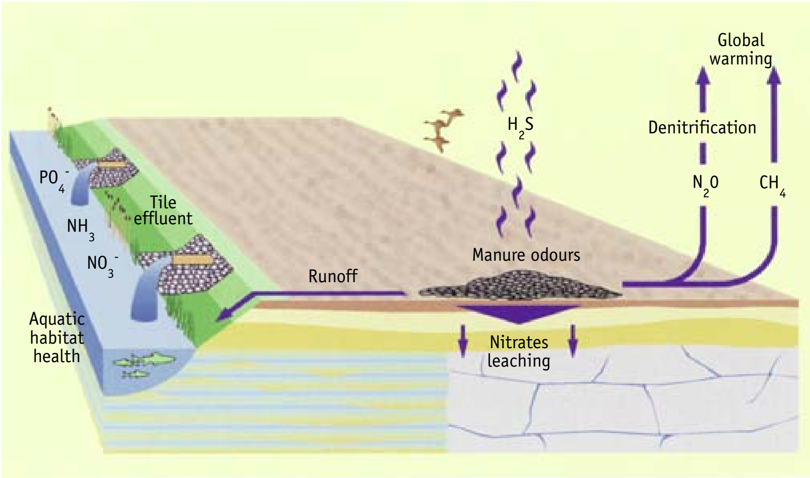
ENVIRONMENTAL RISKS OF MANURE AND OTHER ORGANIC MATERIALS

If not handled properly, farm-based nutrients can be a major pollution problem. Manure and other nutrient materials are assets when well-managed, but are pollution risks when poorly managed. The following chart summarizes how manure and other wastes can pollute or be nuisances.

RESOURCE	POLLUTANT AND ITS EFFECT
AIR	• ammonia (NH_3) gases from volatilized manure – cause odours • nitrogen gases (N_2, N_2O) from denitrification – N_2O adds to greenhouse gases • methane (CH_4) from decomposing manure in barns and in storage – adds to greenhouse gases • sulphide gases – are foul-smelling and add to the production of acid rain
SURFACE WATER AND AQUATIC HABITATS	• phosphates in solution or soil-attached from runoff or tile effluent – can cause excessive algae blooms since P is the limiting nutrient • ammonia (NH_3) from manure runoff to surface waters – is toxic to fish and other aquatic organisms • nitrates in solution – will reach surface waters from runoff or tile effluent and can cause excessive algae blooms • bacteria and pathogens from stored and applied manure – can reduce quality and safety of surface waters • biological debris – organic matter from manure creates in-water habitat for bacteria and pathogens
GROUNDWATER	• nitrates in solution – can leach into groundwater, making it unsuitable as drinking water for humans, livestock watering or cleaning facilities • bacteria and pathogens (disease-causing organisms and single-cell pathogens) – can contaminate where wells are improperly located, constructed, sealed, or in need of repair

To minimize these environmental risks, nutrient management planning is Ontario's tool of choice.

Manure and other nutrient materials are assets when well-managed, but are pollution risks when poorly managed.



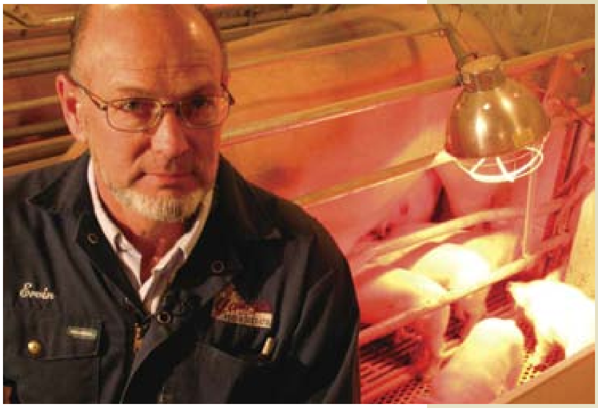
NUTRIENT MANAGEMENT PLANNING – AN OVERVIEW

Across the province, farmers are developing customized nutrient management plans, wherein:

- all nutrients are inventoried – organic, inorganic, those that a crop needs, those removed by a crop, and those already in the soil
- all nutrients are managed – according to land base, production goals, proximity to water resources, farmstead layout, equipment, and odour and safety concerns.

