MANURE TREATMENT AND HANDLING OPTIONS

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Abstract

Manure treatment and handling will need to be an integral part of the nutrient management systems on livestock farms. No one manure system will meet the varied needs of farms with their specific nutrient management situations. The method of manure handling that will best suit each farm will vary depending on labor, land and capital resources and the manure itself. Several criteria that each farm manager will need to evaluate the treatment system that will best meet their needs are presented. A variety of treatment systems that are available are presented.

Why are alternative manure handling and treatment methods needed?

There are a wide variety of farms. They vary in their resources and their environmental concerns. Some farms have access to more capital, skilled labor, management ability, land resources, water resources, and markets than other farms. Different manure treatment and handling methods will be needed to match the resources and needs of different farms.

Manure has been traditionally applied fresh to the land as a fertilizer and soil amendment. Although this practice will continue, many farms will need to change this relatively simple manure handling to more complex storage and treatment methods to respond to the environmental concerns that are increasingly being raised.

Society has recognized that animal agriculture can lead to excess nitrates in the ground water, pathogens in the drinking water and excess nutrients, BOD, and sediment in surface water. To avoid these problems manure will increasingly be spread on dry soils in fields where the chance of runoff and leaching are low. Environmental agencies are prescribing these changes. There are now many state, provincial, and federal **regulations** on the timing and amounts of manure spreading (Wright and Staehr). In order to hold the manure until the appropriate time to spread, manure storage will be a standard practice on most farms.

Storage of manure creates peak labor needs as the manure is spread. Increasingly manure will need to be stored for spreading in the late spring and summer for maximum crop uptake to avoid the nutrient losses that occur with water movement off the land. This peak demand for labor will push farms to find ways to move manure quickly and with more **efficiency**. Larger tankers, bigger truck-mounted spreaders and more irrigation or draghose applications are ways equipment can be used more efficiently and economically (Dougherty et al). Using nurse trucks and temporary storage to feed the irrigation systems, draghose system, or spreading equipment increases the volume of manure that can be applied in a given time.

Manure storages that are open to precipitation, the need to catch and contain runoff from livestock yards, and the efficiencies of pumping liquid over truck or tractor hauling will increase the use of liquid manure handling systems. Chopper pumps, larger pipes, dilution, separation of solids, and some treatment systems help make manure pumping more feasible. Properly designed irrigation or draghose systems provide a uniform application of the manure that can be difficult with some spreaders.

Nitrogen losses from storages can range from 10% to 40% depending on the type of storage, the length of storage, the temperature and the management. Nutrients can segregate in a storage to some degree. Agitation to obtain a homogenous material to spread is recommended for best fertilizer use. Uncovered storages will vary in moisture content, often gaining moisture in the winter and losing some from evaporation in the summer. It is very important to obtain representative samples from a storage to predict the nutrient values of the manure.

Risk reduction may increase the use of dryer manure handling methods. Catastrophic failures of liquid manure storages create a huge environmental impact. They attract the attention of environmental agencies as well as the media. Even small spills of liquid manure can cause big problems since, in a liquid form, manure will move off site quickly. Solid manure systems do not have this disadvantage. A break in a solid manure storage is just an inconvenience. Small spills of solid manure can be easily cleaned up. Solid manure is less volatile and more likely to be aerobic, so there will be less volatile organic compounds leaving the storage or the field on which it is spread.

Larger manure storages to hold a year's worth of manure will be needed. Manure storage sites may be located away from the barns and closer to the fields to decrease unloading time (Wright et al). Manure from storages is already generating many complaints about **odor**. When manure is stored, it starts to decompose anaerobically. The by-products of incomplete anaerobic decomposition are very smelly. Society objects to bad odors as much, if not more, than to dirty water. Therefore handling the manure or treating it for odor control will become much more common as farms are forced to convert to storing their manure.

Phosphorous has been identified as the most common limiting nutrient in freshwater. As higher phosphorous levels build up in some agricultural soils, soluble phosphorous is released with water flows leaving the fields. Preferential flow allows phosphorous to readily leave tile-drained fields during wet weather applications (Geohring). States, provinces, and federal governments are responding by requiring that farmers adopt phosphorous based nutrient management plans. Manure generally provides a higher amount of the crops' needs of phosphorous than nitrogen. Phosphorous based plans will require manure to be spread thinner and hauled longer distances to cover more fields. Therefore there will be an increased need for treatment that concentrates the phosphorous to make hauling it long distances easier. Treatment that reduces the mass of manure would meet this need as well.

