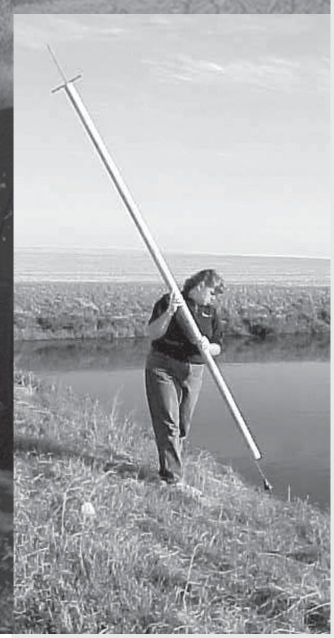
Manure Characteristics

Manure Management Systems Series



MWPS-18 Section 1

SECOND EDITION

Manure Characteristics

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Manure is a valuable source of nutrients for crops and can improve soil productivity. Manure properties depend on several factors: animal species; diet, digestibility, protein and fiber content; and animal age, housing, environment, and stage of production. Manure is characterized in several ways. Important properties for manure collection, storage, handling and utilization include the solids content (the percent of solids per unit of liquid) and the size and makeup of manure solids (fixed and volatile solids, suspended solids, and dissolved solids). Nutrient content, primarily nitrogen, phosphorus, and potassium, is important as it affects land application rates and treatment techniques. Manure components can be characterized as organic and inorganic. To help control disease and parasites, human wastes should not be mixed with animal manures.

Handling Characteristics

The quantity, composition, and consistency of manure greatly influence livestock manure facility design. The handling characteristics of manure vary, depending primarily on the amount and type of solids present, Figure 1. The boundary between handling classifications is not fixed, but varies with specific composition. Manure can be classified, in general, based on how manure must be handled.

Manure handling characteristics vary as consistency changes from liquid to solid. On one end of the spectrum is lagoon liquid with a very low solids content (less than 1%) that can be handled using conventional centrifugal pumps. Lagoon liquid can be irrigated using either big guns or center pivot irrigation systems with small nozzles. On the other end of the spectrum is solid manure that must be handled with front-end loaders and/or pitchforks. Solid manure normally has more than 20% solids. In between are the more difficult to handle manures, the ones containing from 5 to 20% solids. The moisture content of the manure is the main determining characteristic, although solids size, and the presence of bedding also can influence the equipment needed for handling, treating, and transporting. Solids generally

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tend to settle, but very thick manures (more than 10% solids) hinder settling, and may result in a more uniform manure than a settled, thinner one. Sand is another challenging solid that's sometimes used as dairy bedding. Sand requires special settling and handling procedures due to its high density and abrasiveness.

Nutrient values are related to solids concentrations. In general the higher the solids concentration, the higher the nutrient concentration. Estimates are available for most manure types, but to really know what manure contains, representative samples must be analyzed. Estimates and tabular values must be used with caution. They are useful for planning purposes, but once a facility is established, the best way to determine nutrient and handling characteristics is to obtain good representative samples and have them analyzed.

Liquid

Manure with up to 4% solids content can be handled as a liquid with irrigation equipment. Liquids that have had the larger solids removed, or manure with dilution water added may contain 4% or less solids.

Properly designed and managed anaerobic (or aerobic) lagoon treatment systems should have less than 1% solids, typically from 0.1 to 0.5%. However, it's not uncommon for overloaded lagoons to reach as high as 2% solids.

Slurry

Manure with 4 to 10% solids content can be handled as a slurry, but may require special pumps. Swine pit manure typically contains between 2 and 6% solids. Deep pit manure will be toward the upper end of the range, while manure in outside pits will be more liquid. Outside pits may be either concrete, steel, or earthen. When wet-dry feeders or swinging waterers are used, the animals waste less water so solids content may increase to 8 to 12%, resulting in a thicker slurry. Dairy manure with milking parlor washwater added typically is handled as slurry.

Semi-solid

In the 10 to 20% solids content range, handling characteristics vary by the type of solids present. In this range, the percent solids content does not have as much effect on handling characteristics as does the type of manure and the amount of bedding present.

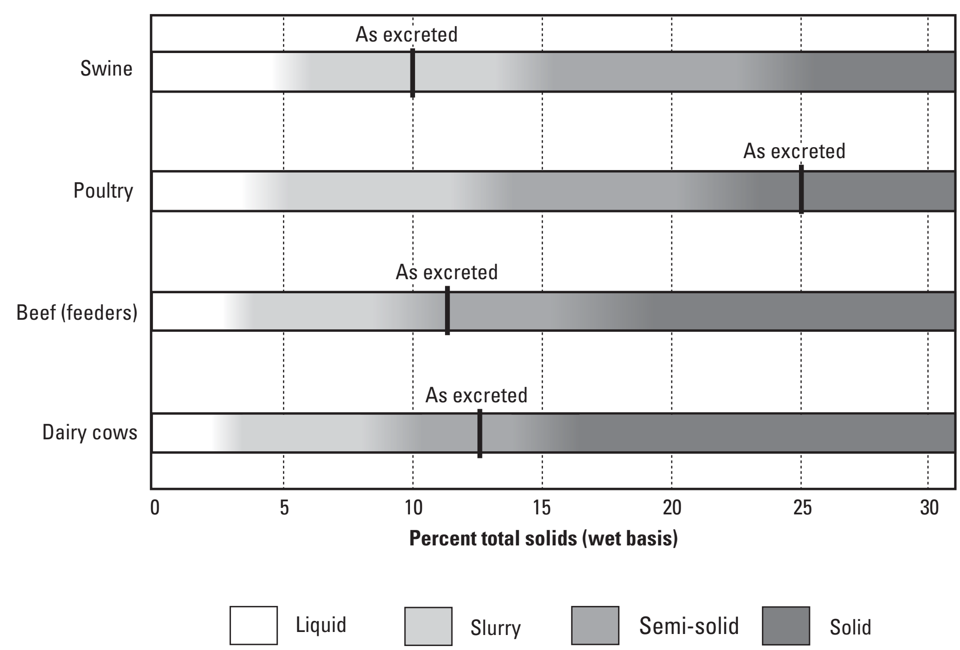


Figure 1. Relative handling characteristics of different types of manure for various species.
NOTE: "As excreted" lines represent the common solids content of manure excreted from a healthy animal.

This range of solids can be very difficult to handle and is typical of many dairy operations. The manure is too thick to pump, and too thin to scoop. Producers with this thick slurry type of manure may have to add water to handle the manure as a liquid, and will need special pumps to agitate and move the manure. Usually, handling the manure with a front-end loader doesn't work well because the liquid *runs around* the bucket during forward movement. Transfer equipment, such as augers and flight elevators, is sometimes used. Mechanical scrapers or skid loaders with tires attached to the bucket also can be used for manure collection.

Solid

Manure, not using sand bedding, with 20% solids content (80% moisture content) or more can be handled as a solid. It can be stacked, and it can be picked up with a fork or bucket loader. To handle manure with a solids content of less than 15 to 20% as a solid, liquids need to be drained, and the manure must be dried, or bedding must be added.

At 20% solids or slightly less, liquid may seep from the manure stack, so a tall stack is not feasible. Once solids content exceeds 25%, seepage should not be a problem, and tall stacks will retain their shape. Poultry layer manure and poultry litter typically will have 40% solids or more. Bedded swine or bovine manure may have a wide range of solids, but likely will be solid enough to stack easily if adequate bedding is used.

Sampling and Testing Manure

Many states require producers to have a manure nutrient management plan for their operation. Having an accurate manure analysis in addition to having soil analysis and knowing crop yields will help increase the accuracy of the plan and the likelihood of plan approval by the state.

Selecting a Testing Laboratory

Most laboratories that do soil testing and/or feed analysis also will analyze manure samples. The local Extension or NRCS office should be able to assist in locating laboratories that analyze manure. Contact the laboratories before sending samples. To determine which laboratory best meets your needs, get answers to questions such as the following:

- For how many years has the laboratory been performing manure analysis? If possible, choose a laboratory with at least two years of experience in manure testing.
- After the lab receives samples how does it handle those samples? Samples should be tested immediately or should be refrigerated or treated for later testing.
- Is the lab certified by any quality control organizations? Having tests done by a lab that meets quality control standards can help validate results.
- How long does a customer typically wait before results are returned? Be sure you will be able to receive your test results when you need them.

When testing manure for the first time, consider sending samples to multiple (at least three) laboratories and compare results. Samples must be identical to adequately compare laboratory test results. If results are comparable, then select the least expensive laboratory that can return results in the most timely manner. If results vary, eliminate the lab or labs that provided the results that varied most. From the labs that provided results that are closest together, select the laboratory that can return results in the most timely manner.

Obtaining a Sample

Obtaining a representative sample from each manure storage is critical to getting accurate test results. Knowing when to sample, how to collect the sample, and how to ship the sample to the testing laboratory are all important components of getting the best representative sample.

When to Sample. Manure sampling and testing is needed annually to develop a historical track record. Research has found that at the same given site with the same given genetics, diet, housing, management, etc., the moisture and nutrient characteristics of the manure do not change from year-to-year. Preferably, a manure analysis should be completed just before the manure will be applied to the land.

