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Summary

Swine production is an important agricultural enterprise that requires significant attention to waste management. An investigation of the treatment of swine wastewater using constructed wetlands was initiated in Duplin County, North Carolina, in 1992. The investigation used three sets of two 12 ft by 120 ft constructed-wetland cells that contained either natural wetland plants or water tolerant agronomic plants. Sets of cells contained rush/bulrushes, bur-reed/cattails, or soybean in soil saturated culture and rice. High ammonia-N levels, which are toxic to plants, were the primary concern. Ammonia-N concentrations in wastewater were kept below 100 ppm by dilution with freshwater. Nitrogen loading rates of 2. 7 and 9 lb/ac/day were used for the first and second year of operation, respectively. Ammonia-N inflow ranged from 21 to 88 ppm. Soluble phosphorus inflow ranged from 6 to 12 ppm. Mean outflow ammonia-N ranged from 1 to 8 ppm. Mean outflow soluble phosphorus ranged from 2 to 10 ppm. Overall total mass removal for nitrogen and phosphorus was 90 and 80%, respectively. Mean estimated above-ground dry matter production for rush/bulrushes and bur-reed/cattails was 7 and 9 ton/ac, respectively. Rice yield was 2,500 lb/ac (56 bu/ac) and soybean cultivar Young yielded 3,600 lb/ac (59 bu/ac). Redox conditions of the wetland soils in all cells in summer were highly anaerobic, and no nitrate-N accumulated. Mean nitrate-N levels increased (up to 4 ppm) during the cooler autumn and winter periods, probably due to more oxidative conditions and lower denitrification activity. Denitrification measurements indicated that the system is nitrate limited for denitrification. Phosphorus mass removal decreased substantially in the second year due to anaerobic conditions and limited capacity of the wetland soil. It appears that more oxygen would be beneficial for long-term removal of both nitrogen and phosphorus. Enhanced oxidation, treatment efficiency, and sustainability might be obtained by sequencing other land treatment methods such as overland flow or media filter with constructed wetlands.

Project Description

The project objectives were to 1) evaluate constructed wetlands and modify them as needed for treatment of swine wastewater in the southeastern United States; 2) determine appropriate wetland vegetation to provide optimum wastewater treatment; and 3) evaluate alternative harvestable crops that can be grown in a wetland environment and help remove nutrients from the system.

Three sets of two 12 ft by 120 ft constructed-wetland cells were built in Duplin County, North Carolina, in 1992. Sets of cells contained rush/bulrushes, bur-reed/cattails, or soybean in soil saturated culture and rice. Wastewater generated from the swine facility received primary treatment in an anaerobic lagoon. The lagoon effluent was diluted with freshwater in order to avoid plant toxicity to ammonia-N when it was applied to the wetlands. Nitrogen loading rates of 2.7 and 9 lb/ac/day were used for the first and second year of operation, respectively. Daily composite samples for water quality analyses were collected from the wastewater inflow and outflow effluents by seven automated samplers. Water samples were analyzed for chemical oxygen demand, total nitrogen, ammonia-N, nitrate-N, total phosphorus, and soluble phosphorus. Six V-notch weirs and six electronic flowmeters were installed at the inlet and outlet of each set of cells. Flow data and nutrient concentration data were used to calculate nutrient balances. The study was complemented by continuous monitoring of the aerobic/anaerobic conditions of the soil using redox probes, an intensive sampling of the soil/water column, and denitrification assays to gain better insight into the nutrient cycling capabilities of the wetland system.

Results

The effluent from the storage lagoon was anaerobic with chemical oxygen demand ranging from 397 to 950 ppm. Total nitrogen and total phosphorus mean concentrations were 364 and 94 ppm, respectively. Most of the total nitrogen (95%) and total phosphorus (86%) were in the form of ammonia-N and soluble phosphorus. Nitrate-N was low due to the anaerobic conditions of the waste.

The 1993 and 1994 means for above-ground dry matter productions by rush/bulrushes and cattails/bur-reed were 7 and 10 tons/ac, respectively. Rice yield was 2,500 lb/ac (56 bu/ac), and the soybean cultivar Young yield of 3,600 lb/ac (59 bu/ac) was much higher than the state average of 1,600 lb/ac (27 bu/ac).

Quarterly means of ammonia-N inflow ranged from 22 to 49 ppm. Mean outflow ammonia-N was 3 ppm or lower for the rush/bulrushes throughout the year. The discharge of ammonia-N in bur-reed/cattails cells ranged from 1 to 8 ppm. Nitrate-N in the inflow was below 2 ppm. During the warmer periods, nitrate-N in the discharge waters was < 0. 5 ppm. In the cooler period of Oct. 1993-Mar. 1994, nitrate-N in discharge waters ranged from 2 to 10 ppm.

