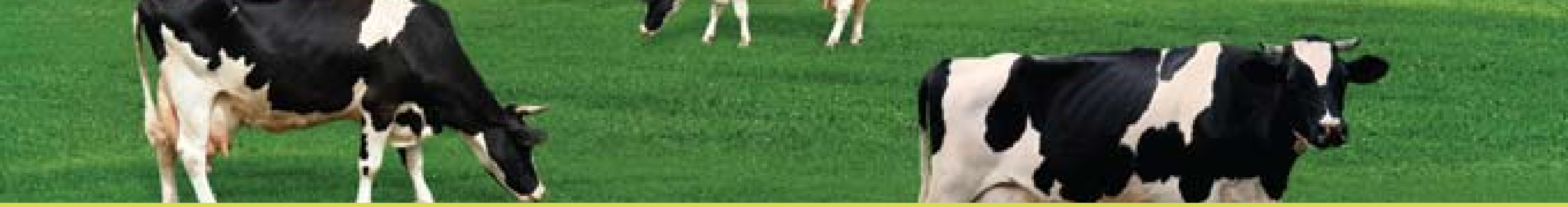


Chapter 4.
MANURE TREATMENT

This chapter defines and explores the characteristics, advantages and disadvantages of three types of manure treatments:

- anaerobic digestion
- solid-liquid separation
- composting

Manure is usually applied to the land in its unaltered state, but in some situations manure may be 'treated' to alter its management. Manure treatment is often completed to change the moisture content of the material, making it easier to manage the manure or to reduce the environmental risks associated with manure management. Any treatment that changes the moisture content of manure will also affect the concentration and content of nutrients in the manure.

In situations where available cropland acreage is insufficient to recycle all of the manure produced by an operation, manure may be treated to change application dynamics and potentially make it practical to transport and apply the manure on land further from the operation. Treating manure may also make it a more favourable product for off-farm users to purchase or receive as a nutrient source.

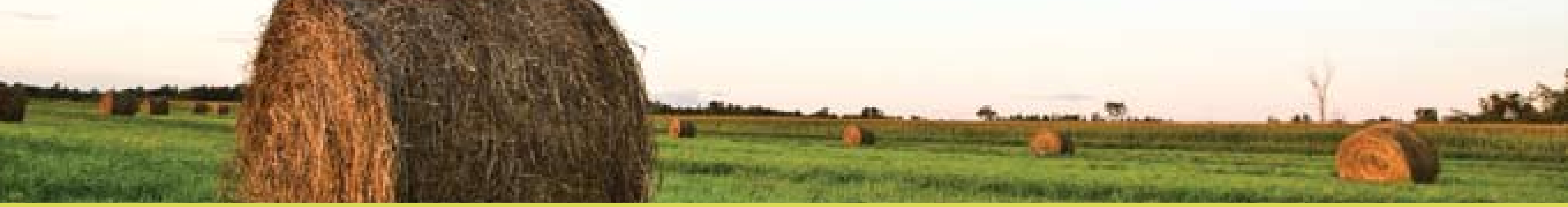
New treatment processes are continually being developed or adapted for manure. Manure managers who are interested in adopting new treatment technologies should be prepared to evaluate new technologies by participating in educational workshops, talking to people using and managing these technologies, and researching the technologies and their adaptability for local conditions. The adoption of manure treatment technologies can be very costly and time consuming in the short-term and the benefits may only be realized in the long-term. Potential benefits include: reduced manure volume, creation of value-added products, increased ease of manure management and reduced environmental risk.

Some of the most common methods of manure treatment in Alberta are anaerobic digestion, solid-liquid separation and composting.

Anaerobic Digestion

Solid-Liquid Separation

Composting



4.1 ANAEROBIC DIGESTION

The anaerobic digestion process is gaining attention in the agricultural industry because of its potential for renewable energy production and manure stabilization. These potential benefits are significant against the current backdrop of rising energy costs and growing environmental concerns.

Generally speaking there are two anaerobic digestion system configurations suitable for Canada:

Completely mixed: This type of system consists of a large tank in which new and old material is mixed. These systems are suitable for manure with lower dry matter content of 4% to 12%.

Plug flow: Typically this type of system consists of long channels in which the manure moves along as a plug. These systems are suitable for thicker liquid manure with 11% to 13% dry matter.

