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Chapter 4 Agricultural Waste Characteristics

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651.0400 Introduction

(a) Purpose and scope

Wastes and residues described in this chapter are of an organic nature and agricultural origin. Other by-products of nonagricultural origin that may be managed within the agricultural sector are also included. This chapter provides information for estimating characteristics of livestock and poultry manure and other agricultural residuals. The information provided is useful for the planning and design of agricultural waste management system (AWMS) components including:

- storage function components such as ponds and tanks
- treatment function components such as lagoons and composting
- utilization function components such as land application

The information may also be useful in formulating the environmental impact of manure and other agricultural wastes.

This chapter includes table values for the typical characteristics of manure *as excreted* by livestock and poultry based on typical diets and animal performance levels in 2003. These typical values are most appropriate for use when:

- planning estimates are being made on a scale larger than a single farm such as county or regional estimate of nutrient excretion
- a rough estimate is needed for farm planning
- farm-specific information of animal performance and feed intake is not available

Much of the as excreted data included in the tables of this chapter were developed using equations that are now available for predicting manure content, primarily nitrogen and phosphorus, dry matter, and, depending upon species, other potential characteristics for beef, swine, and poultry excretion. The fundamental model (fig. 4–1) on which these equations are based is:

$$\text{Nutrient excretion} = \text{Nutrient feed intake} - \text{Nutrient retention}$$

$$\text{Dry matter excretion} = \text{Feed dry matter intake} \times \left(1 - \text{dry matter digestibility}\right) + \text{Dry matter in urine}$$

Of the total excreted solids, dry matter in urine typically contributes 10 to 20 percent of the volume.

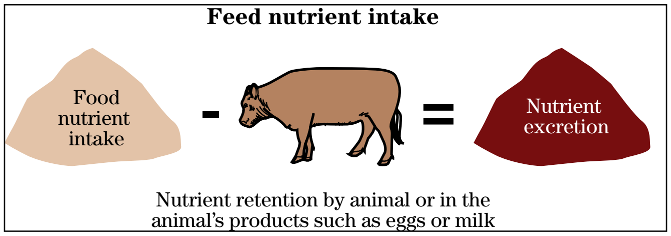
These equations allow an estimate of as excreted manure characteristics relevant to a wide range of dietary options and animal performance levels commonly observed in commercial production. Considered are factors related to the feed efficiency in animal performance and to feed intake including crude protein, phosphorus, and dry matter. A full presentation and description of these equations is beyond the scope of this chapter. They are, however, available in the American Society of Agricultural and Biological Engineers Standard D384.2. See *http://www.asabe.org/standards/index.html.*

For dairy and horses, regression analysis was performed on large data sets to determine appropriate equations.

In a number of situations, consideration should be given to using equations instead of the as excreted values presented in the tables of this chapter. Typical or average estimates of as excreted manure eventually become out-of-date due to changes in animal genetics, performance potential, feeding program strategies, and available feeds. If the timeliness of the data presented in this chapter becomes problematic, consideration should be given to computing values using equations. Other situations when use of equations should be considered are when:

- comprehensive nutrient management plans are being developed specific to a farm and its AWMS
- data is available for a livestock or poultry operation's feeding program and animal performance
- a feeding strategy or technology designed to reduce nutrient excretion is being used

Figure 4–1 Mass balance approach used for developing table values for beef cattle, swine, and poultry



The chapter also provides table values for the typical characteristics of manure at transfer from housing or from storage and treatment facilities. These values are useful for long-term planning for utilization of manure and other wastes; but, they should not be used in determining a field-specific application rate.

(b) Variations and ranges of data values

In most cases, a single value is presented for a specific waste characteristic. This value is presented as a reasonable value for facility design and equipment selection for situations where site-specific data are not available. Waste characteristics are subject to wide variation; both greater and lesser values than those presented can be expected. Therefore, much attention is given in this chapter to describing the reasons for data variation and to giving planners and designers a basis for seeking and establishing more appropriate values where justified by the situation.

Site-specific waste sampling, testing, and data collection are essential for the utilization function of an AWMS. Such sampling can result in greater certainty and confidence in amount of nutrients available. Care must be exercised to assure that samples are representative of the waste stream and arrive at the laboratory in a timely manner. Since manure and other waste products are in continual flux, it must also be kept in mind that the results from such testing are only valid for the time when the samples were taken.

651.0401 Definitions of waste characterization terms

Table 4–1 contains definitions and descriptions of waste characterization terms. It includes abbreviations, definitions, units of measurement, methods of measurement, and other considerations for the physical and chemical properties of manure, waste, and residue. The physical properties—weight (Wt), volume (Vol), moisture content (MC), total solids (TS), volatile solids (VS), fixed solids (FS), dissolved solids (DS), and suspended solids (SS)—are important to agricultural producers and facility planners and designers. They describe the amount and consistency of the material to be dealt with by equipment and in treatment and storage facilities. Of the chemical constituents, nitrogen (N), phosphorus (P), and potassium (K) are of great value to waste systems planners, producers, and designers. Land application of agricultural waste is the primary waste utilization procedure, and N, P, and K are the principal components considered in development of an agricultural waste management plan.

Volatile solids (VS) and 5-day Biochemical Oxygen Demand (BOD_5) are used in the planning and design of certain biological treatment procedures.

Data on biological properties, such as numbers of specific micro-organisms, are not presented in this chapter. Micro-organisms are of concern as possible pollutants of ground and surface water, but they are not commonly used as a design factor for no-discharge waste management systems that use wastes on agricultural land.

When expressed in units of pounds per day or as a concentration, various solid fractions of manure, waste, or residue are often measured on a wet weight basis (% w.b.), a percentage of the “as is” or wet weight of the material. In some cases, however, data are recorded on a dry weight basis (% d.w.), a percentage of the dry weight of the material. The difference in these two values for a specific material is most likely very large. Nutrient and other chemical fractions of a waste material, expressed as a concentration, may be on a wet weight or dry weight basis, or expressed as pounds per 1,000 gallons of waste.

The term “agricultural waste” was coined by those who pioneered the technology. For them, the term seemed appropriate because it was generic and could be used in the context of the wide variety of materials under con-

Table 4–1 Definitions and descriptions of waste characterization terms

Physical characteristics

Term	Abbreviation	Units of measure	Definition	Method of measurement	Remarks
Weight	Wt	lb	Quantity or mass	Scale or balance	
Volume	Vol	ft^3; gal	Space occupied in cubic units	Place in or compare to container of known volume calculate from dimensions of containment facility	
Moisture content	MC	%	That part of a waste material removed by evaporation and oven drying at 217 °F (103 °C)	Evaporate free water on steam table and dry in oven at 217 °F for 24 hours or until constant weight	Moisture content (%) plus total solids (%) equals 100%
Total solids	TS	%, % w.b. [1/]; % d.w. [2/];	Residue remaining after water is removed from waste material by evaporation; dry matter	Evaporate free water on steam table and dry in oven at 217 °F for 24 hours or until constant weight	Total of volatile and fixed solids; total of suspended and dissolved solids
Volatile solids	VS, TVS	%, % w,b. [1/]; % d.w. [2/];	That part of total solids driven off as volatile (combustible) gases when heated to 1,112 °F (600 °C); organic matter	Place total solids residue in furnace at 1,112 °F for at least 1 hour	Volatile solids determined from difference of total and fixed solids
Fixed solids	FS, TFS	%, % w.b.; % d.w.	That part of total solids remaining after volatile gases driven off at 1,112 °F (600 °C); ash	Weight (mass) of residue after volatile solids have been removed as combustible gases when heated at 1,112 °F for at least 1 hr is determined	Fixed solids equal total solids minus volatile solids
Dissolved solids DS; TDS	DS, TDS	%, % w.b.; % d.w.	That part of total solids passing through the filter in a filtration procedure	Pass a measured quantity of waste material through 0.45 micron filter using appropriate procedure; evaporate filtrate and dry residue to constant weight at 217 ºF	Total dissolved solids (TDS) may be further analyzed for volatile solids and fixed dissolved solids parts %
Suspended solids	SS, TSS	%, % w.b.; % d.w.	That part of total solids removed by a filtration procedure	May be determined by difference between total solids and dissolved solids	Total suspended solids may be further analyzed for volatile and fixed suspended solids parts

1/ % w.b. = percent wet basis
2/ % d.w. = percent dry weight basis

Table 4–1 Definitions and descriptions of waste characterization terms—Continued

Chemical properties

Term	Abbreviation	Units of measure	Definition	Method of measurement	Remarks
Ammoniacal nitrogen (total ammonia)		mg/L µg/L	Both NH_3 and NH_4 nitrogen compounds	Common laboratory procedure uses digestion, oxidation, and reduction to convert all or selected nitrogen forms to ammonium that is released and measured as ammonia	Volatile and mobile nutrients; may be a limiting nutrient in land spreading of wastes and in eutrophication. Recommended methods of manure analysis measures ammonium nitrogen (NH_4-N)
Ammonia nitrogen	NH_3-N	mg/L µg/L	A gaseous form of ammoniacal nitrogen		
Ammonium nitrogen	NH_4-N	mg/L µg/L	The positively ionized (cation) form of ammoniacal nitrogen		Can become attached to the soil or used by plants or microbes
Total Kjeldahl nitrogen	TKN	mg/L µg/L	The sum of organic nitrogen and ammoniacal nitrogen	Digestion process which converts all organic nitrogen to ammonia	
Nitrate nitrogen	NO_3-N	mg/L µg/L	The negatively ionized (anion) form of nitrogen that is highly mobile		Nitrogen in this form can be lost by denitrification, percolation, runoff, and plant microbial utilization
Total nitrogen	TN; N	%; lb	The summation of nitrogen from all the various nitrogen compounds		Macro-nutrient for plants
Phosphorus	TP, SRP P P_2O_5	mg mg/L lb lb	Total phosphorus (TP) is a measure of all the forms of phosphorus, dissolved or particulate, that is found in a sample. Soluble reactive phosphorus (SRP) is a measure of orthophosphate, the filterable (soluble, inorganic) fraction of phosphorus, the form directly taken up by plant cells. P is elemental phosphorus. P_2O_5 is the fertilizer equivalent phosphorus	Laboratory procedure uses digestion and/or reduction to convert phosphorus to a colored complex; result measured by spectrophotometer or inductive coupled plasma	Critical in water pollution control; may be a limiting nutrient in eutrophication and in spreading of wastes
5-day Biochemical oxygen demand	BOD_5	lb of O_2		Extensive laboratory procedure of incubating waste sample in oxygenated water for 5 days and measuring amount of dissolved oxygen consumed	Standard test for measuring pollution potential of waste
Chemical oxygen demand	COD	lb of O_2	Measure of oxygen consuming capacity of organic and some inorganic components of waste materials	Relatively rapid laboratory procedure using chemical oxidants and heat to fully oxidize organic components of waste	Estimate of total oxygen that could be consumed in oxidation of waste material

sideration. Now, the concern of many is that the word waste implies that the material is only suitable for disposal and as such, detracts from proper utilization. Even though another word or term might better convey the beneficial aspects, agricultural waste is so entrenched in the literature it would now be difficult to change. Further, a consensus replacement term that is appropriate in every context has not come to the forefront. It must be understood that it was neither the intent of those who initially developed the technology nor the authors of this chapter (with its continued use) to imply the materials being discussed are worthless and are only suitable for disposal. Rather, the materials are to be viewed as having value both monetarily and environmentally if properly managed, regardless of what they are called.

