



AEX-715-08

# Estimating Manure Production, Storage Size, and Land Application Area

Jing Tao, Graduate Research Associate, Environmental Science Graduate Program  
Karen Mancl, Ph.D., Professor, Department of Food, Agricultural, and Biological Engineering

## Introduction

Livestock manure can be either a valuable resource or an environmental pollutant. Generally, manure refers to feces and urine produced by animals. It contains organic matter and nutrients, which has fertilizer value when applied on the land and used by crops. The proper handling and management of manure can augment or replace purchased commercial fertilizer, while avoiding harm to the environment. The quantity, composition, and consistency of manure influence the selection and the design of manure-handling facilities. These characteristics also affect the nutrients available for land application when manure is used as fertilizer. The properties of manure depend on several factors: animal species; feed ration digestibility, protein, and fiber content; animal age and productivity; manure management and handling, and the environment. The waste system may also add bedding, soil, water, hair, etc.

Manure with 20–25% solids content (75–80% moisture content) can usually be handled as solid. In the 10–20% solids content range, handling characteristics vary depending on the types of solids present. Manure with 4–10% solids content can usually be handled as a liquid, but may need special pumps. Manure with 0–4% solids content is handled as a liquid with irrigation or flushing consistency. Liquids that have had the larger solids settled or filtered out or manure with dilution water added may have 4% or less solids.

Several handbooks and bulletins provide the data on production and characteristics of fresh manure for different types of livestock (MWPS–18, 1993: *Livestock Waste Facilities Handbook*; OSU Extension Bulletin 604: *Ohio Livestock Manure Management Guide*; ASAE Standards D284.1, 2003: *Manure Production and Characteristics*). Farmers and manure-handling technicians can use these data to calculate estimates of volume and composition for their livestock farms. This fact sheet introduces how to do these calculations and presents an example.

## Example

A residential boarding school has a stable of 25 horses for student riding lessons and a chicken house for 250 exotic chickens. The students care for the chickens and gather the eggs. A solid-manure system is used, and animal manures are stored for land application. Develop a manure management plan including manure weight, volume and characteristics, storage size and land application area based on agronomic rates.

Use MWPS–18, *Chapter 2, Animal Waste Characteristics*, for data of manure production and storage. Chickens for eggs are layers in poultry. Use *Ohio Agronomy Guide*, 14th edition (OSU Extension Bulletin 472-05, <http://ohioline.osu.edu/b472/>), *Chapter 3, Soil Fertility*, for nutrients removed by crops.

**A. Estimate manure characteristics and production daily.**

**Step I.** Estimate total weight and volume of daily manure production.

**Daily manure weight, lb/day = manure production rate, lb/day \* number of animals**

**Daily manure volume, gal/day = manure production rate, gal/day \* number of animals**

**Solution:**

The estimated data of manure production rate and characteristics can be obtained in Table 2-1 of MWPS-18. Different sources may have various estimates for manure characteristics. Since these sources only list the best estimates from different research, farmers and manure-handling technicians should measure the characteristics of the manure that they need to handle at a reliable lab. This example only shows how to calculate manure production based on reference data.

**Example of table 2-1 (MWPS-18): Manure production and characteristics as produced**  
 Values are approximate. The actual characteristics of a manure can easily have values 30% or more above or below the table values. The volumes of waste that a waste handling system has to handle can be much larger than the table values due to the addition of water, bedding, etc. For example, liquid waste systems for swine farrowing and gestation units may have to handle twice as much waste volume as indicated; swine nurseries 3–4 times as much, because of large amounts of wash and wasted water.