In warmer climates of the United States, the time of year when sampling occurs is critical to obtaining the proper information on lagoon operation. For example, samples taken during the summer will normally have lower analysis values than samples taken during the winter. In this case, surface sample during colder months (e.g. February) then sample the entire structure in the summer (e.g. July). The other option would be to sample annually before manure application.

How to Collect Samples. A representative sample is critical to obtaining a reliable manure analysis. Manure nutrient composition can vary significantly within the same storage. Tables 1 and 2 show the manure composition variations at different depths for unagitated lagoons and an unagitated deep pit.

Agitation of manure is one of the most critical operations to perform before taking a manure sample. Nitrogen and potassium can be adequately sampled from pits by obtaining a vertical profile sample without agitation, but phosphorus requires agitation. Agitation homogenizes the manure mixture and provides a more consistent nutrient analysis as the manure is being removed.

Table 2 shows that phosphorus can vary 300% or more from top to bottom without agitation. Continuous agitation is needed, even during pump out, to ensure that the phosphorus and solids stay suspended. Do not shut off the agitator to fill a tanker or to pump to a sprinkler or towed-hose system. Additionally, agitation re-suspends settled solids and ensures that most or all of the manure will flow to the inlet of the pump or removal device.

Deep-pit buildings are particularly susceptible to solids buildup if not properly agitated. Many underfloor pits were not designed for convenient, effective agitation. Slurry storage may require several hours of agitation before the manure is sufficiently mixed for pumpout. Table 3 shows that the manure sampled from a pit that had been agitated for at least four hours had relatively uniform results from the first to last sample.

The practice of removing a load of manure from the pit by vacuum and then blowing the manure back into the pit usually does not provide sufficient

Table 1. Variations in unagitated lagoons.
Case studies from one swine and one dairy single-stage lagoon. Sampling depths of 2 feet and 14 feet. Lagoon depth is 18 to 20 feet. Based on data presented in *Livestock Waste: A Renewable Resource*, 1980, pg. 254 to 256.

		Swine		Dairy	
Component	**Unit**	**2 ft Depth**	**14 ft Depth**	**2 ft Depth**	**14 ft Depth**
Total solids (TS)	lbs per 1,000 gal	20	170	135	265
Volatile solids (VS)	lbs per 1,000 gal	10	85	90	177
Nitrogen (N)	lbs per 1,000 gal	4	10	3	7
Ammonical Nitrogen (NH_4-N)	lbs per 1,000 gal	3	6	3	2
Phosphorus (P_2O_5)	lbs per 1,000 gal	2	15	4	7
Potassium (K_2O)	lbs per 1,000 gal	5	8	6	8

Table 2. Variations in samples from unagitated deep-pit swine buildings.
Variation in 174 liquid swine pits in Iowa. Pits have vertical sides.

Component	Unit	Top	Middle	Bottom	Vertical Profile
Nitrogen (N)	lbs per 1,000 gal	36	35	51	38
Ammonical Nitrogen (NH_4-N)	lbs per 1,000 gal	27	27	33	27
Phosphorus (P_2O_5)	lbs per 1,000 gal	18	21	72	31
Potassium (K_2O)	lbs per 1,000 gal	28	22	25	27

Table 3. Sample comparison from well agitated deep-pits during pumping.
Samples taken from six deep pits in Iowa. All pits were agitated for at least four hours before the first load was removed and were agitated continuously during pumping. A 75-hp pump or larger was used for agitation.

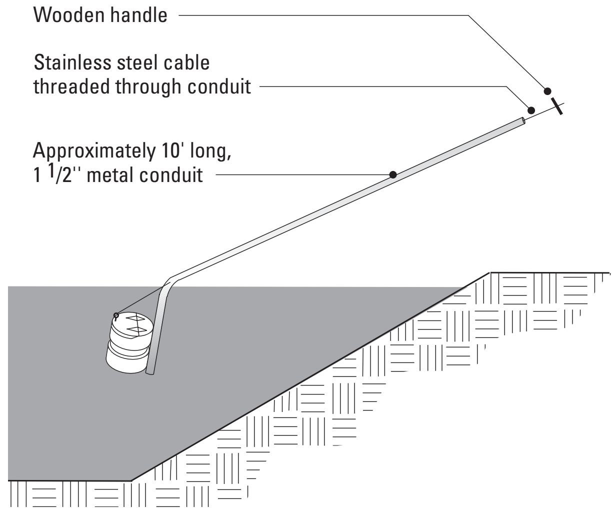
Component	Unit	Profile Sample[a]	First Load	Middle Load	Last Load
Nitrogen (N)	lbs per 1,000 gal	48.6	56.8	57.8	59.5
Ammonical Nitrogen (NH_4-N)	lbs per 1,000 gal	34.4	38.9	37.9	37.8
Phosphorus (P_2O_5)	lbs per 1,000 gal	49.8	40.3	42.2	50.3
Potassium (K_2O)	lbs per 1,000 gal	31.4	25.0	27.9	25.8

[a]A representative sample of the entire pit depth.

Sampling Procedures	Sampling Devices

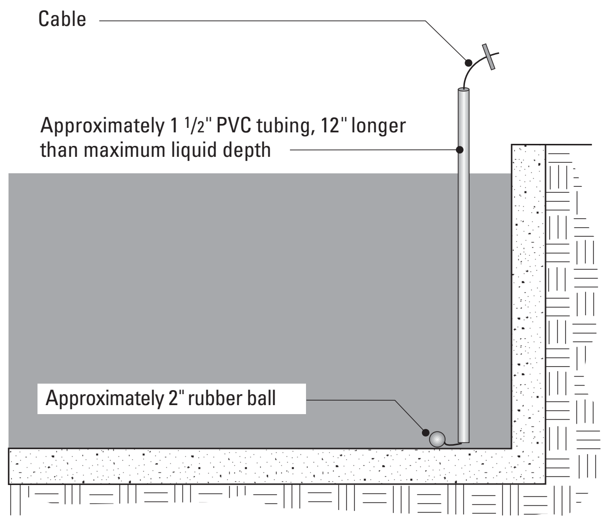
Liquid Manure

1. Dip sampler below the basin or lagoon surface.
2. Pull cable to open top and collect sample.
3. Close container.
4. Dump sample into a 5-gallon bucket.
5. Repeat steps 1-4 until samples from *4 to 6 locations* are taken.
6. Stir the liquid in the bucket until a uniform mixture is obtained.
7. To collect laboratory sample, continue stirring the mixture. **While the mixture is still in a swirling motion**, dip a cup into the mixture.
8. Follow shipping procedures in Table 4 (Steps 2-4).



Vertical Profile

1. Insert tube vertically until the tube hits the bottom of the storage.
2. Lift the tube just enough to allow ball to seal the end of the tube after string or cable is pulled. (See opposite page for several tube variations.)
3. Pull the tube out without releasing the slurry.
4. Dump the slurry into a 5-gallon bucket.
5. Stir the slurry until a uniform mixture is obtained.
6. To collect laboratory sample, continue stirring the mixture. **While the mixture is still in a swirling motion**, dip a cup into the mixture.
7. Follow shipping procedures in Table 4 (Steps 2-4).



Solid Manure

1. Insert tube into solid manure.
   NOTE: Tube may be difficult to insert into solid manure with feathers. A sharp spade can be used to obtain samples with feathers.
2. Dump manure into a 5-gallon bucket. A rod may be needed to push manure out of tube.
3. Repeat the first two steps until *10 to 15 locations* have been sampled.
4. Mix the manure until a uniform sample is obtained.
5. Follow shipping procedures in Table 5, (Steps 3-5).

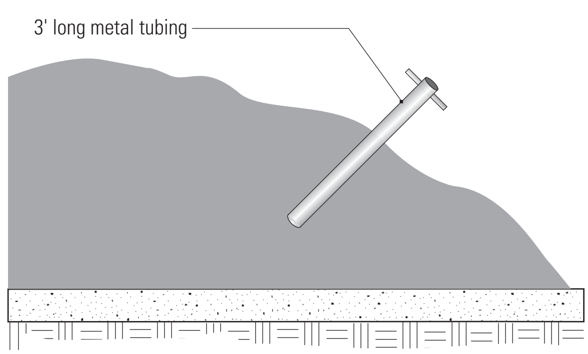
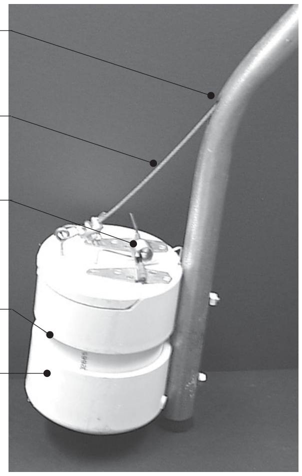


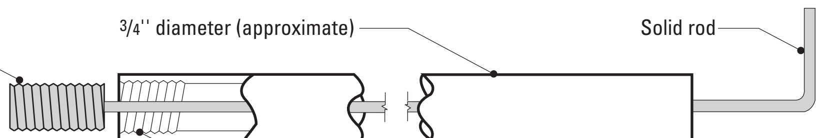
Figure 2. Using devices to obtain samples.

