MANURE MANAGEMENT, TREATMENT, AND UTILIZATION

# Manure Characteristics, Testing, and Sampling

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Manure is a byproduct from livestock and poultry production. It is a mixture of animal dung and urine, feed residue, and other on-farm wastes, such as cleaning water or milking wastewater. Manure contains organic matter and nutrients that can improve soil health by increasing soil nutrient cycling and nutrient retention, water holding capacity, and resiliency to extreme growing conditions. It can reduce production costs by supplying essential crop nutrients to partially or fully replace the need for inorganic fertilizers.

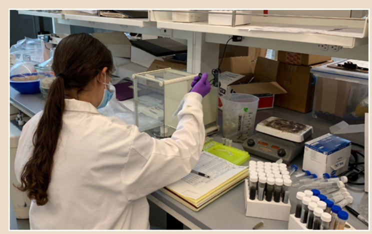
Manure is a valuable resource when appropriately used as crop fertilizer or processed into byproducts. However, excessive nutrients from manure application can result in soil and water pollution. Manure can be a liability when costly storage and treatment are needed.

More and more states are passing legislation to better regulate field manure application to reduce pollution. Appropriate timing, and application rate and method of manure land application based on manure characteristics can substantially benefit environmental protection.

Using book values for manure nutrient estimations can be problematic because measured farm data can vary widely, from a small percentage to several-fold (Dou et al., 2001). Therefore, manure sampling and testing are strongly recommended to help producers and growers obtain and use reliable manure characteristics to:

- address environmental concerns and keep in regulatory compliance,

*Manure contains organic matter and nutrients that can improve soil health and increase crop production.*



*Laboratory testing is recommended to determine manure properties, including nutrient values.*

*Liquid manure sampling in lagoons can be combined with lagoon agitation and pumping.*

*Solid manure sampling during loadout has been proven a convenient approach.*

- maintain or improve soil health by using organic matters and nutrients in manure that are more stable than in chemical fertilizers, and
- save money by reducing the need for purchasing chemical fertilizers.

Many Extension publications on manure sampling have been published over the years in different states. (See the reference list on pages 13-14.) The purpose of this publication is to provide updated and research-based knowledge and experiences for livestock and poultry producers, crop growers, Extension educators and specialists, and other stakeholders to use. Some highlights in this publication include:

- Manure characteristics and examples of their temporal and spatial variations.
- Manure testing and a list of 77 manure testing laboratories in the U.S. and Canada, including 62 Manure Analysis Proficiency (MAP) laboratories and 52 Certified Manure Testing (CMT) laboratories in 2021.
- Design considerations for manure sampling.
- Various tools and approaches for liquid and solid manure sampling.

# Manure Characteristics

Manure has its own physical, chemical, and biological characteristics that are important for assessing manure nutrient values and planning for effective manure collection, storage, transportation, treatment, and utilization.

## Physical properties

Manure physical properties describe the amount and consistency of the material to be dealt with by equipment in storage and treatment facilities, and in manure applications. They are important to agricultural producers, and facility planners and designers (USDA, 2008, Ch. 651.0401). Important manure physical properties include:

- weight (Wt)
- volume (Vol)
- moisture content (MC)
- total solids (TS)
- volatile solids (VS)
- fixed solids (FS)
- dissolved solids (DS)
- suspended solids (SS)

Manure weight and volume can often be determined on farms. The other physical properties are usually determined in testing laboratories. The most important physical properties in manure are moisture content or total solids because they affect the ways that manure is collected, stored, transported, and land applied. Moisture content and total solids can be converted with each other:

$$\text{total solids (\%)} = 100\% - \text{moisture content (\%)}$$

$$\text{moisture content (\%)} = 100\% - \text{total solids (\%)}$$

The other four types of solids (VS, FS, DS, and SS) are useful when manure is going through some treatment processes, e.g., solid separation, anaerobic digestion for bioenergy production.

## Chemical constituents

Manure land application as fertilizer is the primary use of manure. Three manure chemical constituents are of great value as fertilizer:

- nitrogen (N)
- phosphorus (P)
- potassium (K)

In addition to N, P, and K, which are the principal components considered in development of a manure management plan (USDA, 2008, Ch. 651.0401), manure contains other chemical constituents that usually include:

- sulfur (S)
- calcium (Ca)
- magnesium (Mg)
- sodium (Na)
- copper (Cu)
- iron (Fe)
- manganese (Mn)
- zinc (ZN)

## Biological properties

Chemical oxygen demand (COD), and 5-day Biochemical Oxygen Demand ($BOD_5$) are used in planning and design of certain biological procedures for treating liquid manure. For example, the COD can be used to estimate methane production potential of manure under anaerobic digestion. The COD and $BOD_5$ are used to determine pollution potentials of manure.

## Variations in manure characteristics

Multiple studies have demonstrated that variations in characteristics of manure at livestock and poultry farms are inherent and challenging for manure management and land application (e.g., Dou et al., 2001; Davis et al., 2002; Miller et al., 2019). Manure characteristics can be affected by many factors (Anonymous, 2015), such as:

- animal species
- feed ingredients and rations used
- water sources
- bedding materials
- manure collection method
- manure storage design
- microbial community in manure
- manure storage time and decomposition
- climate and weather conditions (Davis et al., 2002)
- farm management practices

Manure characteristics can have significant temporal and spatial variations.

### *Temporal variations*

Manure temporal variations are related to different seasons or manure storage durations. Seasonal changes in ambient temperature and other weather conditions can affect the physical and biochemical degradation processes of manure in animal buildings and manure storages. In animal buildings, the impact of seasonal weather changes may be indirect by seasonal adjustment of building ventilation and heating. However, although temporal variations in manure could be substantial and related to seasons, clear variation patterns and correlation between different manure characteristics can be difficult to illustrate, as shown in the two-year variation example in Figure 1.

Manure characteristics can also vary in much shorter time spans. For example, research showed that manure on manure belts in laying hen houses could lose approximately 2.5% moisture and 0.2% ammonia nitrogen concentration per day within 3 days of fresh manure from birds (Li and Ni, 2021).

### *Spatial variations*

Manure spatial variations can be substantial among different animal buildings and manure storages. The ranges in nutrient and TS concentrations in Table 1 demonstrate the variations among six under-floor manure pits and at different manure depths. The *Range* values show variations at different locations. The *Mean* values among *Surface*, *Middle*, and *Bottom* show considerable differences in TKN and K, which are lower in the pit bottom than in the surface, and in TS, which are twice as high in the pit bottom than in the surface.

Manure spatial variations are also related to locations within the same animal building, manure pile, manure tank or pit, or lagoon. These variations can be significant and are among the main issues that should be addressed when determining manure characteristics.

A manure-depth study revealed significant variation in several selected manure characteristics attributed to pile stratification.

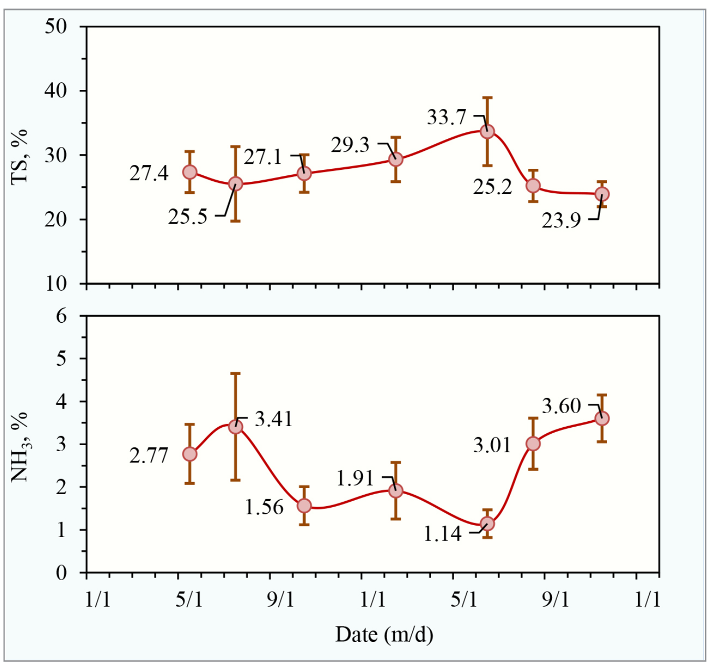



**Figure 1.** An example of two-year temporal variations in manure total solids and ammonia nitrogen ($NH_3$) concentrations in two laying hen houses. The error bars are standard deviations. Adapted from Li and Ni (2021).

**Table 1.** An example of manure spatial variations in six swine under-floor deep pits at different manure depths of 12–37 inches.

| Depth | TKN (%) | P (%) | K (%) | TS (%) |
|---|---|---|---|---|
| | | Surface | | |
| Range | 15.5–21.1 | 5.6–8.2 | 9.6–15.6 | 0.9–3.1 |
| Mean | 16.9 | 6.5 | 11.0 | 2.1 |
| | | Middle | | |
| Range | 12.6–20.0 | 5.2–10.0 | 7.1–16.0 | 0.9–3.5 |
| Mean | 16.7 | 6.7 | 11.0 | 2.3 |
| | | Bottom | | |
| Range | 6.8–11.5 | 3.5–8.1 | 2.8–6.5 | 3.1–5.5 |
| Mean | 9.7 | 5.2 | 5.1 | 4.2 |

Note: Surface = 6-inch below manure surface. Middle = middle depth of manure. Bottom = 4-inch from pit bottom. Unpublished research data.

