USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Runoff Water Quality and Crop Responses To Variable Manure Application Rates

Duration: March 01, 2000 to Febuary 28, 2001

Federal Funds Requested: $14,583

Non-Federal Matching Funds: $14,900

Principle Investigators:

Dr. Neil C. Hansen
Dept. of Soil, Water, and Climate
College of Agriculture, Food, and Environmental Science

Dr. Sagar Goyal
Department of Veterinary Diagnostic Medicine
College of Veterinary Medicine

Congressional District: 13A

Statement of Problem

Reduced oxygen levels and high levels of fecal coliform bacteria are common water quality problems in Minnesota. Agricultural runoff is one non-point source of this contamination. Manure handling practices are becoming the focus of increasing regulation by state and county ordinances. These regulations have met opposition due to the economic impact on producers and because of doubt that they will improve water quality. Both producers and regulators are looking for research to document the effects of the various manure handling and application approaches on water quality.

One question related to manure handling centers on recommended manure application rates. Some propose to limit manure application rates to the crop requirement for phosphorus rather than the more prevalent nitrogen based recommendation. It is assumed that the lower phosphorus-based rates will result in improved water quality. This, however, may not be the case. Some research (Ginting et al., 1998) has shown that manure applied to cropland at nitrogen based rates improved infiltration and reduced runoff compared to soils without manure. The lower runoff resulted in lower phosphorus losses despite an increase in the phosphorus level in the soil. It is not know whether similar improvements in infiltration would result when manure is applied at phosphorus-based rates. From a water quality perspective, the ideal rate is one that minimizes the total transport of contaminants in runoff. This project will evaluate how manure application at varying rates impact soil hydraulic properties, runoff, and the transport of

both phosphorus and pathogens in runoff. Crop production will also be assessed to evaluate the producer's risk of applying manure at phosphorus-based rates.

Statement of Results and Benefits

Livestock producers and society want to protect water in their environment. Applications of manure to cropland can contaminate water if applied improperly. Contamination of water with excess nutrients limits the use and function of water. Movement of manure-borne pathogens to surface waters may compromise public health. This study will shed new light on land application of manure and the impact on phosphorus and pathogen loss to surface water. The results will be helpful to both livestock producers and regulators in refining current manure management guidelines.

Nature and Objectives

This project involves field research to monitor runoff from snowmelt and rainfall events in cultivated land. Both chemical and biological water quality standards will be evaluated. The specific project objectives are to:

1. Determine how manure applied at various rates impact soil hydraulic properties and the loss of nutrients in surface runoff.

2.Determine the presence of the pathogens *Salmonella anatum,* coliphages, and fecal coliform indicator bacteria in runoff water.

Methods, Procedures, and Facilities

The study is located at the West Central Research and Outreach Center in Morris, MN on a calcareous soil with uniform slope. Runoff plots sized 22 m by 3 m will be bordered with corrugated sheet metal driven vertically into the soil to isolate surface runoff. On the down-slope side of the plot a metal collection flume will channel runoff to a tipping bucket flow meter. The tipping buckets can be monitored continuously with a data logger to determine runoff rate and volume. A fraction of the runoff from individual events will be composited and collected for quantification of the target organisms. Plots were cropped to corn in 1999 and soybeans will be grown in 2000. Experimental treatments are:

1. Control - no manure applied to the plot

2. Low - liquid swine manure applied at half the phosphorus-based rate

3. Med. - liquid swine manure applied equal to a phosphorus-based rate

4. Hi. - liquid swine manure applied at double the phosphorus-based rate

Manure was broadcast applied on October 25, 1999 and immediately incorporated by disking. The manure application rate for the medium treatment was based on soil test results and University of Minnesota phosphorus fertilizer recommendation (Rehm et al., 1995). The low and high rates were one half and two times that rate. The same approach will be used to determine manure application rates in the fall of 2000. This will widen the range in soil phosphorus levels being evaluated.

Secondary tillage in the spring will be done with a field cultivator and harrow. All tillage will be done up and down the slope. Soybeans will be planted in 75 cm wide rows. No nitrogen fertilizer will be applied to the soybean crop. Soybean yields will be measured and compared and phosphorus uptake will be determined.