Sampler Details

Liquid Manure



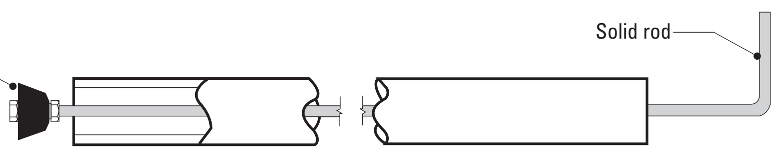
Vertical Profile



Sampling Procedure

- Let threaded rod rest on bottom of storage
- Turn tubing until threaded rod is secured in tubing
- Remove sample

Alternative Design I

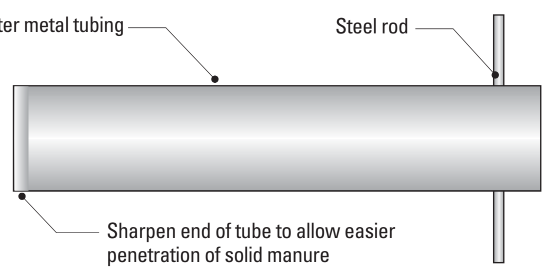


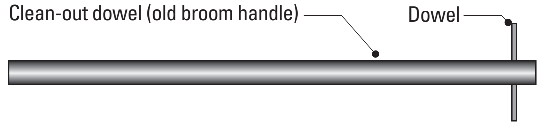
Sampling Procedure

- Let stopper rest on bottom of storage
- Push PVC tubing on to stopper
- Remove sample

Alternative Design II

Solid Manure





agitation to suspend solids. Agitation of manure storage facilities releases gases that may increase odor levels and present a health hazard. Considerations should be given to weather and wind conditions, time of day, and day of the week to minimize the possibility of odors affecting neighbors while the pit is being agitated.

In the past, agitating lagoons before pumpdown was not a common practice. The relatively large volume of lagoons and relatively clean water on the lagoon surface did not indicate a compelling need for agitation. Over the years, however, the effects of sludge buildup and nutrient accumulation have became more obvious. Sludge allowed to build up over a number of years before being removed may create a significant management problem. The sludge will displace needed treatment and storage volume if not periodically removed. Lagoons receiving significant amounts of bedding may experience high rates of sludge buildup.

Lagoons are typically difficult to agitate because of their large size, but because nutrients, particularly phosphorus, tend to concentrate in sludge, thoroughly mixing during agitation is important. Effective agitation may require two or more agitators operating simultaneously at different locations around the lagoon. Continuous agitation is needed during pumping to ensure a uniform manure mixture. Extremely large lagoons may require the use of dredging equipment similar to that used in the municipal sector.

Tables 4 and 5 list procedures to use when obtaining a manure sample.

How to Ship Samples. After obtaining a sample or samples, place the container in a plastic bag. The plastic bag will help prevent leaks. If possible, deliver the manure samples to the laboratory in person. For

Table 4. Procedure for collecting manure samples from liquid or slurry storages.

1. Obtain liquid manure. (Listed in order of sampling preference)
a. Agitate, sample and test before land application. Mix well before collection to obtain a uniform sample. ***b. Without agitation, sample using a long tube to sample the vertical profile.*** See Figure 2. ***c. Take several samples during emptying.*** Combine samples and send to a laboratory. Use results to determine the nutrient content during next application event. Quick, on-the-farm tests for ammonium-nitrogen can help adjust application rates while emptying storage. These tests take only about 10 minutes and provide reasonable estimates of ammonium-nitrogen. ***d. Take without agitation and sample from the surface*** then follow the remaining sample procedures and send to testing laboratory. After test results are returned, use Equations 3 and 4 to determine an estimated nutrient content.
2. Fill a quart-sized plastic container with a screw-on lid approximately TWO-THIRDS FULL of the sample.
Do not use a glass container. Do not completely fill the container. Close the lid tightly.
3. Label the container and ship to laboratory.
Include the name, sample number, location, and date.
4. Preserve the sample by freezing if samples can not be shipped to the laboratory immediately.

CAUTION:

Agitating deep-pit liquid manure storages

- Gases released from agitated liquid manure can kill people and animals in a very short time.
- Remove people and animals from the building if possible before agitation.
- Open doors, vent openings, or windows, and turn on all fans to provide adequate ventilation when agitating.

Table 5. Procedure for collecting manure samples from semi-solid and solid storages.

1. Obtain samples from 10 to 15 locations in the manure stack or on the feedlot.
2. Mix these to make a composite sample.
3. Place the sample in a gallon-size plastic bag, twist, and tie tightly.
4. Label the container and ship to laboratory. Include the name, sample number, location, and date.
5. Preserve the sample by freezing if samples can not be shipped to the laboratory immediately.

accurate analysis keep the samples frozen or refrigerated during shipment. If this is not possible, package the sample in a strong, insulated container, such as a styrofoam-lined cardboard box. Add ice to the container, and ship the fastest way available. Some commercial laboratories provide sample containers, mailing boxes, and shipping instructions. Contact the laboratory for complete instructions before shipping.

Laboratory Tests

A manure analysis for land application should provide at least the following basic information:

- Dry matter (DM) or moisture content.
- Ammonium nitrogen (NH_4-N).
- Total nitrogen or Total Kjeldahl nitrogen (TKN).
- Phosphorus (P_2O_5).
- Potassium (K_2O).

Figure 3 shows an example of a manure test analysis.

In addition to determining nutrient concentration, a manure analysis also can be used to determine whether a lagoon is operating properly. A manure analysis for a lagoon should also include:

- pH.
- Electrical conductivity (EC).
- Chlorides (to monitor salt levels).

The minimum pH level for a lagoon to operate properly is about 6.5. If the pH is below 6.5, then hydrated lime or lye should be added to the lagoon until the pH level is raised to 7.0. An electrical conductivity test for lagoons has been shown to be a good indicator of ammonium nitrogen. Use Equations 1 and 2 to estimate ammoniacal nitrogen in lagoons.

Testing Frequency. Tests should be performed before each land application event, or on a yearly

ABC Manure Testing Laboratory, Inc.

Producer: MWPS Farms — **Date Received: Oct. 6, 2000**
Type: Swine — **Date Reported: Oct. 16, 2000**

ANALYTICAL RESULTS

	ACTUAL ANALYSIS	TOTAL NUTRIENTS lbs/1,000 gal
Total Moisture	96.0%	
Total Nitrogen	0.59%	50
Ammonium-Nitrogen	0.46%	39
Phosphorus (P_2O_5)	0.41%	35
Potassium (K_2O)	0.47%	40

VALUE ASSESSED ON "AS RECEIVED BASIS"

	AVG. VALUE	SAMPLE VALUE
N-Value	$0.18/lb	$9.00/1,000 gal
P_2O_5-Value	$0.25/lb	$8.75/1,000 gal
K_2O-Value	$0.12/lb	$4.80/1,000 gal

Figure 3. Example of manure test analysis.

basis initially so a historical record can be tracked. If annual manure analyses do not vary significantly in five years, then sample manure every three years. During non-test years the average test results can be used to determine land application rates. However, many factors including broken or leaky waterers, changes in diets, weather differences that cause changes in cooling water demand or evaporation, and precipitation falling on outdoor pits can cause differences in nutrient concentrations. The previous analysis can be a guideline for application rates until a current analysis is available, if similar management practices have been used.

Reading and interpreting laboratory analyses. Samples sent to different laboratories may return with significantly different values being reported for the same elements analyzed. Does this mean that there may be an error in one of the analyses? The answer is "Not necessarily." The two laboratories may actually be reporting the same results but may be presenting the information in different ways. If, for example, manure samples from the same pit were sent to two different laboratories and one lab reported a level of 0.41% P_2O_5 and the other lab reported 0.18% P, a first conclusion might be that the labs disagree. Actually, these labs are reporting the same value but expressing it in a different manner.

To be able to compare results, first determine whether the reports are presenting the element concentration in the elemental form or in a molecular form. If a laboratory is using the elemental form in its reports, the elemental results will be listed with an elemental extension. The molecular form will not have an extension.

For example, if a laboratory is reporting the elemental form of nitrate (called nitrate-nitrogen), the report will list NO_3-N. The "-N" on the end means the results are being presented as elemental nitrogen. Elemental P and K are reported simply as P or K. Converting back and forth between elemental and molecular forms can be accomplished by using the ratios of the molecular weights:

- 4.43 units NO_3 equals 1.0 unit NO_3-N.
- 1.22 units NH_3 equals 1.0 unit NH_3-N.
- 1.29 units NH_4 equals 1.0 unit NH_4-N.
- 2.29 units P_2O_5 equals 1.0 unit P.
- 3.07 units PO_4 equals 1.0 unit P.
- 1.21 units K_2O equals 1.0 unit K.

In the example, the first lab is reporting the elemental phosphorus as P_2O_5. To convert to the molecular form (P), divide 0.41% by 2.29:

$$0.41\% \ (P_2O_5) \div 2.29 = 0.18\% \ (P)$$

The two lab results agree with each other. A conversion table has been included at the end of this publication to assist with this type of unit conversion.