Anaerobic digestion is a naturally occurring process through which organic matter, such as crop residue, manure, spilt feed, food and meat processing waste, is broken down by micro-organisms in the absence of air. Most anaerobic digesters are operated in the temperature range of 15 to 45°C. The pH of the slurry in the digester is maintained between 6.5 and 7.5. The typical retention time of organic matter in the anaerobic digesters varies from two days to 60 days, depending on the type of digester and the concentration of organic matters processed.

The effluent coming out of the digester after the completion of the digestion process is known as digestate. Digestate may be processed to produce several value-added products and to reuse water as shown in Figure 4.1.

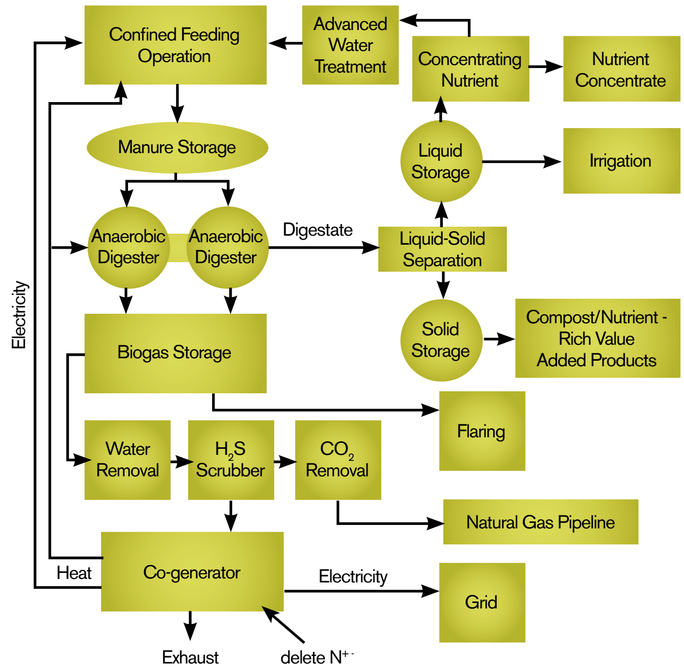
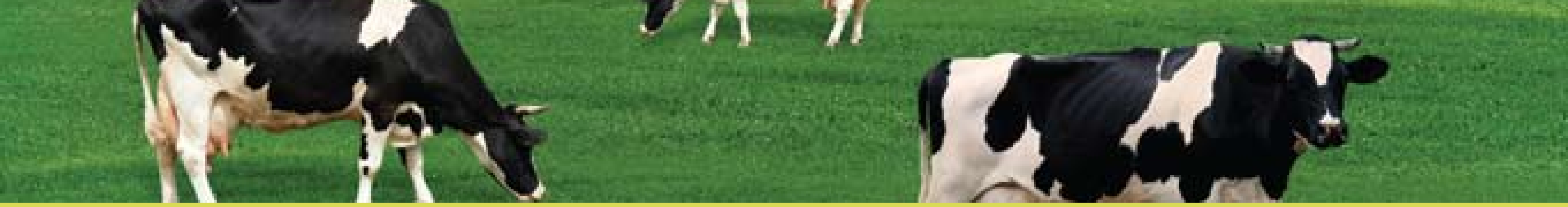


Figure 4.1 Schematic of the anaerobic digestion process

The first step in processing the digestate is separating the liquid and solid portions. Since the digestate has nutrient value, both the liquid and solid portions can be applied on land like manure. In addition, both streams may be further processed. For example, the liquid portion may be used for flushing purposes or purified further using advanced water treatment technologies to meet other water requirements on the farm. However, additional processing always requires additional investment.

In addition to the digestate, the anaerobic process converts some organic compounds to methane (CH_4) and carbon dioxide (CO_2) gases. The combination of these gases, ranging from 50 to 75% CH_4 and 25 to 45% CO_2, is known as biogas. Like natural gas, biogas can also be used as a fuel in power generators, engines, boilers and burners.

Biogas from anaerobic digesters also contains trace gases such as water vapour, hydrogen sulphide (H_2S),



nitrogen, hydrogen and oxygen. The water and H_2S gases require removal (see Figure 4.1) before biogas is used to produce energy. Biogas may also potentially be added to the natural gas lines if carbon dioxide is removed from the biogas.

