Fertilizer Nutrients in Dairy Manure

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Many dairy producers fall into one of two categories:

- They are willing to make high capital and labor outlays to maximize the usage of their dairy wastes for crop production
- 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 waste disposal.

Producers in the first category usually use slurry systems with tanks for waste storage, and tank wagons with injectors to transport and apply the waste. Producers in the second category use lagoons for storage/treatment, and irrigation equipment to transport and apply the waste to their fields.

To have value, wastes 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 dairy wastes.

To keep the addition of nutrients from waste and fertilizer in balance with the nutrient removal by crops requires a record-keeping system, preferably with laboratory tests of the nutrient content of the wastes being applied. The quantities of wastes added and crops removed should be measured or, at least estimated as accurately as possible. Reliable nutrient data requires that the waste be kept well mixed during the loading, sampling, transport and land application processes.

Fresh manure nutrient production

Typical nutrient production values for various weights of dairy cattle are listed in Table 1 for fresh manure.

Table 1
Daily/annual production of the major nutrients in pounds for various weights of dairy cattle (as contained in freshly excreted manure; reference ASAE Data D384.1)

Size	Nutrient production (pounds per day per year)		
Pounds	Nitrogen	Phosphate[1]	Potash[2]
150	0.07/24.64	0.032/11.66	0.052/19.05
250	0.11/41.06	0.053/19.44	0.087/31.76
500	0.22/82.12	0.106/38.87	0.174/63.51
1,000	0.45/164.25	0.213/77.74	0.348/127.02
1,400	0.63/229.95	0.298/108.84	0.487/177.83

[1]Phosphate (P_2O_5) = 2.27 x P.
[2]Potash (K_2O) = 1.2 x K

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. 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, cow loafing, manure storage, etc.) should be kept under roofs — not open lots.

Table 2 lists the average nutrients available in dairy waste handled and stored in the usual methods.

Table 2
Average nutrient levels in dairy waste.[1]

	Nitrogen				
Waste type	Total	Organic	Ammonium	P_2O_5	K_2O
Solid[2] with bedding	9	4	5	4	10
Solid[3] without bedding	9	5	4	4	10
Lagoon[4]	69	23	46	79	144
Liquid (slurry)[5]	26	16	10	14	26

[1]Actual values are highly dependent on dilution, bedding and other factors. Variations of 50 percent from average values are not uncommon.
[2]pounds per ton (21 percent dry matter, Source: MWPS18, Table 10-6).
[3]pounds per ton (18 percent dry matter, Source: MWPS18, Table 10-6).
[4]pounds per acre-inch.
[5]pounds per 1,000 gallons (Source: MU publication WQ201) Note: P_2O_5 = 2.27 x P; K_2O = 1.2 x K.

Frequently, total nitrogen (N) in dairy lagoon effluent is composed of approximately two-thirds ammonium nitrogen and one-third 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. Organic nitrogen must be mineralized before it is available to plants. Table 3 shows the percent of organic nitrogen mineralized (released to crops) during the first few years after application. Nearly all of the phosphorous and potassium are available the year of application.

Table 3
Manure organic nitrogen available by year

Manure applied	Percent of organic-N available during current year
Current year	40 to 60
1 year ago	10
2 years ago	5
3 years ago	5

Most volatilization (ammonia) losses occur within the first 24 hours after land application, if the waste is not incorporated. The rate of loss increases with increasing temperature. Table 4 shows the decrease in plant-available ammonia-N as incorporation is delayed.

Table 4
Manure ammonia-nitrogen loss by days until incorporated into the soil

Days until incorporation	Percent of ammonia-N available for crops
0 to 2	80
2 to 4	60
4 to 7	40
greater than 7	20

Nitrogen applied in excess of crop needs can leach through the soil after conversion to the nitrate form and cause groundwater contamination. The potential for nutrient removal and surface water pollution by runoff is high when manure is applied to frozen soil. 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.

A comparison of typical nitrogen losses for solid, liquid (slurry), and lagoon systems during handling and storage are given in Table 5. Losses are highly variable due to seasonal, temperature, moisture, climatic and other factors.

Table 5
Typical nutrient losses during handling and storage

System	**Nitrogen lost (percent)**	**P lost (percent[1])**	**K lost (percent[1])**
Solid			
Daily scrape and haul[2]	5 to 35	5 to 15	5 to 15
Manure pack[2]	20 to 40	10 to 20	10 to 20
Solids on open lot			
Scrape once per year[3]	50	20 to 40	30 to 50
Daily scrape and haul[3]	25	10 to 20	15 to 25
Separated solids, 90 days storage[3]:	30	10 to 20	10 to 20
Liquid (slurry)			
Anaerobic pit[2]	15 to 30	5 to 20[4]	5 to 20[4]
Above-ground storage[2]	10 to 30	5 to 15	5 to 15
Manure Basin; or runoff: storage pond, 120 to 180 days storage[3]	40	5 to 50[5]	5 to 50[5]
Liquid — lagoon[2]	70 to 80	50 to 80[5]	30 to 80[5]
Lagoon, 365 day storage[3]	90	50 to 80[5]	30 to 80[5]

[1]Authors' estimates.
[2]From MWPS18.
[3]From Missouri Manual 121, for Missouri DNR approval, use design data from Missouri manuals.
[4]From Oregon State University Publication EC-1102.
[5]Losses vary widely, pending on degree of agitation during pump-out.

