CHAPTER 3b

Poultry Manure Production and Nutrient Content

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Knowledge of the amount of manure and plant nutrients produced on a poultry farm is the first step in the proper operation of a manure handling and utilization system. The nutrient content of poultry manure will vary with the digestibility of the ration, animal age, amount of feed wasted, the amount of water wasted, the amount of bedding used, and the number of times the poultry house is cleaned in a year. The data provided in this chapter is to be used for general planning purposes. South Carolina regulations (Standards for the Permitting of Agricultural Animal Facilities: R.61-43) require poultry producers to have manure samples analyzed annually and to determine manure volumes to establish land application rates.

NUTRIENT CONTENT OF POULTRY MANURE

Poultry manure contains all 13 of the essential plant nutrients that are used by plants. These include nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), manganese (Mn), copper (Cu), zinc (Zn), chlorine (Cl), boron (B), iron (Fe), and molybdenum (Mo). Plant nutrients originate from the feed, supplements, medications, and water consumed by the animals. Using poultry manure as a fertilizer for crops or trees may provide a portion, or all, of the plant requirements. The amount of nutrients provided depends on the nutrient content of the manure (lb of nutrient / ton of manure) and the amount of manure applied (ton of manure / acre). The amount of manure applied per acre (called the ***application rate***) is typically based on the nitrogen needs of the plants. However, phosphorous requirement can also be used to determine the application rate (for more details see Chapter 5, Waste Utilization). South Carolina regulations can also limit the land application rate of poultry manure based on the copper, zinc, or arsenic content of the manure.

The nutrient content of poultry manure from several types of poultry facilities is compared in Tables 3.1 and 3.2. The nutrient values in these tables (Table 3.1and 3.2) can be used for general planning before a new poultry farm is constructed, or prior to the expansion of an existing farm. In the case of an existing poultry farm, sample analysis from the poultry manure on a particular farm must be used to perform nutrient balances for land application. These values were compiled from a database that combines data taken on South Carolina poultry farms with mean values from North Carolina State (Barker, 1990), and information provided in the *Poultry Waste Management Handbook* (NRAES, 1999).

Table 3.1. Broiler and turkey manure nutrient content as removed from the production house (lb/ton). Nutrient data complied from Barker, (1990), NRAES-132 (1999), and data compiled from South Carolina farms.

	CHICKEN				TURKEY			
	Broiler Litter	Broiler Cake [1]	Roaster Litter	Breeder Litter	Grower Litter	Grower Cake [1]	Poult Litter	Breeder Litter
Moisture (%)	21.5	40.0	22.5	33.5	26.5	45.0	20.0	22.0
TS (%)	78.5	60.0	77.5	66.5	73.5	55.0	80.0	78.0
Density (lb/cu. ft.) [2]	27	34 [3]	27	35	30	35 [3]	26	27
Nutrient Content (lb/ton)								
NH_4-N	11	12	14	8	12	20	10	8
Organic-N	60	34	57	26	42	25	30	27
Nitrate-N	0.7	NR[4]	NR	NR	0.3	NR	NR	NR
Total-N	72	46	71	34	54	45	40	35
PAN								
Surface Spread	42	26	41	20	31	25	23	20
Incorporated	45	30	45	22	35	31	26	23
P_2O_5	69	53	72	56	64	47	43	47
K_2O	46	36	46	33	39	30	27	18
Ca	44	34	42	89	37	26	26	72
Mg	8.1	7.0	8.7	7.5	6.9	5.4	5.1	4.6
S	12.1	9.2	14	8.2	8.7	6.3	6.1	7.4
Zn	0.64	0.60	0.68	0.57	0.61	0.47	0.46	0.50
Cu	0.53	0.41	0.50	0.22	0.52	0.48	0.39	0.40
Mn	0.71	0.69	0.75	0.63	0.70	0.56	0.53	0.43
Na	10	10	13	8.5	7.4	5.5	4.7	4.3
As	0.06	NR	NR	NR	0.005	NR	NR	NR

[1] Surface manure cake removed between flocks and prior to adding additional bedding (NRAES, 1999).
[2] Litter Density (lb/cu. ft.) = 77.29 - 0.643 TS (%), $r^2 = 0.9751$ (does not include caked litter).
[3] Density value from NRAES (1999)
[4] NR = Not Reported

QUANTITY OF MANURE PRODUCED FROM POULTRY HOUSES

The quantity of litter or manure can vary greatly from farm-to-farm. Estimates of the amount of layer manure produced per animal unit per year are given in Table 3.2. The moisture content and the litter depth at the time the house is cleaned out are the primary factors that affect the amount of litter produced in broiler and turkey houses. The numbers of flocks that are grown on the litter also affect the total quantity that must be handled. However, a litter depth and moisture content measurement prior to clean-out will include the effects of multiple flocks. Table 3.3 can be used to estimate the tons of manure per 1,000 square feet (ft^2) of floor area. The moisture content can be obtained from a manure analysis report.

Table 3.2. Layer manure characteristics and quantity as removed from the house (NRAES, 1999 and Barker, 1990).

