PERFORMANCE OF TORPEDO GRASS (*Panicum repens*) IN A TERTIARY TREATMENT SYSTEM FOR PULP MILL WASTE WATER

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Introduction

The use of constructed wetlands to further process or polish industrial effluent is gaining in popularity (1). While the technology for use of these systems to process municipal waste is well documented (2,3), the technology for industrial applications is not well known. This is, in part, because industrial effluent tends to be more site specific and industry, overall, has only recently begun to see the potential benefits that these systems offer.

The University of Southern Mississippi, in a joint research project with the Georgia-Pacific Corporation, has been conducting research to determine the efficacy of constructed wetlands as a tertiary effluent treatment system for pulp mill effluent. This project will enable us to define necessary specifications for construction of a full-scale treatment system and make recommendations regarding its day-to-day management. The pilot project was initiated in spring 1989 and has progressed through two growing seasons.

Purpose

One of the primary considerations for design specifications in this application is which plant or plants offer the best overall performance in water quality enhancement while requiring minimum maintenance. The purpose of this paper is to relate information and observations regarding performance and behavior of *Panicum repens* through two growing seasons in the Leaf River pilot project. Productivity and surface coverage were monitored as well as responses to the local climate, seasonality, and the impact of subfreezing temperatures. Additionally, competitive ability versus invading species was noted.

Literature Review

It is generally recognized that vegetation contributes little to the direct polishing of effluent in tertiary treatment systems (1,4,5,6) but provides surface area for colonization by microorganisms that perform the actual chemical treatment of the effluent. Vegetation may aid in the removal of some nutrients (4,7,8,9,10). Nitrogen and phosphates may be accumulated into plant biomass.

There are two main types of constructed wetlands (11,12): free surface water systems and subsurface flow systems. Usually tertiary treatment systems are developed as variations on the rock-reed design (1,6,11,13,14,15,16,17), a type of subsurface flow system. In these systems, rock, or another permeable substrate, is placed beneath emergent vegetation and effluent flows through the substrate (11). Microbial treatment of effluent occurs in the substrate. In free surface water systems, plants are planted directly into a soil base above an impermeable pond substrate. Effluent flows through the stems of emergent vegetation, above the substrate. Vegetation provides the structural support for microbial communities rather than a permeable substrate (11). Thut (18) conducted a pilot study on a subsurface flow system on pulp mill effluent and found reductions in TSS, BOD, organic nitrogen, and ammonia.

Panicum repens has demonstrated features which suggest that it may be a prime candidate for tertiary treatment systems. For example, it is a mat-forming grass that tolerates high salinity and periodic inundation (19). It is also known to grow in deeper water by forming floating mats that extend over open water (20). *Panicum repens* is considered to be an introduced grass species in the Southeastern United States (19,21). It has become naturalized from Florida to Texas and is considered a noxious weed in much of this area.

System Design

Pilot Facility: In 1989, three one-third acre ponds were constructed on the grounds of the Georgia Pacific Leaf River Pulp Operations mill as part of a pilot study designed to develop a manageable biological tertiary treatment system for effluent from the mill prior to its return to the Leaf River. Initial design of the Leaf River system was done by B. C. Wolverton and called for all three ponds to be planted with *P. repens* with the free surface water format. Following secondary treatment, effluent is pumped from the clarifier to the experimental ponds (see figure 1). Each pond is equipped with a flow gauge and valve to regulate the amount of water entering the pond. Flow rate can be regulated at both the flow gauge and at the pump at the clarifier. An adjustable weir is located at the opposite end of each pond from the inlet pipe to control depth. Outflow empties into a common drain and exits via the mill effluent system.

Torpedo grass was planted in a layer of topsoil placed above the clay hardpan of the pond bottom in June of 1989. Pond 1 was sprigged June 5, pond 3 was sprigged June 9, and pond 2 was sprigged June 12. Sufficient effluent was run through the system to maintain moisture until the plants had become established, but flow rate was kept low enough to prevent the accumulation of standing water. The system was flooded at the beginning of July. The system was not fertilized. Other than the pond substrate, the only source of plant nutrients was effluent.