The variables most affected were moisture, potassium and weed seeds (Brinton et al., 2012). For samples taken in two 2-floor manure-belt laying hen houses, the manure TS and ammonia nitrogen concentrations varied significantly among 24 different house sections (Figure 2). On broiler farms, the nutrient concentrations of litter in a house can also vary considerably depending on other specific locations, e.g., around feeders and around drinkers (Ritz et al., 2014).

## Manure Testing

Manure characteristics must be determined using established and standardized physical, chemical, and biological methods. Research demonstrated that book values for manure nutrient content are of limited usefulness in nutrient management. The discrepancies between book

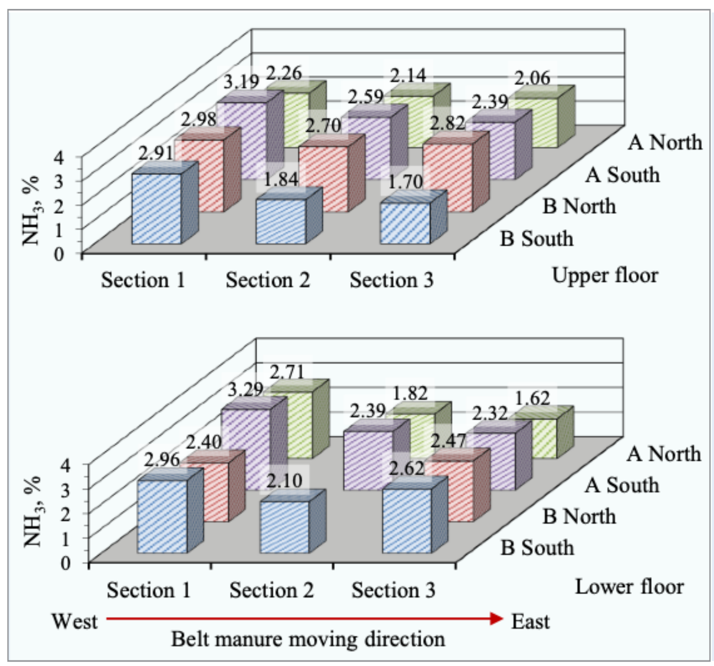



**Figure 2.** An example of 3-dimensional variations in manure ammonia nitrogen concentrations in two manure-belt laying hen houses (A and B). Each house was 460 feet long (west–east), 64 feet wide (south–north), and 38 feet high (two floors). Adapted from Li and Ni (2021).

values and the measured farm data varied widely, from a small amount to severalfold (Dou et al., 2001).

Underestimating the nutrient value of manure can lead to overapplication of nutrients, resulting in money wasted on fertilizer and potential environmental pollution. Overestimating the nutrient value can lead to lower crop yields and profits. Therefore, manure testing should be conducted for a specific batch of manure source at a specific time. Although some of the manure characteristics (e.g., pH) can be measured on-site, manure testing is usually done in laboratories using special equipment and test reagents following standardized methods.

### Selection of laboratories

If manure characteristics are to be determined in professional laboratories, it is recommended that the laboratory or laboratories are selected and contacted before manure sampling. This is because different laboratories may have different requirements and instructions on sampling procedure and recording as well as sample volume, preservation, and shipping (including scheduling and weekend delivery details). Many laboratories provide sample containers and other materials. It is necessary to follow the instructions of specific laboratories to reduce errors in manure testing results.

Most manure samples from livestock and poultry farms are analyzed in commercial laboratories, which are open to the public, by paying a fee. There were 77 manure testing laboratories in the U.S. and Canada in 2021 (See Appendix 1). The advantages of commercial laboratories include specialization and permanent staff. This means more consistent operations of sample testing. The following can be considered for selection of laboratories (Lorimor et al., 2004):

- Is the laboratory certified or recognized by any quality control organization? If possible, choose one with at least two years of experience in manure testing.
- How does the laboratory handle samples after it receives them? Would the samples be tested immediately, refrigerated, or pre-treated for later testing?
- How long does a customer typically wait before results are returned, and how are results delivered? Some laboratories can provide result reports electronically in spreadsheets and/or for online download. This is useful and can save time when result data from large number of samples need to be further processed.
- What are the costs of sample analysis?

### Manure Analysis Proficiency (MAP) Laboratories

Manure Analysis Proficiency (MAP) is a program designed to help laboratories improve their manure analysis methods and bring the industry results closer together. According to the Minnesota Department of Agriculture, 62 manure analysis laboratories in the U.S. and Canada were in the MDA program in 2021 (Appendix 1).

Laboratories participating in the MAP program receive unknown manure samples to analyze at least twice a year. Their results are compared with other laboratories in the program. Based on their results, some MAP laboratories are invited to become certified for manure testing (MDA, 2021b).

### Certified Manure Testing (CMT) Laboratories

Fifty-two (52) manure analysis laboratories in the U.S. and Canada were certified by the Minnesota Department of Agriculture for manure testing in 2021 (Appendix 1). All these laboratories were certified for Total Nitrogen and Total Phosphorus. Many laboratories also elected to become certified for other tests, including Total Potassium, Total Solids, Electrical Conductivity, Copper, Sulfur, and Zinc (MDA, 2021a).

However, inter-laboratory variations can still be expected. A recent assessment of manure sample analysis results from eight randomly selected MAP-certified laboratories showed accurate and precise for total nitrogen, most variability in ammonium, and significant differences in phosphorus and potassium (Sanford et al., 2020).

### Non-Commercial Laboratories

Many research and education institutions, whether public or private, and government agencies have capacities to perform manure testing. Some of them maintain top levels of quality control, e.g., U.S. EPA labs. Others may not have experienced and long-term staff to run the tests or only test manure samples occasionally. This may affect the consistency of analytical results because sample analysis depends on consistent operations, in addition to proper instrument maintenance, standard methods, and equipment calibrations.

Most of these laboratories usually are for internal use only and not open to the public. In some specific situations, e.g., collaboration relationship, it may be advantageous to have the manure samples analyzed at these laboratories for reasons such as close proximity to the sampling site, possible quick turnout, lower costs analysis, etc.

### Manure Testing Price

Most of the commercial laboratories post manure testing fees on websites or can provide the cost schedule upon request. Fees differ from laboratory to laboratory but not significantly. To test one sample for N, P, and K, the cost could be about $30 (Table 2). Package costs are usually available and are lower compared with analyzing individual parameters. Prices may change without notice.

## Manure sampling

### Importance of manure sampling

Proper manure sampling is necessary because laboratories can test only tiny portions (i.e., samples) of the large volumes of manure on livestock and poultry farms. The purpose of sampling is to collect samples that can represent the entire batch of manure being tested (Coffey et al., 2000). Using appropriate methods in manure sampling is essential to reduce errors due to variations in manure characteristics and obtain representative samples. Poorly sampled systems will be detrimental to the accuracy of testing results and can be unfavorable for a manure management program.

**Table 2.** Examples of manure testing costs posted on the internet by three laboratories in 2021.

| Parameter | Lab 1 | Lab 2 | Lab 3 |
|---|---|---|---|
| N, P, K | $28 | | |
| TS, TKN, P, K | | $30 | |
| N, P, K, organic N | $36 | | |
| N, P, K, organic N, Ca, Cu, Fe, Mg, Mn, Na, S, Zn | $50 | | |
| TS, TN, P, K, S, Ca, Mn, Na, Fe, Mg, Cu, Zn, pH, AN, Organic N | | $35 | $40 |
| TS, TN, P, K, S, Ca, Mn, Na, Fe, Mg, Cu, Zn, pH, AN, Organic N, Ash, Organic carbon, Organic matter, C:N ratio | | $40 | |
| C:N ratio | $11 | | $40 |

Safety and personal protection measures should be implemented. Pre-sampling planning can improve work efficiency. Using effective and practical tools and correct methods can reduce manure characterization errors.

## Safety and personal protection in manure sampling

Precautions for safety are of utmost importance during manure sampling. Incidents involving injuries and deaths during manure operations have been frequently reported (Nour et al., 2021). Potential incidents during manure sampling should be prevented.

Indoor and outdoor manure storages are potentially hazardous places to work, especially liquid manure storages. Exposure to toxic manure gases can cause suffocation, falls, entanglement, and drowning. Protection measures should be adequately planned and followed. For example, wear gloves and appropriate personal protective equipment during sampling (Field, 1980).

Hydrogen sulfide is the most dangerous toxic gas from liquid manure storages. Liquid manure can serve as a reservoir of large amount of hydrogen sulfide bubbles that can be suddenly released to the air when the manure is disturbed (Ni et al., 2009). Studies in swine barns show that agitation of liquid manure may result in a surge of hydrogen sulfide concentrations to 20 ppm (Lim et al., 2004), 36 ppm (Hoff et al., 2006), even to a dangerous level of more than 1,000 ppm (Chénard et al., 2003). Fatalities have occurred during manure operations in confined animal buildings as well as at an open-air lagoon site (Shutske et al., 2017). Manure sampling during agitation should be avoided for safety reasons, or conducted with great caution and with proper protection.

