pork industry handbook



MICHIGAN STATE UNIVERSITY EXTENSION

# Swine Manure as a Plant Nutrient Resource

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Swine manure contains nutrients that can support crop production and enhance the soil's chemical and physical properties. Thus, manure can be an asset to a pork production operation if its nutrient value is maximized. The purpose of this fact sheet is to provide information on which to base decisions concerning the handling, storage, application and use of swine manure as a plant nutrient source. Discussed here are the factors that affect manure's nutrient content, how to minimize nutrient loss, general fertilizer recommendations for various crops, when to apply manure to certain soil types, plus related management suggestions for maximizing manure value and reducing the impact of manure on water pollution and odor complaints.

## Factors Affecting the Nutrient Value of Manure

The types and amounts of nutrients in swine manure and their eventual uptake by plants will vary considerably from farm to farm. The major determinants of manure nutrient content and availability are: (a) composition of rations fed to swine; (b) amount of feed, bedding and/or water added to the manure; (c) method of manure collection and storage; (d) method and time of land application, including use of additives which preserve nutrient value; (e) characteristics of the soils; and (f) type of crop to which the manure is applied. The following is a brief discussion of just how these factors affect swine manure nutrient value and what might be done to minimize nutrient loss.

### Composition of the ration

The levels of nutrients and presence or absence of certain feed additives in swine rations will be reflected in the nutrient composition of manure. For example, changing the levels of inorganic salts (sodium (Na), calcium (Ca), potassium (K), magnesium (Mg), phosphate, and chloride) and feed additives (copper, antibiotics, or enzymes) in rations will change the concentrations of these elements and possibly the rate of decomposition of organic matter in the manure. For instance, the use of a phytase enzyme in swine rations to release unavailable phosphorus (P) can reduce the phosphorus content of manure from 25% to 40% reducing the acreage needed for manure application and the potential for P buildup in the soil. Reducing crude protein levels and supplementing with specific amino acids to balance the ration can reduce the nitrogen (N) content of manure from 22% to 41% reducing the acreage needed for manure application. Copper sulfate in rations fed to pigs will decrease dry matter degradation resulting in sludge buildup in storage, less storage capacity and possible difficulty in pit emptying.

### Amount of feed, bedding and/or water

Bedding and water that get into manure dilute its nutrient concentration, thus lessening its value as a plant nutrient resource when applied to the land. Feed spillage, on the other hand, will increase manure nutrient concentration for land application. Be aware that feed spillage and inadequate agitation prior to manure removal results in sludge (solids) buildup and more difficult removal with vacuum-type equipment. Wet or liquid feeding can reduce manure storage volume required by 50% compared to conventional dry feeders where water is supplied separately by a nipple-type waterer. Because of reduced water spillage, the nutrient concentration in manure is increased considerably.

## Method of collection and storage

The type of housing and/or manure handling method greatly affect the nutrient concentration of swine manure (Table 1). Major N loss occurs when manure is dried by sun and air movement or is leached by rain in an open lot system. In contrast, comparatively little N is lost from a manure pack under a completely covered feedlot or anaerobic (without oxygen) storage systems. Nitrogen loss from manure is greatest in long-term partial treatment systems, such as lagoons.

uniform application of the manure as compared to knife channels. Generally, incorporation with sweeps (only 4 in. to 8 in. below the surface) takes less fuel and this method may be desirable for sandy soils, where the nutrients need to be placed near the root zone to minimize leaching. Knife injectors may be most desirable in heavy soils if sub-soiling is necessary to break up the clay plow pan. Minimum tillage injection system, can be used to lift the soil for manure placement with minimal disturbance to the surface residue cover.

Generally, P and K losses are neglible and are not affected by method of application. However, incorporation of manure minimizes P and K losses in the event of surface runoff during rainfall.

Nitrogen loss by ammonia ($NH_3$) volatilization from surface applications is greater during dry, warm windy days than on days that are humid and/or cold. Ammonia loss is generally greater during the spring and summer months. A majority of the ammonia is lost within 24 hours of surface application. Manure should be applied as uniformly as possible to prevent local concentrations of ammonium-nitrogen ($NH_4^+$-N) or other inorganic salts that can reduce germination and yields.

**Table 1. Typical nutrient losses from swine manure as affected by method of handling and storage.***

| Manure handling and storage method | N loss, % | $P_2O_5$ loss,% | $K_2O$ loss, % |
|---|---|---|---|
| **Solid Systems** | | | |
| Manure pack | 20-40 | 5-10 | 5-10 |
| Paved lot | 40-60 | 20-40 | 30-50 |
| **Liquid Systems** | | | |
| Anaerobic deep pit** | 15-30 | 5-15 | 5-10 |
| Above ground storage** | 5-25 | 5-15 | 5-15 |
| Earthen storage pit** | 20-40 | 10-20 | 10-20 |
| Lagoon*** | 70-85 | 50-85 | 50-75 |

* Based on composition of manure applied to land vs. composition of freshly excreted manure, adjusted for dilution effects of the various systems.
** Concentrated manure with little water added.
*** Manure plus dilution water added for biological treatment and odor control.

Phosphorus and K losses are negligible for all but open lot and lagoon manure handling systems. In an open lot, 20% to 40% of the P and 30% to 50% of the K can be lost to runoff and leaching, unless control systems (settling basins, detention ponds) are used. With a lagoon, 50% to 85% of the P in manure may settle out in the sludge layer and be unavailable if only the liquid is irrigated on the land. If agitated, the P and K in the lagoon sludge can be applied to cropland with the liquid.

