AGRONOMIC IMPLICATIONS OF DAIRY EFFLUENT WATER REUSE

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ABSTRACT

New Mexico dairies generate a waste-water stream that is often used for land application. The water contains nitrogen that must be applied according to statutory limits or can be based on agronomic considerations. However, the effluent water also contains other nutrients as well as salinity components that may have a greater impact on crop production and environmental sustainability. A survey of New Mexico dairy lagoons was done in the fall of 2003 in order to assess relevance to published nutrient values as well as to establish what dilutions would be necessary to meet nitrogen needs and reduce salinity components. The mean dilutions needed for meeting statutory nitrogen application rates was 3.73 : 1 versus 4.36 : 1 if mineralization and volatilization factors were considered. The mean dilution was 1.9 : 1 to keep salinity less than 3 dS/m but was greater for both sodium and chloride ions. Dilutions for sodium averaged 4.5 : 1 while chloride average 4.7 : 1. These dilutions are slightly greater than what is required for nitrogen. Best management practices of lagoon water effluent should include actual analyses of lagoon water taking into account salinity components for the long-term sustainability and profitability of crop production.

INTRODUCTION

New Mexico is one of the ten major dairy-producing states. Dairies are concentrated in four distinct regions of the state. Areas near Roswell and the Mesilla Valley are affecting agriculture in at least two important ways: 1) the generation of large amounts of manure and effluent in a small area and 2) increased demand for certain crops such as alfalfa and hay feed. All three areas must utilize wastewater in a limited area or rely on evaporation to avoid land application. The New Mexico Department of the Environment regulates land application of nitrogen from dairies with statutory authority to limit total-N application to 125 percent of what is reasonably expected to be removed by a managed crop. Utilizing dairy wastes as soil amendments on cropland may improve soil quality and increase yields if salinity is controlled or managed effectively (Kurunç et al., 2004). However, process water can include elements such as sodium and chloride as well as total salinity that can limit primary production. In many cases fresh irrigation water is limited for crop production and effluent water may be used to make up the difference needed for optimum crop production.

MATERIALS AND METHODS

Seventy-seven dairy lagoon waters were sampled in 2003 to evaluate key properties that affect its use for crop production. Water availability, nitrogen species, total salinity, and salinity components are the most important factors that will determine acceptable application rates. All water samples were collected as a composite of at least five subsamples from near where the water was removed for land application. No facility was equipped to agitate their lagoons prior to application as is recommended by Peters et al., 2003. The samples were put on ice and then shipped to Ward Laboratories, Kearney, NE, for analysis. Analyses included total-N, organic-N, ammonium-N, total phosphorus, potassium, magnesium, calcium, sodium, chloride, electrical conductivity, and pH. Samples were not preserved for nitrogen species by acidification.

Nutrient results were converted to pounds per acre-inch and sodium and chloride were converted to meq/L for evaluating the water sources for irrigation purposes. Dilutions were calculated based on meeting a 200 lb total-N/A and a crop water requirement of 24 acre-inches. This quantity of water is less than what would be required for optimum growth but does reflect the quantity needed during the most rapid period of growth for a crop such as corn. Dilutions were also calculated for effluent water where 35 percent of the organic-N was assumed to mineralize and 10 percent of the ammonium-N was assumed to volatilize. No losses were assumed for denitrification. Parameter statistics include the mean, median, standard error, maximums and minimums. Dilutions for nitrogen requirements were compared to dilutions needed to minimize the effects due to chloride, sodium, and total salinity.

RESULTS AND DISCUSSION

Nitrogen

Seventy-five of seventy-seven sampled lagoons are presented here. Sierra county sample results were so different from the other locations that they were dropped from this analysis. There were no differences among counties as determined by using the least squares means procedure in SAS, 1997. Mean total-N was 413 mg N/L (Table 1). Nearly 62 percent of the nitrogen in the sampled lagoons was in the ammonium form and ranged from 21 to 99 percent. Nitrate-N concentrations were less than 0.8 mg/l for all lagoons with a mean of 0.3 mg/L which contributes a negligible amount of inorganic-N compared to ammonium-N.

Agronomists working with land application of effluent water under the statutory constraints of the Water Quality Control Commission realize that applications of organic N containing effluent may not meet the nitrogen needs of a given crop. The traditional approach is to estimate the mineralization of the organic fraction and assign a percentage loss of ammonia based on conditions at the time of application. Denitrification could also occur but is excluded from this example. The example put forth here suggests that the mean application rate to stay within statutory limits would be 3.73 acre-inches of effluent (Table 2). The mean rate to apply is slightly higher at 4.35 acre inches if using the assumption of 35 percent mineralization from the organic-N and a 10 percent loss of the ammonium. The minimum rates between the two methods were similar at near 0.8 acre-inches. The maximum calculated application rate, however, was almost 5.2 acre-inches more than that of the statutory rate.