Animal	Size, lb	Total manure production			Water, %	Density lb/ft <sup>3</sup>	TS lb/day	VS lb/day	BOD <sub>5</sub> lb/day	Nutrient content, lb/day		
		lb/day	ft <sup>3</sup> /day	gal/day						N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Poultry, Layers	4	0.21	0.0035	0.026	74.8	60	0.064	0.048	0.013	0.0029	0.0025	0.0014
Poultry, Broilers	2	0.14	0.0022	0.016	74.8	63	0.044	0.034	0.0024	0.0017	0.0009	—
Horse	1,000	51	0.81	6.06	79.5	63	15	10	1.7	0.30	0.161	0.301

Source: American Society of Agricultural Engineers, data adapted from 1992 ASAE standard D384.1

Horse manure weight = 51 lb/day \* 25 horses = 1275 lb/day

Chicken manure weight = 0.21 lb/day \* 250 chickens = 52.5 lb/day

**Total manure weight = 1327.5 lb/day**

Horse manure volume = 6.06 gal/day \* 25 horses = 151.5 gal/day

Chicken manure volume = 0.026 gal/day \* 250 chickens = 6.5 gal/day

**Total manure volume = 158 gal/day**

**Step II.** Estimate solids, liquid content, and water percentages.

**Total solids, lb/day = total solids rate, lb/day \* number of animals**

**Liquid content, lb/day = total manure weight, lb/day – total solids, lb/day**

**Water % = sum of (Water % \* manure weight for each type of animal) / total manure weight**

**Solution:**

Horse manure total solids = 15 lb/day \* 25 horses = 375 lb/day

Chicken manure total solids = 0.064 lb/day \* 250 chickens = 16 lb/day

**Total solids = 391 lb/day**

$$\text{Liquid content} = 1327.5 \text{ lb/day} - 391 \text{ lb/day} = 937.5 \text{ lb/day}$$

$$\text{Water \%} = (79.5 \% * 1275 \text{ lb/day} + 74.8\% * 52.5 \text{ lb/day}) / 1327.5 \text{ lb/day} = 79.3\%$$

Water % is in the range of 75–80% and suggests handling as solid manure.

**Step III.** Estimate BOD<sub>5</sub> and nutrients (N, P, K) in manure production.

$$\text{BOD}_5 \text{ production, lb/day} = \text{BOD}_5 \text{ production rate, lb/day} * \text{number of animals}$$

$$\text{Nutrient production (N, P}_2\text{O}_5, \text{K}_2\text{O), lb/day} = \text{nutrient production rate, lb/day} * \text{number of animals}$$

$$\text{Phosphate (P), lb/day} = \text{P}_2\text{O}_5 \text{ production, lb/day} * \text{transfer coefficient to P}$$

$$\text{Potassium (K), lb/day} = \text{K}_2\text{O production, lb/day} * \text{transfer coefficient to K}$$

**Solution:**

$$\text{Horse manure BOD}_5 = 1.7 \text{ lb/day} * 25 \text{ horses} = 42.5 \text{ lb/day}$$

$$\text{Chicken manure BOD}_5 = 0.013 \text{ lb/day} * 250 \text{ chickens} = 3.2 \text{ lb/day}$$

$$\text{Total BOD}_5 = 45.7 \text{ lb/day}$$

$$\text{Horse manure N} = 0.3 \text{ lb N/day} * 25 \text{ horses} = 7.5 \text{ lb N/day}$$

$$\text{Chicken manure N} = 0.0029 \text{ lb N/day} * 250 \text{ chickens} = 0.7 \text{ lb N/day}$$

$$\text{Total N} = 8.2 \text{ lb N/day}$$

$$\text{Horse manure P}_2\text{O}_5 = 0.161 \text{ lb P}_2\text{O}_5/\text{day} * 25 \text{ horses} = 4.0 \text{ lb P}_2\text{O}_5/\text{day}$$

$$\text{Chicken manure P}_2\text{O}_5 = 0.0025 \text{ lb P}_2\text{O}_5/\text{day} * 250 \text{ chickens} = 0.6 \text{ lb P}_2\text{O}_5/\text{day}$$

$$\text{Total P}_2\text{O}_5 = 4.6 \text{ lb P}_2\text{O}_5/\text{day} \quad \text{Total P} = 4.6 \text{ lb P}_2\text{O}_5/\text{day} * 0.44 = 2.0 \text{ lb P/day}$$

