Report as of FY2007 for 2006IA94B: "Impact of Swine Manure Application on Phosphorus, NO3-N, Bacteria, and Antibiotics Concentrations in Surface Runoff and Subsurface Drainage Water"

Publications

Project 2006IA94B has resulted in no reported publications as of FY2007.

Report Follows

Problem Statement and Research Objectives

The agricultural sector, including animal production, has been identified as a leading source of water quality impairment in the nation's soil and water resources (USEPA, 1995). Over 56,000 km of rivers in the United States has been contaminated and 40% of these are unfit for fishing or swimming (USEPA/USDA, 1998). The non point source pollution originating from agricultural fields has not only contaminated the adjoining streams and lakes but also has left the far reaching effects such as the hypoxic zone in the Gulf of Mexico. Concentration of animals into larger production facilities is a cause for water quality concerns. When manure is misapplied (especially over applied) the quality of nearby waters can be compromised. Bacterial movement to surface and groundwater from manure applications is also of concern, however, and the same studies showed differences in bacterial numbers between treated and untreated plots from swine manure. More information is needed on the movement of N, P, bacteria and antibiotics associated with manure through soils and wetlands, and on the processes involved as the manure liquid moves through the soil water system on different landscapes. The proposed project will also bring very useful information for the state of Iowa to know the contribution of bacteria from liquid swine manure in contaminating surface and groundwater supplies.

Animal production systems, especially swine and poultry, in Iowa have changed significantly in recent years. Iowa is #1 swine producing state in the country. Today's animal production systems are becoming larger, and the public is concerned about the impacts of animal production facilities on surface and groundwater quality. Of particular concern are surface runoff losses of antibiotics, pathogens, nitrogen (N) in the forms of NH_4-N, NO_3-N, and organic-N, and phosphorus (P) as PO_4-P and organic-P, and leaching losses of NO_3-N, PO_4-P, antibiotics and bacteria into subsurface drainage water. Presence of pathogens and antibiotics in water bodies can be major sources of health related concerns. Antibiotics are commonly used as feed additive in animal production. Most of the antibiotics fed to animals are excreted in urine or manure. Once excreted, these antibiotics can enter surface and/or ground waters through non-point source pollution from manure-applied lands.

Determining the water quality effects of applying liquid swine manure to croplands will help us determine whether swine manure is a viable source of plant nutrient without polluting Iowa's water sources from two major water quality deterioration nutrients, N and P. If manure-born bacteria and manure containing antibiotics are moving through the soil profile into subsurface drainage water and to the deeper groundwater, manure application rates and methods may need further adjustments to minimize water quality deterioration from pathogens and other bacteria from swine manure. If the bacteria detected in the water quality tests are not from manure, further research may be needed to understand these processes better. Understanding the processes that are occurring in the soil-water system after the application of manure will help engineers and scientists design better, more efficient, and less polluting landscape treatment systems for managing excessive animal manure from large livestock production facilities. We expect to develop and recommend appropriate manure and nutrient management practices to producers to reduce the water contamination potential from manure applications and enhance the use of swine manure as an alternative to the use of inorganic fertilizers for sustainable agriculture. Not much data is available on the presence of antibiotics in water bodies. This study will attempt to create a new/additional data set on the presence of nutrients, pathogens and antibiotics in surface and subsurface drainage waters for public use from controlled manure management systems.

This research will be conducted on 36, 0.4 ha (1 acre) experimental plots at the Iowa State University Northeast Research Center near Nashua, Iowa. The overall objective of this project is to investigate the impact of swine manure on water quality and understand the soil microbial and chemical processes occurring within the soil profile of swine manure receiving croplands. The secondary objective is to evaluate different nutrient management systems and implement the best systems on Iowa's landscape so that effluents from watersheds can be discharges to Iowa's water bodies safely. Rather than answering the question "what's happening?" the proposed project will also answer the question "why is it happening in the proposed treatment system?"
Specific objectives of this proposal are:

i) to determine the impact of recommended rates of swine manure, based on N and P uptake requirements of crops on water quality,
ii) to study long-term effects of over-application of swine manure on nitrogen, phosphorus, and bacteria leaching to shallow groundwater, and
iii) to study the effects of spring and fall injection methods of swine manure application on crop yields, and nitrogen, phosphorus, bacteria and antibiotics concentrations in surface runoff and shallow groundwater.

