Why?

- Facilitates disposal of accumulated waste materials – solid manures, lagoon effluents, treatment plant effluents, sludges
- Allows utilization of nutrients and organics in waste materials – good fertilizer source and soil conditioner
- Fairly inexpensive if transportation is limited – costs are offset by savings on commercial fertilizer purchase

Concerns

- Over-application can lead to pollution of nearby waterways
- Extreme over-application may cause plant toxicity
- Wastes may contain salts that must be managed during application
- Wastes may contain pathogenic bacteria
- The balance of major nutrients in the waste (N-P-K) may not match the balance of nutrients required by the crop; for example, if you apply waste to meet nitrogen requirements, you’ll likely over-apply phosphorus and potassium; if you apply to meet phosphorus requirements, you’ll need to supplement with commercial nitrogen
- The area required for proper disposal of wastes may exceed that available to the producer – this can be a particular problem with poultry
- Some producers are not careful to provide uniform application over the required area – application rates are commonly much higher near the waste source and lower at more distant parts of the property

Basic Process for Manure Nutrient Management

- Determine the nutrient requirements of the desired crop and yield
- Determine the nutrients available in the waste
- Select a nutrient for basing application calculations (Historically, nitrogen has been used for determining application rates. However, nitrogen-based application typically leads to gross over-application of phosphorus. In many states, high phosphorus application in some areas has led to degradation of nearby streams. Consequently, many states are now considering or have adopted phosphorus-based application rates with supplement of commercial nitrogen.)
- Calculate land requirements and application rates
- Determine application rates for other major nutrients and determine supplemental applications when necessary
Information Needed

Soil Fertility and Crop Requirements

- Requires soil samples be collected from the application area
- Analysis services provided for a nominal fee by state Extension services – ask your county Extension agent for contact information
- Soil test will likely yield suggested application rates (lb/ac) for N-P-K as follows:
  - nitrogen as N
  - phosphorus as P$_2$O$_5$
  - potassium as K$_2$O
- To ease calculations, convert P$_2$O$_5$ and K$_2$O to elemental P and K as follows:
  \[ P = P_2O_5 \times 0.4364 \]  
  \[ K = K_2O \times 0.8301 \]
- Crop nutrient requirements may be available in handbooks or from state Extension service personnel. Information for a particular crop’s requirements may be provided by the soil testing service based on the soil analysis.

Manure/Waste Nutrient Content

- As with soil samples, samples of manure, effluent, or sludge may be sent to an analytical lab for analysis
- The state Extension laboratory likely provides this service, contact your county Extension agent for more information
- Nutrient content likely will be reported as elemental N, P, and K (note: these likely won’t match the reported forms from the soil analysis, hence the conversions given above)
- Units for the nutrient content report frequently are % on a mass basis (mass of nutrient per mass of waste material times 100)

Losses of Nitrogen

- Nitrogen is subject to losses while waste materials are stored and applied
- If the waste is stored prior to land application (this does not include time the waste spends in treatment – such as in the lagoon), up to 50% of the nitrogen may be lost to volatilization of ammonia and transformation to gaseous nitrogen
- Nitrogen also may be lost during application

<table>
<thead>
<tr>
<th>Table 1. Application losses for nitrogen.</th>
<th>Percent Losses of N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadcast application without incorporation</td>
<td>10-30</td>
</tr>
<tr>
<td>Broadcast with immediate incorporation</td>
<td>1-5</td>
</tr>
<tr>
<td>Knifing</td>
<td>0-2</td>
</tr>
</tbody>
</table>
Sprinkler irrigation: 15-40

- Finally, not all nitrogen applied will be available to the crop. Of the nitrogen left after storage and application losses, only 50% is considered Plant Available Nitrogen (PAN)
- Phosphorus and potassium do not experience significant losses during storage and application and are considered to be completely available to crops

Land Application of Wastes – Basic Procedure and Equations

Determine Nutrient Requirements for Desired Crop and Yield
- From soil analysis report, select the recommended application rates for N, P, and K
- If recommendations for P and K are expressed as $\text{P}_2\text{O}_5$ and $\text{K}_2\text{O}$, respectively, convert recommended application rates to elemental form using the conversions given in Equations 1 and 2.