	High-Rise, Deep-pit Stored on Unpaved Surface	Under Cage Scraped Paved Alley, Removed Every 2 Days
Moisture (%)	47.0	65
Density (lb/cu. Ft.)	51.0	62
Manure Production (ton Manure/AU-yr)	5.0	7.1
Nutrient Content (lb/ton)		
NH_4-N	12.0	14.0
Organic-N	22.0	14.0
Total-N	34.0	28.0
PAN		
Surface Spread	19.2	15.4
Incorporated	22.8	19.6
P_2O_5	51	32
K_2O	26	20
Ca	76	41
Mg	5.7	5.5
S	4.8	7.1
Zn	0.35	0.31
Cu	0.058	0.034
Mn	0.44	0.29
Na	3.3	2.8
As	NR	NR

Example 3.1. A laying operation houses 100,000 hens with an average weight of 4.0 lb per bird using a high-rise, deep-pit type manure storage. Estimate the amount of manure that will be applied to cropland each year.

Step 1. Calculate the total number of animal units (AU) on the farm.
100,000 birds x 4 lb/bird = 400,000 lb of live-weight.
1 AU = 1,000 lb of live-weight.
Therefore, the number of animal units = 400,000 lb / 1,000 lb per AU = 400 AU.
Step 2. Determine the amount of manure produced per animal unit from Table 3.2.
From Table 3.2 it can be seen that 5.0 tons of manure is produced per AU per year.
Step 3. Calculate the total amount of layer manure produced per year in tons.
5.0 tons/AU/year x 400 AU = 2,000 tons of manure per year.

Example 3.2. A broiler producer determined that the average litter depth in his poultry house was 4.0 inches. The moisture content of the litter, based on Clemson University Agricultural Service Laboratory results, was 24%. The poultry house floor measures 40 ft by 500 ft. Estimate the total amount of litter in the house.

Step 1. Use Table 3.3 to determine the amount of litter per 1,000 square feet of floor area.
In Table 3.3 find the value where the column for a litter depth of 4.0 inches crosses the row for a moisture content of 24%. The value given in the table (shown shaded) is 4.74 tons of litter per 1,000 ft^2 of floor area.

Step 2. Calculate the floor area of the poultry house.

The house floor area is 40 x 500 = 20,000 ft^2.

Step 3. Calculate the total amount of litter in the house.

First divide the total floor area by 1,000 ft^2= 20,000 ft^2 ÷ 1,000 ft^2 = 20. This is the total number of the floor area units (that is, 1,000 ft^2 units) in the house. Now multiply the number of floor area units by the amount of litter per 1,000 ft^2.

The total amount of litter = 20 x 4.74 tons/1,000 ft^2 = 94.8 tons of litter.

If the litter is removed from the house after 3 flocks of 25,000 birds then 1.26 tons of litter is produced per 1,000 birds sold.

Table 3.3. Table to estimate the amount of litter removed from chicken and turkey houses. Shaded value is for example 3.2

Moisture Content (%)	Inches of Litter in the House at Clean-Out						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0
	Tons of Litter / 1000 ft^2 of Floor Area						
10	0.81	1.21	1.62	2.02	2.43	2.83	3.24
11	0.84	1.25	1.67	2.09	2.51	2.93	3.34
12	0.86	1.29	1.73	2.16	2.59	3.02	3.45
13	0.89	1.33	1.78	2.22	2.67	3.11	3.56
14	0.92	1.37	1.83	2.29	2.75	3.21	3.67
15	0.94	1.41	1.89	2.36	2.83	3.30	3.77
16	0.97	1.45	1.94	2.42	2.91	3.39	3.88
17	1.00	1.50	1.99	2.49	2.99	3.49	3.99
18	1.02	1.54	2.05	2.56	3.07	3.58	4.09
19	1.05	1.58	2.10	2.63	3.15	3.68	4.20
20	1.08	1.62	2.15	2.69	3.23	3.77	4.31
21	1.10	1.66	2.21	2.76	3.31	3.86	4.42
22	1.13	1.70	2.26	2.83	3.39	3.96	4.52
23	1.16	1.74	2.31	2.89	3.47	4.05	4.63
24	1.18	1.78	2.37	2.96	3.55	4.14	***4.74***
25	1.21	1.82	2.42	3.03	3.63	4.24	4.84
26	1.24	1.86	2.48	3.09	3.71	4.33	4.95
27	1.26	1.90	2.53	3.16	3.79	4.43	5.06
28	1.29	1.94	2.58	3.23	3.87	4.52	5.17
29	1.32	1.98	2.64	3.30	3.95	4.61	5.27
30	1.34	2.02	2.69	3.36	4.03	4.71	5.38
31	1.37	2.06	2.74	3.43	4.12	4.80	5.49
32	1.40	2.10	2.80	3.50	4.20	4.90	5.59
33	1.43	2.14	2.85	3.56	4.28	4.99	5.70
34	1.45	2.18	2.90	3.63	4.36	5.08	5.81
35	1.48	2.22	2.96	3.70	4.44	5.18	5.92
36	1.51	2.26	3.01	3.76	4.52	5.27	6.02
37	1.53	2.30	3.07	3.83	4.60	5.36	6.13
38	1.56	2.34	3.12	3.90	4.68	5.46	6.24
39	1.59	2.38	3.17	3.97	4.76	5.55	6.34
40	1.61	2.42	3.23	4.03	4.84	5.65	6.45

Density (lb/cu. Ft.) = 77.29 - 0.643 TS (%), r^2 = 0.9751.

