EXTENSION

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Application of Liquid Animal Manures Using Center Pivot Irrigation Systems

William L. Kranz, Extension Irrigation Specialist
Richard K. Koelsch, Extension Livestock Bioenvironmental Engineer
Charles A. Shapiro, Extension Soil Scientist-Crop Nutrition Specialist

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Animal manure management practices are being scrutinized to ensure that the potential for environmental pollution is minimized. Manure from large and small production facilities must be distributed in a manner that limits the potential for surface runoff, deep percolation and drift to off-target areas. The purpose of this Extension Circular is to provide guidance in selecting center pivot equipment and system management needed to safely apply manure to the land.

Introduction

Animal manure by its very nature conjures up different images depending on the source animal and the size of the production facility. One image is that animal manure is capable of supplying many nutrients needed for crop production. However, some producers regard manure distribution as a "waste disposal" problem rather than distribution of a valuable resource.

A second image is that unmanaged land-applied animal manure is a potential source of point and non-point source pollution. Nebraska animal production facilities produce approximately 7.5 million tons of animal manure each year. As the number of animals per enterprise has increased, there has not always been a corresponding increase in the land available for application and crop utilization of the manure. These factors have led to state and federal regulation of manure storage and distribution systems.

The selection of an appropriate application method for manure can be important for several environmental, agronomic and engineering issues. Application methods should be evaluated based upon their potential impact on:

- Odors
- Water quality
- Soil conservation and quality
- Pathogen transmission
- Phytotoxic effects on plants

Odor Control

It is important to recognize that various types of manure storage are not equal in their odor-producing potential. *Figure 1* presents the relative odor production potential during liquid manure application from different manure storage facilities. Anaerobic processes are excellent odor reduction processes if allowed to proceed to completion where volatile organic compounds (VOCs) are converted to methane and water. Treatment lagoons have substantially lower VOC emissions (a primary source of odor) as compared to other storage facilities. Center pivot distribution of effluent from a purple lagoon or adequately sized anaerobic lagoon can be accomplished with minimal odor while spray irrigation from an under-building pit or undersized lagoon has a very high odor potential. Lower odor storage systems illustrated in *Figure 1* provide environments that allow anaerobic processes to proceed to completion.

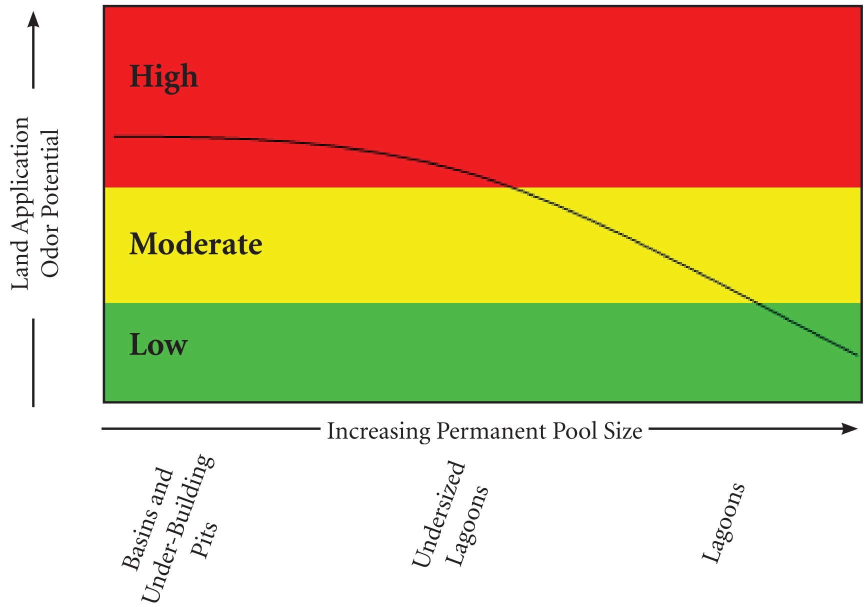

Figure 1. Relative odor emissions of liquid manure application from different manure storage systems.

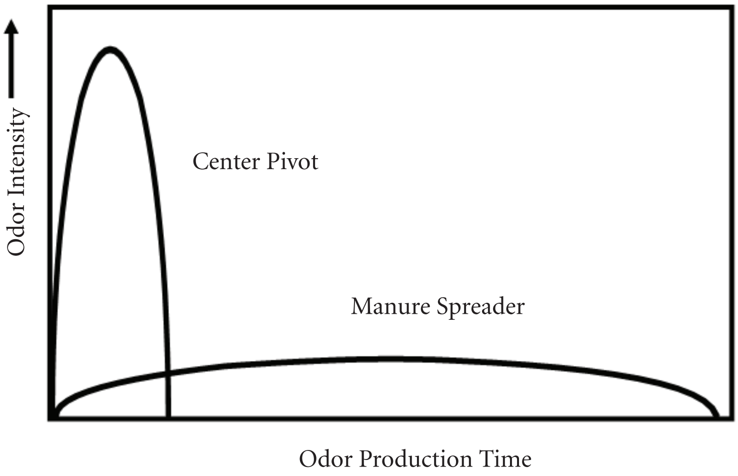

Figure 2. Odor intensity vs. Duration of odor exposure for two manure application systems.

Properly functioning lagoons can often be identified by measurement of electrical conductivity (EC). An EC of less than 6 mmho/cm is generally necessary for purple sulfur bacteria to thrive and produce a low odor purple lagoon. Anaerobic bacteria that convert VOCs to odorless methane and water perform poorly as EC levels exceed 8 to 10 mmho/cm, resulting in lagoon contents that will be more odorous during irrigation.