Determine the Total Mass or Volume of Waste to be Applied

For solid wastes:
- All calculations for solids use the mass of dry manure/waste generated
- Determine the total mass of manure produced ($TM$) using the values available in the ASABE handout on manure production and characteristics if not provided otherwise:

$$TM = N \times M \times t_{\text{acc}}$$  \hspace{1cm} (3a)

$$TM = N \times M_{\text{fa}}$$  \hspace{1cm} (3b)

$N$ = number of animal
$M$ = manure produced per day per animal, lb/a·d or kg/a·d
$t_{\text{acc}}$ = time of waste accumulation, days
$M_{\text{fa}}$ = total manure produced per finished animal, lb/fa or kg/fa

For liquid wastes or effluents:
- Determine the volume of effluent to be discharged – this depends on your treatment or holding system and will include the volume of waste produced by the animals plus any flush water and spilled water used in the operation

$$WV = N \times V \times t_{\text{acc}}$$  \hspace{1cm} (4a)

$$WV = N \times V_{\text{fa}}$$  \hspace{1cm} (4b)

$WV$ = waste volume in ft$^3$ or L
$V$ = volume of manure produced per day per animal, ft$^3$/a·d or L/a·d
$V_{\text{fa}}$ = volume of manure produced per finished animal, ft$^3$/a or L/a
• If you’re discharging lagoon effluent, the discharge volume will likely be the volume of accumulated waste (waste volume from the lagoon sizing calculations) plus the runoff volume (runoff volume from the lagoon sizing calculations) minus evaporation from the surface of the lagoon (local evaporation rate multiplied by the surface area of the lagoon)

• For industrial wastewater treatment systems, multiply your effluent discharge rate \( (Q \text{ leaving the plant}) \) by the time between applications

Determine the Nutrient Content in the Waste

For solid wastes:

• Use the \% nutrient content from the waste sample analysis with the total mass calculated earlier \( (TM) \) to determine the pounds of nutrient in your total mass of dry waste or use the nutrient data from the ASABE manure characteristics standard:

\[
M_N = TM \times \frac{\% \text{ nutrient content}}{100} \quad (5a)
\]

\[
M_N = N \times M_{\text{nut}/a-d} \times t_{\text{acc}} \quad (5b)
\]

\[
M_N = N \times M_{\text{nut}/a} \quad (5c)
\]

For liquid wastes and effluents:

• Use the \% nutrient content from the waste sample analysis with the total volume of waste/effluent to determine the pounds of nutrient in your liquid volume or use the nutrient data from the ASABE manure characteristics standard – need mass of nutrient per volume of liquid (lb nutrient/gal, lb nutrient/ft\(^3\), or kg nutrient/L)

• Conversions that may be needed:

1 ft\(^3\) = 7.48 gal
1 gal = 8.34 lb for water

Determine Nitrogen Losses and PAN

• Determine how much nitrogen is lost due to storage

• If you pull waste directly from a treatment system, such as a lagoon, for immediate land disposal and you have laboratory analyses conducted on the applied material, you can assume storage losses are negligible (assume the storage loss is 0)

• If you store wastes, check with ASABE, NRCS, or Midwest Plan Service documents to get estimates of nitrogen losses

• Calculate the nitrogen remaining after storage

• Determine how much nitrogen is lost due to application. Use approximate values provided in this handout or seek further information from ASABE, NRCS, or Midwest Plan Service documents. Typical values are given in Table 1 above.

• Finally, determine the amount of nitrogen that is plant available (PAN) – this is approximately 50\% of the nitrogen remaining after application
Considering both losses, the final amount of Plant Available Nitrogen (PAN) is:

\[ PAN = M_N \times 0.5 \times \left(1 - \frac{N_{\text{loss}}}{100}\right)_{\text{stor}} \times \left(1 - \frac{N_{\text{loss}}}{100}\right)_{\text{app}} \]  

where \( M_N \) is the mass of nitrogen available in the waste as calculated with Eq 5.

Select a Nutrient on Which to Base your Application per Acre

- As stated earlier nitrogen historically is the nutrient used as the basis for determining waste application per acre
- Check with your county Extension agent or with your state regulatory agency to determine if phosphorus-based application per acre is required for your area

Determine the Acreage Required for Application

- Use the recommended application per acre for your selected nutrient from the soil analysis report and the mass available of that nutrient (PAN or total phosphorus)
- The required application area is:

\[ A = \frac{\text{mass nutrient}}{\text{application per acre}} \]  

Determine the Amounts of Other Nutrients Applied

- The total manure application for solid wastes (tons/ac):

\[ \text{ton/ac} = \frac{\text{total mass (in tons)}}{A \text{ (in acres)}} \]  

- Irrigation depth for liquid wastes (in) using total waste volume in ft³:

\[ I = \frac{\text{total waste volume} \times 12}{A \times 43560} \]  

- Application per acre for remaining nutrients:

\[ \text{App per ac} = \frac{\text{mass nutrient}}{A} \]  

- The difference between the actual application per acre calculated above and that recommended in the soil analysis report is the amount of nutrient over-applied or, if under-applied, that must be supplemented with commercial fertilizer.
Example

A dairy has 300 cows under free stall barns and on paved open lots. Manure from the lots and the barns is scraped and piled for land application to forage and grazing land nearby. Manure and waste from the premilk holding area and the milking parlor are flushed to an on-site lagoon. Approximately 1,000,000 gallons of lagoon effluent are available every 6 months for irrigation and fertilization. Soil analyses of the forage and grazing area recommend application rates of 95 lb/ac N, 50 lb/ac P₂O₅, and 110 lb/ac K₂O. Analysis of the solid waste yields nutrient concentrations of 0.53% N, 0.13% P, and 0.4% K. Finally, analysis of the lagoon effluent yields nutrient concentrations of 0.027% N, 0.005% P, and 0.065% K.