Nearly all land applied effluent is used for irrigated crop production. Declining water tables and limits to water withdrawal from both surface and aquifer water reduces the amount of water available for crop production. Adjudicated water-rights in some parts of New Mexico limit the annual ground water withdrawal to 36 acre-inches. Nitrogen from effluent water should be applied according to soil test results. Nitrogen should be applied to match the nitrogen needs for the crop. Corn would need most of the nitrogen from effluent water up to the R1 stage of growth which could correlate to approximately 24 acre-inches of water. The mean dilution under NMED limitations with limited water would be approximately 9:1 versus 7.7:1 using the stated agronomic approach (Table 2). Once this dilution is established then the dilutions needed to minimize the effects of sodium, chloride, and total salinity needs to be considered.

Salinity

Irrigation water salinity should be kept below 3 dS/m. Effluent water salinity exceeds limits as a suitable irrigation water source (Table 3). Dilution is necessary in order to reduce the effects of salinity on plant performance. The mean salinity of the reported lagoon samples was 5.5 dS/m. The mean dilution was 1.9 : 1 or close to 2:1 in order to keep the applied salinity to less than 3 dS/m (Table 4). Diluting the effluent to meet nitrogen needs could keep salinity from being a serious problem even at the maximum salinity dilution of 4.6:1. The better the irrigation water quality the less effluent will be tolerated. In almost all cases, applying the effluent water in a diluted form to meet the yearly calculated N application rate is sufficient to reduce the effects of total salinity. However, it is important that effluent water not be applied to a growing crop without being diluted. Pre-mixing the irrigation water with the effluent water before land application is key to making salinity a nominal concern.

Specific ion concerns

Specific ion effects can be problematic for different crops. The mean dilution to keep sodium below extreme problematic conditions is less than the N based dilution. However, the dilution could be as high as 21:1 to avoid problems in which case less nitrogen would be applied to the field. Chloride dilutions were similar to sodium with a mean dilution of 4.7:1 and a maximum of 20:1 in order to reduce the chloride concentration to less than 3 meq/L.

Long-term expectations

Soil test phosphorus can be expected to increase in New Mexico soils with the addition of effluent water. The amount of phosphorus supplied at the mean application rate to meet statutory nitrogen requirements would be near 55 pounds per acre (125 lb P_2O_5 per acre). A comparison of fields that have received manure versus no manure is given in Table 5.

Potassium could also be a concern especially with grass crops. The ratio of monovalent to divalent cations in forages should be kept at levels that won't induce grass tetany problems. Applications would average 515 pounds K per acre (618 lb K_2O/A) at the statutory nitrogen application rate. Potassium loading varied from 26 lb K/acre inch of effluent to 471 lb/acre inch. Water soluble levels of potassium in the soil have also increased in fields receiving manure and effluent water (Table 6).

CONCLUSIONS

Given the range of effluent water characteristics it is best if "book" values are not used. Decisions should be based on individual lagoon water characteristics. This is particularly important when total salinity, sodium, or chloride contents are excessive. Fields that receive effluent water are usually used in the long-term as the infrastructure needed to deliver water is not something that can be easily moved from one location to another. Annual soil sampling that includes salinity assessment and a complete assessment of nutrients will help optimize the beneficial reuse of effluent water on New Mexico soils.

REFERENCES

Kurunc, A. R.P. Flynn, and A.L. Ulery. 2004. Dairy lagoon effluent effects on soil chemical properties, corn yield and nutrient uptake. J. Agron. 3:219-222.

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Table 1. Lagoon water nitrogen characteristics.

County	n	Total-N				Org-N				NH_4-N			
		Mean	SE	Max	Min	Mean	SE	Max	Min	Mean	SE	Max	Min
		mg/l											
Chaves	7	327	28	445	241	153	24	246	55	181	34	357	104
Curry	18	350	53	801	69	146	29	395	1	203	28	406	32
Dona Ana	7	407	113	1010	86	181	94	714	25	225	31	296	61
Eddy	3	449	159	760	237	152	25	194	107	297	135	566	130
Lea	12	475	84	1228	215	208	59	760	34	268	30	468	126
Roosevelt	26	451	49	1347	146	158	21	393	4	293	40	998	80
Torrance	1	223	-	-	-	105	-	-	-	118	-	-	-
Valencia	1	548	-	-	-	176	-	-	-	387	-	-	-
Pooled	75	413	28	1347	69	164	16	760	1.3	250	18	998	32

The mean fraction of ammonium-N to total-N was 0.62 with a standard error of 0.02, a minimum of 0.21 and a maximum of 0.99. There were no significant differences among counties.

