Chapter 7.
MANURE APPLICATION

This chapter explores:

- manure application technologies
- calibration and maintenance of application equipment
- bio-security and equipment cleaning
- timing of manure application
- soil compaction related to manure application
- odour control during application
- manure application tips
- manure application safety
- calculating manure application rates
- record keeping

7.1 LAND APPLICATION

Deciding where, how and when to apply manure involves many considerations to ensure a practical, cost-effective system that minimizes environmental risks, meets regulatory requirements, and suits the specific needs of your operation.

7.1.1 Manure Application Technology

Choosing a method of manure application depends on the physical characteristics of manure (liquid or solid), type of operation, manure handling and storage, type of spreader and cost. The application system you choose will have implications for nutrient management and environmental risk, in particular nutrient placement and nutrient retention. All manure application technologies should meet the criteria of practicality, durability, desirable distribution pattern and minimal environmental impact.

Solid Manure

Most solid manure (20% or more solids) or compost is spread using broadcasting equipment, followed by tillage to incorporate the material into the soil. Delayed incorporation can result in increased odour, risk of nutrient loss in runoff and volatilization losses of ammonia-nitrogen, especially for non-composted manure.

Truck-mounted box spreaders improve travel times from storage to field compared to tractor pulled spreaders, which affects the length of time required to apply stockpiled manure. Soil compaction can be a problem, but is usually reduced by using dual or flotation tires, or by simply delaying application until field conditions are dry (for more information on compaction see page 70).

FOR MORE DETAILED INFORMATION regarding the regulated requirements for manure application and setbacks, contact Alberta Agriculture and Rural Development (ARD) Confined Feeding Operation (CFO) Extension Specialists or Natural Resources Conservation Board (NRCB) staff or go to www.agriculture.alberta.ca/aopa.

Liquid Manure
Liquid manure (less than 20% solids) can be surface-applied or directly injected into the soil. Liquid manure is typically stored under anaerobic conditions, which alters the decomposition processes, resulting in the production of more odour than solid manure. Delayed incorporation can result in increased odour, risk of nutrient loss in runoff and volatilization losses of manure ammonia-nitrogen.

Odour and related nuisance concerns have driven improvements in liquid manure application technology. Injection systems, drag-hose equipment, and other methods that limit the exposure of manure to the air have partially mitigated the odour problems. At the same time, these application methods reduce nitrogen loss, and therefore, preserve the fertilizer value of manure.

There are several things to consider when deciding on the type of application system that best suits your situation. The following describes some of the typical liquid manure application systems and considerations for each:

Injection systems: Manure injection uses ground openers, such as discs, cultivator shovels, or narrow knives, to open the soil creating a furrow. Typically, the openers are mounted on a tool bar, and a manifold directs the manure into the furrow created by the opener. Some machines then close the furrow using a packing wheel.

Injection is an effective method of manure application provided the manure is applied at proper rates and meets the following guidelines:

- Manure does not pool on the soil surface.
- Soil covers all the manure, and trenches are closed after application.

Proper injection provides excellent odour control, low runoff potential and low nutrient loss through volatilization. The majority of ammonia-N lost from manure application occurs in the first 24 hours after application. Injection is a one-pass application, which reduces the number of passes over the field compared to broadcast application plus incorporation.

The injection application requires more horsepower, fuel and time than the broadcast application, not including any additional incorporation passes. The amount of soil disturbance created by injection implements depends on the type of opener and the speed of application.

Injection Systems

Dragline systems: Dragline or direct-flow systems pump manure from the manure storage through an umbilical line directly to a manure application toolbar. The tractor drags the umbilical hose across the field as the attached toolbar either broadcasts or injects the manure. Equipment purchase costs are higher for this system than for spreader systems, primarily because of the cost of transfer pipe, but dragline systems typically reduce the time for manure application by at least 50% by eliminating the time spent loading and transporting manure to the field. The elimination of the application tank removes the majority of the weight of the application equipment, reducing soil compaction issues related to liquid manure application and reducing the fuel requirements for application.

The most significant risk to dragline systems is the potential for a spill to occur. If a break occurs in the umbilical line, a large amount of manure can be spilled from the system unless the pump is shut off. So in addition to operating the applicator in the field, dragline systems require staff to monitor or automatic shut-offs for the pump unit at the lagoon in case the umbilical line breaks.

Dragline Systems

Aerway and Broadcast systems: Manure is placed on top of the soil, crop and crop residue. Examples of broadcasting equipment include dribble bar, trail-hose, trail-hose with sleighshoe or Aerway™ attachments or splash plate.

Broadcast application is often seen as the cheapest method of application since it is fast, but without any incorporation, it can result in significant amounts of odour and ammonia-N loss from liquid manure application. The greater the time-lag between application and incorporation, the greater the amount of ammonia-N loss.