Methods

The field experiments for this proposed study were conducted at the Iowa State University's Northeast Research Center near Nashua, Iowa. The soils at the site include Floyd loam (fine-loamy, mixed, mesic Aquic Hapludolls), Kenyon loam (fine-loamy, mixed, mesic Typic Hapludolls), and Readlyn loam (fine-loamy, mixed, mesic Aquic Hapludolls) (Kanwar et al., 1997). These soils have a seasonally high water table and benefit from a subsurface drainage system. Subsurface drains at this site were installed in 1979 at 1.2-m depth and with 28.5-m spacing. The site has 36 plots, 0.4-ha (58.5 m x 67 m) in size with fully documented tillage and cropping records for the past 25 years. Each plot has an independent drainage sump with flow meter for measuring subsurface drain flows and collecting composite water samples for chemical and bacteria analysis. Drainage water sampling frequency averaged three times a week if subsurface drains were flowing. Subsurface drain water samples were collected and refrigerated until chemical analyses were made. More details on subsurface drainage system and water quality monitoring program at this site are given by Kanwar et al. (1999).

The field experiments conducted at the site can be divided into three phases. The ***First phase*** of research experiments were conducted from 1990 to 1992 where effects of four tillage systems of chisel plow (CP), moldboard plow (MB), ridge tillage (RT) and no-tillage (NT) systems on subsurface drain water quality were investigated. In addition, during the first phase, three cropping systems of continuous corn, corn-soybean and soybean-corn with N-application rate of 202 kg-N ha^{-1} for continuous corn, and 168 kg-N ha^{-1} for rotated corn were applied in a randomized complete block design and results of the first phase of the study are reported by Kanwar et al. (1997). In the fall of 1992, new experiments were implemented at this site as part of the ***second phase*** of the study which lasted from 1993 to 1998. In the second phase of this study, tillage systems were reduced to two (chisel and no-till) and nine N-management treatments were studies averaging N-application rates of 110 and 156 kg-N ha^{-1} with single preplant and late spring soil test based N-application to rotated corn plots, respectively. The average N-application rates from swine manure for continuous corn and rotated corn plots in the second phase were 160 and 136 kg-N ha^{-1}, respectively. The results of the second phase of the study were reported by Kanwar et al. (2005), and Bakhsh et al. (2004, 2005). ***The third phase*** of research experiments at this site began in the fall of 1999 with a six year plan of work to evaluate six different nutrient management systems using swine manure as a primary source of plant nutrients. In the third phase of the study, continuous corn production system was eliminated and more N-management treatments, using swine manure, were implemented with average N-application rate of 168 kg-N ha^{-1} (or 150 lb-N/ac) either fertilized with UAN or liquid swine manure. Table 1 gives experimental treatments established for the six year (2000-2006) study currently being conducted at the Nashua research site.

Table 1. Experimental treatments for the Nashua site for the manure management study.

Treat-ment No.	# of plots per tre-atment	Application timings and source of N	Crop	Tillage	Application method	Application rate, kg/ha	
						N-based rate	P-based rate
1	3	Spring (UAN)	Corn	CP	Incorporated	168	As needed*
	3	-	Soybean	CP	-	-	As needed
2	3	Fall (manure)	Corn	CP	Inject	168	-
	3	-	Soybean	CP	-	-	As needed
3	3	Fall (manure)	Corn	CP	Inject	168(manure+UAN)	-
	3	-	Soybean	CP	-	-	As needed
4	3	Fall (manure)	Corn	CP	Inject	168(manure+UAN)	P-based (corn uptake)**
	3	Fall (Manure)	Soybean	CP	Inject	200 (soybean removed)	P-based (soybean uptake)***
5	3	Fall (UAN)	Corn	CP	LCD***	168	
	3	-	Soybean	CP	-	-	- As needed
6	3	Spring	Corn	NT	Inject	168	
	3		Soybean	NT	-	-	- As needed