## Sampling plan

Making a good sampling plan ensures well-prepared sampling sessions and consistent nutrient data collection. Depending on the farm size and manure source, a sampling plan can be simple or with more details. A plan may include:

- Time of sampling
- Location of sampling, including batches of manure sources to sample (i.e., barns, manure storages, lagoons, or composts) and specific location points where subsamples are to be taken
- Number of composite samples to be tested in a laboratory
- Labeling and recording method
- Tools and safety equipment
- Training of sampling personnel
- Other work and arrangement associated with sampling at specific farms

### *Time of sampling*

In most cases, manure sampling is to determine values of the manure and make adjustment to the nutrient management plans before land application. The best time of sampling depends on types of manure. It can be selected before manure application, after an adequate slurry agitation, during manure pumping or load-out, or while liquid or solid manure is being land applied.

For liquid manure, many researchers recommend samples be taken within 1 to 2 weeks of land application to reduce the impact of temporal variations.

In poultry houses, it is recommended not to sample the litter when it is still being used as a bedding. Instead, wait until clean-out to obtain samples when house litter is mixed (Ritz et al., 2014).

Composts may be sampled within 1 to 2 months prior to application because they have already undergone many decomposition processes and thus contain more stable compounds that are less likely to change significantly over weeks or even months (Ward, 2020). Research shows that repeated sampling after two weeks of matured compost indicated no appreciable differences between points of time except for weed seeds (Brinton et al., 2012).

### *Location of sampling*

Because of the spatial variations in manure characteristics, sampling locations should cover different manure storages, e.g., barns, pits, lagoons, if manure in these storages are all to undergo the same testing. Samples should be taken at different locations and depths within the same manure storage. If sampling during manure application, samples can be taken from different loads to cover the beginning, middle, and end of application.

Like liquid manure, solid manure also varies in nutrient content across storage. Collecting representative samples of solid manure from static piles requires consideration of both the quantity and depth of samples (Maguire et al., 2009; Miller et al., 2019). Non-representative locations, e.g., wet spots in poultry houses due to water leakage and top or edges of the pile where a crust has formed, should be avoided for sample taking.

### *Number of composite samples*

Composite samples, each of which is a mixture of multiple subsamples, can reduce the number of samples to be tested, thus cutting the cost of testing and other related costs, such as materials and shipping. The number of composite samples can be determined by the types of manure and the quantity of manure. Usually, each barn or manure storage unit should have at least one composite sample to be tested (Roberts et al., 2016).

### *Number of subsamples for each composite sample*

Statistically, the larger the number of subsamples from adequately selected sampling locations, the more representative the composite sample is.

Taking more or fewer subsamples is a balance of sampling time/cost and sample representativeness. The recommended numbers of subsamples for each composite sample differ by different researchers from different studies. Some suggestions from research listed in Table 3 are for consideration in actual farm situations.

### *Sample labels and sample recording*

It is useful to record the sample information as much as possible and in a concise, systematic way, especially for large farms and long-term manure management. Designing a sample label coding system can help manage manure data. Code elements can be added or removed from the example in Figure 3, depending on the actual farm situation.

A computer spreadsheet and/or hardcopy table to record the labels of multiple samples can be made during sampling planning or after sampling. Labels can be directly written on or printed and firmly stuck to the sample bottle or bag before sample taking.

## From subsamples to composite samples

### *Grab sampling and column sampling*

A grab sample is a single, discrete sample collected from one depth and/or at a particular location in a storage. A column/profile sample is a spatially continuous sample, or a column, along the depth of a manure storage at a particular location. Grab sampling and column sampling can be applied to both liquid manure (Figure 4) and solid manure (Figure 5). The manure characteristics of a grab sample or a column sample are also related to specific sampling time.

**Table 3.** Recommended numbers of subsamples per composite sample for different manure sources.

| Manure type | Recommendations |
|---|---|
| **Pit or lagoon** | ~8 areas around the pit or lagoon [1, 2] |
| | 3 – 5 with agitation.<br>>40 without agitation [3] |
| **Poultry house** | 20 – 30 different areas in the house [1] |
| | > 10 during building clean-out from in-house piles or truck spreader [4] |
| **Solid manure or litter** (beef, dairy, horse, sheep, and chicken) | 6 grab samples were required from single source piles [7] |
| | > 25 grab samples for multisource manure piles [7] |
| | 6 grab samples for single source piles. |
| | ~25 grab samples for multisource manure piles [6] |
| | 8 at spots throughout the pile to a depth of 12" [5] |
| | 8 different areas in the waste [1] |
| | > 100 for NH4-N and nitrate (NO3-N) due to their relatively low concentrations [6] |
| **Compost** | 6 throughout the compost pile at a depth of 0-12" [5] |

[1] (Maguire et al., 2009), [2] (Sharara and Owusu-Twum, 2020); [3] (Dou et al., 2001); [4] (Ritz et al., 2014); [5] (Ward, 2020); [6] (Davis et al., 2002); [7] (Miller et al., 2019)

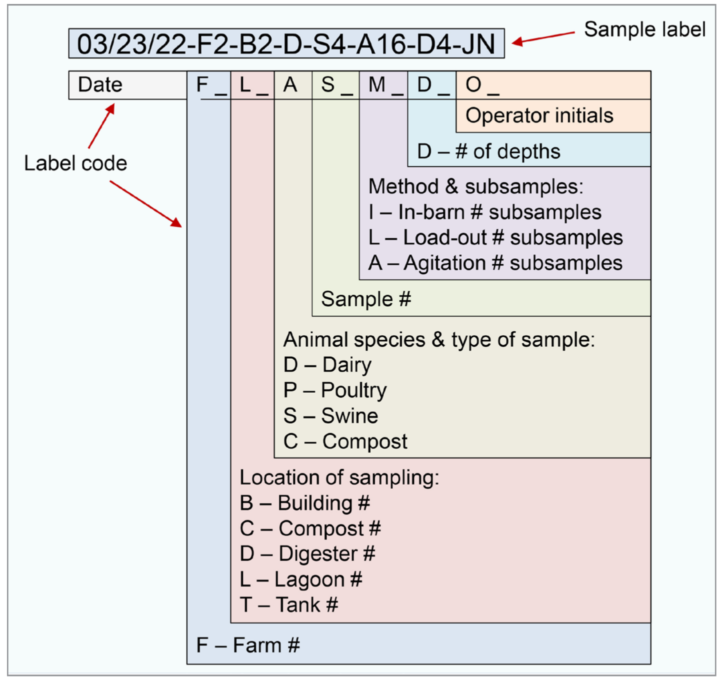



**Figure 3.** An example of manure sample label code system.

### *Two-bucket method*

In a group of selected sampling locations, if each location represents an equal amount (volume or weight) of the bulk manure as the other locations, it is important to use equal volume of subsample from all locations to make a composite sample. This will ensure that the subsamples are correctly represented in the weighted mean of the sample analysis results. In case of taking subsamples from flowing manure (e.g., from the pumping-out manure stream), the same principle should be applied. That is, if each of several subsamples represents equal volume (or pumping duration) of the pumped-out manure, the same volume of subsample should be used to make the composite sample.

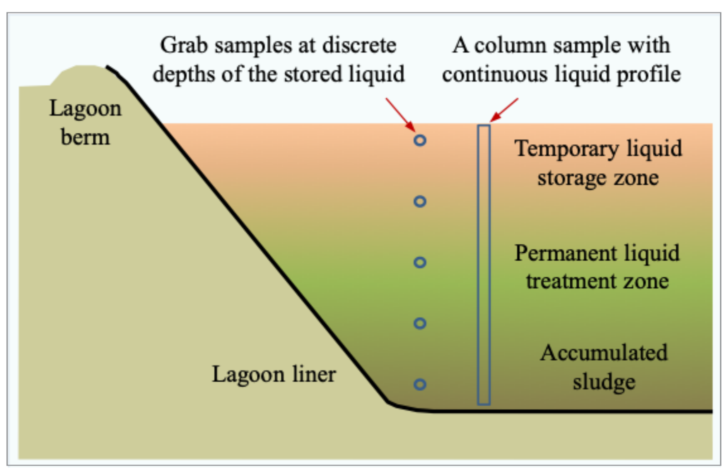



**Figure 4.** Illustrations of grab samples and column samples for liquid manure in a lagoon. Adapted from Zhang and Hamilton (2009) and Sharara and Owusu-Twum (2020).

