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Fertilizer Nutrients in Livestock and Poultry Manure

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Many livestock and poultry producers fall into one of three categories: (1) they are willing to make high capital and labor outlays to maximize the use of their manure for crop production; (2) they are willing to minimize the amount of nutrients returned to the land for crop production in exchange for a relatively low-cost and low-labor method of manure handling; or (3) they have insufficient acreage to make use of the nutrients in their manure and depend on neighbors to accept or buy all or a portion of their manure.

Producers in the first category usually use slurry systems with tanks for manure storage, and tank wagons with injectors (or drag-hose systems) to transport and apply the manure. Producers in the second category use lagoons for storage / treatment, and irrigation equipment to transport and apply the manure to their fields. Producers in the third category may use their equipment to apply manure on neighbors' land or they may sell their manure through a broker.

To have value, manure nutrients must be used in a manner that results in a salable product. This publication describes methods of recovering a portion of the plant nutrient value of animal manure.

To keep the addition of nutrients from manure and fertilizer in balance with the nutrient removal by crops requires a record-keeping system that includes soil tests, laboratory analysis of the manure nutrient content, manure application rates, and crop yields. To obtain reliable nutrient data, it is necessary that the manure be well mixed before and during the loading, sampling, transport and land application processes.

Fresh manure nutrient production

Typical nutrient production values for various species and weights of animals are listed in Table 1 for fresh manure that has not been treated or altered.

Example calculation of manure volume produced: Find the volume of manure that must be hauled annually from 100 head of 1,400-pound lactating dairy cows (not including any wash water, rainwater or evaporation) using the manure production value from Table 1.

Table 1. Daily production of the major nutrients in the manure from various species and weights of animals (freshly excreted manure).

Animal	Size (lb)	Total manure (ft^3/day)	Water (%)	Nutrient content (lb/day)		
				(N)	(P_2O_5)*	(K_2O)*
Dairy cattle						
Heifer	150	0.2	88	0.05	0.01	0.04
	250	0.32	88	0.08	0.02	0.07
	750	1	88	0.23	0.07	0.22
Lactating cow	1,000	1.7	88	0.58	0.3	0.31
	1,400	2.4	88	0.82	0.42	0.48
Dry cow	1,000	1.3	88	0.36	0.11	0.28
	1,400	1.82	88	0.5	0.2	0.4
Veal	250	0.14	96	0.04	0.03	0.06
Beef cattle						
Calf	450	0.42	92	0.14	0.1	0.11
High-forage	750	1	92	0.41	0.14	0.25
	1,100	1.4	92	0.61	0.21	0.36
High-energy	750	0.87	92	0.38	0.14	0.22
	1,100	1.26	92	0.54	0.21	0.32
Cow	1,000	1	88	0.31	0.19	0.26
Swine						
Nursery	25	0.04	89	0.02	0.01	0.01
Grow-finish	150	0.15	89	0.08	0.05	0.04
Gestating	275	0.12	91	0.05	0.04	0.04
Lactating	375	0.36	90	0.18	0.13	0.14
Boar	350	0.12	91	0.05	0.04	0.04
Sheep	100	0.06	75	0.04	0.02	0.04
Poultry						
Layer	4	0.004	75	0.0035	0.0027	0.0016
Broiler	2	0.003	74	0.0023	0.0014	0.0011
Turkey	20	0.014	75	0.0126	0.0108	0.0054
Duck	6	0.005	73	0.0046	0.0038	0.0028
Horse	1,000	0.8	78	0.28	0.11	0.23

* Phosphate (P_2O_5) = 2.29 x P, Potash (K_2O) = 1.21 x K

Source: MWPS-18, *Manure Management Systems Series,* Section 1, Manure Characteristics.

Notes: Values do not include bedding. The actual nutrient content can vary + or - 30% from table values. Increase nutrients by 4% for each 1% feed wasted above 5%.

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

2.4 (ft^3/day) per head x 100 head x 365 days = 87,600 ft^3 = 655,000 gallons = 131 loads at 5,000 gallons/load

Table 2 lists the daily production of the major nutrients in pounds per day for swine manure in deep-pit buildings and the volume of manure produced daily.

Example calculation of manure volume produced: Find the required deep-pit volume to contain the manure produced in six months by 1,000 head of grow-finish swine with an average weight of 150 pounds using dry feeders as follows (refer to Table 2):

0.16 (ft^3/day) per head x 1,000 head x 183 days = 29,280 ft^3 = 218,865 gallons

Note: In calculating pit depth required, make allowance for clearance under the floor for any pit ventilation and for gas accumulation.