Effectiveness of anaerobic treatment processes (anaerobic lagoons) to control odor is also affected by management factors that affect the biological processes. Thus, management of a facility is a critical factor in defining the potential odor emissions during land application. For example, center pivot distribution from an anaerobic lagoon in July will produce much less odor than in March because of the increased biological treatment that occurs during the warmer summer months. Design and management recommendations for reducing the odor associated with the manure storage will be discussed later. Minimizing manure storage odor is the first step in reducing odor associated with center pivot application.

From strictly an air quality perspective, there is little question that center pivot distribution systems offer a large potential for odor release during a short time period. These systems deliver a large volume of manure to the field in a short time and provide substantial opportunity for releasing odor-producing compounds directly into the air (more intense but shorter period of time for odor exposure). In contrast, surface application with a tanker or a spreader will release significant odors. However, because of this equipment's inability to deliver product rapidly, some level of odor will be produced over a longer period of time (see *Figure 2*). The significance of the intensity and duration of odors often depends on the location of the field site and the ability to minimize application when the wind direction would carry odors in an undesirable direction.

Minimizing Pivot Application Odors

Manure storage and center pivot design considerations for minimizing odor production and release by the pivot include:

- *Anaerobic lagoons with a large permanent pool.* Total lagoon storage capacity should be adequate to maintain up to 50 percent of the manure storage needs in a permanent pool. This level of permanent pool will assure a stable bacteria population for processing odor-producing compounds and satisfactory dilution of new manure additions.
- *Use low pressure drop nozzles (if nozzle plugging can be minimized).* Distribution of the lagoon water close to the soil surface will reduce the potential for transport of the lagoon water off the application area by wind. Use of low-pressure nozzles on drop tubes will also reduce the intensity of odor production when compared with high-pressure impact sprinklers mounted on top of the pivot pipeline. However, selection of low-pressure nozzles on drops must assure that no runoff occurs. This topic is discussed in more detail later.
- *Earthen basins, formed storages, and undersized lagoons* are less acceptable for pivot irrigation. Since these types of storage facilities typically do not support appropriate bacterial populations, the intensity of odor production can be much greater than for properly sized anaerobic lagoons. Consequently, since these storage facilities also do not

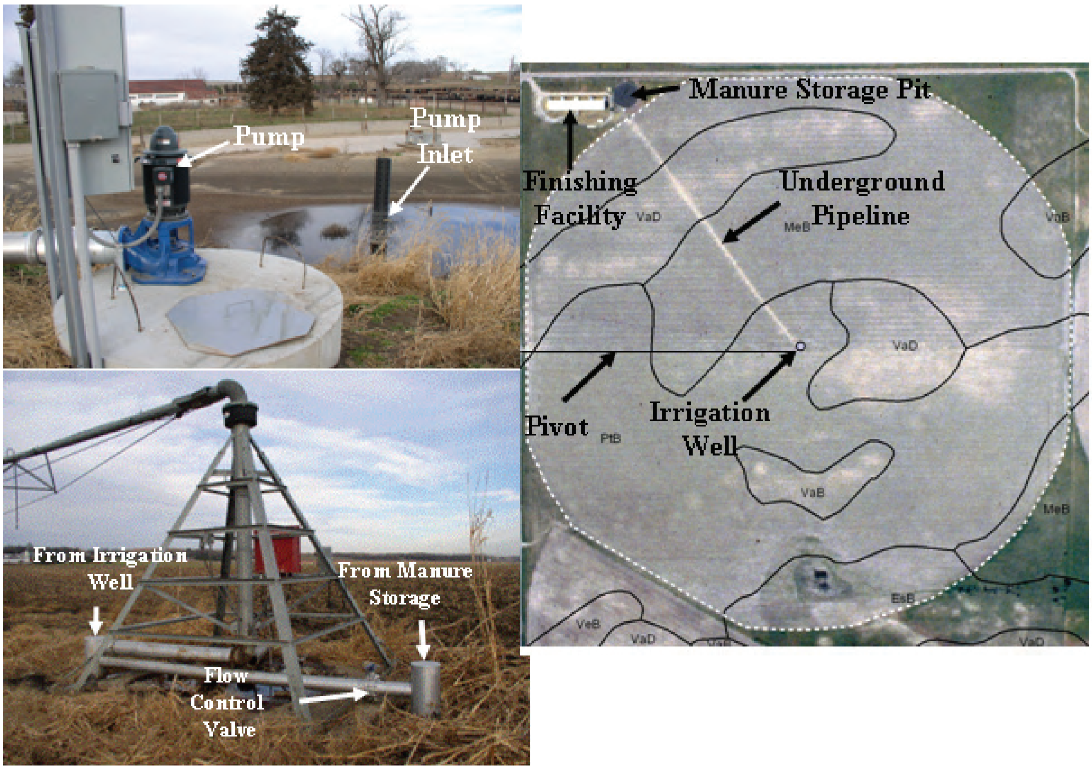

Figure 3. Inset upper left shows a pump installation. Inset to lower left shows a connection at the pivot point. Far right image shows an aerial view of a swine growing/finishing facility with manure storage pit and buried PVC pipeline to a center pivot used for application of a manure fresh water mixture.

contain very large volumes of water, use of ground applicators should be considered especially when the distribution site is close to neighbors.