## Method of application

Maximum nutrient benefit is realized when manure is incorporated into the soil immediately after land application (Table 2). This minimizes N loss to the air and/or runoff and allows the soil micro-organisms to start decomposing the manure, thus making nutrients available to the plant sooner. In addition, incorporation of manure into the soil minimizes potential odor problems. With liquid systems, the practice of injecting, chiseling or knifing the manure beneath the soil surface is especially effective in minimizing odor problems if there is a good soil cover to seal the manure incorporaton.

Use of wide sweeps for injection can give a more

**Table 2. Typical nitrogen losses to the air as affected by application method.**

| Application Method | Type of Manure | N loss,%* |
|---|---|---|
| Broadcast without cultivation | Solid | 15-30 |
| | Liquid | 10-25 |
| Broadcast with cultivation** | Solid | 1-5 |
| | Liquid | 1-5 |
| Injection | Liquid | 0-3 |
| Irrigation (sprinkle) | Liquid | 30-40 |

* Percent of total nitrogen in manure applied which was lost within 3 days after application.
** Cultivation within a few hours after application.

## Time of Application

Liquid manure should be applied as near to the planting date as possible to maximize nutrients available for plant growth, especially in areas with high rainfall or porous soil and if no nitrification inhibitor is used (see later section). However, if planting takes place immediately after heavy manure applications, lowered germination and reduced seedling growth could occur as a result of salt accumulation near the surface. As an alternative, consider late fall or winter applications because of labor availability and because the soil is less subject to compaction. Although fall-winter applications may result in 15% to 50% total nitrogen loss due to leaching and denitrification, more time in the field allows soil microorganisms to more fully decompose manure and release nutrients for the following cropping season. This is highly recommended for solid manure which contains much organic matter.

## Nitrification Inhibitors

Loss of N from liquid manure by leaching or denitrification can be greatly reduced with nitrification inhibitors. These products inhibit the action of certain soil bacteria that convert ammonium N to nitrate N which can be easily leached by water movement through the soil or converted into nitrogen gas through denitrification. Thus, these products reduce potential N losses from manure and/or commercial fertilizer, especially with fall applications where N losses can range from 15% to 50% due to leaching and/or denitrification over the wintering period.

The addition of nitrification inhibitors, such as N-Serve®, to liquid swine manure (if used as the only source of nitrogen for corn) minimizes N losses and increases corn yields. This beneficial effect is more evident with fall manure applications than with spring applications unless spring soil conditions are extremely wet which increases potential leaching and denitrification. Since currently available nitrification inhibitors are volatile compounds, the manure and inhibitor mixture must be injected or immediately incorporated into the soil after application to assure beneficial response. Do not add inhibitors to storage pits as they will be lost to the air.

Methods for adding the inhibitors to manure include:

- through an open hatch prior to manure loading
- through a separate aspirator tube with vacuum systems
- into a manure pump ( on the suction side) at the time of loading

Maximum benefits from using a nitrification inhibitor are attained when the rate of N added to the soil is equal to plant needs. Therefore, laboratory analysis is recommended to insure that proper amounts of N are being applied.

## Application Site Soil Characteristics

Properties of soil, such as water infiltration rate, water-holding capacity, texture, and cation exchange capacity affect how much manure can be efficiently utilized by crops. Due to increased soil aeration, organic matter in manure is decomposed more rapidly in coarse-textured soil than in fine-textured soil and more rapidly under warm, moist conditions than under cold, dry conditions. However, fine-textured soils will retain the nutrients longer in the upper profile where they are available to plant roots.

Because fine-textured soils have slow water infiltration rates, the amount of liquid manure (especially lagoon effluent applied by irrigation) applied at any one time should be limited so runoff does not occur. Likewise, carefully limit applications on high clay soils where drying has resulted in deep soil fissures (cracks) through which manure can quickly reach tile lines or ground water. After wetting, these soils expand and applications can be increased. Tillage of the soil surface improves the water infiltration rate of soils. Coarse-textured soils, on the other hand, are quite permeable and can accept higher rates of liquid manure at any one time without danger of runoff. However, because most coarse-textured soils have a low cation exchange (nutrient-holding) capacity, manure may have to be restricted to several small applications during the growing season to minimize the chance of soluble nutrients reaching the ground water.

An added advantage of applying swine manure on the land is the fact that it enhances soil structure and increases organic matter content, thus improving a soil's tilth, its nutrient-holding and water-holding capacities and reduceing soil erosion. However, soil improvement through manure application is a long-term process, and initially the amounts that can be applied are restricted by soil characteristics.

## Nutrients Required by the Crop

The amounts of nutrients from manure which can be utilized by crops are a function of the type of crop being grown, yield potential of the crop, and soil test level. Thus to be able to calculate the appropriate manure application rate, one must have a realistic estimate of the productivity of the field to be manured and a current soil test.

Nitrogen can be utilized by most crops, but is of most value to corn, forage grasses, and cereal grains. Legumes can effectively utilize the N in manure but no economical benefit from the manure N will be obtained. Therefore, manure application to legume forages or soybean land should not be considered as an economical alternative to other crops unless there is extra manure from the operation that needs to be land applied. Average N recommendations for corn, grain sorghum, small grains, forage grasses (including pastures), and legumes are summarized in Table 3. These values are guidelines, so check with local crop consultants or the Cooperative Extension Service for crop requirements and fertilizer recommendations in your area. Since N is quite mobile, it is important that the total available N in applications from manure, fertilizer, and other sources made to a field does not exceed the recommendations in Table 3 or recommendations for your specific areas. Applications significantly above these rates can result in nitrate movement to surface and ground waters. Proper use of the appropriate application rates, together with uniform spreading of the manure, should produce good yields and prevent environmental damage.

