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## EC89-117 Fertilizing Crops with Animal Manure

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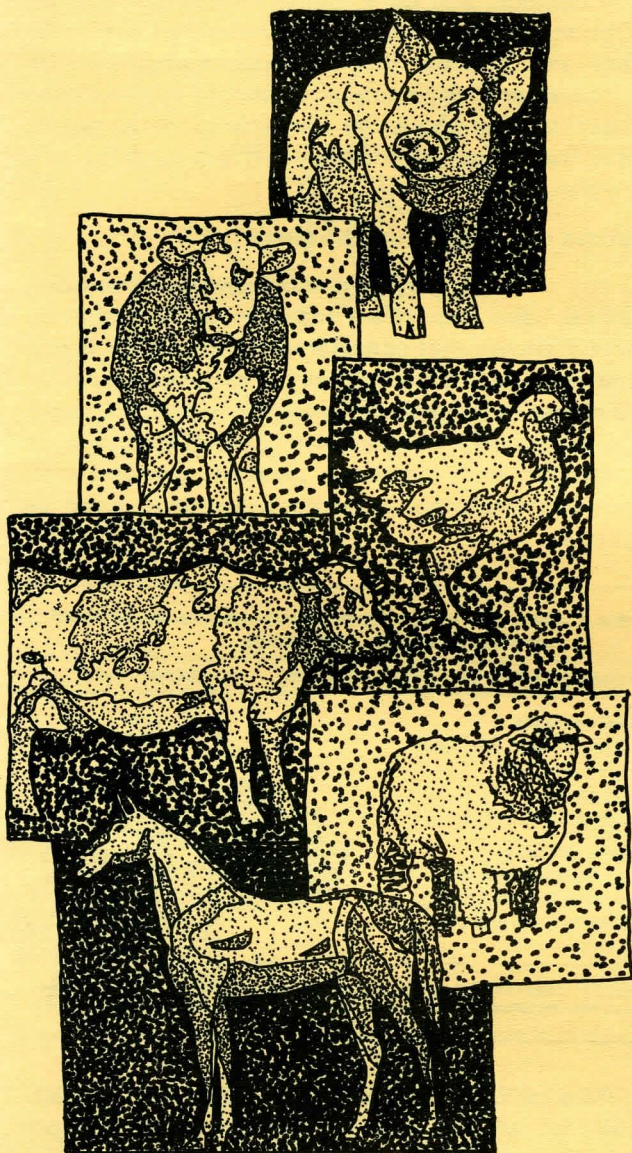
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# Fertilizing Crops With Animal Manure

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# Fertilizing Crops With Animal Manure<sup>1</sup>

Until the mid 1970s, livestock manure was considered a liability because its value as a nutrient source rarely offset the cost of handling, storing and applying manure to the land. Usually the goal was to dispose of manure as conveniently and cheaply as possible.

Today concern about the environment, significantly higher fertilizer prices and tight profit margins have caused many livestock producers to re-evaluate their manure handling programs. Manure is being viewed as an asset to be stored and applied in a way that maximizes its value as a fertilizer.

Land application of animal manure can provide a hedge against the high price and possible short supplies of commercial fertilizers. Animal manure application increases soil organic matter content and enhances soil structure, improving the soil tilth and nutrient- and water-holding capacities. Proper land application is compatible with prevention of soil and water pollution.

This publication provides information on which to base decisions concerning the use of animal manure as a fertilizer. Discussed are: the factors that affect manure's nutrient content; how to manage manure to minimize nutrient loss; plant-availability of manure nutrients; how to determine manure application rates and supplementary commercial fertilizer rates. A worksheet (with examples) takes you step by step through the process of calculating proper application rates and land needed for utilizing manure.

Decisions on manure handling and disposal involve other considerations such as: labor availability and cost; type of livestock production system; equipment needs; manure application scheduling; and conflicts with other production activities. These other factors must be taken into account when planning a manure management system.

## Factors Affecting the Nutrient Content of Animal Manure

The amounts and plant-availability of nutrients in manure vary considerably from farm to farm. The factors that influence manure nutrient content and availability for each animal species are: (a) composition of the rations fed to livestock; (b) method of waste collection and storage; (c) ration, bedding, soil and/or water added; and (d) method and time of land application.

## Ration Composition

The levels of nutrients in the manure are a reflection of the ration. Changing the levels of inorganic salts (sodium, calcium, potassium, magnesium, phosphate and chloride), feed additives (sulfa drugs or antibiotics) and other elements (copper, arsenic) in rations changes the concentrations of these elements and, possibly, the rate of decomposition of organic matter in the manure. Changing the kinds and amounts of roughages or concentrations in rations alters the composition of manure and its value as a fertilizer.

## Method of Collection and Storage

Type of housing system and the manure handling method used also affect manure nutrient content. *Table 1* shows that considerable nitrogen (N) is lost when manure is dried naturally or exposed to rain, as is the case in an open-lot livestock system. Nitrogen loss is reduced in a completely covered feedlot. Loss of nitrogen from manure is generally greatest with long-term treatment or storage systems, such as lagoons.

**Table 1. Nitrogen losses from animal manure as affected by method of handling and storage**

| <i>Manure handling and storage method</i> | <i>Nitrogen loss<sup>a</sup></i> |
|---|----------------------------------|
| <b>Solid systems</b>                      | <b>pct.</b>                      |
| Daily scrape and haul                     | 15-35                            |
| Manure pack                               | 20-40                            |
| Open lot                                  | 40-60                            |
| Deep pit (poultry)                        | 15-35                            |
| <b>Liquid systems</b>                     |                                  |
| Anaerobic deep pit                        | 15-30                            |
| Above ground storage                      | 15-30                            |
| Earthen storage pit                       | 20-40                            |
| Lagoon                                    | 70-80                            |

<sup>a</sup>Based on composition of manure applied to the land vs. composition of freshly excreted manure, adjusted for dilution effects of the various systems.

Phosphorus (P) and potassium (K) losses are negligible for all but open-lot and unagitated lagoon manure handling methods. In an open-lot, 20-40 percent of the phosphorus and 30-50 percent of the potassium can be lost to runoff and leaching. However, much of these nutrients can be retained by use of runoff control systems such as settling basins and detention ponds.

With an unagitated lagoon, 50-80 percent of the phosphorus in manure may settle out in the sludge layer and be unavailable if only the liquid is applied to the land.