On-Farm Tests

On-farm tests can provide a practical means of monitoring approximate nutrient content of liquid manure during land application. **On-farm tests should be used in conjunction with but not in place of laboratory tests**. As with samples sent to laboratories, samples from well-agitated storages are desirable for the most accurate analysis using on-farm testing.

Equation 1. Ammoniacal nitrogen estimation in lagoons 20 to 25 feet deep.

$$\text{Estimated ammoniacal nitrogen}\left(\frac{\text{mg}}{\text{L}}\right) = \left(0.0908 \times \left(\text{Electrical Conductivity, } \frac{\mu\text{mho}}{\text{cm}}\right)\right) + 73.8 \qquad \textbf{(r = 0.98)}$$

Equation 2. Ammoniacal nitrogen estimation in lagoons 8 to 12 feet deep.

$$\text{Estimated ammoniacal nitrogen}\left(\frac{\text{mg}}{\text{L}}\right) = \left(0.0937 \times \left(\text{Electrical Conductivity, } \frac{\mu\text{mho}}{\text{cm}}\right)\right) - 181 \qquad \textbf{(r = 0.98)}$$

The most popular on-farm testing methods are the conductivity pen and the hypochlorite reaction meter. Both testing methods measure ammonium nitrogen that is used to estimate total nitrogen. The conductivity pen measures the flow of electrons due to the cations and anions of a solution. Ammonium nitrogen generally is one of the dominant cations in manure. The local water supply and salts in the ration can affect the readings of the conductivity pen, so the pen needs to be calibrated for each individual site.

The hypochlorite reaction meter is a small coffee-can sized canister with a screw-on lid. Manure slurry and a reaction agent are placed in the canister before sealing. Hypochlorite from the reaction agent oxidizes the ammonium nitrogen in the slurry to produce nitrogen gas (N_2). Results are obtained by reading a pressure gauge that measures the production of nitrogen gas.

Using Test Results

Some knowledge of the manure analysis procedure will help make the test results more understandable. Base land application on the most current test results. Apply manure based on soil tests and crop needs. Many states have regulations dictating whether application should be based on nitrogen needs or phosphorus needs.

In many cases the results of the manure analysis will not be available before land-applying the manure. In these cases, analysis results from prior pumping events can be used to anticipate the present analysis (and estimate proper application rate), and the current analysis, when available, can then be used to calculate the nutrients actually applied.

If the sample was collected from the surface of an unagitated deep-pit swine building, assume the test results represent approximately 95% of the total nitrogen, and 60% of the phosphorus.

Use Equations 3 and 4 to estimate the actual nutrient content of the manure when the sample was taken from the top of an unagitated pit. Top sampling is reliable for determining nitrogen content but can result in significant inaccuracies when used for estimating phosphorus content.

Manure Composition

Nutrient content, primarily nitrogen, phosphorus, and potassium, is important when calculating land application rates and determining treatment techniques.

Nitrogen, phosphorus, and potassium are the major nutrients of manure. Nutrients are divided between soluble and insoluble states. Soluble nutrients are more readily available for crop usage. Insoluble nutrients may not be available for crop usage for up to a year or more. Figure 4 shows the approximate distribution of the major nutrients in the feces and urine. Soluble nutrients are found in the liquid (urine), and insoluble and some soluble nutrients are found in the solids (feces) of as-excreted manure. Typically, 80% of the phosphorus is in the settled solids of manure storages and is insoluble. As much as 80% of the potassium is found in the liquid and is highly soluble. Nitrogen is split almost evenly between the solids and liquid; therefore, nitrogen is about 50% soluble and 50% insoluble.

Manure components also can be characterized as organic and inorganic. The secondary elements (sulfur,

Equation 3. Estimated uniform nitrogen content for a swine pit when top samples are taken and analyzed. This equation can be used for samples taken from vertical-sided formed storages (e.g. deep pit buildings, covered and uncovered outdoor concrete and steel structures.)

$$\text{Estimated nitrogen content} = \frac{(\text{Nitrogen Test Results})}{0.95} \qquad \mathbf{(r = 0.91)}$$

Equation 4. Estimated uniform phosphorus content for a swine pit when top samples are taken and analyzed. This equation can be used for samples taken from vertical-sided formed storages (e.g. deep pit buildings, covered and uncovered outdoor concrete and steel structures.) **NOTE:** Calculated values can vary significantly from actual concentrations.

$$\text{Estimated phosphorus content} = \frac{(\text{Phosphorus Test Results})}{0.60} \qquad \mathbf{(r = 0.71)}$$

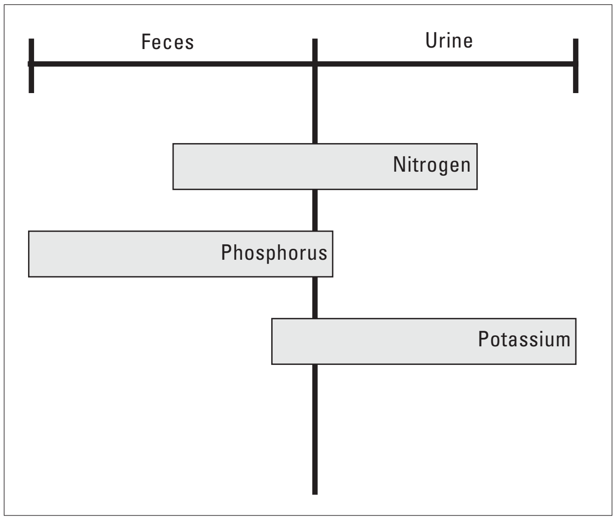


Figure 4. Distribution of nutrients between feces and urine. Based on NRCS *Agricultural Waste Management Field Handbook,* Part 651.

calcium, and magnesium) are required by crops in substantial amounts. Micronutrients including zinc, boron, iron, and copper also are needed in minute quantities.

Common Manure Composition

Use the following tables to help plan storage size and to develop initial nutrient management plans before the first time the storage is emptied. These tables also can be used for site evaluation feasibility studies to estimate land requirements for manure nutrient applications. Tables presented in this section are based on reliable research data and professional standards.

Raw Excreted Manure. Raw excreted manure is the manure that is defecated directly from the animal. Table 6 presents data for raw excreted manure that has not been treated or altered.

Liquid Pit Manure. Deep pit systems located underneath buildings serve to isolate manure from the outdoor environment, which minimizes some unknowns such as rainfall addition or evaporation losses and minimizes manure volumes to be treated or land applied. Isolating the manure from rainfall/runoff typically results in manure with higher total solids, and makes the manure sensitive to management inputs. An outside covered storage also will isolate the stored manure from the outside environment. Table 7 lists characteristics for liquid manure.

Uncovered, outdoor liquid pit systems (concrete, steel, and earthen) are subject to rainfall and roof and land runoff if not diverted from the storage. In humid regions such as the Midwest, the manure in an outdoor, uncovered pit will have lower nutrient concentration because of the addition of rainwater, compared to manure stored under roof. In dry climates, nutrient content of the manure may be higher because of water evaporation. Manure storage volumes will also be larger in humid areas, depending on any drainage area, such as the sides of an earthen storage, that contributes to the volume. Additional water will cause total manure volume to be larger, and volatilization losses of nitrogen also may be greater, resulting in fewer nutrients per head per unit time accumulating.

Lagoon. Many livestock production facilities use anaerobic lagoons, especially in the southern areas of the United States. Lagoons are similar in concept to outdoor liquid pits, but lagoons are a treatment system where very large dilution volumes are present, resulting in a high volume, high nutrient loss, and low nutrient concentration manure mass.

Dilution water is added to control ammonia and salt concentrations, so bacteria can function properly. When raw manure is diluted, the amount of dilution water becomes more of a controlling factor in determining the nutrient concentration per volume than the actual manure itself. Lagoons are designed to enhance microbial digestion of organic material and volatilization of nitrogen compounds. The result is significantly reduced, annual, per-head nutrient availability from lagoons as compared to liquid pit systems.

Lagoon depth is an important factor in determining nutrient retention. Research in Missouri has shown a relationship between lagoon depth and nitrogen concentrations. Deep lagoons (20 to 25 feet) had average nitrogen levels that were approximately twice the levels of shallow lagoons (8 to 12 feet). The difference is thought to be due to different surface area-to-volume ratios that affect ammonia volatilization. Table 8 shows estimated lagoon nutrient accumulations.

Lagoons receiving only milking center effluent (no manure) and precipitation falling directly on the lagoon generally remain partially aerobic and reasonably odor-free. Lagoons should be designed to store milking center effluent for six to eight months.

Table 6. Daily manure production and characteristics, as-excreted (per head per day)[a].

Values are as-produced estimations and do not reflect any treatment. Use these values only for planning purposes. The actual characteristics of manure for individual situations can vary ± 30% or more from table values due to genetics, dietary options and variations in feed nutrient concentration, animal performance, and individual farm managment.