Phosphorus and K applied in excess of the amounts removed in harvested crops will accumulate in soils and increase soil test levels. Thus nutrient application requirements will be a function of crop yield and soil test level (Table 3). While application of manure P and K above the amounts utilized by crops is normally not considered harmful, repeated high rates of application can result in extremely high soil test levels. Periodic soil testing is recommended on fields receiving manure applications. Since manure applications that meet the N needs of crops will generally contain more P and possibly K than the crop can utilize, follow specific state guidelines limiting manure applications to soils with high P or K test levels.

## Nitrogen Credit from Legumes

Legumes, such as alfalfa and soybeans, have the capability to use nitrogen from the air during plant growth. This results in an accumulation of residual nitrogen in the soil after cropping which can serve as a N source for subsequent cropping seasons. If a legume crop was grown on land the previous year, a credit for the N from the legume should be used to adjust N fertilizer applications. Similarly, manure application rates also should be adjusted (reduced). Credits for the average amounts of N available from legumes or other previous crops generally range from 30 to 40 lb/acre. Check with your crop consultant to determine if a different N credit shoud be assigned. With good stands of legumes, N credits as high as 80 to 100 lb/acre may be used. Care should be taken to ensure that the appropriate credit is taken.

**Table 3. Typical N, $P_2O_5$ and $K_2O$ removal by various crops.***

| Crop | Units | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|---|
| | | **Pounds removed per unit production** | | |
| Corn grain | bu | 1.0 | 0.4 | 0.3 |
| Corn stover | ton | 21 | 8 | 37 |
| Corn, silage (35% dry matter) | ton | 8 | 3 | 9 |
| Soybeans, grain** | bu | 4 | 0.8 | 1.5 |
| Soybeans, residue** | ton | 24 | 7 | 16 |
| Wheat grain | bu | 1.5 | 0.6 | 0.4 |
| Wheat straw | ton | 13 | 4 | 25 |
| Wheat, grain & straw | bu | 1.5 | 0.7 | 1.4 |
| Oats grain | bu | 0.7 | 0.3 | 0.4 |
| Oats straw | ton | 12 | 5 | 33 |
| Oats grain, & straw | bu | 1.0 | 0.4 | 1.2 |
| Barley grain | bu | 1.0 | 0.4 | 0.3 |
| Barley straw | ton | 14 | 5 | 31 |
| Barley grain, & straw | bu | 1.4 | 0.6 | 1.3 |
| Rye grain | bu | 1.0 | 0.5 | 0.3 |
| Rye straw | ton | 10 | 6 | 17 |
| Rye grain, & straw | bu | 1.4 | 0.8 | 1.0 |
| Sorghum, grain | bu | 1.0 | 0.4 | 0.4 |
| Alfalfa** | ton | 56 | 13 | 50 |
| Orchard grass | ton | 40 | 17 | 63 |
| Brome grass | ton | 33 | 13 | 51 |
| Tall fescue grass | ton | 39 | 19 | 53 |
| Blue grass | ton | 26 | 18 | 60 |
| Clover-grass | ton | 41 | 13 | 39 |
| Sorghum-sudan grass | ton | 40 | 15 | 56 |
| Small grain silage (45% dry matter) | ton | 20 | 4.5 | 27 |
| Coastal Bermuda grass | ton | 56 | 13 | 7 |

*Data represent nutrient removal only. Adjust $P_2O_5$ and $K_2O$ application rates by fertilizer recommendations from soil tests. Due to specific soil/climate conditions in your area, use local or state nutrient removal rates. Adapted from MWPS-18 (Revised, 1996)

**Legumes get most of their N from the air, so additonal N from swine manure or inorganic N fertilizer is not needed. However, they have the capability to utilize N if manure is applied as indicated.

**Table 4. Typical annual manure production and composition*.**

| Type of Livestock | Manure produced | Total N | $NH_4^+$ | $P_2O_5$ | $K_2O$ |
|---|---|---|---|---|---|
| | | **Nutrients produced, lbs/yr** | | | |
| **Solid Manure** | **Ton/yr** | | | | |
| Farrow (per sow cap) | 2.4 | 21.6 | 8.4 | 14.4 | 9.6 |
| Nursery (per pig cap) | 0.2 | 3.2 | 1.2 | 1.9 | 1.0 |
| Grow-Fin (per pig cap) | 1.1 | 16.8 | 6.3 | 9.5 | 5.3 |
| Breed-Gest (per sow cap) | 1.0 | 9.0 | 5.0 | 7.0 | 5.0 |
| Far-Fin (per productive sow) | 8.6 | 124 | 48 | 73 | 41 |
| Feeder pig (per productive sow) | 2.3 | 24 | 10 | 16 | 10 |
| Far-Fin (per pig sold/yr) | 0.5 | 7 | 3 | 4 | 2 |
| **Liquid Manure Pit** | **Gal/yr** | | | | |
| Farrow (per sow cap) | 1,400 | 21 | 11 | 17 | 15 |
| Nursery (per pig cap) | 130 | 3 | 2 | 2 | 3 |
| Grow-Fin (per pig cap) | 530 | 17 | 10 | 14 | 13 |
| Breed-Gest (per sow cap) | 450 | 11 | 5 | 11 | 11 |
| Far-Fin (per productive sow) | 4,540 | 130 | 74 | 106 | 103 |
| Feeder pig (per productive sow) | 1,180 | 25 | 13 | 22 | 22 |
| Far-Fin (per pig sold/yr) | 250 | 7 | 4 | 6 | 6 |
| **Lagoon** | **Gal/yr** | | | | |
| Farrow (per sow cap) | 2,100 | 6.3 | 5.8 | 3.2 | 3.2 |
| Nursery (per pig cap) | 220 | 0.9 | 0.8 | 0.7 | 0.7 |
| Grow-Fin (per pig cap) | 950 | 4.8 | 4.3 | 2.9 | 3.8 |
| Breed-Gest (per sow cap) | 900 | 3.2 | 2.9 | 3.2 | 3.6 |
| Far-Fin (per productive sow) | 7,740 | 36 | 32 | 23 | 29 |
| Feeder pig (per productive sow) | 2,040 | 7.1 | 6.4 | 5.5 | 5.9 |
| Far-Fin (per pig sold/yr) | 430 | 2 | 2 | 1 | 2 |