Example 3.3. It was determined that the litter in a broiler house is 6.25 inches deep on the average and the moisture content of the litter is 22%. How much litter is in the house per 1,000 ft^2 of floor space? How much litter is in a house that has a floor area of 20,000 square feet?

Step 1. Table 3.3 only has values tabulated up to 4.0 inches. Therefore, the amount of litter for any depth can be calculated using the amount of litter in 1 inch at the corresponding moisture content. From Table 3.3 it was found that 1.0 inch of litter at a moisture content of 22% contains 1.13 tons per 1,000 ft^2.
Step 2. Calculate the amount of litter in 6.25 inches as follows:

1.13 tons per 1,000 ft^2/1 inch x 6.25 inches = 7.06 tons / 1,000 ft^2 of floor area.

Step 3. Calculate the amount of litter in a house with a floor area of 20,000 ft^2.

20,000 ft^2 x 7.06 tons ÷ 1,000 ft^2 = 141.2 tons of litter/house.

If the litter is removed from the house after 6 flocks of 25,000 birds then 0.94 tons of litter is produced per 1,000 birds sold.

In many cases, an estimate of the amount of litter produced is needed before a facility is constructed. Table 3.4 can be used to estimate the amount of litter produced per 1,000 birds sold or per animal unit sold (1 AU = 1,000 lb live weight). However, the actual litter produced will vary greatly from farm-to-farm depending on the types of bedding used, bedding frequency, number of times the houses are cleaned out per year, number of turns per house per year, and the moisture content of the litter.

Table 3.4. Estimates of litter production from poultry production houses (NRAES, 1999).

Bird Type	Average Live Weight (lb/bird)	Litter Production per 1,000 Birds Sold (tons/1,000 birds)	Litter Production per Animal Unit Sold (tons/AU sold)
Broiler			
Whole litter	2.25	1.25	0.56
Manure cake		0.40	0.18
Roaster	4.0	2.6	0.65
Broiler Breeder	7.0	24.0 tons/1,000 birds/year	3.43 tons/AU/year
Turkey poult	2.5	1.0	0.40
Turkey grower hen			
Whole litter	10.0	8.0	0.80
Manure cake		2.5	0.25
Turkey grower tom, light			
Whole litter	13.0	10.0	0.77
Manure cake		3.3	0.25
Turkey grower tom, heavy			
Whole litter	17.0	14.0	0.82
Manure cake		4.4	0.26
Turkey breeder	20.0	50 tons/1,000 birds/year	2.5 tons/AU/year

Example 3.4. A heavy tom turkey grow-out house produces 5,781 birds per flock. The goal is to produce 3.25 flocks per year with one clean-out per year. Extra litter will be added between flocks. Estimate the amount of litter that will be removed from a house each year.

Step 1: Determine the amount of litter produced per 1,000 birds sold.
From Table 3.4 the amount of litter produced is 14 tons/1,000 birds sold.
Step 2: Calculate the amount of litter removed after 3.25 flocks.
5,781 birds/flock x 3.25 flocks x 14 tons of litter ÷ 1,000 birds = 263 tons/house/year

EFFECT OF LITTER STORAGE ON NUTRIENT CONTENT

Once litter is removed from a poultry house, the methods used to store the litter prior to land application can significantly reduce the nitrogen content of the litter as shown in Table 3.5. The moisture content of the litter can change substantially depending on the storage method used. If litter is stored in an uncovered pile, extra moisture will be added from rain. As a result, the litter weighs more, attracts more flies, has a stronger odor, and almost a third (30 %) of the total nitrogen will be lost. *Uncovered piles are not recommended for long-term storage of poultry litter*.

If poultry litter is to be stockpiled before land application for more than 1 or 2 days, it should be covered with a tarp until it will be utilized. Not only will this practice conserve valuable nitrogen, reducing the storage losses to 17%, it will also reduce odor, flies, and the potential for the generation of polluted runoff.

Stacking sheds are pole buildings that are used to store litter prior to land application. Some composting often occurs while the litter is in storage as indicated by heating of the litter. The composting activity results in a loss of moisture and approximately a 26% reduction in total-N. Flies and odor are less of a problem for litter stored in stacking sheds as compared to an uncovered pile. The amount of nitrate-N can be significant in poultry litter that has gone through several “heats” in a stacking shed. Manure stored in stacking sheds should be tested for nitrate-N in addition to ammonium-N, and organic-N (see the next section).

Table 3.5. Nitrogen losses from litter storage methods (calculated on a dry matter basis, lb/dry ton) and typical moisture contents (based on data collected on South Carolina poultry farms and Barker, 1990).

Type of Storage	Typical Moisture Contents (%)	NH_4-N Lost (%)	Total-N Lost (%)
Uncovered Pile	39 - 47	21	30
Covered Pile	16 - 19	13	17
Stacking Shed	7 - 15	11	26

The storage method does not generally affect the amount of phosphorous or potassium on a dry matter basis. However, the concentrations of P_2O_5 and K_2O, on an as sampled basis (lb / wet ton), will vary greatly with the moisture content of the litter.