Table 3 lists the annual production of the major nutrients in pounds per year for liquid pit manure from various animals and the weight of manure

Table 2. Daily production of the major nutrients in swine manure in deep-pit buildings.

Animal	Size[a] (lb)	Total manure (ft^3/day)	Nutrient content (lb/day) (N)	(P_2O_5)*	(K_2O)*
Nursery	25	0.04	0.02	0.01	0.01
Wean-finish (wet/dry feeders) [b, c]	135	0.09	0.05	0.04	0.02
Wean-finish (dry feeders) [c, d]	135	0.12	0.05	0.04	0.03
Grow-finish (wet/dry feeders) Wean-finish (wet/dry feeders) [b]	150	0.12	0.06	0.05	0.03
Grow-finish (dry feeders) [d]	150	0.16	0.06	0.05	0.03
Gestating	275	0.12	0.05	0.04	0.04
Lactating	375	0.36	0.18	0.13	0.14
Boar	350	0.12	0.05	0.04	0.04

*Phosphate (P_2O_5) = 2.29 x P, Potash (K_2O) = 1.21 x K
[a] Weights represent the average size of the animal during the stage of production.
[b] Dry feeders used in conjunction with cup or swing waterers have similar results as wet/dry feeders.
[c] Wean-finish values calculated based on pigs spending 25% of their time in the nursery and 75% of their time in the grow-finish.
[d] Using nipple waterers.
Source: MWPS-18, *Manure Management Systems Series,* Section 1, Manure Characteristics. Actual nutrient values can vary ±30%. Values listed are typical of what can be found at the time of pumping. Includes dilution and spillage water. Increase nutrients by 4% for each 1% feed wasted above 5%.
Note: Use only for planning purposes. These values should not be used in place of a regular manure analysis.

Table 3. Estimated liquid pit manure characteristics.

Livestock stages	Production: Manure (lb/yr)	Total N (lb/yr)	NH_3-N* (lb/yr)	P_2O_5* (lb/yr)	K_2O* (lb/yr)	Units	Concentration (lb/1,000 gallons of manure): Total N	NH_3-N	P_2O_5	K_2O
Farrowing	11,500	21	11	17	15	per pig space	15	8	12	11
Nursery	1,000	3	2	2	3	per pig space	25	14	19	22
Grow-finish (deep pit)	3,500	21	14	18	13	per pig space	50	33	42	30
Grow-finish (wet/dry feeder)	2,500	22	15	16	12	per pig space	75	50	54	40
Grow-finish (earthen pit)	3,500	13	10	9	8	per pig space	32	24	22	20
Breeding-gestation	7,000	21	10	21	20	per pig space	25	12	25	24
Farrow-finish	37,500	126	72	108	103	per production sow	28	16	24	23
Sow per pig	2,000	7	4	6	6	per pig sold per year	28	16	24	23
Farrow-feeder	10,000	25	13	22	23	per production sow	21	11	18	19
Dairy cow	54,000	200	39	97	123	per mature cow	31	6	15	19
Dairy heifer	25,000	96	18	42	84	per head capacity	32	6	14	28
Dairy calf	6,000	19	4	10	17	per head capacity	27	5	14	24
Veal calf	3,500	11	9	9	17	per head capacity	26	21	22	40
Dairy herd	73,000	271	53	131	193	per mature cow	31	6	15	22
Beef cows	30,000	72	25	58	86	per mature cow	20	7	16	24
Feeder calves	13,000	39	12	26	35	per head capacity	27	8	18	24
Finishing cattle	25,500	89	24	55	79	per head capacity	29	8	18	26
Broilers	83	0.63	0.13	0.4	0.3	per bird space	63	13	40	29
Pullets	49	0.35	0.07	0.21	0.2	per bird space	60	12	35	30
Layers	130	0.89	0.58	0.81	0.5	per bird space	57	37	52	33
Tom turkeys	282	1.79	0.54	1.35	1	per bird space	53	16	40	29
Hen turkeys	232	1.67	0.56	1.06	0.9	per bird space	60	20	38	32
Ducks	249	0.45	0.24	0.36	0.3	per bird space	22	5	15	8

* Phosphate (P_2O_5) = 2.29 x P, Potash (K_2O) = 1.21 x K, NH_3-N (ammonia N) = 1.22 x NH_3
Source: MWPS-18, *Manure Management Systems Series,* Section 1, Manure Characteristics.
Note: Use only for planning purposes. These values should not be used in place of a regular manure analysis.

produced annually. The concentration of nutrients per 1,000 gallons is also listed.