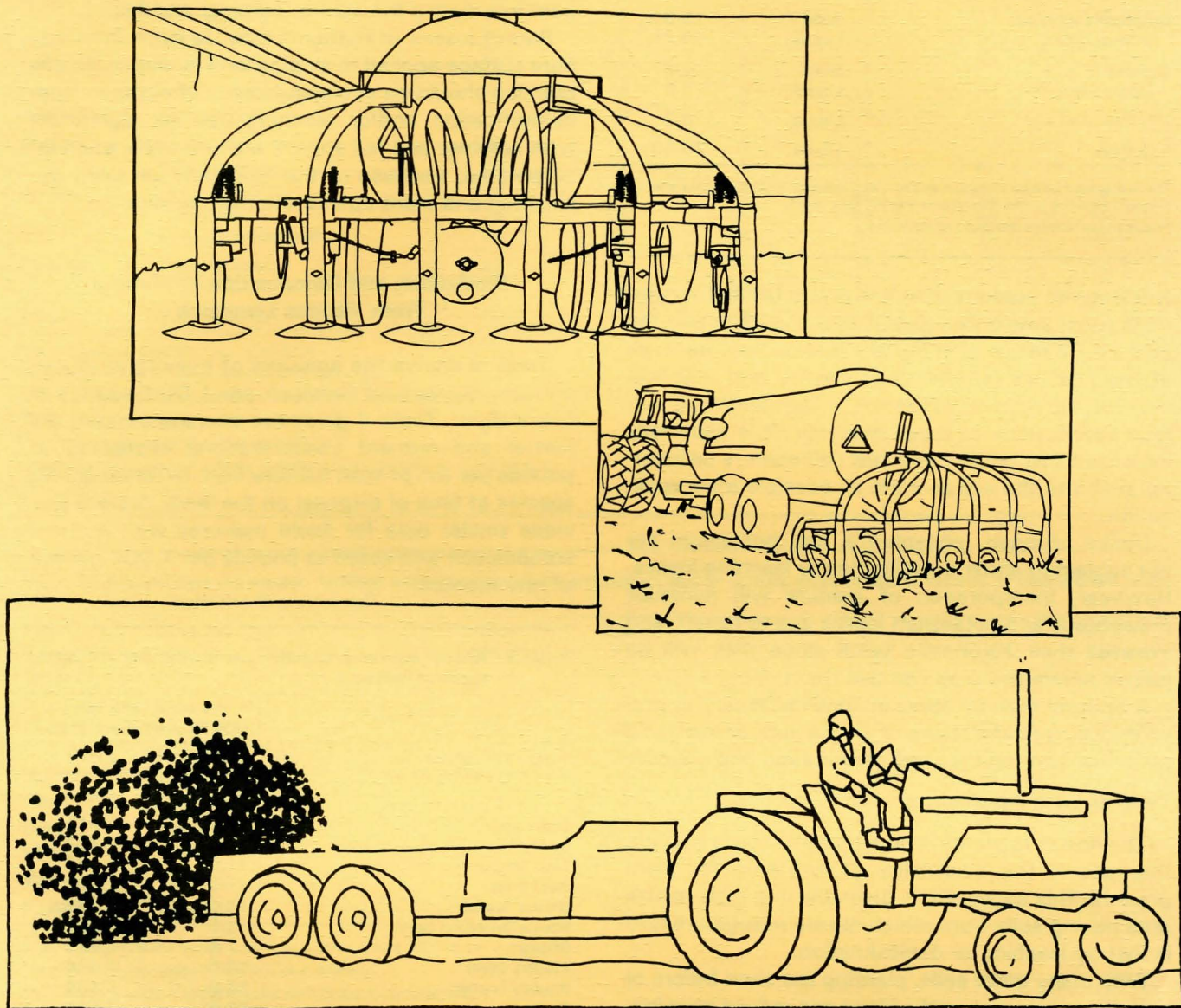
Addition of bedding or water increases the total nutrient content in manure but increases weight and volume of manure much more. The overall effect is

<sup>1</sup>Adapted from "Utilization of Animal Manure as Fertilizer," ID101, Purdue University, West Lafayette, Indiana.



to reduce the concentration of the nutrients. The added bulk increases handling cost when transported and spread on the soil. Feed spillage also increases the manure's nutrient content.

In liquid manure systems, however, feed spillage together with inadequate agitation can cause sludge buildup, making removal difficult.



### Method of Land Application

Animal manure is applied to land by surface broadcasting using a manure spreader, with irrigation water or tank wagon followed by plowing or disking, by broadcasting without incorporation, or by injection (knifing) under the soil surface. Maximum nutrient benefit is realized when manure is incorporated into the soil immediately after application (*Table 2*).

With solid manure, immediate incorporation not only minimizes nitrogen loss to the air, it allows soil microorganisms to start decomposing the organic fraction of the manure. This increases the rate at which nutrients become available to the crop.

With liquid manure systems the practice of injecting, chiseling or knifing the manure beneath the soil surface also reduces nitrogen volatilization and potential runoff. Incorporation of either solid or liquid manure reduces odor problems. Large nitrogen losses usually result from application by irrigation equipment. Actual losses depend on  $\text{NH}_4\text{-N}$  (ammonium) content, and increase as the irrigation water pH increases.

Nitrogen loss by ammonia volatilization from surface applications is greater on dry, warm, windy days than on days that are humid and/or cold. That means loss generally is higher during the late spring



**Table 2. Nitrogen losses from animal manure to the air as affected by method of application**

| Method of application                            | Type of manure | Nitrogen loss <sup>a</sup> |
|--|----------------|----------------------------|
|  |                | pct.                       |
| Broadcast <i>without</i> incorporation           | Solid          | 15-30                      |
|  | Liquid         | 10-25                      |
| Broadcast <i>with</i> incorporation <sup>b</sup> | Solid          | 1-5                        |
|  | Liquid         | 1-5                        |
| Injection (knifing)                              | Liquid         | 0-2                        |
| Irrigation                                       | Liquid         | 30-40                      |

<sup>a</sup>Percent of total nitrogen in manure applied which was lost within three days after application; wind and temperature effects may increase losses.

<sup>b</sup>Incorporation within a few hours of application.

and summer seasons than it is in late fall and winter. Also, most ammonia volatilization occurs within the first 24-72 hours after surface application. Because of the high pH (alkalinity) of poultry and veal calf manure, nitrogen volatilization is high following surface applications of these manures. It is **especially important** that poultry and veal calf manure be incorporated into the soil as soon as possible after application.