Development of **by-products** that can be sold at a profit off the farm could help maintain profitability while improving the environment. Compost or organic matter that can be used as a soil amendment may develop into a market that farms can take advantage of. Organic farms and landscapers are growing businesses that may be looking for more of this type of material.

Pathogens from manure can easily enter the environment (Geohring). Both society and regulators are increasingly trying to reduce the amount of pathogens or indicator organisms in drinking water and contact recreational water. Detection methods for disease-causing microorganisms have become more sophisticated in their ability to trace the source of the pathogen. Soon treatment for pathogen reduction will be needed.

Gas releases that form smog, greenhouse gases, or contribute to acid rain may be regulated in North America in the future. Europe is regulating the amount of ammonia that farms can release. Controlling these gases will require immediate incorporation of manure or treatment methods to control the gases released during storage, handling and spreading of manure.

Incorporation of manure to control odors or reduce gas emissions will have nutrient management consequences. Since the volatilization of ammonia will not occur, there is the potential to substantially increase the amount of nitrogen available for crop uptake. This handling method will increase the nitrogen to phosphorous ratio to lower the excess phosphorous that manure spread at nitrogen application rates often provides. Incorporation, with its increased preservation of nitrogen, will require more acres of land when spreading manure at the nitrogen application rate.

Depending on the location and the management's personal values, each farm can have different environmental concerns. Those in a watershed that supplies drinking water may be more interested in controlling pathogens and phosphorus. Those upstream of a fresh water lake may be more concerned with sediment and phosphorus. Those with close or sensitive neighbors may be more concerned with odors. Those in a porous aquifer may be more concerned with nitrogen leaching and pathogens. Others may only be concerned about BOD loading that cause fish kills locally. Nutrient loading far downstream may be a concern to some farms. Some farms may be driven to increase the efficiency of their manure handling systems to control costs. Manure handling and treatment methods will be required to deal with each of these issues.

Manure treatment systems

Anaerobic Digestion for methane production can almost completely control odors from manure. It requires skilled operation and management to run the biological process, the material handling, and the energy utilization. It helps to have a use for extra heat since as much as 75% of the energy produced is wasted as heat. Many of the existing systems have a high capital cost and may be dependent on above market prices for energy. Liquid manure of uniform consistency unmixed with runoff should be used as the feed to a digester.

Evaluations using AgSTAR computer programs supplied by USDA, EPA, and the Department of Energy show that it may be economically feasible for farms with 800+ cows to use anaerobic digestion to reduce the odors, while recovering the costs by producing electricity (Jewell 1997). Selling the electricity through a utility is a problem. Keeping both the initial capital costs and the operating costs low will be critical to the economic success of this treatment.

In warmer climates the anaerobic process can occur in an uninsulated covered lagoon. The cover floats on top of the lagoon, capturing methane that is produced and sometimes preventing the dilution of the manure with rainwater. This is a less expensive way to build and operate an anaerobic digester. Some exiting manure storage facilities can be retrofitted with a cover, thus making the addition of methane generation and odor control less costly. The covers have to be substantial to withstand the rigors of the weather they are exposed to.

The nutrients are not removed by anaerobic digestion. There is a small shift of about 5% of the organic nitrogen to ammonia. This may be a benefit to crop production if the effluent is applied right away During storage the ammonia may volatilize. Nutrients (and solids) will tend to settle out of the anaerobic effluent. There may be as much as 5 to 8% less nutrients in the top layers of the effluent storage compared to the bottom sludge. There is a loss of solids in this treatment process resulting in a 2 to 3% increase in the moisture content of the effluent compared to the raw manure entering the system.

Anaerobic Treatment Lagoons are often used to break down solids in manure in the same manner as an anaerobic digester. Because lagoons operate at ambient temperature rather than at an elevated temperature, lagoons break down solids more slowly than anaerobic digesters. Hence, lagoons require a very dilute manure, about 1 to 2 percent solids. When lagoon temperature is high enough, the proper mix of bacteria will break down solids and produce methane and carbon dioxide, both odorless gases. However, the bacteria won't function properly at low temperatures, and neither does the lagoon. The result of an improperly functioning lagoon is an accumulation of solids, an overloaded lagoon, and potential odor problems when lagoon temperatures rise in the spring. Treatment lagoons are not popular north of the Mason Dixon Line partially because they require a large land area and treatment is seasonal.

