8 Manure and the Protection of Water, Air & Soil

Manure is a valuable source of nutrients and organic matter that can replace or reduce the need for chemical fertilizer and improve soil quality. However, there are risks associated with using manure.

This chapter provides an overview of the potential risks associated with manure application and use, including:
- nutrient and pathogen transport to water sources;
- odour generation; and
- impacts on soil quality.

Various beneficial management practices (BMPs) that producers can use as part of their manure management program to reduce these risks are also provided.

8.1 Provincial Legislation

Each of the three provincial governments on the Prairies has legislation that applies to manure management. Producers should be familiar with all of the legislation that could affect their manure management practices.

Alberta:
Agricultural Operation Practices Act. Regulation 267/2001. Queens Printer for the Province of Alberta.

Manitoba:
Manitoba Livestock Manure and Mortalities Management Regulation. *The Environment Act.* Regulation 42/98. Chapter E125 of the *Continuing Consolidation of the Statutes of Manitoba*. Queens Printer for the Province of Manitoba.

The Pesticide and Fertilizers Control Act. Chapter P40 of the *Continuing Consolidation of the Statutes of Manitoba*. Queens Printer for the Province of Manitoba.

The Farm Practices Protection Act. Chapter F45 of the *Continuing Consolidation of the Statutes of Manitoba*. Queens Printer for the Province of Manitoba.

Saskatchewan:
Agricultural Operations Act 1995. The Agricultural Operations Regulations: Intensive Livestock Provisions. The Queens Printer, Regina, Saskatchewan.

8.2 Surface and Groundwater Quality

Surface water and groundwater are integral to ecosystems and have multiple uses, including water for drinking as well as other agricultural, industrial and municipal demands. Surface water is also relied upon for fishing and recreation. Manure management should incorporate the application of practices that minimize the risk of nutrient and pathogen contamination of surface and groundwater.

8.2.1 Nutrient Loss to Surface Water

The nutrients of primary concern to surface water quality are nitrogen and phosphorus due to ammonia toxicity and eutrophication.

Ammonium
Although surface waters naturally contain very low levels of both ammonium (NH_4^+) and ammonia (NH_3), they are toxic to fish at higher concentrations.

The concentration of each depends on the pH and temperature of the water. As pH and temperature of the water increase, the ammonium converts to the more toxic ammonia form. Ammonia is very toxic to fish at relatively low concentrations.

Relative to surface water, manure can contain very high concentrations of nitrogen in the form of ammonium. It is essential that manure management practices minimize the risk of manure entering surface water. The greatest risk of ammonium from manure entering surface water is through direct runoff or erosion soon after application. When manure is properly applied to the soil, the ammonium enters the soil N cycle. It can be converted to nitrate, held on the soil's cation exchange sites or taken up directly by plants.

Phosphorus

Eutrophication is the enrichment of water bodies by nutrients, particularly nitrogen (N) and phosphorus (P). Phosphorus is the nutrient that most commonly limits plant growth in fresh water bodies. Excess P entering water can result in increased production of algae and other aquatic plants, thereby affecting the quality of water and the diversity of organisms present.

Large colonies of algae, commonly referred to as blooms, can significantly deplete oxygen levels when they die and decompose, which can result in fish-kills. Blooms of cyanobacteria (blue-green algae) can also release toxins that are harmful to aquatic life, livestock and humans if they ingest the water.

How does P enter surface water?

Three conditions are necessary for P to enter surface water, as follows:

- there must be a supply of P **(source)**;
- a mechanism to carry the P to surface water **(transport)**; and
- there must be a connection between the source of P and the water body **(connection)**.

Source: Manure, chemical P fertilizer and soil P are the most significant non-point sources of P. Both manure and chemical fertilizer P inputs contribute to the soil P pool.

Chemical fertilizer can be formulated to meet both the N and P requirements of the crop. Manure nutrients are often not in balance with the nutrient requirements of the crop. Therefore, manure application rates can be based on the requirements for only one of the primary macronutrients. On the Prairies, manure is most often applied to meet the N requirements of the crop. In these cases, manure P may be applied in excess of the crop's needs.

Repeated yearly applications of manure at rates that exceed crop requirements for P result in a buildup in soil test P. Increases in soil test P benefit crop yields until soil test P reaches a level adequate for crop production, after which there is no agronomic benefit. Unfortunately, as the fertility status of a field is improved for crop production, the source of P available for transport to surface water also increases. This is because as soil test P increases, the soluble forms of P also tend to increase. For this reason, it is very important that soil P levels be managed to optimize crop production and minimize risk to water quality.

Transport: Phosphorus can be transported by water from agricultural land in sediment (particulate) form via water erosion, and in soluble forms via runoff or erosion. In most watersheds, P transport from fields results from surface flow, although P loss via sub-surface flow can occur under certain conditions (e.g. sandy, acidic or peaty soils, or soils with tile drainage).