Example calculation of the value of manure produced: Find the value of the P_2O_5 in a 5,000 gallon load of liquid pit manure produced by mature dairy cows (refer to Table 3 and assume $0.26/lb for P_2O_5 applied in the liquid manure):

15 lb P_2O_5 /K-gallons x 5 K-gallons x $0.26/lb = $19.50 (K-gallons = 1,000 gallons)

NOTE: This calculation assumes that a soil test indicates phosphate is needed. If phosphate level in the soil is already high, the P_2O_5 applied in the liquid manure may have a negative value, which should be deducted from the value of the N and K_2O in the manure. Missouri policy recommends that intense phosphorus nutrient management be considered when soil test phosphorus levels are rated *high* or greater.

Table 4 shows estimated lagoon nutrient accumulations for various animals. Nutrient concentrations in all properly operating lagoons are very low because of the high volume of dilution water, nutrient settling and ammonia volatilization. Lagoon effluent nutrient characteristics for different animal species (e.g., swine, beef, dairy and sheep) are similar. Using an estimated nutrient concentration of 4-2-3 pounds (N-P_2O_5-K_2O) per 1,000 gallons will be representative of many lagoons. About 80 to 90 percent of nitrogen in well-seasoned, steady-state anaerobic lagoons is in the ammonia form and is subject to high losses from volatilization when land applied without incorporation.

Table 4. Estimated manure and nutrients from lagoon effluent (lb per year).

Production	Units	Manure produced	Total N	NH_3	P_2O_5	K_2O
Grow-finish	lb per pig space	8,000	4	4	2	3
Farrow-finish	lb per production sow	64,000	36	32	23	29
Breeding-gestation	lb per pig space	11,500	5	4	4	5
Farrowing	lb per sow	16,500	8	7	6	8
Dairy cow	lb per mature cow	91,000	46	41	19	33
Dairy herd	lb per mature cow	138,000	70	63	30	50
Fattening cattle	lb per head capacity	44,000	27	24	21	27
Broilers	lb per bird space	130	0.14	0.1	0.07	0.1

Source: MWPS-18, *Manure Management Systems Series,* Section 1, Manure Characteristics.
Note: Use only for planning purposes. These values should not be used in place of a regular manure analysis.

Table 5. Estimated dairy milking center effluent characteristics.

Component	Units	Milkhouse	Milkhouse and parlor	Milkhouse, parlor & holding area (scraped & flushed): Holding area manure excluded	Milkhouse, parlor & holding area (scraped & flushed): Holding area manure included
Volume	ft^3/day per 1,000 lb animal	0.22	0.6	1.4	1.6
Moisture	percent	99.72	99.4	99.7	98.5
Nitrogen (N)	lb per 1,000 gal	0.72	1.67	1	7.5
Phosphorus (P_2O_5)*	lb per 1,000 gal	0.58	0.83	0.23	0.83
Potassium (K_2O)*	lb per 1,000 gal	1.5	2.5	0.57	3.33
Carbon:nitrogen (C:N)	ratio	10	12	10	7

*Phosphate (P_2O_5) = 2.29 x P, Potash (K_2O) = 1.21 x K
Source: MWPS-18, *Manure Management Systems Series,* Section 1, Manure Characteristics.
Note: Use only for planning purposes. These values should not be used in place of a regular manure analysis.

Example calculation of the value of manure produced: Find the value of the K_2O in the lagoon effluent produced annually from a 1,000-head grow-finish unit (refer to Table 4 and assume $0.16/lb for K_2O applied in the lagoon effluent):

3 lb K_2O/pig space-year x 1,000 pig spaces x $0.16/lb = $480.00

NOTE: This calculation assumes that a soil test indicates potash is needed.

Example calculation of the annual volume of effluent from a 100-cow milking parlor and milkhouse plus the manure and flush water from the holding area assuming the average cow weight is 1,400 lb each (reference Table 5):

1.6 ft^3/day x 100 cows x 1400 lb/1000 lb x 365 days/year = 81,760 ft^3 = 611,565 gallons

Table 6 lists the percent of original nutrient content of manure retained by various manure management systems.