Nitrogen losses from anaerobic lagoons vary from 65% to 80%. Phosphorous settles to the bottom as part of the sludge. Nutrient management plans need to contain provisions to remove the sludge occasionally to keep the operating volume at design amounts. This high nutrient sludge may require additional land to avoid exceeding the application rates.

There are some lagoon systems that work well in more northern latitudes (Wright and Perschke). The Bion System that uses lagoons as a treatment system has reduced odors on some farms in New York State. The system consists of shallow ponds (1-2 foot deep) that settle the solids for recovery and potential sale. Then the liquids go to a slightly aerated deep pond and are recycled as flush water for the cow alleys. A large land area for the treatment system is needed. Yet odor control has been good.

This system loses about 25% of the nitrogen to the atmosphere and can catch a lot of extra water in the large ponds. The solids from this system typically contain 40% of the nitrogen and 50% of the phosphorous. The liquids typically contain 35% of the nitrogen and the remaining 50% of the phosphorous. Bion systems with the addition of a series of recirculating terraces and overland flow treatment have been used to completely reduce the total nutrients and mass of effluent from a 350 cow dairy with 100 acres of land (Wright et al 2000).

Other lagoon systems that have had varying success use mechanical separation to remove the solids, then two or more lagoons in series to degrade the manure liquids. Often aerators are added to help break down the liquid manure for recycling back to the barns as flush water. The systems that control odor the best are properly sized for the climate. Analyses of the effluent should be obtained each time from every treatment system to use to determine application rates.

Aeration replaces anaerobic decomposition with the nearly odorless aerobic process. Composting, oxidation ditches, and aerobic lagoons all greatly reduce odor. Equipment and operating costs are high. With 10 cent per kW electric it can cost more than $1.30 per cow per day to completely aerate the manure. It is important to follow responsible design criteria. Too often, undersized aerator motors are installed due to the high electrical requirements.

Partial Aeration as an odor control method has been tried with mixed results. Perhaps by aerating only the upper surface of the lagoon the oxygen helps break down some of the volatile organic compounds as they migrate up and out of the manure storage. Perhaps adding some oxygen reduces the competitive advantage obligatory anaerobes have in most manure systems. They may be the organisms that produce most of the worse volatile organic compounds. This kind of treatment will likely volatilize more ammonia leaving the stored manure with less nitrogen and the same amount of phosphorous.

The **Sequencing Batch Reactor** (SBR) promises to be an excellent way to control odors and concentrate phosphorous (Kuwahara). It will operate on a mechanical basis to produce alternating aerobic and anaerobic conditions. Solid separation will be followed by dilution with processed gray water, and then alternating aerobic and anaerobic conditions in an enclosed tank. This will drive off the nitrogen and concentrate the phosphorus as a settleable solid. After dewatering the solid the outputs will be the original separated manure solids, a high phosphorus bacterial solid and gray water that can be spray irrigated. The cost of this system will be higher than the less controlled anaerobic lagoons. Preliminary estimates for the whole system are on the order of $150 per cow per year.

The expected nitrogen losses to the atmosphere from a SBR are about 29%. The solids, after composting, contain 20% of the original mass and 60% of the original nitrogen. The gray water will only contain 12% of the original nitrogen. The gray water is very low in phosphorous with only 5% of the original. The rest of the phosphorous will be in the composted solids.

Composting has been used on excessively bedded dairy manure, separated dairy manure solids and on the drier manure produced by other animal species to reduce odors. The costs of composting may be offset by sales of the compost. Most dairy manure is too wet initially to compost well. It needs to have a moisture content of less than 75% to heat up and start composting easily.

There may be niche opportunities on some farms with a source of a high carbon waste stream. Farms with cheap sources of old hay, waste paper, bark, sawdust, or even recycled compost may be able to add enough solids to support a composting operation. Charging tipping fees for the material brought in or aggressively marketing the compost produced can add a profitable enterprise to the dairy operation.

Biodrying of the manure by recycling dry compost as the amendment in the alleys, and using the heat generated in the aerobic decomposition to dry the manure/compost mix with forced air has been proposed. Odor reduction, volume reduction, weight reduction, and pathogen reduction would occur. Equipment for solids handling is available on most farms, so adoption by many farms should be easy. Storage of solids is safer environmentally than liquid storage because of the lower risk of catastrophic failure. The compost material may be marketed as an income source and as a way to move the nutrients off the farm. The management of the drying process will be critical and the costs of the operation may be high. Additional amendment may be required.

