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Environmental Considerations for Manure Application System Selection

Selection and operation of manure application equipment must consider environmental issues along with materials handling and economic factors.

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Land application of livestock manure faces growing scrutiny because of potential surface and groundwater contamination and odor nuisances. Producers must consider features of a manure application system that enhance their ability to use manure's nutrients, and provide ways to minimize nuisances experienced by neighbors during manure application.

Environmental Considerations

Manure spreader as a fertilizer applicator. The fundamental principle underlying both best management practices and future regulatory requirements for manure application will be efficient crop use of applied nutrients. Manure spreaders will need to be managed as any other fertilizer or chemical applicator. Spreaders will need to provide a uniform application of manure, a consistent application rate between loads, and a simple means of calibration. Appropriate equipment selection (see *Table I*) and careful operator management will contribute to efficient use of nutrients.

Timeliness of manure nutrient applications. The ability to move large quantities of manure during short time periods is critical. Limited times of opportunity exist to apply manure to meet crop nutrient needs and minimize nutrient loss. Investments and planning decisions that enhance the farm's capacity to move manure or that store manure in closer proximity to the fields on which it is be applied will enable improved timing of manure applications.

Conservation of nitrogen. The availability of nitrogen and phosphorus in manure as applied is usually out of balance with crop needs. Typically, high soil phosphorus levels result from manure application. The ammonium fraction, originally representing roughly half the potentially available nitrogen, is lost by long-term open lot manure storage, anaerobic lagoons, and surface spreading. Systems that conserve ammonium nitrogen and provide nutrients more in balance with crop needs increase manure's economic value.

Odor nuisances. Odor nuisances are the primary driving factor of more restrictive local zoning laws for agriculture. Better management of manure nutrients through increased reliance on manure storage and land application of manure in brief time periods add to odor nuisances. Manure application systems that minimize odor deserve consideration.

Soil compaction. Manure spreaders are heavy. The manure alone in a 3,000 gallon liquid manure tank weighs more than 12 tons. Manure often is applied in late fall and early spring when soil moisture levels and compaction potential are higher. Impact of manure application on potential soil compaction deserves consideration.

Table I. Environmental comparison of various manure application systems.

	Uniformity of Application	**Conservation of Ammonium**	**Odor**	**Compaction**	**Timeliness of Manure Application**
Solid Systems					
Box spreader: tractor pulled	fair	very poor	fair	fair	poor
Box spreader: truck mounted	fair	very poor	fair	fair	fair
Flail spreader	fair	very poor	fair	fair	poor
Dump truck	very poor	very poor	fair	poor	fair
Liquid Systems: Surface Spread					
Liquid tanker with splash plate	poor	poor	poor	poor	fair
Liquid tanker with drop hoses	fair	fair	good	poor	fair
Big gun irrigation system	poor	poor	very poor	excellent	excellent
Center pivot irrigation system	fair	poor	very poor	excellent	excellent
Liquid Systems: Incorporation					
Tanker with knife injectors	good	excellent	excellent	poor	fair
Tanker with shallow incorporation	good	excellent	excellent	poor	fair
Drag hose with shallow incorporation	good	excellent	excellent	good	good

Solid Manure Application Systems

Manure of 20 percent solids or more is typically handled by box and flail-type spreaders. Box type spreaders range in size from under three ton (100 cubic feet) to 20 ton (725 cubic feet). Box spreaders provide either a feed apron or a moving gate for delivering manure to the rear of the spreader. A spreader mechanism at the rear of the spreader (paddles, flails or augers) distributes the manure. Both truck-mounted and tractor-towed spreaders are common.

Flail type spreaders provide an alternative for handling drier manure. They have a partially open top tank with flails for throwing manure out the side of the spreader. Flail units have the capability of handling a wider range of manure moisture levels ranging from dry to thick slurries.