Example calculation of the value of manure produced: Find the average gross value of the K_2O retained in the manure from 200 head of 1,100 lb beef feeders fed a high-energy ration in an open lot (in a cool, humid region) for 180 days (refer to Table 1 for the daily K_2O production and to Table 6 for the average percent of original manure nutrient content retained and assume $0.16/lb for K_2O in the manure to be land applied):

0.32 lb K_2O/animal-day x 200 animals @1100 lb x 180 days x 0.625 retained x $0.16/lb = $1152.00

NOTE: This calculation assumes that a soil test indicates potash is needed.

Table 7 lists some of the important characteristics of beef manure from open feedlots in an arid region.

Example calculation of the weight of manure produced: Find the weight of manure to be hauled per year from 200 head of 1,000 lb beef feeders fed in an unsurfaced lot in a dry climate:

9.60 lb/animal-day x 200 animals @1000 lb x 365 days/2,000 lb/ton = 350.4 tons = 70 five-ton loads

Table 6. Percent of original nutrient content of manure retained by various management systems.

Management system	Beef			Dairy			Poultry			Swine		
	N	P	K	N	P	K	N	P	K	N	P	K
	Percent											
Manure stored in open lot, cool, humid region	55-70	70-80	55-70	70-85	85-95	85-95				55-70	65-80	55-70
Manure stored in open lot, hot, arid region	40-60	70-80	55-70	55-70	85-95	85-95						
Manure liquids and solids stored in a covered, essentially watertight structure	70-85	85-95	85-95	70-85	85-95	85-95				75-85	85-95	8 5-95
Manure liquids and solids stored in an uncovered, essentially watertight structure	60-75	80-90	80-90	65-75	80-90	80-90				70-75	80-90	80-90
Manure liquids and solids (diluted less than 50%) held in waster storage pond				65-80	80-95	80-95						
Manure and bedding held in roofed storage				65-80	80-95	80-95	55-70	80-95	80-95			
Manure and bedding held in unroofed storage, leachate lost				55-75	75-85	75-85						
Manure stored in pits beneath slatted floor	70-85	85-95	85-95	70-85	90-95	90-95	80-90	90-95	90-95	70-85	90-95	90-95
Manure treated in anaerobic lagoon or stored in waste storage pond after being diluted more than 50%	20-35	35-50	50-65	20-35	35-50	50-65	20-30	35-50	50-60	20-30	35-50	50-60

Source: *Agricultural Waste Management Field Handbook*, Part 651, Table 11-5.
Note: Use only for planning purposes. These values should not be used in place of a regular manure analysis.

Table 8 lists some of the important characteristics of beef feedlot runoff stored in a pond.

Example calculation of the value of the ammonia nitrogen (NH_3-N) per acre-inch of effluent from a beef feedlot runoff pond: (Assume that 25 percent of the **ammonia** nitrogen (NH_3-N) will be lost (volatilized) during land application by sprinkler irrigation (from Table 13), one acre-inch = 27,153 gallons, and a value of $0.26 per pound of N).

1.50 lb/K-gallon x 27.153 K-gallons
x 0.75 retained x $0.26/lb of N
= $7.94 per acre-inch

Table 7. Estimated beef feedlot manure characteristics.

Component	Units	Unsurfaced lot[a]	Surfaced lot[b] High-forage diet	Surfaced lot[b] High-energy diet
Manure weight	lb/day per 1,000-lb animal	17.50	11.70	5.30
Moisture	percent	45.00	53.30	52.10
Total solids (TS)	percent wet basis	55.00	46.70	47.90
	lb/day per 1,000-lb animal	9.60	5.50	2.50
Nitrogen (N)	lb/day per 1,000-lb animal	0.21	--	--
Phosphorus (P_2O_5)*	lb/day per 1,000-lb animal	0.14	--	--
Potassium (K_2O)*	lb/day per 1,000-lb animal	0.03	--	--
Carbon:nitrogen (C:N)	ratio	13:1	--	--

*Phosphate (P_2O_5) = 2.29 x P, Potash (K_2O) = 1.21 x K
[a] Dry climate (annual rainfall less than 15 inches); annual manure removal.
[b] Dry climate; semiannual manure removal.
Source: MWPS-18, *Manure Management Systems Series,* Section 1, Manure Characteristics, Table 16.
Note: Use only for planning purposes. These values should not be used in place of a regular manure analysis.

Table 9 lists typical ranges of nutrient contents of anaerobic lagoon systems. Climatic effects such as rainfall and runoff from open lots can significantly affect the concentration of nutrients in lagoons. Additionally, some nutrients are concentrated in the sludge layer and may not be available if the lagoon is not agitated.