The higher the arc of the broadcast application (i.e. irrigation or high-angle splash plate application), the greater the odour produced and ammonia-N lost. The loss of ammonia-N translates to a direct loss of value from the manure application, either in the form of reduced crop production potential or the requirement for purchasing nitrogen to replace the N that was lost. Technology such as trail-hose or low-angle manure application significantly reduces the contact between

Broadcast Systems

the air and the manure, thereby reducing the amount of odour and ammonia-N lost during application.

Low-angle manure application reduces the arc of application, directing the liquid manure toward the soil surface. In a trail-hose application system, liquid manure is discharged through tubes, which run along the ground, directly onto the soil surface. This application method is also referred to as sub-canopy manure application. It increases the amount of manure applied directly to the soil and reduces the amount applied to stubble or cover crops, which reduces issues associated with refusal of grazing and more importantly reduces ammonia-N losses. A sleighshoe attachment works with the trail-hose system to move aside trash cover or forage crops so that manure is deposited directly on the soil, reducing the amount of odour and ammonia-N lost during application. The Aerway™ system creates slots in the soil surface, directly in front of the trail-hoses, assisting with manure infiltration.

An issue with trail-hose technology is the risk of hoses plugging during application. The frequency of plugging depends on the solid content of the material; lower solid

content means lower risk of plugging. For this reason, it is a good idea to include choppers and agitation in the distribution system. The manure can go through a chopper as it is pumped into the tank as well as when it is being pumped from the tank into the trail-hose system. In addition, the tank can have agitation inside to help keep solids in suspension.

Five important criteria can be used to compare performance of manure application equipment:

- manure placement
- nitrogen conservation
- odour nuisance
- soil compaction
- timeliness of manure application

The performance of selected application systems in relation to these characteristics is summarized in Table 7.1.

Table 7.1 Performance[1] of Selected Application Systems for Key Manure Application Considerations

Application system	Uniformity of Application	Ammonium – N Conservation	Odour Control	Soil Compaction	Timeliness of Application
Solid Spreading Systems					
Box Spreader, Tractor-pulled	F	VP	F	F	P
Box Spreader, Truck-mounted	F	VP	F	F	F
Liquid Spreading Systems					
Liquid Tank Spreader with Splash Plates	P	P	P	P	F
Liquid Tank Spreader with Drop Hoses	F	F	G	P	F
Liquid Tank Spreader with Knife Injectors	G	E	E	P	F
Liquid Tank Spreader with Shallow Incorporation	G	E	E	P	F
Drag-hose System with Shallow Incorporation	G	E	E	G	G

1 VP = Very Poor, P = Poor, F= Fair, G = Good, E = Excellent
From Koelsch, R. and Humenik, F. Not dated.

7.2 CALIBRATION AND MAINTENANCE OF MANURE APPLICATION EQUIPMENT

To be able to apply manure at desired rates, you need to know the performance capabilities of your application equipment. Equipment calibration should address the rate and uniformity of application. The two main reasons for calibrating manure spreaders are:

- to provide information on the actual rate applied, and therefore, the exact amount of nutrients applied.
- to allow for an accurate rate of application. In this case, speed and delivery rate need to be determined.

There are two calibration techniques:

1. The load-area method involves estimating the weight or volume of manure in a loaded spreader and then determining the area required to spread an entire load (or several loads).
2. The weight-area method involves weighing the manure spread over a known area to calculate the rate at which the manure was applied.

Select your calibration technique based on your application equipment and the type of manure. For injected liquid manure, use the load-area method since injected manure cannot be collected. For surface applications of liquid, solid, or compost manure, use the weight-area method.

Steps for the weight-area method are:

Step 1. Set a series of straight-walled pails or jars (for liquid manure) or several plastic sheets (for solid manure) in the application path of the spreader.
Step 2. Apply manure over the sheets or pails.
Step 3. Collect the sheets and weigh them or measure the depth of the liquid in the pails and jars, and note the average.
Step 4. Use Table 7.2 to determine application rates.

Table 7.2 Calibrating Manure Spreaders

Solid Manure Calibrations Using a 40-in X 48-in Sheet (opened feedbag)				**Liquid Manure** Calibrations Using a Straight-Walled Pail/Jar			
Manure Per Sheet		Application Rate		Depth of Manure in Pail		Application Rate	
lb	kg	tons/acre	t/ha	inches	cm	gallons/acre	L/ha
1	0.45	1.6	3.6	1/10	0.25	2,250	25,200
2	0.91	3.2	7.2	1/8	0.30	3,000	33,600
3	1.40	4.8	10.7	1/4	6.00	5,500	616,000
4	1.80	6.4	14.3	3/8	0.90	8,500	952,000
5	2.30	8.0	17.9	1/2	1.30	11,250	126,000
7	3.20	11.2	25.0	5/8	1.60	14,000	156,000
10	4.50	16.0	35.9	3/4	1.90	17,000	190,400
15	6.7	24.0	53.8	1	2.50	22,500	252,000

With the exception of tractors, most farm implements and equipment are used heavily, but for short periods of time. Manure application equipment is no different, and like all farm equipment, it should be ready to use and reliable when needed.