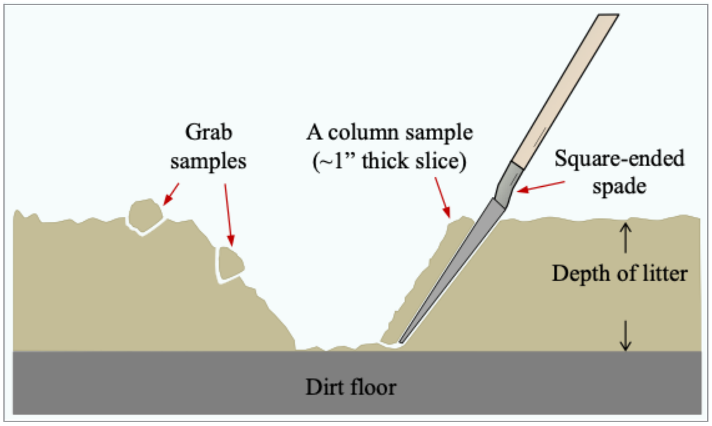



**Figure 5.** Illustrations of grab samples and a column sample for solid manure in a broiler house. Adapted from Lory and Fulhage (1999).

To satisfy this requirement, a two-bucket mixing method is recommended (Figure 6). This method requires a subsample bucket and a composite sample bucket. Both buckets can usually be 5-gallon plastic buckets. Some researchers (e.g., Maguire et al., 2009) recommend that galvanized containers not be used because metals in the container, such as zinc, may contaminate the sample.

After a subsample is taken from the bulk manure, put it in the cleaned subsample bucket and thoroughly mix to achieve homogeneity as much as possible. Mixing of the manure in the bucket can be done manually. In case of liquid manure, a variable-speed battery-powered drill and a mixer (e.g., paint mixer) can also be used for mixing.

For liquid subsample, while stirring the liquid manure, ensuring that the subsample is completely mixed and any solids are suspended, quickly take a fixed amount (e.g., 250 mL for each and all subsamples) and put it in the composite sample bucket.

For solid subsample, also take a fixed amount (e.g., 250 mL) and put it in the composite sample bucket after the subsample is thoroughly crumbled and mixed in the subsample bucket. The subsample bucket is then cleaned and dried before being used for the next subsample.

When all the subsamples are taken and transferred to the composite sample bucket, a composite sample in the bucket can be taken after mixing the content in the bucket the same way as in the subsample bucket. Clean the composite sample bucket for the next sample.

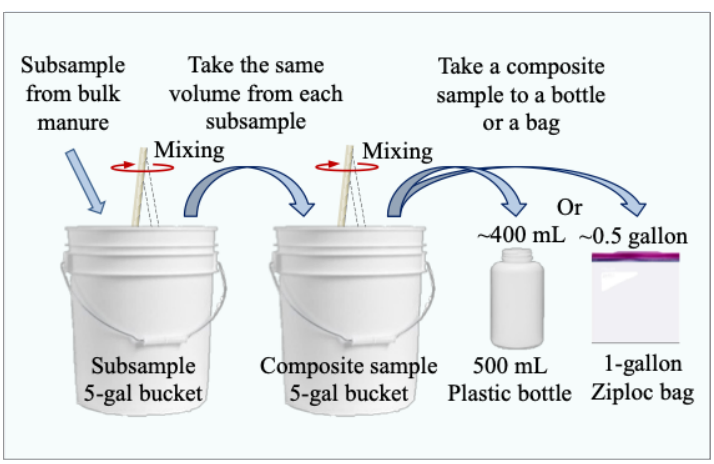



**Figure 6.** The two-bucket method for subsample and composite sample making.

### *Sample volume and sample container*

Generally, manure testing requires a sample volume of 250–400 mL (~8–14 oz.) for a liquid sample and 250–500 g (~0.5–1 lb.) for a solid sample. However, different manure testing laboratories may have slightly different requirement on sample volumes. Some labs may also require pretreatment of certain samples by acids, e.g., using sulfuric acid ($H_2SO_4$) to lower the pH to < 2.0 for ammonia analysis. Contact the selected testing lab before sampling to make sure the sample volume and pretreatment satisfy the lab requirements.

The composite liquid sample should be put into a clean, labeled, 500-mL (or one-pint), and widemouthed plastic bottle with a screw-type lid. Some testing laboratories provide plastic sample bottles (Figure 7). Fill the sample bottle to only 75–80% full. The headspace is for off-gassing from the liquid. After the bottle is closed tightly, it can be placed in a plastic bag and sealed in case of bottle leakage. Glass bottles are not recommended because they can break in response to gas expansion. For solid manure, place the composite sample into a Ziploc bag of 1-quart to 1-gallon size, squeeze the air out of the bag, and seal the bag. The sample bag can be put into a second bag for better sealing. The bottles and bags filled with samples can be kept in a cooler with some ice or dry ice to keep the samples cool.

## Liquid manure sampling tools

### *Custom and commercial samplers*

Taking a grab sample, especially below the storage surface, or taking a column sample in liquid manure storage requires special samplers. Most of the liquid manure samplers reported in the literature were custom-made. Some commercial products are available. Searching the internet using keywords such as "sludge sampler," "septic sampler," "tank sampler" and "grab sampler." Although most of these products are designed for sludge or septic sampling, they can be adopted for manure sampling.

### *Cup-pole grab sampler*

The cup-pole grab sampler is a simple design (Figure 8). It does not have a remotely controllable cup cover; therefore, it

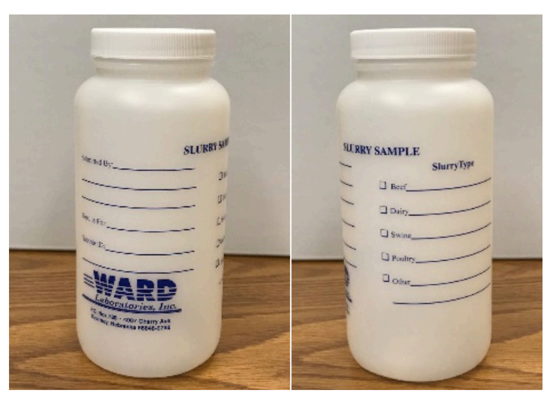



**Figure 7.** Example of plastic bottles for slurry samples provided by Ward Laboratories.

**Figure 8.** An example of using a cup-pole sampler to sample manure from a tanker. Photo from University of Minnesota Extension, used with permission.

cannot guarantee that liquid manure is sampled from a particular depth within the manure storage. However, if only the surface manure or well-mixed manure (e.g., in pumping-out manure stream) is sampled, a cup-pole sampler is practical and convenient. A short-pole cup sampler can also be used to control the volume of a subsample to be transferred to a composite sample bucket (Figure 6).

### *Closing-opening grab sampler*

A closing-opening grab sampler usually consists of a sample chamber, a remotely controllable liquid inlet to the container, and a pole (Figure 9). The liquid sample inlet can be controlled remotely. Various designs of this type of samplers have been reported (e.g., Lorimor et al., 2004), but their principle and operation are the same.

The following steps can be taken for grab sampling:

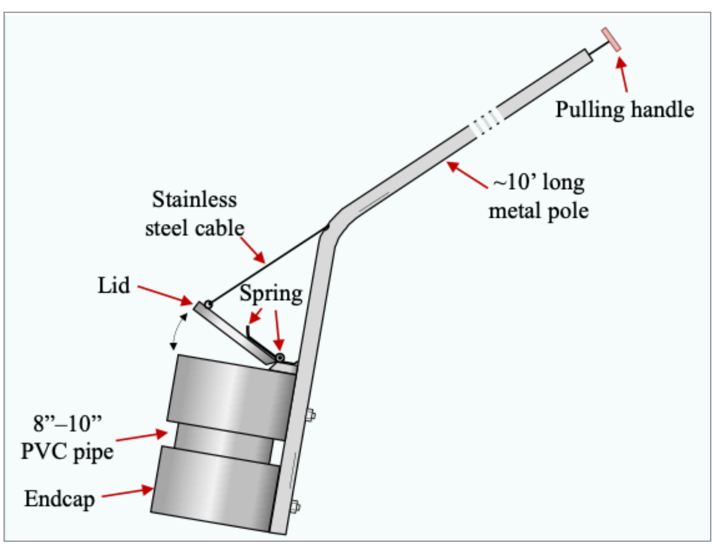



**Figure 9.** Example of a closing-opening grab sampler. Adapted from Lorimor et al. (2004).

1. Lower the inlet-closed sample chamber into the manure storage, reaching a desired depth and holding the sample chamber at that depth;
2. Open the chamber inlet to allow slurry manure at that depth to flow into it;
3. Close the chamber inlet to prevent the sample from flowing out of the container or mixing with slurry manure at other depths; and
4. Retreat the chamber out of the manure storage, open the inlet, and pour the sample into the subsample bucket.

### *Closing-opening grab and column sampler*

The closing-opening samplers use a pipe as both the sample container and sampler pole (Figure 10, samplers 1 and 2). They can take grab as well as column samples. For grab sample taking, the sampler pipe inlet is closed until it reaches the desired depth. The inlet is controlled to open at that specific depth to allow the liquid to flow into the sample pipe. The inlet is then closed, and the sampler is retrieved.

For column/profile sample taking, the sampler inlet is kept open while the sampler is slowly lowered into the storage until it reaches the desired depth (e.g., at the bottom of the storage). This allows the liquid manure at different depths to fill in the pipe and form a column sample. The pipe inlet is then tightly closed, and the sampler is retrieved from liquid manure storage.