Wastes are often given descriptive names that reflect their moisture content such as liquid, slurry, semisolid and solid. Wastes that have a moisture content of 95 percent or more exhibit qualities very much like water are called liquid waste or liquid manure. Wastes that have moisture content of about 75 percent or less exhibit the properties of a solid and can be stacked and hold a definite angle of repose. These are called solid manure or solid waste. Wastes that are between about 75 and 95 percent moisture content (25 and 5 percent solids) are semiliquid (slurry) or semisolid (chapter 9). Because wastes are heterogeneous and inconsistent in their physical properties, the moisture content and range indicated above must be considered generalizations subject to variation and interpretation.

The terms “manure,” “waste,” and “residue” are sometimes used synonymously. In this chapter, manure refers to materials that have a high percentage of feces and urine. Other material that may or may not have significant feces, and urine is referred to as waste or a related term such as wastewater. The term *as excreted* refers to feces and urine prior to any changes due to dilution water addition, drying, volatilization, or other physical, chemical, or biological processes. Litter is a specific form of poultry waste that results from floor production of birds after an initial layer of a bedding material, such as wood shavings, is placed on the floor at the beginning of and perhaps during the production cycle.

Because of the high moisture content of as excreted manure and treated waste, their specific weight is very similar to that of water—62.4 pounds per cubic foot. Some manure and waste that have considerable solids content can have a specific weight of as much as 105 percent that of water. Some dry wastes, such as litter, that have significant void space can have specific weight of much less than that of water. Assuming that wet and moist wastes weigh 60 to 65 pounds per cubic foot is a convenient and useful estimate for planning waste management systems.

Because moisture content of manure is transitory, most testing laboratories report results in terms of dry weight (d.w.). However, equipment is calibrated and storage structures sized based upon wet weight. As such, it is important to understand the relationship of wet basis (w.b.) and dry basis (d.w.).

When test data is reported in terms of its wet basis, the base is its hydrated weight.

$$\text{Percent wet basis} = \frac{\text{weight of constituent}}{\text{wet weight of sample}}$$

When test data is reported in terms of its dry weight, the base is its dry weight.

$$\text{Percent dry basis} = \frac{\text{weight of constituent}}{\text{dry weight of sample}}$$

Residue after oven drying the sample is the total solids. Since the dry weight is equal to the total solids, they are always 100 percent d.w.

The fixed solids are the nonorganic portion of the total solids. The weight of fixed solids is determined by a test that involves heating a sample of the waste to 1,112 °F. The fixed solids are the ash that remains after the material driven off by the heating is the volatile solids.

Example 4–1

Given: A laboratory sample of manure weighing 200 grams is oven dried. After oven drying, the sample weighs 50 grams. Following oven drying, the remaining 50 grams is heated to 1,112 °F. After this heating, 20 grams remain.

Calculate:

Moisture content (MC)

$$\begin{aligned} MC &= \text{wet weight} - \text{dry weight} \\ &= 200 \text{ grams} - 50 \text{ grams} \\ &= 150 \text{ grams} \end{aligned}$$

Percent moisture (%MC)

$$\begin{aligned} \%\,MC &= \frac{MC}{\text{wet weight}} \times 100 \\ &= \left(\frac{150 \text{ grams}}{200 \text{ grams}}\right) \times 100 \\ &= 75\% \end{aligned}$$

Percent total solids dry basis (%TS)

$$\begin{aligned} \%TS\ \text{w.b.} &= \left(\frac{\text{dry weight}}{\text{wet weight}}\right) \times 100 \\ &= \left(\frac{50 \text{ grams}}{200 \text{ grams}}\right) \times 100 \\ &= 25\% \end{aligned}$$

After the 50-gram dry sample (originally 200-gm wet sample) is heated to 1,112 °F, the sample now weighs 20 grams. Since the fixed solids are what remain, they are:

Percent fixed solids (%FS)

$$\begin{aligned} FS &= 20 \text{ grams} \\ VS &= TS - FS \\ &= 50 \text{ grams} - 20 \text{ grams} \\ &= 30 \text{ grams} \end{aligned}$$

Percent volatile solids both wet basis and dry weight basis. (% VS w.b. and % VS d.w.)

$$\begin{aligned} \%VS\ \text{d.w.} &= \frac{30 \text{ grams}}{50 \text{ grams}} \times 100 \\ &= 60\% \end{aligned}$$

Following are a number of relationships that may be used to evaluate the constituents of manure or other wastes.

$$\frac{\%\,\text{dw}}{\%\,\text{wb}} = \frac{\text{(oven dry weight of manure)}}{\text{(weight of manure at excreted moisture content)}}$$

$$\frac{\%\,\text{wb}}{\%\,\text{dw}} = \frac{\text{(weight of manure at excreted moisture content)}}{\text{(oven dry weight of manure)}}$$

$$\%\ \text{dry matter} = \left(\frac{\text{dry weight}}{\text{wet weight}}\right) \times 100$$

$$\%\ \text{moisture} = 100 - \%\ \text{dry matter}$$

$$\%\ \text{dry matter} = 100 - \%\ \text{moisture}$$

$$\%\text{w.b.} = \%\ \text{d.w.} \times \left(\frac{(100 - \%\ \text{moisture})}{100}\right)$$

$$\%\ \text{d.w.} = \left(\frac{\%\ \text{w.b.} \times 100}{100 - \%\ \text{w.b.}}\right)$$

$$\text{weight of manure (wet)} = \underset{\text{solids (dry)}}{\text{weight of total}} + \underset{\text{moisture}}{\text{weight of}}$$

Carbon is a component of all organic wastes. Quantifying it is important because of carbon's impact on soil quality and greenhouse gas emissions. Adding manure and other organic material to the soil improves the soil's structure and tilth and increases its nutrient storage capacity. As the soil sequesters the carbon in the manure, it reduces the emissions of carbon dioxide and methane into the air.

The carbon content of a material can be determined using the following equation if the material's volatile solids are known.

$$C = 0.55 \times VS$$

where:
C = carbon (% C d.w.)
VS = volatile solids (%VS d.w.)

Example 4–2

The testing laboratory reports that the manure's volatile solids on a dry weight basis are 60 percent. Compute the percentage d.w. carbon content of the sample.

$$\begin{aligned}\%\ \text{C d.w.} &= 0.55 \times \%\ \text{VS d.w.}\\ &= 0.55 \times 60\\ &= 33.0\ \%\ \text{d.w.}\end{aligned}$$

The manure has a moisture content of 80 percent. Compute the percentage of carbon contained in the manure on a wet basis.

$$\begin{aligned}\%\ \text{C w.b.} &= \%\ \text{C d.w.} \times \frac{(100 - \%\ \text{moisture})}{100}\\ &= 33.00 \times \frac{(100 \times 80)}{100}\\ &= 6.6\%\end{aligned}$$

Knowing the carbon to nitrogen ratio (C:N) can be important. For example, the C:N is an important aspect of the compost recipe (ch. 10). If the C:N is high, such as it might be in a manure containing organic bedding such as sawdust, the carbon can tie up nitrogen from the soil when land applied. The C:N can be determined using the following equation.

$$\text{C} : \text{N} = \frac{\text{C}}{\text{TN}}$$

where:
C:N = carbon to nitrogen ratio
C = carbon (%C d.w.)
TN = total nitrogen (%TN d.w.)

Example 4–3

Determine the C:N ratio for a manure that contains 2.1 percent d.w. of total nitrogen and a carbon content of 33.0 percent d.w.

$$\begin{aligned}\text{C:N} &= \frac{\text{C}}{\text{TN}}\\ &= \frac{33.0}{2.1}\\ &= 15.7 : 1\end{aligned}$$

The following are equations for converting nutrient levels reported on dry basis to a wet basis:

$$\text{nutrient level, wet basis} = \frac{\text{nutrient level, dry basis} \times (100 - \%\ \text{moisture})}{100}$$

$$\text{nutrient level, wet basis} = \frac{\text{nutrient level, dry basis} \times \%\ \text{dry matter total solids}}{100}$$

Example 4–4

A manure testing laboratory reports that the manure has a nitrogen content of 11.5 percent d.w. The manure sampled contained 85 percent moisture. Compute the pounds of nitrogen per ton of manure as it will be transferred for utilization.

$$\begin{aligned}\text{nutrient level, wet basis} &= \frac{\text{nutrient level, dry basis} \times (100 - \%\ \text{moisture})}{100}\\ &= \frac{11.5 \times (100 - 85)}{100}\\ &= 1.725\%\end{aligned}$$

$$\begin{aligned}\text{lb N/ton} &= 1\ \text{ton} \times 2{,}000\ \text{lb/ton} \times \frac{1.725}{100}\\ &= 34.5\ \text{lb/ton}\end{aligned}$$

651.0402 Units of measure

In this chapter, English units are used exclusively for weight, volume, and concentration data for manure, waste, and residue.

