Estimation of N and P in Florida Dairy Wastewater for Silage Systems

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Abstract

Manure management is an integral concern of Florida dairymen. Wastewater from nine dairy sprayfields on seven north Florida dairies with overhead sprinkler or gun irrigation facilities was collected biweekly from early September 1992 to January 1993. Samples were taken from the pump area of either anaerobic lagoons or settling ponds, rainfall, and from effluent plus rainfall in sprayfields. All unfiltered and filtered samples were analyzed for total Kjeldahl N, NH_4^+, NO_3^-, and P. Concentrations of different forms of N and for P were site-specific, likely due to differences in wastewater and manure handling and disposal systems and herd sizes. Based on effluent analysis, dairies were applying large and differential amounts of solids through their irrigation systems to sprayfields. This was confirmed by filtered samples, accounting for only as much as 55% of the total Kjeldahl N in unfiltered samples for one dairy. Filtered NH_4^+ levels were 41% to 85% of total Kjeldahl in unfiltered samples. Based on literature, it was estimated that most dairies were under-fertilizing existing crops for N and applying slightly above or about the right amount of P. Essentially no nitrate was produced in dairy effluent that was applied to the sprayfields.

Introduction

Typical water use per 100 dairy cows per week is 122,500 gallons during the hot season in Florida (Van Horn, et al., 1993). Heightened environmental concerns and need for resource conservation have caused implementation of water use permits and other possible regulatory actions in many states. A theoretical balanced N cycle for a dairy was suggested by Van Horn et al. (1991). They proposed that over 80% of waste N was lost in some manure handling systems before reaching the crop in the field. The concentrations and ratios of nutrients in wastewater can affect forage growth and yield (Butler et al., 1986; Johnson et al., 1991). Excess application of wastewater has been shown to reduce growth and increase leaching of NO_3^- (Hubbard et al., 1986; Hubbard et al., 1987; Hubbard and Sheridan, 1989).

Multiple cropping forage system possibilities are numerous for dairy producers (Table 1) (Gallaher and Cummings, 1976; Gallaher, et al., 1991; Johnson, et al., 1991; Mitchell and Gallaher, 1979). A typical net return of $322/acre (30 ton silage per year) from doublecropped corn for silage was reported by Gallaher et al. (1991). If nutrients from wastewater were to provide nutrients for the corn silage crops instead of applying fertilizers, net return would increase to $536/acre, a net $214/acre increase.

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Choice of a dairy forage production system that produces high quality forage (Table 1) and best utilizes recycled nutrient wastewater would be dependent upon nutrient concentrations and ratios in the dairy wastewater. Nitrogen losses from soil in the form of ammonia (NH_3) can range from 20 to 90% of applied N (Hargrove, 1988). Under laboratory conditions, N losses in the form of NH_3 have been shown to be as great as 90% when N is applied to the surface of sandy soils with very low buffering capacity (Fenn and Hossner, 1985).

According to a summary from extension publications from several states (Killorn, 1993), nutrient contents of manure from dairy feedlots ranged from 17 lb N/ton in the summer months to 12 lb N/ton in winter months. For P, it was concluded that there was about 9 lb/ton in summer compared to 7 lb/ton in the winter. It was further estimated that only 25% of the total N applied in dairy fresh or liquid manure that was not soil-incorporated was available to growing crops in the year of application. The ammonium (NH_4^+) in dairy manure and wastewater is immediately available to plants. An average of about 50% of total N in animal manures was estimated to be in the ammonium form (Killorn, 1993). Van Horn et al., (1991) estimated 40 to 50% of total N was in the ammonium form for fresh excretions of manure for lactating dairy cows depending on diet. If manure and manure effluent is broadcast and is not incorporated into the soil the NH_3/NH_4^+ balance is more likely to shift in favor of greatly enhanced losses of N in the form of volatilized NH_3.

Table 1. Nitrogen and P removal by multiple cropping systems.

Location*	N	P	K	Crop 1	crop 2	Crop 3
	Nutrient			Multiple Cropping System		
		Pounds/acre		Winter	Spring/Summer	Summer/Fall
Georgia-I	262	31	246	Wheat	Corn	
Georgia-1	321	37	280	Wheat	Forage Sorghum	Forage Sorghum
Georgia-1	296	34	311	Wheat	Sudax	Sudax
Georgia-1	265	32	264	Rye	Corn	
Georgia-1	324	37	316	Rye	Forage Sorghum	Forage Sorghum
Georgia-1	323	38	347	Rye	Sudax	Sudax
Georgia-I	251	28	223	Oat	Corn	
Georgia-l	312	38	293	Oat	Forage Sorghum	Forage Sorghum
Georgia-I	280	33	311	Oat	Sudax	Sudax
Georgia-l	250	32	273	Barley	Corn	
Georgia-l	298	40	306	Barley	Forage Sorghum	Forage Sorghum
Georgia-I	321	37	358	Barley	Sudax	Sudax
Georgia-2	452	57	302	Rye	Corn	Bermudagrass
Florida-3	357	69	402	Wheat	Corn	Forage Sorghum
Florida-4	292	42	228	—	Corn	Corn
Florida-4	339	48	293	—	Corn	Sudax
Florida-4	319	45	231	—	Corn	Forage Sorghum
Florida-4	318	39	222	—	Forage Sorghum	Forage Sorghum
Florida-4	380	48	296	—	Sudax	Sudax

