Nutrient Utilization And Cropping

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Introduction

There have been three significant factors in the last 50 years that have shaped the way we view and manage manure nutrients. The first of these was the development of the technology to make cheap nitrogen. This was associated with the war effort and drastically changed the way we carefully saved and utilized manure. For the first time, manure was thought of as a low value waste produce.

After that development livestock producers managed (or mismanaged) manure as a worthless byproduct for about 15 years. Then in the 1960s, society raised her hand and said 'enough'. Degraded surface water that was unsightly, produced odors, killed fish, and threatened public health in drinking water all led to reforms in manure management practices to protect surface waters. Feedlots were no longer allowed to locate on and dump their wastes into the nearest stream. Producers were again encouraged to spread their manure back on the cropland that produced the feed for the herd. This concern translated into support for research and Extension efforts to do a better job. Concrete slats were developed to reduce the labor needed to collect manure. Equipment manufacturers developed new pumps that could agitate and move thick slurries and apply them to fields through big guns. Taking a page from the handling of human waste, hydraulic or flush systems reduced the time spent scraping manure. Mechanical separators were developed to remove solids, providing a bedding material and reducing the clogging/plugging problems in liquid handling systems. As these new labor saving components in manure handling were developed, herd sizes grew in response to the market.

These new larger dairies and other livestock units, many of them generating great volumes of manure and wastewater, posed a new problem. Taking a page from other segments of American business, livestock producers began to specialized. They were in the business to produce milk. Feed could be contracted for from other agricultural specialists. More cows were gathered on smaller land areas. As a result, groundwater was threatened. In the 1980s, effort was directed to looking at nutrient management as one means of reducing the threat to groundwater sources. Certainly livestock producers were not alone as the widespread use of cheap and effective agricultural chemicals were mismanaged throughout the many phases of production agriculture. In some areas we may still be doing that, but we have learned many things.

Nutrients Generated

As animals have gotten bigger and feed rations have improved, the characteristic of the manure and wastewater has changed. Most values are shown as a single number when in fact any value represents a range. These values will vary by season, ration, stage of lactation, climate and management system. Recent values published in the 1991 SCS Agricultural Waste Management Field Handbook serve as an excellent reference source. Values reported from that source on as "excreted" manure in lb/day per 1000 lbs of animal waste are shown in Table 1.

Table 1: Nutrients generated by various dairy animals.

	Nutrients for Dairy Animals (lbs/day/1000# live weight)		
	Lactating Cows	Dry Cows	Heifers
N	0.45	0.36	0.31
P	0.07	0.05	0.04
K	0.26	0.23	0.24

These values do not include bedding or waste water from the milking parlor, but do include a fraction to account for spilled feed.

Nutrient Losses

Determining the amount of nutrients produced and passed by an animal in the urine and feces by a given cow is relatively easy. Following that through the system to land application is a bit more difficult. In an attempt to make some scientific guesses about the pathways and fate of nutrients, we need to know the form of the original nutrient.

About one half of the nitrogen passed by a dairy animal is in the urine, with the remaining half in the feces. Most of that fraction in the urine is in the ammonia form and most of the nitrogen in the feces is in the organic form. Over 80% of the phosphorus in manure is in the feces, while about 80% of the potassium is in the urine. This information is very helpful when evaluating losses of nutrients through various manure management components. For example, most of the potassium will be lost in an open lot system when the manure is scraped up at infrequent intervals. That is the potassium in the urine will not be collected and managed with the solids. A solid separator would allow a dairy operator to remove and haul off-farm a majority of the phosphorus (in the solids) if that were a nutrient that was being applied in excess of crop utilization.

System variation is large, but the table below is included to allow you to place in perspective the magnitude of nutrient losses you might experience with each of the following manure management systems.

Table 2. Percentage of original nutrient content of dairy manure retained by various storage systems.

Method	N	P	K
Daily spreading	80	90	90
Dry (with roof)	70	90	90

Earthen storage	55	60	70
Lagoon/flush	30	40	60
Open lot	60	70	65
Pits (slats)	75	95	95
Scrape/storage tank	70	90	0
None (grazing) — 100% of nutrients retained			

By reviewing Table 2 you can see which management component might be selected to assist a producer who wishes to conserve or lose nutrients from the manure management system.

After the losses occur in the storage/treatment component, there are additional losses during the application of manure/wastewater to the field. Some values of application losses are shown in Table 3.

Table 3: Percentage of original manure nutrient content delivered to cropland and available for plant uptake (these figures reflect application and preutilization losses).