The table values for as excreted manure from livestock is expressed in three different formats. They are in terms of mass or volume per:

- day per 1,000 pounds of livestock live weight (lb/d/1000 lb)

and

- finished animal (f.a.) for meat producing animals

or

- day-animal (d-a) for other animals

Excreted manure table values are given in the NRCS traditional format of mass or volume per day per 1,000 pounds live weight for all livestock and poultry types and production groupings. The 1,000 pounds live weight or animal unit (AU) is often convenient because there is a commonality of expression, regardless of the species or weight of the individual species.

A 1,000-pound AU is 1,000 pounds of live weight, not an individual animal. For example, a 1,400-pound Holstein cow is 1.4 AU (1400/1000 = 1.4). A 5-pound laying hen would be 0.005 AU (5/1000 = 0.005). The challenge in using table values in this format is for young animals. Since these animals are gaining weight, an animal weight that is representative of the time period being considered must be determined.

As an alternative, table values for excreted manure from livestock and poultry being fed for an end result of meat production are given in terms of mass or volume per finished animal. The table values given in this format are the mass or volume for one animal's finishing period in the feeding facility. Manure production expressed in this manner eliminates the problems of determining a representative weight of the animal for its tenure at a facility. Breeding stock weight for beef or swine is not given in this format because the animal's weight is stable, and they are usually retained year-round.

Table values are also given in terms of mass or volume per day-animal for dairy animals, beef and swine breeding stock, and layer chickens. The young stock included in the tables with this format, such as dairy calves and heifers, are expressed as mass or volume per day-animal that is representative for the span of time when they are in this age category.

Food processing waste is recorded in cubic feet per day (ft^3/d), or the source is included such as cubic feet per 1,000 pounds of potatoes processed.

The concentration of various components in waste is commonly expressed on a milligram per liter (mg/L) basis or parts per million (ppm). One mg/L is milligrams of solute per liter of solution. One ppm is one part by weight of solute in one million parts by weight of solution. Therefore, mg/L equals ppm if a solution has a specific gravity equal to that of water (1,000,000 mg/L or 1 kg/L). Generally, substances in solution up to concentrations of about 7,000 mg/L do not materially change the specific gravity of the liquid, and mg/L and ppm are numerically interchangeable. Concentrations are sometimes expressed as mg/kg or mg/1,000g, which are the same as ppm.

Occasionally, the concentration is expressed in percent. A 1 percent concentration equals 10,000 ppm. Very low concentrations are sometimes expressed as micrograms per liter (µg/L). A microgram is one millionth of a gram.

Various solid fractions of a manure, waste, or residue, when expressed in units of pounds per day or as a concentration, can be expressed either on a wet basis (% w.b.) or on a dry weight basis (% d.w.). The percent w.b. is the "as is" or wet weight of the material, and the d.w. is with the moisture removed. The difference in these two bases for a specific material is most likely very large. Nutrient and other chemical fractions of a waste material, expressed as a concentration, may be on a wet weight or dry weight basis, or expressed as pounds per 1,000 gallons of waste.

Amounts of the major nutrients, nitrogen (N), phosphorus (P), and potassium (K), are occasionally expressed in terms of the elemental nutrient form. However, laboratory analysis reports are more commonly expressing the nutrients in manure as a common fertilizer equivalent, P_2O_5 for P and K_20 for K. When comparing the nutrient content of a manure, waste, or residue with commercial fertilizer, the conversion factors listed in table 4–2 should be used, and comparisons on the basis of similar elements, ions, and/or compounds should be made. Nitrogen is always expressed as the nitrogen form such as Total N, NO_3-N, and NH_4-N).

Table 4–2 Factors for determining nutrient equivalency

Multiply	By	To get
NH3	0.824	N
NH4	0.778	N
NO3	0.226	N
N	1.216	NH_3
N	1.285	NH_4
N	4.425	NO_3
PO_4	0.326	P
P_2O_5	0.437	P
P	3.067	PO_4
P	2.288	P_2O_5
K_2O	0.830	K
K	1.205	K_2O

651.0403 Animal waste characteristics

Whenever locally derived values for animal waste characteristics are available, those values should be given preference over the more general data used in this chapter.

(a) As excreted manure

When compared to other types of manure data, the data given for as excreted manure characteristics is the most reliable. The properties of manure and other wastes will vary widely when modified by management actions. For example, manure that has been flushed, feedlot manure, and poultry litter will have material added and/or lost from the as excreted manure. Variations in other types of manure data in this chapter and other references result largely from additions/losses due to different management practices.

The primary concern of this chapter is livestock manure and waste produced in confinement and semiconfinement facilities. Not considered is manure produced by livestock and poultry on pasture or range. Manure produced in this manner is generally not collected for further management by transfer, storage, and treatment. As such, its management is significantly different than manure produced in confinement.

To determine the as excreted production of an animal using the table values given in units per day per 1,000 pounds livestock animal unit requires that a representative weight of the animal in question be determined. This approach is quite simple for mature animals that have reached their final weight. However, for feeder livestock and other immature livestock whose weight is changing daily, the challenge in using units of mass or volume/d/1,000 lb AU is to correctly determine the weight of the animal that is representative over the period of time being considered. For example, determining representative weight for an animal that has a beginning weight of 400 pounds and an ending weight of 800 pounds is much more complicated that merely averaging the two weights. Averaging in this manner does result in a conservative assumption. However, presentation of tabular data in units per finished animal eliminates this problem because a value is given for the animal's entire finishing period.

Facilities for meat-producing animals are rarely in full production 365 days per year due to uneven growth rates of animals, time required for facility cleaning after a group, and availability of animals for restocking a facility. Planning based on number of finished meat animals provides a more realistic planning estimate for annual manure volume and nutrient production.

The values given in the as excreted tables dairy, beef, swine, poultry, and equine were determined by one of the following two approaches.

- Use of a nutrient balance estimate of excretion that assumes feed intake minus animal retention equals excretion. This approach is used for all beef, swine, and poultry animal groups.
- Use of existing research data and regression analysis for dairy and equine.

Table values are estimated for dietary intake and animal performance levels common for livestock and poultry management in 2003 using the equations. Beef, poultry, and swine excretion characteristics are based on a calculation using equations that considers dietary nutrient intake minus animal nutrient retention using dietary and performance measurements typical for the industry at the time these data were published. Nutrient retention estimates followed common industry methodologies used for estimating animal nutrient requirements. Total nitrogen, total phosphorus, and dry matter excretion were estimated by these methods for all species. Available research data or models allowed additional excretion estimates for some species. Dry matter excretion is estimated to be a function of dry matter intake minus dry matter digestibility.

Dairy and equine manure characteristics were developed using existing research data and regression analysis to identify relationships between feeding programs, animal performance, and excretion. A regression analysis involves the study of relationships between variables.

For some values, particularly potassium, previously published excretion values were used instead of the equation methods used exclusively for nitrogen and phosphorus. As with most minerals, the amount of these nutrients (minerals) consumed can vary significantly due to regional differences. For example, some forages can be quite high in potassium because of high amounts of available potassium in the soil. In these situations, the amount of potassium consumed will be the major determinant in amount of potassium excreted. Development of modeling equations for estimating excretion of these other minerals is warranted, but they are not available at this time. Until these models are available, consideration should be given to adjusting the table values to a greater value if nutrient consumptions are very high.

Where dietary intake and animal performance level based excretion estimates could not be made, current references were reviewed, including the 1992 version of the NRCS Agricultural Waste Management Field Handbook (AWMFH); the American Society of Agricultural Engineers Standard D384.2; Manure Production and Characteristics, March 2005; and Manure Characteristics in Midwest Plan Service Publication MWPS–18, Section 1.

The as excreted table values for veal and sheep are from the 1992 version of the AWMFH.

As previously stated, table values given in this chapter are based on common dietary intake for livestock and poultry. If feed rations are atypical, excreted values should be computed by use of equations or by other means to more closely reflect actual values of the operation under consideration rather than using the table values. For example, table values may not be appropriate when by-products from the ethanol industry are included in feed rations. The rapid growth of the ethanol industry primarily for production of oxygenated fuel and, to a much lesser extent, the alcohol beverage industry, has resulted in its by-products being available as a competitively priced feed ingredient for dairy, beef, and, to some extent, swine and poultry. Use of these ethanol products may increase both nitrogen and phosphorus in the excreted manure beyond the values given in the tables.

Another example of when the table values are not appropriate is when beef cattle are fed high forage diets. Since beef cattle are ruminants, they can utilize forages, which are generally lower in digestibility, as well as concentrates, which are generally higher in digestibility. Depending upon the stage of production, the roughage-to-concentrate ratio can vary tremendously. When poorly digestible forages (fiber) are fed as compared to concentrates, volumes of manure produced are much greater than the values given in the tables.

(b) Common management modifications

How the manure is managed following excretion will often result in changes to its basic physical and chemical characteristics. These management actions include those related to wasted feed, wasted water, flush water, precipitation/evaporation, bedding (litter), soil, and biological activity. Management following excretion can also result in drying. For example, manure excreted in feedlots in arid parts of the country can lose substantial moisture because of evaporation. Dust, hair, and feathers from the livestock and poultry can also add to manure, but only in limited amounts.

(1) Wasted feed

Wasted feed can add nutrients and solids to the waste stream. Even though management can minimize the amount of feed wasted, a certain amount of feed that is presented to livestock and poultry will not be eaten. Correcting the excreted values to account for what could be considered normal wasted feed would usually be small compared to the range of values in the excreted manure that result from variations in diet intake and animal performance levels. However, if wasted feed appears to be excessive, the table values should be adjusted to account for it.

(2) Wasted water

Wasted water must be expected and controlled. Excess moisture content and increased waste volume can hamper equipment operation and limit the capacity of manure handling and storage facilities. Faulty waterers and leaky distribution lines cause severe limitations. Excess water from foggers and misters used for cooling stock in hot weather may also need to be accounted for in system design.

(3) Flush water

Flush water added to the waste stream will affect the consistency of the manure to the extent fresh water is added to the system. Using recycled water for flushing minimizes the amount of water added and needing to be managed.

(4) Precipitation/evaporation

Precipitation and evaporation can impact the physical characteristics of manure significantly, depending on the region. In regions of high precipitation, the added water can impact the consistency of the manure unless management excludes it. Evaporation, on the other hand can reduce the amount of water in the manure. But again, management of the manure will determine its impact. For example, allowing a crust to form on a waste storage pond will reduce evaporation.