BIOGAS IS A HIGHLY CORROSIVE AND FLAMMABLE GAS, and it contains traces of hydrogen sulphide (H_2S). Exposure to high concentrations of H_2S is harmful and may result in human fatality. Therefore, digester plant operators must be trained to handle H_2S and other biogas hazards.

Electricity can be produced from biogas using internal combustion engines and power turbines. While producing electricity, heat energy can also be recovered by using a sophisticated generator known as a co-generator. Co-generators usually contain an internal combustion engine or power turbine and heat exchanger to capture the heat generated while electricity is produced. Thus, co-generators have higher efficiency in energy production when compared to other electricity generators.

DIGESTER PLANT OPERATORS should follow standard safety procedures such as wearing safety gear, especially for hearing protection, as co-generators are generally noisy. The plant area should be fenced and have appropriate warning signs like "Danger, H_2S Area," "Stop" or "High Voltage."

Part of the heat energy produced during power generation is often used to heat the anaerobic digester. The rest is used to meet the various heating requirements of the farm.

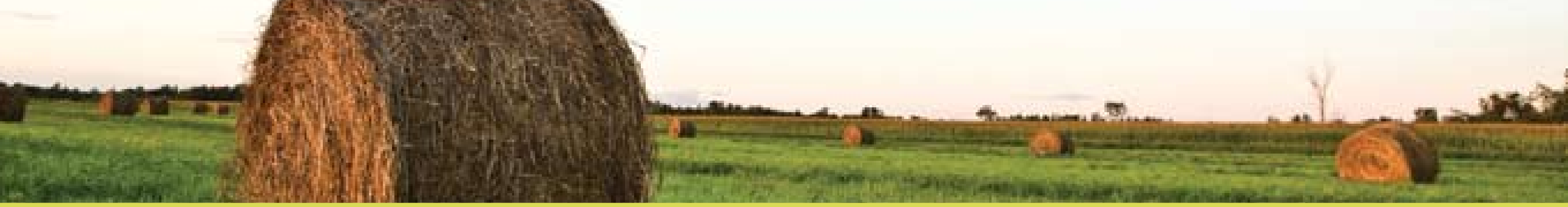
Electricity produced by the digester system can be used to meet the farm's electricity demand. The excess electricity may be sold to neighbouring communities or to the electricity supplier using the grid. Information regarding connecting excess electricity into the grid can be obtained from the electricity supplier.

Advantages of Anaerobic Digestion

- Odour reduction.
- Reduction of disease-causing micro-organisms (pathogens) – harmful pathogens like *E. coli* bacteria are considerably reduced when this process is used.
- Biogas production – biogas is known as renewable energy and reduces greenhouse gas emissions.
- Energy production.
- Nutrient retention for fertilizer use.
- Land application of solid and/or liquid digestate on cropland – this can help offset fertilizer costs.
- Soil conditioner production – the solid portion of the digestate may be sold as a nutrient-rich soil conditioner.
- Additional water for farm use – the liquid portion of digestate may be used for washing or flushing purposes or further purified for other farm water needs.
- Tipping fees for feedstock materials – tipping fees can be collected from producers or industries who want to sell manure or other biological materials as feedstocks for the digester.

Disadvantages of Anaerobic Digestion

- High capital costs may range from a few hundred thousand to a few million dollars. Some of the feasibility studies in North America



concluded that the payback period ranges from 5 to 16 years, when operated under optimum to worst conditions.

- Facility management expertise required.
- Labour and maintenance costs.
- Suitable only for very large operations.
- Utility connections may be difficult.
- Creation of two manure streams – Both solid and liquid materials must be managed.
- Process is sensitive to variation – high failure rates have been reported due to inadequate process control.

4.2 SOLID-LIQUID SEPARATION

Solid-liquid separation is a treatment technology that divides manure into solid and liquid fractions. This technology is used primarily with liquid or slurry manure systems.

Effective solid-liquid separation can remove a substantial amount of the organic solids from fresh liquid or slurry manure. The process creates a nutrient-rich solid fraction that has the economic potential to be hauled farther for land application now that the water fraction has been removed. In addition, the solid fraction has the potential to be composted and then land applied, sold or used as bedding in barns. The remaining liquid fraction contains fewer and smaller solids that are less likely to settle than in the original slurry. The liquid fraction still contains nutrients and can be applied to fields as a nutrient source or as irrigation water. Alternatively, the liquid fraction can be treated, recycled and reused within the operation as wash or flush water.