Whether composting with passively aerated windrows or using the biodrying process, most of the nitrogen in the ammonia form is lost to the atmosphere. Some poultry operations which start composting with a dry (50% moisture) manure end up with higher nitrogen in the dried/composted product. If the composting operation allows the moisture content to fall below 40% the biological activity slows, thus preserving the nitrogen. There have been some experiments where nitrogen lost from compost was re-adsorbed when finished compost was used as the biofilter for the escaping gases.

Solid Separation of the manure solids mechanically can produce a "solid" portion (15-30% DM) and a "liquid" portion (4-8% DM). Liquids are easier to handle than a semi-solid. Solids can be recovered for bedding, soil amendment or exported off the farm. High capital and operating costs for the mechanical equipment have caused some farms to quit separating. Maintenance of the equipment is a problem. Marketing of the solids may not be successful on all farms.

The solid portion is typically about 20% of the original mass. The nutrient content of the solid and the liquid are the same for dairy manure. That is 20% of the phosphorous and nitrogen is in the separated solid and 80% is in the separated liquid.

Soil Treatment by mixing manure into a naturally aerated biologically active surface layer with an anaerobic lower layer, may result in N removal, P concentrated in the soil, and the effluent spray irrigated for disposal. Nutrients and odor would be reduced in the liquid effluent. P would be concentrated in the soil treatment area so that a dairy would not be tied to a large land requirement based on manure disposal limits. Management of this system year round may be difficult. Build up of nutrients in the soil treatment zone will require removing and replacing the soil material on a regular basis. Capitol cost for the impermeable layer and drainage system may be high.

Total Resource Recovery by combining the plug flow methane production process with solid separation, and hydroponically recovering the nutrients from the separated liquids would eliminate the waste and maximize production of useful by-products (Jewell 1999). Odors would be controlled. Energy would be recovered. Nutrients would be recycled. There would be no waste. Capital costs will be very high. Operating costs may not offset by-product sales and savings in a cheap energy, cheap nutrient situation.

Manure Handling Options will have different relative values on farms. Of course, every farm is different both in their resources and their goals. Table 1 shows various manure handling options and their relative characteristics. Every farm will need to evaluate the characteristics they are concerned with and the manure handling and treatment options that reflect actual conditions for that farm.

Conclusions

- There are advantages and disadvantages to each system that may be more or less important to each farm.
- There are existing treatment systems that work well.
- Documentation of the mass and nutrient flows and the design processes are needed for farmers to make decisions.
- Each different manure handling and treatment system needs to be evaluated for it's effect on the nutrients that will be land applied.
- Nutrient utilization and by-product sales are important in reducing the cost of a manure handling system. Marketing the separated solids or other by-products and fully utilizing the nutrients in the manure can help pay for treatment systems.

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Table 1. Manure Handling Options will have different relative values on each farm. Of course every farm is different both in their resources and their goals. This scale is an attempt to compare the systems with each other. For a specific farm, the relative values would have to be reevaluated to reflect actual conditions for that farm.

Scale: 1 = poor 10 = good

	Daily spread	Liquid Storage	Odor Control	Solid Separation	Compost	Biodrying	High Solids Methane	Methane	Wetland	Soil treatment	SBR	Total Resource Recovery
Runoff and Leaching	1	4	5	5	6	7	7	6	8	9	9	10
Odors	5	1	5-10	2	9	9	9	10	8	8	10	10
Small farm	5	3	?	2	5	7	6	3	6	9	4	5
Large farm	2	7	?	6	2	5	6	8	8	6	7	6
N reduced	5	4	n/a	5	4	4	4	6	7	8	10	10
P export	2	1	n/a	3	5	5	5	4	6	7	9	10
Pathogen Control	1	3	?	3	7	7	7	6	5	1-5	8	10
Nutrients Recycled	5	8	6	7	4	4	4	9	2	2	2	10
Compaction	1	5	6	6	8	8	8	9	9	10	10	10
Capital Costs	9	3-7	?	5	7	4	2	2	4	4	3	1
Operating Costs	5	7	?	5	3-8		3-8	3-8	5-7	5-7	2-4	?
Material Sales	2	3	4	6	9	10	10	7	6	5	8	10
Time to Implement	10	9	1-9	9	9	5	3	7	7	2	3	1
Simplicity	10	8	1-9	6	7	5	2	2	5	4	3	1

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