USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Effect of Liquid Swine Manure Application to Water Quality from Soil Infiltration Areas and Wetlands

Focus Categories: WQL, WW, WL

Keywords: Manure, Animal Waste, Subsurface Drainage, Bacteria

Duration: 3/1/2000 – 2/28/2001

Federal funds requested: $9,194

Non-federal funds pledged: $26,185

Principal Investigators:

Jeffery Lorimor
Agricultural and Biosystems Engineering
Iowa State University
Ames, IA 50011

Larry Halverson
Agronomy Department
Iowa State University
Ames, IA 50011

Congressional District: Iowa, 3rd Congressional District

State of Critical Water Problems

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. Recent research at Iowa State University (Prantner et al., 1999) has shown that soil filtration of liquid swine manure through soil, and subsequent wetland treatment of effluent from the infiltration area removes a high percentage of nutrients (70-90% of N and P).

Bacterial movement to surface and groundwater from manure applications is also of concern. The same studies showed differences in bacterial numbers between treated and untreated plots from swine manure. More information is needed on the movement of bacteria 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. Specifically we need to know if bacteria moving through infiltration areas are coming from the applied manure, or are they simply indigenous bacteria from the soils.

Little research has been conducted in this area. The proposed project will provide very useful information for the state of Iowa about the contribution of bacteria from liquid swine manure to surface and groundwater supplies.

Statement of Results or Benefits

Determining the bacteriological effects of applying manure to croplands and wetlands, will help determine whether soil filtration and wetland treatment is a viable treatment option. If manure-born bacteria are moving through the soil profile, manure application rates and methods may need further adjustments to minimize water quality deterioration, making the treatment system less beneficial. 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 land/wetland treatment systems for managing excessive animal manure from large livestock production facilities.

Nature, Scope, and Objectives of the Research

This research will be a laboratory scale project conducted on small field plots and lysimeters, both in the laboratory and in the field. A full field scale unit will not be tested, as too many uncontrolled variables exist in full field scale projects. The overall objective of this project is to understand the soil microbial and chemical processes occurring within infiltration areas and wetlands used to treat liquid swine manure to enable effluents to be of sufficient quality to be discharged to Iowa's water bodies safely. (Discharges from animal facilities are not allowed now, but may become an option in the future if effective treatment systems can be developed). 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?" Instead of determining whether bacteria are present in the soil filtrate and wetland effluent , we will determine whether the source of that bacteria is from swine manure or from naturally occurring activities in the soil-water system.

Methods, Procedures, and Facilities

Two sets of soil containers already exist at the Agronomy and Agricultural Engineering Research Center near Boone, Iowa that will be used for this experimental study. A set of 18 (9 pairs) of 210L plastic containers are presently located in the field and are available for the study. In each set of two containers, the first is designed for soil infiltration, the second just below first set will serve as a wetland. They are designed so that flows in and out of each container can be monitored and sampled for nitrogen, phosphorus, and bacteria. This set of containers is subject to climatic and hydrologic events occurring throughout the year.

The second set of equipment is a series of 15, 20 x 112 cm plastic soil columns (5 treatments x 3 replications) that have been constructed and filled with a reconstructed soil. This set of columns is inside a laboratory near Ames where it is isolated from outside daily climatic and hydrologic events. Both sets of containers (in the field and in the lab) have soil in them, and are ready for this study.

Manure will be obtained from ISU swine research facilities near Ames. A “thin” manure (less than 2% solids) will be used to minimize soil sealing which can be a problem with thicker manure.

To determine whether the bacteria from the manure are actually transported through the soil columns, genetically marked bacteria will be used as tracers. The general approach will be as follows: Manure will be obtained and stored until it’s applied to the soil columns. E. coli and a psuedomonad or a bacillus species from the manure system of interest will be isolated. Genetically marked bacterium, to differentiate manure bacteria from indigenous soil bacteria, will be used. The genetic marker used will be a green fluorescent protein which will provide a readily visible marker since it makes the bacteria turn bright green color.

Once the genetically marked bacteria are constructed, they will be re-introduced into the manure and maintained in the manure for some period of time (1-2 weeks) to determine if the marker has decreased their ability to survive in the manure. The manure with the marked bacteria will then be applied to the soil. As a control we will determine whether the marked bacteria can survive in soil for an extended period of time.