In Figure 10, the open and close of sampler 1 is controlled with a rubber stopper that is connected to a handle via a rigid rod. The rubber stopper can be pushed open and pulled closed. Sampler 2 uses a ball valve to control the inflow of liquid. The valve is shut off to create air pressure in the airtight PVC pipe and keep the manure from flowing into the pipe. When the valve is open, air is released to reduce pressure and allow liquid manure to flow into the pipe. The check value prevents the manure in the pipe to flow out when the sampler is retrieved from the manure storage.

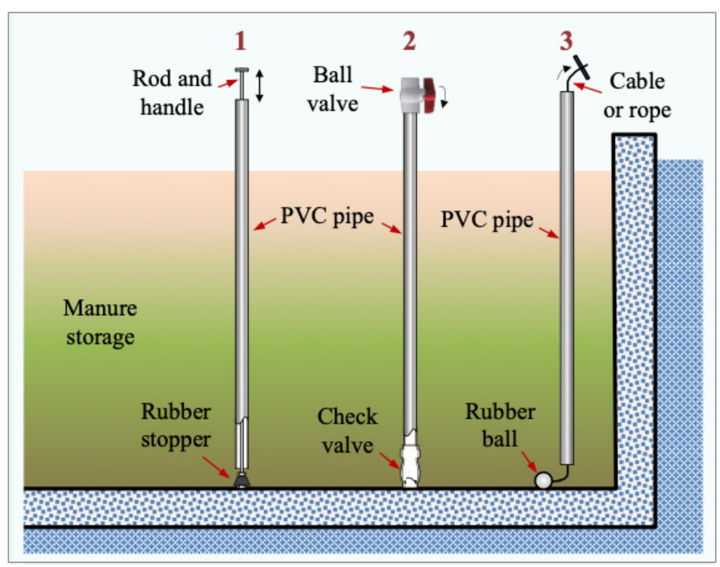



**Figure 10.** Illustration of two closing-opening samplers (1 and 2) and a closing-only sampler (3). Adapted from Lorimor et al. (2004) and NAME (2021).

### *Closing-only sampler*

A closing-only sampler usually uses a pipe-pole as the sample container and a rope to control the closing of the sample inlet (Figure 10, sampler 3). The inlet remains open while the sampler is lowering slowly into the liquid manure. Because the sampler does not control at which depth the container inlet opens, it is suitable only for taking column samples.

## Liquid manure sampling

### *Sampling with and without agitation*

Liquid manure is usually more difficult to sample than litter or dry manure. When liquid manure is stored for months in in-barn pits or stored/treated in lagoons, solids settle toward the bottom and nutrients stratify into layers with varying concentrations. Therefore, waste materials applied as slurry from a pit or lagoon should be mixed prior to sampling (Maguire et al., 2009). Some researchers recommend that the manure should be mixed or agitated (see the third sidebar photo on page 1) for 2 to 4 hours to ensure that a representative sample is obtained (Coffey et al., 2000). Studies show that manure nutrient variability can be substantially reduced through reasonable efforts of agitation or mixing during storage unloading (Dou et al., 2001).

However, part of the solids can still settle down quickly to the bottom shortly after agitation. For this reason, subsamples of liquid manure should always be taken at different depths of manure storages with or without liquid manure agitation.

In some cases, premixing the surface liquid in the lagoon is not needed, provided it is the only waste component that is being pumped for land application (Maguire et al., 2009).

### *Lagoon sampling*

Manure sampling in lagoons can have different situations. Several relevant sampling methods have been recommended.

To sample manure in the entire lagoon, use the column sampling method and allow subsamples to be taken from the full depth and multiple locations of the lagoon (Coffey et al., 2000). The locations of subsample taking can be randomly or systematically selected (Westerman et al., 2008; Maguire et al., 2009; Mukthar et al., 2009). The systematic method is usually to divide the lagoon into several equal areas (Figure 11). Due to the large sizes of lagoons, a flat-bottomed boat can be used to measure the actual depth and take column samples in lagoons (Figure 12).

To sample effluent for irrigation in the lagoon, grab subsamples should be collected at least 6 feet (~2 m) from the edge of the lagoon at a depth equivalent to that of the irrigation intake line in the lagoon, usually about 6 inches (~15 cm) deep. Floating debris and scum should not be taken as sample. Farms where multistage lagoon systems exist should have the samples collected from the lagoon that they intend for crop irrigation (Maguire et al., 2009).

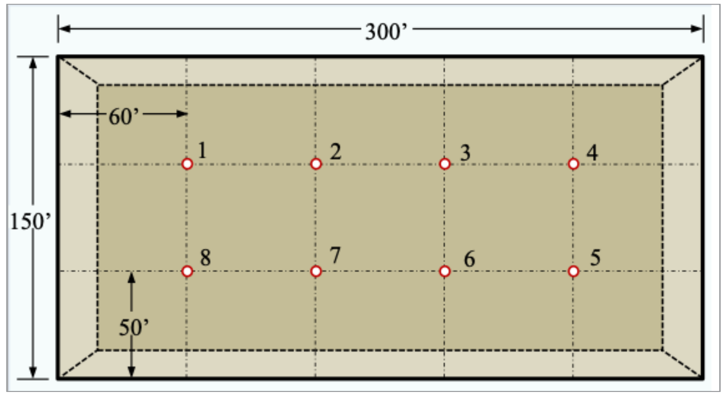



**Figure 11.** An example of eight selected sampling locations in a lagoon. Adapted from Westerman et al. (2008).

### *In-barn deep manure pit sampling*

In-barn deep manure pit sampling is similar to lagoon sampling. Because the barns are usually divided by equal-size pens, systematically distributed sampling locations can be easily located by selecting relevant pens and sampling points. Use small diameter sampler that can go through opening of slatted floor.

Use column sampler to take profile manure samples with or without pit agitation. Precaution should be taken to avoid toxic gases from manure. Manure gases in deep pit barns can have much higher concentrations and pose greater danger than open-air lagoons.

### *Tanker or spreader sampling*

Grab samples can also be taken from a liquid manure- or sludge-loaded tanker or spreader before hauling for land application (Sharara and Owusu-Twum, 2020). Immediately after filling the tanker or spreader, use a clean plastic sampler or bucket to collect manure from the unloading port or the opening near the bottom of the tanker/spreader. Be sure the port or opening does not have a solids accumulation (Rieck and Miller, 1995).

**Figure 12.** Depth profile sampling work at a dairy lagoon with two people in a flat-bottomed boat. Photo from Mukthar et al. (2009), used with permission.

### *Sampling during pumping-out*
Manure can be sampled during pumping out from lagoons or in-barn deep pits (Figure 13). If sampling is during manure pumping, it is necessary to take multiple grab subsamples at certain time intervals from the manure being pumped out so the subsamples will come from different portions and duration of the pumping-out manure. A study by Derikx et al. (1997) in The Netherlands demonstrated reduced bias when sampling from manure pumping hose using customer-designed sampling devices.

### *Sampling during field application*
Liquid manure can be sampled during field application. This method requires simple tools and can be done by placing several catch pans or buckets randomly in the field to collect liquid manure that is land applied by an irrigation system. Inexpensive aluminum or plastic pans and buckets can be used to catch manure (Figure 14). Immediately after the manure has been applied, make one composite sample from collected manure (Rieck and Miller, 1995). However, the samples can be tested only after the manure is already applied.

## Solid manure sampling tools
Most of the sampling tools for solid manure are different from liquid manure sampling, although plastic buckets are still needed to prepare subsamples. A wheelbarrow can help move the samples and other tools (Coffey et al., 2000). The main tools and materials that are needed to sample poultry litter while the entire house is being cleaned out include: (1) a shovel, (2) a wheelbarrow, (3) two 5-gallon plastic buckets, and (4) 1-gallon plastic freezers or Ziploc bags.

For grab sample taking, shovels, spades, or trowels are often sufficient. In manure piles or manure windrows, these tools can be used to dig into different depths.

For column sampling, a tube tool illustrated in Figure 15 was introduced. However, a tube may be difficult to insert into solid manure with feathers in place; in this case, a sharp spade is recommended (Lorimor et al., 2004; Maguire et al., 2009). Another tool introduced by Miller et al. (2019) is the Dutch Auger (Figure 15).

**Figure 13.** An example of manure sampling during pumping out.

**Figure 14.** Using aluminum pans to catch manure samples from liquid tank spreaders, recommended by Rieck and Miller (1995).

## Solid manure sampling
Solid manure sampling can be required in animal buildings (on floor, on under-cage manure belt, manure windrows, or indoor composting), at outdoor manure piles, and field manure applications. Outdoor manure piles can usually be much larger in size compared with indoor manure storage. Sampling in large manure piles to obtain core manure can be more challenging. Sampling in field application of solid manure can be conducted similar to liquid manure sampling.

### *Sampling in animal living (holding) area*
Animals drop manure in different types of their living or holding areas, whether indoors or outdoors. Therefore, solid manure can spread out and accumulate:

- on solid floor or slotted floor
- on manure belt in layer houses
- in gutters or in dry stacks
- in cumulated litter in poultry houses
- on open paved feedlots

A point method and a trench method (Figure 16) are recommended by Lory and Fulhage (1999) for sampling in poultry houses. With the point method, the sampling area is divided into several zones and multiple subsamples are taken in each zone.