Example calculation of the average value of the ammonia nitrogen (NH_3-N) per acre-inch of effluent from an anaerobic beef lagoon: (Use the ammonia N content from Table 9a, assume that 25 percent of the ammonia nitrogen (NH_3-N) will be lost (volatilized) during land application by sprinkler irrigation (from Table 13), and a value of $0.26 per pound of N.)

50 lb of (NH_3-N)/acre-inch x 0.75 retained x $0.26/lb of N
= $9.75 per acre-inch

Table 8. Beef feedlot runoff pond characteristics.

Component	Units	Runoff pond Supernatant	Runoff pond Sludge
Moisture	%	99.7	82.8
Total solids (TS)	% wet basis	0.30	17.2
Nitrogen (N)	lb per 1,000 gal	1.67	51.7
Ammonia N (NH_3-N)*	lb per 1,000 gal	1.50	--
Phosphorus (P_2O_5)*	lb per 1,000 gal	--	17.5
Potassium (K_2O)*	lb per 1,000 gal	7.50	14.2

*Phosphate (P_2O_5) = 2.29 x P, Potash (K_2O) = 1.21 x K,
NH_3-N (ammonia N) = 1.22 x NH_3
Source: MWPS-18, *Manure Management Systems Series,* Section 1, Manure Characteristics, Table 17.
Note: Use only for planning purposes. These values should not be used in place of a regular manure analysis.

Table 9. Nutrient content of anaerobic lagoon systems.

Animal	Total Kjeldahl N	Ammonia N*	Phosphorus (P_2O_5)*	Potassium (K_2O)*
a. Nutrient content (pounds per acre-inch)				
Swine	100–300	85–250	40–80	100–300
Dairy	80–150	45–80	50–100	100–200
Beef	40–120	40–60	80–250	100–250
Poultry	80–170	60–120	50–150	400–500
b. Nutrient content (pounds per 1,000 gallons)				
Swine	3.7–11	3.1–9.2	1.5–2.9	3.7–11
Dairy	2.9–5.5	1.7–2.9	1.8–3.7	3.7–7.4
Beef	1.5–4.4	1.5–2.2	2.9–9.2	3.7–9.2
Poultry	2.9–6.3	2.2–4.4	1.8–5.5	15–18

*Phosphate (P_2O_5) = 2.29 x P, Potash (K_2O) = 1.21 x K,
NH_3-N (ammonia N) = 1.22 x NH_3

Source: MWPS-18, *Manure Management Systems Series,* Section 2, Manure Storages, Table 5-5.

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

Table 10. Nutrient concentrations in various types of solid manure, pounds per wet ton.

Manure type	Total Kjeldahl N	Ammonia N*	Phosphorus (P_2O_5)*	Potassium (K_2O)*
Poultry litter[1]	40–80	10–20	30–60	30–50
Separated dairy solids[2], 23% DM	5.8–7.4	0.3–0.7	1.8–2.4	2.4–3.6
Swine hoop structures[3]	15	6	12.6	14.4
Mortality compost[4]	15–25	3–6	1–3	4–8

[1] Range of values from NRCS-AWMFH, MWPS-18, Section 2, and University of Missouri studies.

[2] Performance of screen separator at University of Missouri dairy farm

[3] Study averages from Iowa State University. Rhodes Research Farm using cornstalk bedding

[4] Swine mortality compost, University of Missouri

* Phosphate (P_2O_5) = 2.29 x P, Potash (K_2O) = 1.21 x K,
Ammonia N (NH_3-N) = 1.22 x NH_3

Source: MWPS-18, *Manure Management Systems Series,* Section 2, Manure Storages, Table 5-3.

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

Table 10 lists typical nutrient concentrations in various types of solid manure. Solid manure usually contains the manure as it is excreted by the animal and may be mixed with considerable bedding. Most of the phosphorous and potassium excreted by the animal is usually contained in the manure hauled to the field.

Example calculation of the average value of the total Kjeldahl N per wet ton of poultry litter: (Use the total Kjeldahl nitrogen content from Table 10, assume that 22.5 percent of the nitrogen will be lost (volatilized) from land application on fescue pasture without incorporation (from Table 13), and a value of $0.26 per pound of N.

Table 11. Nutrient concentrations in slurry manure, pounds per 1,000 gallons.