- *Dilute liquid manure with fresh water (four to five parts fresh water to one part liquid manure).* Dilution to this level will assure that the application does not result in direct or indirect crop damage and will reduce the intensity of odors produced during lagoon water application. To accomplish this goal, the center pivot will need to be plumbed so that both fresh water and lagoon water can be applied simultaneously. An example of this arrangement is presented in *Figure 3.*

Manure storage management considerations for minimizing odor production and release during application using a center pivot include:

- *Apply liquid manures during periods when biological processes are most active.* June through fall application of anaerobic lagoon effluent has the least odor. Winter and spring applications will produce the greatest odors due to limited biological activity to stabilize odor-producing chemicals.

- *Establish purple sulfur-fixating bacteria by maintaining a sufficient permanent pool.* Three of the criterion for maintaining a purple lagoon are to: 1) Annually pump a portion of the lagoon storage volume off the lagoon surface to prevent salt buildup (higher EC) due to water evaporation from the lagoon surface; 2) Leave approximately half of the lagoon water in storage to provide a continual source of purple bacteria; and 3) Do not agitate the lagoon.

- *Annually test liquid manure electrical conductivity (EC) and ammonia (NH_3) levels.* Regular chemical analysis of the lagoon water will clearly identify chemical buildups that could be toxic to desirable anaerobic bacteria. EC levels can be tested more regularly using inexpensive handheld meters available from laboratory supply stores. An EC reading greater than 10 mmho/cm and an NH_3 concentration greater than 670 ppm (150 lbs. NH_3/acre-inch) are indications of a poorly functioning lagoon.

- *Increase fresh water addition.* When high evaporation or low rainfall increase EC levels above 10 mmhos/cm, increase the volume of water used for flushing manure from the barn, cleaning, pit recharging, or other facility maintenance activities. Retest the liquid regularly to assure that the proper dilution is reached and maintained.
- *Stop adding manure to the lagoon for two weeks* prior to pumping effluent to allow bacteria to process odorous compounds.

Management practices specific to the center pivot that can reduce odor production during application include:

- *Irrigate during late morning and early afternoon hours* since odors disperse more quickly when air temperature and winds are rising.
- *Monitor wind direction* and stop the application when the wind direction can impact neighbors. One way to monitor wind direction is to install a wind vane or windsock at the storage facility. Historical prevailing wind information can be found for 28 Nebraska sites at *http://manure.unl.edu/wind/wind.html*. Real-time wind direction can be obtained from local weather forecasts or from the Internet.
- *Monitor wind speed*. Shut down pivot when wind is likely to remain calm. Wind is necessary to mix odors with fresh air to decrease the overall odor level. The best option is to purchase and use a handheld wind speed detector. Several Internet sites such as the Weather Channel (*http://www.weather.com*) can be used to obtain real-time local humidity, wind, and air temperature conditions and forecasts.

Water Quality

When water quality issues are considered, application of lagoon water via a center pivot has the least potential environmental impact if the system is properly designed and operated. Key advantages of a center pivot from a water quality point-of-view are:

- The ability to apply nutrients more uniformly than spreaders or tankers. Uniform applications allow producers to be confident in the nutrient application rate.
- Application can occur during the growing season when soil water deficits are likely and high crop uptake limit losses due to surface runoff and leaching.

One of the advantages of using center pivots to apply liquid animal manures — the ability to apply a large volume of material in a short amount of time — also can be a disadvantage. The biggest concern associated with center pivot application of liquid animal manure is the ability to over-apply liquid and/or nutrients. Though most center pivots are capable of applying water at rates similar to land applicators (0.2-0.3 inches per acre), the temptation to use the system to supplement rainfall with liquid animal manure could result in over-application of manure. One of the goals of a Comprehensive Nutrient Management Plan (CNMP) is to determine the appropriate application rate. The Nebraska Livestock Waste Permit system requires documentation of nutrients applied and how soil chemical properties change over time. To avoid over-application, a nutrient analysis must be completed for the liquid manure being applied and application rates must be adjusted to not exceed crop nutrient requirements.

The timing of center pivot application, similar to any other method of manure application, influences the risk to ground and surface water quality. Applications in the early spring and late fall can result in surface runoff and leaching of nitrates due to rainfall on wet soils. Multiple applications during the late spring and summer months limit opportunities for surface runoff and leaching when applications are based on scientific irrigation scheduling procedures.

Finally, application of manure through a center pivot provides the potential for contaminating fresh water resources that may be located within the application area. Some field sites include small surface water catchments or streams that should not receive manure application. To guard against contamination of surface waters, the CNMP process includes requirements for setbacks and manure application restrictions. Some of these may control the use of center pivots near surface water and other environmentally sensitive areas.

Soil Conservation and Quality

Ground application methods can have a negative impact on soil quality due to soil compaction and destruction of crop residue leading to greater erosion potential. Center pivot irrigation has little negative impact on soil physical properties.

Application of manure slurry can have a positive impact on soil quality including increased organic matter content and reduced runoff potential. Field research at the Haskell Agricultural Laboratory has documented an increase in organic matter due to improved biological activity in the soil resulting from the carbon and nutrients contained in liquid swine manure. However, the low solids content of most irrigation-applied lagoon water is likely to result in only modest increases in soil organic content or runoff reduction when applied at agronomic rates.

In drier regions of the state, repeated application of liquid manures with high salt content can lead to salt buildup in the soil profile if the combination of precipitation and irrigation is not sufficient to leach the salts from the crop root zone. Salt contained in liquid animal manure can also be a problem if the soil profile contains an impermeable layer. In this case, the water that normally moves salt through the profile is held above the impermeable layer and can result in a salt buildup if plants remove the water leaving the salt behind. High soil salt content can result in loss of soil structure, increase plant water stress, and change plant ecosystems. In areas with limited precipitation and irrigation, chemical analysis results should be compared with information indicating when salt content is too great.