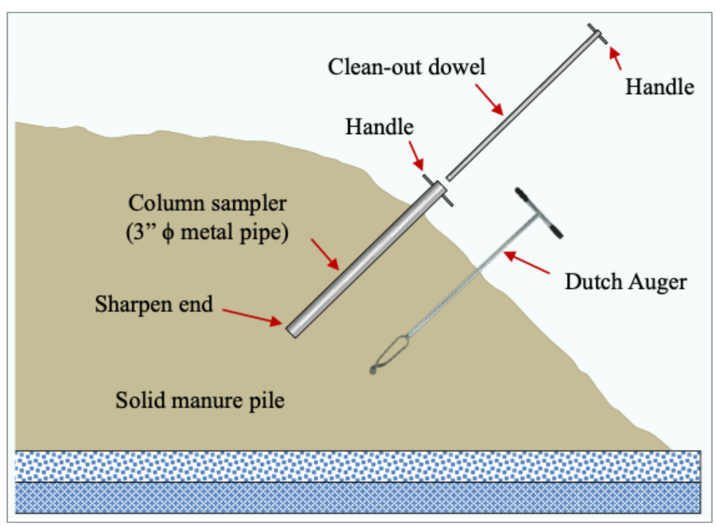



**Figure 15.** Illustration of solid manure sampling in a pile with a column sampler (drawn according to Lorimor et al., 2004) and a Dutch Auger for grab samples (reported by Miller et al., 2019).

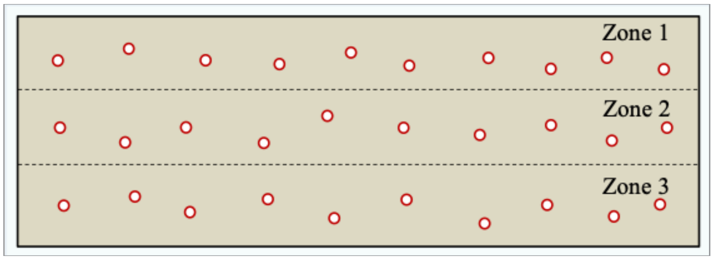



**Figure 16.** Points (red circles) of solid manure sampling in poultry houses. Adapted from Lory and Fulhage (1999).

The trench method can be applied in areas with accumulated deep manure. Sample only to the depth the house will be cleaned; avoid collecting soil from underneath the litter (Maguire et al., 2009). Avoid sampling at the locations that are not representative, such as locations of water leaking or excessive feed spill-out.

### *Sampling in manure windrows*

Solid manure windrows can be found in lower-floor manure storages in some animal buildings, such as in high-rise laying hen houses, and in indoor or outdoor manure composting. The heights of windrows usually do not exceed 6 feet. In some broiler houses, litter is composted in-house in windrows between cycles of birds.

Column samples can be taken in manure windrows using a square-ended spade. Dig to the depth of sampling and remove a sample by slicing appropriately sized vertical sections from the exposed wall of litter (Lory and Fulhage, 1999). Ensure that an equal amount of manure is removed along all depth. Research has revealed significant variation of several selected test parameters attributed to pile stratification, especially moisture and potassium, at different sampling depths in compost windrows (Brinton et al., 2012). Therefore, it is important to take subsamples at different depths.

### *Sampling for large stockpile manure*

Large solid manure stockpiles store manure in piles for later use. They can be in different shapes, such as cone piles and rectangular piles, or wedge piles, and be indoors or outdoors. Research shows that stockpiled litter typically has higher levels of phosphorus and potash than whole house litter removed directly from the house (Ritz et al., 2014). The DM concentrations of manure piles decreased at depths greater than 0.4 m (Miller et al., 2019). Nitrogen concentrations can change substantially in the stockpiles, particularly if the storage site is exposed to fluctuating weather conditions, because rainfall generally moves water-soluble nutrients down into the pile (Ritz et al., 2014).

Because manure stockpiles can be very large, there is often an issue of taking subsamples deep in the piles. Measurements can be biased unless 70–80% of grab samples are collected from the pile interior (Miller et al., 2019). Therefore, collecting representative samples of solid manure from static piles requires consideration of both the quantity and depth of grab samples. More than 25 grab samples are often required for multisource manure piles, whereas an average of six grab samples is required from

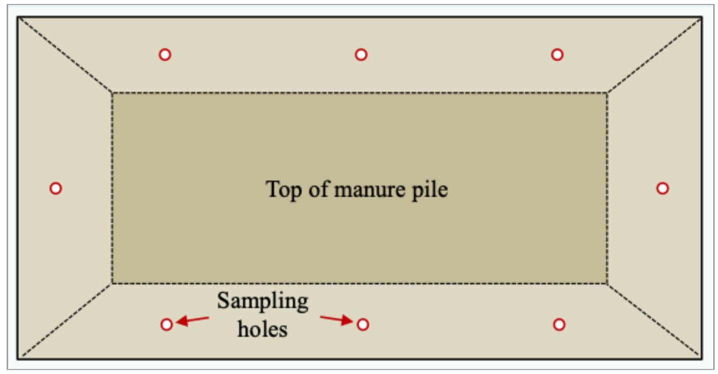



**Figure 17.** Suggested sampling locations for a rectangular solid manure pile. Adapted from Miller et al. (2019).

single source piles, as illustrated in Figure 17 (Miller et al., 2019). It is also recommended to collect at a depth of 18 inches from the surface of the pile and as close as possible to its land application date (Ritz et al., 2014). Avoid sampling outdoor stockpiling manure during rainy conditions.

A good sampling opportunity is during stockpiled manure removal for land application. Take one shovelful subsample from a truckload of removed manure. Depending on the volume of manure being removed, the subsamples can be taken from each truckload or one from several truckloads. The subsamples can then be thoroughly crumbled and mixed for composite samples (Coffey et al., 2000).

### *Sampling during manure loadout and field application*

Sampling from truckloads appears to be more convenient and less variable than sampling from chicken houses (Tasistro et al., 2004). Grab samples can be taken from different truck loadouts that represent different locations of solid manure in animal buildings.

Solid manure sampling can also be conducted in the field like liquid manure when it is being land-applied (Figure 18). This ensures that losses that occur during handling, storage, and application are considered (Rieck and Miller, 1995).

**Figure 18.** A field demonstration of sampling using tarps during solid manure application.

Sampling of solid manure during land application can be done with the following method:

1. Spread a plastic sheet or tarp on the field. The size of the sheets or tarps can be from 6 feet x 6 feet to 10 feet x 10 feet.
2. Drive the tractor and manure spreader close by or over the top of the plastic sheet or tarp to spread manure on.
3. Collect the manure sample on the sheet or tarp and transfer to a clean plastic bucket.
4. Repeat the sample collections from different truckloads and make composite samples.

## Sample storage and shipping

### *Sample storage*

Ideally, manure samples should be mailed or delivered to a testing laboratory as soon as possible, usually the day they are collected, to minimize nutrient losses and biodegradation. If manure samples must be held longer than 24 hours, do not let manure samples sit in hot areas, such as the dashboard or trunk of a vehicle. Instead, place the sample bottles or bags in a bigger sealed plastic bag; remove as much air from the bag as possible before sealing. Using double bags to seal the samples will reduce the manure odor release during storage.

Sealed manure samples can be kept in plastic coolers with ice for a limited time before shipping. They can also be kept in refrigerators or freezers until they can be shipped to the testing lab (Rieck and Miller, 1995; Coffey et al., 2000; Maguire et al., 2009). However, some testing laboratories recommend keeping the samples cool, not freezing. Therefore, testing laboratories should be contacted to get instructions before sampling and sample storage.

### *Sample shipping*

Care must be exercised to assure that samples arrive at the laboratory in a timely manner. Before shipping the samples to the testing laboratory, check the following:

1. Clean the sample bottles or bags. For liquid manure, make sure the bottle covers are on snugly. Leave a headspace, about 20–25% of the bottle volume. For solid manure, squeeze out air from the sample bags as much as possible and seal.
2. Use a waterproof pen to clearly mark all sample bottles and bags; or use the unique sample identification labels on the bottles and bags. (See "Sample labels and sample recording," page 6). The labels can be protected by covering them with clear packing tapes or sealing tapes.
3. Place sealed samples in a second or even third plastic bag to prevent manure spillage and odor release.
4. Fill out online or on hard copies the submittal paperwork, provided by the testing laboratory, with required information.
5. Keep a copy of the sample labels and submittal form for your record.
6. Pack the samples with sufficient ice packs in cooler(s) or Styrofoam cooler(s) for insulated shipping.

Manure samples should be mailed or shipped early in the week (Monday through Wednesday) to avoid arrivals on the weekend. Also, avoid shipping near holidays; that could delay the delivery (Coffey et al., 2000).