Separation efficiency depends on many factors, including the density, size and shape of particles, which depend on the source and quantity of bedding material, the amount of parlour water added, and seasonal changes in biological activity in storage ponds. The characteristics of the treatment technology, including treatment time, facility design and operation, also affect separation efficiency.

Several methods can be used to separate solids from liquids. The effectiveness of most separators improves as the solid content increases. The process is more effective with fresh rather than stored manure.

4.2.1 Separation Techniques

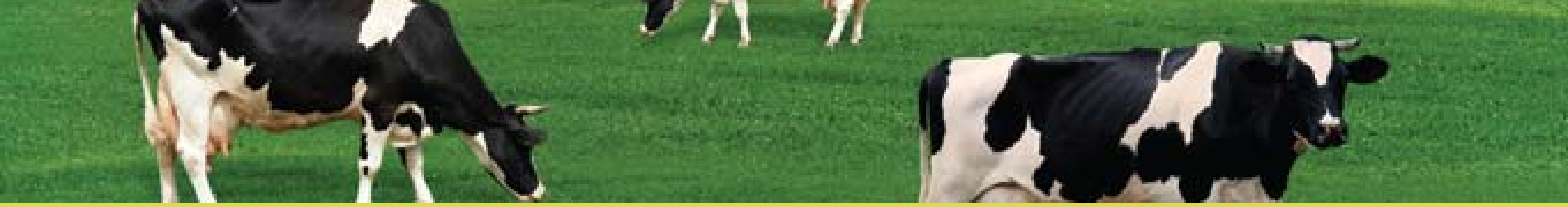
Sedimentation: This technique uses gravity to settle solids out of the slurry.

- Multi-cell earthen storages. This is the most basic and least effective method of solid-liquid separation.

Mechanical separation: This technique uses gravity plus mechanical means to separate the solids and liquids.

- *Centrifugal separators.* Several separators of this type have appeared on the market. They are generally high in price, low in capacity and not as effective as a press separator in producing a low-moisture solid fraction.
- *Screens.* Many variations of screen separators exist, including a simple, stationary sloped bar screen, a vibrating screen and screens with mechanical assistance. Most separators on the market at present are variants of the screen separator, usually with mechanical assistance in the form of scrapers, screws and/or hydraulic head to provide additional separating force. The screw press separates solids more efficiently than other technologies. These separators can be very cost prohibitive for some operations, yet practical for large operations.

Evaporation ponds: These may be effective in arid regions where much more water is removed by evaporation than is added by precipitation.



Dehydration: This method uses heat to remove moisture and is unpopular because of the high initial cost, maintenance and energy requirements.

Coagulation and flocculation: This relatively new technique for solid-liquid separation uses chemicals to aggregate suspended solids (coagulation) to form particles capable of settling out and to convert particles into large, rapidly settling flocs (flocculation).

4.2.2 Implications of Implementing Solid-Liquid Separation

Phosphorus (P) reduction in liquid fraction: About 96% of the P in manure is contained within the solid fraction. Therefore, P compounds are largely removed with the separated solids. Nitrogen (N) and P contents in the separated solids may be as high as 2% and 5%, respectively, depending on manure characteristics and the type of separation equipment. The addition of chemicals to the manure before separation can enhance P removal from the liquid fraction, significantly increasing the P content in the separated solids. The nutrient-rich, low-moisture solid fraction can be economically transported farther, allowing for the movement of nutrients farther from the yard, and reducing the risk of nutrient accumulation in nearby soils that have had frequent manure application in the past. Liquid from the separation process can be applied to nearby fields with a lower risk of nutrient accumulation because it contains less nitrogen, phosphorus and other constituents.

Water reuse and conservation: The separated liquid fraction can be treated using chemicals or ultraviolet light to kill pathogens. This allows the recycled water to be reused in the facility for livestock cooling, washwater or cleaning, reducing the need to use fresh water for these purposes. The recycled water could potentially be reused as a possible source of drinking water for livestock; however the cost of water treatment increases as the final water quality increases.