* Composition and production of manure as it leaves storage for land application. Annual volume per animal unit assuming wash water and dilution (water spillage). Nitrogen adjusted for average volatile nitrogen losses. Adapted from ID-101- Animal Manure as a Plant Nutrient Resource (1994)

## Availability of Manure Nutrients to the Crops

Table 4 shows typical amounts of manure produced annually by hogs when stored as a solid, a slurry in a liquid pit, or a dilute liquid in a lagoon, and gives the average annual N, $NH_4^+$, $P_2O_5$ and $K_2O$ available from manure with various pork production systems. Table 5 gives the average total N, $NH_4^+$ $P_2O_5$ and $K_2O$ composition per unit volume (per 1,000 gal) or weight (per ton ) of typical liquid and solid manures, respectively, at the time of application on the land.

The actual nutrient value of manure from a particular farm might differ considerably due to the factors discussed above. Nevertheless, these figures can serve as a guide in determining land application rates if a nutrient analysis of manure is not available. For accurate rate calculations, it is strongly recommended that the nutrient content of manure be determined by laboratory analysis. At least total solids, total N, $NH_4^+$-N, P and K analyses, and possibly Ca & Mg should be obtained on well-mixed representative samples from each manure pit or storage area.

Check with your Cooperative Extension Service or University for more details on how to collect samples and where to obtain an analysis.

Not all manure nutrients are readily available to a crop in the year of application. To be utilized by plants, nutrients must be released from the organic matter in manure by microbial decomposition and be put into a chemical form that is soluble in water.

Most manure N is in ammonium ($NH_4^+$) and organic forms. Potentially, all of the ammonium-N can be utilized by plants in the year of application. However, if manure is broadcast on the soil surface and not quickly incorporated, considerable ammonium N will be lost to the air as ammonia ($NH_3$) gas, as discussed earlier. Nitrogen in the organic form must be converted (mineralized) into inorganic forms (ammonium; $NH_4^+$ and nitrate; $NO_3$) before it can be used by plants. From 25% to 50% of this organic N may become available the year of application. Organic N released during the 2nd, 3rd and 4th cropping years after application is usually about 50% , 25% and 12.5%, respectively, of that mineralized in the initial season.

If the soil organic matter levels are low, some N can be tied up (immobilized) in the soil and released in subsequent years resulting in much less available the first year. In addition, manure contributes considerable organic matter to the soil and increases bacterial activity which can tie up inorganic N making it not immediately available to the growing plant.

Nearly all of the P and K in manure is available for plant use the year of application. Since the P levels present in most manure are quite high, it is often cost effective to determine manure application rates based on P needs and add supplemental amounts of commercial anhydrous ammonia or liquid N fertilizer. Another management approach is to rotate the fields that receive manure if excess P is applied so that P can be efficiently utilized in subsequent cropping seasons and P buildup in the soil is minimized.

## Determining How Much Swine Manure Can Be Applied

If you know the fertilizer needs of crops grown on your land (fertilizer recommendation or Table 3) and the nutrient content of the swine manure at the time of application (manure analysis or Table 5), you can determine how much manure should be applied to the land and if additional commercial fertilizer will be needed for efficient crop production. In addition, by knowing the crop nutrient needs (Table 3) and the approximate amount of manure produced from the swine operation per year (Table 4), you can determine how much land area is needed for manure disposal.

Applying manure to the land at such a rate that the amount of available nutrients meets the amount needed by the growing crop insures efficient use of manure nutrients and minimizes the chances of leaching. Check with local regulatory agencies concerning specific restriction on land application rates in your area.

**Table 5. Average total nitrogen (N), ammonium nitrogen ($NH_4^+$), phosphate ($P_2O_5$) and potash content ($K_2O$) of manure at the time of land application.[1,2]**

| | Solid Manure lb/ton | | | | Liquid Manure Pit lb/1000gal | | | | Lagoon lb/1000gal | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type of Livestock | N[4] | $NH_4^+$[5] | $P_2O_5$[6] | $K_2O$[7] | N[4] | $NH_4^+$[5] | $P_2O_5$[6] | $K_2O$[7] | N[4] | $NH_4^+$[5] | $P_2O_5$[6] | $K_2O$[7] |
| Farrow | 9 | 4 | 6 | 4 | 15 | 7.5 | 12 | 11 | 3 | 2.8 | 1.5 | 1.5 |
| Nursery | 13 | 5 | 8 | 4 | 25 | 14 | 19 | 22 | 4 | 3.5 | 3 | 3 |
| Grow-Fin | 16 | 6 | 9 | 5 | 33 | 19 | 26 | 25 | 5 | 4.5 | 3 | 4 |
| Breed-Gest | 9 | 5 | 7 | 5 | 25 | 12 | 25 | 24 | 3.5 | 3.2 | 3.5 | 4 |

1 Estimates as removed from storage at time of land application. Dilution water and bedding additions were assumed to change nutrient values. Dry matter estimates: solid manure, 18% (16-20%); liquid manure, 6% (4-8%); lagoon effluent, 1% (0.3-2%). Adapted from ID-205, Swine Manure Management Planning (1995)

2 Application conversion factors: 1bu.= 40-60 lb. solid manure; 1,000 gal. = about 4 tons; 27,154 gal. = 1 acre in.

3 Includes feedlot runoff water and is sized as follows: single cell - 2 cu. ft./lb. animal weight; two-cell lagoon -*cell 1*, 1-2 cu. ft./lb. animal wt. and *cell 2*, 1 cu. ft./lb. animal weight.