Table 2. Dilutions needed in order to reduce season applied nitrogen to the statutory 200 lb N/A (plus 25 percent) or to 200 lb of nitrogen using a mineralization potential of 35 percent of the organic fraction and a 90 percent recovery of applied ammonium-N. The mean acre-inches of water is shown. Dilutions are based on 24 acre-inches applied water.

Statutory					Mineralization / Volatilization				
x Fresh water : 1 effluent water				acre-inches	x Fresh water : 1 effluent water				acre-inches
Mean	SE	Min	Max	Mean	Mean	SE	Min	Max	Mean
9.0	0.6	1.5	29.3	3.7	7.7	0.3	1.1	27.7	4.4

Table 3. Lagoon water salinity and dry matter characteristics from a fall sampling in 2003.

County	n	Total-Salinity				Sodium				Chloride			
		Mean	SE	Max	Min	Mean	SE	Max	Min	Mean	SE	Max	Min
		mg/l				meq/l				meq/l			
Chaves	7	4.7	0.6	7.6	2.9	12.2	2.9	27.2	5.0	12.4	2.4	24.7	6.0
Curry	18	5.0	0.5	10.2	2.2	9.8	2.3	38.8	1.7	12.6	2.3	38.6	4.6
Dona Ana	7	5.3	0.4	6.9	3.6	18.8	3.3	34.4	4.6	16.7	3.6	34.9	3.6
Eddy	3	5.5	1.5	8.5	3.9	9.2	3.9	17.0	4.9	11.4	4.3	20.0	7.0
Lea	12	5.3	0.4	7.8	3.5	8.9	5.9	15.6	4.5	10.7	1.4	22.0	5.8
Roosevelt	26	6.3	0.5	13.4	3.4	16.5	3.2	60.8	3.3	16.5	3.2	58.2	3.3
Torrance	1	3.1	-	-	-	4.7	-	-	-	7.2	-	-	-
Valencia	1	5.0	-	-	-	15.8	-	-	-	12.9	-	-	-
Pooled	75	5.5	0.2	13.4	2.2	13.0	1.4	60.8	1.7	13.6	1.2	58.2	3.0

Table 4. Dilutions needed to keep selected salinity parameters below levels that would cause severe problems with soil or plant productivity. Nitrogen is included again as a point of reference when basing applications on potential mineralization and volatilization in order to meet a 200 pound/acre plant requirement.

		Fresh water : 1 effluent water			
	rule	Mean	SE	Min	Max
Nitrogen (mineralized)	= 200 lb/A	7.7	0.3	1.1	27.7
e.c.	< 3 dS/m	1.9	0.1	0.8	4.6
Sodium	<3 meq/L	4.5	0.5	0.4	21.0
Chloride	<3 meq/L	4.7	0.4	1.0	20.1

Table 4. Other lagoon water characteristics.

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County	n	P				K				pH	DM
		Mean	SE	Min	Max	Mean	SE	Min	Max	Mean	Mean
		mg/l									fraction
Chaves	7	32	4.5	19	52	355	86	123	687	7.9	0.35
Curry	18	60	9.5	17	186	658	115	207	2060	7.8	0.56
Dona Ana	7	67	29.0	17	240	408	102	114	958	7.5	0.49
Eddy	3	52	18.3	22	85	784	444	331	1673	8.0	0.64
Lea	12	82	19.5	25	277	543	79	206	943	7.7	0.69
Roosevelt	26	71	7.8	29	181	727	96	170	2080	7.8	0.62
Torrance	1	33	-	-	-	230	-	-	-	7.4	0.20
Valencia	1	68	-	-	-	532	-	-	-	7.5	0.45
Pooled	75	65	3.3	17	277	609	30	113	2080	7.8	0.57

There were no significant differences among counties. Statistics for each county are shown to show the distribution and number of samples submitted for each county.

Table 5. Soil test phosphorus from New Mexico production fields receiving manure and/or effluent water.

P (Olsen) range			No manure	Manured
lo	hi		*Frequency*	*Frequency*
0	3		20	0
4	7		38	0
8	11		32	0
12	15		21	0
16	19		17	0
20	23		11	0
24	30		8	0
31	38		8	0
39	57		2	3
58	77		0	1
78	116		0	4
117	154		0	3
155	232		0	1
233	387		0	2
>387			0	0
		n=	157	14

Table 6. Water extractable potassium (New Mexico standard) from New Mexico production fields that either have used manure and / or effluent water or not.

K (water)			No Manure / Effluent	Manure / Effluent
Range			*Frequency*	*Frequency*
lo	hi		67	0
0	40		58	2
41	80		18	2
81	120		4	5
121	160		4	0
161	200		3	1
201	240		1	0
241	280		1	0
281	320		1	4
		n=	157	14