Ease of handling and transport: The removal of solids from the liquid fraction makes handling, pumping and application of the liquid easier. There is a lower potential to plug transfer pipes due to the reduction in solids, and less power is required to pump the same volume of material. The liquid fraction is easier to pump long distances in an irrigation system because it requires less pressure at the pump, minimizing the risk of ruptured seals and thus manure spills. As well, transportation of the solid fraction costs less due to the reduction in volume when liquids are removed.

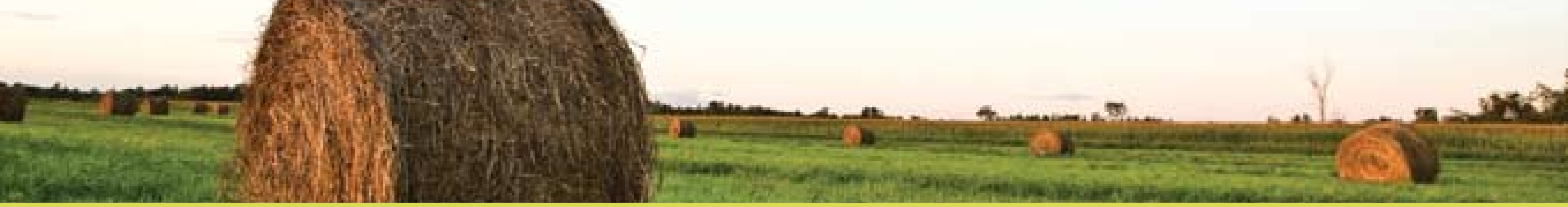
Odour reduction in liquid fraction: Odour generation largely depends on the amount of odour-producing organic substances remaining in the liquid. The separation process reduces the amount of organic compounds in the liquid fraction, reducing the organic loading and therefore the amount of odour released during storage, handling and application.

Lagoon volume reduction: Separating manure solids from the slurry before putting it into a lagoon reduces total slurry storage volume by 6 to 10% daily and volatile solids loading and lagoon treatment volume by 30 to 50%.

Two manure streams are created: Because this process creates two separate manure streams, two handling systems are needed: one for the liquid fraction and the other for the solid fraction.

Cost: Along with the capital, labour and maintenance costs of the separating device, some mechanical separation systems have high operating costs. The two handling systems must each be designed, operated and maintained, thereby increasing the cost of using a solid-liquid separator.

Increased management requirements: An operator must be knowledgeable to ensure the system is functioning properly. Regular maintenance is required to avoid breakdowns, depending on the type of separator. The increased concentration of P in the solid fraction must be managed properly to prevent P accumulation and environmental risks associated with P accumulation in fields.



4.3 COMPOSTING

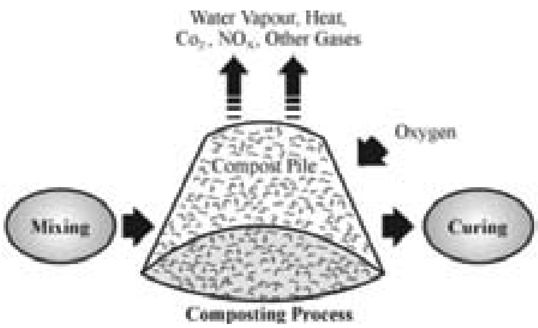


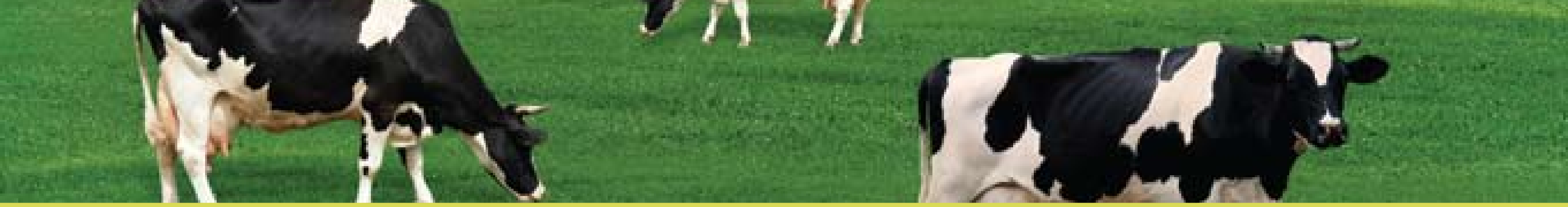
Figure 4.2 Basic Composting Process

Manure composting is an aerobic, biological decomposition process that transforms solid manure and bedding material into stable, soil-like or humus-like material.