Georgia-I = Unpublished research data (average of 3 years) by R.N. Gallaher, Georgia Experiment Station, Experiment, GA, 1972-1975. Dry land management on a Cecil Sandy clay loam soil.

Georgia-2 = Data from Johnson, et al., 1991, Georgia Experiment Station, Tifton, GA. Study conducted under irrigation.

Florida-3 = Data from Mitchell and Gallaher, 1979. Sulfur fertilization of corn seedlings. Soil and Crop Sci. Sci. Soc. Fla. Proc. 39:40-44. Soil type was an Arredondo tine sand, experiment was irrigated.

Florida-4 = Data from Gallaher, et al., 1991, Florida Experiment Station, Gainesville, FL. Study conducted under irrigation.

Phosphorus availability the year of application of dairy manure and effluent is estimated to be about 70% (Killorn, 1993). The effect of application of P in manure and effluent should be monitored by a soil testing program.

The objectives of this research were: (a) to quantify N and P composition of dairy waste applied to sprayfields from anaerobic lagoon and liquid manure handling systems; (b) to identify changes, if any, in dairy wastewater composition of N and P over a 4-month period; and (c) to determine forms of N and amounts of N and P applied to sprayfields used to grow forages in multiple cropping systems.

Materials and Methods

All wastewater and rainwater samples were analyzed using standard analysis procedures (Clescari et al., 1989). Wastewaters from nine dairy spray fields with overhead sprinkler or gun irrigation facilities were collected biweekly from early September 1992 to January 1993 (Table 2). Dairy wastewater was soil-surface applied in sprayfields for all dairies in the study. Samples were taken from the pump area of lagoons and ponds, rainfall gauges, and from effluent plus rainfall collected in sprayfields. Large volume rain gauges were placed in two locations of each sprayfield for replicated samples. Concentrated H_2S0_4 was added to the rain gauges to ensure no losses of N received from the effluent that was

Table 2. Characteristics of seven Florida dairies, nine sprayfields, and manure handling, irrigation, and multiple cropping systems.

Florida County	Cows	Manure	Irrigation	Multiple cropping*
	System			
	(no.)			
Gilchrist West (GW)	1,640	Anaerobic lagoon Spread manure	Stationary Guns	W/C/C W/C/S
Gilchrist East (GE)	1,640	Anaerobic lagoon Spread manure	Center pivot W/C/S	W/C/C
Levy South (BP)	2,000	2 settling ponds	Center pivot (seven)	O+R/C/C R/C
Levy South (BC)	2,000	2 settling ponds	Center pivot (seven)	O+R/C/C RIC
Lafayette South (KB)	500	Anaerobic lagoon	Guns	R/BG
Levy North (AL)	2,500	3 settling ponds lagoon/spread	Center pivot	R/C/S R/C+PP;C/BG
Gilchrist South (WH)	2,500	anaerobic lagoon spread manure	Center pivot	F/C/S
Lafayette North (SHI)	500	pond/waste wash recycledlspreads	Center pivot	O/C/S O/PP
Suwannee (SHN)	450	Pond/lagoon spread manure	Gun	O/C/S O/C/C;O/BG

*O=oat; R=rye; C=corn; S=sorghum; PP=perennial peanut; BG=bermuda grass; F=winter small grain; W=wheat

Table 3. Amount and source of water collected in 4 months from nine sprayfields on seven north Florida dairies.

Dairv	Effluent	Rainfall	Total
		Water Source	
	----------	Inches	----------
GW*	13.93	4.25	18.18
GE	10.29	4.25	14.54
BO	9.49	4.52	14.01
BC	5.16	1.35	6.51
KB	4.18	9.65	13.83
AL	2.66	8.80	11.46
WH	4.35	3.15	7.50
SHI	1.38	8.65	10.03
SHN	2.24	6.40	8.64

*See code identity in Table 2.

Table 4. Cumulative Kjeldahl N and forms of N and P in effluent plus rainfall collected in 4 months from nine sprayfields on seven north Florida dairies.