	Size[a]	Total manure[b]			Water[c]	Density[c]	TS[d]	VS[c]	BOD_5	Nutrient content		
Animal	**(lbs)**	**(lbs)**	**(cu ft)**	**(gal)**	**(%)**	**(lb/ft³)**	**(lb/day)**	**(lb/day)**	**(lb/day)**	**(lbs N)[d]**	**(lbs P_2O_5)[d]**	**(K_2O)**
Dairy												
Calf	150	12	0.18	1.38	88	65	1.4	1.2	0.19	0.06	0.01[c]	0.05
	250	20	0.31	2.30	88	65	2.4	2.0	0.31	0.11	0.02[c]	0.09
Heifer	750	45	0.70	5.21	88	65	6.7	5.7	0.69	0.23	0.08[c]	0.23
	1,000	60	0.93	6.95	88	65	8.9	7.6	0.92	0.30	0.10[c]	0.31
Lactating cow	1,000	111	1.79	13.36	88	62	14.3	12.1	1.67	0.72	0.37[c]	0.40
	1,400	155	2.50	18.70	88	62	20.0	17.0	2.34	1.01	0.52[c]	0.57
Dry cow	1,000	51	0.82	6.14	88	62	6.5	5.5	0.75	0.30	0.11[c]	0.24
	1,400	71	1.15	8.60	88	62	9.1	7.7	1.04	0.42	0.15[c]	0.33
	1,700	87	1.40	10.45	88	62	11.0	9.3	1.27	0.51	0.18[c]	0.40
Veal	250	6.6	0.11	0.79	96	62	0.26	0.11	0.04	0.03	0.02	0.05[d]
Beef												
Calf (confinment)	450	48	0.76	5.66	92	63	3.81	3.20	1.06	0.20	0.09	0.16
	650	69	1.09	8.18	92	63	5.51	4.63	1.54	0.29	0.13	0.23
Finishing	750	37	0.59	4.40	92	63	2.97	2.42[d]	0.60	0.27	0.08	0.17
	1,100	54	0.86	6.46	92	63	4.35	3.55[d]	0.89	0.40	0.12	0.25
Cow (confinment)	1,000	92	1.46	10.91	88	63	11.0	9.38	2.04	0.35	0.18	0.29
Swine												
Nursery	25	1.9	0.03	0.23	89	62	0.21	0.17	0.06	0.02	0.01	0.01
	40	3.0	0.05	0.37	89	62	0.33	0.27	0.10	0.03	0.01	0.02
Finishing	150	7.4	0.12	0.89	89	62	0.82	0.65	0.23	0.09	0.03	0.04
	180	8.9	0.14	1.07	89	62	0.98	0.78	0.28	0.10	0.04	0.05
	220	10.9	0.18	1.31	89	62	1.20	0.96	0.34	0.13	0.05	0.06
	260	12.8	0.21	1.55	89	62	1.41	1.13	0.41	0.15	0.05	0.08
	300	14.8	0.24	1.79	89	62	1.63	1.30	0.47	0.17	0.06	0.09
Gestating	300	6.8	0.11	0.82	91	62	0.61	0.52	0.21	0.05	0.03	0.04
	400	9.1	0.15	1.10	91	62	0.82	0.70	0.28	0.06	0.04	0.05
	500	11.4	0.18	1.37	91	62	1.02	0.87	0.35	0.08	0.05	0.06
Lactating	375	17.5	0.28	2.08	90	63	1.75	1.58	0.58	0.17	0.11	0.13
	500	23.4	0.37	2.78	90	63	2.34	2.11	0.78	0.22	0.15	0.18
	600	28.1	0.45	3.33	90	63	2.81	2.53	0.93	0.27	0.18	0.21
Boar[c]	300	6.2	0.10	0.74	91	62	0.57	0.51	0.20	0.04	0.03	0.03
	400	8.2	0.13	0.99	91	62	0.75	0.67	0.26	0.06	0.05	0.05
	500	10.3	0.17	1.24	91	62	0.94	0.84	0.33	0.07	0.06	0.06
Poultry												
Broiler	2	0.19	0.003	0.023	74	63	0.050	0.038	0.011	0.0021	0.0014	0.0010
Layer	3	0.15	0.002	0.017	75	65	0.037	0.027	0.008	0.0026	0.0008	0.0012
Turkey (female)	10	0.47	0.007	0.056	75	63	0.117	0.088	0.034	0.0078	0.0051	0.0034
Turkey (male)	20	0.74	0.012	0.088	75	63	0.186	0.139	0.054	0.0111	0.0074	0.0048
Duck	4	0.44	0.007	0.053	73	62	0.118	0.089	0.016	0.0043	0.0034	0.0026
Sheep												
Feeder lamb[c]	100	4.1	0.06	0.5	75	63	1.05	0.91	0.10	0.04	0.02	0.04
Horse												
Sedentary	1,000	54.4	0.88	6.56	86[d]	62	7.61	6.5	1.52	0.18	0.06	0.06[d]
Intense exercise	1,000	55.5	0.90	6.70	86[d]	62	7.78	6.6	1.56	0.30	0.15	0.23[d]

TS = total solids; VS = volatile solids; BOD_5 = the oxygen used in the biochemical oxidations of organic matter in five days at 68 F, which is an industry standard that shows wastewater strength.

[a] Use linear interpolation to obtain values for weights not listed in the table.

[b] Calculated using TS divided by the solids content percentage.

[c] Based on MWPS historical data.

[d] Values calculated or interpreted using diet based formulas being considered for the ASAE Standards D384: *Manure Production and Characteristics.*

A lagoon surface area of 50 to 60 square feet per cow and a 5-foot design depth are recommended if effluent production rates are not known. Table 9 lists common milkhouse and milking parlor effluent characteristics.

Nutrient concentrations in all properly operating anaerobic lagoons are very low because of the high volume of dilution water, nutrient settling, and ammonia volatilization. Because of the natural variability and very low concentration, lagoon effluent nutrient characteristics for different animal species operations (e.g. swine, beef, dairy, and sheep) are very similar. Operation management and climatic variations have the greatest influence on lagoon effluent nutrient differences. Using an estimated nutrient concentration of 4-2-3 pounds (N-P_2O_5-K_2O) per 1,000 gallons will be a good representative of many lagoons. Approximately 80% to 90% of nitrogen in well-seasoned steady state anaerobic lagoons is in the ammonia form.

Solid. Like lagoons, solid manure with or without bedding is highly variable. Table 10 lists solid manure characteristics. When bedding is used, the amount of bedding will likely affect the nutrient concentration of the mixture more than the manure itself does. When a lot of bedding is used, nutrient concentrations will be low. On the other hand, the total nutrient retention may be greater when more bedding is used. Total nutrient losses from bedded manure are typically less than losses from liquid systems. Some reasons for the reduced loss are that the solid bedding soaks up and holds the nutrient-

Table 7. Estimated liquid pit manure characteristics.
Use only for planning purposes. These values should not be used in place of a regular manure analysis

	Production						Concentration			
	Manure	Total N	NH_3-N	P_2O_5	K_2O		Total N	NH_3-N	P_2O_5	K_2O
Livestock Stages	(lb/yr)					Units	lbs/1,000 gallons of manure			
Farrowing	11,500	21	11	17	15	per pig space	15	8	12	11
Nursery	1,000	3	2	2	3	per pig space	25	14	19	22
Grow-Finish (deep pit)	3,500	21	14	18	13	per pig space	50	33	42	30
Grow-Finish (wet/dry feeder)	2,500	17	12	13	12	per pig space	58	39	44	40
Grow-Finish (earthen pit)	3,500	13	10	9	8	per pig space	32	24	22	20
Breeding-Gestation	9,100	27	13	27	26	per pig space	25	12	25	24
Farrow-Finish	37,500	126	72	108	103	per production sow	28	16	24	23
	2,000	7	4	6	6	per pig sold per year	28	16	24	23
Farrow-Feeder	10,000	25	13	22	23	per production sow	21	11	18	19
Dairy Cow	54,000	200	39	97	123	per mature cow	31	6	15	19
Dairy Heifer	25,000	96	18	42	84	per head capacity	32	6	14	28
Dairy Calf	6,000	19	4	10	17	per head capacity	27	5	14	24
Veal Calf	3,500	11	9	9	17	per head capacity	26	21	22	40
Dairy Herd	73,000	271	53	131	193	per mature cow	31	6	15	22
Beef Cows	30,000	72	25	58	86	per mature cow	20	7	16	24
Feeder Calves	13,000	39	12	26	35	per head capacity	27	8	18	24
Finishing Cattle	25,500	89	24	55	79	per head capacity	29	8	18	26
Broilers	83	0.63	0.13	0.40	0.29	per bird space	63	13	40	29
Pullets	49	0.35	0.07	0.21	0.18	per bird space	60	12	35	30
Layers	130	0.89	0.58	0.81	0.51	per bird space	57	37	52	33
Tom Turkeys	282	1.79	0.54	1.35	0.98	per bird space	53	16	40	29
Hen Turkeys	232	1.67	0.56	1.06	0.89	per bird space	60	20	38	32
Ducks	249	0.45	0.24	0.36	0.33	per bird space	22	5	15	8

rich liquids, and also the carbon typical of many bedding types increases the carbon-to-nitrogen ratio.