Preventive maintenance is essential to reduce the risk of down-time and serious malfunction - the kind that could cause personal injury or environmental damage. When preparing manure application equipment for storage, you want to ensure the equipment will be in good working condition next time you need it. Clean-up should be done as soon as possible (within hours) after application, since dried-up manure is difficult to clean and high salt content in the liquid manure can cause rapid rusting.

FOR MORE INFORMATION on manure application, get the Nutrient Management Planning Guide from ARD's Publications Office or download it from www.agriculture.alberta.ca.

Suggested maintenance for various pieces of manure equipment:

Pumps

- Run clean water through pump, then drain to protect from freezing.
- Cover metal with protective lubricant.
- If belt-driven, loosen the V-belt to reduce tension.

Electric motors

- Lubricate bearings.
- Cover motor to protect from dust and moisture.
- Lock control box.

Combustion engines

- Drain and replace oil when not in use.
- Remove spark plugs, place clean oil in spark plug holes, crank engine and replace plugs.
- Drain cooling system.
- Drain all fuel from engine and tank.
- Lubricate all moving parts.
- Remove battery.

Pipelines

- Flush with clean water. Empty washwater into manure or runoff storage, or collect and land apply the washwater.
- Be very careful when using an air system as compressed air can cause pipes to explode or be rapidly displaced. Proper equipment and operator training are necessary before an air system is utilized.
- Check for and repair leaks, and verify that repair worked.
- Keep valves open.
- Clean all pipe connections.
- Store portable units in a clean, dry place.

Hoses

- Flush with clean water to prevent crusting.
- Store on reels under roof.

Tankers

- Flush tanks and pumps with clean water.
- Drain tanks and hoses.
- Lubricate wheels and all moving parts.
- Never enter tanker without proper safety precautions.
- Prevent liquid manure from spilling onto roadways and take-off from storages or stop signs by using riser (chimney) to extend the loading opening.
- Ensure PTO guards always cover PTO shafts.

7.3 BIO-SECURITY AND EQUIPMENT CLEANING

Bio-security is a growing concern for producers, industry, government agencies and consumers. Maintenance and improvement of human, livestock and crop health are critical issues for producers and in most years determine bottom line financial performance. Manure applicators working on a variety of different operations need to be aware of the potential bio-security hazards their operation and practices may come in contact with.

BIO-SECURITY IS EVERYONE'S RESPONSIBILITY.

The most common bio-security concerns arise from the manure and interaction with the livestock. Manure can contain 10 billion bacteria per gram. More than

150 pathogens can cause zoonotic infections, which are infections that can move between animals and humans. Many types of bacteria, viruses and protozoans can be found in manure, such as: *Salmonella, E. coli, Brucella* spp. *Leptosipira* spp., *Listeria monocytogenes, Yersinia enterocolitics, Cryptosporidia, Giardia,* porcine reproductive and respiratory syndrome (PRRS), EMC virus, Johne's disease, bluetongue, transmissible gastroenteritis (TGE), foot and mouth disease (FMD), bovine rhinotracheitis (IBR) and influenza.

In addition to livestock and human bio-security concerns, the transfer of soil-borne pathogens via application equipment can also be a significant concern for crop health. Clubroot, caused by *Plasmodiophora brassicae,* is a serious disease of canola, mustard and other crops in the cabbage family. Resting spores are most likely to spread via contaminated soil carried from field to field by equipment. Tillage equipment represents the greatest risk of spreading the disease as soil is frequently carried on shovels and discs from field to field.

The transmission of pathogens from one operation to another can have significant economic and productive consequences. There is a real risk of disease transfer between livestock populations (barns) or between fields (e.g. clubroot) through the activities and actions of manure application. The risk of disease transfer is estimated to be low, but adopting bio-security protocols and practices can help to ensure custom manure applicators protect themselves as well as their clients from the spread of disease. Manure applicators could be targeted as the cause of an outbreak even if they were not responsible just because they were at the barn before a disease broke out.