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**Appendix 1.** List of 77 Manure Test Laboratories in the U.S. and Canada in 2021.

| Name and address | S/P* | Contact phone, fax, and email | Note ** |
|---|---|---|---|
| Agricultural Diagnostic Laboratory, University of Arkansas.<br>1366 West Altheimer Dr, Fayetteville, AR 72704 | AR | Tel.: (479) 575-3908<br>Email: agrilab@uark.edu | MAP<br>CMT |
| A & L Western Agricultural Laboratories Inc.<br>1311 Woodland Ave Ste 1, Modesto, CA 95351 | CA | Tel.: (209) 529-4080. Fax: (209) 529-4736 | MAP<br>CMT |
| Denele Analytical Inc.<br>865 S. Kilroy Road, Turlock, CA 95380 | CA | Tel.: (209) 634-9055. Fax: (209) 634-9057<br>Email: info@denelelabs.com | MAP |
| Denele Analytical Inc.<br>40 N. East St, Suite B, Woodland, CA 95776 | CA | Tel.: (530) 666-9056. Fax: (530) 666-9058<br>Email: info@denelelabs.com | |
| JMLord Inc.<br>4184 N. Knoll Dr., Fresno, CA 93722 | CA | Tel.: (559) 268-9755. Fax: (559) 486-6504<br>Email: jmlord@jmlordinc.com | MAP<br>CMT |
| Valley Tech Agricultural Laboratory<br>2120 South K St, Tulare, CA 93274 | CA | Tel.: (559) 688-5684 | MAP<br>CMT |
| Waypoint Analytical California, Inc.<br>4741 E Hunter Ave Ste A, Anaheim, CA 92807 | CA | Tel.: (714) 282-8777. Fax: (714) 282-8575<br>Email: supportca@waypointanalytical.com | |
| Colorado State University.<br>1231 Libbie Coy Way, NESB Room A320, Fort Collins, CO 80523 | CO | Tel.: (970) 491-5061<br>Email: soiltestinglab@colostate.edu | |
| Agrolab Inc.<br>101 Clukey Dr, Harrington, DE 19952 | DE | Tel.: (302) 566-6094. Fax: (302) 566-6136 | MAP |
| Delaware Department of Agriculture, Agriculture Compliance<br>2310 S. DuPont Highway Dover, DE 19901 | DE | Tel.: (302) 698-4525<br>Email: sarah.sickler@delaware.gov | MAP<br>CMT |
| University of Florida, Livestock Waste Testing Laboratory<br>2390 Mowry Road, Wallace Building #631, Gainesville, FL 32611 | FL | Tel.: (352) 392-1950. Fax: (352) 392-1960<br>Email: soilslab@ifas.ufl.edu | |
| University of Georgia, Agricultural & Environmental Service Lab.<br>2400 College Station Rd, Athens, GA 30602 | GA | Tel.: (706) 542-5350. Fax: (706) 369-5734 | MAP<br>CMT |
| Waters Agricultural Laboratories Inc.<br>257 Newton Road P.O. Box 382 Camilla, GA 31730 | GA | Tel.: (229) 336-7216. Fax: (229) 336-7967<br>Email: info@watersag.com | MAP<br>CMT |
| AgSource Laboratories<br>1701 Detroit St, Ellsworth, IA 50075 | IA | Tel.: (515) 836-4444<br>Email: ellsworth@vas.com | MAP<br>CMT |
| Foundation Analytical Laboratory Inc.<br>723 Sleezer Road, Cherokee, IA 51012 (with manure) | IA | Tel.: (712) 225-6989 | MAP<br>CMT |
| Waypoint Analytical Iowa Inc.<br>700 Park Drive, Atlantic, IA 50022 | IA | Tel.: (800) 434-0109; (712) 243-6933. Fax: (712) 243-5213<br>Email: rmedina@waypointanalytical.com | MAP<br>CMT |
| Dairyland Laboratories Inc. Idaho Lab<br>150 Bridon Way, Jerome, ID 83338 | ID | Tel.: (208) 324-7511. Fax: (208) 324-2936 | MAP |
| Stukenholtz Laboratory Inc.<br>2924 Addison Ave. E., P.O. Box 353, Twin Falls, ID 83303 | ID | Tel.: (208) 734-3050; (800) 759-3050. Fax: (208) 734-3919<br>Email: frontoffice@stukenholtz.com | MAP<br>CMT |
| Western Laboratories Inc.<br>211 W Highway 95, Parma, ID 83660 | ID | Tel.: (208) 649-4360 | MAP |
| SGS North America Inc<br>117 E Main St, Toulon, IL 61483 | IL | Tel.: (309) 286-2761. Fax: (309) 286-6251 | |
| Waypoint Analytical Illinois, Inc.<br>2902 Farber Dr. Champaign, IL 61822 | IL | Tel.: (217) 359.7680. Fax: (217) 359.7605<br>Email: supportil@waypointanalytical.com | |
| A&L Great Lakes Laboratories Inc.<br>3505 Conestoga Drive, Fort Wayne, Indiana 46808 | IN | Tel: (260) 483-4759. Fax: (260) 483-5274<br>Email: lab@algreatlakes.com | MAP<br>CMT |
| Sure Tech Laboratories<br>7501 Miles Dr., Indianapolis, IN 46231 | IN | Tel.: (317) 243-1502 | MAP<br>CMT |
| ServiTech Headquarters and Laboratory<br>1816 East Wyatt Earp, P.O. Box 1397, Dodge City, KS 67801 | KS | Tel.: (620) 227-7509 | MAP<br>CMT |
| University of Kentucky<br>103 Regulatory Services Bldg., Lexington, KY 40546-0275 | KY | Tel.: (859) 257-2785 | MAP<br>CMT |
| Waters Agricultural Laboratories Inc<br>2101 Calhoun Road, Highway 81, Owensboro, KY 42301 | KY | Tel.: (270) 685-4039. Fax (270) 685-3989<br>Email: kyinfo@watersag.com | MAP<br>CMT |
| Dairyland Laboratories Inc. Michigan Lab<br>Suite A, 4900 West Dickman Road, Battle Creek, MI 49037 | MI | Tel.: (269) 753-0048 | |

