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THE POTENTIAL OF USING CONSTRUCTED WETLANDS TO TREAT ANIMAL WASTE IN THE VIRGIN ISLANDS

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ABSTRACT

The increase of intensive livestock farming in the Virgin Islands, most recently with the addition of a 400 animal unit dairy on St, Croix, can lead to a subsequent decrease in coastal and ground water quality due to pollution from animal wastes. Confining livestock to smaller areas to improve production efficiency also concentrates animal wastes. Runoff of these wastes to nearby guts or leaching into groundwater aquifers can contaminate waters with bacteria, nutrients, BOD and TSS (total suspended solids). Removal of riparian vegetation (vegetation native to guts and natural drainages) to increase available acreage, vegetation depletion by livestock grazing and loafting activities, and direct access of livestock to streamside areas has eliminated the buffer strips that formerly protected from direct pollution. Affordable, effective wastewater used for human consumption. Constructed wetlands are being used increasingly to treat both municipal and agricultural wastewater in the United States with great degrees of success. This innovative wastewater treatment practice has potential for use in the Virgin Islands to inexpensively and effective remove pollutants from wastewater and protect the quality of our waters.

INTRODUCTION

THE ADVERSE EFFECTS OF ANIMAL WASTE

Runoff containing animal wastes can pollute surface and ground water, contaminating local drinking water supplies and coastal waters. Animal wastes include manure, washdown water, cleaners and disinfectants, feed, and product waste (spilt milk, broken eggs, etc.). One cow can produce as much waste as 11 people; pigs produce 6-8 pounds of manure per 100 pounds weight per day; one chicken house can produce 10 tons of waste per day (U.S. EPA, 1993).

Animal wastes contribute oxygen-demanding substances, nutrients, organic materials, suspended solids and pathogens to receiving waters. The decomposition of organic materials can deplete dissolved oxygen supplies in water resulting in anoxic conditions. Methane, amines, and sulfide are produced in anoxic waters, causing the water to have an unpleasant odor, taste, and appearance. This renders coastal waters unsuitable for fishing, swimming and other recreational uses (U.S. EPA, 1993).

Suspended solids and nutrients in animal wastes deposited into waterbodies can accelerate eutrophication by encouraging excessive algal growth. Excessive algae and sediments smother coral reefs and seagrass beds, decrease light penetration for aquatic plant growth, and smother bottom-dwelling organisms. This increased turbidity can also interfere with fish feeding and spawning habits.

Animal diseases can be spread and/or transmitted to humans through contact with animal feces. Runoff from pastures, feed lots and other animal facilities can contain extremely high concentrations of bacteria and other pathogens. These high concentrations can lead to beach closures, contaminated shellfish, and contaminated drinking water.

Livestock wastewater has a number of different sources -- feedlots, milking parlors, loafing areas, housing facilities, manure storage and application areas, and pasture runoff. This waste is a major management problem for farmers due to a number of factors: high waste strength and volume, high construction and operation costs for treatment, lack of adequate land disposal areas, time consuming and labor-intensive operations, and lack of technical information and financial assistance.

ANIMAL WASTE IN THE VIRGIN ISLANDS

There are currently 6 dairy, 100 livestock, and 3 poultry farms in the Virgin Islands (USVI Bureau of Economic Research, 1990). In 1987, these facilities produced a wide variety and number of animals:

Type of Animal	Number
Horses	324
Sheep	3134
Goats	3315
Hogs	2536
Cattle:	
Cows	2499
Heifers	1130
Bulls	488
Chickens	5326
Turkeys and Other	727

Given the environmental conditions of the Virgin Islands -- steep slopes, high intensity rainfall events, close proximity of any given area to coastal waters, shallow depth to fractured bedrock, clayey soils, and unconfined aquifers -- animal wastes can rapidly and easily enter both surface and ground waters where they can contaminate drinking water supplies and coastal waters. Few farms have sufficient waste storage and treatment facilities and many allow animals to stand or wallow in guts and ponds, directly polluting surface waters.