The form of P that is lost from the field will depend on the form of the nutrient that is applied, management practices, soil type and topography. Losses from cultivated land can take the form of either particulate or soluble P. Particulate P losses dominate when soil erosion rates are significant. When soil erosion rates are very low, such as in areas under permanent pasture, forage or forest, it is the soluble P that is predominantly released in runoff.

Connection: In order to impact surface water, the source of the P must be connected to the water body through transport mechanisms. In some fields, P is transported from one area of the field to another, but does not always reach surface watercourses.

Source, transport and connection should all be considered when developing effective on-farm management solutions that minimize the risk of P loss from agriculture to aquatic environments.

8.2.2 Nutrient Loss to Groundwater

The main nutrient concern to groundwater quality is nitrogen in the form of nitrate due to nitrate contamination of groundwater.

Nitrate

The maximum acceptable concentration of nitrate in drinking water is 10 mg/L nitrate-N (or 45 mg/L nitrate). This level has been set by Health Canada based on methemoglobinemia in human infants. Methemoglobinemia, or Blue Baby Syndrome, is currently the only health condition widely accepted as being directly related to high nitrate levels in drinking water. Ingestion of nitrate-contaminated water is not the only cause of this illness. While methemoglobinemia due to elevated nitrate levels in drinking water is recognized as a possible concern, to date, there are no reported incidences of this condition across the Prairies.

Although nitrate-N levels are very low in manure, the organic-N and ammonium-N can be converted to nitrate when manure is applied to soil. Nitrate is highly soluble in water and, unlike P, is not bound by soil particles. Therefore, as excess water moves down through the soil profile, such as after snowmelt or heavy rainfall, it can carry with it any nitrate present. The magnitude of nitrate leaching depends on the amount of nitrate in the soil, the amount of water moving through the soil, and the texture of the soil which influences the rate of percolation.

Monitoring Deep Nitrate Movement and Nitrate Recovery

In addition to routine, agronomic soil testing in the 0 to 60 cm (0 to 24 inch) range, which is used to determine fertilizer recommendations, deep soil nitrate testing can be used to determine if nitrate has leached below the root zone. Every three to five years, soil samples can be taken to a depth of 100 to 150 cm (40 to 60 inches) and tested for nitrate. This is particularly important for fields that have received manure applications that have exceeded the annual crop requirement.

If deep, leached nitrates are detected, producers should consider lowering application rates or discontinuing application, and establishing deep-rooting forage crops such as alfalfa. Such forages readily absorb nitrate-N and their deep root penetration allows them to reach greater depths than annual crops. Since manure can be applied to a standing forage crop, forages also offer an excellent opportunity to extend the window of manure application to include the summer months. Low-disturbance injectors further improve the options for liquid manure application on forage land.

Regulating Soil Nitrate Levels
Regulations in Manitoba and Alberta contain limits for nitrate levels in soils that receive manure.

- In Manitoba, the Livestock Manure and Mortalities Management Regulation includes nitrate-N limits for soils that receive manure. (*The Environment Act*. Regulation 42/98. Chapter E125 of the *Continuing Consolidation of the Statutes of Manitoba*. Queens Printer for the Province of Manitoba.)

- In Alberta, the Standards and Administration Regulation requires that a person have sufficient land for the application of manure so that the application limits for nitrate-nitrogen in Schedule 3, Table 3 are not exceeded. (*Agricultural Operation Practices Act*. Regulation 267/2001. Queens Printer for the Province of Alberta.).

8.2.3 Pathogen Loss to Surface and Groundwater

Livestock manure contains bacteria, viruses, protozoa and parasites, some of which may be pathogenic (cause disease) in humans. These pathogens can also be found in faeces from wildlife, birds, pets and humans and can enter surface water if animals have direct access to the water or through the discharge of sewage treatment systems. Manure can also enter surface water through runoff or erosion from agricultural fields or because of an accidental spill. For these reasons, drinking untreated surface water is never a recommended practice.

Although the soil tends to act as a natural filter that protects groundwater from contamination by pathogens, there may be a risk of micro-organisms moving through the soil profile to groundwater where the water table is shallow and overlain by coarsely textured material. Microbial transport to groundwater may also be a concern in areas where fractured bedrock is found at or near ground surface or in areas characterized by Karst features such as sinkholes. Manure can also reach groundwater directly through poorly constructed wells.