Unlike nitrogen, phosphorus and potassium are not subject to either volatilization or leaching losses. However, incorporation of manure will minimize phosphorus and potassium losses due to runoff, and increase their agronomic value since they will be placed where the crop can use them.

A uniform manure application is necessary to prevent local concentrations of ammonium or inorganic salts that can reduce seed germination and yields.

#### Time of Land Application

The nearer to planting time that manure is applied, the greater the availability of nutrients for plant growth. This especially is desirable in a high rainfall area having soils from which nitrate nitrogen readily is lost by leaching or denitrification.

With many other soils, planting too soon before or after heavy manure applications can reduce germination and seedling growth because of potentially high salt concentrations near the soil surface. For that reason liquid application is suggested after corn is four to six inches tall.

Normally producers must program manure application times to fit availability of labor and suitable cropland. Other factors determining application time are the amount of manure storage capacity on the farm, and prevailing weather conditions. It is important not to drive over wet soils with heavy equipment because of the severe compaction that may result.

Timing options available include: (i) early spring applications on land to be planted to row crops

(best); (ii) spring and summer applications to meadows following hay cutting; (iii) late summer and fall applications following small grain harvest; (iv) fall applications on land following row crop harvest; (v) winter application on level soils to be seeded to row crops next season. Manure also can be applied to pastures during the spring, summer and fall.

Runoff losses of nutrients may be large from manure surface-applied to sloping land in winter, so this practice should be avoided. Losses of nitrogen from denitrification and/or leaching can be significant with summer and fall applied manure even when incorporated, because of the long time between application and plant uptake the next season.

#### Production and Composition of Manure From Various Livestock

Table 3 shows the amounts of manure produced annually by various livestock per 1,000 pounds of live weight. Table 4 gives the average percent dry matter and nutrient concentrations expressed as pounds per ton of solid manure from different animal species at time of disposal on the land. Table 5 provides similar data for liquid manures with nutrient composition expressed as pounds per 1,000 gallons of raw manure.

**Table 3. Annual manure production per animal unit for various types of livestock**

| Type of livestock   | Raw manure production per 1,000 lb. animal weight <sup>a</sup> |        |
|---------------------|--|--------|
|                     | Solid  | Liquid |
|                     | ton/yr   | gal/yr |
| Dairy cow           | 15.0   | 3,614  |
| Veal calf           | 7.5  | 1,752  |
| Beef feeder         | 11.0   | 2,738  |
| Beef cow            | 11.5   | 2,884  |
| Swine feeder        | 18.0   | 4,380  |
| Swine breeding herd | 6.5  | 1,533  |
| Sheep               | 7.5  | 1,679  |
| Poultry layer       | 10.0   | 2,336  |
| Poultry broiler     | 13.0   | 3,139  |
| Turkey              | 11.0   | 2,592  |
| Horse               | 8.5  | 2,044  |

<sup>a</sup>Raw manure includes feces and urine.

The actual fertilizer value of manure for a specific farm might differ considerably from Tables 4 and 5 due to the factors discussed above. Nevertheless, these figures can serve as a guideline in determining land application rates if a nutrient analysis of manure is not available. **For accurate manure application rate calculations, the nutrient content of manure must be determined by laboratory analysis.** How to obtain such an analysis is discussed at the end of this publication.



**Table 4. Approximate dry matter, fertilizer nutrient composition and dollar value of various types of animal manure at time applied to the land — solid handling systems<sup>a</sup>**

| Type of livestock   | Bedding vs. no bedding       | Dry matter | Total N <sup>b</sup> | NH <sub>4</sub> <sup>c</sup> | P <sub>2</sub> O <sub>5</sub> <sup>d</sup> | K <sub>2</sub> O <sup>e</sup> | Value per ton <sup>f</sup> |
|---------------------|------------------------------|------------|----------------------|------------------------------|--|-------------------------------|----------------------------|
|                     |                              | pct.       |                      | lb/ton                       |  |                               |                            |
| <b>Swine</b>        | Without bedding              | 18         | 10                   | 6                            | 9  | 8                             | \$ 5.22                    |
|                     | With bedding                 | 18         | 8                    | 5                            | 7  | 7                             | 4.16                       |
| <b>Beef cattle</b>  | Without bedding <sup>g</sup> | 52         | 21                   | 7                            | 14   | 23                            | 9.57                       |
|                     | With bedding                 | 50         | 21                   | 8                            | 18   | 26                            | 11.03                      |
| <b>Dairy cattle</b> | Without bedding              | 18         | 9                    | 4                            | 4  | 10                            | \$ 3.65                    |
|                     | With bedding                 | 21         | 9                    | 5                            | 4  | 10                            | 3.70                       |
| <b>Sheep</b>        | Without bedding              | 28         | 18                   | 5                            | 11   | 26                            | \$ 8.33                    |
|                     | With bedding                 | 28         | 14                   | 5                            | 9  | 25                            | 7.40                       |
| <b>Poultry</b>      | Without litter               | 45         | 33                   | 26                           | 48   | 34                            | \$24.51                    |
|                     | With litter                  | 75         | 56                   | 36                           | 45   | 34                            | 26.32                      |
|                     | Deep pit (compost)           | 76         | 68                   | 44                           | 64   | 45                            | 36.01                      |
| <b>Turkeys</b>      | Without litter               | 22         | 27                   | 17                           | 20   | 17                            | \$12.31                    |
|                     | With litter                  | 29         | 20                   | 13                           | 16   | 13                            | 9.51                       |
| <b>Horses</b>       | With bedding                 | 46         | 14                   | 4                            | 4  | 14                            | \$ 4.22                    |

<sup>a</sup>Manure spreader capacity: 1 bu. = 40-60 lb.

<sup>b</sup>Ammonium N plus organic N, which is slow releasing.

<sup>c</sup>Ammonium N, which is available to the plant during the growing season.

<sup>d</sup>To convert to elemental P, multiply by 0.44.

<sup>e</sup>To convert to elemental K, multiply by 0.83.

<sup>f</sup>Based on a per lb. value of \$.20 for available N, \$.30 for P<sub>2</sub>O<sub>5</sub> and \$.13 for K<sub>2</sub>O.

<sup>g</sup>Open dirt lot.