The results shown in Table 3.5 illustrate that it is very important to collect a representative sample of the litter prior to application and have it analyzed for the nutrient and moisture content. The nutrient content (lb / wet ton) of a sample collected from the house prior to clean-out will be different from litter that has been stored in a covered pile or stacking shed. *Note that the percent loss values are not to be used with the concentrations of nitrogen but the total pounds of nitrogen.*

QUANTITY OF PLANT NUTRIENTS FOR LAND APPLICATION

The nutrient production on a particular farm should be determined by having a representative sample analyzed by a competent laboratory and by keeping records of the amount of litter or manure removed from the houses. The calculations to determine the amount of plant nutrients that must be accounted for in a nutrient management plan are demonstrated in the following example.

Example 3.5. A broiler producer has 4 houses that each has a floor area of 20,000 ft^2. The producer is typically able to raise 6 flocks of 25,000 birds per year. Farm records indicate that the total litter production per house is 169.6 tons/year. Laboratory analysis indicates that the litter contains 11 lb NH_4-N/ton, 60 lb organic-N/ton, 69 lb P_2O_5/ton, and 46 lb K_2O/ton. In most cases, the litter will be stored for 30 to 60 days in a covered pile prior to land application to insure that the litter is applied 30 days pre-plant or to actively growing hay fields. Based on this information calculate:

(1) the total amount of plant nutrients removed from each house per year,
(2) the total amount of plant nutrients that need to be land applied per year for the farm, and
(3) the total amount of litter produced per 1,000 birds sold

Step 1: The total amount of plant nutrients removed from each house per year is

11 lb NH_4-N/ton	x	169.6 tons/house/year	=	1,866 lb NH_4-N/house/year,
60 lb Organic-N/ton	x	169.6 tons/house/year	=	10,176 lb Organic-N/house/year,
		Total-N	=	12,042 lb Total-N/house/year
69 lb P_2O_5/ton	x	169.6 tons/house/year	=	11,702 lb P_2O_5 /house/year, and
46 lb K_2O/ton	x	169.6 tons/house/year	=	7,802 lb K_2O/ house/year.

Step 2: From Table 3.5, the estimated storage losses for nitrogen from a covered pile are 13% for NH_4-N and 17% for the total-N. Therefore, the amount of ammonium-N, total-N, and organic-N that is to land applied per house per year is:

1,866 lb NH_4-N/house/year – (1,866 lb NH_4-N x 0.13) = 1,623 lb NH_4-N/house/year,
12,042 lb Total-N/house/year – (12,042 lb TN x 0.17) = 9,995 lb Total-N/house/year, and
Organic-N = Total-N – NH_4-N = 8,372 lb Organic-N/ house/year.

Step 3: The total amount of plant nutrients to be land applied for all four houses is:

6,492 lb NH_4-N/year (1,623 x 4),
33,488 lb Organic-N/year (8,372 x 4),
46,808 lb P_2O_5/year (11,702 x 4), and
31,208 lb K_2O/year (7,802 x 4).

Step 4: The amount of litter produced per 1,000 birds sold is calculated as shown below.

25,000 birds/flock x 6 flocks/house/year x 4 houses = 550,000 birds sold

Total litter produced = 4 houses x 169.6 tons/house = 678.4 tons

Litter production per 1,000 birds sold

= (678.4 tons ÷ 550,000) x 1000 = 1.23 tons / 1,000 birds sold

It is often necessary to estimate the amount of nutrients that will be generated from a poultry house or farm prior to obtaining site-specific data. These values can be used to estimate the amount of land that will be needed for land application during initial planning (see chapter 5). Estimates of the amount of ammonium-N, organic-N, P_2O_5, and K_2O removed from common types of poultry facilities is given in Table 3.6.

Table 3.6. Estimates of plant nutrient production on poultry farms (based on Table 3.1, 3.2, and 3.4).

Farm Type	Production Unit	NH_4-N	Organic -N	P_2O_5	K_2O
		Pounds per Production Unit			
Broiler	1000 birds sold	14	75	86	58
Roaster	1000 birds sold	36	148	187	120
Broiler breeder	***1000 birds/year***	192	624	1,344	792
Turkey poult	1000 birds sold	10	30	43	27
Turkey, grower hens	1000 birds sold	96	336	512	312
Turkey, grower light toms	1000 birds sold	120	420	640	390
Turkey, grower heavy toms	1000 birds sold	168	588	896	546
Turkey breeder	***1000 birds/year***	400	1,350	2,350	900
Layers, high-rise, deep pit	***1000 birds/year***	240	440	1,020	520
Layers, under cage scrape alley, removed every 2 days	***1000 birds/year***	398	398	909	568

Example 3.6. A 4-house broiler farm produces 550,000 birds per year. Use Table 3.6 to estimate the amount of plant nutrients to be land applied per year if the litter is spread within two days of clean-out. Since 550,000 birds are produced per year the nutrient production values for broiler farms given in Table 3.6 are multiplied by 550 (550,000 ÷ 1,000). The amount of N, P, and K produced on this farm is:

14 lb NH_4-N x 550 = 7,700 lb NH_4-N/year,
75 lb Organic-N x 550 = 41,250 lb Organic-N/year,
86 lb P_2O_5 x 550 = 47,300 lb P_2O_5/year, and
58 lb K_2O x 550 = 31,900 lb K_2O/year.