4 Ammonium-N plus organic N, which is slow releasing.

5 Ammonium N, which is available to the plant during the growing season.

6 To convert to elemental P, multiply by 0.44.

7 To convert to elemental K, multiply by 0.83.

## The Worksheet

A worksheet (with example) is provided to help you arrive at the proper application rates. Use the P and K analysis of a soil test, along with crop fertilizer recommendations of your local area to adjust theses rates to your soil conditions.

A laboratory analysis is the most accurate way to determine the nutrient value of manure from your swine operation. For names of commercial laboratories that provide soil and/or manure analyses, contact your local County Extension Office. Check with the laboratory for specific procedures on obtaining and sending representative samples for analyses. Suggested sampling procedures can be found in the last section of this fact sheet.

The worksheet procedure is separated into six sections as follows:

- swine inventory
- manure composition and soil information
- nutrient needs of crop
- determine annual rate of manure application
- determine amount of additional fertilizer needed
- determine amount of land required to dispose of annual manure production.

## Developing a Fertilizer/Manure Application Plan

Some producers apply enough manure on the land to meet crop nutrient needs and then unnecessarily add commercial fertilizer. This practice not only wastes money and much of the manure's potential value as a plant nutrient resource, but also can cause nutrient imbalance in the soil and increase nutrient leaching or runoff into water sourses. Repeated applications of excess of manure result in a wasteful buildup of P and K in soils.

Pork producers should develop a manure nutrient management plan that *first* maximizes the use of manure nutrients and then supplements with commercial fertilizers *only* if additional nutrients are needed for the crop. The major elements of such a plan include:

- periodic analysis of the manure produced in the pork operation
- a routine soil testing program
- keeping accurate records of fields manured and the application rates used
- sufficient storage capacity for timely application
- field availability for manure application
- uniform applications and proper timing of manure application across the entire field
- applying manure to meet crop nutrient needs based on realistic yield potentials
- applying manure to a field every two or three years to more efficiently use all the nutrients in the manure.

For computer software and details on how to develop a specific manure management plan for your operation, check with your state Cooperative Extension Service.

## Suggestions for Proper Land Application

Here are some suggestions to help insure safe and effective application of swine manure to cropland.

- Calibrate the spreader or irrigation equipment. With spreading or injection units, calculate covered area as the swath width times the distance traveled. The application rate then is the net volume or weight of the loaded spreader divided by the covered area. For example, if 3,000 gallons/acre are to be injected with a 2,000 gallon tanker having a 10-foot wide swath, adjust the speed so that the tanker travels 4,356 feet to apply 3,000 gal (43,560 ft$^2$/acre divided by 10 ft.). Since the tanker holds 2,000 gallons, the producer would therefore need to travel 2,904 feet (4,356 ft x 2,000/2,963), to inject each load. A similar calibration method can be used with solid manure spreaders.
- Volumes spread by irrigation are calculated as pump capacity in gallons/min times minutes of operation and area is length of travel times swath covered for a traveling gun, or 0.78 times the square of the applica tion area diameter for a stationary gun.
- Unless immediately incorporated in the soil, apply manure to the surface at reasonable distances from streams, ponds, open ditches, residences, and public buildings to reduce runoff and odor problems and to avoid neighbor complaints. Check local and state regulations.
- If you have a solid manure system with daily scrape and haul management, spread raw manure frequently, to minimize farmstead odor problems, especially dur ing the summer. Spread early in the day when the air is warming and rising rather than later when the air is cooling and settling. Do not spread on days when the wind is blowing toward sensitive areas or when the air is still and seems to hang.
- During periods of the year when the soil is frozen, apply manure only to flat or level land. Do not apply to frozen land with slopes greater than 2% unless there is a dense vegetative cover crop. Check local and state regulations regarding frozen ground policies.
- Consider irrigating diluted manures (lagoon or runoff liquids) during dry weather to supply needed water as well as nutrients to growing crops.
- If irrigating manure on growing crops, do not apply during the heat of the day. After manure application, irrigate with clean water to wash the plants off, thereby avoiding leaf burn from "salts" in the manure.
- Don't apply liquid manure on water-saturated soils where runoff and denitrification is likely.
- Thoroughly agitate liquid manures in pitis to insure removal of settled solids. This is important for uniform applications of the nutrients and for obtaining accurate, representative samples for analysis.
- Make safety your first priority when removing manure from tanks or pits. That includes removing animals or increasing ventilation to the maximum in slatted floor areas over manure pits during agitation because of oxygen deficiency or toxic gas emission from accumu lation in the manure pit. If animals are left in buildings during agitation, monitor their behavior carefully. **Do not enter manure storage structures at any time without life-support equipment (oxygen tank and mask).**
- Make certain that all below-ground manure storage (tank or earthen structure) is protected against accidental entry.

# Worksheet for Determining Swine Manure Application Rates and Size of Disposal Area

Example: A swine producer has a feeder pig finishing operation with 1890 pig capacity in enclosed buildings with deep pits. Manure is handled from liquid storage and is injected into the soil. The area to be used for manure application had received 4,000 gal./acre of finishing house manure last year. To maximize use of finishing house manure as fertilizer, what is the proper manure application rate, how much supplemental commercial fertilizer will be needed, and how many acres of cropland can utilize the manure?