Manure application frequency and rate will be the primary independent variables investigated. Treatments in the outdoor system will be:

Manure – one application only based on soil moisture holding capacity

Manure – applied every two weeks based on soil moisture holding capacity

Water only – applied every two weeks based on soil moisture holding capacity

Treatments in the indoor columns will be:

Manure – one application only at 150 lbs N/ac, followed by water applications to cause leaching

Manure – one application only at soil moisture holding rate, followed by water applications to cause leaching

Manure – applied every two weeks at greater than soil moisture holding rates to cause leaching

Water only – applied every two weeks at greater than soil moisture holding rates to cause leaching

The application rates at both sites (except for one indoor treatment) will be based on the water holding capacity of the soil rather than nutrient rates. Nutrients will be over-applied, as the system is intended for treatment and eventual release rather than for crop production. The continued water applications are necessary to provide enough water to maintain the health of wetlands. The effluents from the columns, infiltration areas, and wetlands will be monitored for the marked bacteria. At the end of the experiment, the soil will be sampled at 1-foot increments to know the number of genetically marked and naturally occurring bacteria in the soil.

Nutrients will be monitored at each stage of the treatment process. Although not a primary focus of the research, nutrient information may lend valuable information for interpreting the microbial results, and is always of interest on it's own merits.

Related Research

Much research has been done on the use of wetlands to remediate high nutrient concentrations. Some peat lands near Michigan have been studied for their ability to treat waste waters from agricultural and industrial efflents. Southern marshes and hardwood swamps in Florida have been reported to remove 90% of the total nitrogen and phosphorus that has entered the wetland. Tidal marshes have also been studied for waste treatment capabilities, but extreme variability in the environment and complex ecosystem components cause difficulty in studies. Prantner et al. (1999) have conducted a preliminary study on the role of infiltration areas and wetlands in removing some of the agricultural pollutants from the animal manure. The actual treatment capacity of these wetlands is still unknown (Hantzsche, 1985). van der Valk and Jolly (1992) state that restored or created wetlands should be used for the purpose of rural nonpoint source (NPS) pollution reductions, as opposed to natural wetlands. In Table 1.4, Hammer (1994) lists the advanced discharge requirements for the treatment of livestock wastewaters, after primary treatment with lagoons.

Plants conduct gases to and from the sediments through their gas exchange mechanisms. Oxygenation, however, is achieved only in a small area surrounding the root (Wetzel, 1993). These aerobic zones support some bacteria. Most of the wetland remains anaerobic, and can support only anaerobic bacteria. According to Wetzel (1993), microbiota and their metabolism almost solely regulate wetlands. Hatano et al. (1993) states that plants significantly affect the microbial populations of constructed wetlands. Bacteria dominate in wetlands, with actinomycetes often present. Actinomycetes offer a wide range of enzymatic activities. Fungal populations are usually quite small, and function similarly to the actinomycetes (Hatano et al., 1993). Harmful organisms are also found in treatment wetlands. These kinds of bacteria include *Salmonella* spp., *Campylobacter fetus, Shigella* spp., and *Leptospira* spp. The highly publicized fecal coliform bacteria are also potentially harmful bacteria. Potentially dangerous viruses include the hepatitis A virus, rotavirus, and enteroviruses.

Table 1.4. Advanced discharge standards (Hammer, 1994).

FACTOR	STANDARD
BOD and TSS	<70 kg/ha/d, <20 mg/L
Dissolved Oxygen	>4 mg/L
TKN or NH_3-N	<3 kg/ha/d
NH_3-N	<4 mg/L
PO_4-P	<0.2 kg/ha/d, <1 mg/L
Hydraulic Loading	<500 m3/ha/d
Retention Time	>10 days
Fecal Coliforms	< 100 CFU/100 mL
pH	6-9

Plants store carbon and other nutrients, but individual nutrient contents of the tissue of plants varies. Large amounts of carbon are also created by plants, of which the breakdown of the organic carbon competes with any breakdown by bacteria of additional organic material added through attempts at waste treatment. Microorganisms need carbon for the denitrification process. Carbon can be the source of energy for bacteria, can accumulate in the sediments, or can be transported to other ecosystems (Gutenspergen and Stearns, 1985).