Animal	Total Kjeldahl N	Ammonia N*	Phosphorus (P_2O_5)*	Potassium (K_2O)*
Swine	30–75	20–60	20–50	20–30
Dairy	25–35	10–15	15–20	20–30
Beef	30–40	10–25	15–30	25–35
Poultry	60–80	15–60	35–45	30–95

* Phosphate (P_2O_5) = 2.29 x P, Potash (K_2O) = 1.21 x K,
Ammonia N (NH_3-N) = 1.22 x NH_3

Source: MWPS-18, *Manure Management Systems Series*, Section 2, Manure Storages, Table 5-4.

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

Table 12. Nitrogen lost and retained with various handling and storage regimes.

System	Nitrogen lost	Nitrogen retained
	Percent	
Solid		
Daily scrape and haul	20–35	65–80
Manure pack	20–40	60–80
Open lot	40–55	45–60
Deep pit (poultry)	25–50	50–75
Litter	25–50	50–75
Liquid		
Underfloor pit*	15–30	70–85
Above-ground tank*	10–30	70–90
Holding pond	20–40	60–80
Anaerobic lagoon	70–85	15–30

*Indicates losses due to agitation.

Data source: MWPS-18, Third Edition, Table 10-1.

Note: Typical losses between excretion and land application, including losses incurred in transporting to storage, adjusted for dilution in the various systems. These losses are in addition to land application losses.

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

Table 13. Percent of nitrogen of that in applied manure still available to the soil.

Application method	Percent remaining/delivered		
Injection	95		
Sprinkling	75		
Broadcast (fresh solids)	40		
Days between application and incorporation	**Soil conditions**		
	Warm dry	**Warm wet**	**Cool wet**
1	70	90	100
4	60	80	95
7 or more	50	70	90

Note: Ammonia volatilization causes the predicted losses.

Source: *Agricultural Waste Management Field Handbook,* Part 651, National Engineering Handbook. 1992.

60 lb of N/ton x 0.775 retained x $0.26/lb of N
= $12.09 per ton

Table 11 lists typical ranges of nutrient concentrations in slurry manure. Slurry manure is relatively concentrated, especially if the manure is from a covered pit and contains no rainwater. Slurry manure usually contains 5 to 10 percent solids and can be handled as a liquid with manure pumps and tank wagons.

Example calculation of the gallons of swine slurry manure required to knife-in (inject) 200 pounds (net after application loss) of total Kjeldahl N per acre for corn production: (Use the average total Kjeldahl nitrogen content at 52.5 lb / K-gallon from Table 11 and assume a 5 percent nitrogen loss (from Table 13)).

200 lb N/K-gallon /(52.5 lb of N/K-gallon x 0.95)
= 4.01 K-gallons = 4,010 gallons

Nutrient losses/availability

Losses in nutrient value are inherent in any system of manure management, both during the collection and storage phase and the land application phase, especially nitrogen losses due to volatilization and denitrification. In the collection and storage phase, nitrogen can be lost to the air as ammonia and from manure stored in open lots by leaching and runoff, additionally. Table 14 lists typical nutrient losses incurred with some common systems of manure handling and storage. About 20 to 40 percent of the phosphorous and 30 to 50 percent of the potassium can be lost by leaching and runoff from open lots. Thus, to minimize nutrient losses as well as to reduce pollution problems from rainfall runoff, all operations (feeding, loafing, manure storage, etc.) should be kept under roofs — not in open lots. Phosphorous in lagoons tends to settle out of the liquid and concentrate in the sludge layer. Research at the University of Missouri suggests that as little as 5 to 10 percent of the excreted phosphorous may be pumped from unagitated lagoons using normal pumpdown procedures. Most of the remaining phosphorous will remain in the sludge layer. Potassium is soluble and evenly distributed in the liquid portion of the lagoon. Lagoons normally only have 20 to 30 percent of their volume pumped, depending on the ratio of treatment volume to total volume. A large amount of the potassium may remain in the treatment volume. Research at the University of Missouri suggests that as little as 15 to 30 percent of the excreted potassium may be pumped from unagitated lagoons.

