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Land Application of Manure

and Environmental Concerns

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As of January 2008, 1.81 million head of cattle, 182,000 head of hogs and 1.9 million turkeys were raised in North Dakota (NASS-ND, USDA 2008). These livestock and poultry facilities are generating substantial amounts of manure and wastewater, which pose a considerable challenge for livestock producers.

The most common manure disposal method is land application because animal manure contains nutrients and organic matter that can be applied to meet crop nutrient requirements and improve the soil's physical and biological conditions. However, to meet the nutrient requirement of crops, applying large quantities of manure (tons/acre vs. pounds/acre with commercial fertilizers) is necessary.

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If manure is not applied properly to fields, the potential for surface and groundwater pollution increases from runoff and leaching. Similarly, field application of manure also poses odor and air emissions concerns (ammonia, NH_3) depending on land application methods (for example, surface vs. injection) and equipment (sweep, chisel, disc tools, etc.).

Some of these concerns resulting from land application of manure can be minimized by adopting best management practices. The aim of this publication is to provide producers and manure applicators with information on how to minimize environmental concerns associated with land application of manure.

Manure can be applied by broadcasting or surface spreading, surface incorporation and subsurface injection. Of these, surface spreading is low in cost but produces higher odor and ammonia losses. Surface application also poses the greatest challenge in uniform application.

Odor from land spreading of manure is not always a serious concern in North Dakota. However, in the long run, it might be an environmental issue and nuisance to rural populations as manure application continues to increase because of increased fertilizer values.

Typically, partial or full incorporation of manure provides a better alternative to reduce odor, surface runoff and ammonia emissions as compared with surface spreading with no incorporation.

Subsurface injection of manure is the best option to minimize runoff, odor and ammonia emissions. Studies show that injection of manure can reduce odor emissions by 85 percent and ammonia volatilization by 90 percent. In addition, subsurface injection reduces the chance of crop contamination and pathogen activity. Furthermore, manure injection techniques prevent surface runoff, increase water infiltration and improve root development due to soil loosening and aeration of the soil.

Manure Types

Based on livestock facilities, manure can be handled and stored as a liquid (less than 5 percent dry matter), slurry (5 percent to 10 percent dry matter), and solid (more than 15 percent dry matter). **Figure 1** shows relative consistency of various types of manure as excreted by the common animal species. Depending on manure consistency, manure application equipment and application methods differ significantly.

Manure Application Methods

Broadcasting or surface spreading (Figure 2)

This is a common method of solid or liquid manure application in North Dakota but it has the highest risk of runoff, particularly when liquid or slurry manure is not incorporated or when applied on frozen or snow-covered ground. According to the "North Dakota Livestock Program Design Manual," manure should not be applied on frozen, snow-covered or saturated soils if runoff is likely.

Some studies also suggest that even with immediate incorporation, pollutants are more susceptible to surface runoff if not injected because incorporation may expose soil to erosion and pollutants can be carried off-site with sediments in the runoff.