$$\text{Horse manure K}_2\text{O} = 0.301 \text{ lb K}_2\text{O} / \text{day} * 25 \text{ horses} = 7.5 \text{ lb K}_2\text{O} / \text{day}$$

$$\text{Chicken manure K}_2\text{O} = 0.0014 \text{ lb K}_2\text{O} / \text{day} * 250 \text{ chickens} = 0.4 \text{ lb K}_2\text{O} / \text{day}$$

$$\text{Total K}_2\text{O} = 7.9 \text{ lb K}_2\text{O/day} \quad \text{Total K} = 7.9 \text{ lb K}_2\text{O} / \text{day} * 0.83 = 6.5 \text{ lb K/day}$$

### ***B. Estimate storage of manure for 180 days.***

**Step I.** Estimate approximate storage capacity required per day, expressed in cubic feet or gallons. For solid storage, include half the volume of bedding materials when estimating the storage volume. For liquid storages, include additional dilution volumes, such as wash water, runoff water, etc. For storages without runoff waters, plan for 10 percent to 25 percent dilution volume.

Shavings are usually used as bedding for horse. No bedding is needed for layers.

$$\text{Daily bedding volume, ft}^3/\text{day} = \text{estimated shavings, lb/day}/1000 \text{ lb animal weight} * \text{weight of one animal, lb} * \text{number of animals} / \text{density of shavings, lb/ft}^3$$

$$\text{Daily storage volume, ft}^3/\text{day} = \text{total manure volume, gal/day} * 0.15 \text{ ft}^3/\text{gal} + 0.5 * \text{bedding volume, ft}^3/\text{day}$$

**Solution:**

Use Table 2-3b and Table 2-4 of MWPS-18 for the data of bedding.

<b>Example of table 2-3b (MWPS-18): Bedding material density</b>		
<b>Form</b>	<b>Material</b>	<b>Density lb/ft<sup>3</sup></b>
<i>Loose</i>	Shavings	9

<b>Example of table 2-4 (MWPS-18): Bedding requirements for dairy cattle</b>	
<b>Housing system</b>	<b>Type of bedding</b>
	<b>Shavings</b>
<i>Free stall housing</i>	lb/day per 1,000 lb weight
	3.1

**Daily bedding volume** = 3.1 lb/day/1000 lb \* 1000 lb \* 25 / 9 lb/ft<sup>3</sup> = **8.6 ft<sup>3</sup>/day**

**Daily storage volume** = 158 gal/day \* 0.15 ft<sup>3</sup>/gal + 0.5 \* 8.6 ft<sup>3</sup>/day = **28 ft<sup>3</sup>/day**

**Step II.** Estimate approximate storage capacity required for desired storage length. Typical storage periods are 90 days, 180 days, and a year.

**Storage size, ft<sup>3</sup> = daily storage volume, ft<sup>3</sup>/day \* number of days**

**Solution:**

For 180-day storage, **storage size** = 28 ft<sup>3</sup>/day \* 180 days = **5040 ft<sup>3</sup>**

**C. Estimate land application of manure.**

**Step I.** Estimate the annual manure nutrient production for each nutrient (N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O).

**Annual manure nutrient production, lb/yr = daily nutrient production, lb/day \* number of days for a year**

**Solution:**

**Annual N production, lb/day** = 8.2 lb N/day \* 365 days/yr = **2993 lb N/yr**

**Annual P<sub>2</sub>O<sub>5</sub> production, lb/day** = 4.6 lb P<sub>2</sub>O<sub>5</sub>/day \* 365 days/yr = **1679 lb P<sub>2</sub>O<sub>5</sub>/yr**

**Annual K<sub>2</sub>O production, lb/day** = 7.9 lb K<sub>2</sub>O/day \* 365 days/yr = **2883.5 lb K<sub>2</sub>O/yr**

**Step II.** Estimate the total acres of cropland needed for manure application based on crop nutrient needs. Proper land application of animal manures can yield an economic return by wisely using the available nutrients to meet crop nutrient needs. Excess application of manure is wasteful and can lead to excess nutrients in the soil, pollution of surface and ground water, harm to crops, and soil contamination.