Frequently, total nitrogen (N) in lagoon effluent is composed of 80 to 90 percent ammonium nitrogen and 10 to 20 percent organic nitrogen. The ammonium nitrogen is equivalent to nitrogen fertilizer and, except for losses to the air, is available to plants in the year of application. The amount of ammonia nitrogen lost to the atmosphere as a gas is difficult to predict because the process depends on many factors such as soil and atmospheric temperature, wind and humidity conditions at the time of spreading, application method and timing of application relative to the nitrogen uptake period (growing season). To minimize volatilization losses of the ammonia nitrogen, manure should be incorporated as soon as possible after surface application. Manure applied to cool, wet soil does not dry readily and thus does not volatilize for several days. Manure applied to hot, dry soil dries quickly and loses most of the ammonia fraction within 24 hours, particularly if there is a hot, dry wind. Dried manure, such as that from a feedlot in an arid or semiarid climate, has already lost much of its ammonia nitrogen and there is little additional loss with time until incorporation. Lagoon effluent applied by irrigation is assumes to be incorporated as soon as it enters the soil. Published values for plant-available ammonia nitrogen from surface-applied manure range from 20 to 80 percent. If manure is a significant part of a crop fertility program, the farmer must consider the possible need for supplemental application of commercial fertilizer nitrogen in the event that plant-available nitrogen is in the lower end of the range noted above. The Missouri Department of Natural Resources (MDNR) requires that a value of 60 percent (40% loss) be used in estimating plant-available (surface-applied, no incorporation) ammonia nitrogen unless supporting data or procedures suggest otherwise.

Organic nitrogen must be mineralized (converted to the ammonium form by soil bacteria) before it is available to plants. The rate at which this conversion takes place depends on several factors such as manure type, soil moisture, temperature and pH. Published values suggest that 20 to 90 percent of the organic nitrogen in manure may be converted to plant-available forms during the year in which it is applied. After several years of uniform application (usually about 3 years or more), the nitrogen available from the organic portion of applied manure will tend to stabilize. The MDNR requires that a value of 45 to 62 percent (depending on manure type) be used in estimating cumulative availability of organic nitrogen unless supporting data or procedures suggest otherwise.

Most volatilization (ammonia) losses occur within the first 24 hours after land application, if the waste is not incorporated. Manure spread on the surface and not worked into the soil may lose most of the volatile nitrogen compounds such as ammonia gas to the atmosphere. This lost nitrogen is not available for plant growth. The rate of loss increases with increasing temperature and is greater during dry, warm, windy days than during humid or cold days. Thus, ammonia loss is generally greater during late spring, summer and early fall.

Table 13 shows the decrease in plant-available nitrogen as incorporation is delayed.

Example calculation of the average gross value of the annual nitrogen production from 10,000 laying hens averaging 4 lb/bird if the deep pit manure is

incorporated 4 days after land application: (Use the N value from Table 1, the deep pit handling and storage loss from Table 12, the land application loss for wet and warm conditions from Table 13, and a value of $0.26 per pound of N.)

0.0035 lb of N/bird-day x 10,000 birds x 365 days/year x 0.625 after handling & storage x 0.80 after land application loss x $0.26/lb of N = $1660.75 per year

Nitrogen applied in excess of crop needs can leach through the soil after conversion to the nitrate form and cause groundwater contamination. Manure should not be applied on snow or frozen soil due to the potential for nutrient removal by runoff and resulting surface water pollution. Once incorporated into the soil, phosphorous and potassium are bound to soil particles such that the principal mode of loss is by soil erosion.

Solid and liquid manure should be plowed down or otherwise incorporated into the soil as soon as possible after land application to minimize odors and volatilization of nitrogen. Lagoon effluent applied by irrigation to soil dry enough to "take water" is assumed to be immediately incorporated, but some volatilization losses do occur with sprinkler irrigation. Although incorporating manure is an effective manure management tool, the vulnerability of the soil to increased erosion risks and other environmental considerations should be evaluated. Additionally, when soil test phosphorus is *very high* to *excessively high,* any phosphorus applied may increase leaching and surface runoff.

Table 14 compares typical nitrogen losses for solid, liquid (slurry), and lagoon systems during handling and storage. Losses are highly variable because of seasonal temperature, moisture, climatic and other factors.

Solid manure systems

In the future, it is likely that only poultry operations, smaller livestock operations and open-lot beef feeding operations will be handling manure as a solid. To handle dairy manure as a solid, one practice is to add about 4 pounds of dry straw per cow per day to reduce the moisture content of fresh manure and allow it to be handled as a solid. When this manure is applied to the land, all available nitrogen may be "tied up" by soil microorganisms during the process of decaying the straw. If the decaying process takes place during crop production time, a nitrogen allowance should be made for the decay process, in addition to the nitrogen required for crop production. A second and common practice employed to allow manure to be handled as a solid is to store semisolid manure and allow the liquids to drain off to a holding pond. The liquid is frequently drained through a "picket fence" dam.