Beneficial management practices for manure applicator bio-security include:

- Call the operation first; know what its bio-security requirements are and make sure you have the necessary supplies to follow them.
- Never go on farm without permission.
- Manure applicators should not enter a farm building for any reason.
- When moving between operations, move from the operation with the highest health standard to the lowest – during the day or week.
- Remember that small mistakes can lead to big issues.
- Pay special attention to any equipment that enters the buildings/barns.
- Change or clean boots between farms (i.e. boot exchange). Know how to clean and disinfect boots properly, using a boot brush to remove organic matter before washing in warm, soapy water. Dry boots before applying the proper disinfectant for the required amount of time. Or wear disposable boots supplied by the establishment.
- Bring a clean pair of coveralls to each facility visited or wear disposable coveralls supplied by the establishment. Wear layers instead of a winter coat, as it can be difficult to clean repeatedly.
- Wear gloves when handling manure or manure application equipment.
- Clean and disinfect all equipment and machinery between facilities – most importantly to kill pathogens but also to help maintain a professional / clean image.
- Clean your vehicle, and do not park it in manure or standing water. Clean and disinfect tires, mud flaps, wheel wells and floor mats before driving to another location.
- Tillage equipment represents the greatest risk of spreading a soil-borne disease as soil is frequently carried on shovels, discs and other openers. Almost all new soil-borne disease infestations begin near the field access, which indicates that contaminated equipment is the predominant spreading mechanism.

Be vigilant and diligent in removing potentially contaminated soil and crop debris from field equipment before leaving each field. Cleaning equipment involves knocking or scraping off soil lumps and sweeping off loose soil. After removal of soil lumps, wash equipment with a power washer, preferably with hot water or steam. Finish by misting equipment with weak disinfectant (1 to 2% active ingredient bleach solution). The use of a disinfectant without first removing soil is not recommended as soil inactivates most disinfectants.

- In situations where bio-security risk is uncertain, obtain advice from experts.
- Implement bio-security training for employees.

Table 7.3 Examples of Disinfection Agents

Agent	Details	Application Time
Vinegar	50/50 vinegar/water	30 min.
Sodium Carbonate	100 g/L water	30 min.
Citric Acid	2 g/L water	30 min.
Virkon (available at UFA & Co-op dealers)	2% solution	10 min.

7.4 TIMING OF MANURE APPLICATION

7.4.1 Seasonal Timing of Application

The goal of application is to get the manure to the desired crop when it needs the nutrients, in the right amount and with the least environmental impact. Notifying your neighbours of your intent to apply will ease their concerns.

Spring application is the most desirable for Alberta conditions because the time of high nutrient availability from manure matches the time of crop uptake. The greater the time-lag between manure application and when the crop can use the nutrients, the higher the risk of nutrient losses.

Unfortunately, timelines for application in the spring are usually tight due to inclement weather, risk of soil compaction and time required for other activities such as seeding. For this reason, it is important to carefully weigh the pros and cons of applying manure during the fall versus the spring. If fall application is chosen, it is important to ensure that those fields receiving manure are not prone to flooding or runoff, and that manure is applied before the ground is frozen.

Table 7.4 Manure Application Timing Considerations

Season	Beneficial Management Practices	Watch For:
Spring	• Apply to crops with the highest nitrogen requirement; high-yielding crops use N more efficiently. • Incorporate surface-applied manure within 24 hours. • Adopt good neighbour practices. • Side dress in row crops, i.e. dribbling. • Apply to land designated for annual crops before seeding. • Apply to row crops as side dressing after plants emerge. • Apply to well-drained soils.	• Soil compaction from tanker loads and traffic. • Runoff from excessive application rates or poor soil conservation practices. • Denitrification – loss of N gases to atmosphere on moist, poorly drained soils and cold, wet soils. • Rill erosion along strips and runoff. • Manure spills in irrigation or tractor-mounted systems. • Excessive odour and drifts. • Weather and soil conditions that promote ammonia-N loss. • Wet soils that are prone to compaction. • Excessive application, which can create a pollution hazard. • Planting too soon after heavy manure application, which can create ammonia toxicity and reduce germination and seed growth.
Summer	• Apply liquid manure to grassy pastures and hayfields – land is dry and less prone to compaction. • Apply liquid manure to forage and pastures to be reseeded/rotated. • Side dress liquid manure on row crops. • Apply liquid manure on cereal stubble. • Apply liquid manure to forage crops as soon as possible after harvest and before regrowth. • Apply to grasslands. • Apply to pasture early to avoid trampling regrowth. • Compost manure to reduce odour and break up clumps. • Do not apply to mature crops; they don't need nutrients.	• Risk of ammonia loss increases if not incorporated. • Rill erosion and runoff along injection strips. • "Smothering" of forages (mainly an issue with solid manures not spread uniformly and/or spread at high rates). • Loss of N if there is no rainfall within 72 hours of manure application. Rain helps nitrogen soak in.
Fall	• Apply solid or liquid manure prior to seeding winter cereals or cover crops. • Apply manure after corn and soybean harvest and incorporate the manure within 24 hours of application. • Apply to annual cropland that will be planted with winter cover crops.	• Risk of ammonia loss if not incorporated, no rain and temperature is >10°C. • Risk of leaching if not absorbed by actively growing crop cover – avoid application on sandy soils. • Risk of denitrification on cold, wet and poorly drained soils. • Soil compaction from spreader loads and traffic can be a risk on moist or wet soils. • Apply only on well-drained soils. • Manure that soaks in too slowly on wet fields is at risk of running off with excessive water.