Application method	%N	%P	%K
Injection	95	100	100
Broadcast	80	100	100
Broadcast w/immed. cultivation	95	100	100
Sprinkling	75	100	100
Grazing	85	100	100

This discussion has moved quickly through some of the losses that occur between the cow and the field. While quite variable, this will allow you to calculate the strength of the nutrients that you are about to land apply. The best value would come from a representative sample of the material that will be spread on the field. Concern about ground water pollution has lead most state agencies to talk about application of manures at the agronomic rate. This means that you should be allowed to (or limited to) put on the field about what is taken off in the crop. As one goes to the field to land apply your manure/wastewater, how do you determine the application rate?

There is a good database on the nutrient content of the harvested crop for most of the crops grown. An example of some of these are shown in Table 4.

Table 4: Rates of nutrients used by various crops.

Crop	Unit	Rate (lb) N	Rate (lb) P	Rate (lb) K
Alfalfa, immature & early bloom	per ton	65.0	5.3	42.0
Alfalfa hay, midbloom to mature	per ton	45.0	4.54	36.0
Canarygrass hay	per ton	40.0	7.3	63.0
Orchardgrass	per ton	38.4	6.1	37.6
Cereal grain hay	per ton	24.0	3.4	10.0
Grass hay	per ton	25.0	3.6	19.4
Barley/oats	per ton	4.0	5.0	7.2

Crop	Unit	Rate (lb) N	Rate (lb) P	Rate (lb) K
Alfalfa/grass silage	per ton/wet	22.0	2.9	9.0
Red clover silage	per ton/wet	14.5	2.0	12.0
Corn silage	per ton/wet	7.0	2.5	6.6
Corn earlage	per ton/wet	25.5	4.6	5.6
Grazed grass (by region, range indicated)	per acre	50-165	19-24	87-110
Harvested grass (by region, range indicated)	per acre	80-220	2-28	92-132

However, we know nutrients do not only go into the crop. The problem begins when we evaluate the very complex question of where the nutrients go in field applied manure. Let us follow nitrogen as it has six pathways of movement. Phosphorus and potassium are limited to 4, since they cannot be lost as a gas. The six pathways for nitrogen are: volatilization as ammonia into the atmosphere, loss as nitrogen gas from denitrification, move with surface water in runoff, lost below the root zone in leaching, taken up by the crop and added to the reservoir of nitrogen in the soil organic matter.

As you would expect, the amount of nitrogen that goes into each of the pathways will vary with a wide variety of conditions. Volatilization losses will be influenced by the form of the nitrogen (% as ammonia) in the manure/wastewater. For example, if the manure management system did not collect, or the system has already lost the ammonia in the urine, then the volatilization losses will be reduced. Usually as the manure application rate goes up, the amount of ammonia lost will go up. However, the percent of the total amount of nitrogen lost through this pathway will decrease.

Denitrification, a biological process, will be influenced by the soil type and moisture content as they change saturated conditions and available oxygen supplies. Small micro-sites of anaerobic conditions are required to promote the conversion of nitrate (NO_3) to nitrogen gas. Research reports suggest from 2-50% of the nitrogen may be lost through this mechanism. The climate (rainfall frequency, intensity and duration) are very important in calculating expected losses of nitrogen in surface runoff or deep leaching. Soil permeability, slope and ground cover, is also very influential in effecting water movement. The amount of nitrogen that will be added to or taken from the soil reservoir are influenced by climate and a host of soil properties, such as organic matter content, pH, etc. The above examples are listed to show that amount of nitrogen that goes into each pathway varies considerably.

One of the most influential factors in determining the percent in each pathways is the application rate. With small annual application, one would expect crop uptake to utilize a high percentage of the crop. With increased application the amounts over crop uptake will move in other pathways. Should it rain the day after spreading, the amount going with runoff would be expected to increase. As you can imagine the list of variables are quite large and the serious reader is encouraged to refer to other more complete research reports for a complete coverage of this topic.

Nitrogen Losses From Research Study

However, to provide a prospective of possible nitrogen movement, the data below is shared from a research study conducted at three sites in Oregon. Dairy manure was put on pasture (ryegrass-orchard grass) in several applications through the two-year study. The above mentioned six pathways were monitored throughout the study. One site was on the Oregon Coast (92"/yr rainfall) in a silt loam soil. Sites two and three were close together in the Willamette Valley (42"/yr rainfall) and the soil types were a silty clay loam (poorly drained) and a heavy silt loam. At all three sites manure was applied on triplated plots at target rates of 0, 150, 300 and 450 pounds of nitrogen per acre per year.