## Calculations

### Section A. Swine Inventory

1. Average building or feedlot inventory (list capacity for each building).

| Building No. | Animal Category | Average Inventory: Example | Average Inventory: Your Farm |
|---|---|---|---|
| 1. | Farrowing Sow and Litters | | |
| 2. | Nursery Pigs | | |
| 3. | Growering Finishing Pigs | 1890 | |
| 4. | Breeding-Gestation Sows/Gilts | | |

### Section B. Manure Composition and Soil Information

1. Manure composition
   Values from chemical analysis of manure* or Table 5.

| Composition | Example | Your Farm |
|---|---|---|
| Total N | 33 lb./ 1000 gal | lb./ |
| Ammonium N | 19 lb./ 1000 gal | lb./ |
| Phosphorus ($P_2O_5$) | 26 lb./ 1000 gal | lb./ |
| Potasium ($K_2O$) | 25 lb./ 1000 gal | lb./ |

*Laboratory data often are given in parts per million (ppm). To convert ppm to pct., divide by 10,000. To convert % nutrient in manure to nutrient per ton of solid manure or per 1000 gal. of liquid manure: % nutrient in manure x 20 = lb. nutrients/ton; % nutrient in manure x 85 = lb. nutrients/1000 gal.

2. Soil information

| Soil | Example | Your Farm |
|---|---|---|
| Texture | silty clay loam | |
| Soil pH | 6.2 | |
| Available P* | 50 lb./acre | lb./acre |
| Exchangeable K* | 175 lb./acre | lb./acre |

*Maintenance removal rates are used for P and K because soil test levels are high enough that no specific recommendation is needed.

**Section C. Nutrient Needs of Crop**

| | Example | Your Crop |
|---|---|---|
| Crop to be grown | corn, grain | ______ |
| Expected yield per acre | 150 bu. | ______ |

Nutrients needed per acre (based on soil test report or Table 3)*

| | Example | Your Crop |
|---|---|---|
| N | 150 lb./acre | ______ lb./acre |
| $P_2O_5$ | 60 lb./acre | ______ lb./acre |
| $K_2O$ | 45 lb./acre | ______ lb./acre |

*Maintenance removal rates are used for P and K because soil test levels are high enough that no specific application is needed. N need = 150 bu x 1.0 lb/bu. (from Table 3) = 150 lb/acre.

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**Section D. Determine Annual Rate of Manure Application**

1. Organic N in manure (per ton or per 1000 gal.)
Lb. total N (B.1) - (lb. ammonium N (B.1) + lb. nitrate N (B.1)( = lb. organic N

Example: 33 - (19 + — ) = 14 lb. organic N/1000 gal
Your farm ______ - (______ + ______) = ______lb. organic N/______

2. Calculate amount of organic N in manure (per ton or 1000 gal.) available the first year.
Lb. organic N (D.1) x mineralization factor (use .35) = lb. available organic N

Example: 14 x .35 = 4.9 lb. available organic N/1000 gal
Your farm:______ x______ = ______lb. available organic N/______

3. Plant-available N in manure (per ton or 1000 gal.) (Use either a or b below.)
   a. Incorporated application of manure
   Lb. available organic N (D.2) + lb. ammonium N (B.1) + lb. nitrate N (A1) = lb. plant-available N

   Example: 4.9 + 19 + — = 23.9 lb. available N/1000 gal
   Your Farm:______ + ______ + ______ = ______lb. available N/______

   b. Surface application of manure (assumes approximately 1/3 ammonium N will be lost by ammonia volatilization)
   Lb. available organic N (D.2) + [lb. ammonium N (B.1) x .66] + lb. nitrate N (B.1) = lb. plant-available N

   Example: N/A + [______ x.66 ] + ______ = ______lb. available N/ ______
   Your farm:______ + [______ x.66 ] + ______ = ______lb. available N/ ______

4. N fertilizer recommendation adjusted for residual N from manure applications the last 3 years
   a. Residual N from manure applied 1 year ago (if none, proceed to b.)
   Lb. organic N (D.1) x mineralization factor (use .18) x tons or 1000-gal. units manure applied / acre (your records) = lb. residual N/acre

   Example: 14 x .18 x 4.0 = 10.1 lb. residual N/acre
   Your farm: ______ x .18 x ______ = ______lb. residual N/acre

b. Residual N from manure applied 2 years ago (if none, proceed to c.)
Lb. organic N (D.1) x mineralization factor (use .09) x tons or 1000-gal. units manure applied/acre (your records) = lb. residual N/acre

Example: _–_ x .09 x _–_ = _–_lb. residual N/acre
Your farm: _____ x .09 x _____ = _____lb. residual N/acre

c. Residual N from manure applied 3 years ago (if none, proceed to step d.)
Lb. organic N (D.1) x mineralization factor (use .04) x tons or 1000-gal. units manure applied/acre (your records) = lb. residual N/acre

Example: _–_ x .04 x _–_ = _–_lb. residual N/acre
Your farm: _____ x .04 x _____ = _____lb. residual N/acre

d. Total residual N from applications over 3 years
From 1 year ago (D.4a) + from 2 years ago (D.4.b) + from 3 years ago (D.4.c) = total lb. residual N/acre

Example: _10.1_ + _–_ + _–_ = _10.1_total lb. residual N/acre
Your farm: _____ + _____ + _____ = _____total lb. residual N/acre

e. Adjusted N requirement of crop
Lb. N needed by crop (C) - lb. residual N (D.4.d) = lb. additional N required/acre

Example: _150_ - _10.1_ = _139.9_lb. N required/acre
Your farm: _____ - _____ = _____lb. N required/acre

5. Annual rate of manure (per ton or 1000-gal.) to be applied

a. Application rate based on amount of N needed by crop
Lb. additonal N required (D.4.e) ÷ lb. available N in manure (D.3.a or D.3.b) = tons or 1000-gal. units of manure/acre

Example: _139.9_ ÷ _23.9_ = _5.854_manure "units"/acre
Your farm: _____ ÷ _____ = _______manure "units"/acre

b. Application rate based on amount of $P_2O_5$ needed by crop
Lb. $P_2O_5$ needed by crop (C) ÷ lb. $P_2O_5$ in manure (B.1) = tons or 1000-gal. units of manure/acre.