Sample Collection

Soil - Soil samples will be taken prior to manure application to determine phosphorus level. These samples will be used to determine background concentrations of the target organisms. Soil will be sampled again immediately after manure application to determine the concentration of target organisms in the soil after application. To determine organism survival in the soil, samples will be taken once weekly until soil freezes, and again after soil thaws in the spring until no pathogens can be detected in three consecutive samples.

Water - Water samples will be collected at each runoff event (rain and snow melt).

Manure - A sample of the liquid manure will be collected at the time of application.

Laboratory Analysis

Soil - Extractable soil phosphorus will be determined by the method of Olson method (Olsen and Sommers, 1982). Other soil fertility analyses and characterizations will be performed such as organic matter content, pH, nitrogen and potassium. Pathogenic organisms in soil will be quantified using standard methods *(APHA, 1995; Goyal et al., 1980; Wang et al., 1985).*

Water - Water samples from each plot at each runoff event will be quantitatively analyzed total solids concentration, total and soluble phosphorus, and for Salmonella sp., coliphages, and fecal coliform using standard methods (APHA, 1995; Goyal et al., 1980; Wang et al., 1985).

Manure - Five representative sub-samples of manure will be pooled to constitute a single sample, which will be analyzed for nutrient content including total nitrogen, phosphorus, and potassium. The presence and concentration of microorganisms will be determined as described above.

Related Research

Many surface waters in Minnesota are affected by agricultural non-point source pollution (Payne, 1994). Among the most prevalent water quality problems are low dissolved oxygen concentrations and bacterial contamination (MPCA, 1999). In these systems, phosphorus is commonly the limiting factor for accelerated eutrophication. Consequently, much attention is given to reducing phosphorus inputs. Phosphorus from non-point sources is primarily transported via runoff in either soluble forms or associated with eroded sediments. Land applied animal manure is extensive in Minnesota. Understanding the relationship between manure application rate and the loss of phosphorus and pathogens in runoff is vital to developing environmentally sound manure management guidelines.

Recommended manure application rates are currently based on the amount of nitrogen in the manure that will be available to a subsequent nitrogen responsive crop. Nitrogen based applications rates result in phosphorus additions that exceed crop needs and cause an accumulation of phosphorus in the soil. The concentration of phosphorus lost in runoff is positively correlated to the concentration of phosphorus at the soil surface (Pote et al., 1996). Further manure addition to soils where phosphorus concentrations are elevated can pose an environmental risk (Sharpley et al., 1994; Romkens and Nelson, 1974).

Edwards and Daniel (1993) showed that the concentrations of total and soluble phosphorus in runoff are linearly related to the rate of hog manure applied to the surface of fescue plots. However, water quality impacts must consider the loading of contaminants as well as the concentration of contaminants in edge of field runoff. Unlike phosphorus concentration in runoff, the loading of phosphorus can not be predicted based on the soil phosphorus level. Manure addition to soil can improve soil physical properties and reduce the amount of runoff and erosion. A reduction in runoff and erosion can offset, to a degree, an increase in the concentration of phosphorus at the soil surface. Ginting et al. (1998) showed that net loss of total phosphorus in runoff from corn grown after application of solid beef manure was less than for corn grown with no manure addition. This was true when manure was incorporated (moldboard plow system) or surface applied (ridge till system). Mueller et al (1984a, 1984b) showed that surface applied solid dairy manure reduced runoff, erosion, and total phosphorus losses if the manure was incorporated (chisel plow). Without incorporation (no-till), applied manure reduced runoff and erosion relative to treatments without manure, but total phosphorus losses were higher due to high concentration of phosphorus in runoff. Thus, the impact of manure addition on the net loss of phosphorus in runoff depends upon the combined effects of the manure on runoff and phosphorus concentration. At what point does the build-up of soil phosphorus from applied manure become more important than the reduction in runoff? This study will help answer that question and will help refine current manure application guidelines.

Runoff from agricultural sources has been widely implicated for biological water quality problems. Research on how pathogens are transported in runoff has received little

attention. Highly publicized incidents of contaminated water supplies have brought this issue to the forefront.