It is recommended that baseline soil samples be collected and analyzed to determine the Sodium Adsorption Ratio (SAR), Electrical Conductivity (EC), and Base Saturation level to get the exchangeable sodium percentage. If these values change over time, adjustments in application can be made before there are negative impacts to soil, soil drainage rates, and plant stress.

Pathogen Transmissions to Animals and Humans

The risk to grazing animals for *E. coli* O157:H7 transmission following effluent irrigation of forages appears to be modest according to Dr. Dale Hancock, Epidemiologist, College of Veterinary Medicine, Washington State University. He further judges the risk for salmonella transmission to be greater, but not well defined. Grazing animals are likely to experience exposures to these same pathogens through other pathways and from other sources. Though the risk of transmission to grazing animals is low, following effluent application with a fresh water application can minimize the risk. If possible, apply manure at the beginning of the pasture rest time to assure that any pathogens will be washed from vegetative surfaces.

Effluent applications to harvested forages and grains pose a greater risk. Pathogens can live for extended periods in and on grains and forage. Significant increases in some pathogen populations are possible during storage. However, the biological process associated with silage and high moisture corn storage fermentation appears to inhibit pathogen survival. For any animal feed that is to be harvested, manure or effluent should not be applied within one month of harvesting. Application of animal manure to crops grown for direct human consumption must be avoided due to potential health issues.

Phytotoxic Effects to Plants

Concentrated manures contain salt and ammonia at levels that can damage plants if applied directly to plant leaves. Research conducted at the Haskell Agricultural Laboratory indicated that manure electrical conductivity (EC) levels greater than 6 mmho/cm could damage corn and soybeans if applied before the 8-leaf stage in corn or the V3 stage in soybeans. When EC levels were greater than 12 mmho/cm, some plant mortality and stunting was documented when liquid swine manure was applied regardless of the timing of application. EC levels less than 6 mmho/cm were safe when applied any time of the growing season. *Table 1* presents a summary of data collected following liquid swine manure to corn and soybeans during the 2002-growing season. Similar results have been reported by producers following application of concentrated liquid swine manure to alfalfa and pasture.

Table 1. Effect of liquid swine manure EC level and application timing on corn and soybean yields at the Haskell Agricultural Laboratory. (ns=statistically not significant, and s=statistically different yields between treatments)

	Manure EC Level mmho/cm			
	0.6	*6.4*	*11.7*	*20.3*
Corn Growth Stage				
8-leaf	175	181	154	149
14-leaf	163	186	179	185
Significance Level	*ns*	*ns*	*s*	*s*
Soybean Growth Stage				
3-trifoliate (V3)	46	41	42	5
Beginning Flowering (R1)	44	43	39	24
Significance Level	*ns*	*ns*	*ns*	*s*

Rules and Regulations

The storage and distribution of animal manure is governed by rules developed by the Nebraska Department of Environmental Quality based on enabling legislation passed by the Nebraska Unicameral and signed by the governor. The rules are presented as Title 130 Livestock Waste Control Regulations that describe requirements for small, medium, and large production facilities (see details at *http://www.deq.state.*

ne.us/). Included in Title 130 is a permitting system that defines what manure management systems are required and provides a means of documenting the manure storage, handling and distribution practices that will be followed by the facility.

Setback Requirements

The most recent revision of Title 130, Chapter 9 includes setback requirements to protect surface and groundwater supplies. Section 005 of Title 130 states that

"005. For large concentrated animal feeding operations, manure, litter, and process wastewater may not be stockpiled or applied closer than 100 feet to any down-gradient surface waters, open tile line intake structures, well heads, or other conduits to surface or ground water, except that one of the following two compliance alternatives may be substituted for the application setback requirement:

> **005.01** A 35 foot wide vegetated buffer where the application of manure, litter, or process wastewater is prohibited. For the purposes of these regulations vegetated buffer means a permanent strip of dense perennial vegetation established parallel to the contours of and perpendicular to the dominant slope of the field for the purposes of slowing water runoff, enhancing water infiltration, and minimizing the risk of any potential nutrients or pollutants from leaving the field and reaching surface waters; or

005.02 A satisfactory demonstration that a setback or buffer is not necessary because implementation of alternative conservation practices will provide pollutant reductions equal to or better than reductions that would be achieved by the 100 foot setback.

006 For small and medium concentrated animal feeding operations and animal feeding operations not required to seek permit coverage, manure, litter, and process wastewater may not be stockpiled or applied closer than 30 feet of any streams, lakes and impounded waters identified in Chapter 6 and Chapter 7 of Title 117 (Nebraska Administrative Code) – Nebraska Surface Water Quality Standards, unless in accordance with a Department approved nutrient management plan. "

A key interpretation of the rule by the Nebraska Department of Environmental Quality is that if land for a distance of 100 feet down-gradient around the wellhead drains away from the well, the well is not down-gradient and thus the 100 foot setback requirement is not applicable. If the land does not drain away from the wellhead for 100 feet, there are two ways to meet setback requirements: 1) sprinklers on a portion of the center pivot can be shut off when manure is being applied; or 2) if the well is located within the irrigated area but away from the center point, manure application could be discontinued when the center pivot crosses over the well location.

Determining Manure Application Rates

The nutrient management planning approach requires farmers to account for all nutrient sources available from soil, water, commercial fertilizer and manure and balance them with the best estimate of crop needs. Proper application rates depend upon manure chemical analysis, expected crop yield, field slope and drainage, application method, and water resource vulnerability. New rules require animal production facility permits to conduct a phosphorus risk assessment before manure application based upon topography and proximity to surface water. This method helps minimize soil phosphorus (P) movement to sensitive waters that can help reduce the development of algal blooms in surface water. For some crops, however, using P-based manure application rates may require commercial fertilizer application to fully meet crop nitrogen requirements.

