Monitoring Soil Nutrients and Water Quality on Soils Irrigated with Liquid Swine Effluent

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Introduction

Liquid swine effluent is a valuable source of crop nutrients, but is limited by a low concentration per unit volume. Innovative approaches to applying liquid swine effluent to agricultural land include tanker application and drag-line hoses. Another option has been implemented by a swine barn in Saskatchewan.

Elite Stock Farm Ltd. (ESFL) is an intensively managed swine barn located southwest of Outlook, near the South Saskatchewan River. In 1994, ESFL initiated a program to inject the liquid fraction of swine effluent along with irrigation water into irrigation pivots for application to agricultural land (Henry, 1997).

Monitoring of soil nutrient concentration and water quality has been ongoing at ESFL since 1994. Data collected has included: field and laboratory measurements of effluent chemistry, monitoring quantity of effluent applied by irrigation, soil nutrient analysis, crop nutrient uptake, and groundwater quality measurements. The monitoring data has been summarized three times, most recently in 2008 (Japp and Schoenau, 2008). This poster will provide a synopsis of the findings since 1994.

Background and Objectives

The analysis of soil and water at ESFL was carried out to assess the nutrient load applied to lands receiving liquid swine effluent, to evaluate the nutrient balance, and to assess the health of the aquifer feeding the ESFL supply well, which underlies much of the application area.

Elite Stock Farm began operating in 1990 as a 540-sow farrow to finish operation, with an expansion in 1993. In 1994, ESFL began injecting the liquid fraction of the swine manure into irrigation pivots along with river water.

There are four effluent cells at Elite. The first cell is bottom loaded, and the next three cells overflow through a pipe from the preceding cell. Most of the solids remain in cell 1. Effluent from cells 3 and 4 can be injected directly into an irrigation line, while a separator is used to remove the solids from cell 1 and 2 before injection

Summary of Findings

Effluent Analysis

Ammonium-N made up 74% of the total N for all cells from 2002-07, which was higher than previously reported (Table 1).

In cells 1-3, P concentration increased 6-10 fold from 2002-07. In cell 1, P concentration increased 10 fold from 1997-2007. The higher P content in cell 1, and to a lesser extent in cell 2, is because P tends to be bound to the solid fraction.

Potassium and sulfur concentration showed little variation since 1997.

Sodium Adsorption Ratio (SAR) was calculated in 2005 and 2006 only. SAR ranged from 2 to 14 amongst all cells. Higher SAR levels at ESFL appear to be related to instances of low Ca^{2+}, rather than high Na^{+}.

Since the 2000 report, effluent analysis was based on only one sample, limiting confidence in comparisons.

Table 1. Comparison between nutrient content of effluent previously reported (Henry 1997 and 2000) and the most recent measurement available (2007).

Year	Cell	pH	E.C.	Total N	NH_4-N	Total P	Total K	Total S
			mS cm^{-1}	--------- lbs 1000 gal^{-1} ---------				
1997	1	--	19.2	43	32	2	11	--
1999	1	7.1	16.0	29	18	7	11	2
2007	1	--	14.4	59	39	22	12	6
1997	2	--	--	--	--	--	--	--
1999	2	7.3	15.0	39	23	22	13	4
2007	2	--	15.4	45	32	13	13	4
1997	3	--	17.9	25	20	1	9	--
1999	3	7.8	15.0	24	14	1	13	1
2007	3	--	17.2	27	24	3	11	1
1997	4	--	14.8	18	19	1	9	--
1999	4	--	--	--	--	--	--	--
2007	4	--	15.2	21	20	1	10	1
1997	All	--	17.3	28.7	23.7	1.3	9.7	--
1999	All	7.4	15.3	30.7	18.3	10.0	12.3	2.3
2007	All	--	15.6	38.0	28.8	9.8	11.5	3.0

Monitoring Soil Nutrients

From 2000-2007, total N applied ranged from 40 to >300 lbs N ac^{-1} and over 450 lbs N ac^{-1} in a small area that received overlap application from two pivots. Despite repeated annual applications at high rates of N, soil test N generally remained below the average background for irrigated soils in the district (Table 2). Effluent N applied in excess of crop needs may accumulate in organic forms, or be lost through leaching, volatilization and denitrification.