There are presently no large confined feedlots (greater than 150 head) in the Virgin Islands. However, there are approximately sixteen small feedlots (for hogs and dairy as well as poultry facilities) on St. Croix and St. Thomas. Waste treatment systems that are typically used at these facilities consist of lagoons that only provide partial treatment, removing settleable solids and some BOD5, with effluent from the lagoons then discharged into guts.

Currently, a large dairy has completed construction on St. Croix. It will start operations with a 200-head fully confined animal facility utilizing a solids separator to process all washwater and product waste. Effluent will then flow into an aerobic lagoon for treatment to remove further suspended solids (TSS) and BOD5, with resulting effluent to be used for improved pasture irrigation.

Due to the scarcity of water in the Virgin Islands, as evidenced by our current drought, many agencies and individuals have been looking into similar types of systems to reclaim wastewater (both agricultural and municipal) for irrigation purposes. One system with great potential for application in the Virgin Islands is a constructed wetland system (or artificial wetland).

ALTERNATIVE WASTE TREATMENT METHODS -- CONSTRUCTED WETLANDS

A constructed wetland is an aquatic ecosystem with rooted emergent hydrophytes that is designed, constructed and managed to treat agricultural or municipal wastewater. These systems build on the physical, chemical, and biological processes inherent in wetlands in order to treat wastewater naturally instead of using complicated and expensive mechanical systems. The interaction of plants, microscopic organisms, aerobic and anaerobic substrates, and a meandering water column can remove nutrients, organic compounds, pathogens, and metallic ions and increase oxygen and pH levels in a variety of wastewaters (TVA, 1992). The most frequently recommended type of system is a surface flow constructed wetland in which wastewater flows across plant beds within a basin or cell that also has a free-water surface.

Constructed wetlands are easy to design, build, maintain, and operate as compared to mechanical systems. They are an affordable, effective, and environmentally pleasing method of protecting water quality. In a typical constructed wetlands treatment system, depending on pre-treatment and target discharge levels, construction costs range from 10% to 50% less costly as compared to conventional treatment systems, and operation and maintenance costs are 5% to 10% of conventional treatment costs (TVA, 1992).

In an ideal system, wastewater is distributed evenly across the surface of the constructed wetland, which generally consists of two or more cells. The bottom of each cell is levelled and the vegetation is dense. The wetland treats agricultural wastewater using natural processes: solids settle and are filtered; organics are used as food by microorganisms; nutrients and metals are attenuated by plants, microorganisms, and soil; and pathogens are removed with the solids and gradually die with time.

Constructed wetlands usually utilize plant species native to the given area. The plants provide the right conditions for micro-organisms that live in the wetland. Wetland plants only remove a small fraction of the pollutants present in wastewater, most treatment is provided by the numerous bacteria and other micro-organisms that live on the host plants.

A lagoon, pond, or other pre-treatment solids trap is usually used in front of a constructed wetland system to remove heavy and coarse solids. Much of the organic solids that settle out of the wastewater in the lagoon are aerobically or anaerobically digested. Any remaining sludge is removed and either disposed of, composted, or land-applied as fertilizer. The pretreatment lagoon then discharges liquid effluent to the constructed wetland.

The constructed wetland includes one or more wetland cells in series or parallel. Multiple cells improve the effectiveness of the system and provide for flexible operation and maintenance. Construction is simple -- a bulldozer can be used to level the site and build small dikes around the system. PVC pipe is usually used to distribute and collect wastewater and to control water levels in the wetlands. Water levels are normally very shallow, ranging from 3 to 12 inches. Uncontaminated stormwater runoff is routed away from the system or can be stored and used for dilution if needed. A constructed wetland can be designed to either discharge treated wastewater or to have no discharge whatsoever.

