**Bioreactor Results from 2013-2014**

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In today's agriculture field tiling is a common practice to increase crop production by draining excess water out of the plant root profile, creating a more favorable growing environment. Of major concern is the elevated concentration of nitrate-nitrogen in tile water that leaves the site and eventually makes its way into the Mississippi river, emptying out into the Gulf of Mexico, creating a hypoxic zone. A hypoxic zone is created by high levels of nutrients, such as nitrate ($NO_3$) nitrogen, which trigger large blooms of algae growth. When the algae bloom dies it falls to the bottom of the gulf and bacteria decompose the algae. The decomposition process consumes most of the oxygen in a significant area of Gulf water near the shoreline. Without oxygen aquatic life in the area flees or dies. The hypoxic zone, or dead zone, in the Gulf has averaged about 5000 square miles over the last 5 years.

In the summer of 2012 a 14 acre field was pattern tiled and a woodchip based bioreactor was constructed at the tile discharge point. The bioreactor is a biological system for converting $NO_3$-N to dinitrogen gas, in effort to reduce $NO_3$-N flow into the watershed. The bioreactor is approximately 60 feet long, 20 feet wide and 5 feet deep. The bioreactor is filled with 3 feet of woodchips, covered with woven fabric (Pro5 Weedbarrier), and 2 feet of topsoil on top of the fabric. Tile water flows into the bioreactor and through the bed of woodchips. Woodchips, a carbon source, provide the material for certain denitrifying bacteria to colonize. Depending on conditions, these bacteria can transform nitrate into dissolved dinitrogen gas as the water passes through the bioreactor. The bacteria basically steal the oxygen from the nitrate molecule. The dinitrogen gas, which is harmless, eventually escapes to the atmosphere.

The denitrification potential of bioreactors is influenced by the rate of water flow through the bioreactor, as well as temperature, pH, dissolved oxygen, and oxidation/reduction potential. Sizing of the bioreactor in relation to the area drained has not been established yet. Bioreactors may be the best fit for fields receiving manure application where nutrient availability is variable, more so than in agricultural drainage systems where nitrogen best management practices that reduce nitrate-nitrogen concentrations in tile water are already in place. Bioreactors could be one of many methods to reduce environmental damage from nutrient discharge.

## Cropping Procedures

In the fall of 2012 solid dairy manure was applied to the field at a rate of 152 lbs/available/N/ac. The field was disk-chiseled after manure application.

In the spring of 2013 instrumentation was installed at the site to measure tile flow rate and the concentration of nitrate nitrogen in the tile water entering and exiting the bioreactor. After instrumentation was installed the field was seeded to organic corn on May 26$^{th}$. The corn was

chopped for silage on September 20th, the field was disk-chiseled and field cultivated, and then seeded to organic winter wheat on September 24th.

In 2014 the winter wheat was chopped for wheatlage on June 11th, tilled on June 26th, and seeded to organic soybeans on June 27th. The soybeans were harvested on October 16th.

**Results**

The average concentration of nitrate nitrogen in tile water entering the bioreactor throughout the year in 2013 was 22 ppm (1st year manure) and in 2014 was 13 ppm (2nd year manure). The concentration of nitrate-nitrogen measured in soil in a 0-2 foot nitrate-nitrogen test on May 30th 2013 was 13 ppm, and on May 30th 2014 was 7 ppm.

In 2013, for the 14 day period ending June 11th, 1810 gallons of water flowed through the reactor each day, with nitrates entering at a concentration of 22 ppm and exiting with a concentration of 3 ppm. During the period of June 21st through June 25th the bioreactor was overwhelmed with 108,851 gallons of water flowing through each day (June 21st through June 23rd we recorded 7.49 inches of precipitation) in which no measurable denitrification took place. When water flow returned to more normal rates, from June 27th through July 18th, an average of 6,815 gallons per day flowed through the reactor reducing nitrates from 17 ppm to 3 ppm.

In 2014 with a 4 day flow event of 8,961 gallons per day, ending June 3rd, nitrate concentration in the water was reduced from 8 ppm entering the reactor to 2 ppm exiting the reactor. A 10 day flow event of 9,578 gallons per day, ending June 13th, reduced nitrates from 13 ppm to 7 ppm. Similar sized substantive nitrate reductions were measured on events ending on June 27th (8,380 gallons per day, 4 days, 15 ppm to 9 ppm) on July 3rd (6,770 gallons per day, 6 days, 13 ppm to 5 ppm) on July 14th (6,474 gallons per day, 11 days, 16 ppm to 4 ppm) and on August 29th (6,922 gallons per day, 9 days, 13 ppm to 2 ppm).

Very modest/minimal nitrate reductions were achieved at higher daily flow rates. An event ending June 23rd (15,921 gallons per day, 3 days, 14 ppm to 11 ppm), June 20th (29,647 gallons per day, 3 days, 13 ppm to 11 ppm), and June 17th (33,684 gallons per day, 4 days, 10 ppm to 9 ppm).

**Conclusions**

2013 and 2014 results indicate that a wood chip based bioreactor, sized 60 feet x 20 feet with a 3 foot depth of wood chips, will substantially reduce the nitrate concentration of tile water when under 10,000 gallons of water flow through on a daily basis.

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**Nitrate-Nitrogen Concentration of Tile Water Entering and Exiting the Bioreactor.**

| Ending Date of Flow Event | Gallons | Days | Gallons per Day | ppm NO3-N Entering the Bioreactor | ppm NO3-N Exiting the Bioreactor |
|---|---|---|---|---|---|
| 5-7-2013 | 6,247 | 8 | 781 | 22 | 9 |
| 6-11-2013 | 25,377 | 14 | 1,810 | 22 | 3 |
| 6-25-2013 | 544,253 | 5 | 108,851 | 22 | 24 |
| 7-18-2013 | 149,946 | 22 | 6,815 | 17 | 3 |
| | | | | | |
| 5-15-2014 | 161 | | | | |
| 5-30-2014 | 6,857 | 15 | 457 | 12 | 1 |
| 6-3-2014 | 35,844 | 4 | 8,961 | 8 | 2 |
| 6-13-2014 | 95,780 | 10 | 9,578 | 13 | 7 |
| 6-17-2014 | 134,736 | 4 | 33,684 | 10 | 9 |
| 6-20-2014 | 88,942 | 3 | 29,647 | 13 | 11 |
| 6-23-2014 | 47,764 | 3 | 15,921 | 14 | 11 |
| 6-27-2014 | 33,519 | 4 | 8,380 | 15 | 9 |
| 7-3-2014 | 40,622 | 6 | 6,770 | 13 | 5 |
| 7-14-2014 | 71,217 | 11 | 6,474 | 16 | 4 |
| 7-25-2014 | 20,801 | 11 | 1,891 | 15 | 3 |
| 7-26 to 8-20 | 0 | | | | |
| 8-29-2014 | 62,294 | 9 | 6,922 | 13 | 2 |
| 9-8-2014 | 16,311 | 10 | 1,631 | | |