ESTIMATION OF PLANT AVAILABLE NITROGEN

Not all of the nitrogen in poultry manure is immediately available for plant use. The nitrogen that is available for plant use is called the plant available nitrogen (PAN). Nitrogen (N) can be present in manure as ammonium-N, organic-N, and nitrate-N.

Ammonium Nitrogen and Volatilization Losses

A portion of the nitrogen in poultry manure is in the ammonium (NH_4^+) form. Ammonium (NH_4^+) and ammonia (NH_3^-) can interchange rapidly depending on the pH. Ammonium will convert to ammonia at a pH that is greater than 6.5. Increasing the pH (more alkaline or less acid) increases the amount of ammonia and decreases the amount of ammonium. Most manure has a pH close to 7.0. Therefore, ammonium and a small fraction of ammonia are present. The Clemson University Agricultural Services Laboratory reports a single value for the ammonium nitrogen content of manure. This value includes both ammonical forms of nitrogen (NH_4^+ and NH_3^-). Therefore, whenever the term ammonium nitrogen (also abbreviated NH_4-N) is used in this book, it should be understood that both ammonia and ammonium are included.

Ammonia (NH_3^-) is a gas and can be readily lost to the air by ***volatilization***. Volatilization is a process that is similar to evaporation. Volatilization losses can occur from the surface of manure whenever it is exposed to air. Ammonia-N can be lost from litter while it is in the house, while it is in storage, and after land application. The nutrient content of manure is typically measured using a representative sample of the form of manure that is to be land applied. Therefore, volatilization loss resulting from handling and storage of manure has already occurred, and only an estimate of the application loss is used to estimate the amount of ammonium-N that is available.

The amount of ammonium nitrogen that is lost from poultry manure depends on the method of land application as shown in Table 3.7. If manure is spread on the ground without being mixed into the soil by a tillage operation (called ***incorporation***), then a large portion of the ammonia nitrogen can be lost to the atmosphere. Ten to fifteen percent of the NH_4-N is lost from surface applied manure each day if rain does not fall on the field. A significant rain (0.25 inches or more) will carry most of the ammonium nitrogen into the soil. All of the NH_4^+ can be converted to ammonia and can be lost if it does not rain for several weeks. Incorporation of manure on the same day it is applied can reduce the volatilization losses to 5 to 30%. Incorporation of manure conserves valuable nitrogen and increases the precision of using manure as a fertilizer.

Table 3.7. Estimates of ammonia nitrogen loss based on land application method.

	Loss of Ammonia Nitrogen	
Application Method	Range	Recommended Value
Surface application without incorporation	10 - 100%	50%
Surface application with incorporation the same day or irrigation of liquid manure	5 - 30%	20%

The ammonium-N availability factor is calculated from the ammonia loss as follows:

$$NH_4\text{-N Availability Factor} = (100 - \text{Percent Loss}) \div 100. \quad (3.1)$$

Although NH_4-N and NH_3-N both exist in manure and soil they have extremely different properties. Ammonium (NH_4^+) is a charged molecule dissolved in the soil water and can be readily used by plants. Ammonia (NH_3) is a gas and is not significantly taken up by plants. Ammonium does not leach from soil except for extremely coarse sands. However, ammonium typically is converted in the soil to nitrate-N (NO_3^-) which can be easily leached from soil.

Organic Nitrogen and Mineralization

Organic nitrogen (organic-N) is the most abundant form of nitrogen in animal manure with a high solids content (10% total solids or more). Organic-N is not available to plants until it has been decomposed by microbes to ammonium-N. The process of converting organic nitrogen to ammonium-N is called ***mineralization***. Conversion of organic-N to ammonium-N does not occur immediately, and not all of the organic-N is mineralized. Sometimes animal manure with a high solids content is referred to as a slow-release N source because the organic-N is made available over time and not all at once. How fast and how completely this occurs depends on a number of factors including: soil temperature, soil moisture, soil pH, type of manure, and the extent of incorporation.

The amount of organic-N that is available during the first growing season can range from 30 to 80%. Field measurements taken at the Pee Dee Research Station (Quisenberry, 1998) indicate an average of 60% of the organic-N is mineralized. This is the value used to estimate the plant available nitrogen by the Clemson University Ag. Service Laboratory. However, since many factors influence mineralization, the conversion of organic-N to NH_4-N may be more or less than 60%. Organic-N does not leach from soil. Erosion is the only way that organic-N can be lost from the soil.

Nitrate Nitrogen

If poultry manure is stored in a predominantly anaerobic condition then very little nitrate nitrogen will be present and is generally not measured. ***Anaerobic*** means oxygen is excluded. ***Aerobic*** treatment systems, like composting, maintain elevated levels of oxygen in the manure through natural or mechanical aeration. The elevated oxygen levels will result in a significant amount of nitrate nitrogen in the manure. Therefore, poultry manure that receives a significant amount of aeration must also be analyzed to determine the nitrate -N content. The composting activity that can occur in a stacking shed can introduce a significant amount of air and as a result nitrate can be present in a significant amount (5 to 10% of total-N). Dry litter (less than 15% moisture content) from production houses can also contain significant amounts of nitrate-N. All of the nitrate-N is available to the crop and is an important component of some commercial fertilizers (ammonium nitrate for example).