***As needed: application rate of P from fertilizer based on soil P test to meet P-uptake of corn

** P-based: application rate of P from swine manure on the basis of P removal by corn

*** P-based: application rate of P from swine manure on the basis of P removal by soybean

*** LCD: Localized compaction and doming applicator

In the third phase of this study (2000 to 2006), we are evaluating the effects of six different nutrient management treatments on subsurface water quality. Treatments 1 and 2 compare the effects of N application rates of 168 kg-N ha^{-1} (or 150 lb-N/ac) from liquid UAN fertilizer and swine manure on water quality. Treatments 3 and 4 include manure application rates based on P needs for both corn and soybean (with supplemental application of N from UAN if needed to meet corn N-uptake needs). Treatment 5 include N-application rate of 168 kg-N ha^{-1} (or 150 lb-N/ac) from UAN-fertilizer to corn using Localized Compaction and Doming (LCD) applicator for improved N-uptake and reduced NO_3-N leaching. Treatment 6 include spring application of liquid swine manure at application rates of 168 kg-N ha^{-1} (or 150 lb-N/ac) for no-till system using a new applicator designed for no-tillage conditions. Each treatment is replicated three times in a corn-soybean rotation. Soil and water samples from this study are analyzed for NO_3-N, PO_4-P, and bacteria to determine the impacts of proposed six treatments on soil and water quality. The major outcome of this research will be to determine the impact of manure applications to croplands, based on N and P uptake needs of crops, on water quality. Beginning 2004, selected surface runoff and subsurface drain water samples from major rainwater events in May and June are being analyzed for antibiotics in objective (ii) in addition to NO_3-N, phosphorus (P) as phosphate-phosphorus (PO_4-P) and bacteria. For bacteria, we are analyzing for total E. coli and fecal coliform bacteria.

For measuring antibiotics in surface runoff and subsurface drain water, this study deals with assessing the effect of land application of antibiotic laced swine manure on antibiotic losses in surface runoff and tile drainage water. Two antibiotics studied are chlortetracycline and tylosin. Preliminary data from last year showed very little transport of chlortetracycline and tylosin through Nashua soils into tile drainage water. This year we found only couple of detects of these two antibiotics. Another study at the University of Minnesota has shown that about 0.07% of the applied tylosin was transported as dissolved tylosin in surface runoff. Laboratory studies have shown that these two antibiotics are tightly adsorbed by soils and most of the manure-applied antibiotics are remaining in place where they are applied. One more year of data on antibiotics will give us a better understanding on the transport or leaching of these compounds to surface runoff or groundwater.

Progress Report March 1, 2006 to February 28, 2007

In this ongoing research study at the Northeast Research Farm near Nashua, Iowa, we are evaluating the effects of six different nutrient management treatments on subsurface water quality. Table 1 lists the experimental treatments, nitrogen application rates for each of the six treatments, and total average manure N and P applied. We collected soil and water samples from this study from about April 2006 to November 2006 and were sent to the laboratory for analyzing for NO_3-N, PO_4-P, and bacteria to determine the impacts of the six treatments on soil and water quality. Till today only water samples were analyzed for NO_3-N and the results are reported in Table 3. The water samples are being analyzed for PO_4-P, and bacteria and these analyses will be completed by April/May 2007. Once these samples are analyzed, we would be able to complete our results for a total of six years and draw final conclusions of this study. In addition, we have completed the data on crop yields which is given in Table 4. For simplicity and for better understanding of the local review team, we have reproduced the data in tables 2, 3, and 4 in English units rather than in metric system. Between March 1 2007 and August 1 2007 we plan to analyze all the lab data collected in 2006 and prepare summaries for the six year data set of this study and write the completion report of this study.