**Annual cropland area required to apply manure, ac = annual manure nutrient production, lb/yr / (crop nutrient needs, lb/bu or lb/ton \* crop yield goal, bu/ac or ton/ac)**

**Solution:**

Manure is to be applied to cropland in a corn-and-soybean rotation. The corn yield goal is 150 bushels per acre, and the soybean yield goal is 50 bushels per acre. Crop nutrients needs data is available in Table 3-2 of Bulletin 472-05, *Ohio Agronomy Guide*. Use grain data for corn.

**Example of table 3-2 (Ohio Agronomy Guide, Bulletin 472-05): Approximate amounts of primary macronutrients removed by various crops**

Crop (Removal Units)	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Corn grain (lb/bu)	0.9	0.4	0.3
Soybean (lb/bu)	3.8*	0.8	1.4

### Annual cropland required

**Corn:** Area for N = 2993 lb/yr / (0.9 lb/bu \* 150 bu/ac) = **22 ac/yr**

Area for P<sub>2</sub>O<sub>5</sub> = 1679 lb/yr / (0.4 lb/bu \* 150 bu/ac) = **28 ac/yr**

Area for K<sub>2</sub>O = 2883.5 lb/yr / (0.3 lb/bu \* 150 bu/ac) = **64 ac/yr**

**Soybean:** Area for N = 2993 lb/yr / (3.8a lb/bu \* 50 bu/ac) = **18 ac/yr**

Area for P<sub>2</sub>O<sub>5</sub> = 1679 lb/yr / (0.8 lb/bu \* 50 bu/ac) = **42 ac/yr**

Area for K<sub>2</sub>O = 2883.5 lb/yr / (1.4 lb/bu \* 50 bu/ac) = **41 ac/yr**

\*Inoculated legumes fix nitrogen from the air.

Based on crop nutrient removal, **at most 64 acres will be needed during the corn rotation years** as the application of potassium needs the largest cropland area in this example. If potassium is not considered the limiting nutrient for manure application, the required land is reduced to 28 acres based on phosphorus. No manure is needed to meet nitrogen requirements during the soybean-rotation years because legumes can fix nitrogen from the air. If manure is applied, the limiting nutrient for application is phosphorus, requiring **at most 42 acres of soybean ground**. Additional commercial fertilizer will be needed to supplement the other crop nutrients requirements. Manure can be applied only at the N rate, over applying P and K in year one. The manure plan will recommend no additional P and K be applied in subsequent years until excess nutrients are removed. Then another manure application and the cycle starts over again.

### Source of manure production and characteristics

MWPS-18, 1993: *Livestock Waste Facilities Handbook*, Midwest Plan Service, Iowa State University

OSU Extension Bulletin 604: *Ohio Livestock Manure Management Guide*, <http://ohioline.osu.edu/b604/>

ASAE Standards D284.1, 2003: *Manure Production and Characteristics*, <http://www.manuremanagement.cornell.edu/Docs/ASAESTandard.pdf>

OSU Extension Bulletin 472-05: *Ohio Agronomy Guide*

## EMPOWERMENT THROUGH EDUCATION

Visit Ohio State University Extension's web site "Ohioline" at: <http://ohioline.osu.edu>

Ohio State University Extension embraces human diversity and is committed to ensuring that all research and related educational programs are available to clientele on a nondiscriminatory basis without regard to race, color, religion, sex, age, national origin, sexual orientation, gender identity or expression, disability, or veteran status. This statement is in accordance with United States Civil Rights Laws and the USDA.

Keith L. Smith, Ph.D., Associate Vice President for Agricultural Administration and Director, Ohio State University Extension

TDD No. 800-589-8292 (Ohio only) or 614-292-1868