Requirements to achieve the best results from manure composting are:

- The moisture content of the material to be composted should be between 40 and 65%. If the moisture content is below 40%, the process is slow; if the moisture content is above 65%, the process may become anaerobic, which can create more odour. Since liquid manure is about 96% water, the solids must be separated from the liquid fraction in order for the solids to be composted. This requires solid-liquid separation. Housing systems using straw or shavings for bedding can produce solids suitable for composting.
- The material should have a carbon to nitrogen ratio (C:N) between 20:1 and 30:1. If the C:N ratio is too low, ammonia-N will volatilize (gas off) and be lost from the compost; if the ratio is too high, the process will take longer because nitrogen is in short supply compared to carbon.
- An oxygen content greater than 10% is ideal; the minimum oxygen content for composting is approximately 5%. Although oxygen naturally enters the material, its entry needs to be accelerated and oxygen needs to be available throughout the entire compost pile. This can be accomplished either by regular mechanical turning or by forcing air through the material using pipes and fans.
- A pH of 6.5 to 8.0 is required to promote the growth of the bacteria and fungi needed for manure decomposition. Most animal manures have a pH of approximately 6.8 to 7.4. The pH level of the compost may be adjusted by varying the mix of acidic and alkaline material.
- A temperature of 55°C to 60°C must be attained in the compost pile. Temperatures maintained at 55°C or greater for 15 days will eliminate most pathogens and weed seeds. Temperatures will be higher in the interior of the pile than the outer edges so the pile should be turned regularly to ensure that all of the material reaches and maintains those high temperatures.

THE MANURE COMPOSTING CALCULATOR
determines the amount of carbon source material and water needed to create a good compost mix. The Manure Composting Calculator is available at www.agriculture.alberta.ca



Advantages of Composting

- Reduces manure mass and volume, which can reduce hauling costs.
- Reduces odour during land application.
- Destroys pathogens.
- Kills weed seeds.
- Creates a soil conditioner.
- Converts nutrients into more stable forms.
- Creates a more consistent product that is easier to spread.
- Creates a product that has the potential to be sold.

Disadvantages of Composting

- Results in loss of ammonia-nitrogen.
- Requires time and labour.
- Poor management can lead to offensive odours and greenhouse gas emissions.
- Most practical for larger operations.
- May require the purchase and maintenance of composting equipment.
- Requires land for laying out windrows or piles for composting.
- If choosing to sell the final product, it requires marketing and potentially proper labeling.
- Requires a properly designed site for composting and potential leachate catchments.

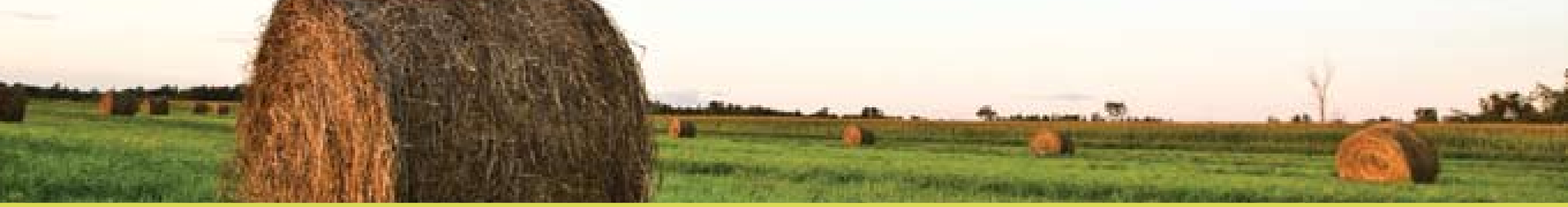
4.3.1 Composting Techniques

Various methods can be used for composting, including windrows, static piles with passive aeration, static piles with forced aeration, and reactor composting. All methods require careful management to ensure the elements of the composting process are supplied, maintained and optimized; otherwise the full benefits of composting will not occur.

Windrow composters can be used to accelerate the composting process.