With the growing concern about manure contamination of water and air resources, both box and flail spreaders must be capable of performing as fertilizer spreaders. Typically such equipment has been designed as disposal equipment with limited ability to calibrate application rates or maintain uniform and consistent application rates. Several considerations specific to solids application equipment follow:

- The operator must control application rate. Feed aprons or moving push gates, hydraulically driven or PTO powered, affect the rate of application. Does the equipment allow the operator to adjust rate of application and return to the same setting with succeeding loads?
- Uniformity of manure application is critical for fertilizer applicators. Variations in application rate both perpendicular and parallel to the direction of travel are common. Uniformity can be checked by laying out several equally sized plastic sheets and weighing the manure falling on each sheet *(Figure 1)*. A 50 percent variation in net manure weights represents a similar variation in crop-available nutrients.
- Transport speed and box or tank capacity affect timely delivery of manure. Often 50 percent or more of the time hauling manure is for transit between the feedlot or animal housing and field. Truck-mounted spreaders can provide substantial time savings over tractor-pulled units for medium and long distance hauls. Increased box or tank capacities speed delivery.
- Ammonia losses are substantial for solid manure application that is not incorporated. Most of the ammonia nitrogen, representing between 20 and 65 percent of the total available nitrogen in manure, will be lost if not incorporated within a few days.

Figure 1. Strategic location of several equally sized plastic sheets can provide an indication of uniformity of application of solid wastes.

Liquid Manure Application System Options

Tank wagons traditionally are used to surface apply liquid or slurry manure. This has allowed disposal of manure at a relatively low financial cost, but has included some hidden costs including soil compaction, loss of ammonium nitrogen and odor. Alternative delivery systems that speed manure movement, unique options for incorporating manure, and systems that minimize mixing manure and air will enhance liquid application of manure.

Remote Manure Storages

Remote manure storage is an integral part of many unique delivery systems. Locating manure storage near fields to receive manure as opposed to near animal housing has several potential advantages. Manure is transported by pump or tanker to a remote storage throughout the year, minimizing labor for moving manure during field application. Remote sites may provide location options where odor or visual nuisances are less of a concern or soil permeability is such that storage construction costs can be reduced.

Moving Liquid Manure

Commercial application of weigh cells to manure tank wagons provides equipment operators with information on weight of manure applied. Weigh cells enhance operators' ability to accurately estimate application rates and more accurately predict nutrients available from manure application.

The standard 2,000 to 4,000 gallon tractor-pulled tanker cannot move manure fast enough for some livestock operations. In some regions, over-the-road tankers are being employed to shuttle manure from the manure storage to the edge of the field. Manure is then transferred to separate liquid application equipment or remote storage. Often, used semi-tractor milk- or fuel- tankers with capacities of 6,000 gallons or more are purchased for shuttle duty. Prior to doing this, producers should check truck licensing and inspection requirements and carrying capacity of local bridges.

Pumping liquid manure from the manure storage to the field is becoming increasingly common. Manure of up to 8 percent solids is being pumped several miles to a remote storage or field application equipment. Pipe friction is the primary limiting factor. Manure at solids content below 4 percent can be treated as water in estimating friction losses. An additional allowance for friction loss is required for pumping manure with above 4 percent. Manure handling systems that involve addition of significant dilution water or liquid-solids separation equipment provides a slurry most appropriate for this application.

To pump manure above 4 percent solids longer distances requires heavy duty equipment. Aggressive chopper units often are installed just prior to the pump when solids separation equipment is not used. Industrial slurry pumps are selected to overcome pipe friction losses and avoid potential wear problems. Buried PVC piping with higher pressure ratings (e.g. 160 psi) generally is selected. Because manure leaks are far more hazardous than water leaks, carefully assemble and test joints. Give special care to crossing streams and public roads. If public roads are crossed, appropriate local governments maintaining these roads should be approached early in the planning process.

Flexible Hose Systems

Flexible hose delivery systems tied to a field implement or injector unit pulled by a tractor provide an alternative method for moving liquid manure quickly *(Figure 2)*. A common approach begins with a high volume, medium pressure pump located at the liquid manure reservoir. Manure is delivered to the edge of the field (at the field's mid-point) by standard 6 or 8 inch irrigation line. At this point, a connection is made to a 660 foot long, 4 inch diameter soft irrigation hose. Often two lengths of hose are used. Manure is delivered to a tractor with toolbar-mounted injectors or splash plates immediately in front of a tillage implement.

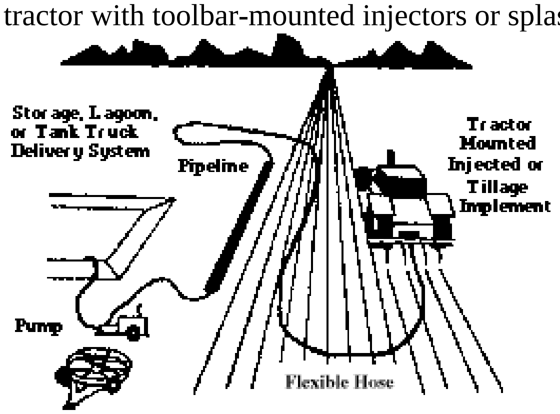

Figure 2. Towed hose systems move manure from storage to field via a pump, pipeline, and soft hose that is pulled behind the tractor and application equipment.