(5) Bedding

Livestock producers use a wide range of bedding materials as influenced by availability, cost, and performance properties. Both organic and inorganic materials have been used successfully. Unit weights of materials commonly used for bedding dairy cattle are given in table 4–3.

Quantities of bedding materials used for dairy cattle are shown in table 4–4. The total weight of dairy manure and bedding is the sum of the weights of both parts. The total volume of dairy manure and bedding is the sum of the

Table 4–3 Unit weights of common bedding materials 1/

Material	Loose	Chopped
	- - - - - -lb/ft^3- - - - - -	
Legume hay	4.3	6.5
Non legume hay	4.0	6.0
Straw	2.5	7.0
Wood shavings	9.0	
Sawdust	12	
Soil	75	
Sand	105	
Ground limestone	95	

1/ Adapted from the 1992 version of the AWMFH

Table 4–4 Daily bedding requirements for dairy cattle 1/

Material	Barn type		
	Stanchion stall	Free-stall	Loose housing
	- - - - - - - - - lb/d/1000 lb - - - - - - - - - -		
Loose hay or straw	5.4		9.3
Chopped hay or straw	5.7	2.7	11
Shavings or sawdust		3.1	
Sand, or limestone		35 2/	

1/ Adapted from the 1992 version of the AWMFH

2/ Table 13, Manure Characteristics, Midwest Planning Service Section 1.

manure volume plus half of the bedding volume. Only half of the bedding volume is used to compensate for the void space in bedding materials. Typically, broiler producers replace the bedding material after three to six batches or once or twice a year. The typical 20,000-bird house requires about 10 tons of wood shavings for a bedding depth of 3 to 4 inches.

(6) Soil

Soil can also be added to manure after it is excreted. Its presence is most common on dairies and beef operations where cattle are confined in earthen feedlots or are pastured as a part of their routine. Dry soil adheres to the animals' bodies in limited amounts. Wet soil or mud adheres even more, and either falls off or is washed off at the dairy barn. Soil and other inorganic materials used for freestall base and bedding are also added to the manure. Soil or other inorganic materials commonly added to manure can result in a waste that has double the fixed solids content of as excreted dairy manure.

(7) Biological activity

Biological activity can begin almost immediately after manure has been excreted. This activity, of course, changes both the physical and chemical aspects of the manure. The manure can be managed to either increase or decrease biological activity. For example, manure can be treated in a waste treatment lagoon for the specific purpose of providing the environment for biological activity to reduce the pollution potential of the manure. Another example is managing the manure so that urine and feces mixes. This mixing initiates biological activity that releases ammonia resulting in a decrease in the nitrogen content of the manure. Separating urine and feces will eliminate this nutrient loss.

(c) Dairy

Manure characteristics for lactating and dry cows and for calves and heifers are listed in table 4–5.

Quantities of dairy manure vary widely from small cows to large cows and between cows at low production and high production levels. Dairy feeding systems and equipment often waste feed, which in most cases is added to the manure. Dairy cow stalls are often covered with bedding materials that improve animal comfort and cleanliness. Virtually all of the organic and inorganic bedding materials used for this purpose will eventually be pushed, kicked, and carried from the stalls and added to the manure. The characteristics of these bedding materials will blend with those of the manure. Quantities of bedding materials added to cow stalls and resting areas are shown in table 4–4.

Dairy cattle excretion varies dramatically with milk production as illustrated in table 4–5. Higher producing herds will have higher feed intake and greater total manure and manure nutrient excretion. Recognition of herd milk production is critical to making reasonable estimates of manure excretion. Concentration of nutrients fed also varies significantly between herds. Farm management decisions on degree of addition of supplemental protein and minerals can have substantial impact on the quantity of nitrogen and phosphorus that must be addressed by a nutrient management plan. The equations should be used instead of the as excreted table values to reflect this variation.

Milking centers—The amount of water used by dairies ranges widely. Since the amount used will have a significant impact on the volume that must be managed, the preferred approach is to actually measure it. Table 4–6 provides a range of water usage for various operations. Table 4–7 gives typical characterization of milking center wastewater.

Example 4–5

Estimate the daily production of volume manure and pounds of N, P, and K for 500 lactating Holstein cows with an average weight of 1,400 pounds and with an average milk production of 100 pounds per day.

Using table 4–5(a), for 500 Holstein lactating cows:

$$\begin{aligned}
\text{Volume} &= 2.6\ \text{ft}^3/\text{d-a} \times 500 = 1{,}300\ \text{ft}^3/\text{d} \\
\text{N} &= 1.0\ \text{lb/d-a} \times 500 = 500\ \text{lb/d} \\
\text{P} &= 0.19\ \text{lb/d-a} \times 500 = 95\ \text{lb/d} \\
\text{K} &= 0.49\ \text{lb/d-a} \times 500 = 245\ \text{lb/d}
\end{aligned}$$

Using table 4–5(b), for 500 Holstein lactating cows:

$$\begin{aligned}
\text{Volume} &= 1.9\ \text{ft}^3/\text{d}/1000\ \text{lb AU} \times 500 \times \frac{1400}{1000} \\
&= 1{,}330\ \text{ft}^3/\text{d} \\
\text{N} &= 0.76\ \text{lb/d}/1000\ \text{lb AU} \times 500 \times \frac{1400}{1000} \\
&= 532\ \text{lb/d} \\
\text{P} &= 0.14\ \text{lb/d}/1000\ \text{lb AU} \times 500 \times \frac{1400}{1000} \\
&= 98\ \text{lb/d} \\
\text{K} &= 0.35\ \text{lb/d}/1000\ \text{lb AU} \times 500 \times \frac{1400}{1000} \\
&= 245\ \text{lb/d}
\end{aligned}$$

Table 4–5 Dairy manure characterization—as excreted

(a) In units per day-animal [1/]

Components	Units	Lactating cow [2/] Milk production, lb/d				Milk-fed calf	Calf	Heifer	Dry cow [2/]
		50	**75**	**100**	**125**	**125 lb**	**330 lb**	**970 lb**	
Weight	lb/d-a	133	148	164	179		27	54	85
Volume	ft^3/d-a	2.1	2.4	2.6	2.9		0.44	0.87	1.4
Moisture	% wet basis	87	87	87	87		83	83	87
Total solids	lb/d-a	17	19	21	23		3.0	8.3	11.0
VS [3/]	lb/d-a	14	16	18	20		3.0	7.1	9.3
BOD	lb/d-a	2.9						1.2	1.4
N	lb/d-a	0.90	0.97	1.04	1.11	0.017	0.14	0.26	0.50
P[a]	lb/d-a	0.15	0.17	0.19	0.21		0.02	0.04	0.07
K[a]	lb/d-a	0.41	0.45	0.49	0.52		0.04	0.11	0.16

1/ ASAE D384.2, March 2005

2/ Assumes 1,375 lb lactating cow and 1,660 lb dry cow. Excretion values for P and K not in bold are based on the assumption that intake is equal to excretion

3/ VS based on 85% of TS

(b) In units per day per 1,000 lb animal unit

Components	Units	Lactating cow milk production, lb/d				Milk-fed calf	Calf	Heifer	Dry cow
		50	**75**	**100**	**125**	**125 lb**	**330 lb**	**970 lb**	
Weight	lb/d/1000 lb AU	97	108	119	130		83	56	51
Volume	ft^3/d/1000 lb AU	1.6	1.7	1.9	2.1		1.3	0.90	0.84
Moisture	% wet basis	87	87	87	87		83	83	87
Total solids	lb/d/1000 lb AU	12	14	15	17		9.2	8.5	6.6
VS	lb/d/1000 lb AU	9.2	11	12	13		7.7	7.3	5.6
BOD	lb/d/1000 lb AU	2.1						1.2	0.84
N	lb/d/1000 lb AU	0.66	0.71	0.76	0.81	0.11	0.42	0.27	0.30
P	lb/d/1000 lb AU	0.11	0.12	0.14	0.15		0.05	0.05	0.042
K	lb/d/1000 lb AU	0.30	0.33	0.35	0.38		0.11	0.12	0.10

(c) Jersey cows in units per day per 1,000-lb animal unit [1/]

Components	Units	Lactating cow milk production, lb/d		
		45	**60**	**75**
Weight	lb/d/1000 lb AU	116	130	144
Total solids	lb/d/1000 lb AU	15	17	19
N	lb/d/1000 lb AU	0.72	0.80	0.88
P	lb/d/1000 lb AU	0.12	0.13	0.15
K	lb/d/1000 lb AU	0.42	0.46	0.50

1/ Excretion values were determined using intake based equations. Although the intake-based equations were developed for Holsteins, Blake et al. (1986) and Kauffman and St-Pierre (2001) found similar dry matter digestibility between breeds. Excretion estimates were determined using average dry matter intakes for Jersey cows (NRC 2001). Nutrient excretion estimates were based on cow consuming a diet containing 17 percent CP, 0.38 percent P, and 1.5 percent K.