Often no-till management is practiced to minimize soil erosion

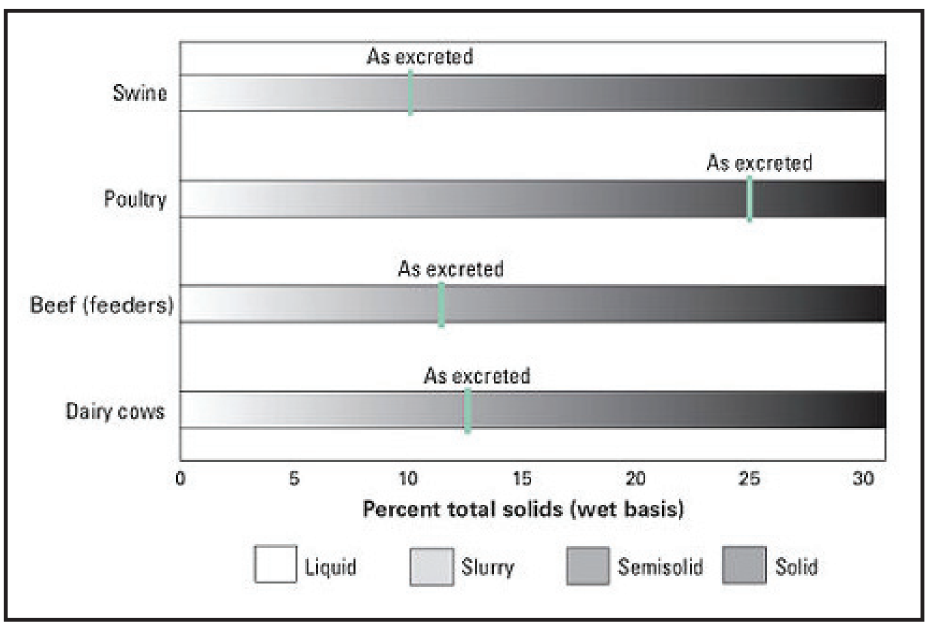

Figure 1. Relative consistency of various types of manure *(Fulhage et al., 2001)*

Figure 2. Surface spreading/broadcasting application unit for solid (left) and liquid (right) manure

in runoff, but it is incompatible with surface manure application due to concerns with odor and nutrient losses. Also, according to the "North Dakota Livestock Program Design Manual," manure must be injected or incorporated within eight hours if applied within one-half mile of an occupied residence (other than the owner's residence), building or public area where people may be present.

Manure injection

An alternative to surface spreading liquid manure is to apply it below the soil surface. Injection is a widely accepted best management practice in North America and Europe. However, it is not widely practiced in North Dakota due to the fact that most of the manure produced is in solid form.

Many injection tools are available for liquid manure, but no injection tool is commercially available for injecting solid manure.

Recently, Hubert Landry of the Prairie Agricultural Machinery Institute (PAMI) has developed a prototype of a solid-manure injection unit **(Figure 3)**, which can inject solid manure successfully. This new technique will be a breakthrough to inject solid manure while minimizing environmental concerns associated with surface spreading of solid manure.

For liquid manure, different types of injection tools (for example, knife, tine, disc, sweep, etc.) are commercially available. However, sweep injection tools (for example, a V-shaped winged tool) provide better mixing of manure and soil as well as minimizing manure exposure to air because of quick adsorption and distribution of liquid manure into loose soil

Figure 3. Solid-manure injection system
(Hubert Landry, Prairie Agricultural Machinery Institute, PAMI)

(Figure 4). Minimizing exposure of manure to air will decrease odor and ammonia emissions. In addition, injection of liquid manure can reduce runoff by up to 94 percent (Ball Coelho et al., 2009) and often results in greater yields.

Other manure application options

Because of the heavy loads, both surface spreading and injection cause some soil compaction, especially in wet soil conditions. Drag-hose manure application systems provide an alternative that lessens soil compaction **(Figure 5)**. This system pumps manure from a lagoon through flexible hoses to a manure distributor mounted on the tractor and then it is deep-injected into the soil.

These deep-tillage tools also help break up the plow pan from previous tillage events. However, this system is not widely used by individual producers due to high investment costs, but custom applicators are available. Also, this system is not feasible in standing crops since the drag hose can cause physical damage to crops.

Gaining in popularity is the AerWay SSD® **(Figure 6)**, a shallow incorporation tool that is very effective in minimizing surface runoff and leaching of pollutants through soil macropores. Several researchers have indicated that the AerWay system can be used as a best management practice to minimize both surface and subsurface water pollution. Others also indicated that this tool can be used to minimize odor and air emissions.

