2015

Investigation of bacteria transport and resistance mechanisms and implications for water quality from confinement swine and beef grazing production systems in Iowa

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Abstract
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Keywords
Agricultural and Biosystems Engineering, Agronomy, Chemical and Biological Engineering, Manure nutrient and compost management, Soils and agronomy, Water quality quantity and management

Disciplines
Agronomy and Crop Sciences | Biochemical and Biomolecular Engineering | Bioresource and Agricultural Engineering | Environmental Microbiology and Microbial Ecology | Water Resource Management

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Budget:
$63.500 for year one
$63,800 for year two
$34,800 for year three

ECOLOGY

Q What can we learn from comparing cropping systems and fertilization about N export, bacterial survival and bacterial transport mechanisms that will help us better manage cropping systems?

A Over three years, fecal indicator bacteria present in tile drainage water from swine-amended cropland were extremely low, except in high precipitation events. Fall-injected swine manure had low concentrations of pathogen indicator and resistant organisms, but higher N export in tile drain water. Indicator isolates collected from manure and tested for resistance to multiple antibiotics exhibited higher resistance than those pulled from the soil and water isolates.

Background

Corn and soybean producers in Iowa are increasingly challenged to maximize crop production to supply feed, fiber, and more recently, biofuels, while at the same time managing soils by utilizing fertilizers and animal manures efficiently and also minimizing negative impacts on water quality. Nitrate loss through subsurface drainage systems is of primary concern, but there are emerging questions about the export potential of pathogens, along with the acquisition and proliferation of antibiotic resistance in these organisms. As a result, new practices and technologies are needed to significantly reduce nitrate losses at minimal cost while also considering their potential to reduce bacteria movement into tile drainage systems.

This study was conducted to explore questions related to the fate and transport of nutrients and bacteria from land receiving manure applications. The work was organized as two separate studies that are integrated to address agricultural bacteria and nutrient issues from multiple perspectives. A monitoring study was conducted at the ISU Northeast Iowa Research and Demonstration Farm near Nashua, Iowa. This study builds on former funding from the Leopold Center to examine impacts of different agricultural systems on water quality.

In addition to continuing the nutrient-focused study, in 2012 the researchers began to monitor the site for a pathogen indicator and antibiotic resistance in this indicator. The second component of this study investigated the mechanisms of pathogen indicator transport, specifically if transport is particle mediated and to identify factors contributing to pathogen–particle interactions.

Approach and methods

Experimental data was collected at the ISU Northeast Iowa Research and Demonstration Farm. This study site has 36 - 0.4 ha plots, with a state-of-the-art surface and

Students collect tile drain water and soil samples at the ISU Northeast Iowa Research and Demonstration Farm near Nashua.

subsurface water quality monitoring system. The water quality monitoring system was installed in 1988, and since then three major water quality studies have been completed on the effects of tillage, crop rotations and nutrient management practices on surface and groundwater quality at this site.

The overall objectives of the nutrient aspects of this study were to evaluate the impacts of various cropping and nutrient management systems on drainage water quality. With three replicates per treatment and cropping phase (i.e., each cropping phase is present in each year), the treatments included allow for these varied comparisons:

- Cropping practices with the use of a winter cover crop (treatment 1 vs. 5)
- Use of swine manure before corn and soybeans or corn only (treatments 2 vs. 3)
- Continuous corn systems with and without stover removal compared to a corn-soybean system (treatments 2 vs. 4)
- Use of a no-till, corn-soybean system (treatments 2 vs. 6)

Results and discussion

In the spring and summer of 2012, 2013, and 2014, the research team collected weekly grab samples directly from the tile lines and analyzed them for bacteria and antibiotic resistant bacteria concentrations. Flow meters and data loggers installed within each sump recorded instantaneous tile flow data throughout the growing season.

Average NO_3-N concentrations in tile water with a cover crop were the lowest in the corn and soybean phases of the production system. Fecal indicator bacteria concentrations present in drained swine-amended cropland were extremely low during normal flow conditions.

Similarly, very low concentrations of resistant enterococci were detected in the weekly tile drainage samples across all treatments and only slightly higher concentrations of resistant enterococci were detected in samples collected during storm events. Enterococci isolates were collected and tested for resistance to Macrolide-Lincosamide-Streptogramin B (MSLB) antibiotics. The macrolides used were tylosin (TYL), azithromycin (AZI) and erythromycin (ERY) as well as the lincosamide lincomycin (LIN). Also tested were vancomycin (VAN) and tetracycline (TET). Of the 22 isolates collected from the manure samples, 100 percent exhibited resistance to TET, LIN, and TYL. Overall 91 percent were resistant to ERY, 95 percent were resistant to AZI, and 0 percent was resistant to VAN. Isolates collected during storm events had higher percentages of resistance than isolates collected on a weekly basis.