Table 4–6 Dairy water use for various operations

(a) Milking center

Operation		Water use
Bulk Tank	Automatic	50–60 gal/wash
	Manual	30–40 gal/wash
Pipeline	In parlor	75–125 gal/wash
Pail milkers		30–40 gal/wash
Miscellaneous equipment		30 gal/d
Cow Preparation	Automatic	1–4.5 gal/wash/cow
	Estimated avg.	2 gal/wash/cow
	Manual	0.25–0.5 gal/wash/d
Parlor floor		
Cleaned with a hose		20–40 gal/milking
Flush		800–2100 gal/milking
Well water pre-cooler		2 gal/gal of milk cooled
Milkhouse		10–20 gal/d

(b) Alley flushing[2]

Alley slope (%)	Flow depth (in)	Flow rate (gpm)[1]	Flush volume (gal)[1]
1.0	7.0	1,306	220
1.5	5.0	933	156
2.0	4.0	747	125
2.5	3.4	635	106
3.0	3.0	560	94

[1] Per foot of alley width

[2] Table adapted from the Midwest Plan Service Dairy Housing and Equipment Handbook, 2000

Table 4–7 Dairy waste characterization—milking center [1]

		Milking center [2]			
Component	Units	MH	MH+MP	MH+MP+HA [3]	[4]
Volume	ft^3/d/1000 lb	0.22	0.60	1.4	1.6
Moisture	%	100	99	100	99
TS	% w.b.	0.28	0.60	0.30	1.5
VS	lb/1000 gal	13	35	18	100
FS	lb/1000 gal	11	15	6.7	25
COD	lb/1000 gal	25	42		
BOD	lb/1000 gal		8.4		
N	lb/1000 gal	0.72	1.7	1.0	7.5
P	lb/1000 gal	0.58	0.83	0.23	0.83
K	lb/1000 gal	1.5	2.5	0.57	3.3
C:N ratio		10	12	10	7.0

[1] Adapted from the 1992 version of the AWMFH

[2] MH–Milk house; MP–Milking parlor; HA–Holding area

[3] Holding area scraped and flushed—manure excluded

[4] Holding area scraped and flushed—manure included

(d) Beef

Table 4–8 lists characteristics of as excreted beef manure. Feedlot manure varies widely because of climate, type of feedlot surface, and management. Typical values for feedlot manure are given later in table 4–16. Nutrient loss from feedlot manure is highly influenced by management factors such as moisture control, animal density, and cleaning frequency. The type of feedlot surface, earthen or paved, has impacts, as well. The soil in unsurfaced beef feedlots is readily incorporated with the manure due the animal movement and cleaning operations. Surfaced feedlots produce more runoff than unsurfaced lots. Runoff water from beef feedlots also exhibits wide variations in nutrient content character (table 4–9).

Moisture content of beef feedlot manure drops significantly over time from its as excreted 90 percent to about 30 percent. If the feedlot surface is too dry, dust will become a problem. If it remains too wet, odor may become a concern. Feedlot surface moisture of 25 to 35 percent will generally minimize odor, fly, and dust problems. For characteristics of manure solids from a beef feedlot, see table 4–16.

Nitrogen loss from feedlots can be by runoff, leaching, and ammonia volatilization. As much as 50 percent of the nitrogen deposited on feedlots may be lost as ammonia. The major source of ammonia is urea from urine, which can easily be converted to ammonia (NH_3), a gas. Urea may account for 40 percent to more than 50 percent of nitrogen excreted in manure; therefore, it has a potential for rapid loss. The volatilization of nitrogen as ammonia depends on temperature, moisture content, pH, air movement, and other factors. Ammonia is soluble in water, which could be a potential threat if feedlot runoff comes in contact with surface or ground water.

Once excreted, phosphorus is fairly stable. The usual path of phosphorus loss is through runoff. As such, feedlot runoff control measures will reduce the environmental impact of phosphorus.

Feeding of by-products from the food and corn processing industries is becoming common in beef cattle production. Use of distillers grains from the production of ethanol is growing rapidly in regions with significant corn production. Cattle diets commonly contain 20 percent distillers grains on a dry matter basis and 40 percent inclusion is becoming increasingly common. The distillers by-product contains a concentrated source of both protein and phosphorus. Use of these by-products can typically results in higher intakes of protein and phosphorus, resulting in higher excretion of nitrogen and phosphorus (table 4–8). Nutrient management plans will need to reflect the impact of by-product feeding.

Table 4–8 Beef waste characterization—as excreted

(a) Cow and growing calf in units per day-animal [1/]

Components	Units	Beef cow in confinement	Growing calf confined 450–750 lb
Weight	lb/d-a	125	50
Volume	ft³/d-a	2.0	0.8
Moisture	% w.b.	88	88
TS	lb/d-a	15	6.0
VS	lb/d-a	13	5.0
BOD	lb/d-a	3.0	1.1
N	lb/d-a	0.42	0.29
P	lb/d-a	0.097	0.055
K	lb/d-a	0.30	0.19

1/ Beef cow values are representative of animals during nonlactating period and first 6 months of gestation

(b) Cow and growing calf in units per day per 1,000 lb animal unit [1/]

Components	Units	Beef cow in confinement [2/]	Growing calf confined 450–750 lb [3/]
Weight	lb/d/1000 lb AU	104	77
Volume	ft³/d/1000 lb AU	1.7	1.2
Moisture	% w.b.	88	88
TS	lb/d/1000 lb AU	13	9.2
VS	lb/d/1000 lb AU	11	7.7
BOD	lb/d/1000 lb AU	2.5	1.7
N	lb/d/1000 lb AU	0.35	0.45
P	lb/d/1000 lb AU	0.08	0.08
K	lb/d/1000 lb AU	0.25	0.29

1/ Beef cow values are representative of animals during nonlactatin period and first 6 months of gestation
2/ Equals table 4–8a value x (1000 lb/1200 lb wt.)
3/ Equals table 4–8a value x (1000 lb/650 lb avg. wt.)

Table 4–8 Beef waste characterization—as excreted—Continued

(c) Finishing cattle excretion in units per finished animal [1/]

Components	Units	Finishing cattle Corn, no supplemental P	Finishing cattle Corn with supplemental P	Finishing cattle Corn with 25% wet distillers grains	Corn with 30% wet corn gluten feed
Weight	lb/f.a.	9,800	9,800		
Volume	ft^3/f.a.	160	160		
Moisture	% w.b.	92	92		
TS	lb/f.a.	780	780		
VS	lb/f.a	640	640		
BOD	lb/f.a.	150	150		
N	lb/f.a.	53	53	75	66
P	lb/f.a.	6.6	8.3	10	11
K	lb/f.a.	38	38		

1/ Assumes a 983 lb finishing animal fed for 153 days

(d) Finishing cattle in units per day per 1,000 lb animal unit [1/]

Components	Units	Finishing cattle Corn, no supplemental P	Finishing cattle Corn with supplemental P	Finishing cattle Corn with 25%wet distillers grains	Corn with 30% wet corn gluten feed
Weight	lb/d/1000 lb AU	65	65		
Volume	ft^3/d/1000 lb AU	1.1	1.1		
Moisture	% w.b.	92	92		
TS	lb/d/1000 lb AU	5.2	5.2		
VS	lb/d/1000 lb AU	4.3	4.3		
BOD	lb/d/1000 lb AU	1.0	1.0		
N	lb/d/1000 lb AU	0.36	0.36	0.50	0.44
P	lb/d/1000 lb AU	0.044	0.056	0.069	0.076
K	lb/d/1000 lb AU	0.25	0.25		

Table 4–9 Nitrogen content of cattle feedlot runoff (Alexander and Margheim 1974) [1/2]

Annual rainfall	Below-average conditions [3/]	Average conditions [4/]	Above-average conditions [5/]
		lb N/acre-in	
<25 in	360	110	60
25 to 35 in	60	30	15
>35 in	15	10	5

1/ Adapted from the 1992 version of the AWMFH

2/ Applies to waste storage ponds that trap rainfall runoff from uncovered, unpaved feedlots. Cattle feeding areas make up 90 percent or more of the drainage area. Similar estimates were not made for phosphorus and potassium. Phosphorus content of the runoff will vary inversely with the amount of solids retained on the lot or in settling facilities.

3/ No settling facilities are between the feedlot and pond, or the facilities are ineffective. Feedlot topography and other characteristics are conducive to high solids transport or cause a long contact time between runoff and feedlot surface. High cattle density—more than 250 head per acre.

4/ Sediment traps, low gradient channels, or natural conditions that remove appreciable amounts of solids from runoff. Average runoff and solids transport characteristics. Average cattle density—125 to 250 head per acre.

5/ Highly effective solids removal measures such as vegetated filter strips or settling basins that drain liquid waste through a pipe to storage pond. Low cattle density—less than 120 head per acre.

(e) Swine

Swine waste and waste management systems have been widely studied, and much has been reported on swine manure properties. Table 4–10 lists characteristics of as excreted swine manure from feeding and breeding stock. Breeding stock manure characteristics, also shown in table 4–10, are subject to less variation than those for growing animals.

Table 4–10 Swine waste characterization—as excreted

(a) Mature swine in units per day-animal [1/]

Components	Units	Sow Gestating 440 lb	 Lactating 423 lb	Boar 440 lb
Weight	lb/d-a	11	25	8.4
Volume	ft^3/d-a	0.18	0.41	0.13
Moisture	% w.b.	90	90	90
TS	lb/d-a	1.1	2.5	0.84
VS	lb/d-a	1.0	2.3	0.75
BOD	lb/d-a	0.37	0.84	0.29
N	lb/d-a	0.071	0.19	0.061
P	lb/d-a	0.020	0.055	0.021
K	lb/d-a	0.048	0.12	0.039

1/ Table 1.b, ASAE D384.2, March 2005

(b) Immature swine in units of per finished animal

Components	Units	Nursery pig 27.5 lb	Grow to finish 154 lb
Weight	lb/f.a	87	1200
Volume	ft^3/f.a.	1.4	20
Moisture	% w.b.	90	90
TS	lb/f.a.	10	120
VS	lb/f.a.	8.7	99
BOD	lb/f.a.	3.4	38
N	lb/f.a.	0.91	10
P	lb/f.a.	0.15	1.7
K	lb/f.a.	0.35	4.4

(c) Mature swine in units per day per 1,000 lb animal unit

Components	Units	Sow Gestating [1/]	 Lactating [2/]	Boar [3/]
Weight	lb/d-1000 AU	25	59	19
Volume	lb/d-1000 AU	0.41	0.97	0.30
Moisture	% w.b.	90	90	90
TS	lb/d-1000 AU	2.5	5.9	1.9
VS	lb/d-1000 AU	2.3	5.4	1.7
BOD	lb/d-1000 AU	0.84	2.0	0.66
N	lb/d-1000 AU	0.16	0.45	0.14
P	lb/d-1000 AU	0.05	0.13	0.05
K	lb/d-1000 AU	0.11	0.28	0.09

1/ Table 4–10(a) value × (1000 lb/440 lb avg. wt.)
2/ Table 4–10(a) value × (1000 lb/423 lb avg. wt.)
3/ Table 4–10(a) value × (1000 lb/440 lb avg. wt.)