**Table 5. Approximate dry matter, fertilizer nutrient composition and dollar value of various types of animal manure at time applied to the land — liquid handling systems<sup>a</sup>**

| Type of livestock   | Manure storage      | Dry matter | Total N <sup>b</sup> | NH <sub>4</sub> <sup>c</sup> | P <sub>2</sub> O <sub>5</sub> <sup>d</sup> | K <sub>2</sub> O <sup>e</sup> | Value per 1,000 gal <sup>f</sup> |
|---------------------|---------------------|------------|----------------------|------------------------------|--|-------------------------------|----------------------------------|
|                     |                     | pct.       |                      | lb/1,000 gal                 |  |                               |                                  |
| <b>Swine</b>        | Liquid pit          | 4          | 36                   | 26                           | 27   | 22                            | \$16.16                          |
|                     | Lagoon <sup>g</sup> | 1          | 4                    | 3                            | 2  | 4                             | 1.79                             |
| <b>Beef cattle</b>  | Liquid pit          | 11         | 40                   | 24                           | 27   | 34                            | \$18.28                          |
|                     | Lagoon <sup>g</sup> | 1          | 4                    | 2                            | 9  | 5                             | 3.87                             |
| <b>Dairy cattle</b> | Liquid pit          | 8          | 24                   | 12                           | 18   | 29                            | \$12.29                          |
|                     | Lagoon <sup>g</sup> | 1          | 4                    | 2.5                          | 4  | 5                             | 2.44                             |
| <b>Veal calf</b>    | Liquid pit          | 3          | 24                   | 19                           | 25   | 51                            | \$18.28                          |
| <b>Poultry</b>      | Liquid pit          | 13         | 80                   | 64                           | 36   | 96                            | \$37.20                          |

<sup>a</sup>Application conversion factors: 1,000 gal = about 4 tons; 27,154 gal = 1 acre inch.

<sup>b</sup>Ammonium N plus organic N, which is slow releasing.

<sup>c</sup>Ammonium N, which is available to the plant during the growing season.

<sup>d</sup>To convert to elemental P, multiply by 0.44.

<sup>e</sup>To convert to elemental K, multiply by 0.83.

<sup>f</sup>Based on a per lb value of \$.20 for available N, \$.30 for P<sub>2</sub>O<sub>5</sub> and \$.13 for K<sub>2</sub>O.

<sup>g</sup>Includes feedlot runoff water and is sized as follows: **single cell lagoon** — 2 cu ft/lb animal wt; **two-cell lagoon** — cell 1, 1-2 cu ft/lb animal wt and cell 2, 1 cu ft/lb animal wt.

### Availability of Manure Nutrients to Crops

Not all the nutrients present in manure are readily available to a crop in the year of application. To be utilized by plants, manure nutrients must be converted into soluble inorganic ions by microbial decomposition.

Most of the nitrogen in animal manure is in ammonium (NH<sub>4</sub>) and organic forms. All of the ammonium potentially is available to the crop during the first

year after manure application. However, if manure is broadcast on the soil surface and not incorporated, about one-third of the ammonium will be lost to the air as ammonia (NH<sub>3</sub>) gas. About five percent is lost when manure is injected or incorporated.

Nitrogen in the organic form must be converted into inorganic forms (ammonium and nitrate) before it can be used by plants. The amounts of organic nitrogen converted to plant-available forms during the



first cropping year after application vary according to both livestock species and manure handling system. *Table 6* gives the proportions of organic nitrogen released (mineralized) from various types of manure during the first season. The amounts further released during the second, third and fourth cropping

**Table 6. Proportions of organic nitrogen in various manures mineralized during the first cropping season after application**

| Livestock species | Manure handling system | Mineralization factor |
|-------------------|------------------------|-----------------------|
| Swine             | Fresh                  | 0.50                  |
|                   | Anaerobic liquid       | 0.35                  |
|                   | Aerobic liquid         | 0.30                  |
| Beef cattle       | Solid without bedding  | 0.35                  |
|                   | Solid with bedding     | 0.25                  |
|                   | Anaerobic liquid       | 0.30                  |
|                   | Aerobic liquid         | 0.25                  |
| Dairy cattle      | Solid without bedding  | 0.35                  |
|                   | Solid with bedding     | 0.25                  |
|                   | Anaerobic liquid       | 0.30                  |
|                   | Aerobic liquid         | 0.25                  |
| Sheep             | Solid                  | 0.25                  |
| Poultry           | Deep pit               | 0.45                  |
|                   | Solid with litter      | 0.30                  |
|                   | Solid without litter   | 0.35                  |
| Horses            | Solid with bedding     | 0.20                  |

years after application are usually about 50, 25 and 12.5 percent, respectively, of that mineralized in the initial season.

Generally, 80-90 percent of the phosphorus and 80-100 percent of the potassium in animal manures are available to plants the first year. In most cases, we can assume that all of the phosphorus and potassium in manures is plant-available.

### Determining How Much Animal Manure to Apply

In order to calculate manure application rates, crop nutrient requirements first must be determined.

First, account for nutrients already in the soil. A soil test will determine the need for the major nutrients. Soil tests are essential to determine fertilizer rates and to calculate proper manure application rates. A composite surface (zero to six inch) and subsurface sample(s) are needed to characterize the soil in each uniform area (20-80 acres) of a field. Two subsurface samples are recommended, eight to 24 inch and 24-36 inch. The surface sample is used to determine pH, lime requirement, phosphorus, potassium, zinc and sulfur needs. Residual nitrate levels are determined with the surface and subsurface samples.

Second, if the fields are irrigated, the irrigation water should be tested for nitrate concentration. Nitrogen applied in the irrigation water will reduce the

need for supplemental nitrogen from manure or fertilizer. In addition, previous legume crops supply nitrogen, and this nitrogen reduces the total supplemental nitrogen needed to be applied. *Table 7* contains the nitrogen recommendations for corn production.

**Table 7. Nitrogen recommended for corn at various yield goals based on 50 lbs residual nitrogen in soil profile (NebGuide G74-174).**

| Yield Goal + | Recommended Nitrogen |
|--------------|----------------------|
| bu/acre      | lbs N/acre           |
| 60           | 60                   |
| 80           | 80                   |
| 100          | 100                  |
| 120          | 120                  |
| 140          | 150                  |
| 160          | 170                  |
| 180          | 200                  |
| 200          | 220                  |
| 220          | 250                  |
| 240          | 280                  |

+ If a residual nitrogen soil test is available, adjust the table values. If soil test values are different than 50 lbs, adjust nitrogen rate by the number of lbs residual Nitrogen is greater (or less) than 50. For example: If a soil test indicates 100 lbs residual nitrogen, reduce table rates by 50 lbs nitrogen.