Determine the area needed for nitrogen-based application of the solid and liquid wastes. Assume that no nitrogen is lost during storage, 20% of nitrogen is lost during application, and 50% of applied nitrogen is plant-available.

Determine the Nutrient Requirements

- Nitrogen: $N = 95 \text{ lb/acre}$
- Phosphorus: $P = 50 \times 0.4364 = 22 \text{ lb/acre}$
- Potassium: $K = 110 \times 0.8301 = 91 \text{ lb/acre}$

Determine the Total Mass or Volume of Waste to be Applied

For solid wastes:
- Number of animals: $N = 300$
- From ASABE manure generation handout
  - mass as removed for dairy on scraped concrete lot is 40 kg/cow·d
- Total mass removed daily: $TM_1 = 40 \text{ kg/cow·d} \times 300 \text{ cows} \times 2.2 \text{ lb/kg} = 26,400 \text{ lb/d}$
- Determine mass of solids accumulated annually
- Total annual mass of solids: $TM = 26,400 \text{ lb/d} \times 365 \text{ d/yr} \div 2,000 \text{ lb/ton} = 4818 \text{ tons}$

For liquid wastes:
- The volume to be applied every 6 months is 1,000,000 gallons, as given

Determine the Nutrient Content in the Waste

For solid wastes:
- Nitrogen: $N = 0.0053 \times 4818 \text{ ton} \times 2000 \text{ lb/ton} = 51,071 \text{ lb}$
- Phosphorus: $P = 0.0013 \times 4818 \text{ ton} \times 2000 \text{ lb/ton} = 12,527 \text{ lb}$
- Potassium: $K = 0.0040 \times 4818 \text{ ton} \times 2000 \text{ lb/ton} = 38,544 \text{ lb}$
For liquid wastes:
- mass = (%/100) × density × volume
- Nitrogen: N = 0.00027 × 8.34 lb/gal × 2(10^6) gal = 4504 lb
- Phosphorus: P = 0.00005 × 8.34 lb/gal × 2(10^6) gal = 834 lb
- Potassium: K = 0.00065 × 8.34 lb/gal × 2(10^6) gal = 10,842 lb

Determine Nitrogen Losses and PAN
- From the problem statement, storage losses = 0% and application losses = 20%
- From the problem statement, PAN = 50% applied nitrogen

For solid wastes:
- Nitrogen after application = (1-0.20) × 51,071 = 40,857 lb
- PAN = 0.5 × 40,857 = 20,428 lb PAN

For liquid wastes:
- Nitrogen after application = (1-0.20) × 4504 = 3603 lb
- PAN = 0.5 × 3603 = 1801 lb PAN

Select a Nutrient on Which to Base your Application Rates
This problem specifies nitrogen-based application, so use nitrogen for area calculations

Determine the Acreage Required for Application
For dry wastes:
\[ A = \frac{20428 \text{ lb}}{95 \text{ lb/ac}} = 215 \text{ ac} \]

For liquid wastes:
\[ A = \frac{1802 \text{ lb}}{95 \text{ lb/ac}} = 19.0 \text{ ac} \]

Determine the Application Rates for Other Nutrients
For dry wastes:
- Waste application: TDW app rate = 4818 tons / 215 ac = 22.4 tons/ac
- Phosphorus application: P app rate = 12527 lb P /215 ac = 58.3 lb/ac
- Potassium application: K app rate = 38544 lb K / 215 ac = 179.3 lb/ac
Compare the P and K application rates to those recommended in the soil analysis report (22 lb/ac for P and 92 lb/ac for K) - we’re over-applying P and K to this field

For liquid wastes:

\[
I = \left( \frac{2000000}{7.481} \right) \times 12 \text{ in}
\]

Irrigation depth: \( I = \frac{2000000}{7.481 \times 43560} = 3.9 \text{ in} \)

Phosphorus application: P app rate = \( \frac{834}{19.0} \text{ lb P/19.0 ac} = 43.9 \text{ lb P/ac} \)

Potassium application: K app rate = \( \frac{10842}{19.0} \text{ lb K/19.0 ac} = 571 \text{ lb K/ac} \)

Again, we’re over-applying P and K to the field