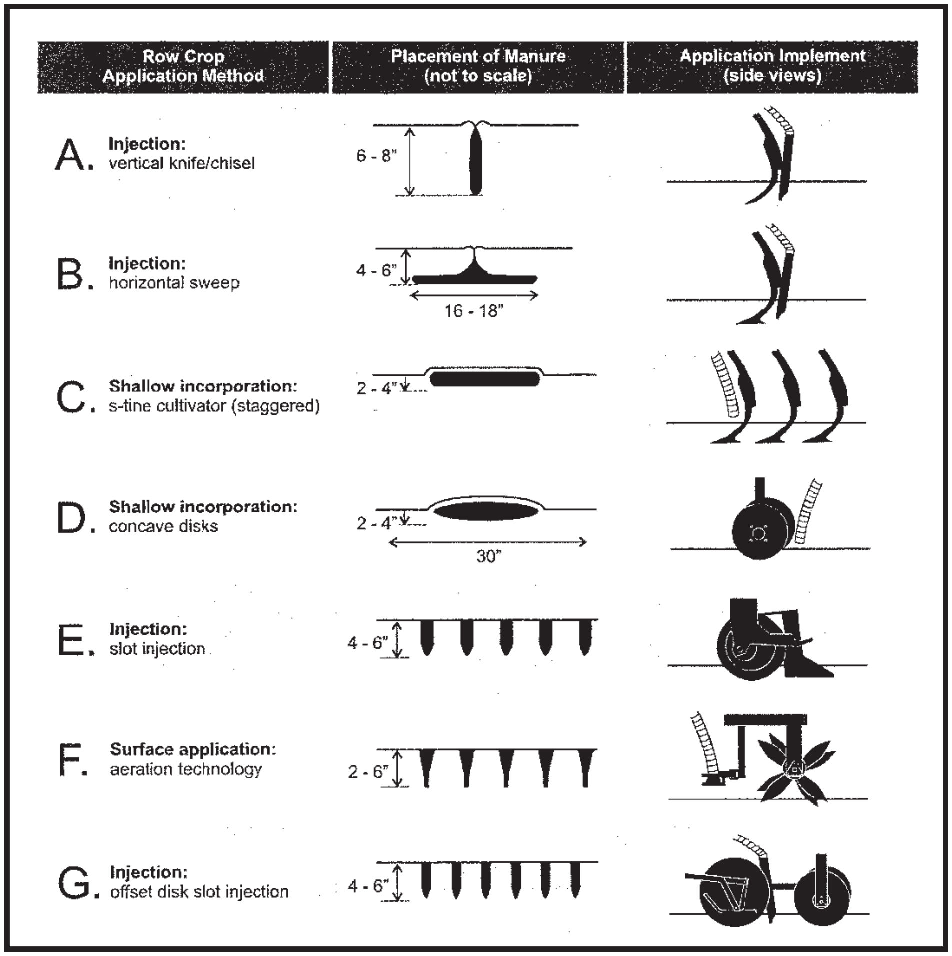

Figure 4. Equipment options for injection or direct incorporation *(Jokela and Cote, 1994)*

Figure 5. Drag-hose manure application system

Figure 6. AerWay SSD® injection unit

With the AerWay system, liquid manure is released into cavities created by tines that rapidly absorb liquid manure resulting in minimum exposure to the air reducing odor and runoff. Recently, this injection technique has been studied on grassland and it conserved more ammonia than broadcasting or surface banding.

Environmental Concerns and Management Practices

The main environmental problem caused by land application of manure is water (runoff of nutrients and leaching) and air pollution (odor and ammonia emissions). The following sections briefly describe these concerns and management options.

Water Quality

As stated previously, land application of manure is the predominant method of manure utilization. Excessive rates or inappropriate methods of manure application that lead to surface runoff are the main culprits in eutrophication of surface water systems. Eutrophication is caused by high rates of phosphorus (P) addition to the water systems.

Similarly, land application of manure can contribute to groundwater contamination from nitrate leaching. The amount of phosphorus delivery to runoff is influenced by the P source, soil P level, rate and method of manure application, field slope and distance to surface water (Daverede et al., 2004; Allen and Mallarino, 2008).

The highest risk of P losses in runoff is likely when manure is broadcast on the surface and followed by intermittent rain. Broadcast or unincorporated manure concentrates P at the soil surface, where it may be easily transported with runoff water.

Runoff transport of P from broadcast or unincorporated manure increases with the application rate; however, the potential P loss will decline through time as more soluble P in the manure interacts with the soil. On the other hand, incorporation or injection of manure into the soil reduces runoff significantly without increasing the risk of soil erosion.

Therefore, selection of application method plays an important role in minimizing water quality degradation. Manure application must be made in a manner that does not contribute to water pollution.

In North Dakota, zero till is a well-accepted management practice where continuous macropores (earth worm channels, cracks, etc.) are more highly developed than in tilled soils.

Recently, tile drainage is gaining acceptance in North Dakota to reduce salt accumulation and standing water issues. Under zero-tillage and tile-drainage conditions, established macropores favor rapid movement of pollutants by establishing preferential flow pathways. These pathways are direct conduits that allow for the flow of surface-applied nonincorporated liquid manure movement to ground water and tile lines (Thiagarajan et al., 2007).