Example: _60_ ÷ _26_ = _2.308_manure "units"/acre
Your farm: ______ ÷ _____ = ______manure "units"/acre

c. Application rate based on $K_2O$ needed by crop.
Lb. $K_2O$ needed by crop (C) ÷ lb. $K_2O$ in manure (B.1) = tons or 1000-gal. units of manure/acre.

Example: _45_ ÷ _25_ = _1.8_manure "units"/acre
Your farm: ______ ÷ ______ = ______manure "units"/acre

d. Rate selected
If your aim is to supply all the crop's N ,$P_2O_5$ and $K_2O$ needs from manure, select the higher of the three values (D.5.a, D.5.b or D.5.c). If your aim is to maximize use of the nutrients in manure, select the lower of the three values. Then supplement with commmercial fertilizer to supply the rest of the nutrients required by the crop.

Example:_1.8_manure "units"/acre
Your farm:_____manure "units"/acre

**Section E. Determine Amount of Additional Fertilizer Needed**

1. Nitrogen (Do not complete if manure rate selected supplies the required N.)

   a. Available N added by the manure
   Manure rate/acre (D.5.d) x lb. available N in manure (D.3.a or D.3.b) = lb. available N applied/acre

   Example: 1.8 x 23.9 = 43 lb. available N applied
   Your farm:_____ x _____ = _____lb. available N applied

   b. Additional fertilizer N required
   Lb. N still required/acre (D.4.e) - lb. N applied/acre (E.1.a) = lb. fertilizer N needed/acre

   Example: 139.9 - 43 = 96.9 lb. fertilizer N needed/acre
   Your farm:_____ - _____ = _____lb. fertilizer N needed/acre

2. Phosphorus (Do not complete if manure rate selected supplies the required amount of $P_2O_5$.)

   a. $P_2O_5$ added by the manure
   Manure rate/acre (D.5.d) x lb. $P_2O_5$ in manure (B.1) = $P_2O_5$ applied/acre

   Example: 1.8 x 26 = 46.8 lb. $P_2O_5$ applied/acre
   Your farm:_____ x _____ = _____lb. $P_2O_5$ applied/acre

   b. Additional fertilizer $P_2O_5$ required
   Lb. $P_2O_5$ needed by crop/acre (C) - lb. $P_2O_5$ applied/acre (E.2.a) = lb. fertilizer $P_2O_5$ needed/acre

   Example: 60 - 46.8 = 13.2 lb. fertilizer $P_2O_5$ need/acre
   Your farm: _______ - _______ - _____ lb. fertilizer $P_2O_5$ need/acre

3. Potassium (Do not complete if manure rate selected supplies the required amount of $K_2O$)

   a. $K_2O$ added by the manure
   Manure rate/acre (D.5.d) x lb. $K_2O$ in manure (B.1) = lb. $K_2O$ applied/acre

   Example: — x — = — lb. $K_2O$ applied/acre
   Your farm:_____ x _____ = _____lb. $K_2O$ applied/acre

   b. Additional fertilizer $K_2O$ required
   Lb. $K_2O$ needed by crop/acre (C) - lb. $K_2O$ applied/acre (E.3.a) = lb. fertilizer $K_2O$ needed/acre

   Example: — - — = — lb. fertilizer $K_2O$ needed/acre
   Your farm:_____ - _____ = _____lb. fertilizer $K_2O$ needed/acre

**Section F. Determine Amount of Land Required to Dispose of Annual Manure Production**

1. Annual manure nutrient production per animal, expressed as pounds of nutrient per animal. Tons or 1000-gal. units of manure/animal (Table 4) x lb. nutrient in manure (B.1 and D.3.a or D.3 b) x No. animals (A) = lb. nutrients/yr.

   Example:
   Growing-finishing:
   N = .530 x 23.9 (D.3.a or b) x 1890 = 23,940.6 lb. available N/yr.
   $P_2O_5$ = .530 x 26 (B.1) x 1890 = 26,044.2 lb. $P_2O_5$/yr
   $K_2O$ = .530 x 25 (B.1) x 1890 = 25,042.5 lb. $K_2O$/yr.

Your farm:
N = ______ x ______ (D.3a or b) = ________lb. available N/yr.
$P_2O_5$ = ______ x ______ (B.1) ______lb. $P_2O_5$/yr
$K_2O$ = ______ x ______ (B.1) = ______lb. $K_2O$/yr

Total nutrient production/yr. from enterprise:
N = 23,941 lb. (growing-finishing) + ——— lb. (nursery) + ——— lbs. (farrowing) + ——— lb. (breeding - gestation) = 23,941 lb. available N/yr.
$P_2O_5$ = 26,044 lb. (growing-finishing) + ——— lb. (nursery) + ——— (farrowing) + lb. (breeding - gestation) = 26,044 lb. available $P_2O_5$/yr
$K_2O$ = 25,042 lb. (growing-finishing) + ——— lb. (nursery) + ——— lbs. (farrowing) + ——— lb. (breeding - gestation) = 25,042 lb available $K_2O$/yr

Your farm:
N = ________lb. (growing-finishing) + ________lb. (nursery) + ________lb. (farrowing) + ________lbs. (breeding - gestation) = ________lb. available N/yr
$P_2O_5$ = ________lb. (growing-finishing) + ________lb. (nursery) + ________lb. (farrowing) + ________lb. (breeding - gestation) = ________lb. available $P_2O_5$/yr
$K_2O$ = ________lb (growing-finishing + ________lb. (nursery) + ________lb. (farrowing) + ________lbs. (breeding - gestation) = ________lb. available $K_2O$/yr

2. Total cropland area required for annual manure application, expressed as acres/year. Lb. manure nutrient/yr. (F.1) ÷ lb. nutrient needed by crop (C or D.4e) = acres needed/yr.