(d) Immature swine in units of per day per 1,000 lb animal unit

Components	Units	Nursery [1/]	Grow to finish [2/]
Weight	lb/d/1000 lb AU	88	65
Volume	ft^3/d/1000 lb AU	1.4	1.1
Moisture	% w.b.	90	90
TS	lb/d/1000 lb AU	10	6.5
VS	lb/d/1000 lb AU	8.8	5.4
BOD	lb/d/1000 lb AU	3.4	2.1
N	lb/d/1000 lb AU	0.92	0.54
P	lb/d/1000 lb AU	0.15	0.09
K	lb/d/1000 lb AU	0.35	0.24

1/ Table 4–10(c) value × (1000 lb/27.5 lb avg. wt.)/36 days fed
2/ Table 4–10(c) value × (1000 lb/154 lb avg. wt.)/120 days fed

Example 4–6

Estimate the total volatile and fixed solids produced daily in the manure of a grow-to-finish pig with an average weight of 154 pounds with a 120-day feeding period.

From table 4–10(b), in terms of mass per finished animal, read TS = 120 lb per finished animal and VS = 99 lb per finished animal.

To calculate the daily total solid production per day, divide the per finished animal VS value by the tenure of the animal in the feeding period.

$$\text{lb VS/d} = \frac{99}{120} = 0.82 \text{ lb VS/d}$$

To calculate FS daily production, the fixed solids per finished animal must be first determined.

$$\begin{aligned} \text{FS} &= \text{TS} - \text{VS} \\ &= 120 - 99 \\ &= 21 \text{ lb} \end{aligned}$$

The daily FS production is calculated by dividing the per finished animal FS production by the animal's tenure in the feeding period.

$$\text{lb FS/d} = \frac{21}{120} = 0.18 \text{ lb FS/d}$$

Example 4–7

Estimate the average daily volatile solids production in the manure of 1,000 grow-to-finish pigs with an average weight of 154 pounds over the 120 days feeding period.

Using table 4–10(b), select

VS = 99.00 lb/f.a.

VS production for 1,000 animals =
99.00 lb/f.a. × 1000 f.a. = 99,000 lb
VS daily production = 99,000 lb/120 d = 825 lb/d

Using table 4–10d, select

VS = 5.4 lb/d/1000 lb AU

$$\begin{aligned} \text{VS lb/d} &= 5.36 \text{ lb/d/1000 AU} \times 1000 \text{ animals} \times 154 \text{ lb/animal} \\ &= 832 \text{ lb/d} \end{aligned}$$

(f) Poultry

Because of the high degree of industry integration, standardized rations, and complete confinement, layer and broiler manure characteristics vary less than those of other species. Turkey production is approaching the same status. Table 4–11 presents waste characteristics for as excreted poultry manure.

Table 4–16 lists data for poultry flocks that use a litter (floor) system. Bedding materials, whether wood, crop, or other residue, are largely organic matter that has little nutrient component. Litter moisture in a well-managed house generally is in the range of 25 to 35 percent. Higher moisture levels in the litter result in greater weight and reduced mass concentration of nitrogen.

Most broiler houses are now cleaned out one or two times a year. Growers generally have five or six flocks of broilers each year, and it is fairly common to take the "cake" out after each flock. The cake generally consists of the surface crust and wet spots that have clumped together. About 1 or 2 inches of new bedding is placed on the floor before the next flock.

When a grower manages for a more frequent, complete cleanout, the data in table 4–16 will require adjustment. The birds still produce the same amount of N, P, and K per day. However, the density and moisture content of the litter is different with a more frequent cleanout. The nutrient concentrations may also be lower since there is less time for the nutrients to accumulate, and the ratio of bedding to manure may be higher. A further complication is that nitrogen is lost to the atmosphere during storage while fresh manure is being continually deposited. This can create significant variations based on litter management.

Table 4–11 Poultry waste characterization—as excreted

(a) Layer waste characterization in units of per day animal [1/]

Components	Units	Layers
Weight	lb/d-a	0.19
Volume	ft^3/d-a	0.0031
Moisture	% w.b.	75
TS	lb/d-a	0.049
VS	lb/d-a	0.036
BOD	lb/d-a	0.011
N	lb/d-a	0.0035
P	lb/d-a	0.0011
K	lb/d-a	0.0013

1/ Table 12(a) ASAE D384.2, March 2005

(b) Layer in units of per day per 1,000 lb animal unit

Components	Units	Layers [1/]
Weight	lb/d/1000 lb AU	57
Volume	ft^3/d/1000 lb AU	0.93
Moisture	% w.b.	75
TS	lb/d/1000 lb AU	15
VS	lb/d/1000 lb AU	11
BOD	lb/d/1000 lb AU	3.3
N	lb/d/1000 lb AU	1.1
P	lb/d/1000 lb AU	0.33
K	lb/d/1000 lb AU	0.39

1/ Table 4–11(a) value × (1000 lb/3 lb avg. wt.) × (0.90)

Table 4–11 Poultry waste characterization—as excreted—Continued

(c) Meat production poultry in units per finished animal [1]

Components	**Units**	**Broiler**	**Turkey (toms)**	**Turkey (hens)**	**Duck**
Weight	lb/f.a.	11	78	38	14
Volume	ft^3/f.a.	0.17	1.3	0.61	0.23
Moisture	% w.b.	74	74	74	74
TS	lb/f.a.	2.8	20	9.8	3.7
VS	lb/f.a.	2.1	16	7.8	2.2
BOD	lb/f.a.	0.66	5.2	2.4	0.61
N	lb/f.a.	0.12	1.2	0.57	0.14
P	lb/f.a.	0.035	0.36	0.16	0.048
K	lb/f.a.	0.068	0.57	0.25	0.068

1/ Table 12(a) ASAE D384.2, March 2005

(d) Meat production poultry in units per day per 1,000 lb animal unit

Components	**Units**	**Broiler** [1]	**Turkey (toms)** [2]	**Turkey (hens)** [3]	**Duck** [4]
Weight	lb/d/1000 lb AU	88	34	48	102
Volume	ft^3/d/1000 lb AU	1.4	0.57	0.77	1.7
Moisture	% w.b.	74	74	74	74
TS	lb/d/1000 lb AU	22	8.8	12	27
VS	lb/d/1000 lb AU	17	7.1	9.8	16
BOD	lb/d/1000 lb AU	5.3	2.3	3.0	4.5
N	lb/d/1000 lb AU	0.96	0.53	0.72	1
P	lb/d/1000 lb AU	0.28	0.16	0.20	0.35
K	lb/d/1000 lb AU	0.54	0.25	0.31	0.50

1/ Table 4–11(c) value × (1000 lb /2.6 lb avg. wt.) / 48 days on feed
2/ Table 4–11(c) value × (1000 lb /17.03 lb avg. wt.) / 133 days on feed
3/ Table 4–11(c) value × (1000 lb /7.57 lb avg. wt.) / 105 days on feed
4/ Table 4–11(c) value × (1000 lb /3.51 lb avg. wt.) / 39 days on feed

Example 4–8

Determine the volume of litter and the amount N, P, and K produced for a 20,000-bird broiler house for six flocks between cleanouts. Assume the house is initially bedded with 10 tons of sawdust and that it is top-dressed with 5 tons between each flock.

Using table 4–11(c), select for broilers

Volume = 0.17 ft^3/f.a.
N = 0.12 lb/f.a.
P = 0.035 lb/f.a.
K = 0.068 lb/f.a.

For six 20,000-bird flocks the excreted amounts are:

Volume = 0.17 ft^3/f.a. × 6 flocks × 20,000 f.a./flock =
20,400 ft^3

N = 0.12 lb/f.a. × 6 flocks × 20,000 f.a./flock =
14,400 lb

P = 0.035 lb/fa × 6 flocks × 20,000 fa/flock =
4,200 lb

K = 0.068 lb/f.a. × 6 flocks × 20,000 f.a./flock =
8,160 lb

The sawdust used does not add nutrients, but it adds to the volume of the litter.

From table 4–3, select for sawdust 12 lb/ft^3

Volume of sawdust placed =
(10 tons + 5 top-dressings × 5 ton each)
= 35 tons
(35 tons × 2000 lb/ton) / 12 lb/ft^3 = 5,833 ft^3

As a rule of thumb, the volume of the sawdust will be reduced by approximately half due to volatilization of carbon, removal of cake, and consolidation and filling of voids with poultry excrement.

Volume of sawdust added to manure =
5,833 ft^3 × 0.5 = 2,916 ft^3

Total volume of litter =
excreted volume + volume of sawdust =
20,400 ft^3 + 2,916 ft^3 = 23,317 ft^3

Layer lagoon sludge is much denser than pullet lagoon sludge because of its high grit or limestone content. Layer lagoon sludge accumulates at the rate of about 0.0294 cubic foot per pound of total solids added to the lagoon, and pullet lagoon sludge accumulates at the rate of 0.0454 cubic foot per pound total solids. This is equivalent to about 0.6 cubic foot per layer and 0.3 cubic foot per pullet annually.

(g) Veal

Data on manure characteristics from veal production are shown in table 4–12. Sanitation in veal production is an extremely important factor, and waste management facilities should be planned for handling as much as 3 gallons of wash water per day per calf.

(h) Sheep

As excreted manure characteristics for sheep are limited to those for the feeder lamb (table 4–13). In some cases, bedding may be a significant component of sheep waste.

(i) Horse

Table 4–14 lists characteristics of as excreted horse manure. Because large amounts of bedding are used in the stables of most horses, qualities and quantities of wastes from these stables generally are dominated by the kind and volume of bedding used.