Because of the high risk of preferential flow in established zero-till fields, manure should be subsurface injected or surface applications should be followed by light soil stirring.

Excessive rainfall following manure application also plays a key role in nutrient runoff. For example, P concentration is much higher in runoff water within 24 hours of manure application than runoff delayed for a few days (10 to 16 days) after manure application. Therefore, delaying manure application before a forecasted rainfall event can decrease sharply the risk of P loss from surface-applied liquid manure and minimize environmental concern.

Air Quality

Most air quality complaints are odor nuisance concerns from people who live near concentrated animal feeding operations (CAFOs).

Odor from CAFOs is produced primarily by incomplete fermentation of livestock manure. Unfortunately, odor is not caused by a single substance, but a large number of compounds including ammonia, hydrogen sulfide and other volatile organic compounds (VOCs) (Laor et al., 2007).

Odor can be generated from livestock housing, manure handling and storage systems, and during and following land application of manure to the land. Of these, approximately 50 percent of the ammonia (NH_3) emissions occur from surface spreading of manure (Portejoie et al., 2003).

Emissions of ammonia are responsible for the acidification and eutrophication of deposited ammonia in the environment (Koerkamp et al., 1998). Ammonia emissions also decrease the nutrient value of manure and represent a significant loss of fertilizer value.

Studies suggest that injection of manure below the soil surface can reduce ammonia volatilization by about 90 percent compared with surface application.

Like NH_3, hydrogen sulfide (H_2S) is a pollutant gas that is colorless, heavier than air and highly soluble in water and has the characteristic odor of rotten eggs at low concentrations. H_2S is produced when sulfur (usually added as a feed additive or naturally occurring in drinking water) bearing organic matter is decomposed by anaerobic bacteria and sulfate is reduced to H_2S.

Any excreted sulfur that is not in the form of hydrogen sulfide is reduced to H_2S. Although emissions of H_2S from land application is not well-documented, odor (which is a complex compound) complaints from land application are a concern and the odor can be recognized from distances.

Control Strategies

The livestock and poultry industry is a smaller proportion of ag vs. crop production in North Dakota yet is vital to the state's economy. As the livestock and poultry industry expands, manure handling and management may be an issue in the foreseeable future. However, modification of current manure management practices and application methods can reduce environmental concern.

Emissions control during land application is the most effective way to minimize ammonia loss and retain fertilizer value. For example, incorporation of manure into soil or injection below the soil surface can minimize both odor and ammonia emissions when compared with surface spreading.

As mentioned before, zero till and tile drainage are prone to pollutant movement to surface and groundwater due to continuous macropores. Manure should not be applied on frozen, snow-covered or saturated soils if runoff or tile drainage is likely.

Several studies indicated that partial incorporation or aeration will result in reduced pollutant movement in tiled water due to the disruption of macropores from the tillage action of tools.

Similarly, partial incorporation or aeration also reduced surface runoff as well as odor and ammonia emissions. Therefore, manure management practices are a unique opportunity to mitigate environmental concern associated with manure application.

Any reduction of ammonia emissions from land-applied manure would be the most economically effective first step to reduce ammonia emissions.

Apart from manure application technology, a number of other management practices exist that can reduce NH_3 emissions at little or no cost. For example, ammonia emissions are likely to be higher if manure is applied during hot, dry and windy weather. Similarly, emissions can be reduced notably (up to 25 percent) during summer application if liquid manure is spread in the evening rather than during the daytime.

However, increased humidity in summer evenings may cause long-distance transportation of odorous compounds. A shift in the time of manure application may help minimize odor and ammonia emissions if done at the right time of year.

Furthermore, depending on weather, if liquid manure is applied shortly before or during a slight rain, emissions are reduced considerably because the ammoniacal fraction of the manure is washed into the soil. However, applying manure at this time increases the risk of runoff if the rain is heavier than expected. Therefore, watching the weather and spreading manure at a time when the weather is more favorable is better.

No one single method is good enough to reduce emissions and runoff completely. Producers may need to adopt multiple best management practices to minimize environmental impacts resulting from land application of manure. Finally, to minimize environmental concerns associated with manure application, livestock producers and stakeholders need to be aware of the issues.

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