Nitrogen applied in irrigation water up to pollination can also be subtracted from the recommended nitrogen rate on a pound for pound basis.

If no soil residual nitrogen values are available credits of 40, 100, 100 and 50 lbs nitrogen per acre can be taken for previous crops of soybeans, alfalfa, sweet clover and red clover, respectively.

Instructions for adjusting nitrogen recommendations due to soil nitrogen, irrigation water nitrogen and previous crops are in the table footnotes. The table can be used directly if a nitrogen soil test is unavailable.

Fertilizer recommendations are based on soil test levels, soil type, yield goal, and previous cropping history. It is important that all pertinent information be provided on the soil test information sheet. Yield goals should be established at no more than five percent higher than the five year average for the field unless significant changes in management have occurred.

After the supplemental nutrient needs of the crop and the nutrient content of animal manure are known, you can determine (i) how much manure can be applied safely to how much land, and (ii) if additional commercial fertilizer is needed for efficient crop production. Following is a worksheet for making these application rate calculations. It presents an example situation using hypothetical manure and soil/crop data, then provides space for inserting the data that reflect your situation.

Soil tests and fertilizer recommendations, along with manure analyses, are necessary to calculate proper agronomic application rates. However, if manure analysis information is lacking, the data in *Tables 4* and *5* can be used to calculate approximate rates.



# Worksheet for Determining Animal Manure Applications Rates and Size of Disposal Area

## Example Situation

A swine feeder has a modified open front finishing unit (110' x 30'). The daily capacity is 400 head. Manure is collected to land without immediate incorporation. The manure contains 4,200 ppm total N, 3,100 ppm ammonium N, 1,397 ppm P, and 2,167 ppm K. The area to be manured received 3,000 gallons per acre each of the last three years and will be planted to corn this spring (180 bushel per acre yield goal). The crop will receive 12 inches of irrigation water containing 10 ppm  $\text{NO}_3^-$ -N. Soil tests

taken on the field indicate there is 75 lbs of residual nitrogen in the soil, and that 40 lbs  $\text{P}_2\text{O}_5$  is recommended for optimum crop growth. No other nutrients are recommended.

To maximize use of the manure as fertilizer, what is the proper manure application rate? How much, if any, supplemental commercial fertilizer will be needed? How many acres of cropland will be required to dispose of the manure?

### A. Determine Manure Composition

- Values from manure are chemically analyzed on a wet weight (as is) basis. (Laboratory data often are given in ppm [parts per million]; to convert to percent [pct.], divide by 10,000. If composition data is not available, go to Step A.2 and use appropriate figures from *Table 4* or *5*). To convert from lbs/1,000 gals to percent, divide by 85. To convert from lbs/ton to percent divide by 20.

|                                   |   | Our example |              | Your farm |       |
|-----------------------------------|---|-------------|--------------|-----------|-------|
|                                   |   | %           | ppm          | %         | ppm   |
| Total N                           | = | <u>.42</u>  | <u>4,200</u> | _____     | _____ |
| Ammonium N                        | = | <u>.31</u>  | <u>3,100</u> | _____     | _____ |
| $\text{P}_2\text{O}_5$ (P x 2.29) | = | <u>.32</u>  | <u>3,200</u> | _____     | _____ |
| $\text{K}_2\text{O}$ (K x 1.20)   | = | <u>.26</u>  | <u>2,600</u> | _____     | _____ |

- Amount of each nutrient in manure (per ton or per 1,000 gal).

Pct. nutrient (A.1) x 20 = lb nutrient/ton

Pct. nutrient (A.1) x 85 = lb nutrient/1,000 gal.

|                        |   | Our example<br>(calculated from A.1) | Your farm<br>(calculated from A.1 or<br>derived from <i>Tables 4</i> or <i>5</i> ) |
|------------------------|---|--------------------------------------|--|
| Total N                | = | <u>36</u> lbs/ <u>1,000 gal</u>      | _____ lb/ _____  |
| Ammonium N             | = | <u>26</u> lbs/ <u>1,000 gal</u>      | _____ lb/ _____  |
| $\text{P}_2\text{O}_5$ | = | <u>27</u> lbs/ <u>1,000 gal</u>      | _____ lb/ _____  |
| $\text{K}_2\text{O}$   | = | <u>22</u> lbs/ <u>1,000 gal</u>      | _____ lb/ _____  |



**B. Determine Nutrient Needs of the Crop**

|   | Our example | Your farm |
|---|-------------|-----------|
| 1. Crop to be grown   | <u>Corn</u> | _____     |
| 2. Yield goal, bu/acre  | <u>180</u>  | _____     |
| 3. Inches of irrigation water   | <u>12</u>   | _____     |
| 4. a. Nitrate conc. in water (ppm)  | <u>10</u>   | _____     |
| b. Soil residual nitrate lbs/acre   | <u>75</u>   | _____     |
| 5. Nutrients needed for crop (from fertilizer recommendation or <i>Table 7</i> )  |             |           |
| N required (assumes 50 lbs residual N in soil)  | <u>200</u>  | _____     |
| P <sub>2</sub> O <sub>5</sub> required  | <u>40</u>   | _____     |
| 6. Adjust N requirement for nitrate N in irrigation water and nitrogen in the soil. (Go to C.1 if a non-irrigated crop is grown and soil nitrate level is unknown.) |             |           |

a. N added in irrigation water:

$$\begin{array}{ccccccc} \text{NO}_3\text{-N Conc. (B.4.a)} & \times & 2.7 & \times & \frac{\text{in water applied}}{12} & = & \text{N added in} \\ \text{in ppm} & & & & & & \text{irrigation} \\ & & & & & & \text{water} \end{array}$$

Our example: 10 ppm  $\times 2.7 \times \frac{12 \text{ inches}}{12} = \underline{27}$  lbs N/acre

Your farm: \_\_\_\_\_ ppm  $\times 2.7 \times \frac{\text{inches}}{12} = \underline{\hspace{2cm}}$  lbs N/acre

b. Adjusted N requirement for crop:

Irrigation water:

$$\begin{array}{ccccc} \text{Unadjusted N} & - & \text{N in irrigation} & = & \text{adjusted N} \\ \text{required (B.5)} & & \text{water (from B.6a)} & & \text{required} \end{array}$$

Our example: 200 lbs N/acre  $- \underline{27}$  lbs N/acre = 173 lbs N/acre

Your farm: \_\_\_\_\_ lbs N/acre  $- \underline{\hspace{2cm}}$  lbs N/acre = \_\_\_\_\_ lbs N/acre

Soil residual nitrogen:

Subtract any residual nitrogen greater than 50 lbs from adjusted N requirement.

$$\begin{array}{ccc} \text{Adjusted N} & - & (\text{Residual nitrate N}) = \text{Applied N required} \\ \text{required (B.6b)} & & \end{array}$$



Our example:

$$\underline{173} \text{ lbs N/acre} - (\underline{75} \text{ lbs residual N} - 50) = \underline{148} \text{ lbs applied N requirement}$$

Your farm: \_\_\_\_\_ lbs N/acre - ( \_\_\_\_\_ lbs residual N - 50) = \_\_\_\_\_ lbs applied N requirement.

**C. Determine Annual Rate of Manure**

1. Organic N in Manure (per ton or per 1,000 gal).

Lbs total N (A.2.) - lbs ammonium N (A.2.) = lbs organic N

Our example:  $\underline{36} - \underline{26} = \underline{10}$  lbs organic N/ 1,000 gal

Your farm: \_\_\_\_\_ - \_\_\_\_\_ = \_\_\_\_\_ lbs organic N/ \_\_\_\_\_

2. Organic N in manure (per ton or per 1,000 gal). Available the first year after addition.

Lbs organic N x mineralization factor (Table 6) = lbs available organic N

Our example:  $\underline{10} \times \underline{.35} = \underline{3.5}$  lbs available organic N/ 1,000 gal

Your farm: \_\_\_\_\_ x \_\_\_\_\_ = \_\_\_\_\_ lbs available organic N/ \_\_\_\_\_

3. Plant-available N in manure (per ton or 1,000 gal). (Use either "a" or "b" below)

a. Incorporated application of manure.

Lbs available organic N (C.2.) + lbs ammonium N (A.2.) = lbs plant available N per ton or 1,000 gal

Our example: \_\_\_\_\_ + \_\_\_\_\_ = \_\_\_\_\_ lbs available N/ \_\_\_\_\_

Your farm: \_\_\_\_\_ + \_\_\_\_\_ = \_\_\_\_\_ lbs available N/ \_\_\_\_\_

b. Surface application of manure (assumes 1/3 ammonium N lost by ammonia volatilization)

Lbs available organic N (C.2.) + [lbs ammonium N (A.2.) x .66] = lbs plant available N per ton or 1,000 gal

Our example:  $\underline{3.5} + [\underline{26} \times .66] = \underline{20.7}$  lbs available N/ 1,000 gal

Your farm: \_\_\_\_\_ + [ \_\_\_\_\_ x .66] = \_\_\_\_\_ lbs available N/ \_\_\_\_\_



4. N fertilizer recommendation adjusted for residual N from cumulative manure applications the last 3 years. (If none proceed to 5.a)

a. Amount of manure applied to field during last 3 years.

Total amount applied = \_\_\_\_\_ + \_\_\_\_\_ + \_\_\_\_\_ = tons or 1,000 gal units/acre

Our example: 3,000 + 3,000 + 3,000 = 9,000 gal/acre

Your farm: \_\_\_\_\_ + \_\_\_\_\_ + \_\_\_\_\_ = \_\_\_\_\_ /acre

b. Amount of organic N applied to field during last 3 years.

Total manure applied (C.4a) \_\_\_\_\_ x \_\_\_\_\_ lbs organic N/ton or 1,000 gal (C.1) = \_\_\_\_\_

Our example: 9,000 gal /acre x 10 lbs/ 1,000 gal = 90 lbs organic N/acre

Your farm: \_\_\_\_\_ /acre x \_\_\_\_\_ lbs/ \_\_\_\_\_ = \_\_\_\_\_ lbs organic N/acre

c. Residual N from organic N applied during last 3 years.

lbs organic N (C.4b.) applied x mineralization factor [(Table 6)/4] = lbs residual N/acre

Our example: 90 x ( .35 /4 ) = 8 lbs residual N/acre

Your farm: \_\_\_\_\_ x ( \_\_\_\_\_ /4 ) = \_\_\_\_\_ lbs residual N/acre

d. N requirement of crop adjusted for previous manure additions

Lbs N needed by crop (B.6bi, B.6bii, or B.5) - lbs residual N from manure (C.4c) = adjusted lbs N required/acre

Our example: 148 - 8 = 140 lbs N required/acre

Your farm: \_\_\_\_\_ - \_\_\_\_\_ = \_\_\_\_\_ lbs N required/acre

5. Annual rate of manure (per ton or 1,000 gal) to be applied

a. Application rate based on amount of N needed by crop.

Adjusted lbs N required per acre (C.4d) = \_\_\_\_\_ tons or 1,000 gal  
Lbs available N in manure (C.3a or c.3b) units of manure/acre

Our example: 140 / 20.7 = 6.76 1,000 gal units manure/acre

Your farm: \_\_\_\_\_ / \_\_\_\_\_ = \_\_\_\_\_ manure/acre



b. Application rate based on amount of  $P_2O_5$  needed by crop.

$$\frac{\text{lbs } P_2O_5 \text{ needed by crop (B.5)}}{\text{lbs } P_2O_5 \text{ in manure (A.2b)}} = \frac{\text{tons or 1,000 gal}}{\text{units of manure/acre}}$$

Our example:  $\frac{40}{1} \times 27 = 1.48$  1,000 gal units manure/acre

Your farm: \_\_\_\_\_ / \_\_\_\_\_ = \_\_\_\_\_ manure/acre

c. Rate selection: If your aim is to supply all the crop's N and  $P_2O_5$  needs from manure, select the **higher** of the two values (C.5a or C.5b). If your aim is to maximize use of the nutrients in manure, select the **lower** of the two values, then supplement with commercial fertilizer to supply the rest of the nutrients required by the crop. Or select a value in between that is convenient and suits your equipment and time requirement.