The flexible towed hose system distributes manure at rates of up to 1,000 gallons per minute. A one million gallon storage can be emptied in three to four days. Avoiding use of heavy tank wagons reduces soil compaction. Incorporating manure conserves ammonium nitrogen and minimizes odor.

Surface Application of Liquid Manure

Surface application of liquid slurries provides a low cost means of handling the manure stream from many modern confinement systems. Tank wagons equipped with splash plates are commonly used to spread manure. Surface application suffers from several disadvantages including:

- ***Ammonia losses.*** Surface application of slurries results in losses of 10 to 25 percent of the available nitrogen due to ammonia volatilization *(Table II)*.
- ***Odor.*** Aerosol sprays produced by mixing manure and air carry odors considerable distances *(Table III)*.
- ***Uniformity.*** Splash plates and nozzles provide poor distribution of manure nutrients. Wind can add to

this challenge.

A few recent developments attempt to address these concerns. Boom style application units for attachment to tank wagons or towed irrigation systems are appearing commercially. These systems use nozzles or drop hoses for distributing a slurry. They can help reduce odor concerns and improve uniformity of distribution.

Table II. Nitrogen losses during land application. Percent of total nitrogen lost within 4 days of application.

Application Method	Type of Waste	Nitrogen Lost (%)
Broadcast	Solid	15-30
	Liquid	10-25
Broadcast with immediate incorporation	Solid	1- 5
	Liquid	1- 5
Knifing	Liquid	0- 2
Sprinkler irrigation	Liquid	15-35

Table III. Odor emission rates during land spreading of pig slurry from manure storage.

Application Method	**Total Odor Emissions**[1]
Conventional tanker with splash plate	1322
Irrigation	6250
Shallow incorporation	503
Deep injection	689
Low trajectory spreader with 15 trailing hoses	130

[1]Odor units per 1,000 gallons of slurry applied as measured by olfactometer.

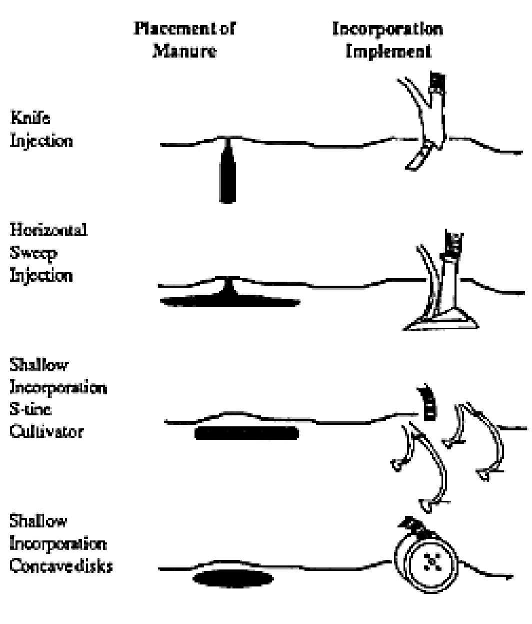

Figure 3. Options for incorporation of manure in the soil.

Liquid Manure Application on Grassland and Cereal Grains

Traditionally, manure application on grassland, legume crops and cereal grains has been limited to surface broadcasting. Losses of ammonia, manure contamination of foliage, and odor nuisances have been problems. For many reasons, manure injection generally has not been considered an acceptable alternative.

Alternative application methods are appearing. Flexible drop hoses supported on a boom can apply manure beneath the crop canopy on the soils surface. A variation of this is the use of a sliding shoe to which the drop hose is attached. The sliding metal shoe rides on the surface of the ground, scraping the surface free of residue and creating a depression in which manure is placed. This method is effective in reducing ammonia losses and minimizing odor due to reduced mixing of air and manure. Yield improvements suggesting that the sidedressing of nutrients to the crop have more than offset any crop damage by the sliding shoe.