	Plant Nutrient Form and Type of Analysis					
Dairy	Unfiltered N	Filtered N	Filtered NH_4+	Filtered NO_3^-	Unfiltered P	Filtered P
	----------	----------	Pounds/acre	----------	----------	----------
GW*	373**	206	153	1.14	60	57
GE	569	411	243	0.63	102	97
BO	329	306	183	0.48	73	111
BC	158	118	87	40.35	11	11
KB	209	133	111	6.30	32	11
AL	215	191	109	0.76	41	34
WH	113	104	76	19.07	16	18
SHI	164	138	92	2.20	33	38
SHN	55	53	46	0.22	17	24

*See code identity in Table 2.

**Amounts = total water received (Table 3); concentrations determined from rain gauges.

Table 5. Average Kjeldahl N and *forms* of N and P in pond effluent collected biweekly in 4 months from seven north Florida dairies.

	Plant Nutrient Form and Type of Analysis					
Dairy	Unfiltered N	Filtered N	Filtered NH_4+	Filtered NO_3^-	Unfiltered P	Filtered P
	----------	----------	Pounds/acre	----------	----------	----------
GW*	38.7	15.0	10.3	0.04	7.7	1.8
GE	38.8	15.0	10.3	0.04	7.7	1.8
BO	33.4	27.1	15.8	0.01	7.4	3.9
BC	23.5	20.1	15.7	0.01	9.5	5.9
KB	46.7	37.2	27.0	0.01	7.8	0.7
AL	59.8	39.2	26.4	0.02	13.8	2.0
WH	29.4	22.3	17.5	0.01	6.1	3.3
SHI	73.3	42.5	44.1	0.01	16.3	2.1
SHN	30.2	25.5	15.0	0.02	7.1	2.3

*See code identity in Table 2.

sprayed on the field from one 2-week period to the next. Rain gauges were also used to collect data on rainfall.

All unfiltered and filtered samples were analyzed for total Kjeldahl N, and P using standard analysis procedures (Clescari et al., 1989). Total Kjeldahl N was analyzed using a semi-micro Kjeldahl digestion method (Gallaher, et al., 1976) followed by colorimetric determination with an autoanalyzer. A 30-mL portion of either unfiltered or filtered sample was placed into 100-mL digestion tubes along with 3.2 grams salt-catalyst (9:1 salt-catalyst ratio of anhydrous K_2SO_4:$CuSO_4$), and 10 mL of concentrated H_2SO_4. The water samples were evaporated slowly over several hours in an aluminum block digester at 150 °C then digested at 375 °C for a minimum of *2.5* hours (Gallaher, et al., 1975). Samples were cooled, vortexed while being diluted with deionized water, and brought to 75 mL volume at room temperature. Filtered samples were analyzed for NH_4^+ and NO_3^- concentrations using automated cadmium reduction and phenate processes, respectively (Alpkem Rapid Flow Analyzers).

Total P was determined on filtered samples by colorimetry. Total P was determined on unfiltered samples as follows: 100 mL of water was evaporated to dryness in pyrex beakers on a hotplate over several hours. Beakers were placed in a muffle furnace and ashed for a minimum of 8 hours. Upon cooling, 2 mL concentrated HC1 plus 20 mL of deionized water were added to each beaker and slowly evaporated to dryness on a hotplate. Upon cooling, *2* mL of concentrated HC1 plus 20 mL of deionized water were added to each beaker once more. A watch glass was placed over each beaker and samples were brought to a vigorous boil, removed from the hotplate and cooled. Each sample was washed into volumetric flask and brought to 100 mL volume. The same digestion procedure was conducted on the deionized water, HCl, and blank beakers to account for any possible contamination of P. These ashed samples were analyzed for P using colorimetry.

Results and Discussion

Effluent and rainwater received on the nine sprayfields ranged from 18.2 inches/acre to 6.5 inches/acre for GW and BC dairies, respectively for the 4-month period (Table 3). Total effluent received on sprayfields was highly positively related to the total N and NH_4^+ applied (Tables 4 and 5). Differences in unfiltered and filtered N analysis indicated that a significant amount of manure solids were applied through the irrigation systems (Table 4). In contrast to GW dairy, 93% and 89% of total N was in filtered samples compared to unfiltered for the BP and AL dairies, which indicated that these systems, which utilized settling ponds to separate manure, provided cleaner water for irrigation (Table 4).