8.2.4 BMP's for Minimizing the Risk of Nutrient and Pathogen Loss to Surface and Groundwater

There are various practices that can be implemented to minimize the risk of nutrient and pathogen loss to surface and groundwater. These include:

Manure/Nutrient Management Planning:
Develop a manure/nutrient management plan:
- test soils annually for nutrient concentrations;
- test manure for nutrient concentrations;
- match manure application rates to crop nutrient requirements;
- apply manure uniformly and at agronomic rates;

- optimize the N:P ratio of manure to more closely match the N:P ratio of crop requirements:
  - improve phosphorus use efficiency to minimize P excretion from livestock (eg. Phytase additive for swine and poultry)
  - minimize N losses during collection, handling and storage of manure
  - adopt application practices such as injection or incorporation to reduce the opportunity for ammonia volatilization

Soil Conservation:
Implement practices to reduce runoff and soil erosion:
- adopt reduced tillage which allows for incorporation of manure;
- practice contour tillage; and
- maintain adequate cover on the soil surface using crop residue or cover crops.

Surface and Groundwater Protection
- establish appropriate setbacks and buffer strips between land application areas and streams, lakes, ponds and wells;
- establish settling basins where erosion rates are high;
- do not apply manure on frozen soil or snow-covered ground;
- avoid storing or applying manure in ground water recharge areas;
- establish deep rooted crops such as alfalfa to take up nitrate that is below the root zone of other crops; and
- restrict animal access to surface water.

It is also important to ensure that wells are properly protected and drinking water quality is routinely monitored. Everyone should:
- ensure proper well construction, including casing and caps; and
- test and treat, as necessary, surface and groundwater used for domestic purposes.

8.3 Odour

There are three primary sources of odour from a livestock operation:
- livestock housing;
- manure storages or treatment units; and
- lands that receive livestock manure.

Manure odours, defined by human response, are the compounded result of hundreds of different gases associated with manure decomposition and animal metabolic activities. The more offensive gases are by-products of anaerobic decomposition of manure. Liquid manure storage systems promote anaerobic decomposition, particularly deeper in the manure storage structure.

Sensitivity to odour varies greatly from one individual to another and can be affected by a number of factors. The FIDO(H) factors (Frequency, Intensity, Duration, Offensiveness and Hedonic Tone) will impact odour tolerances. Personal testimonials indicate that odour can be a source of psychological stress, and in some cases, is reported to be the source of physical symptoms including nasal irritations, headaches and nausea. To date, studies have not demonstrated significant health hazards to neighouring residents caused by manure odours, however data from clinical and engineering studies suggest that further research is warranted.

Feedlot Cattle

Odours released during land application can cause nuisance. Odour emission is a function of the type and form of the manure, its exposure to the air and the length of time it is exposed. Fine manure droplets that spend more time exposed to the air will have the greatest opportunity to release manure gases.

The "big gun" irrigation system has the most potential for creating odour nuisance. The high-pressure spray nozzles form a fine mist of liquid manure that is projected into the air and can travel long distances with maximum air contact. For this reason, they are not recommended.

Minimizing the exposure of the manure to the air can greatly reduce odours. Injection or incorporation as soon as possible after application is very effective in reducing or eliminating odours during land application.

8.3.1 BMP's for Reducing Odour

There are various practices that can be implemented to minimize odour nuisance, including:

- considering neighbours when agitating, cleaning pens or applying manure;
- informing neighbours in advance of agitating and applying manure;
- avoiding land application on weekends if neighbours are located downwind where odour can be a nuisance;
- injecting manure into the soil whenever possible;
- using low-level application equipment if injection is not possible and incorporating the manure as soon as possible after application; and
- discontinuing the use of "big gun" manure irrigation systems;
- manure treatment options may be considered where nearby land uses may be sensitive to odours (eg. Composting).

8.4 Soil Quality

Manure plays an important role in improving soil quality, which has excellent short- and long-term benefits for agricultural crop production. The improvement in soil quality also has potential benefits for the environment such as:

- improving crop yields, thereby increasing nutrient uptake by plants; and
- improving soil structure, which increases infiltration and reduces runoff and erosion.

Manure should be properly managed to ensure that soil quality is maintained or improved. Improper manure management has the potential to negatively affect soil quality through:

- increased salinity and sodicity;
- micronutrient and metal buildup; and
- compaction.

8.4.1 Salinity and Sodicity

Salinity

Manure and soil contain the salts of ammonium, calcium, magnesium, potassium and sodium. When manure is applied to soil, varying quantities of salts are also applied depending on the characteristics of the manure. In areas of adequate precipitation and drainage, these salts are normally leached through the soil profile and do not create a problem for crop production. However, in areas with borderline saline soils and low annual precipitation, manure additions may cause a salt build-up in excess of crop tolerance.