Table 4–14 values apply to horses 18 months of age or older that are not pregnant or lactating. The representative number applies to 1,100-pound horses, and the range represents horses from 880 to 1,320 pounds. Sedentary would apply to horses not receiving any imposed ex-

Table 4–12 Veal waste characterization—as excreted [1/]

Component	Units	Veal feeder
Weight	lb/d/1000 lb AU	60
Volume	ft^3/d/1000 lb AU	0.96
Moisture	%	98
TS	% w.b.	2.5
	lb/d/1000 lb AU	1.5
VS	lb/d/1000 lb AU	0.85
FS	lb/d/1000 lb AU	0.65
COD	lb/d/1000 lb AU	1.5
BOD_5	lb/d/1000 lb AU	0.37
N	lb/d/1000 lb AU	0.20
P	lb/d/1000 lb AU	0.03
K	lb/d/1000 lb AU	0.25
C:N ratio		2.0

1/ Adapted from the 1992 version of the AWMFH

Table 4–13 Lamb waste characterization—as excreted [1/]

Component	Units	Lamb
Weight	lb/d/1000 lb AU	40
Volume	ft^3/d/1000 lb AU	0.63
Moisture	%	75
TS	% w.b.	25
	lb/d/1000 lb AU	10
VS	lb/d/1000 lb AU	8.3
FS	lb/d/1000 lb AU	1.8
COD	lb/d/1000 lb AU	11
BOD^5	lb/d/1000 lb AU	1.0
N	lb/d/1000 lb AU	0.45
P	lb/d/1000 lb AU	0.07
K	lb/d/1000 lb AU	0.30
C:N ratio		10

1/ Adapted from the 1992 version of the AWMFH

Table 4–14 Horse waste characterization—as excreted

(a) Horse in units/day-animal

Components	Units	Sedentary (1,100 lb)	Exercised (1,100) lb
Weight	lb/d-a	56	57
Volume	ft^3/d-a	0.90	0.92
Moisture	% w.b.	85	85
TS	lb/d-a	8.4	8.6
VS	lb/d-a	6.6	6.8
BOD	lb/d-a	1.1	1.1
N	lb/d-a	0.20	0.34
P	lb/d-a	0.029	0.073
K	lb/d-a	0.060	0.21

(b) Horse in units/d/1,000 lb animal unit

Components	Units	Sedentary[1/]	Exercised[1/]
Weight	lb/d/1000 lb AU	51	52
Volume	ft^3/d/1000 lb AU	0.82	0.84
Moisture	% w.b.	85	85
TS	lb/d/1000 lb AU	7.6	7.8
VS	lb/d/1000 lb AU	6.0	6.2
BOD	lb/d/1000 lb AU	1.0	1.0
N	lb/d/1000 lb AU	0.18	0.31
P	lb/d/1000 lb AU	0.026	0.066
K	lb/d/1000 lb AU	0.05	0.19

1/ Table 4–14(a) value × (1000 lb/1100 lb avg. wt.)

ercise. Dietary inputs are based on minimum nutrient requirements specified in Nutrient Requirements of Horses (NRCS 1989). Intense represents horses used for competitive activities such as racing. Dietary inputs are based on a survey of race horse feeding practices (Gallagher et al. 1992) and typical feed compositions (forage=50% alfalfa, 50% timothy; concentrate = 30% oats, 70% mixed performance horse concentrate).

(j) Rabbit

Some properties of rabbit manure are listed in table 4–15. The properties refer only to the feces; no urine has been included. Reliable information on daily production of rabbit manure, feces, or urine is not available.

Table 4–15 Rabbit waste characterization—as excreted [1/]

Components	Units	Rabbit
VS	% d.b.	0.86
FS	% d.b.	0.14
COD	% d.b.	1.0
N	% d.b.	0.03
P	% d.b.	0.02
K	% d.b.	0.03
C:N ratio		16

1/ Adapted from the 1992 version of the AWMFH

651.0404 Manure as transferred for utilization

Many physical, chemical, and biological processes can alter manure characteristics from its original as-excreted form. The as transferred for utilization production and characteristics values reported in table 4–16 allow for common modifications to excreted manure resulting from water addition or removal, bedding addition, and/or treatment processes. These estimates may be helpful for individual farm long-term planning prior to any samples being available and for planning estimates addressing regional issues. Whenever possible, site-specific samples or other more localized estimates should be used in lieu of national tabular estimates. To use table 4–16 to develop individual year nutrient management plans for defining field-specific application rates would be a misuse of the data. Where site-specific data are unavailable, this table may provide initial estimates for planning purposes until site-specific values are available. Chapter 11 of this handbook also presents another method of calculating as transferred for utilization values. The nutrient accounting methodology presented in chapter 11 adjusts as excreted nutrient values utilizing nutrient loss factors based on the type of management system in place.

Table 4–16 Manure as transferred for utilization

(a) Values [1]

	Mass (lb/hd/d)	Moisture (% wb)	TS (% wb)	VS (% TS)	TKN (% wb)	NH3-N (% wb)	P (% wb)	K (% wb)
Beef								
Earthen lot	17	33	67	30	1.2	0.10	0.50	1.3
Poultry								
Leghorn pullets	No data	65	40		2.1	0.85	1.0	1.1
Leghorn hen	0.066	59	40		1.9	0.88	1.2	1.3
Broiler litter	0.044	31	70	70	3.7	0.75	0.60	1.4
Turkey litter	0.24	30			2.2		0.33	1.2
Dairy								
Scraped earthen lots	77	54	46		0.70		0.25	0.67
Scraped concrete lots	88	72	25		0.53		0.13	0.40
Lagoon effluent	234	98	2	52	0.073	0.08	0.016	0.11
Slurry (liquid)	148	92	8	66	0.30	0.14	0.13	0.40
Equine								
Solid manure								
Residential	71	43	65	26	0.76		0.24	0.99
Commercial	101							
Swine								
Finisher-Slurry, wet-dry feeders	6.6–8.8	91	9.0		0.70	0.50	0.21	0.24
Slurry storage-dry feeders	9.9	94	6.1		0.47	0.34	0.18	0.24
Flush building	35	98	2.0		0.20	0.14	0.07	0.17
Agitated solids and water		98	2.2		0.10	0.05	0.06	0.06
Lagoon surface water		99.6	0.40		0.06	0.04	0.02	0.07
Lagoon sludge		90	10		0.26	0.07	0.25	0.07

1/ Adapted from ASAE D384.2, table 19

Table 4–16 Manure as transferred for utilization—Continued

(b) Expressed as 1,000-lb animal units

Type of production	Mass in lb/AU/d, wet basis	Moisture, % wet basis [2/3]	Total solids % wet basis [3/]	Total solids, lb/AU/d	Volatile solids, % of TS	Volatile solids, lb/AU/d	Total Kjehldahl Nitrogen, % wet basis	Total Kjehldahl Nitrogen, in lb/AU/d [4/]	NH_3-N % wet basis	NH_3-N lb/AU/d	P % wet basis	P lb/AU/d	K % wet basis	K lb/AU/d
Beef earthen lot	17	33%	67%	11	30.2%	3.4	1.18%	0.20	0.10%	0.017	0.50%	0.084	1.25%	0.21
Poultry leghorn hen	17	59%	40%	6.6			1.85%	0.31	0.88%	0.15	1.21%	0.20	1.31%	0.22
Poultry broiler litter	17	31%	70%	12	70.0%	8.3	3.73%	0.63	0.75%	0.13	0.60%	0.10	1.37%	0.23
Poultry turkey litter	23[1/]	30%					2.18%	0.51			0.33%	0.077	1.23%	0.29
Dairy scraped earthen lots	57	54%	46%	26			0.70%	0.40			0.25%	0.14	0.67%	0.38
Dairy scraped concrete lots	65	72%	25%	16			0.53%	0.34			0.13%	0.084	0.40%	0.26
Dairy lagoon effluent	171	98%	2%	3.4	52.0%	1.8	0.07%	0.12	0.08%	0.14	0.02%	0.034	0.11%	0.19
Dairy slurry (liquid)	108	92%	8%	8.7	66.0%	5.7	0.30%	0.32	0.14%	0.15	0.13%	0.14	0.40%	0.43
Equine solid manure	64	43%	65%	42	26.3%	11	0.76%	0.49			0.24%	0.15	0.99%	0.64
Swine finisher, slurry w/ wet/ dry feeders	50	91%	9%	4.5			0.70%	0.35	0.50%	0.25	0.21%	0.11	0.24%	0.12
Swine slurry storage w/ dry feeders (sows)	23	94%	6%	1.4			0.47%	0.11	0.34%	0.077	0.18%	0.041	0.24%	0.054
Swine flush building (sows)	80	98%	2%	1.6			0.20%	0.16	0.14%	0.11	0.07%	0.056	0.17%	0.14

1/ Assuming raising an equal number of tom and hen turkeys

2/ Assuming moisture is equivalent to water, and whatever is not water is dry matter [TS+VS]

3/ Percent moisture plus percent TS can add up to more than 100% because solids estimates do not include solids in urine

4/ TKN includes ammonia N plus organic N. If the manure storage is aerobic, there would also be nitrate N

651.0405 Other wastes

(a) Residential waste

NRCS is seldom called on to provide assistance to municipalities; however, the information provided here may be useful in area-wide planning. Rural residential waste components are identified in tables 4–17 and 4–18. Table 4–17 lists the characteristics of human excrement. Household wastewater (table 4–18) can be categorized as graywater (no sanitary wastes included) and blackwater (sanitary wastewater). In most cases, a composite of both of these components will be treated in a septic tank. The liquid effluent from the septic tank generally is treated in a soil absorption field.

Municipal wastewater of residential origin is usually categorized into raw (untreated) and treated types (table 4–19). Secondary (biological) treatment is common for wastewater that is to be applied to agricultural land. Municipal wastewater sludge may also be in the raw, untreated form or in the treated (digested) form. Municipal compost is usually based on dewatered, digested sludge and refuse, but can contain other waste materials, as well.

Liquid and solid wastes of residential origin generally are not a source of toxic materials. Some industrial waste, however, may contain toxic components requiring careful handling and controlled distribution. Planning of land application systems for industrial waste must include thorough analyses of the waste materials.

(b) Food wastes and wastewater

Food processing can result in considerable quantities of solid waste and wastewater. Processing of some fruits and vegetables results in more than 50 percent waste. Many of these wastes, however, can be used in by-product recovery procedures, and not all of the waste must be sent to disposal facilities. Food processing wastewater may be a dilute material that has a low concentration of some of the components of the raw product. On the other hand, solid waste from food processing may contain a high percentage of the raw product and exhibit characteristics of that raw product.

Tables 4–20 and 4–21 present characteristics of wastewater and sludge from the processing of milk and milk products.

Characteristics of wastewater and sludge from the meat and poultry processing industries are listed in tables 4–22 and 4–23.