Solid manure systems

In the future, it is likely that only the smaller dairy operations will be handling dairy 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 semi-solid manure and allow the liquids to drain off to a holding pond. The liquid is frequently drained through a "picket fence" dam.

Liquid manure systems

Liquid systems (also called slurry systems) offer greater utilization of nutrients, if maximizing nutrient utilization is the goal. Therefore, liquid systems require the maximum soil-plant filter acreage for disposal. Storage losses with a manure slurry are lower than with solids or lagoons, especially if stored in above-ground tanks (Table 5). Knifing liquid into the soil minimizes application losses (Table 4). 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 obtain the greatest utilization of the plant nutrients in their dairy waste. Table 6 lists typical nutrient availability per year for lagoon and liquid systems for three herd sizes.

Table 6
Typical nutrient availability per year for lagoon and liquid systems for three herd sizes (from MU publication MP666)

For a lagoon system	**Herd size**		
Nutrients produced (pounds per yr)[1]	**100**	**200**	**300**
1. Ammonia nitrogen	2,623	3,912	4,876
2. Organic nitrogen	1,312	1,956	2,438
3. Phosphorus	1,994	2,973	3,710
4. Potassium	6,838	10,198	12,770
Pounds of fertilizer nutrient equivalent available			

For a lagoon system	Herd size		
Nutrients produced (pounds per yr)[1]	**100**	**200**	**300**
5. Ammonia nitrogen (line 1 x 50 percent[2])	1,312	1,956	2,438
6. Organic nitrogen (line 2 x 70 percent[2])	918	1,369	1,707
7. Phosphate (line 3 x 2.3[1])	3,440	5,128	6,400
8. Potash (line 4 x 1.2[1])	7,385	11,014	13,792
For a liquid manure tank system	**Herd size**		
Nutrients produced (pounds per yr)[5]	**100**	**200**	**300**
15. Ammonia nitrogen	7,027	14,054	21,081
16. Organic nitrogen	11,225	22,450	33,675
17. Phosphorus	4,212	8,424	12,636
18. Potassium	15,444	30,880	46,332
Pounds of fertilizer nutrient equivalent available			
19. Ammonia nitrogen (line 15 x 50 percent[6])	3,514	7,027	10,541
20. Organic nitrogen (line16 x 70 percent[7])	6,735	13,470	20,205
21. Phosphate (line 17 x 2.3[2])	7,266	14,531	21,797
22. Potash(line 18 x 1.2[2])	16,680	33,350	50,039

[1]Average analysis of lagoon waste.
[2]Average percent available to plant.
[3]Conversion of phosphorus to phosphate.
[4]Conversion of potassium to potash.
[5]Average analysis of tank liquid manure.
[6]Assumes 50 percent incorporated with 80 percent loss and 50 percent incorporated within two days with 20 percent loss. Value will increase if 100 percent incorporated within two days.
[7]Assumes not spread on same fields each year (50 percent available year 1 plus 10 percent year 2).

Lagoon systems

This is the system of choice for producers wanting to minimize one or more of the following:

- Required soil-plant filter acreage

- Labor costs
- Capital investment.

Manure management systems employing lagoons for long-term storage are the least efficient in respect to nutrient utilization (Table 5). Losses of up to 90 percent of the nitrogen during storage is typical. Up to 80 percent of the phosphate may remain in the lagoon bottom sludge if the lagoon is not agitated when pumped. Land application from lagoons via pipes, pumps and sprinkler irrigation is quite efficient in time, cost and nutrient utilization, since mechanical incorporation is not required to prevent excessive volatilization losses (Table 4). Table 6 shows the estimated nutrient availability per year for lagoon and liquid systems for three herd sizes.

References

- ASAE Data D384.1, "*Manure Production and Characteristics.*" ASAE Standards, 1991. St. Joseph, Michigan 49085-9659.
- Missouri Manual 121, *Design Guidelines for Animal Waste Management for Concentrated Animal Feeding Operations.* Second Edition, July 1989. Missouri Department of Natural Resources — Water Pollution Control Program, P.O. Box 176, Jefferson City, MO 65102.
- Oregon State Extension Publication EC-1102, "Selecting a Dairy Waste Management System for the Willamette Valley." 1982. Oregon State University, Corvallis, OR 97331.