Table 7.4 Manure Application Timing Considerations (continued from page 69)

Season	Beneficial Management Practices	Watch For:
Winter	• Have enough storage capacity so that manure does not have to be spread on frozen or snow-covered ground. • In case of emergency winter application: - Contact the NRCB for permission to apply on frozen or snow-covered ground. - Apply on level field and non-sensitive areas. - Reduce application rates. - Increase setback distances from surface water. - Avoid spreading on land with history of floods or heavy runoff. - Apply to fields with heavy crop residue or seeded to perennial forages or winter cover crops where there is less possibility of runoff or flooding.	• Manure applied on frozen or snow-covered ground is at risk of being carried away by runoff and polluting surface water and impacting water quality. • Wet soils are prone to compaction.

Winter application is not a best management practice. Sometimes there are opportunities to apply and incorporate manure to unfrozen soils with no snow cover, but these conditions are rare. No crop is in place to absorb the surface-applied nutrients and there's too great a risk to surface water from snowmelt runoff.

There may be times when winter application is necessary; for example, if the storage has filled prematurely, it would to better to spread some manure in winter rather than face a spill when the storage overflows. A preferred approach is to have alternative storage pre-arranged in the event of a premature filling. If a winter application situation arises, contact your local NRCB office to discuss the situation prior to spreading.

7.4.2 Timing Application to Fit Weather Conditions

Beyond the seasonal timing of manure application, the weather conditions during the actual time of application also have implications for nutrient loss. The predominant form of crop-available nitrogen in manure is ammonium (NH_4–N), which is prone to loss through volatilization. Warm and dry conditions favour greater volatilization compared to moist, cool conditions (see Table 6.3).

The concentration of ammonium-N is significantly greater in liquid manure than in solid manure, so the concerns with ammonium-N losses are much greater and can be more costly from liquid manure application. Using a system that gets manure into the soil as soon as possible after application and applying the manure during cool, moist conditions minimize the opportunity for NH_4–N to volatilize.

7.5 SOIL COMPACTION

Hauling manure over fields can lead to soil compaction. Soil compaction takes place when soil particles are squeezed together, reducing the pore space between them, thereby reducing the space available for air and water in the soil.

Compaction can develop in any soil type. The changes in the physical condition of the soil can reduce its productive capacity and sometimes require costly and difficult measures to rectify. The decrease in pore space reduces air and water infiltration and increases the potential for surface runoff. Plant roots have difficulty penetrating the soil, restricting root growth, reducing nutrient and water uptake, and lowering yield potential. Compacted soil is also slower to warm in the spring and more difficult to till.

Factors affecting compaction are:

- Soils are generally most susceptible to compaction when they are wet, such as in the spring after snowmelt or following heavy rainfall.
- Medium- and fine-textured soils and soils low in organic matter compact easier.
- Frequent tillage increases the potential for compaction because soil structure is degraded.
- Frequent wheel traffic increases the risk of compaction.
- Heavy loads increase the risk of compaction. Although application equipment that can transport large amounts of manure may reduce the number of trips from the storage to the field, a larger total axle weight can cause greater compaction with a single pass. Large volume equipment can also cause compaction at greater depths making remedial tillage more difficult.
- Tire configurations where the equipment's weight is concentrated onto a small area increase the risk of compaction.

BMPs to reduce soil compaction during manure application include:

- Increase the volume of manure storage to provide for more application opportunities to facilitate applying manure when field conditions are favourable.
- Use dragline application systems for liquid manure to reduce traffic and equipment weight on fields.
- Restrict repeated vehicle traffic to specific areas of the field (e.g. use designated pathways).
- Apply manure when field conditions are favourable, and avoid conditions in which soils are more prone to compaction (e.g. following snowmelt or heavy precipitation).
- Minimize the axle weight of application equipment, reduce axle weight to less than 10 tons/axle, and use systems with more axles and tires.
- Maximize the footprint (the area over which the equipment's downward pressure is exerted by the tires) through the use of:
  - lower tire pressure
  - larger tires
  - radial tires
  - more tires (such as tandem axles)
  - equipment with front-wheel assist, four-wheel drive
  - track vehicles
- Modify cropping and tillage practices to provide more application windows; for example, apply manure prior to fall crops, after silage cuts or between forage cuts.
- Consider that crop rotation and reduced tillage may be more effective than deep tillage to lessen the impact of soil compaction.

Use equipment that minimizes compaction.

7.6 ODOUR CONTROL DURING APPLICATION

Odour control needs particular attention during land application. This is the time when your manure handling practices are most apparent to neighbours. This may also be the time when your reputation for environmental safety is questioned.