Table 1. Experimental treatments at the Nashua water quality research site

Application timings and source of N	Crop	Application rate, lb/ac	
		N based rate	P based rate
System 1. Spring UAN 150 lb N/ac	Corn	150	60
	Soybean	-	44
System 2. Fall manure150 lb N/ac	Corn	150	-
	Soybean	-	-
System 3. Fall P based manure/UAN 150 lb N/ac	Corn	150	60**
	Soybean	-	44
System 4. Fall manure 150 lb N/ac	Corn	150	-
(Plots receive manure both years)	Soybean	200	-
System 5. UAN w/LCD 150 lb N/ac (Side dress)	Corn	150	60
	Soybean	-	44
System 6. Spring manure 150 lb N/ac (No-till)	Corn	150	-
	Soybean	-	-

*As needed: application rate of P from fertilizer based on soil P test needed to meet P-uptake of corn
**P-based: application rate of P from swine manure on the basis of P removal by corn
***LCD: Localized compaction and doming applicator

Tables 3 and 4 summarize experimental data for the years 2000 through 2006. Table 3 gives yearly average NO_3-N concentrations and yearly average total NO_3-N losses with tile water. Treatment 4, where swine manure was applied every year to corn as well as soybeans resulted in the highest six year (2000-2006) average NO_3-N concentrations in tile water of 39.8 mg/l and 36.6 mg/l for corn and soybean plots, respectively indicating an effect of continuous applications of swine manure for six years. Treatment 6, with spring application of manure to corn plots only resulted in the lowest overall average NO_3-N concentrations of 16.2 mg/l and 12.4 mg/l in the tile water from corn and soybean plots, respectively. These results show that NO_3-N leaching to groundwater under manure applications can be managed under proper N application rates and timings. Table 4 shows that treatment # 4, with fall manure application to corn, resulted in highest six year average corn yield of 185 bushels/acre, and average soybean yield of 59 bushels/acre.

Table 2. Effects of experimental treatments on average NO_3-N concentrations and losses with tile drain water.

NO3-N Conc. in tile water, mg/l	2001		2002		2003		2004		2005		2006		2001-2006	
Experimental Treatments	CS	SC	CS	SC	CS	SC	CS	SC	CS	SC	CS	SC	CS	SC
1. Spring UAN 150 lb N/ac	14.2	18.8	11.4	18.8	21.7	18.2	30.2	18.6	19.2	16.4	13.9	12.5	18.4	17.2
2. Fall manure 150 lb N/ac	24.9	15.8	16.9	19.3	26.8	16.1	36.5	20.0	26.1	14.0	19.7	16.2	25.1	16.9
3. Fall P based manure150 lb N/ac	16.9	12.7	8.8	16.1	21.6	16.3	33.1	20.4	24.7	15.8	17.4	15.2	20.4	16.1
4. Fall manure 150 lb N/ac	25.9	31.5	31.8	20.7	29.4	44.6	70.4	50.1	40.8	43.2	40.5	29.6	39.8	36.6
5. UAN w/LCD 150 lb N/ac	12.6	18.4	12.4	20.3	19.4	20.5	19.6	22.1	20.6	15.2	14.6	18.3	16.5	19.1
6. Spring manure 150 lb N/ac	12.4	8.3	9.6	9.3	18.1	11.1	23.1	18.8	21.6	10.8	12.5	15.9	16.2	12.4
NO_3-N Loss in tile water lb/ac	2001		2002		2003		2004		2005		2006		2001-2006	
Experimental Treatments	CS	SC	CS	SC	CS	SC	CS	SC	CS	SC	CS	SC	CS	SC
1. Spring UAN 150 lb N/ac	10.3	17.2	0.4	1.8	11.2	12	27.5	15.8	8.8	8.3	7.5	6.3	10.9	10.2
2. Fall manure 150 lb N/ac	19.4	28.3	6.4	2	15.3	21.3	50.1	19.4	14.0	21.1	21.2	8.9	21.1	16.8
3. Fall P based manure150 lb N/ac	15.4	11.2	0.1	1	14.8	6.4	16.1	28.7	19.4	9.2	10.5	11.0	12.7	11.3
4. Fall manure 150 lb N/ac	21.7	41.6	3.7	1.8	18.4	40.4	64.1	58.8	29.8	30.7	23.8	16.6	26.9	31.6
5. UAN w/LCD 150 lb N/ac	13.6	27.8	3	3.5	11.9	20.1	15.1	14.3	18.3	7.8	13.7	11.7	12.6	14.2
6. Spring manure 150 lb N/ac	20.8	17.2	4.6	6.2	21.3	15.7	17.2	32.3	25.4	14.2	12.3	17.9	16.9	17.3