The survival time of pathogens in the soil environment is an important factor controlling their transfer from the soil to runoff. Pathogens that persist for a long time and are retained near the soil surface are at most risk of being suspended and transported to surface waters in runoff. Manure application rate impacts the concentration of pathogens near the soil surface. Other factors such as manure placement and time of application are also important. Some work has been done on the persistence of manure born pathogens after land application (Johnston et al. 1996). In this study, *Salmonella anatum* was mixed and land applied with liquid swine manure. The bacteria survived in the soil for at least 27 days. Survival was slightly longer in the upper three inches of the soil than for deeper depths. However, the depth of soil important for the transfer of contaminants to runoff water is less than a half of an inch (Zhang et al., 1997). The survival of pathogens in this surface region is not known. More information is needed to understand the mechanisms of pathogen transport in surface runoff. In this project we will evaluate the relationship of pathogen survival time to their transport in runoff over varying manure application rates.

References

APHA. 1995. Standard Methods for the Examination of water and wastewater, 19th Ed. Amer. Pub. Hlth. Assn., Washington, DC.

Edwards, D.R. and T.C. Daniel. 1993. Runoff quality impacts of swine manure applied to fescue plots. Trans. Am. Soc. Agric. Eng. 36:71-80.

Ginting, D., J.F. Moncrief, S.C. Gupta, and S.D. Evans. 1998. Interaction between manure and tillage system on phosphorus uptake and runoff losses. J. Environ. Qual. 27: 1403-1410.

Goyal, S.M., Zerda, K.S., and Gerba, C.P. 1980. Concentration of coliphages from large volumes of water and wastewater. Appl. Environ. Microbiol. 39:85-91.

Johnston, Lee J., Ajariyakhajorn, Chaunpis, Goyal, Sagar, Robinson, R. Ashley, Clanton, Charles J., Evans, Sam D., and Warnes, Dennis D. 1996. Survival of bacteria and virus in ground piglet carcasses applied to cropland for disposal. Sine Health and Prod. 4:189-194.

Mueller, D.H., R.C. Wendt, and T.C. Daniel. 1984a. Soil and water losses as affected by tillage and manure application. Soil Sci. Soc. Am. J. 48:896-900.

Mueller, D.H., R.C. Wendt, and T.C. Daniel. 1984b. Phosphorus losses as affected by tillage and manure application. Soil Sci. Soc. Am. J. 48:901-905.

MPCA. 1999. TMDL List of Impaired Waters. http://www.pca.state.mn.us/water/pubs/tmdl-list98.pdf. Minnesota Pollution Control Agency. St. Paul, MN.

Olsen, S.R., and L.E. Sommers. 1982. Phosphorus. P. 403-430. In A.L. :age et al. (ed) Methods of soil analysis. Part 2. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI.

Payne, Gregory A. 1994. Sources and transport of sediment, nutrients, and oxygen-demanding substances in the Minnesota River basin, 1989-92. U.S. Geological Survey. Water-Resources Investigations Report 93-4232.

Pote, D.H., T.C. Daniel, A.N. Sharpley, P.A. Moore, Jr., D.R. Edwards, and D.J. Nichols. 1996. Relating extractable soil phosphorus to phosphorus losses in runoff. Soil Sci. Soc. Am. J. 60:855-859.

Rehm, G., M. Schmitt, and R. Munter. 1995. Fertilizer recommendations for agronomic crops in Minnesota. Minnesota Extension Service BU-6240-E. University of Minnesota. St. Paul, MN.

Romkens, M.J.M. and D.W. Nelson. 1974. Phosphorus relationships in runoff from fertilized soils. J. Enivron. Qual. 3:10-13.

Sharpley, Andrew N., S.C. Chapra, R. Wedepohl, J.T. Sims, T.C. Daniel, and K.R. Reddy. 1994. Managing agricultural phosphorus for protection of surface waters: issues and options. J. Environ. Qual. 23:437-451.

Wang, D.S., Gerba, C.P., Lance, J.C., and Goyal, S.M. 1985. Comparative removal of enteric bacteria and poliovirus by sandy soils. J. Env. Sci. Hlth. A20:617-624.

Zhang, X.C., D. Norton, and M.A. Nearing. 1997. Chemical transfer from soil solution to surface runoff. Water Res. Res. 33:809-815.