Table 7.5 Odour Control During Manure Application

Application BMP	Benefits	Drawbacks
Increase use of bedding.	• Reduces odours when wastes are handled as solids. • Keeps animals cleaner.	• Increases labour associated with solid systems and bedding. • Doesn't apply to liquid systems. • Increases volume of manure to be spread, increasing application costs.
Inform neighbours of your intentions.	• Shows your concern, improves relations. • Helps identify times when it may be inappropriate to spread for social reasons.	• Hard to satisfy everyone. • Requires planning ahead. • May require adjustments of plans.
Pre-till before manure application.	• Increases soil contact and infiltration. • Reduces odour.	• May risk excessive tillage and soil degradation.
Apply in cool weather.	• Reduces volatilization.	• May reduce opportunities to apply. • Don't apply to frozen soil.
Avoid application on calm, humid days, particularly if not incorporating.	• Avoids climatic conditions most conducive for odour. • Preserves nutrients.	• May restrict spreading in the summer months when soil conditions are ideal.
Apply when conditions are dry.	• Reduces anaerobic conditions.	• May reduce opportunities to apply.
Monitor wind direction when hauling manure to fields.	• Can take advantage of predominant wind directions to naturally direct odours away from sensitive areas.	• May reduce opportunities to apply. • Unpredictable – wind direction can change during application.
Avoid high-trajectory manure-spreading equipment.	• Reduces air/manure contact. • Increases control of spread.	• Other technologies may be more expensive and time-consuming.
Use dribble-bar applicators to keep manure close to the ground.	• Reduces air contact. • Applies to no-till systems. • Can potentially side dress in row crops.	• Applies to liquid systems only. • Offers less effective odour control than injection.
Inject manure in a concentrated band.	• Prevents contact of manure with air. • Allows manure to be spread post-emergence in row crops such as corn, increasing period available for manure application.	• Applies to liquid systems only. • Makes for slower application and requires more horsepower.
Incorporate as soon as possible after application.	• Reduces air/manure contact. • Preserves manure N.	• Can be more challenging for standing crops and in high crop-residue management system.

7.7 MANURE APPLICATION SAFETY

Safe operating procedures are the best way to prevent farm accidents related to manure handling. Safety procedures include:

- Use locked and signed entrances to keep people, pets and livestock out of any confined spaces or areas storing liquid manure.
- Keep storage area ventilation systems working and functional.
- Never fill a storage or tank completely.
- Evacuate livestock facilities when agitating and removing liquid manure from an in-barn storage and increase ventilation in barns to dilute H_2S concentrations and reduce impacts on animals.
- Use agitation tags and warning tape.
- Tarp over pump-up from in-barn pits to reduce air movement into and over in-barn pits and back up into the barn.
- Use sub-surface agitation, and do not direct agitation towards walls or pillars.
- Use H_2S detection systems to monitor the facility and area for H_2S levels.
- Watch for moving parts, such as PTO shafts and impellers.
- Handle transfer equipment with caution; there are high pressures in hoses and pipes. Before using an air system in pipelines, be very careful to ensure you have the proper equipment and adequate operator training.
- Put warning signs on all vehicles and equipment used on public roads.
- Keep brakes in good working order.
- Have emergency plans and post them where they are easily accessible to all staff and family members.
- Train all staff and family members in safety procedures.

7.8 MANURE APPLICATION TIPS

Manure should be applied with the goal of maximizing nutrient value while minimizing risk to the environment and risk of odours.

7.8.1 Tips for Applying Manure on Forages

Productive forage fields have high fertility needs, so nutrient levels need to stay high. Manure nutrients can work as well as commercial fertilizers and save you money. Consider your options for manure application, both for fields to which manure can be applied and for timing of application.

Injection disks with furrow closing packers.