Our example: 3,000 gal manure/acre selected value based on equipment & convenience

Your farm: \_\_\_\_\_ manure/acre \_\_\_\_\_

#### D. Determine Amount of Additional Fertilizer Required

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

a. Available N added by the manure.

$$\begin{array}{ccc} \text{Manure rate/acre} & \times & \text{lbs available N in manure} \\ \text{(C.5c)} & & \text{(C.3a or C.3b)} \end{array} = \begin{array}{c} \text{lbs available N} \\ \text{applied/acre} \end{array}$$

Our example:  $\frac{3,000 \text{ gal}}{1} \times 20.7 \text{ per 1,000 gal} = 62.1$  lbs available N applied/acre

Your farm: \_\_\_\_\_ x \_\_\_\_\_ = \_\_\_\_\_ lbs available N applied/acre

b. Additional fertilizer N required.

$$\begin{array}{ccc} \text{Adjusted lbs N required/acre} & - & \text{lbs N applied/acre} \\ \text{(C.4d)} & & \text{(D.1a)} \end{array} = \begin{array}{c} \text{lbs fertilizer} \\ \text{N/acre} \end{array}$$

Our example:  $140 - 62.1 = 78$  lbs fertilizer N needed/acre

Your farm: \_\_\_\_\_ - \_\_\_\_\_ = \_\_\_\_\_ lbs fertilizer N needed/acre

2. Phosphorus. (Do not complete if manure rate selected supplies the required  $P_2O_5$ .)  
(In our example only 1,480 gal/acre manure needed to supply  $P_2O_5$ .)

a.  $P_2O_5$  added by the manure.

$$\begin{array}{ccc} \text{Manure rate/acre} & \times & \text{lbs } P_2O_5 \text{ in manure} \\ \text{(C.5c)} & & \text{(A.2)} \end{array} = \begin{array}{c} \text{lbs } P_2O_5 \\ \text{applied/ac} \end{array}$$

Our example: \_\_\_\_\_ x \_\_\_\_\_ = \_\_\_\_\_ lbs  $P_2O_5$  applied/acre

Your farm: \_\_\_\_\_ x \_\_\_\_\_ = \_\_\_\_\_ lbs  $P_2O_5$  applied/acre



$$\text{b. Lbs P}_2\text{O}_5 \text{ needed by crop/acre (B.5)} - \text{lbs P}_2\text{O}_5 \text{ applied/acre (D.2a)} = \text{lbs fertilizer P}_2\text{O}_5 \text{ needed/acre}$$

Our example: \_\_\_\_\_ - \_\_\_\_\_ = \_\_\_\_\_ lbs fertilizer P<sub>2</sub>O<sub>5</sub> needed/acre

Your farm: \_\_\_\_\_ - \_\_\_\_\_ = \_\_\_\_\_ lbs fertilizer P<sub>2</sub>O<sub>5</sub> needed/acre

### 3. Potassium.

a. K<sub>2</sub>O added by the manure.

$$\text{Manure rate/acre (C.5c)} \times \text{lbs K}_2\text{O in manure (A.2)} = \text{lbs K}_2\text{O applied/acre}$$

Our example: \_\_\_\_\_ x \_\_\_\_\_ = \_\_\_\_\_ lbs K<sub>2</sub>O applied/acre

Your farm: \_\_\_\_\_ x \_\_\_\_\_ = \_\_\_\_\_ lbs K<sub>2</sub>O applied/acre

b. Additional fertilizer K<sub>2</sub>O required.

$$\text{Lbs K}_2\text{O needed by crop/acre (B.5)} - \text{lbs K}_2\text{O applied/acre (D.3a)} = \text{lbs fertilizer K}_2\text{O needed/acre}$$

Our example: \_\_\_\_\_ - \_\_\_\_\_ = \_\_\_\_\_ lbs fertilizer K<sub>2</sub>O needed/acre

Your farm: \_\_\_\_\_ - \_\_\_\_\_ = \_\_\_\_\_ lbs fertilizer K<sub>2</sub>O needed/acre

## E. Determine Amount of Land Required to Dispose of Annual Manure Production

### 1. Average animal units (a.u.) per year in the livestock enterprise.

$$(\text{avg wt/animal} \times \text{avg no animals/yr}) / 1,000 \text{ lb} = \text{a.u./yr.}$$

Our example: ( 130 x 400 ) / 1,000 = 52 a.u./yr

Your farm: ( \_\_\_\_\_ x \_\_\_\_\_ ) / 1,000 = \_\_\_\_\_ a.u./yr

### 2. Annual manure nutrient production per animal unit, expressed as pounds nutrient per animal unit per year.

$$\text{Tons or gals of manure/a.u./yr (Table 3)} \times \text{lbs nutrient in manure (A.2 and C.3b)} = \text{lbs nutrients/a.u./yr}$$

Our example:

N : 4,380 x 20.7 per 1,000 gal (C.3a or b) = 91 lbs available N/a.u./yr

P<sub>2</sub>O<sub>5</sub> : 4,380 x 27 (A.2.) = 118 lbs P<sub>2</sub>O<sub>5</sub>/a.u./yr

K<sub>2</sub>O : \_\_\_\_\_ x \_\_\_\_\_ (A.2.) = \_\_\_\_\_ lbs K<sub>2</sub>O/a.u./yr



Your farm:

N : \_\_\_\_\_ x \_\_\_\_\_ (C.3a or b) = \_\_\_\_\_ lbs available N/a.u./yr

P<sub>2</sub>O<sub>5</sub> : \_\_\_\_\_ x \_\_\_\_\_ (A.2) = \_\_\_\_\_ lbs P<sub>2</sub>O<sub>5</sub>/a.u./yr

K<sub>2</sub>O : \_\_\_\_\_ x \_\_\_\_\_ (A.2) = \_\_\_\_\_ lbs K<sub>2</sub>O/a.u./yr

3. Annual manure nutrient production from the livestock enterprise, expressed as pounds year.

a.u./yr (E.1) x lbs manure nutrient/a.u. (E.2) = lbs manure nutrient/yr

Our example:

N : 52 x 91 = 4,732 lbs available N/yr

P<sub>2</sub>O<sub>5</sub> : 52 x 118 = 6,136 lb P<sub>2</sub>O<sub>5</sub>/yr

K<sub>2</sub>O : \_\_\_\_\_ x \_\_\_\_\_ = \_\_\_\_\_ lb K<sub>2</sub>O/yr

Your farm:

N : \_\_\_\_\_ x \_\_\_\_\_ = \_\_\_\_\_ lbs available N/yr

P<sub>2</sub>O<sub>5</sub> : \_\_\_\_\_ x \_\_\_\_\_ = \_\_\_\_\_ lbs P<sub>2</sub>O<sub>5</sub>/yr

K<sub>2</sub>O : \_\_\_\_\_ x \_\_\_\_\_ = \_\_\_\_\_ lbs K<sub>2</sub>O/yr

4. Total cropland area required for annual manure application, expressed as acres year.

Our example: N : 4,732 / 140 (C.4d) = 34 acres/yr

P<sub>2</sub>O<sub>5</sub> : 6,136 / 40 (B.5) = 153 acres/yr

Your farm: N : \_\_\_\_\_ / \_\_\_\_\_ (C.4d) = \_\_\_\_\_ acres/yr

P<sub>2</sub>O<sub>5</sub> : \_\_\_\_\_ / \_\_\_\_\_ (B 5) = \_\_\_\_\_ acres/yr

The first line is number of acres required if you base manure application rate on crop's N needs. The second line is number of acres required if you base manure application rate on the crop's P<sub>2</sub>O<sub>5</sub> needs.



### Summary of the Worksheet Example

The example shows that the proper manure application rate on land producing 180 bushels of corn per acre is 6,760 gallons per acre (C.5a) if the manure is used to supply all the nitrogen needed by the crop, or 1,480 gallons/acre if the fertilizer value is maximized (C.5b).

The example calculations also determined that this 400-head swine feeding operation requires a mini-

mum of 34 acres at the 6,760 gallons-per-acre manure application rate, or a maximum of 153 acres at the 1,480 gallons-per-acre rate (E.4).

If manure was applied to maximize its fertilizer value (1,480 gals per acre), calculations indicate that an additional 109 pounds of nitrogen are needed per acre to meet the corn nutrient requirements (calculations not shown). A typical application of 3,000 gals per acre would require 78 lbs of additional nitrogen per acre.

## Other Management Considerations in Fertilizing Crops with Animal Manures

### Developing a Fertilizer/Manure Application Plan

Some producers are applying enough manure on the land to meet crop nutrient needs and then unnecessarily adding commercial fertilizer. This practice wastes money and much of the manure's fertilizer value. It also can cause nutrient accumulation in the soil and increase the chances of nutrient leaching into ground water, or runoff into surface water. This is a particular problem with nitrate.

Salt buildup from manure application usually is not a problem in Nebraska soils. Salt buildup is possible if manure salt concentration is higher than normal, application rate is excessive and rainfall is less than normal. When using manure at the rate that maximizes fertilizer value, salt buildup is unlikely.

Excessive accumulation of phosphorus is a more likely potential problem in Nebraska. If manure is applied at rates that supply all nitrogen requirements, phosphorus levels continually will increase. Phosphorus will build up to a point where there is no need for further phosphorus application.

Livestock and poultry producers should develop a fertilizer application plan that maximizes the use of manure nutrients and supplements with commercial fertilizers only if additional nutrients are needed for the crop. The major elements of such a plan include: (1) periodic analysis of the manure produced in the livestock operation; (2) routine soil testing program; (3) records of fields manured and application rates used; (4) rotating fields for manure application every two to three years or as a soil test dictates to avoid nutrient buildup.

### Applying Manure to the Land

Here are some suggestions to help insure safe and effective application of animal manure to cropland:

- Unless immediately incorporated into the soil, surface apply manure at reasonable distances from streams, ponds, open ditches, residences and public buildings to reduce runoff, odor problems and to avoid neighbor complaints.

- To minimize farmstead odor problems, spread raw manure frequently, especially during the summer. Spread early 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 populated areas or when the air is still.

- When the soil is frozen, apply manure only to relatively level land.

- Agitate liquid manures thoroughly in pits to insure removal of settled solids. This is important for uniform application of the nutrients and for obtaining accurate, representative analysis samples.

- Consider irrigating diluted manures (lagoon or runoff liquids) during dry weather to supply needed water as well as nutrients to growing crops.

- Under furrow irrigated conditions liquid manures should not be used for the first irrigation, reuse pits should be used, and extreme care should be taken to insure uniform application. Otherwise nitrates could move below the root zone or run off the field to non-crop areas.

- If irrigating undiluted manure on growing crops, do it at a time other than during the heat of the day. After manure application irrigate with clean water to wash the plants off, thereby avoiding leaf burn. Depending on crop development, at least 0.3 inch of irrigation water is needed to wash plants thoroughly. Avoid irrigating with manure corn less than six inches tall.

- Don't spread liquid manure on water-saturated soils where runoff is likely to occur.

- Make safety your first priority when removing manure from tanks or pits. Because of oxygen deficiency or toxic gas accumulation, remove animals or increase ventilation in slatted floor areas over manure pits during agitation. If animals are left in buildings during agitation, monitor their behavior carefully. Don't enter manure storage structures without life-support equipment (preferably oxygen tank and mask).



## **Procedures for Sampling and Analyzing Manure**

Laboratory analysis is the most accurate way to ascertain the nutrient value of the manure from your livestock enterprise. The analysis report should include information on dry matter, ammonium N, total nitrogen (ammonium plus organic N), total phosphorus, total potassium content and electrical conductivity (EC). For the names of commercial laboratories providing this service, contact the University of Nebraska-Lincoln Agronomy Department or your county extension personnel.

Keys to the accuracy of a manure analysis are thorough agitation of the manure and proper sampling. A considerable amount of nitrogen can be lost if a sample is not correctly taken, handled and preserved. Here is how to collect both liquid and solid samples.

For liquid manure, agitate the contents of a manure pit to obtain a well-mixed sample. Place the sample in a quart size plastic container with a screw-

on lid, and tighten well. Preserve the liquid sample immediately either by freezing or by adding two to three drops of muriatic acid to lower the pH. Muriatic acid (which can be obtained at hardware stores or autobody supply houses) can be applied with an inexpensive medicine dropper, but be extremely careful when doing so, and wear goggles. Proper handling of the sample is important; an unfrozen one or one without the acid will explode if left at room temperature. When freezing remember that water expands when frozen, so leave room in the container.

For solid manure, obtain samples from several parts of the manure source. Place the composite sample in a plastic bag, twist and tie tightly. For added safety, place in a second plastic bag. Preserve immediately by freezing.

Deliver the liquid or solid 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 at the laboratory until tested.