Table 15 lists the minimum recommended bedding requirements for various housing systems.

Table 14. Typical nutrient losses during handling and storage.

System	N	P*	K*
	Percent lost		
Solid			
Daily scrape and haul[2]	20–35	5–15	5–15
Manure pack[2]	20–40	10–20	10–20
Poultry, deep pit or litter[2]	25–50	5–15	5–15
Solids on open lot			
Scrape once/year[2]	40–55	20–40	30–50
Daily scrape and haul[2]	20–35	10–20	15–25
Separated solids, 90 days storage[1]	30	10–20	10–20
Liquid (slurry)			
Anaerobic pit[2]	15–30	5–20[4]	5–20[4]
Aboveground storage[2]	10–30	5–15	5–15
Manure basin; or runoff storage pond, 120–180 days storage[3]	20–40	5–50[4]	5–50[4]
Liquid — lagoon[2]	70–85	50–80[4]	30–80[4]
Lagoon, 365 days storage[3]	90	50–80[4]	30–80[4]

* Phosphate (P_2O_5) = 2.29 x P, Potash (K_2O) = 1.21 x K, authors' estimate
[1]Authors' estimates.
[2]From MWPS-18.
[3]From Oregon State University Publication EC-1102.
[4]Losses vary widely, pending on degree of agitation during pumpout.

Table 15. Minimum recommended bedding requirements (lb per day per 1,000 lb of animal weight).

Bedding type	Long straw	Chopped straw	Wood shavings	Sawdust	Sand
Density (lb per cu ft)	2.5	7	9	12	—
Housing system					
Dairy					
Stanchion barn	5.4	5.7	—	—	—
Freestall housing	—	2.7	3.1	3.1	35
Loose housing bedded area	9.3	11	—	—	—
Swine (shed lot)	3.5	4.0	—	—	—
Poultry (floor level)	—	—	—	1.6	—

Source: MWPS-18. *Manure Management Systems Series,* Manure Characteristics, Section 1.

Liquid manure systems

Liquid systems (also called slurry systems) offer greater use of nutrients, if maximizing nutrient use is the goal. Therefore, liquid systems require the maximum soil-plant filter acreage for land application. Storage losses with a manure slurry are lower than with solids or lagoons, especially if stored in aboveground tanks (see Table 14). Knifing liquid into the soil minimizes application losses (see Table 13). The addition of nitrification inhibitors to the manure can slow the conversion of ammonium nitrogen to nitrate nitrogen by certain soil bacteria, thus reducing nitrogen losses by leaching and denitrification. This is the system of choice for operators wishing to make the greatest use of the plant nutrients in their manure.

Lagoon systems

This is the system of choice for producers wanting to minimize one or more of the following: (1) the required soil-plant filter acreage, (2) labor costs, and (3) capital investment. Manure management systems employing lagoons for long-term storage are the least efficient in respect to nutrient use (see Table 14). Losses of up to 90 percent of the nitrogen during storage may occur. Up to 80 percent of the phosphate may remain in the lagoon bottom sludge if the lagoon is not properly agitated when pumped. Land application from lagoons by means of pipes, pumps and sprinkler irrigation is efficient in time and cost; however, without further mechanical incorporation, volatilization losses can be substantial (see Table 13).

For further information

ASAE Data D384.1, “Manure Production and Characteristics.” ASAE Standards, 1999. St. Joseph, Mich.

Selecting a Dairy Waste Management System for the Willamette Valley. 1982. Oregon State University Extension Publication EC-1102, Oregon State University, Corvallis.

USDA-Natural Resources Conservation Service. 1992. *Agricultural Waste Management Field Handbook*, Part 651. USDA-NRCS, Washington, D.C.

Available from Extension Publications 1-800-292-0969

MU publications

EQ 201 *Reduce Environmental Problems with Proper Land Application of Animal Manure*

EQ 202 *Land Application Considerations for Animal Manure*

M 115 *Animal Waste Management — Planning and Designing Guidelines*

MP666 *Waste Management Systems for Dairy Herds*

WQ 203 *Estimated Land Area Requirements for Poultry Operations: Conservative Litter Management Approach*

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MWPS-6 *Beef Housing and Equipment Handbook*

MWPS-18 *Livestock Waste Facilities Handbook*

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