Table 7.6 Beneficial Management Practices for Applying Manure to Forages

BMP	Details
Analyze nutrient content of manure.	Use a manure analysis that indicates ammonium-nitrogen, phosphorus and potassium content of the manure to help determine most appropriate application rate. • The nutrient content of manure changes with livestock types and from farm to farm. • Applying too high a rate of ammonium-nitrogen could cause burn damage to forage regrowth. • When an analysis isn't available, a rate of 4000 gal/ac (with the exception of liquid poultry manure and highly concentrated liquid finisher hog manure) is safe for an alfalfa stand. • Since the ammonium-N content in solid manure is relatively low, nitrogen burn to new growth is not a concern (with the exception of high rates of solid poultry manure).
Use manure to establish forage stand.	Manure can be used at relatively high rates before seeding a new forage crop. However, there are a few precautions: • Manure should be applied and incorporated at least 5 days before planting. • High nitrogen and/or salt content in manure can lead to severe root injury in new seedlings, which will reduce plant stand. • New seedlings may also have higher weed pressure when manure is used prior to planting. Alternatively compost may be used to reduce the introduction of weeds.
Apply manure to grassy hay first.	Applying to the oldest and/or grassiest forage stands first will provide stands with needed nitrogen.
Apply right after harvest.	Applying before regrowth will prevent manure contact and potential nitrogen burn on new growth.
Apply to forages during the summer.	In sunny, hot weather, applying manure during late afternoon or early evening will help to minimize nitrogen loss and reduce potential nitrogen burn. Twelve to 18 hours without direct sunshine and with potential dew will reduce manure volatilization.
Watch for rain.	A gentle rainfall totalling about 10 to 12 mm will help incorporate nitrogen from manure. An erosive rain will increase risk of surface water contamination.
Avoid applying manure when soil is wet.	Wheel traffic from a heavy tanker will cause some crown damage and potentially some compaction – another reason to apply to older stands. Irrigating watery manure (<1% DM) will cause less damage to crowns. The benefit of washwaters for forage yields may be as much from the water as from the nutrients.
Modify application equipment.	Applying manure uniformly is difficult. Rates under 3000 gal/ac are hard to apply without applicator modification due to high tractor-speed requirement.
Watch for clumping of manure.	Where solid manure is being applied to forages, exercise extra caution: • In most cases, the manure is not applied uniformly enough. • When manure "clumps", it can cause a significant reduction in the crown stand.
Avoid application to hay or round bale silage.	Take precautions for manure applied to forage that will be used for wrapped, long-hay silage. • In some cases where manure was applied to regrowth, the bacteria from manure caused improper fermentation, which could lead to problems (spoiled areas) in silage.
Watch for manure-borne diseases.	Disease transmission from manure in forage has not been reported as an issue, but the question is raised periodically. • If you have a concern about a particular disease being carried in the manure, question your local veterinarian about how the disease is transmitted. • If the disease is carried in manure, then question how long the organisms survive in the soil under normal weather conditions.

Table 7.6 Beneficial Management Practices for Applying Manure to Forages (continued from page 74)

BMP	Details
Do not apply biosolids on legume forages.	Biosolids, specifically sewage sludge, have almost no potash. Forage crops have high nitrogen and potash needs. Since legume crops naturally produce nitrogen, legume forages have traditionally not been the best economic targets for the nitrogen from manure and biosolids. Livestock manure is a good source for replacing commercial potash; in contrast, biosolids are a poor choice for replacing potash needs of the crop.
Manage soil potassium (K) levels.	Precaution: high soil test levels of potash and high potash levels in manure can lead to high potassium (K) levels in forages, resulting in milk fever in dairy cows. • Alternatives to high K forages include off-farm sources of low K hay and/or dilution with low K forages such as corn silage, or anion/cation balancing.
Reduce fertilizer application.	When applying manure to forages, additional commercial fertilizer (particularly potash) application should be reduced to compensate for nutrients applied from manure.
Manage copper levels.	Precaution: manure containing high levels of copper (i.e. from farms using hog rations high in copper and/or cattle footbaths containing copper sulphate) should never be applied to sheep pasture. • Sheep have a low requirement for copper; their maximum tolerable level is close to their requirement. • A 5000-gal application rate of manure containing a copper level of 5 ppm applied regularly to pastures could kill sheep. • Manure applied to sheep pastures should be analyzed for copper in addition to the common nutrients.

7.8.2 Tips for Applying Manure After Cereal Harvest

- If you have winter cereals in your rotation, you have the opportunity to apply manure when risk of compaction is lowest and when there are fewer demands on your time.
- If you have bone-dry soils that may be cracked, pre-till before applying liquid manure. A light cultivation increases infiltration while reducing the risk of runoff through cracks to groundwater resources. Pre-tillage will also help to reduce odour and nitrogen losses, although not to the same degree as post-application incorporation.
- When manure is applied shortly after harvest, temperatures are usually warm and rainfall limited. Volatilization losses can be high if manure is not incorporated within a day or two.

7.8.3 Tips for Improving Manure Application Uniformity

To maximize the benefits of manure application onto cropland, manure must be spread evenly and at an appropriate density. Variable application rates within a field can cause variations in crop yield.

Getting uniform manure application can be difficult. Calibrating applicators can help improve equipment consistency but you may need to change application practices to improve consistency.

Wind speed and direction often affect the degree of variation in liquid manure application. Variation is also influenced by changes in manure solid content.

The area behind a solid manure spreader that spreads from the back can receive up to two to three times more manure than areas to either side of the spreader. For side spreaders, the application density decreases with increasing distance from the spreader.

To improve uniformity of manure application:

- Heap solid manure evenly on the spreader.
- Determine the width of the spread pattern and determine the amount of overlap required.
- Incorporate perpendicularly to the direction of application.
- Determine differences in manure consistency between the beginning and end of the load and adjust speed accordingly.