This system is especially useful in the Virgin Islands because we have a year-long growing season so that plants and microbes can continually treat the wastewater. The high evapotranspiration rates common to the Virgin Islands are also favorable to this type of system -- a wetland can be designed so that no effluent leaves the wetland, it is all used by the plants. For 150 dairy cows, the estimated required land area for a constructed wetlands system (including pre-treatment) is 1 to 2 acres (U.S. EPA, 1992).

The system should be inspected periodically to detect and correct or manage any potential problems such as short-circuiting of flow, loss of plants, leakage through dikes, and pipe clogging.

Advantages

- low cost construction and operation;
- energy efficient;
- accepts varying waste loads;
- simple operation and maintenance;
- aesthetically pleasing; and attracts wildlife

Limitations

- steep topography;
- shallow topsoil or depth to bedrock;
- limited land space;
  engineers and regulators not yet
- familiar with technology; and
- potential mosquito production

DESIGN CONSIDERATIONS FOR CONSTRUCTED WETLANDS

This practice is applicable where:

- An overall waste management system has been planned;
- Wastewater generated by agricultural production or processing needs treatment;
- Wastewater is of sufficient volume and duration to keep the constructed wetland moist at all times;
- Wastewater or polluted runoff can be discharged to the constructed wetland at a controlled rate;
- Soil, water and plant resources are adequate to properly establish suitable vegeta tion and to allow for proper management of the constructed wetland; and
- Any effluent from the wetland can be either recycled, land-applied, or discharged in accordance with local (V.I. DPNR) and federal (U.S. EPA and NOAA) regula tions (SCS Caribbean Area, 1993).

Plants selected for use in constructed wetlands should be emergent hydrophytic vegetation suitable for tropical climates and tolerant of high concentrations of nitrogen and other pollutants in animal wastewater. Plants used should be native to the given area. Principal plants include:

- Cattail (*Typha* sp.)
- Bulrush (*Scirpus* sp.)
- Maidencane (*Panicum hemitomon*)
- Rushes (*Juncus* sp.)
- Reeds (*Phragmites* sp.)

Other species that can be used include pickerel weed (*Pontedaria cordata*), arrowhead (*Sagittaria latifolia*), canna lily (*Canna flacida*), elephant ear (*Colocasia esculenta*), blueflag iris (*Iris virginica*), giant cutgrass (*Zizaneopsis miliacea*), and water chestnut (*Eleocharis dulcis*). Free floating plants, such as water hyacinth and duckweed, although proven useful in other systems, should not be used due to the need for harvesting (SCS, Caribbean Area, 1993).

System design should be based on treatment objectives, quality of influent, and realistic performance expectations. Minimum treatment objectives based on effluent concentrations from the wetland are:

- Biological Oxygen Demand (BOD_5) < 15 mg/L
- Total Suspended Solids (TSS) < 30 mg/L
- Ammonia + Ammonium-Nitrogen (NH_3-N + NH_4-N) < 10 mg/L

Constructed wetland size can be determined as a function of influent pollutant concentrations, desired effluent pollutant concentrations, wastewater flow rate within the cells, water temperature, evapotranspiration, and the ratio of the volume of the wetland occupied by water to the volume occupied by plants and water.

Technical assistance for installing constructed wetlands systems is available to farmers and homeowners in the Virgin Islands from the UVI Cooperative Extension Service, the USDA Soil Conservation Service, the Environmental Protection Agency, and private consultants. Financialassistance is available from the Small Business Administration under Section 7(a)(12) - Loan Program for pollution control facilities, and USDA ASCS provides 70% cost-share for earth work and materials for the installation of constructed wetlands. Farmers Home Administration also offers loans to construct agricultural wastewater treatment facilities.