| Name and address | S/P* | Contact phone, fax, and email | Note ** |
|---|---|---|---|
| Ag Resource Consulting Inc<br>131 5th St, Albany, MN 56307 | MN | Tel.: (320) 845-6321. Fax: (320) 845-6320 | MAP<br>CMT |
| Agvise Laboratories Inc., Benson Laboratory<br>902 13th Street North, P.O. Box 187, Benson, MN 56215 | MN | Tel.: (320) 843-4109. Fax: (320) 843-2074 | MAP<br>CMT |
| Dairyland Laboratories Inc. Minnesota Lab<br>919 Lincoln Ave, Sauk Rapids, MN 56379 | MN | Tel.: (320) 240-1737. Fax: (320) 240-1838 | |
| Minnesota DHIA Laboratories<br>825 12th St S, Sauk Centre, MN 56378 | MN | Tel.: (320) 352-2028; (800) 369-2697. Fax: (320) 352-6163<br>Email: Cheril@Stearnsdhialab.Com | MAP<br>CMT |
| Minnesota Valley Testing Laboratories Inc<br>1126 N. Front St., Building #1, New Ulm, MN 56073 | MN | Tel.: (507) 240-0304; (800) 782-3557 | MAP<br>CMT |
| International Ag Labs<br>800 W. Lake Ave., PO Box 788, Fairmont, MN 56031 | MN | Tel.: (507) 235-6909. Fax: (507) 235-9155 | MAP<br>CMT |
| Perry Agricultural Laboratory Inc<br>15241 Pike 138, Bowling Green, MO 63334 | MO | Tel. (573) 324-2931. Fax: (573) 324-5558<br>Email: pal@perryaglab.com | MAP<br>CMT |
| University of Missouri, Soil and Plant Testing Laboratory<br>1100 University Ave, Mumford Hall Rm 23, Columbia, MO 65211 | MO | Tel.: (573) 882-0623. Fax: (573) 884-4288 | MAP<br>CMT |
| Waters Agricultural Laboratories Inc.<br>4589 Highway 61 S, Vicksburg, MS 39180 | MS | Tel.: (601) 429-6456<br>Email: msinfo@watersag.com | MAP |
| North Carolina Dept of Agriculture, Agriculture & Consumer Service<br>4300 Reedy Creek Rd, Raleigh NC 27607 | NC | Tel.: (919) 733-2655. Fax: (919) 733-2837 | MAP<br>CMT |
| Waters Agricultural Laboratories Inc.<br>364 W. Park Drive, Warsaw, NC 28398 | NC | Tel.: (910) 293-2108. Fax: (910) 293-2183<br>Email: ncinfo@watersag.com | MAP<br>CMT |
| Agvise Laboratories Inc., Northwood Laboratory<br>804 Highway 15 West, P.O. Box 510, Northwood, ND 58267 | ND | Tel.: (701) 587-6010. Fax: (701) 587-6013 | MAP<br>CMT |
| North Dakota State University, Soil Testing Lab<br>1360 Bolley Drive, Waldron Hall 103, Fargo, ND 58102 | ND | Tel.: (701) 231-8942<br>Email: ndsu.stl@ndsu.edu | |
| American Agricultural Laboratory Inc<br>700 West D St., McCook, NE 69001 | NE | Tel.: (308) 345-3670. Fax: (308) 345-7880 | MAP<br>CMT |
| Midwest Laboratories Inc<br>13611 B Street, Omaha, Nebraska 68144 | NE | Email: contactus@midwestlabs.com<br>Tel.: (402) 334-7770. Fax: (402) 334-9121 | MAP<br>CMT |
| ServiTech Labs<br>1602 Park West Drive, P.O. Box 169, Hastings, NE 68902 | NE | Tel.: (402) 463-3522 | MAP<br>CMT |
| Ward Laboratories Inc<br>4007 Cherry Ave., Kearney, NE 68847 | NE | Tel.: (800) 887-7645 | MAP<br>CMT |
| Dairy One Cooperative Inc<br>730 Warren Road, Ithaca, NY 14850 | NY | Tel.: (800) 344-2697. Fax: (607) 257-6808 | MAP<br>CMT |
| Brookside Laboratories Inc<br>200 White Mountain Dr., New Bremen, OH 45869 | OH | Tel.: (419) 977-2766. Fax: (419) 977-2767<br>Email: Info@blinc.com | MAP<br>CMT |
| Spectrum Analytic Inc<br>1087 Jamison Rd NW, Washington Court House, OH 43160-8748 | OH | Tel.: (800) 321-1562; (740) 335-1562. Fax: (740) 335-1104<br>Email: info@spectrumanalytic.com | MAP<br>CMT |
| Oklahoma State University, Soil Water & Forage Analytical Laboratory<br>371 Agricultural Hall, Stillwater, OK 74078 | OK | Tel.: (405) 744-7771. Fax: (405) 744-9575<br>Email: kendalt@okstate.edu | MAP |
| A&L Canada Laboratories Inc<br>2136 Jetstream Rd, London, Ontario, Canada N5V 3P5 | ON | Tel: (519) 457-2575; (855) 837-8347. Fax: (519) 457-2664<br>Email: alcanadalabs@alcanada.com | MAP |
| SGS Agri Food Laboratories<br>Unit 1, 503 Imperial Rd. N., Guelph, Ontario, Canada N1H 6T9 | ON | Tel.: (800) 265.7175<br>Email: ca.agri.guelph.lab@sgs.com | |
| Stratford Agri Analysis Inc<br>1131 Erie St. PO Box 760, Stratford, Ontario, Canada N5A 6W1 | ON | Tel.: (800) 323-9089; (519) 273-4411. Fax: (519) 273-4411<br>Email: info@stratfordagri.ca | MAP<br>CMT |
| University of Guelph, Laboratory Service Division<br>95 Stone Road West, Guelph, Ontario, Canada N1H 8J7 | ON | Tel.: (877) 863-4235; (519) 823-1268. Fax: (519) 767-6240 | MAP |
| A&L Western Agricultural Laboratories Inc.<br>10220 S.W. Nimbus Ave., Building K-9, Portland, OR 97223 | OR | Tel.: (503) 968-9225. Fax: (503) 598-7702 | |
| Cumberland Valley Analytical Services<br>4999 Zane A. Miller Drive, Waynesboro, PA 17268 | PA | Tel.: (301) 790-1980<br>Email: mail@foragelab.com | MAP<br>CMT |
| Pennsylvania State University, Ag Analytical Services Lab<br>111 Ag Analytical Services Lab, University Park, PA 16802 | PA | Tel.: (814) 863-0841. Fax (814) 863-4540<br>Email: aaslab@psu.edu | MAP<br>CMT |

| Name and address | S/P* | Contact phone, fax, and email | Note ** |
|---|---|---|---|
| Waypoint Analytical Pennsylvania, Inc.<br>280 Newport Rd., Leola, PA 17540 | PA | Tel.: (717) 656.9326. Fax: (717) 656.0910<br>Email: supportpa@waypointanalytical.com | MAP<br>CMT |
| PEI Analytical Laboratories<br>23 Innovation Way, BioCommons Park, Charlottetown, PE, Canada C1E 0B7 | PE | Tel.: (902) 620-3300. Fax: (902) 569-7778<br>Email: peiextension@gov.pe.ca | MAP<br>CMT |
| Belisle Solution Nutrition Inc. Laboratory<br>3295 B rue Principale, Saint-Jean-Baptiste, (Québec) Canada J0L 2B0 | QC | Tel.: (450) 467-6813<br>Email: labo@belisle.net | |
| Research & Development Institute for Agri Environment<br>2700 Einsten Complexe Scientifique, Saint Foy, QC G1P 3W8 Canada | QC | Tel.: (418) 643-2380. Fax: (418) 644-6855<br>Email: bernard.montminy@irda.qc.ca | MAP |
| Clemson University Agricultural Service Laboratory<br>171 Old Cherry Rd, Clemson, SC 29634 | SC | Tel.: (864) 656-2068. Fax: (864) 656-2069<br>Email: agsrvlb@clemson.edu | MAP<br>CMT |
| AgLab Express<br>3600 S Minnesota Ave Suite 200, Sioux Falls, SD 57105 | SD | Tel.: (605) 271-9237. Fax: (605) 271-9238<br>Email: mikebarber@aglabexpress.com | MAP<br>CMT |
| East Prairie Laboratories Inc<br>48598 234th St, Flandreau, SD 57028 | SD | Tel.: (605) 633-1025<br>Email: jared.n@eastprairielaboratories.com | CMT |
| Waypoint Analytical Corporate Headquarters<br>2790 Whitten Rd, Memphis, TN 38133 | TN | Tel.: (800) 264-4522; (901) 213-2400. Fax: (901) 213-2440<br>Email: supporttn@waypointanalytical.com | MAP<br>CMT |
| ServiTech Labs<br>6921 South Bell, Amarillo, TX 79109 | TX | Tel.: (806) 677-0093 | MAP<br>CMT |
| Utah State University Analytical Laboratories<br>Skaggs Research Laboratory, 1541 N 800 E, Logan, Utah 84341 | UT | Tel.: (435) 797-2217<br>Email: usual@usu.edu | MAP<br>CMT |
| Waypoint Analytical Virginia, Inc.<br>7621 Whitepine Rd, Richmond, VA 23237 | VA | Tel.: (804) 743-9401. Fax: (804) 271-6446<br>Email: supportva@waypointanalytical.com | MAP |
| Best-Test Analytical Services, LLC<br>3394 Bell Road Northeast, Moses Lake, WA 98837 | WA | Tel.: (877) 950-2378; (509) 766-7701 | MAP<br>CMT |
| Custom Dairy Services Inc<br>8895 Guide Meridian Rd, Lynden, WA 98264 | WA | Tel.: (360) 354-4344. Fax: (360) 354-1114<br>Email: customdairyservices@frontier.com | MAP<br>CMT |
| Exact Scientific Services Inc<br>1355 Pacific Place Ste 101, Ferndale, WA 98248 | WA | Tel.: (360) 733-1205. Fax: (888) 818-2978<br>Email: lab@exactscientific.com | MAP |
| Soiltest Farm Consultants, Inc.<br>2925 Driggs Dr., Moses Lake, WA 98837 | WA | Tel.: (800) 764-1622; (509) 765-1622. Fax: (509) 765-0314 | MAP<br>CMT |
| AgSource Laboratories<br>106 North Cecil St, Bonduel, WI 54107 | WI | Tel.: (715) 758-2178. Fax: (715) 758-2620<br>Email: bonduel@vas.com | MAP<br>CMT |
| Dairyland Laboratories Inc. Corporate Headquarters<br>217 East Main St, Arcadia, WI 54612 | WI | Tel.: (608) 323-2123. Fax: (608) 323-2184 | MAP<br>CMT |
| Dairyland Laboratories Inc. De Pere Lab<br>1111 Lawrence Drive, De Pere, WI 54115 | WI | Tel.: (920) 336-4521. Fax: (920) 336-4708 | |
| Dairyland Laboratories Inc. Stratford Lab<br>117609 Forward St, Stratford, WI 54484 | WI | Tel.: (715) 687-9997. Fax: (715) 687-9907 | |
| Rock River Laboratory Inc. Headquarters<br>710 Commerce Dr., Watertown, WI 53094 | WI | Tel.: (920) 261-0446<br>Email: office@rockriverlab.com | MAP<br>CMT |
| Wisconsin University Soil and Forage Analysis Lab<br>2611 Yellowstone Dr. Marshfield, WI 54449 | WI | Tel.: (715) 387-2523<br>Email: soil-lab@mailplus.wisc.edu | MAP<br>CMT |
| West Virginia Department of Agriculture<br>60 B Industrial Park Rd, Moorefield, WV 26836 | WV | Tel.: (304) 538-2397. Fax: (304) 538-7088<br>Email: msites@wvda.us | MAP<br>CMT |

* State or Province
** MAP = Manure Analysis Proficiency (MAP) Laboratories; CMT = Certified Manure Testing Laboratories. The listed MAP and CMT laboratories in the table were published as of December 31, 2021. For updated status of these laboratories, please visit the Minnesota Department of Agriculture website: https://www2.mda.state.mn.us/webapp/lis/maplabs.jsp (MAP Laboratories), and http://www2.mda.state.mn.us/webapp/lis/manurelabs.jsp (CMT Laboratories).

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