NUTRIENT LOSS REDUCTION TECHNIQUES FOR ILLINOIS

Constructed Wetlands for Nitrate Removal from Tile Drainage Water

Nitrate loss from tile drained corn-soybean fields is a major contributor to water quality problems. Constructed wetlands are a proven and long-term approach to reducing nitrate losses that do not require cropping system changes.

Statement of the problem: Nitrate nitrogen (nitrate-N) concentrations in tile drainage water from corn and soybean production (and similar row crops) typically range from 10 to 30 ppm nitrate-N, which exceeds the maximum contaminant level for drinking water and has contributed to impaired water quality for the cities of Decatur, Danville and Georgetown, Illinois and Des Moines, Iowa. Additionally, the nitrate loads from tile drained regions in the Midwest disproportionately contribute to the formation of bottom water hypoxia (also known as "the dead zone") in the northern Gulf of Mexico. Careful management of fertilizer and manure nitrogen can reduce tile water concentrations and loadings and maximize farmer profits. However, economically efficient fertilizer and manure management alone is not likely to provide enough reduction to fully address these water quality problems. Even with the most finely tuned management of nitrogen fertilizer, nitrate losses from tile drained fields can be large, especially following low corn yields due to a variety of factors such as drought, wind damage, disease or insect infestations. Seed corn production can produce large nitrate N losses under most conditions because harvested seed yields are usually low in comparison to the N fertilizer applied.

In addition to in-field conservation practices such as cover crops and the 4Rs of nutrient management, farmers, landowners and land managers could also consider whether constructed wetlands might be compatible with their landscape and farming operations. In central Illinois, a properly designed and operated one acre constructed wetland can remove about 50% of the nitrate-N in tile drain discharge leaving 20-25 acres of tile drained row crops before the water enters streams, rivers and drainage ditches.

How do they work?

Wetlands remove nitrate by providing conditions favorable for microbes that can remove some or all of the oxygen from nitrate, converting the nitrogen into gaseous forms. This process is called denitrification and the microbes responsible for it are called denitrifiers or denitrifying bacteria. If the denitrifiers remove all the oxygen from nitrate, which usually occurs, inert and harmless di-nitrogen gas (N_2) is emitted, which makes up 79% of the Earth's atmosphere. But, under some circumstances, nitrogen oxides can be released, such as nitrous oxide (N_2O) which is a potent and undesirable greenhouse gas. To date, measurements have recorded only small amounts of N_2O being emitted from wetlands.

Denitrifiers require readily digestible carbon as a food source and an absence of dissolved oxygen (also called anaerobic or anoxic conditions). When oxygen and digestible carbon are in water, a wide variety of micro-organisms will feed on the carbon and utilize the dissolved oxygen for respiration. Since oxygen is not very soluble in water, an abundant supply of carbon can quickly deplete and eliminate dissolved oxygen in stagnant or slow moving water, thereby creating anaerobic conditions below the water surface. In these conditions, the denitrifying microbes utilize the oxygen portion of the nitrate for respiration, converting the nitrate to gaseous forms in the process. Without vertical mixing, oxygen diffusion into the water from the surface is relatively slow, so as long as there is abundant carbon and little or no vertical mixing of a water column, the deeper water will remain anaerobic and nitrate-N can be converted to gaseous forms by the denitrifiers.

The percentage of nitrate removed in wetlands depends upon the temperature, the quality of the carbon available to the micro-organisms (woody material is less readily available than leaf and stem residues), the nitrate concentration of the drainage water, and how long the water resides in the wetland (called residence time). The residence time will vary depending on the volume of the wetland and the rate of incoming drainage water. Residence times are shorter during and following large rainfall events that produce high rates of drainage discharge, and thus a smaller percentage of nitrate will be removed during these events. Rainfall events that produce low rates of drainage will result in longer residence times, and thus a greater percentage of nitrate removal. In a given year, the percentage of nitrate removed will vary depending on the timing and amount of rainfall and drainage events.

The activity of the microbes and the rate of nitrate-N removal depends upon the water temperature. Consequently, nitrate removal rates in winter and early spring tend to be much lower than in late spring and summer.

What are appropriate locations for constructed wetlands?

Wetlands for treatment of tile drainage water are often located in low lying edges of agricultural fields near a tile drain outlet, so that tile drainage water can be readily delivered into the wetland. However, placement of treatment wetlands is not limited to edge of field tile outlets. Treatment wetlands can also be located in upland areas where they can intercept tile drainage systems. NRCS recommends that treatment wetlands not be located within existing natural wetlands in order to avoid disturbing the wildlife value of natural wetlands.

How are constructed wetlands designed and constructed?

Treatment wetlands are essentially shallow water holding basin. By considering the drainage area, soil types and rainfall frequencies, the wetland can be designed so that the average water residence time provides a desired percentage of nitrate removal. Technical design procedures are described in NRCS National Engineering Handbook, Part 637, Chapter 3 titled "Constructed Wetlands". Designs can incorporate landowners' and operators' interests and concerns regarding maintenance and providing wildlife habitat. As a general guideline, a wetland area that is about 5% of the tile drained area discharging into it will remove about 50% of the nitrate-N.

Earthmoving is typically required to build berms and shape the wetland to achieve adequate depth and residence times. Berms must be designed and constructed to minimize seepage and erosion. Design and construction must also include features so that overflow events don't damage the integrity of the berms. If the wetland receives large quantities of surface flow containing sediment or other solids, a pre-treatment basin may be needed to reduce the sediment delivery to the wetland.

How much do they cost?

The major initial costs of wetlands include land and construction costs, both of which will vary depending on:

- the local land and labor market prices
- the value of the land converted to the treatment wetland; and
- the amount of earthwork required for construction. Ongoing economic considerations include the cost of mainteance, which is usually small, and the lack of crop revenue from area converted to wetland. The loss of crop revenue can be minimized by establishing the wetland in areas with low crop yields.

What management is required?

Periodic inspections are needed to ensure that water levels are appropriate, bank erosion is under control and that plant species are desirable. Many wetlands require little or no additional management, but depending on the setting and design, some may require occasional sediment clean out, reshaping of embankments or control of undesirable vegetation. Wetland berms should be mowed annually to prevent the establishment of trees and woody vegetation that can cause berm failure.

Do constructed wetlands provide any benefits besides nitrate removal?

Besides nitrate removal, constructed wetlands can provide some downstream flood reduction benefit as well as wildlife habitat for a variety of species such as waterfowl, birds, frogs, turtles and muskrats, although muskrats can damage the berms. Wetlands designed for nitrate removal are not expected to remove phosphorus from tile drainage water because there is not a mechanism like denitrification for phosphorus.

Government support for wetland construction

The Farmable Wetland Program under the USDA's Conservation Reserve Program offers the Constructed Wetland Practice (CP-39). CP-39 supports the construction of wetlands that will reduce nutrient loading; improve surface and groundwater quality, provide habitat for waterfowl and other wildlife; and reduce flooding.

Where can I find more information?

- **Illinois Nutrient Loss Reduction Strategy** http://www.epa.illinois.gov/topics/water-quality/watershed-management/excess-nutrients/nutrient-loss-reduction-strategy/index
- **USDA NRCS** http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_025770.pdf
- **Iowa State University Extension** http://www.extension.iastate.edu/Publications/IAN204.pdf

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