Tables 11 and 12 list the density and water-absorbing capabilities of common bedding materials. To estimate the amount of bedding used, weigh the bedding added to each pen per week and multiply by the number of pens and weeks between cleaning. Tables 13 and 14 list approximate bedding requirements.

To estimate the total weight of bedding and manure, add the amount of manure produced per animal from Table 6 (solids and liquids) to the amount of bedding. Subtract any drained liquids (not absorbed by the bedding). If well bedded, neglect drained liquids. Equation 5 can be used to determine the total weight of manure.

To estimate the volume of manure and bedding, add the manure production volume from Table 6 to one-half of the bedding volume. Bedding volume is reduced by one-half during use. Equation 6 can be used to determine the total volume of manure.

Total solids for manure plus bedding can be determined using the graph in Figure 5.

Open Feedlots. Manure from open feedlots can vary widely due to climate, diet, feedlot surface, animal density, and cleaning frequency. Tables 15 and 16 list typical characteristics of beef feedlot and feedlot runoff pond manure.

Milking Center Effluent. Size of parlor, management, and equipment used determine the volume of effluent from milking and cleaning operations. If cow

Table 8. Estimated annual manure and nutrients from lagoon effluent (lbs per year).
Use only for planning purposes. These values should not be used in place of a regular manure analysis.

Production	Units	Manure Produced	Total N	NH_3	P_2O_5	K_2O
Grow-Finish	lbs per pig space	8,000	4	4	2	3
Farrow-Finish	lbs per production sow	64,000	36	32	23	29
Breeding-Gestation	lbs per pig space	11,500	5	4	4	5
Farrowing	lbs per sow	16,500	8	7	6	8
Dairy Cow	lbs per mature cow	91,000	46	41	19	33
Dairy Herd	lbs per mature cow	138,000	70	63	30	50
Fattening Cattle	lbs per head capacity	44,000	27	24	21	27
Broilers	lbs per bird space	130	0.14	0.13	0.07	0.06

Table 9. Estimated dairy milking center effluent characteristics.
Use only for planning purposes. These values should not be used in place of a regular manure analysis
Based on NRCS *Agricultural Waste Management Field Handbook,* Part 651.

				Milkhouse & Parlor and Holding Area (scraped & flushed)	
Component	Units	Milkhouse	Milkhouse & Parlor	Holding Area manure excluded	Holding area manure included
Volume	cu ft per day per 1,000 lbs per animal	0.22	0.60	1.40	1.60
Moisture	%	99.72	99.40	99.70	98.50
Total solids (TS)	% wet basis	0.28	0.60	0.30	1.50
Volatile solids (VS)	lbs per 1,000 gal	12.90	35.00	18.30	99.96
Fixed solids (FS)	lbs per 1,000 gal	10.60	15.00	6.70	24.99
Chemical oxygen demand (COD)	lbs per 1,000 gal	25.30	41.70	—	—
Biochemical oxygen demand (BOD)	lbs per 1,000 gal	—	8.37	—	—
Nitrogen (N)	lbs per 1,000 gal	0.72	1.67	1.00	7.50
Phosphorus (P_2O_5)	lbs per 1,000 gal	0.58	0.83	0.23	0.83
Potassium (K_2O)	lbs per 1,000 gal	1.50	2.50	0.57	3.33
Carbon:Nitrogen (C:N)	ratio	10.0	12.0	10.0	7.0

Table 10. Estimated solid manure characteristics.

Use only for planning purposes. These values should not be used in place of a regular manure analysis.

	Production						Concentration			
	Manure	Total N	NH_3-N	P_2O_5	K_2O		Total N	NH_3-N	P_2O_5	K_2O
Livestock Stages	(lb/yr)					Units	lbs/ton of manure			
Farrowing	4,800	34	7	14	10	per pig space	14	3	6	4
Nursery	480	3	1	2	1	per pig space	13	5	8	4
Grow-Finish	2,100	17	6	9	5	per pig space	16	6	9	5
Breeding-Gestation	2,000	9	5	7	5	per pig space	9	5	7	5
Feeder Pig	4,540	23	11	16	9	per sow space	10	5	7	4
Farrow-Finish	17,140	120	51	69	43	per sow space	14	6	8	5
	950	7	3	4	2	per pig sold	14	6	8	5
Dairy Cow	28,000	140	28	42	84	per mature cow	10	2	3	6
Dairy Heifer	13,000	65	13	20	46	per head capacity	10	2	3	7
Dairy Calf	3,000	15	3	5	8	per head capacity	10	2	3	5
Veal Calf	2,200	10	6	3	7	per head capacity	9	5	3	6
Dairy Herd	40,200	181	40	80	141	per mature cow	9	2	4	7
Beef Cows	13,400	47	20	27	47	per mature cow	7	3	4	7
Feeder Calves (500 lbs)	7,000	32	11	14	28	per head capacity	9	3	4	8
Finishing Cattle	11,800	65	24	41	65	per head capacity	11	4	7	11
Broilers	18	0.41	0.11	0.48	0.32	per bird space	46	12	53	36
Pullets	22	0.53	0.10	0.39	0.30	per bird space	48	9	35	27
Layers	39	0.66	0.23	0.99	0.51	per bird space	34	12	51	26
Tom Turkeys	46	0.92	0.18	1.15	0.69	per bird space	40	8	50	30
Hen Turkeys	46	0.92	0.18	1.15	0.69	per bird space	40	8	50	30
Ducks	60	0.42	0.15	0.54	0.33	per bird space	17	4	21	30

Table 11. Density of bedding materials.

a. Loose bedding.	
Material	**Density (lbs per cu ft)**
Straw	2.5
Wood Shavings	9
Sawdust	12
Sand	105
Non-legume hay	4
Alfalfa	4
b. Baled bedding.	
Material	**Density (lbs per cu ft)**
Straw	5
Wood Shavings	20
Non-legume hay	7
Alfalfa	8
c. Chopped bedding.	
Material	**Density (lbs per cu ft)**
Straw	7
Newspapers	14
Non-legume hay	6
Alfalfa	6

Values are approximate.

Table 12. Absorption properties of bedding materials.

Approximate water absorption and density of dry bedding (typically 10% moisture).

Material	Water absorption (lbs water absorbed per lb bedding)
Wood	
Tanning bark	4.0
Fine bark	2.5
Pine	
Chips	3.0
Sawdust	2.5
Shavings	2.0
Needles	1.0
Hardwood chips, shavings or sawdust	1.5
Shredded newspaper	
	1.6
Corn	
Shredded stover	2.5
Ground cobs	2.1
Straw	
Flax	2.6
Oats	2.5
Wheat	2.2
Hay, chopped mature	
	3.0
Shells, hulls	
Cocoa	2.7
Peanut, cottonseed	2.5

Values are approximate.

Table 13. Minimum recommended bedding requirements (lbs per day per 1,000 lb of animal weight).

Housing system	Long straw	Chopped straw	Shavings	Sawdust	Sand
Dairy					
Stanchion barn	5.4	5.7	—	—	—
Freestall housing	—	2.7	3.1	3.1	35
Loose housing bedding area	9.3	11.0	—	—	—
Swine					
(shed lot)	3.5	4.0	—	—	—
Poultry					
(floor level)	—	—	—	1.6	—

Table 14. Bedding requirements for dairy cows.

Bedding type	Moisture content (%)	Required Bedding (lbs per cow per day)
Green sawdust*		
Stored, uncovered	75	28
Stored, covered	25	19
Dried sawdust		
	10	9
Baled straw		
	10	4

*Green sawdust should be avoided to prevent klebsiella mastitis.

Equation 5. Total weight of manure.

$$\begin{matrix}\text{Total}\\\text{Weight}\end{matrix} = \begin{pmatrix}\text{Manure}\\\text{Weight}\end{pmatrix} + \begin{pmatrix}\text{Bedding}\\\text{Weight}\end{pmatrix}$$

Equation 6. Total solid manure volume using organic bedding.
Does not apply to open feedlots where substantial evaporation occurs.

$$\begin{matrix}\text{Total}\\\text{Volume}\end{matrix} = \begin{pmatrix}\text{Manure}\\\text{Volume}\end{pmatrix} + \left(\frac{1}{2}\right) \times \begin{pmatrix}\text{Organic Bedding}\\\text{Volume}\end{pmatrix}$$

EXAMPLE 1. Estimating bedding needs.
Determine the amount of bedding needed to raise the solids content from 6 to 15%.

SOLUTION:
In Figure 5, find the sloped line that corresponds to the manure's initial dry matter content:

1) Locate the 6% initial manure total solids line (a).
2) Locate 15% on the desired total manure solids axis, then follow the line horizontally until the line crosses the 6% initial manure total solids line (b).
3) Then go down vertically to read the pounds of bedding to be added per 100 pounds manure. This example needs 12 pounds of bedding per 100 pounds to be added to the manure.