Conclusions

Major findings of the study were:

- Seven-year average NO_3-N concentrations in tile water from plots under continuous corn and receiving swine manure every year were the highest of the systems compared. The fall-applied manure to soybean rotation had consistently higher NO_3-N concentrations in tile water when compared to all other soybean

Research being conducted at project site near Nashua, Iowa. (Photo courtesy Michelle Soupir.)

rotations. The two systems receiving UAN spoke-injected application resulted in the lowest NO_3-N concentrations in tile water.

- Overall, five years of data from this study showed that average NO_3-N concentrations in tile water from land with a cover crop were the lowest in the corn and soybean phases of the production system.
- The spring UAN application at 150 lb. N/ac treatment with tillage resulted in the highest average corn yield of 196 bushels/ac compared to all other cropping tillage or nitrogen management systems. While receiving higher nitrogen application rates, the continuous corn treatments exhibited slightly lower corn yields than the rotation treatments. Soybean yields from systems receiving swine manure resulted in the highest average yields of 63.7 to 65.6 bushels/ac, respectively. This occurred in all liquid swine manure systems whether in no-till or a tillage system and whether liquid swine manure was applied prior to soybeans or just before corn.
- Fecal indicator bacteria concentrations present in drained swine-amended cropland are extremely low. Similarly, very low concentrations of resistant enterococci were detected in the weekly tile drainage samples and only slightly higher concentrations of resistant enterococci were detected in samples collected during storm events.
- Enterococci isolates were collected and tested for resistance to multiple antibiotics. The isolates collected from manure exhibited higher resistance than soil and water isolates. Enterococci isolates often were resistant to multiple MSLB antibiotics.
- The particle interactions study is ongoing, but preliminary results found a higher concentration of *E. coli* in manure particles less than 53 µm (2.88 ×106 cell per gram of dry manure).

Several aspects of the project need additional work to increase their usefulness or value:

- The antibiotic resistance investigation and analysis is continuing. Additional work is needed to examine the presence of target antibiotic resistance genes and identify the organisms in which they reside.
- Further understanding of the mechanisms (intrinsic versus acquired resistance) as well as the modes of resistance (target site modification, enzymatic inactivation, bypass pathway, target site alteration) is needed to better understand the environmental fate and transport of resistant organisms.

Impact of results

Many, but not all, of the project objectives were achieved. The long-term nutrient study at Nashua has been extended for two additional years, and the study site continues to provide valuable information. Positive findings were obtained regarding fall injection of swine manure into cropland as low concentrations of pathogen-indicator organisms and resistant enterococci were detected in tile drainage. Findings regarding transport mechanisms are still forthcoming.

Education and outreach

- Several peer-reviewed publications are in progress.
- Nitrate, bacteria, and tylosin concentration results from the 2007-2011 were presented at the New Technology Expo in Ames, Iowa in September 2012 by Leigh Ann Long. (Poster title: "Occurrence and movement of nitrate-N, tylosin, enterococci, and antibiotic-resistant enterococci in tile-drained agricultural fields receiving swine manure.")
- Further results from the 2012 bacteria study were presented by Xiao Liang at the ASABE annual international meeting in Kansas City, Missouri in July 2013 (Title: "Investigation of bacteria transport from subsurface drainage system in Iowa and implications for water quality.")
- Matthew Helmers included some of the results from the Nashua nutrient study in his presentation to the Iowa Environmental Protection Commission in October 2012, a meeting in which the commission was considering implementing a ban on manure application on soybean fields.
- Michelle Soupir recorded a presentation "Impacts of Poultry Manure Application on Water Quality" in fall 2014 for ISU's Iowa Manure Management Action Group (IMMAG) which since has been used by Dan Anderson in manure management training throughout Iowa.

Leveraged funds

These additional funds were leveraged by the grant:

Persistence and Transport of Veterinary Antibiotics and Antibiotic-Resistant Bacteria in Midwestern Farming Systems. USDA-NIFA AFRI Renewable Energy, Natural Resources, and Environment (RENRE): Soil, Air, and Water Processes in Agroecosystems. T. Moorman, M. Soupir, D. Busch, R. Malone. $460,000 ($226,510 sub-contract to ISU). 10/1/13 to 9/30/16.

Occurrence and Movement of Antibiotics, Antibiotic Resistant Bacteria and Resistance Genes in Tile-Drained Agricultural Fields Receiving Swine Manure Application. M. Soupir (PI), T. Moorman, M. Helmers. National Pork Board. $172,127. 4/1/12 to 3/31/15.

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