7.9 SUMMARY OF BMPS FOR APPLICATION

- Remember that odours are more intense and ammonia loss increases with rises in temperature, humidity and wind.
- Have regard for neighbours' concerns when spreading near their homes.
- With liquid manure, use low-trajectory broadcast, surface-banding or injection application technology.
- Incorporate surface-applied manure as quickly as possible following application.
- Avoid applying manure to wet soils and during wet weather to reduce the risks of nutrient loss, runoff and soil compaction.
- Avoid spreading manure if rainfall occurs shortly before application or if heavy rain is predicted within 12 to 24 hours of spreading.
- Avoid surface application on steeply sloped land adjacent to watercourses, lakes, ponds and wetlands.
- Monitor for and be prepared to react to any spills.

7.10 CALCULATING MANURE APPLICATION RATES

Manure application is a system, one that is full of small uncertainties. To maximize the nutrient use efficiency from manure (which will also maximize profit and minimize environmental impact), a systems approach is needed that's sensitive to the unique attributes of manure. Calculating manure application rates and managing manure application timing and methods will reduce the opportunity for nutrient loss to the environment, thereby increasing the economic return from the nutrients applied in the manure.

Calculating manure application rates helps to: ensure that over-application of nutrients is minimized; decrease fertilizer input costs by having a greater understanding of what nutrients have already been supplied to the crop from the manure; and maximize the value realized from the manure nutrient applied.

Calculating manure application rates involves using the following information (some of which was discussed earlier):

- available land base
- soil nutrient content
- crop nutrient requirements
- nutrient content and volume of manure
- application method and conditions

Calculating manure application rates involves the following steps:

1. Determine the crop nutrient requirements for each field. The fields that will benefit the most from manure application will generally be the fields with the lowest soil test for N, P and K and growing crops with the highest N demand.
2. Determine average nutrient contents for the manure from past manure analyses or from book values and the volume of manure available for application.
3. Determine the basis for the application rate, i.e. nitrogen or phosphorus requirements. Calculate a target application rate that supplies 75% to 80% of the N requirement for the crop, or possibly 3 to 4 years of phosphorus requirements.
4. Calibrate the application equipment.
5. Collect samples from the manure storage as it's being emptied; if manure is applied to more than one field, collect samples for each field.
6. Record the actual amount of manure applied on each field.
7. Submit the manure samples for analysis.
8. From the analyzed manure nutrient content and the application rate, calculate the amount of available nutrients applied to each field.
9. Determine the amount of fertilizer required to make up the difference between total crop requirements and the nutrient amounts applied with the manure. Apply that fertilizer with the seed or after seeding.

Once manure application rates have been determined, an operation may find that it has a large surplus of manure in relation to the number of acres available for application. If this is the case, the operation may need to build cooperative relationships with surrounding landowners to secure additional land for manure application and/or it may need to consider alternative treatment measures, such as solid-liquid separation technologies or composting to increase the distance manure can be transported economically. The operation may also consider developing marketing options for the manure produced.

MEETING NITROGEN NEEDS

Nitrogen is mobile; unless it is quickly used by a crop, it could be lost to the air or groundwater. It is recommended that manure be applied to provide approximately 75% to 80% of the crop's nitrogen needs for the following reasons:

- Nitrogen release from organic material depends on the weather, and in cool, damp seasons the crop may not receive enough nitrogen from organic sources for optimum growth and yield.
- Manure application rates are not always uniform, so part of the field may receive insufficient manure to meet crop requirements. A blanket application of mineral N fertilizer helps to increase overall yield by ensuring all parts of the field have received some nitrogen.

7.11 RECORD KEEPING

Recording and keeping all documents related to nutrient management is important. Documents can provide information on how nutrient management is implemented on the farm, and where and when changes are needed. As well, keeping records will help to collect accurate on-farm data that can be used to generate site-specific information.

Suggestions for information that can be maintained include:

- type of animals and stage of production
- manure analyses by type of livestock or by storage unit
- volume or weight of manure produced
- legal land description of each field to which manure is applied
- area of each field to which manure is applied
- volume or weight of manure applied to each field
- date of application and incorporation for each field
- method of manure application and incorporation
- soil test results for each field to which manure is applied
- crop planted and yields by field and by year
- application rates of manure nutrients and fertilizer by field and year
- name of applicator
- weather conditions during manure application
- method of cropping

If manure is transferred off the farm, keep a record of:

- name and mailing address or legal land description of the person to whom control of manure is transferred each year
- date of the manure transfer
- volume or weight of manure transferred

FOR MORE SPECIFIC INFORMATION regarding the regulations for record keeping under AOPA, refer to the *Agricultural Operation Practices Act* or talk to ARD CFO Extension Specialists or NRCB staff, or visit www.alberta.agriculture.ca/aopa.