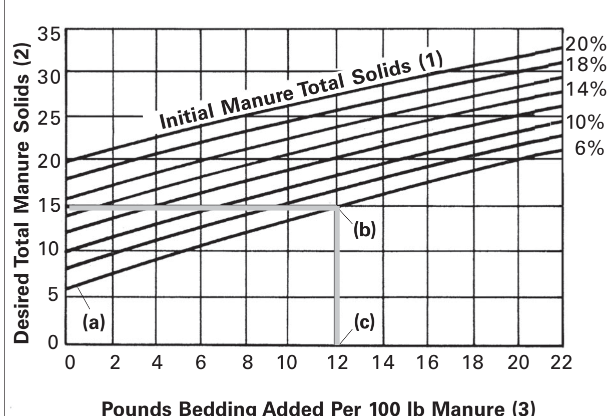


Figure 5. Changing manure dry matter by adding bedding.
Procedure: Find the sloped line that corresponds to the **Initial Manure's Dry Matter** content (1). Follow the line until it meets the horizontal line that corresponds to the **Desired Manure Total Solids** (2). Then go down to read the pounds of bedding to be added per 100 pounds of manure (3) to reach the desired solids content. Letters ingraph are for Example 1.

Table 15. Estimated beef feedlot manure characteristics.
Use only for planning purposes. These values should not be used in place of a regular manure analysis
Based on NRCS *Agricultural Waste Management Field Handbook,* Part 651.

Component	Units	Unsurfaced lot[a]	Surfaced lot[b]	
			High forage diet	High energy diet
Manure Weight	lbs per day per 1,000-lb animal	17.50	11.70	5.30
Moisture	%	45.00	53.30	52.10
Total solids (TS)	% wet basis	55.00	46.70	47.90
	lbs per day per 1,000-lb animal	9.60	5.50	2.50
Volatile solids (VS)	lbs per day per 1,000-lb animal	4.80	3.85	1.75
Fixed solids (FS)	lbs per day per 1,000-lb animal	4.80	1.65	0.75
Nitrogen (N)	lbs per day per 1,000-lb animal	0.21	—	—
Phosphorus (P_2O_5)	lbs per day per 1,000-lb animal	0.14	—	—
Potassium (K_2O)	lbs per day per 1,000-lb animal	0.03	—	—
Carbon:Nitrogen (C:N)	ratio	13:1	—	—

[a] Dry climate (annual rainfall less than 15 inches); annual manure removal.
[b] Dry climate; semiannual manure removal.

Table 16. Beef feedlot runoff pond manure characteristics.
Based on NRCS *Agricultural Waste Management Field Handbook*, Part 651.

Component	Units	Runoff Pond	
		Supernatant	Sludge
Moisture	%	99.7	82.8
Total solids (TS)	% wet basis	0.30	17.2
Volatile solids (VS)	lbs per 1,000 gal	7.50	645
Fixed solids (FS)	lbs per 1,000 gal	17.50	788
Chemical oxygen demand (COD)	lbs per 1,000 gal	11.7	645
Nitrogen (N)	lbs per 1,000 gal	1.67	51.7
Ammoniacal Nitrogen (NH_3-N)	lbs per 1,000 gal	1.50	—
Phosphorus (P_2O_5)	lbs per 1,000 gal	—	17.5
Potassium (K_2O)	lbs per 1,000 gal	7.50	14.2

udders are washed and disinfected, then dried with paper towels, there is very little wasted water. Floors can be washed with relatively little water using a stiff-bristle broom, or hosed down with a lot of water. Small operations tend to use less cleaning water overall, but may require more water per cow per day. Depending on the source, milking center effluent can resemble:

- **Dilute liquid manure**—when it contains large amounts of feed, bedding, and hoof dirt. Some of the solids settle; others float.
- **Dilute milk plant effluent**—during equipment washing. The suspended milk solids do not settle easily. The residual cleaning chemicals are usually concentrated enough to affect subsequent treatment and disposal.
- **Concentrated milk-processing effluent**—if milk-process effluent contains colostrum or medicated or spilled milk. This effluent tends to be very high in readily biodegradable organic material and has a high BOD. Milk-process effluent can create serious problems in waterways if the effluent should reach them. Concentrated milk-processing effluent has the potential to create serious odor problems if it is allowed to degrade anaerobically.
- **Milkhouse and parlor effluent**—cannot be disposed of into field tiles, streams, lakes or ditches. Septic tank or soil absorption systems are **not** recommended for milking center effluent. Milk solids do not settle well in septic tanks, and they can carry over into the soil absorption system, resulting in plugging of the soil to the extent that absorption stops.
- **Clear water**—effluent from final pipeline rinses and water-cooled equipment.

Table 9 lists some common characteristics for milking center effluent.

Nutritional Factors Influencing Manure Composition

Diets fed, as well as the manure storage systems used, and management practices, affect the nutrient content of manure.

Feed Intake. Diets vary with animal type and the stage of the livestock production cycle. For instance, protein requirements decrease, and carbohydrate forms change as an animal grows to maturity, thereby decreasing the concentration of these nutrients excreted as a percent of body weight. Similarly, increased levels of minerals fed (e.g. copper, phosphorus, sodium) increase the levels of those nutrients in the manure. Nutrient analysis of manure should be done regularly, especially when major changes in management or diet formulation occur, to determine proper land application rates. Antibiotics and feed additives (e.g. copper sulfate, rumensin, and carbadox) can reduce solids degradation in manure systems, potentially causing increased solids build up (represented as sludge in the bottom of storages). Conversely, arsenic compounds (e.g. arsonilic acid, roxarsone, and avilamycin) can stimulate anaerobic decomposition and liquidification of manure. In non-ruminants, enzymes (e.g. phytase added to the rations) and reduced phosphorus in the diet can reduce phosphorus excretion from 30 to 50%. Adding feed grade amino acids to rations can reduce nitrogen excretion in manure significantly.

Although sampling and the use of tabular estimates are the most common methods of estimating manure nutrients, alternative modeling methods have been proposed to allow accounting for dietary differences and their effects on manure nutrients. One problem with using tabular values is that manure nutrient estimates sometimes exceed dietary intake of the animals. Nutrient excretion varies with animal diets and the amount of the nutrients retained in the animal bodyweight and other forms of production such as milk and eggs. Use Equation 7 to calculate raw excreted manure nutrients (when no environmental influences are considered).

Most producers know the feed nutrient intake of their animals, which can be calculated as the product of feed intake and feed nutrient concentration. The National Research Council (NRC) provides information for determining nutrient needs of various livestock species to achieve given production rates. Estimating nutrient retention is more difficult.

Changes in dietary intake can have a significant effect on manure nutrients. By more closely balancing the nutrient needs of the animals to the ration, manure nutrients can be significantly reduced. Any technique enhancing feed efficiency has the potential of decreasing nutrient excretion and odor production.

Worksheet 1 can be used to estimate nutrients excreted for a livestock operation.

Diet Nutrient Modification for Non-Ruminant Animals. The bio-availability of phosphorus in feed ingredients for non-ruminants, such as swine and poultry, has traditionally been very low. Because the phosphorus is attached to phytate, and pigs and chickens lack the enzyme phytase, phosphorus availability is low in their digestive systems. Current feed formulation practices correct for the unavailability by adding extra inorganic phosphorus supplements causing undigested phosphorus to be excreted. Increasing the availability of the phosphorus in feed ingredients with phytase, and reducing the level of supplemental phosphorus in the feed, can reduce phosphorus excretion in manure up to 50%. Levels of supplemental phosphorus sufficient to reduce excretions by 50% generally cause decreased animal production. Proper use of phytase or low phytate corn typically can reduce manure phosphorus about 30%. Reduction in phosphorus excretion in manure may reduce the costs of the diet, as well as reduce the cropland base needed for manure spreading.

Different genetic lines require different protein and mineral levels to optimize performance and lean growth. High lean growth genetic lines will very likely require more minerals, including phosphorus (grams per day) and higher levels as a percent of the diet to support rapid lean growth.

The impact of amino acid supplementation with low crude protein diets to reduce nitrogen excretion range depends upon the size of the pig, level of dietary crude protein reduction, and initial crude protein level in the control diet. The average reduction

Equation 7. As-excreted manure nutrient calculation.

$$\begin{array}{c}\text{As-excreted Manure}\\ \text{Nutrients}\end{array} = \begin{pmatrix}\text{Feed Nutrient}\\ \text{Intake}\end{pmatrix} - \begin{pmatrix}\text{Nutrient Retention}\\ \text{(Based on bodyweight or production)}\end{pmatrix}$$

in nitrogen excretion per unit of dietary crude protein reduction was 8.4% but can be as high as 62%. A study has shown that reducing the crude protein level of corn-soybean meal in grow-finish diets by 3% (from 13 to 10% crude protein) and supplementing the diet with lysine, tryptophan, threonine, and methionine reduced ammonium and total nitrogen in freshly excreted manure by 28%. In addition, pH was reduced and dry matter increased in fresh manure and slurry from pigs fed the low crude protein and synthetic amino acid diet compared to other treatments. **Consult a nutritionist before modifying animal diets.**

Operation Management Practices. Feeding management also can affect the composition of manure nitrogen and potentially reduce nitrogen output in the manure. Any technique enhancing feed efficiency has the potential of decreasing nutrient excretion. Use of phase feeding reduced swine nitrogen excretion by 4.4%, and multiphase feeding reduced nitrogen excretion 3.5 to 16.8% in practical feeding studies with traditional and optimal housing facilities.