Since each farm is different, each plan is unique, but all plans are based on shared scientific principles.

A sound plan, when applied with related best management practices, is a win–win for the farm and non-farm population alike. The planning process results in valuable working documents for farmers that usually lead to reduced input costs and more efficient use of time and equipment. Water resources are better protected, and odour is kept to a minimum. The process also demonstrates due diligence to society at large and builds consumer confidence.



"There's a lot of negativity about nutrient management plans. I think most of it has to do with people not understanding it. But once you understand the purpose of it, how it helps you manage your manure better, and the safety for the environment - personally, I think it's good."

Erwin Horst, Perth County

TYPES OF MATERIALS APPLIED ON CROPLAND (“PRESCRIBED MATERIALS” IN THE NMA)

Agricultural Sources

- manure and bedding
- runoff from farm-animal yards and storages
- leachate from on-farm feed storages
- greenhouse and container nursery leachate
- washwaters from agricultural operations
- byproducts of on-farm processes (e.g., fruit and vegetable processing)
- other organic materials from agricultural sources (e.g., compost)

Non-Agricultural Sources

- pulp and paper biosolids
- sewage biosolids (e.g., municipal biosolids)
- organic materials that contain materials other than agricultural source materials (e.g., yard waste compost)

If nutrients are both generated on the farm and applied to the farmland, you may need to complete both a plan and a strategy. NMAN software or the associated workbook, both developed by the Ontario Ministry of Agriculture, Food and Rural Affairs, are tools to help you create your documents. You may wish to avail yourself of training opportunities, or hire a qualified consultant.

Yard compost from off-farm sources is considered a prescribed material.

For the NMA’s purposes, plans and strategies are created for a **farm unit**. A farm unit includes the land and buildings (e.g., barns, greenhouses, etc.) that make up your farm. You have the option of dividing your farm into multiple farm units according to the limitations given in the regulations.

There are many sources for more information available from the Ontario Ministry of Agriculture, Food and Rural Affairs. Please see the back cover for references. One of the most comprehensive is another title in this Best Management Practices series, entitled *Nutrient Management Planning.*

To view current, legally correct compliance information for the Nutrient Management Act, look up: http://www.omafra.gov.on.ca/english/agops/index.html

MANURE MANAGEMENT AS A SYSTEM

Manure management is a system. The scope of the system is strongly influenced by the type of livestock operation, the facilities, local site conditions and management practices. Some of these influences are given or not likely to change – such as the type of operation, soil type and proximity to environmentally sensitive areas. However, facilities and management practices can be changed and improved to meet both business and environmental goals.

The components of a "systems approach" to manure management are described below. Each component of the management system is distinct and interactive – a planned change will impact other components of the system as well as the system itself.

For example, a change in bedding practices will affect how manure is handled and applied. If you apply a systems approach when assessing your operation, you will have more success with selecting and implementing the BMPs for manure management presented in the remainder of the book

Manure Management System Components

1. ***Livestock Management:*** production system, facilities, nutrition and feeding, bedding, and sanitation
2. ***Storage and Handling:*** siting, site investigations, manure and other waste collection, transfer, storage and handling systems, and storage alternatives (treatment)
3. ***Nuisance Reduction:*** facilities and application practices that will reduce odours and prevent other nuisances
4. ***Nutrient Management – Inventory and Risk Assessment:*** accounting for all nutrient sources, testing levels in farm operation plus assessment of environmental risks and limitations
5. ***Water Management:*** proximity to surface waters, depth to water tables and aquifers, environmental protection and other surface water management practices
6. ***Nutrient Management Practices:*** selecting nutrient sources, scheduling applications, calibrating application and monitoring impact
7. ***Cropland Management:*** BMPs protecting soil and water plus practices to reduce nutrient loss, including cropping and tillage practices