Example:
N = 23,941 (F.1) ÷ 139.9 (D.4e) = 171.1 acres/yr.
$P_2O_5$ = 26,044 (F.1) ÷ 60 (C) = 434.1 acres/yr.
$K_2O$ = 25,042 (F.1) ÷ 45 (C) = 556.5 acres/yr.

Your farm:
N = ________(F.1) ÷ ________(D.4e) = ________acres/yr.
$P_2O_5$ = ________(F.1) ÷ ________(C) = ________acres/yr.
$K_2O$ = ________(F.1) ÷ ________(C) = ________acres/yr.

The first line is number of acres required if basing manure application rate on the crop's N needs. The second line is number of acres required if basing manure application rate on the crop's $P_2O_5$ needs. The third line is number of acres required if basing manure application rate on the crop's $K_2O$ needs.

The worksheet example shows that the proper manure application rate on 150-bushel corn land would be 5,854 gal. per acre if the manure is used to supply all N, P, and K needed by the crop or 1,800 gal. if the fertilizer value is maximized (D.5). In the case of our worksheet example, this 1890-head growing-finishing building would require a minimum of 171 acres at the 5,854 gal. per acre swine manure application rate or maximum of 556 acres at the 1,800 gallon/acre rate (F.2).

If manure was applied to maximize its fertilizer value based on K needed (1,800 gal./acre), calculations indicate that an additional 97 lb. of N and 13 lb. of $P_2O_5$ are needed to meet the corn nutrient requirements.

## Estimating the Fertilizer Value of Manure from a Swine Enterprise

Calculating the swine manure fertilizer value produced annually on your farm is important if you are planning a new operation or expansion of your present one. In Section F.1, you calculated the amounts of N, $P_2O_5$, and $K_2O$ produced annually in your swine operation. The value of the nutrients in the manure can be estimated by multiplying the pounds of nutrient produced per year by the price per pound of commercial fertilizer nutrients.

Example:

| | lb/yr (Sec F.1) | | Price | | Value ($) |
|---|---|---|---|---|---|
| Available N | 23,941 | x | 0.16 * | = | $ 3,830.56 * |
| $P_2O_5$ | 26,044 | x | 0.23 | = | $ 5,990.12 |
| $K_2O$ | 25,042 | x | 0.12 | = | $ 3,005.04 |
| | | | Total | | $ 12,825.72 |

Your farm:

| | lb/yr (Sec F.1) | | Price ($/lb.) | | Value ($) |
|---|---|---|---|---|---|
| N | | x | | = | $ |
| $P_2O_5$ | | x | | = | $ |
| $K_2O$ | | x | | = | $ |
| | | | Total | | $ |

*Estimated cost of anhydrous ammonia; the N value would approximately double if based on other liquid nitrogen sources.

The total value is the estimated gross value of the manure nutrients and does not include cost of labor, equipment, maintenance and management of the manure system. However, these are fixed costs which would still be incurred for manure disposal regardless of whether or not the manure is used for fertilizer.

## How to Obtain a Swine Manure Analysis

Laboratory analysis is the most accurate way to ascertain the nutrient value of the manure from your swine enterprise. It should include information on dry matter, (total solids) ammonium N, total nitrogen (ammonium plus organic N), P and K content and possibly Mg and Ca content in some areas. For the names of commercial laboratories that provide this service, contact your County Extension Office. The key to the reliability of a manure analysis is adequate agitation of the manure and proper sampling. However, it is often not practical to agitate a pit just to obtain a few samples. A series of samples from each system over time should be taken for analysis to establish a pattern, to determine the amount of variation in nutrient contents and to make any adjustments of application rates. Assuming similar management of the operation, a producer can use last year's manure analysis as a guide for establishing application rates until results of recent samples are received. Record what manure has been applied to certain fields to make any later nutrient adjustments. Quick on-the-farm nitrogen tests, such as with a N-meter,can provide estimates of available N in liquid manure samples to adjust land application rates if N is the determining nutrient for manure applications, while emptying storages. However, verify these estimates occasionally with subsamples of manure with laboratory analyses.

Considerable nitrogen can be lost if a sample is not correctly taken, handled and preserved. For liquid samples, agitate the contents of a manure pit to obtain a well-mixed sample or take samples while loading the tanker. Place the sample in a quart-sized plastic container with a screw-on lid and tighten well. **(Caution: Be sure of adequate ventilation by opening doors and windows of the swine facility when agitating before taking a liquid sample. Gases liberated could kill animals and people quickly. If possible, remove all animals from the building.)**

Preserve a liquid sample immediately either by freezing or by adding 2-3 drops of muriatic acid to lower its pH. Muriatic acid can be applied with an inexpensive medicine dropper, but be extremely careful when doing so and wear goggles to avoid acid burns.

For solid manure, obtain samples from several parts of the manure source and mix well. Place a composite sub- sample in a plastic bag, twist and tie tightly. For added safety, place the sample in a second plastic bag. Preserve immediately by freezing. Deliver the manure sample to the laboratory personally or package well in a strong, insulated container and ship the fastest way possible. Insist that the sample be kept frozen or refrigerated en route and at the laboratory until tested.



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