Application Rates

Soil testing is essential to accurately determine application rates and to evaluate the impact of manure application on soil chemical levels. The key to determine the appropriate application rates is using proper soil sampling methods. For phosphorus, surface samples (0-8 inches) should contain 12 to 20 individual soil cores. Samples for nitrate analysis should be taken from a minimum soil depth of 2 feet. Fields should be subdivided into sampling units based on soil, topography, crop, yield, and fertilizer histories so that each sample represents an area of no more than 40 acres.

Liquid Manure Testing

Chemical analysis of a representative sample is the foundation of an economic and environmentally sound liquid manure distribution plan. The best scenario is to ascertain the nutrient content of the liquid manure prior to application. Proper sampling of liquid manure requires acquiring samples from several locations (at least 4) of the storage facility. Surface samples are adequate if the liquid will not be agitated prior to application. Detailed discussion of liquid manure sample collection is presented in NebGuide G1450 *Sampling Manures for Nutrient Analysis*.

Keep the sample refrigerated, tightly sealed in a plastic container, and deliver it to the laboratory within 24 hours. Compare manure analysis results with tabular values available from the Comprehensive Nutrient

Management Planning Web site (*http://cnmp.unl.edu/landapplicationworkbook.html*).

Example: Effluent Application Rate: *Determine the manure application rate assuming that the expected yield for irrigated corn is 200 bu/acre (EY = 200 bu/ac), organic matter = 2 percent, average soil nitrate of 5 ppm NO_3-N, irrigation water NO_3-N concentration of 10 ppm and the normal annual irrigation application =10 inches. Chemical analysis of the liquid manure showed an NH_4-N content of 88 lbs N/ac-in and organic N at 30 lbs N/ac-in.*

Based on the University of Nebraska algorithm, nitrogen need should be calculated using the following equation:

$$Lb\text{-}N/ac = 35 + (1.2 \times EY) - (8 \times NO_3\text{-}N_s) - (0.14 \times EY \times OM) - (0.228 * NO_3\text{-}N_w * IRR)$$

Where:

Where:	EY	=	expected yield, bu/ac
	NO_3-N_s	=	average soil nitrate concentration, ppm
	OM	=	average soil organic matter content, %
	NO_3-N_w	=	average nitrate concentration in irrigation water, ppm
	IRR	=	seasonal irrigation depth applied x 0.75, inches.

For this example:

- 275 lb N/acre needed for 200 bu/acre corn *200 (bu/acre)x1.2(lb/bu) +35)*

Entering values into the equation:

- *275 (lb N/acre) - (8 x 5 ppm) - (0.14 x 200 x 2) – (0.228 x 10 x 7.5)*
- 162 lb N/acre needed from lagoon water
- Lagoon water N = Ammonoia N + Organic N
- Lagoon water N = (88 lbs N/ac-in x 0.50) + (30 lbs N/ac-in x 0.35)**
- Lagoon water N = (44 + 10.5) lbs N/ac-in
- Lagoon water N = 54.5 lbs N/ac-in
- Lagoon water application = 162 lb N/ac/54.5 lb N/ac-in
- Lagoon water application = 3.0 ac-in
- (162 (lb N/acre) / 54 (lb N/acre-inch as NH_4-N)
- **3.0 inches of lagoon water should be applied.**

**The University of Nebraska–Lincoln recommendations also ensure that 35% of the organic N is available during the first year after application.

Depending on the weather conditions and the sprinkler package used on the center pivot, 30-70 percent of the ammonia can volatilize during and immediately after application. University of Nebraska recommendations assume that 50 percent of the lagoon water N volatilizes and is not available for plant use. This application should be distributed in three or more application events timed to supply N to match crop uptake.

Nitrogen concentrations vary greatly depending on the type of manure in storage and the type of storage facility. For example, analysis conducted at several demonstration sites in Nebraska indicates that ammonia concentrations equivalent to over 250 lbs N per acre-inch are common in swine lagoons. Holding ponds designed as runoff catchments for outdoor feedlots typically contain concentrations of ammonia of 50-60 lbs N per acre-inch, since most of the ammonia volatilizes off the feedlot area. The key is to collect a representative sample and have it analyzed to accurately determine how much N is in the liquid manure.

Application Equipment

Factors affecting the equipment needed to distribute liquid animal manures are the location of the storage site relative to the application site, the amount of liquid to be pumped, whether the manure will be pumped directly into the center pivot or mixed with fresh water, and the type and makeup of the manure. Some swine lagoon systems forgo application of solids until the storage capacity becomes limited. Likewise, most beef feedlot operators pump just the liquid from their runoff storage facilities postponing the distribution of solids. Dairy facilities typically distribute all of the manure on an annual basis. Different types of liquid manure and concentration of solids in the liquid will require different equipment and management practices.

Backflow protection – Chapter 10 of Title 130 Livestock Waste Control Regulations provide safety equipment requirements necessary when applying liquid animal manure through an onfarm irrigation system. Title 130 requires inclusion of an irrigation pipeline check valve assembly consisting of an irrigation pipeline check valve, vacuum relief valve, inspection port and low-pressure drain. The assembly must be located in the pipeline between the irrigation pump and the point of liquid manure injection into the irrigation pipeline. The Rules and Regulations relevant to application of liquid manure through an irrigation system are equivalent to those expressed in Title 195 — Rules and Regulations Pertaining to Chemigation.