Table 2. Soil test data for all fields in South Saskatchewan Irrigation District #1 (lbs ac^{-1} from a 0-12" sample depth) (Bardak-Meyers, 1996).

Soil test	Irrigation	Dryland
N	129	36
P	40	18
K	916	956

Until 2005, applied P was less than 100 lbs P_2O_5 ac^{-1}. In 2007, some fields received 250-300 lbs P_2O_5 ac^{-1}. In most of the soils evaluated, soil test P was at levels where little or no crop response would be anticipated from further P additions.

Soil test K levels appear to be increasing over time. Occasional year-by-year increases are beyond the level applied. Random sampling or NH_4 displacing K from clay interlayers may be the cause.

Soil Nutrient Budget

A simple, cumulative nutrient budget was completed for the years since 2000. Assumptions were required as crop rotation and yield data were not available for pivots with annual grains, nor was specific pasture utilization available. Average yields and crop removal for an irrigated wheat-canola-barley-wheat rotation were used. For pasture it was assumed that all of the nutrients applied were converted to plant matter and consumed, with retention values employed for cattle that were grazed on the paddocks, and the rest returned as manure and urine.

At ESFL 58 to 87% of N was unaccounted for. Volatilization losses are expected to be very high in this system, both from the application and from exposure to bare soil in the crested wheatgrass (CWG) pasture. Denitrification is also probable, as denitrification can occur in less than saturated conditions, and conditions of high soil moisture are more frequent on irrigated land. Leaching is probable, but after 11 years of groundwater monitoring, no significant nitrate accumulation is occurring.

Groundwater Monitoring

Three piezometers have been measured since 2000 (selected data shown in Table 3). In many, the maximum recorded values to date are in the most recently sampled year. Notably, although NO_3 has increased, the levels are well below safe thresholds. However, of greater concern, all three piezometers showed increases in total and fecal coliforms.

Table 3. Water quality results for piezometer 1A (18.65m below ground).

Date	TDS	pH	EC	Na^+	Ca^{++}	Mg^{++}	K^+	Cl	SO_4	NO_3	HCO_3	Tot Alk	P	B	Hard-ness	SAR	TCOL	FCOL
	mg L^{-1}		µS cm^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}		Orgs dL^{-1}	Orgs dL^{-1}
12-Dec-93	557	7.0	0.9	74	85	26	3	11	263	3.0	240	N/A	0.13	0.1	N/A	1.8	Nil	Nil
12-May-94	608	7.7	**1.0**	71	88	26	3	12	**270**	4.3	238	N/A	0.09	0.07	N/A	1.7	N/A	N/A
31-Oct-94	550	**7.8**	0.9	80	93	**30**	2	13	258	<0.4	126	N/A	0.01	0.05	N/A	1.8	Nil	Nil
11-Oct-95	576	**7.8**	0.9	**83**	**94**	29	4	11	96	0.3	258	N/A	0.07	0.09	N/A	**1.9**	Nil	Nil
04-Nov-96	**734**	7.7	0.9	75	92	27	N/A	13	259	2.0	**266**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12-Dec-05	486	7.5	0.8	47	88	25	**6**	**21**	172	**5.4**	241	**198**	**<5**	**<5**	**324**	1.1	**226**	**<10**

Summary and Conclusions

Based on the evidence, it is concluded that:

1. P content of the effluent has increased; however, this trend is based on a limited number of samples in recent years.

2. Soil nitrate has been high in some cases, observed in spikes associated with high effluent application rates. Generally, soil nitrate is within expectations for irrigated soil.

3. Most fields are showing elevated soil P.

4. Nutrient budgets indicate a large amount of N applied that could not be accounted for. Collection of empirical yield and protein from annually cropped fields, and stocking rates and grazing days for pastures would help refine the budgets.

5. Coliform presence in the groundwater is a concern. Sampling has been infrequent, and it is possible samples were contaminated. Further testing is warranted. Low nitrate levels do not indicate a high degree of leaching.

Acknowledgements

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