Windrows: A windrow is a long, triangular pile with a width (4 to 5 m) about twice its height (1.5 to 2.5 m). The size must be large enough to maintain heat in the windrow and small enough to be managed with the equipment available. The manure piles or windrows are aerated by frequent mechanical turning, which maintains the composting process. A front-end loader or a specifically designed windrow turner can be used for turning.

FOR MORE INFORMATION see Manure Composting Manual, Agdex 400/27-1, available from Alberta Agriculture and Rural Development (ARD).



Advantages

- Mechanical turning moves material from the outer layer of the windrow into the centre. When properly managed, this facilitates the material being exposed to adequately high temperatures for at least 15 days, to kill pathogens and weed seeds.
- Material can be well mixed, promoting uniform breakdown, resulting in a consistent product.
- Generally produces compost faster than passive aeration composting.
- Easier to maintain the desired moisture content in the material as water can be added throughout the material as it is being turned.
- Relatively low capital cost.
- Mechanical turning helps to break up clumps of straw and manure, and adds oxygen to the pile.

Disadvantages

- Cost of windrow turning equipment (capital and operation).
- Relatively higher operational cost as compared to static piles.
- Time is required to turn and manage the windrow.
- Often requires more space than other forms of composting, such as static pile, because room is needed to move the windrows and/or move the equipment around the windrows.

Static pile with passive aeration: Composting piles or windrows are outfitted with aeration tubes throughout to aid in air movement through the material and sustain the composting process.

Advantages

- Less cost and maintenance than forced aeration static pile composting.
- Less capital investment in equipment than for other types of composting methods.

Disadvantages

- Difficult to maintain the proper temperature and moisture conditions in the pile or windrow.
- The proper composting temperature may not be maintained well enough, resulting in the survival of viable weed seeds, especially along the outer layer of the static pile.
- Potential for survival of pathogens if adequate temperatures are not maintained for at least 15 days; this is especially an issue for the material in the outer layer of the pile.
- Difficult to add water evenly throughout the pile to maintain the desired moisture content for composting process.
- Time to compost is longer.
- Final product is not as uniform as compost that is turned and mixed; no mechanical turning happens so clumps of straw and manure are not physically broken up.

Static pile with forced aeration: Forced aeration uses fans or blowers to push air through ducts installed under the composting windrows. The rate of aeration is often dictated by the temperature of the composting media as measured by thermocouples installed within the media. The optimum aeration rate is influenced by a number of factors including the moisture content and porosity of the material.

Advantages

- Potentially lower start-up and maintenance costs than mechanical windrow turning.
- Easier to maintain proper aeration requirements than in passive aeration composting.

Disadvantages

- Potential for survival of pathogens and weed seeds if adequate temperatures are not maintained for at least 15 days, especially in the outer layer of the pile.

- Potential for very inconsistent compost quality.
- May reduce moisture content of the pile faster than passive aeration, resulting in the need to add moisture more often or in greater volumes to maintain ideal compost conditions.

Reactor composting (in-vessel composting): This technique involves composting in drums, silos or channels. Aeration is accomplished by continuous agitation using aerating machines, which operate in concrete bays, or by fans providing air flow from ducts built into concrete floors. Reactor processes are either horizontal or vertical flow. Some vertical reactors allow for mechanical agitation of solids and are usually fed with raw manure on either a continuous or intermittent basis. Horizontal reactors employ either a rotating drum system or a bin structure, which can include mechanical agitation.

Advantages

- Can be designed as a continuous process.
- Allows better control of the process and produces a consistent product with effective weed seed and pathogen kill.

Disadvantages

- Higher initial costs as the process is mechanized and capital intensive.
- Generally less flexible than other methods; reactors are generally built in one location (stationary) and they are sized to accommodate a certain volume of material, so they are unable to take in more material than their sizing allows.

4.3.2 Composting Regulations

The siting and operation of composting facilities that compost only livestock manure with no additives are regulated under Alberta's *Agricultural Operation Practices Act.* The siting and operation of composting facilities that compost livestock manure and also accept other agricultural and non-agricultural waste products are regulated under Alberta's *Environmental Protection and Enhancement Act.* The sale of compost is regulated under Canada's *Fertilizer Act and Regulations,* through the Canadian Food Inspection Agency.

Please see the appropriate acts to find the latest regulations affecting the siting and management of compost facilities and sale of composted material.