EXAMPLES FROM AROUND THE COUNTRY

The Scott dairy farm in Herando, Mississippi is a 117-head dairy. Wastewater from milking equipment, barn wash water, loafing area runoff, and rainfall flows into an earthen lagoon 5140.8 m^3 (183,600 ft^3, areal extent 0.21 ha or 0.53 acre). Runoff is pumped from the lagoon to a holding tank, from which constant wastewater flow moves to three parallel 134.4m^3 (4800 ft^3, areal 1600 ft^2 or 148.8 m^2) wetland cells for treatment. Giant bulrushes (*Scirpus validus*) were planted in the wetland cells at 1-foot intervals. Each cell processes 51 ft^3/day of wastewater. Eighteen water quality indicators are monitored bi-weekly. A fourth cell was built two months after installation to further treat outflow from cell 1. Adding a cell in series halved the amount of contaminants in the effluent (TSS and phosphorus). The wetlands system is very effective in removing the primary targets of the project: Ammonia (91%) and total coliform (96%).

The Auburn University AES, Alabama, has a 500-animal farrowing and finishing swine operation. using a constructed wetlands treatment system. Waste is routed to a two-cell-in-series lagoon system. Wastewater discharges from the lagoons into a mixing pond that also receives water from a farm pond located upstream. Effluent then flows from the mixing pond into five pairs of cells planted with marsh vegetation, then into a wet meadow for final polishing. The treatment area in the cells is 3600 m^2 with an additional 2100 m^2 in wet meadow. System piping provides for variable wastewater application rates and water level control within each cell. The cells were initially planted with cattail (*Typha latifolia*), soft-stem bulrush (*Scirpus Validus*), giant cutgrass (*Zizaniopsis miliacea*), maidencane (*Panicum hemitonom*), common reed (*Phragmites australis*), and water chestnut (*Eleocharis dulcis*). However, other species quickly invaded. Four groundwater wells were installed near the wetlands along with 16 lysimeters installed in 4 of the wetland cells for monitoring.

The 500-animal swine operation is estimated to produce 90 kg BOD_5/day, reduced to 36 kg BOD_5/day (60%) in the final lagoon discharge. Minimum treatment area for 36 kg BOD_5/day at 150 m^2/kg BOD_5/day is 5400 m^2. The total treatment area of the wetlands system and finishing meadow is 5700 m^2 or 158 m^2/kg BOD_5/day.

Results of monitoring show that treatment performance of the wetland is not affected by type of vegetation. Pollutant removal rates are consistent regardless of loading rate. The replicate wetland tier produced significant reductions of TKN, NH_3-N, TP, and fecal streptococci. The wet meadow significantly enhanced removal of TSS, BOD_5 and fecal coliform. Total pollutant removal for the entire system is 90.4% BOD_5, 91.4% TSS, 99.4% fecal coliform, 98.4% fecal streptococci, 75.9% total P, 91.4% TKN, and 93.6% NH_3-N.

The Lajas, Puerto Rico Experiment Station will be conducting a study involving the use of constructed wetlands for treatment of hog waste for a 100-animal farrowing and finishing operation. Construction of the facility is nearly complete. The waste treatment system will consist of a settling pond with effluent routed to six wetland cells with a total area of 600 m^2. Four different wetland species will be planted, including sedges (*Cyperus* sp.), cattails (*Typha* sp.), water chestnut (*Eleocharis dulcis*), and elephant ear (*Colocasia esculenta*). The system is designed to remove nitrogen and phosphorus to levels that meet Commonwealth of Puerto Rico water quality standards.

CONCLUSION -- VIABILITY IN THE VIRGIN ISLANDS

Constructed wetlands offer great potential for treating animal waste in the Virgin Islands. Our year-long growing season and high evapotranspiration rates can greatly enhance the effectiveness of wetland plants and microbes in filtering out, digesting and/or adsorbing pollutants and vastly reducing wastewater volumes. It is even possible to design a system that can completely evapotranspirate the wastewater so that there is no discharge. However, one drawback to this system is the scarcity of suitable land and its cost.

Constructed wetlands are already being successfully used across the U.S. and in other countries.

Nutrients, organic materials, and pathogens can be successfully removed with this "passive" system. This "natural" technology has many advantages both in the Virgin Islands and across the Caribbean, and its advantages far outweigh any disadvantages.

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