Direct Incorporation of Liquid Manure

Options for direct incorporation of liquid manure are growing *(Figure 3)*. Injector knives have been the traditional option. Knives, often placed on 20 to 25 inch centers, cut 12 to 14 inch deep grooves in the soil into which the manure is placed. Limited mixing of the soil and manure and high power requirements are commonly reported concerns.

Injector knives with sweeps that run four to six inches below the soil surface allow manure placement in a wider band at a shallower depth. Manure is placed immediately beneath a sweep (up to 18" wide) improving mixing of soil and manure. Location of the manure higher in the profile minimizes potential leaching and reduces power requirements. Sweeps can be used to apply a higher rate of manure than a conventional injector knife.

Other shallow incorporation tillage implements (s-tine cultivators and concave disks) are options on many liquid manure tank wagons. These systems are most commonly used for pre-plant application of manure. Manure is applied near the tillage tool that immediately mixes the manure into the soil. Speed of application, low power requirements, and uniform mixing of soil and manure have contributed to the growing popularity of this approach. In addition, such systems are being used to side-dress manure on row crops without foliage damage. Side-dressing expands the season during which manure can be applied and improves the use of manure nutrients. All soil incorporation systems also offer the advantage of ammonia conservation and minimal odors.

Irrigation

Various irrigation systems can apply diluted manure from swine and dairy lagoons and runoff from outdoor livestock lots. Higher solids slurries are land applied through large nozzle irrigation units. Irrigation systems can deliver large volumes of liquid in a timely manner, but these advantages are balanced against odor nuisance, high ammonium nitrogen losses, and susceptibility to wind drift. The ideal application for irrigation systems is for waste water from appropriately sized lagoons that have little odor.

Both stationary and self-propelled big gun irrigation systems are commonly used with livestock slurries. Stationary big guns distribute slurries to only about 1.5 acres per setting maximum; traveling units distribute waste up to 10 acres in one setting. Both hard-hose travelers and cable-pulled travelers are used. The drive mechanism for moving the nozzle through the field should be located remote from the nozzle to avoid fouling from manure. The large nozzle of the big gun allows most solids delivered by an aggressive chopper unit and industrial slurry pump to pass unimpeded, so big gun units can apply thicker slurries. Raw dairy manure diluted only with milking parlor effluent effectively has been distributed in this manner.

More diluted slurries, often mixed with irrigation water, are commonly distributed through a variety of sprinkler systems with smaller nozzles. Diluted slurries can be handled through gated pipe and flood irrigation systems. Unequal distribution is a problem with flood irrigation systems. Measures designed to improve distribution of water such as surge flow systems also would enhance flood application of dilute livestock manure slurries.

Nebraska requires a Department of Environmental Quality operating permit for irrigation systems distributing livestock manure or other byproducts that also are tied to a water source. Qualifying for a permit requires installing a check valve assembly on the irrigation system. This check valve assembly includes a check valve, inspection port (at least 4 inches in diameter), vacuum relief valve and low pressure drain (located in the bottom of a horizontal pipe). This equipment is to be located between the water supply and the waste product point of injection. Manure solution discharge must be at least 20 feet from the irrigation water source. Also required for chemigation, but not manure, is an interlock between the two power plants that operate the manure and water pumps. If water quits pumping, so will manure. Although not required for manure application, it is a preferred practice.

Managing irrigation systems applying manure slurries requires additional management less critical for water application alone. Excessive application causes runoff and soil saturation beyond the root zone and has far greater consequences than excess irrigation water applications. Nutrients, organic solids and pathogens can move with the runoff and leaching from manure application. Frequent if not constant visual inspection is needed to avoid runoff and leaching concerns and spot equipment failures early.

Irrigation of livestock manure requires monitoring for odor nuisances. Spray irrigation produces aerosol sprays that can be detected for long distances. Wind direction and impact on neighbors need to be observed closely. An alternative to traveling big guns that reduces odor is a boom fitted with drop tubes to place the manure below the plant canopy on the soil surface. European research shows this is effective in minimizing odors *(Table III)*.

Manure slurries and other waste streams are more corrosive than water. Irrigation and flexible hose application systems should include a way to flush the line with fresh water for 10 to 15 minutes after use. Irrigation pipes used with manure slurries also tend to collect settled solids. These systems often are flushed with a "pig" at the end of each irrigation. The "pig" is a man-made device designed to force out any settled solids prior to shutting the equipment down.

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