Mean inflow soluble phosphorus ranged from 6 to 12 ppm. In the initial period (June-Sept. 1993), outflow values were about 0. 2 ppm, but thereafter they ranged from 2 to 4 ppm. Total

mass removal during the first year for nitrogen and phosphorus was 90 and 80%, respectively. However, the removal efficiency for phosphorus substantially decreased with increasing nutrient load rates in the second year of operation.

Soil redox values were very low from July-Sept. 1993 (+100 to -250 mV) for all plant communities even though the wastewater was diluted > 10 times, and soluble carbon was below 20 ppm. Soil redox values increased from Oct. 1993-Mar. 1994 for rush/bulrushes, and nitrate- N was present in the discharge effluent. The increase in nitrate-N indicated that cooler temperatures had increased oxygen solubility and decreased microbial oxygen demand. A similar effect occurred in the cattails/bur-reed cells, but redox potentials were much lower because cattails are less efficient in the transfer of oxygen to their roots.

The denitrification assays showed that the systems could denitrify much more nitrate-N if it were present. Since nitrification is limited by lack of oxygen, it appears that increased oxygen would be beneficial for long-term removal of both nitrogen and phosphorus. Enhanced oxidation, treatment efficiency, and sustainability might be obtained by sequencing other land treatment methods such as overland flow and filter media with constructed wetlands to increase oxygen content levels in the wastewater.

Technology Transfer

The constructed wetlands system is a component of the Herrings Marsh Run Demonstration Project, an ongoing USDA Water Quality Project that is nested within the Goshen Swamp Hydrologic Unit Project, which is one of 37 projects across the country funded by the USDA. Results of the study will be used by multiple project cooperators interested in innovative swine waste management technologies to support producer recommendations for existing or new swine waste management systems. Project cooperators include Murphy Farms (a major pork producing company) and North Carolina Pork Producers Association. Other cooperators include state and federal agencies, North Carolina Cooperative Extension Service, Duplin County Cooperative Extension Service, USDA-Soil Conservation Service, USDA-Agricultural Stabilization and Conservation Service, USDA-Agricultural Research Service, and North Carolina Agricultural Research Service. Technology transfer is being made and will continue through oral presentations, publications, educational programs, tours, and workshops that target a broad audience (landowner/ producer, technical, waste management, youth, and special interest groups). A workshop titled Constructed Wetland Technology was held in Wilmington, North Carolina, May 1-4, 1994. The workshop, organized by North Carolina State University and sponsored by the project cooperating institutions, attracted 75 attendees, who also participated in a tour to the study site.

Public Affairs Activities

This project was partly funded by the North Carolina Herrings Marsh Run Water Quality Demonstration Project, USDA Project No. 90-EWQD-1-9504; the North Carolina Goshen Swamp Hydrologic Unit Area Project, USDA Project No. 90-EHUA-1-0013; and the Evaluation

of Alternative Constructed Wetland Systems for Swine Wastewater Treatment, USEPA Project No. CR823808-01-0.

The following technical papers:

Hunt, P.G., F.J. Humenik, A.A. Szögi, J.M. Rice, K.C. Stone, T.T. Cutts, and J. P. Edwards. 1993. Constructed wetland treatment of swine wastewater. Presented at the ASAE 1993 International Winter Meeting, Chicago, IL. ASAE Paper 93-2616. ASAE, 2950 Niles Rd., St. Joseph, MI 49085-9659.

Hunt, P. G., F.J. Humenik, A.A. Szögi, J.M. Rice, K.C. Stone, and E.J. Sadler. 1994. Swine wastewater treatment in constructed wetlands. pp. 268-275. In K. L. Campbell, W.D. Graham, and A.B. Bottcher (eds.) Environmentally Sound Agriculture. Proceedings of the Second Conference, 20-22 April 1994, Orlando, FL. Am. Soc. Agric. Eng., St. Joseph, MI.

Hunt, P.G., A.A. Szögi, F.J. Humenik, J.M. Rice and K.C. Stone. 1994. Swine wastewater treatment by constructed wetlands in the southeastern United States. pp. 144-154. In P.J. DuBowy and R.P. Reaves (eds.) Proc. Constructed Wetlands for Animal Waste Management Workshop. Dept. of Forestry and Natural Resources, Purdue University, Lafayette, IN.

Szögi, A.A., P.G. Hunt, F.J. Humenik, K.C. Stone, J.M. Rice and J.E. Sadler. 1994. Seasonal dynamics of nutrients and physico-chemical conditions in a constructed wetland for swine wastewater treatment. Presented at the 1994 ASAE International Winter Meeting, Atlanta, GA. ASAE Paper 94-2602. ASAE, 2950 Niles Rd., St. Joseph, MI 49085-9659.

General public information has been disseminated through a program on UNC public television; feature articles in *Carolina Farmer* magazine; a newsletter published by the Extension Services; and brochures published by the Soil Conservation Service, Kenansville, N.C., offices. Field days are conducted on a quarterly basis, and a major field day will be held during September 1995.