Pump — Centrifugal pumps designed to pump liquids having high solid contents are preferred. Design pump speed should be below 2000 rpm to prevent solids separation inside the pump bowl assembly. *Table 2* presents selection criteria for different types of pumps that could be used to pump liquid manure. When pumping

Figure 4. Floating pump installation for pumping lagoon water to a center pivot.

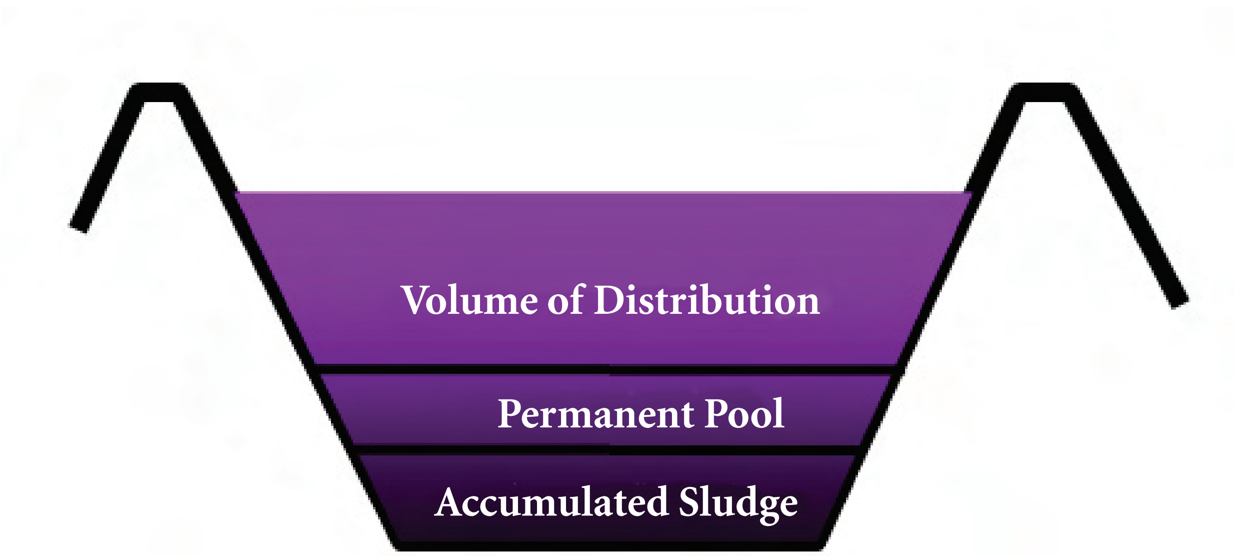

Figure 5. Stratification and design allocation of storage capacity in an anaerobic lagoon.

from large lagoons, it is beneficial to locate the pump inlet away from the sidewalls of the lagoon. This allows the pump to remove liquid closer to the bottom of the lagoon. *Figure 4* shows a floating pump that can be anchored in the lagoon.

Pump inlet — In anaerobic lagoons, most of the solids settle to the bottom of the lagoon to form the sludge layer. An important criterion of the treatment pool (volume for distribution) is sufficient dilution to allow anaerobic bacteria to thrive. Thus, most of the treatment pool typically has solids content less than 1percent *(Figure 5)*. When pumping from a nonagitated lagoon, it is best to position the pump inlet pipe approximately 1.5 to 3 feet below the water surface. If the sludge has accumulated so that it extends into the treatment pool, it is time to remove some of the sludge. The sludge layer has significant solids suspended in the water and will require a pump and distribution system that can handle solids contents in the 3 to 7 percent range.

Table 2. Manure handling pumps.

Pump type	*Maximum solids content %*	*Agitation ability*	*Agitation range ft.*	*Pumping rate gpm*	*Pumping head ft. of water*	*Power requirements hp*	*Applications*
Centrifugal Open & semi-open impeller Vertical shaft chopper	10-12	Excellent	50-75	1,000-3,000	25-75	65+	Gravity irrigation Tanker filling Pit agitation Transfer to storage
Inclined shaft chopper	10-12	Excellent	75-100	3,000-5,000	30-35	60+	Earth storage agitation Gravity irrigation Tanker filling
Submersible transfer pump	10-12	Fair	25-50	200-1,000	10-30	3-10	Agitation Transfer to storage
Closed impeller	4-6	Fair	50-75	500+	200+	50+	Recirculation Sprinkler irrigation
Elevator	6-8	None	0	500-1,000	10-15	5+	Transfer to storage
Helical screw	4-6	Fair	30-40	200-300	200+	40+	Agitation Sprinkler irrigation Transfer to storage Lagoon pumping Tanker filling
Piston Hollow	18-20	None	0	100-150	30-40	5-10	Transfer cattle manure without long fibrous bedding
Solid	18-20	None	0	100-150	30-40	5-10	Transfer cattle manure with unchopped bedding
Pneumatic	12-15	None	0	100-150	30-40	—	Transfer to storage
Self loading tanker Centrifugal, open impeller	6-8	None	0	200-300	N/A	75+	Tanker loading
Vacuum pump	8-10	Poor	20-25	200-300	N/A	50+	Tanker loading

Source: MWPS-18 Livestock Waste Facilities Handbook

Inlet screening — If the storage facility is uncovered, various types of debris will be deposited in the lagoon by wind (plastic, corn leaves, etc.). Other debris enters the lagoon directly from the production facility. Though most of the debris poses few problems for pumps, larger debris should be screened out prior to entering the pump inlet. Large debris can be excluded using a coarse screen with half-inch or smaller perforations. Centrifugal pumps typically have screens included with the foot-valve used to maintain prime.