For details of the monitoring techniques, the reader is referred to the paper on the pathways of nitrogen movement from land spread manures, cited in the references.

The summary of the data is shown in Table 5. While there is much data contained in this table, a complete review and discussion is not possible. However some important items for your consideration include:

1. There is still crop production and other forms of nitrogen movement in all plots, even through the control plots received no manure. This nitrogen comes from the tremendous reserve built up in most agricultural soils.

2. The percent of nitrogen that goes into the crop decreased as application increased. The range was from 120-30% of applied. The 120% occurred because the plants took nitrogen from the existing soil bank in addition to the applied manure.

3. Volatilization losses occur with essentially every manure application. The amount is independent of crop and soil type. It is influenced by application rate, number of applications and amount of ammonia in the applied manure. In these studies manure was applied up to 7 times on one set of plots, which is perhaps more applications than is typical on one piece of ground. The manure was fresh; scraped from a flush alley so it contained some, but not all of the ammonia in the urine. The percent of nitrogen lost to volatilization ranged from 20-27%, the lower percentages coming from the higher application rates.

4. The producer has almost no control over denitrification losses. As stated they are influenced by soil type and moisture content primarily. In this study they ranged from 28-9% of the total nitrogen applied. This was still over 100 lbs of nitrogen per acre on the Quillamook high rate plots.

5. Given the rainfall rates of the areas, the losses with surface and deep leaching water was surprisingly small. Other combinations of soil permeability, spreading/rainfall events and climate could change the values significantly. These are the two forms of loss that provide the greatest pollution potential and concern.

6. The soil reservoir is very large and very influential in studies such as these. In one set of plots over 180 lbs of nitrogen was taken from the existing soil system while in another set of plots over 100 lbs. was returned to the system. In this study the additions in added manure nitrogen was about 5% of the nitrogen that existed in the soil profile.

Conclusions

Manure management systems must recognize all the nitrogen (and other nutrients) losses that occur in the system. Estimates or measurements, where possible, should be made of the fate of all applied nutrients. Sampling and analysis of manure before it is spread can provide the producer a good idea of the concentration of the nutrients going onto the field.

Most certainly the application should be made in recognition of the uptake potential of the crop/crops grown on the site. Particular concern should be given to the movement of nutrients in water from the site, either overland or down through the profile. These are the losses that are of greatest concern today.

Losses as ammonia through volatilization is a concern, but today in the U.S. it is of less importance than the pollution potential moving with water. Losses of nitrogen through denitrification as nitrogen gas poses no threat to our environment.

How much above agronomic rate can we apply manure? The answer is not clear. We know the processes that are involved and have a fair understanding of the factors which influence the rate of movement through the pathways. What happens to the manure application in the field in section 2, range 5, planted to sorghum on August 14 in North Texas or the pasture in Western Washington, just south of Seattle on February 1, is almost unpredictable each year with any degree of confidence.

This makes it difficult for producers and regulators alike. Although we are all going to the same goal, there is considerable room for discussion. Hopefully some of the above factors will provide you with a better understanding of the possible variations.

Table 5. Nitrogen in each of the pathways in kg/ha (lb/ac) per year and as a percentage of actual nitrogen applied in 1991.

Quillamook	0		152		304		456	
	#/ac	%	#/ac	%	#/ac	%	#/ac	%
Crop uptake	157	86	183	120	220	72	213	47
Volatilization	0	0	35	23	65	21	90	20
Denitrification	12	7	38	25	58	19	108	24
Runoff	8	4	8	5	11	4	14	3
Soil water	5	3	7	5	17	6	25	5
Soil nitrogen	-182	-100	-119	-78	-67	-22	6	1
Total	0	0	152	100	304	100	456	100
Amity	0		129		258		387	
Crop uptake	132	78	157	122	161	62	196	51
Volatilization	0	0	35	27	65	25	90	23
Denitrification	21	12	36	28	44	17	47	10
Runoff	10	6	12	9	16	6	18	4
Soil water	6	4	8	6	14	5	20	4
Soil nitrogen	-169	-100	-119	-92	-42	16	16	4
Total	0	0	129	100	258	100	387	100
Waldo	0		129		258		387	
Crop uptake	46	60	76	59	92	36	115	30
Volatilization	0	0	35	27	65	25	90	23
Denitrification	11	14	24	19	31	12	33	9
Runoff	14	18	16	12	18	7	20	5
Soil water	6	8	7	5	12	5	17	4
Soil nitrogen	-77	-100	-29	-22	40	15	112	29
Totals	0	0	129	100	258	100	387	100

References:

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NOTES