Elevated soil salinity can impede the ability of a growing plant to absorb water from the soil, even in conditions of otherwise adequate soil moisture. Different crops have different tolerances to soil salinity. Therefore, salinization will reduce the types of crops that can be produced on salt-affected land. Crops such as peas, field beans, timothy and several clovers have a relatively low tolerance to saline conditions. Oats, flax, wheat, canola, yellow mustard, corn, crested wheat grass, intermediate wheat grass, meadow fescue and reed canary grass will tolerate moderately saline conditions.

Barley is a Moderately Salt Tolerant Crop

Soil salinity can be measured in the laboratory and is expressed as electrical conductivity (EC). Manure management should take into account soil salinity, particularly in areas with borderline saline soils and low annual precipitation. The application rate of manure should not increase soil salinity to a level such that crop choices are limited.

In Alberta, the Standards and Administration Regulation, under the Agricultural Operation Practices Act, states that the land application of manure must not increase the electrical conductivity of soil by more than one deciSeimen per metre (dS/m) and manure must not be applied to soil that has an electrical conductivity of more than 4 dS/m (Agricultural Operation Practices Act. Regulation 267/2001. Queens Printer for the Province of Alberta).

Sodicity

Soil sodicity occurs when the sodium content of the soil is out of balance with calcium and magnesium. It can adversely affect soil structure and, consequently, reduce crop yields. Soil sodicity is expressed by the Sodium Adsorption Ratio (SAR), which is calculated from the measured concentration of sodium relative to calcium and magnesium in a soil extract solution.

8.4.2 BMP's for Managing Salinity and Sodicity

In areas with borderline saline soils and low annual precipitation:

- soil salinity and sodicity should be monitored. If soil testing indicates that EC or SAR values are increasing, manure applications should be adjusted and a qualified agronomist should be consulted.

8.5 Micronutrients and Metals

Manure contains trace levels of micronutrients and other metals. These metals are naturally occurring in prairie soils and therefore may be present in trace levels in feeds as a result of plant uptake.

Micronutrients are required in relatively small amounts for crop and livestock production. These include cobalt (Co), copper (Cu), molybdenum (Mo) and zinc (Zn). Livestock operations that feed micronutrients (during certain phases of the production cycle) at rates that exceed nutritional requirements will produce manure that has elevated levels of those micronutrients. The level of micronutrients in the manure can be determined by manure testing.

Metals that are not micronutrients include cadmium (Cd), mercury (Hg), nickel (Ni) and lead (Pb). These metals are normally found in very low concentrations in manure and are generally not a concern. As with micronutrients the occurrence and concentrations of these metals can be measured through manure testing.

8.5.1 BMP's for Managing Micronutrients and Metals

Operations that feed micronutrients for growth promotion should test their manure for these metals.

8.6 Soil Compaction

Manure application can cause soil compaction due to the use of heavy equipment. Soil compaction takes place when soil particles are squeezed together, reducing the space available for air and water. This decrease in pore space results in reduced aeration, water availability and drainage, which inhibits root growth as well as increases the potential for surface runoff. At near-saturation moisture levels, the soil may be unable to support a load, resulting in rutting, smearing and soil mixing. These changes in the physical condition of the soil can reduce its productive capacity and sometimes require costly and difficult measures to rectify.

The degree to which soil is compacted by heavy equipment traffic depends on the size of the equipment, the tire configuration and the soil conditions at the time of application. Application equipment that can transport large amounts of manure may reduce the number of trips from the storage to the field, however a larger total axle weight can cause greater compaction with a single pass. Larger volume equipment can also cause compaction at greater depths – making remedial tillage more difficult. Soils are generally most susceptible to degradation through compaction and shearing when they are wet, such as in the spring after snowmelt or following heavy rainfall.

8.6.1 BMP's for Reducing Soil Compaction

To reduce compaction during manure application:

- Use drag-hose application systems for liquid manure to reduce traffic on the field;
- Restrict repeated vehicle traffic to specific areas of the field (e.g. designated pathways);
- Apply manure when field conditions are favourable and avoid conditions in which soils are more prone to compaction (e.g. high wetness following snowmelt or precipitation);
- Minimize the axle weight of application equipment;

- Maximize the 'footprint' (the area over which the downward pressure is exerted by the tires) through the use of:
  - Lower tire pressure
  - Larger tires
  - Radial tires
  - More tires (e.g. tandem axles)
  - Equipment with front-wheel assist, four-wheel drive
  - Track vehicles

These techniques should produce a long, narrow footprint, as opposed to a short, wide 'footprint' (e.g. dual tires).

8.7 Summary

Properly managed livestock manure provides many benefits such as improved soil quality, enhanced crop production and a reduced need for chemical fertilizer. There are numerous BMPs available to producers that optimize the benefits of manure application and, at the same time, minimize the potential for negative impacts on the environment. Producers using manure as a fertilizer and /or soil amendment should incorporate the appropriate BMPs into their farming activities in order to maintain the necessary balance between agricultural production and environmental protection.