Table 4–17 Human waste characterization—as excreted [1]

Component	Units	Adult
Weight	lb/d/1000 lb	30
Volume	ft^3/d/1000 lb	0.55
Moisture	%	89
TS	% w.b.	11
	lb/d/1000 lb	3.3
VS	lb/d/1000 lb	1.9
FS	lb/d/1000 lb	1.4
COD	lb/d/1000 lb	3.0
BOD$_5$	lb/d/1000 lb	1.3
N	lb/d/1000 lb	0.20
P	lb/d/1000 lb	0.02
K	lb/d/1000 lb	0.07

1/ Adapted from the 1992 version of the AWMFH

Table 4–18 Residential waste characterization—household wastewater [1]

Component	Units	Graywater	Composite [2]	Septage
Volume	ft^3/d/1000 lb of people	27	38	35
Moisture	%	99.92	99.65	99.75
TS	% w.b.	0.08	0.35	0.25
	lb/d/1000 lb of people	1.3	7.7	5.5
VS	% w.b.	0.024	0.20	0.14
FS	lb/d/1000 lb	0.056	0.15	0.11
N	lb/d/1000 lb	0.0012	0.007	0.0075
NH4-N	lb/d/1000 lb			0.0018
P	lb/d/1000 lb	0.0004	0.003	0.0019
K	lb/d/1000 lb		0.003	0.0025

1/ Adapted from 1992 version of the AWMFH
2/ Graywater plus blackwater

Table 4–19 Municipal waste characterization—residential[1]

		Wastewater		Sludge		
Component	**Units**	**Raw**	**Secondary**	**Raw**	**Digested**	**Compost**[2]
Volume	ft^3/d/1000 lb of people	90	85			
Moisture	%	99.95	99.95			40
TS	% w.b.	0.05[3]	0.05[4]	4.0	4.0	60
VS	"	0.035		3.0	2.1	
FS	"	0.015		1.0	0.90	
COD	"	0.045				
BOD_5	"	0.020	0.0025			
N	"	0.003	0.002	0.32	0.15	0.78
NH_4-N	"		0.001		0.08	
P	"	0.001	0.001	0.036	0.067	0.20
K	"	0.001	0.0012		0.010	0.17

Table 4–20 Dairy food processing waste characterization[1]

	Wastewater	
Product/operation	**Weight lb/lb milk processed**	**BOD_5 lb/1000 lb milk received**
Bulk milk handling	6.1	1.0
Milk processing	4.9	5.2
Butter	4.9	1.5
Cheese	2.1	1.8
Condensed milk	1.9	4.5
Milk powder	2.8	3.9
Milk, ice cream, and cottage cheese	2.5	6.4
Cottage cheese	6.0	34
Ice cream	2.8	5.8
Milk and cottage cheese	1.8	3.5
Mixed products	1.8	2.5

1/ Adapted from 1992 version of the AWMFH

Table 4–21 Dairy food waste characterization—processing wastewater[1]

Component	Units	Industry wide	Whey Sweet cheese	Whey Acid cheese	Cheese wastewater sludge
Moisture	%	98	93	93	98
TS	% w.b.	2.4	6.9	6.6	2.5
VS	% w.b.	1.5	6.4	6.0	
FS	% w.b.	0.91	0.55	0.60	
COD	% w.b.		1.3		
BOD5	% w.b.	2.0			
N	% w.b.	0.077	7.5		0.18
P	% w.b.	0.050			0.12
K	% w.b.	0.067			0.05

1/ Adapted from 1992 version of the AWMFH

Table 4–22 Meat processing waste characterization—wastewater[1]

Component	Units	Red meat Harvesting[2]	Red meat Packing[3]	Red meat Processing[4]	Poultry[5]	Broiler[6]
Volume	gal/1000 lb[7]	700	1,000	1,300	2,500	
Moisture	%					95
TS	% w.b.					5.0
	lb/1000 lb	4.7	8.7	2.7	6.0	
VS	lb/1000 lb					4.3
FS	lb/1000 lb					0.65
BOD^5	lb/1000 lb	5.8	12	5.7	8.5	
N	lb/1000 lb					0.30
P	lb/1000 lb					0.084
K	lb/1000 lb					0.012

1/ Adapted from 1992 version of the AWMFH
2/ Harvesting—Euthanizing and preparing the carcass for processing
3/ Packing—Euthanizing, preparing the carcass for processing, and processing
4/ Processing—Sectioning carcass into retail cuts, grinding, packaging
5/ Quantities per 1,000 lb product
6/ All values % w.b.
7/ Per 1,000 lb live weight harvested

Table 4–22 presents data on raw wastewater discharges from red meat and poultry processing plants. Table 4–23 describes various sludges. Dissolved air flotation sludge is a raw sludge resulting from a separation procedure that incorporates dissolved air in the wastewater. The data on wastewater sludge is for sludge from secondary treatment of wastewater from meat processing.

Table 4–24 presents raw wastewater qualities for several common vegetable crops on the basis of the amount of the fresh product processed. Characteristics of solid fruit and vegetable wastes, such as might be collected at packing houses and processing plants, are listed in table 4–25.

(c) Silage leachate

Silage leachate, a liquid by-product resulting from silage production typically from whole corn plants or sorghums, that drains from the storage unit must be considered in the planning and design of an AWMS. Silage is a forage-type livestock feed that is produced by fermentation at relatively high moisture contents and stored in airtight conditions. Oxygen depletion of surface water is the major environmental concern associated with silage leachate because of its high biological oxygen demand. This oxygen depletion is exacerbated because silage is usually produced in the late summer and early fall when streams are already low in total dissolved oxygen due to

Table 4–23 Meat processing waste characterization—wastewater sludge [1]

Component	Units	Dissolved air flotation sludge			Wastewater sludge
		Poultry	Swine	Cattle	
Moisture	%	94	93	95	96
TS	% w.b.	5.8	7.5	5.5	4.0
VS	% w.b.	4.8	5.9	4.4	3.4
FS	% w.b.	1.0	1.6	1.1	0.60
COD	% w.b.	7.8			
N	% w.b.	0.41	0.53	0.40	0.20
NH_4-N	% w.b.	0.17			
P	% w.b.	0.12			0.04

1/ Adapted from the 1992 version of the AWMFH

Table 4–24 Vegetable processing waste characterization—wastewater [1]

Component	Units	Cut bean	French-style bean	Pea	Potato	Tomato
Volume	ft^3/d/1000				270 [3]	
TS	lb/1000 lb [2]	15	43	39	53 [4]	130
VS	lb/1000 lb [2]	9	29	20	50 [4]	
FS	lb/1000 lb [2]	6	14	19	3 [4]	
COD	lb/1000 lb [2]	14	35	37	71 [5]	96
BOD_5	lb/1000 lb [2]	7	17	21	32	55

1/ Adapted from 1992 version of the AWMFH
2/ lb/1000 lb raw product
3/ ft^3/lb processed
4/ Total suspended solids
5/ Percent of TSS

Table 4–25 Fruit and vegetable waste characterization—solid waste[1/]

Fruit/vegetable	Moisture content	Total solids	Volatile solids	Fixed solids	N	P	K
Banana, fresh	84	16	14	2.1	0.53		
Broccoli, leaf	87	14			0.30		
Cabbage, leaf	90	9.6	8.6	1.0	0.14	0.034	
Cabbage core	90	10			0.38		
Carrot, top	84	16	14	2.4	0.42	0.03	
Carrot root	87	13	11	1.3	0.25	0.04	
Cassava, root	68	32	31	1.3	1.7	0.039	
Corn, sweet, top	80	20	19	1.2	0.7		
Kale, top	88	12	9.7	1.9	0.22	0.06	
Lettuce, top	95	5.4	4.5	0.9	0.05	0.027	
Onion top, mature	8.6	91	85	6.7	1.4	0.02	
Orange, flesh	87	13	12	0.6	0.26		
Orange pulp	84	16	15	1.0	0.24		
Parsnip, root	76	24			0.47		
Potato, top, mature	13	87	72	16	1.2		
Potato tuber					1.6	0.25	1.9
Pumpkin, flesh	91	8.7	7.9	0.8	0.12	0.037	
Rhubarb, leaf	89	11			0.20		
Rutabaga, top	90	10			0.35		
Rutabaga root	90	11			0.20		
Spinach, stems	94	6.5			0.07		
Tomato, fresh	94	5.8	5.2	0.6	0.15	0.03	0.30
Tomato, solid waste	89	11	10	0.9	0.22	0.044	0.089
Turnip, top	92	7.8				0.20	
Turnip root	91				0.34		

[1/] Adapted from the 1992 version of the AWMFH seasonally high temperatures and low flow rates. Since 20 to 25 percent of the total nitrogen in silage leachate is in the form of nitrate, it is also has the potential of being a ground water contaminant.

Generally, the amount of leachate produced is directly influenced by the moisture content of the forage ensiled and the degree of compaction to which the forage is subjected. Silage leachate is typically 95 percent water. It has a pH that can range from 5.5 to 3.6. Table 4–26 lists the range for typical nutrient concentrations in silage leachate.

The range of uncertainty in nutrient content reflects the differences that can occur from year to year and from site to site. Management decisions based on these nutrient concentrations should also consider the associated volumes of leachate that are usually relatively small. In most instances, a practical design and plan for environmental containment should be based on a reasonably high concentration assumption. Operation and management decisions should be based on the results of timely sampling and testing at a specific site.

The factors that influence leachate production from silage include the degree to which the silage crop has been chopped and the amount of pressure applied to the leachate in the silo, but the greatest single factor is the percent of dry matter in the silage. The peak rate of silage leachate production has been measured with silage at 18 percent moisture as 0.5 cubic feet per ton of silage per day. The peak time of leachate production will usually be from 3 to 5 days following ensilage. Leachate production as a function of percent dry matter is given in table 4–27.

This variation in production can make a significant difference in the planning and design of systems to manage this effluent. The actual production rate used for a specific design should be a reasonable conservative estimate that is based on these numbers, local data, and the experience of the managers of the silos.

Table 4–26 Typical range of nutrient concentrations in silage leachate[1/]

Constituent	Concentration lb/ft^3
Total nitrogen	0.09–0.27
Phosphorus	0.02–0.04
Potassium	0.21–0.32

1/ Adapted from Stewart and McCullough

Table 4–27 Leachate production based on percent dry matter of silage[1/]

Dry matter content of silage %	Leachate produced of silage gal/ton
<15	100–50
15–20	50–30
20–25	30–5
>25	5–0

1/ Adapted from Stewart and McCullough

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