The NH_4^+ ranged from *25%* to 85% of total unfiltered N applied to sprayfields (Table 4). Virtually no NO_3^- was applied to sprayfields from dairy wastewater (Table 4). The NO_3^- measured at the BC and WH dairies was due to fertilizer N injection into the center pivot irrigation system to supplement manure nutrients to meet crop needs. Nitrogen deficiency symptoms were evident in crops at both locations, requiring supplemental N fertilization. If we assume that only 25% of the total unfiltered Kjeldahl N was actually available to crops (Killorn, 1993), then N available for crop growth ranged from 142 lb N/acre/4 months to 14 lb N/acre/4 months (Table 4). These low levels of available N would not be sufficient to optimize crop growth for most forage crops over a 4-month period (Gallaher, et al., 1991).

The Kjeldahl N for filtered samples ranged from 39% to 86% of unfiltered samples indicating, as did field samples, that significant and differential quantities of solids were being applied on dairy sprayfields (Table 5). Large quantities of NH_4^+ were found in lagoons and ponds but almost no NO_3^- was found (Tables 5 and 6). Dairies, such as AL and SHI, reused lagoon and pond water for cleaning dairy facilities, which is the likely reason for higher levels of N in samples from these locations (Table 5). Based on the total effluent applied to sprayfields (Table 3) N estimates based on pond and lagoon effluent analysis were made (Tables 6, 7 and 8). Again, the results were extremely site-specific and compared somewhat favorably with field measurements for some dairies but not so well for others (Table 4).

Analysis of spray-field samples (Table 4, 7, and 8) and rainwater (Gallaher, et al., 1994) showed differential amounts of P received by crops. Rainwater P seemed to be high compared to what was reported in southern Florida (Anderson and Howell, 1993). Dust contamination likely occurred due to the 2-week periods between removal of rainfall from gauges.

Most of the P appeared to be associated with solids in the lagoon and pond samples (Tables 5, 6, and 7). Average P in filtered effluent ranged from 0.7 lb/acre-inch to 5.9 lb/acre-inch (Table 5) and was 9% to 69% of unfiltered P (Table 5), indicating high levels of solids in the effluent.

Based on effluent applied (Table 3), estimated P applied based on lagoon and pond analysis (Table 4) by some dairies would have been as much as 111 lb P/acre in a 4-month period. If 70% of this unfiltered P were available to growing crops (Killorn, 1993) then some dairies still applied slightly more P than typical forage crops would have required (Table 1) (Mitchell and Gallaher, 1979; Gallaher, et al., 1991). Most dairies applied 35 lb P/acre or less during this same period and would likely be adequately meeting the P requirements of most forage crops.

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Table 6 Predicted total Kjeldahl N and forms of N and P applied to nine sprayfields based on effluent collected and pond effluent analysis in 4 months from seven north Florida dairies.

	Plant Nutrient Form and Type of Analysis					
Dairy	**Unfiltered N**	**Filtered N**	**Filtered NH_4+**	**Filtered NO_3^-**	**Unfiltered P**	**Filtered P**
	Pounds/acre					
GW*	539**	209	144	0.56	107	25
GE	398	154	106	0.41	79	19
BO	317	257	150	0.10	70	37
BC	121	104	81	0.05	49	30
KB	195	156	113	0.04	33	3
AL	159	104	70	0.05	37	5
WH	128	97	76	0.04	27	14
SHI	102	59	61	0.01	23	3
SHN	68	57	34	0.05	16	5

*See code identity in Table 2.

** Amounts = Total water applications (Table 3) - concentrations determined in storage ponds.

Table 7. Nitrogen available in a 4-month period for crop utilization based on the N and P in filtered samples from samples collected in sprayfields and from pond analysis.

	N			P		
Dairy	**Field**	**Pond**	**Average**	**Field**	**Pond**	**Average**
	Pounds/acre					
GW*	51	52	52	40	18	29
GE	103	39	71	68	13	41
BP	76	64	70	78	26	52
BC	30	26	28	8	21	15
KB	33	39	36	8	2	5
AL	48	26	37	24	4	14
WH	26	24	25	13	10	12
SHI	35	15	25	27	2	15
SHN	13	14	14	17	4	12

*See code identity in Table 2. Nitrogen availability is based on an expected 75% losses due to volatilization and denitrification because the effluent was placed on the soil surface. P availability for immediate uptake is based on 70% of the P in filtered samples.

Table 8. Estimated N and P per month and 12 months based on 75% N losses and 70% P available from filtered samples taken over 4 months (Based on pond analysis).

	N		P	
Dairy	**1 month**	**12 months**	**1 month**	**12 months**
	Pounds/acre			
GW*	13	156	4.5	54
GE	10	120	3.3	40
BP	16	192	6.5	78
BC	7	84	5.3	64
KB	10	60	0.5	6
AL	7	84	1.0	12
WH	6	72	2.5	30
SHI	4	48	0.5	6
SHN	4	48	1.0	12

*See code identity in Table 2.

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