Low-pressure shutoff — To prevent the system from running dry, a low pressure or flow sensing shutoff switch should be wired into the pivot system. The shutoff should be activated based on the pressure in the pipeline leading from the manure pump to the irrigation system. The low-pressure shutoff switch should be protected using a diaphragm or a diffuser fitting to prevent the switch from being plugged with small solids contained in liquid manure. The goal should be to shut both the manure pump and the irrigation system down should the manure pump fail or reach the bottom of the storage facility.

To achieve this goal there are two options: 1) place a low pressure switch on the manure pump outlet to shut it down and run a wire to the pivot to also cause the pivot to shut down; and, 2) place low pressure shutoffs at the manure pump and where the pipeline enters the fresh water that will shut down both systems inde-

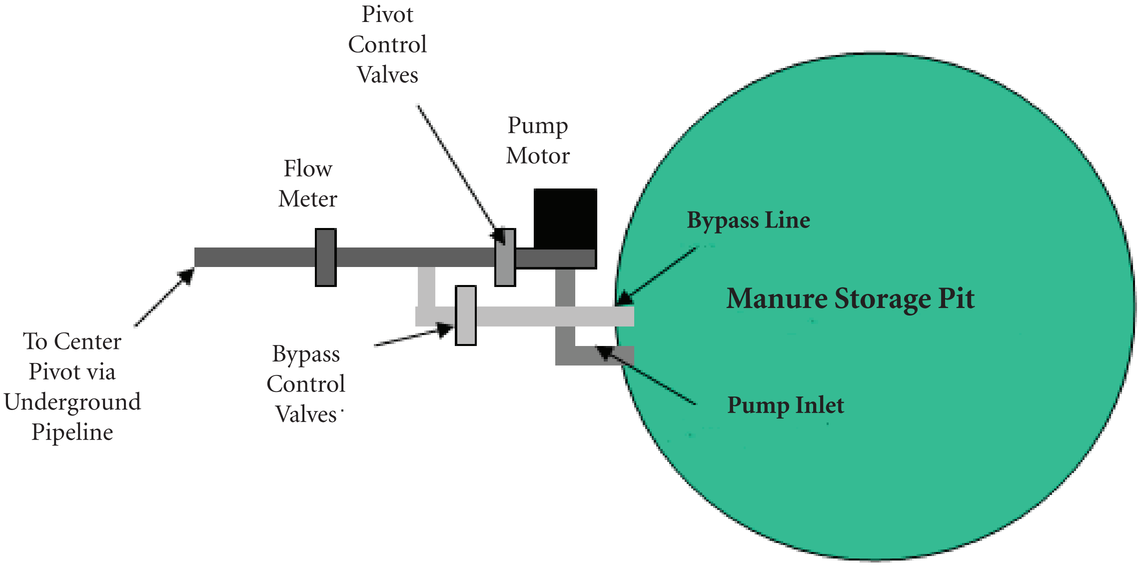

Figure 6. Schematic of a liquid manure pumping installation showing a flow meter, dual flow control valves and the bypass line to direct flow back into the storage facility if necessary.

pendently. Since the manure will contain solids, design should also include a valve at the pivot point to prevent flow from the lagoon into the pivot and also prevent fresh water flow toward the manure storage facility when only fresh water is being applied.

Flow rate regulator — A control valve with flow meter should be installed to allow the flow rate to be monitored and regulated during the application event. The meter and control valve should be placed at the manure pump outlet so that the rate can be adjusted if necessary.

Delivery pipelines — Pipelines should be made of materials resistant to oxidation. The most preferred pipeline material is glued poly-vinyl chloride (PVC). PVC resists chemical degradation due to acids or salty water common to animal production facilities. The delivery pipelines should be installed underground and below the frost line to prevent frost damage. In addition, and particularly if aluminum pipeline is used, the delivery line should be plumbed to allow the liquid manure to be flushed from the pipeline back into the source. Flushing is necessary to prevent the ammonia content in the lagoon water from oxidizing the aluminum pipeline that could result in pipeline leaks. This design option will require a pair of valves at the pump: one to control the flow rate to the center pivot, and a second valve to direct flush water to bypass the pump into the lagoon *(Figure 6)*.

Sprinkler packages — The flow rate distributed by a sprinkler is controlled by the diameter of the nozzle and the operating pressure supplied to the base of the sprinkler. To prevent the nozzles from plugging, it is desirable to have relatively large nozzle openings with medium to high pressures. However, to attain high fresh water application efficiency, it is desirable to have small sprinklers distributing water closer to the soil surface at low pressure. Center pivots equipped with a large number of narrowly spaced sprinkler heads will have small nozzles when compared with center pivots with a few widely spaced sprinklers. Consequently, low to medium pressure impact sprinklers are less prone to plugging than low pressure spray nozzles because the sprinkler spacing is wider and thus the nozzle opening is larger. To reduce the need for dual sprinkler packages, a compromise is often struck between the goal of low susceptibility to plugging and high water application uniformity and efficiency.

When dairy manure is being distributed, large volume guns are usually placed on the center pivot and sequenced on and off to maintain a relatively constant flow rate and pressure entering the system. This is done because of the high solids content of the liquid manure. Sequencing the sprinklers on and off is necessary to equalize the depth of liquid manure applied along the length of the center pivot.

When pumping lagoon water with solid content less than 1 percent, low-pressure sprinklers can generally be used. The nozzle structure should have an open cage with few restrictions that could catch solids. Solids are more likely to get caught on stationary pads with coarse grooves than flat or fine grooved pads. Extremely low operating pressures should be avoided because if solids begin to plug a nozzle, the water pressure (energy) will be insufficient to force solids from the nozzle opening.