Table 4. Corn and soybean yields for various N treatments

Grain yields in bu/ac for six years (2000-2006) as a function of the treatments												
	Point Inject 150 # N		**Fall Manure 150 # N**		**Fall Manure P Based**		**Fall Manure Excessive P**		**LCD 150 # N**		**Spring Manure 150 # N**	
Corn	**System 1**		**System 2**		**System 3**		**System 4**		**System 5**		**System 6**	
2000	164	bc	171	a	166	ab	153	d	161	c	159	d
2001	163	de	177	ab	173*	bc	181	a	159	e	169	cd
2002	192	ab	194	a	191	ab	194	a	189	b	192	ab
2003	156	bc	163	ab	164	ab	167	a	149	c	157	bc
2004	205	a	196	b	202	ab	203	a	205	a	185	c
2005	192	b	191	b	193	ab	198	a	190	b	193	ab
2006	197	ab	200	a	195	b	197	ab	198	ab	188	c
Avg	**181**	**ab**	**184**	**a**	**184**	**a**	**185**	**a**	**179**	**ab**	**177**	**b**
Soybean												
2000	55	c	58	b	58	b	71	a	58	b	54	c
2001	46	c	51	b	43	e	56	a	46	cd	44	de
2002	54	c	56	b	57	b	59	a	54	c	53	c
2003	31	a	29	c	29	abc	28	c	30	ab	28	c
2004	60	a	59	a	59	ab	56	bc	59	a	56	c
2005	66	c	69	b	65	cd	74	a	64	d	69	b
2006	62	b	62	b	65	a	65	a	62	b	63	ab
Avg	**53**	**b**	**55**	**ab**	**54**	**b**	**59**	**a**	**53**	**b**	**52**	**b**

References Cited:

Baker, J.L., M.B. David, and D.W. Lemke. 2005. Understanding nutrient fate and transport, including the importance of hydrology in determining losses, and potential implications on management systems to reduce those losses. In: Gulf hypoxia and local water quality concerns workshop, Sep. 26-28, 2005, Iowa State University, Ames, Iowa. pp. 11-25.

Bakhsh, A. and R.S. Kanwar. 2004. Using discriminant analysis and GIS to delineate subsurface drainage patterns. Trans. ASAE. 47(3):689-699.

Bakhsh, A., J.L. Hatfield, R.S. Kanwar, L. Ma, and L.R. Ahuja. 2004. Simulating nitrate leaching losses from a Walnut Creek watershed field. J. Environ. Qual. 33:114-123.

Bakhsh, A. and R.S. Kanwar. 2005. Spatial clusters of subsurface drainage water NO_3-N leaching losses. J. Amer. Water Reso. Assoc. JAWRA 41:333-341.

Kanwar, R. S., T. S. Colvin, and D. L. Karlen. 1997. Ridge, moldboard, chisel, and no-till effects on subsurface drainage water quality beneath two cropping system. J. Prod. Agric. 10:227-234.

Kanwar, R. S., D. Bjorneberg, and D. Baker. 1999. An automated system for monitoring the quality and quantity of subsurface drain flow. J. Agric Eng. Res. 73:123-129.

Kanwar, R.S., R. Cruse, M. Ghaffarzadeh, A. Bakhsh, D. Karlen, and T. Bailey. 2005. Corn-soybean and alternative cropping systems effects on NO_3-N leaching losses in subsurface drainage water. Applied Eng. in Agric. ASAE, 21:181-188.

USEPA. 1995. National water quality inventory: 1994 Report to Congress. USEPA Office of Water, U.S. Government Printing Office, Washington, DC.

USEPA/USDA. 1998. Unified national strategy for animal feeding operations. Fed. Reg. 63:50192-50209.