Even though nitrate is not always present in a significant amount in poultry manure, it is still an important form of nitrogen. Nearly all of the ammonium-N and organic-N will eventually be converted to nitrate in the soil. Although nitrate is readily taken up by crops, it can be easily lost from the soil. Rainfall or irrigation that results in the movement of water through the root zone of the crop will result in the loss of nitrate by leaching. When soil is saturated, and leaching does not occur, nitrate can be converted to nitrogen gas and be lost to the air. Both of these processes can occur rapidly. Therefore, it is best to apply manure or fertilizer nitrogen very close to the time when the crop's requirement for N is the greatest.

Calculation of Plant Available Nitrogen

The plant available nitrogen (PAN) is the sum of the available ammonium nitrogen, the available organic nitrogen, and the nitrate nitrogen. The estimate of PAN is used to calculate the amount of manure that is needed to satisfy the nitrogen needs of a crop. The equation used to estimate the plant available nitrogen is:

$$\text{Plant Available Nitrogen (PAN)} = [NH_4\text{-N Availability Factor x } NH_4^+\text{-N Content}] + [0.60 \text{ x Organic-N Content}] + [\text{Nitrate-N Content}]. \quad (3.2)$$

The use of equation 3.2 is explained in the following example.

Example 3.7. A poultry producer had the poultry litter tested for plant nutrients by a laboratory. The laboratory results indicated that the litter contained 9.9 lb NH_4 -N per ton and 54.0 lb organic-N per ton. The litter will be applied to cropland using a rear-discharge manure spreader. Calculate the amount of plant available nitrogen per ton of litter. Compare the PAN with the total-N.

Step 1. Determine the NH_4 -N availability factor from Table 3.7 and equation 3.1.
The recommended ammonia nitrogen loss factor for surface application is 50%.
The NH_4 -N availability factor is calculated using equation 3.1 and is 0.50 ((100-50%) ÷ 100).

Step 2. The plant available nitrogen (PAN) is calculated using equation 3.2 as follows:
0.50 x 9.9 lb NH_4 -N/ton + 0.60 x 54 lb organic-N/ton = 37.4 lb /ton.
Note that nitrate-N was not considered since the storage is not aerated.

Step 3. The total-N is the sum of the organic, ammonium nitrogen, and nitrate-N.
In this case, total-N = 9.9 + 54 + 0 = 63.9 lb /ton. The estimate of PAN is 59% of the total-N for this litter analysis.

Example 3.8. The litter removed from a broiler house contains 1,056 lb NH_4-N and 6,912 lb of total-N. If the litter is surface spread on pastureland within 2 days of clean-out, how much plant available nitrogen (PAN) is present in the litter for fertilization?

Step 1. Estimate the amount of organic-N in the litter as the (total nitrogen) – (ammonium nitrogen)
6,912 lb Total-N - 1,056 lb NH_4-N = 5,856 lb organic-N

Step 2. Use equation 3.1, Table 3.7, and equation 3.2 to estimate the amount of PAN contained in the litter.
PAN = 0.50 x 1,056 lb NH_4-N + 0.60 x 5,856 lb organic-N = 4,042 lb PAN

USING AN ANIMAL WASTE ANALYSIS REPORT

South Carolina regulations require poultry producers to have manure samples analyzed at least annually to determine the amount of manure that can be applied to cropland. A sample laboratory report is shown in Table 3.8. This report is for a broiler farm that uses a stacking shed to treat and store litter.

Selection of a Sample Number

The first step in the proper use of a laboratory report is the selection of the sample number. The sample number is determined by the person who sends in the sample. The sample number can be any combination of letters or numbers (up to 5 letters or numbers). Select a sample number that helps to identify the type of manure analyzed. In Table 3.8, the sample number is SSL5. This sample number is an abbreviation for Stacking Shed Litter 5. The number 5 indicates that this is the fifth sample of stacking shed litter that has been sent to the laboratory for analysis. Therefore, the rolling average for PAN, P_2O_5, K_2O, or other nutrients is the average of 5 values.

Lab Number

The lab number, or LAB NO., (100498 in Table 3.8) is assigned by the Agricultural Service Laboratory. This number is needed if you have a question concerning your waste analysis report. The phone number of the Clemson Agricultural Service Laboratory is 864-656-2068.

Moisture Content

The nutrient content results are given on an as-sampled or wet basis. The moisture content of the manure sample has a large effect on the nutrient content and the density. The moisture content is determined by the laboratory and is given near the bottom of the report. In this case, the manure contains 15.22 % water. The solids content of the sample is 84.78 % (100-15.22).

Nutrient Content

The contents of all forms of nitrogen, phosphorous, potassium, and the other nutrients are given in two columns. The first column is in percent (%) or parts per million (ppm). The second column gives the nutrient content in pounds per ton of manure (lbs/ton). If the manure has a high moisture content (94%), then the results in the second column are given in pounds per 1000 gal.

Estimates of Plant Available Nitrogen

The animal waste report provides up to five different values for manure nitrogen. It is very important for animal waste managers to be able to interpret and use these nitrogen results correctly. The ammonium-N, organic-N, and nitrate-N given on the report are the three basic

Table 3.8. Sample animal waste analysis report for poultry manure.