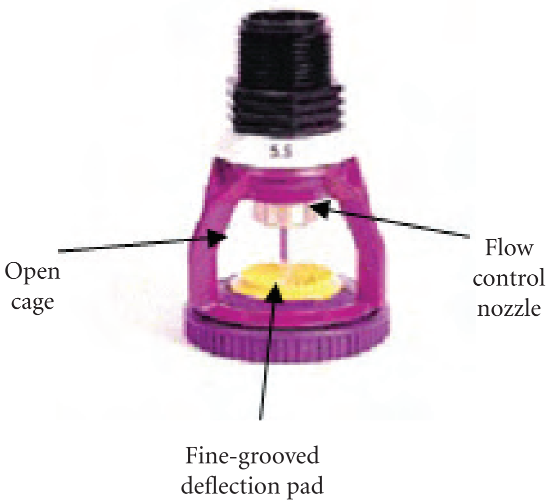

Figure 7. Picture of low pressure spray nozzle with an open cage and fine-grooved deflection pad to prevent solids buildup on the pad, and a flow control nozzle to maintain appropriate pressure in rolling terrain.

Animal hair and grain hulls are prime examples of solids that could easily get caught on sprinklers.

Some production facilities reuse flush water by pumping from the lagoon back into the building. The salt concentration in the lagoon water is increased by this process and can impact the function of the sprinkler heads. Salt-saturated solutions result in crystallization of salt on the sprinkler head. In some instances, the coating on the sprinkler has become thick enough to affect the impact arm operation on medium and high-pressure sprinklers. Low-pressure spray heads with grooved pads can experience buildup on the pad causing water distribution to be less uniform. Though the exact salt concentration that could cause this problem is linked to the nozzle type and operating pressure, electrical conductivity levels below 12 mmhos/cm are typically not a problem.

One issue that commonly occurs when distributing liquid manure through center pivots is that most large solids remain in the pivot lateral. The one thing center pivots have in their favor is that most of the liquid exits the pivot pipeline close to the end of the system rather than near the pivot point. To keep solids in suspension, it is important to maintain the pipeline flow velocity above 4 feet per second for as long as possible. At about 800 feet from the pivot point, the liquid flow velocity typically drops below 4 feet per second in 1300-foot center pivots with 800 gpm flow rates and 6.675-inch diameter pipes.

To prevent solids from building up at the end of the pipeline and to maintain a greater average flow velocity, center pivot design should include sprinklers with relatively large flow rates located at the end of the pipeline. In addition, solids can be directed out of the pipeline through smaller sprinklers by keeping the solids in suspension. Placing a relatively large nozzle or two near the end of the pivot lateral ensures that a significant amount of liquid is discharged near the end of the pipeline. At least one of these sprinklers should run full time to provide an exit point for solids that remain in the pipeline. One way to accomplish this is to install part circle sprinklers for use along field boundaries and a large volume gun for field corners.

Pressure control — Spring-operated pressure regulators should be avoided when pumping animal manure. Solids such as animal hair, bugs, feed-grain hulls and pieces of plant leaves will become trapped in the regulator inlet rendering it nonfunctional and eventually the regulator and sprinkler will become plugged. If the center pivot is installed on rolling terrain, flow control nozzles can provide some consistency in flow sprinkler rate while allowing solids to pass on through.

Corner systems and some end guns are controlled using hydraulically activated valves made for fresh water distribution. Liquid from the pivot lateral is used to activate the valves that are normally closed. If solids make their way into the valve, the valve may become plugged rendering the valve nonfunctional. To prevent control valve malfunction, install a screen in the delivery line between the lateral pipeline and the hydraulic valve. Small T-type filters can be used for this because small amounts of liquid are used when activating the valves. The filter should remove solids larger than 0.01 inch in size. A small 4-inch long T-type housing with an 80-mesh screen should be sufficient, but will need to be cleaned periodically.

Agitation — In order for production facilities to distribute most of the manure solids on an annual basis, the solids must be kept in suspension when pumping. Agitation is necessary when attempting to distribute both liquid and solid components from an earthen storage facility. Agitation is not recommended when pumping from a purple sulfur-fixating lagoon. Without agitation most solids will remain at the bottom of the storage facility and will be very difficult to pump. Large PTO driven agitators are available to back into a lagoon or pond from the edge *(Figure 8)*. Smaller electric motor driven agitators are designed to extend vertically into a below-ground or above ground pit *(Figure 9)*. Depending on the size of the lagoon or pond, agitators need to be operated for at least 6-10 hours prior to starting to ensure that most solids are in suspension. Larger solids will settle to the bottom within about an hour after agitation ceases, so it is important to continue agitation while

Figure 8. Large liquid manure agitation pump used to keep solids in suspension during application via ground applicator or center pivot.

Figure 9. Agitation pump for liquid manure storage pits or tanks. This style of pump can be powered by electric motor or tractor PTO.

pumping liquid manure from the lagoon or pit storage. A number of manufacturers market agitators for use in manure agitation. Commercial applicators sometimes rent agitators to serve this purpose.

Summary

Nebraska's Title 130 Rules and Regulations outline the design, installation, monitoring, and management of animal waste storage and distribution facilities. Center pivots can provide an excellent means of distributing liquid animal manures. The pumping and distribution system must first be designed to apply liquid manure and fresh water application must be secondary. Systems should be designed to apply the liquid manure as uniformly as possible without producing surface runoff or excess odor. Application rates should be based on soil and manure chemical analysis and crop nutrient requirements. Finally, consider environmental conditions and location of neighbors before applying liquid manure using center pivot irrigation systems.

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