Wet-dry feeders result in less water wastage and thicker manure in swine finishing systems. Less water wastage results from swinging nipple waterers causing lower manure volume and higher solids and nutrient concentration. Studies in Nebraska have shown a 25% reduction in manure volume when swine finishers used wet/dry feed systems as compared to dry feeders. Iowa volume field studies support similar reductions and resulting increases in nutrient concentrations.

Many producers include water meters in their buildings today for health monitoring reasons. Water meter records can provide a close estimate of manure volume accumulation in a liquid pit system. Liquid manure accumulation in deep pits should closely mirror water consumption.

Summary

Knowing manure handling characteristics is important in selecting a manure storage and transfer system. Knowing the manure nutrient characteristics is important in developing treatment techniques and a nutrient management plan that will meet the crop needs. Determining the nutrient content of the manure before each land application event will help ensure compliance with a nutrient management plan. Proper sampling and testing of manure from each storage structure is important. When testing manure is not possible before land application, then use a best estimate of the manure nutrient content based either on previous tests or reliable published data. Tables have been provided in this publication to help in sizing manure storages and developing initial nutrient management plans. These tables should not be used in place of reliable tests or production data.

Conversions

Unit	Times	Equals
%	83.4	lbs per 1,000 gallons
%	10,000	ppm
acre-inch	27,200	gallons
gallons	0.0000368	acre-inch
cubic feet	62.4	lbs water
cubic feet	7.48	gallons
gallons	8.34	lbs water
K	1.20	K_2O
N	4.43	NO_3
N	1.22	NH_3
N	1.29	NH_4
P	2.29	P_2O_5
P	3.07	PO_4
lbs water	0.120	gallons
mg per liter	0.001	%
ppm	0.00834	lbs per 1,000 gallons
ton	2,000	lbs

Worksheet 1. Total manure nutrients excreted by a livestock operation based on feed rations.

This worksheet only considers feed intake and not feed disappearance. If excess feed ends up in the manure, then the amount of excess feed and its nutrients needs to be added to the nutrient excreted values for an accurate estimation.

I. Feed Nutrient Intake

Date ________________

Animal Group	A. Daily Feed Intake (lbs DM/day)	B. Feed Nutrient Concentration			C. Total Nutrient in Feed (lbs) = A X B	
		Protein	N[a]	P	N (lbs)	P (lbs)

II. Nutrients Retained

a. Animal

Animal Group (lbs)	D. Number of Animals	E. Average Daily Gain	F. Live Weight Nutrient Concentration		G. Nutrients Retained by Animal = D × E × F	
			N	P	N (lbs)	P (lbs)
Beef			0.016	0.0070		
Dairy			0.012	0.0070		
Pork			0.023	0.0072		
Hens			0.022	0.0060		
Broilers			0.026	0.0060		
Turkeys			0.021	0.0060		

b. Animal Products

Animal Product	H. Production (lbs/day)	I. Animal Products Nutrient Concentration		J. Nutrients Retained by Animal Products (lbs) = H × I	
		N	P	N (lbs)	P (lbs)
Milk[b]		0.0050	0.0010		
Eggs[b]		0.0166	0.0021		
Wool		0.0012	0.0001		

III. Nutrients Excreted

Animal Group	K. Days Fed per Year	L. Animal Nutrient Excreted in Elemental Form = K × (C - G) or = K × (C - J)		
		N (lbs/yr)	P (lbs/yr)	P_2O_5[c] (lbs/yr)

CALCULATION SPACE

[a] N in feed = Protein ÷ 6.25
[b] N in milk = Protein ÷ 6.28; N in eggs = Protein ÷ 6.25; Assumes 3.2% and 10.4% protein in milk and eggs, respectively
[c] lbs P_2O_5 = lbs P × 2.29

EXAMPLE 2. Calculating nutrient excreted based feed intake.
Use Worksheet 1 to calculate the annual nutrients excreted for the following beef finisher operation:

Number of animals:	1,000 head
Start weight:	650 lbs
Market weight:	1,250 lbs
Days to market:	147 days
Number days animals on lot:	350 days
Daily feed intake:	27,000 lbs DM/day
Protein concentration in feed:	0.135
Phosphorus (P) concentration in feed:	0.0035

SOLUTION:

Feed Nutrient Intake
• The first calculation required is to determine the amount of nitrogen in the feed intake. Nitrogen in the feed is calculated in I.B. using the protein concentration the equation listed at the bottom of the page:

$$\text{Nitrogen Concentration} = \frac{\text{Protein concentration}}{6.25} = 0.0216$$

• Total nutrient in the consumed feed is calculated in I.C.:

Nutrients in feed = (Daily Feed Intake) × (Nutrient Concentration)

Nitrogen in feed = (27,000 lbs) × (0.0216) = 583 lbs nitrogen

Phosphorus in feed = (27,000 lbs) × (0.0035) = 94.5 lbs phosphorus

Nutrients Retained
• The first calculation in this section is to determine the average daily gain ot the animals in section II.a.E.:

$$\text{Average Daily Gain} = \frac{\text{(Market Weight) - (Start Weight)}}{\text{Days to Market}} = \frac{\text{(1,250 lbs) - (650 lbs)}}{\text{147 days}} = \text{4.08 lbs/day}$$

• Nutrients retained by the animals is calculated in section II.aG.:

Nutrients Retained = (Number of Animals) × (Average Daily Gain) × (Live Weight Nutrient Concentration)

Nitrogen Retained = (1,000 head) × (4.08 lbs/day) × (0.016) = 65.3 lbs/day

Phosphorus Retained = (1,000 head) × (4.08 lbs/day) × (0.0070) = 28.6 lbs/day

Nutrients Excreted
• Finally, nurtients excreted is calculated in section III.L.:

Nutrients Excreted = (Days fed per year) × ((Feed Nutrient Intake) - (Nutrients Retained))

Nitrogen Excreted = (350 days/yr) × ((583 lbs/day) - (65.3 lbs/day)) = 181,195 lbs N/yr

Phosphorus Excreted = (350 days/yr) × ((94.5 lbs/day) - (28.6 lbs/day)) = 23,065 lbs P/yr

Phosphorus converted to P_2O_5 = (23,065 lbs P/yr) × 2.29 = 52,819 lbs P_2O_5/yr

Worksheet 1. Total manure nutrients excreted by a livestock operation based on feed rations.

This worksheet only considers feed intake and not feed disappearance. If excess feed ends up in the manure, then the amount of excess feed and its nutrients needs to be added to the nutrient excreted values for an accurate estimation.

Date 5/1/2004

I. Feed Nutrient Intake

Animal Group	A. Daily Feed Intake (lbs DM/day)	B. Feed Nutrient Concentration			C. Total Nutrient in Feed (lbs) = A X B	
		Protein	N[a]	P	N (lbs)	P (lbs)
	27,000	*0.135*	*0.0216*	*0.0035*	*583*	*94.5*

II. Nutrients Retained

a. Animal

Animal Group (lbs)	D. Number of Animals	E. Average Daily Gain	F. Live Weight Nutrient Concentration		G. Nutrients Retained by Animal = D × E × F	
			N	P	N (lbs)	P (lbs)
Beef	1,000	4.08	0.016	0.0070	65.3	28.6
Dairy			0.012	0.0070		
Pork			0.023	0.0072		
Hens			0.022	0.0060		
Broilers			0.026	0.0060		
Turkeys			0.021	0.0060		

b. Animal Products

Animal Product	H. Production (lbs/day)	I. Animal Products Nutrient Concentration		J. Nutrients Retained by Animal Products (lbs) = H × I	
		N	P	N (lbs)	P (lbs)
Milk[b]	—	0.0050	0.0010	—	—
Eggs[b]	—	0.0166	0.0021	—	—
Wool	—	0.0012	0.0001	—	—

III. Nutrients Excreted

Animal Group	K. Days Fed per Year	L. Animal Nutrient Excreted in Elemental Form = K × (C - G) or = K × (C - J)		
		N (lbs/yr)	P (lbs/yr)	P_2O_5[c] (lbs/yr)
	350	*181,195*	*23,065*	*52,358*

CALCULATION SPACE

I. B. $\frac{0.135}{6.25} = 0.0216$

C. 27,000 × 0.0216 = 583 N

27,000 × 0.0035 = 94.5

II. E. $\frac{1250\text{-}650}{147} = 4.08$

G. 1,000 × 4.08 × 0.016 = 65.3

1,000 × 4.08 × 0.0070 = 28.6

III. L. 350 × (583 - 65.3) = 181,195

350 × (94.5 -28.6) = 23,065

23,065 × 2.29 = 52,819

[a] N in feed = Protein ÷ 6.25
[b] N in milk = Protein ÷ 6.28; N in eggs = Protein ÷ 6.25; Assumes 3.2% and 10.4% protein in milk and eggs, respectively.
[c] lbs P_2O_5 = lbs P × 2.29

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