A N I M A L   W A S T E   A N A L Y S I S   R E P O R T

Clemson University
Cooperative Extension Service
Agricultural Service Laboratory
Clemson, S.C. 29634-03921

LAB No. 100498

NAME	Farmer, J.Q.	ACCOUNT	CASH MONEY
ADDRESS	312 Sunny Acres Road	DATE	12-2-1998
CITY	Any Where, SC		
ZIP CODE	29341		

SAMPLE NO. SSL5 MANURE: POULTRY LITTER STORAGE: STACKING SHED

------------------------RESULTS REPORTED ON AN AS-SAMPLED BASIS------------------------

			lbs/ton
Ammonium Nitrogen	0.50	%	10.00
Organic Nitrogen	2.27	%	45.44
Nitrate Nitrogen	2814.78	ppm	5.63
INCORPORATED AVAILABLE NITROGEN ESTIMATE			40.90
SURFACE AVAILABLE NITROGEN ESTIMATE			37.90
Phosphorous as P2O5	1.69	%	33.78
Potassium as K2O	2.14	%	42.70
Calcium	1.16	%	23.23
Magnesium	0.28	%	5.60
Sulfur	0.31	%	6.27
Zinc	211.96	ppm	0.42
Copper	220.43	ppm	0.44
Manganese	266.22	ppm	0.53
Sodium	3259.04	ppm	6.52
Arsenic	10.17	ppm	0.02
pH			
Moisture	15.22	%	
Calcium Carbonate Equivalency			

INCORPORATED PLANT AVAILABLE NITROGEN ESTIMATE - 80% of ammonium-N, 60% of organic-N, and 100% of nitrate-N (if determined). Assumes some loss of ammonium-N during application and prior to incorporation.

SURFACE PLANT AVAILABLE NITROGEN ESTIMATE - 50% of ammonium-N, 60% of organic-N, and 100% of nitrate-N (if determined). Assumes the manure will be left on the surface of the soil with no incorporation by plowing or irrigation.

Available nitrogen calculations are estimates and the actual amount received may be more or less than the estimate depending on the composition of the manure, soil type, and environmental conditions.

All of the potash in the animal waste should be plant available in the first year of application. Although not all of the phosphorous is available in the first year, its availability should be comparable to that in commercial fertilizers.

The rate of animal waste to apply for crop production is dependent on the nutrient content of the waste, method of application and incorporation, soil test, crop to be grown, and previous manure applications. In most cases, the plant available nitrogen content of the waste is used to determine the rate of application. Your County Agent can assist you in determining the proper application rate. APPROVED BY ________________________________

Cooperative extension work in agriculture and home economics - state of SOUTH CAROLINA, CLEMSON UNIVERSITY, and the UNITED STATES DEPARTMENT of AGRICULTURE cooperating forms of nitrogen that were discussed previously. The other two values given are estimates of the plant available nitrogen (PAN) based on the method of application. The incorporated available nitrogen estimate of PAN should be used in the following cases:

- when manure will be mixed with the soil by a tillage operation the same day it is applied (disking, plowing, but not no-till drilling),
- when liquid manure is spread using an irrigation system, or during the planning stages when the exact method of application is yet to be decided.

In Table 3.8, the incorporated PAN estimate is 40.90 lbs/ton. Therefore, the incorporated PAN estimate can be obtained from the waste analysis report if the Clemson University Agricultural Service Laboratory is used. If another laboratory is used, use equation 3.2 and Table 3.7 with the results for ammonium-N, organic-N, and nitrate-N.

The surface available nitrogen estimate should be used when litter is spread on the surface without being incorporated. In Table 3.8, the surface applied estimate of PAN is given as 37.90 lb/ton.

Manure Sampling Frequency and Rolling Average

South Carolina regulations require a manure analysis to be obtained for each form of manure that is land applied at least once a year and when ever a significant change in feed composition occurs. Land application is based on a rolling average.

The laboratory results from the most recent analysis should be averaged with all previous manure analyses for a particular form of manure. This is what is meant by a ***rolling average***. Each time manure is collected and sent to a laboratory for analysis, small errors always occur due to: sampling differences in the field, and experimental errors associated with laboratory procedures. Therefore, the best value for the nutrient content of a particular form of poultry manure is the average of as many analyses as possible. Separate, representative manure samples must be collected and analyzed for each form of manure applied each year. That is, litter from a stacking shed and litter taken directly from a poultry house will need a different rolling average if both forms are applied for the same farm.

Recommended Sampling Frequency

South Carolina regulations require the analysis of a representative sample at least one time per year. However, more frequent sampling is recommend. Collect a sample prior to each application during the first two years. Reduce the sampling frequency to 2 to 3 times per year after a stable estimate of the rolling average has been obtained.

When to Begin a New Rolling Average

A new rolling average is begun only when a major change occurs that would be expected to alter the average plant nutrient content of the manure. Examples of these types of changes are:

- addition of a new manure treatment process (such as composting),
- change in the animal population (such as converting from production of light to heavy birds), or

- a major change in the ration is made that will influence nutrient content (such as changing feed sources, reducing nitrogen in the feed by feeding selected amino acids, or feeding phytase to reduce phosphorous).

COPPER, ZINC, AND ARSENIC LIMITS FOR LAND APPLICATION OF POULTRY MANURE

In most cases, the ***agronomic rate,*** or the amount of nitrogen or phosphorous needed to grow a particular crop (see glossary for complete definition), is used to determine how much poultry manure can be applied per acre. However, South Carolina law also requires poultry producers to consider the concentrations of arsenic, copper and zinc in the manure as part of the land application requirements.

In most cases, the regulatory requirements for the application of arsenic, zinc and copper can be satisfied by demonstrating that the concentrations of these elements are below the threshold values given in Table 3.9. The concentration of zinc in poultry manure must be less than 2,800 milligrams per kilogram of dry solids (mg/kg) to be excluded from further consideration. The maximum copper concentration is 1500 mg per kg of dry solids. The maximum arsenic concentration is 41 mg/kg of dry solids.

Table 3.9. Critical dry matter concentrations of arsenic, copper, and zinc in poultry manure (based on Standards for the Permitting of Agricultural Animal Facilities: R.61-43 200.100.B).

Constituent	Monthly Average Concentrations milligrams per kilogram dry weight
Arsenic	41
Copper	1,500
Zinc	2,800

The concentrations of arsenic, zinc and copper provided by the Clemson University Agricultural Service Laboratory (see Table 3.8) are given on an as-sampled basis. Concentrations are given in ppm (parts per million) and in pounds per ton. The moisture content is given in percent. The following equation can be used to convert the as-sampled arsenic, copper and zinc contents, in ppm, to the dry basis concentration:

$$\text{mg/kg (dry basis)} = [\text{Arsenic, copper or zinc content in ppm}] \div (\text{Solids Fraction}). \qquad (3.3)$$

The solids fraction needed in equation 3.3 is calculated from the percent moisture as shown below:

$$\text{Solids Fraction} = (100 - \%\ \text{Moisture}) \div 100. \qquad (3.4)$$

Some laboratories may report the arsenic, copper and zinc content on a dry weight basis. Therefore, it is very important to read all reports carefully to know how the data is presented.

The use of equations 3.3 and 3.4 is demonstrated in the following example.

Example 3.9. Calculate the arsenic, zinc, and copper concentrations for poultry litter using the manure analysis given in Table 3.8. Are the arsenic, zinc or copper concentrations greater than the concern levels as defined in Table 3.9?

Step 1: Calculate the solids fraction using equation 3.4.
The average moisture content in Table 3.8 is 15.22%. The solids fraction is
(100 –15.22) ÷ 100 = 0.848.

Step 2: Calculate the dry matter arsenic concentration using equation 3.3.
The arsenic content from Table 3.8 is 10.17 ppm wet-basis. The dry matter concentration is calculated using the solids fraction from step 1 as follows.
10.17 ppm ÷ 0.848 = 12 mg / kg (dry basis).
Since 12 mg/kg is less than the concern level of 41 mg/kg we do not need to keep records of the amount of arsenic applied to cropland to satisfy regulatory requirements.

Step 3: Calculate the zinc and copper concentrations in the same way as for arsenic.
211.96 ppm zinc ÷ 0.848 = 250 mg zinc / kg (dry basis).
The dry matter zinc concentration is also below the concern level of 2800 mg /kg.
Therefore, zinc will not be a limiting constituent for land application.
220.43 ppm copper ÷ 0.848 = 260 mg copper / kg (dry basis)
This value is also below the concern level as defined by the regulation (1500 mg copper / kg solids).

The results for this example indicate that the dry matter concentrations of arsenic, zinc, and copper (dry basis) are below the level of concern in all cases. However, all poultry producers will need to test manure from their farm to prove that the arsenic, zinc, and copper concentrations are below the established limits.

If manure analysis indicates that arsenic, zinc or copper dry matter concentrations exceed the regulatory limits then the requirements given in Tables 3.10 and 3.11 must be satisfied. Records must be kept to show that the annual loading rates do not exceed the limits given in Table 3.10. Also, the application of arsenic, copper, and zinc must not exceed 37 pounds of arsenic per acre, 1,339 pounds of copper per acre or 2,499 pounds of zinc per acre for the life of the application site (Table 3.10).

Table 3.10. Maximum annual loading rates for arsenic, copper, and zinc in poultry manure (based on Standards for the Permitting of Agricultural Animal Facilities: R.61-4343 200.100.B).

	Annual Constituent Loading Rate	
Constituent	(kilograms per hectare per 365 day period)	(pounds per acre per 365 day period)
Arsenic	2.0	1.8
Copper	75	67
Zinc	140	125

Table 3.11. Maximum cumulative loading rates for arsenic, copper, and zinc (based on Standards for the Permitting of Agricultural Animal Facilities: R.61-4343 200.100.B).

	Cumulative Constituent Loading Rate	
Constituent	(kilograms per hectare)	(pounds per acre)
Arsenic	41	37
Copper	1,500	1,339
Zinc	2,800	2,499

SUMMARY

Knowledge of the nutrient content of poultry manure is an essential element in the design and operation of a poultry manure management system. Manure quantity and nutrient data have been provided that can be used for design and planning purposes. South Carolina regulations require each poultry producer to sample each form of poultry manure that is land applied at least annually. A rolling average is used for each form of manure applied to cropland to determine application rates. Additional details on nutrient balancing will be presented in chapter 5.

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