On April 5 of the second year, we undertook a replanting of the ponds to facilitate recovery from a severe December freeze. The ponds were drained and clumps of vegetation were placed at intervals in areas of the ponds bare of live vegetation. The ponds were kept in a drawdown state until the new plants had become established. In July of the second year, the ponds were flooded and tests were resumed.

Experimental Design and Data Collection: Throughout the study, detention times from one to three days in combination with effluent depths from 30 to 60 cm have been examined. Water quality tests were conducted to determine reductions in biochemical oxygen demand, color, and total suspended solids.

During the first year, *P. repens* biomass was measured monthly to determine the quantity of vegetation present in the system. Wet weight biomass was determined from randomized samples clipped at the surface of the pond substrate. Five samples were taken from each pond at each sampling interval. Samples were sorted prior to weighing to remove dead material. Total biomass above the substrate was determined for each pond.

In the second year of the study, surface coverage and species composition were determined by use of the line intercept method. A stratified random sampling technique was employed to establish four diagonal permanent transects in each pond. Diagonal transects were chosen to minimize the chance of a transect coinciding channelized flow within a pond. Plant biomass was not measured during the second year.

Results and Discussion

Productivity and Coverage of *Panicum repens*: During the first year of the study, *P. repens* grew in near monoculture conditions throughout all three ponds. Figure 2 illustrates individual pond performances in regard to plant biomass in the fall of 1989. Pond 1 exhibited the fastest rate of growth, but by late fall biomass levels in all three ponds were nearly equal.

During the course of the growing season, *P. repens* was observed to form a floating mat, losing its attachment to the substrate. This resulted in an open zone in the water column between the substrate and the plant root mass. The size of this open zone varied as we changed the depth of the system. Torpedo grass began to senesce during late fall and early winter. In late December there was a week of unusually cold weather that resulted in the death of most of the vegetation in the three ponds. During this week, morning low temperatures below zero degrees Fahrenheit (-19 Celsius) were recorded at meteorological stations in the vicinity.

In 1990, mass die-offs of plants occurred during late summer and late fall. In September, following two months of continuous inundation at a depth of 30 cm, there was an extensive die-off of grasses. In December, prior to any hard freeze, there was another extensive die-off. Both die-offs are evident in pond coverage as shown in figure 3. During the summer die-off, replanted areas of the ponds were affected to a greater degree than areas where grasses had successfully overwintered. During the establishment period, vegetative expansion occurred radially outward from the center of a clump. Plant death began at the center of a clump and also progressed toward the periphery. New growth at the edges of the clumps tended to survive longest. The late fall die-off eliminated most of the remaining vegetation in all ponds.

Plants did not appear to be limited by nitrogen and phosphorus availability. An analysis was performed by A & L Eastern Agricultural Laboratories on plant samples taken from the ponds. Plant nutrient levels were compared with the laboratory's composite standard for grasses. Normal grass tissue levels for these nutrients range from 3.00% to 5.00% for nitrogen and 0.30% to 0.60% for phosphorus. Plants growing in effluent were found to have sufficient levels of nitrogen and phosphorus (3.17% and 0.33%, respectively). During 1990, plants rooted along the margins of the system above the effluent level displayed yellowing characteristic of nutrient limitation, while plants of the same species growing in the effluent remained dark green. Plants growing along the bank were deficient in both nitrogen and phosphorus (2.18% and 0.21%, respectively). Duckweed (*Lemna* spp. and *Spirodela* spp.) grew well in open water areas, indicating ample nutrients in the water column. Plants from both areas were found to be deficient in Potassium. This may have contributed to the vegetation die-offs. The pattern of plant death was not inconsistent with the known response of monocots to potassium deficiency (22). However, single causality for this phenomenon is unlikely. *Panicum repens* continued to grow along the pond banks above the effluent with the same potassium deficiency as the dying emergent plants.

Invading Species: During 1989, there was little invasion of the system by other wetland plants. In the second year there was an obvious reduction in the vigor of *P. repens*. This was easily determined subjectively by looking at the plants and objectively through quantification of the vegetation throughout the year. *Cyperus odoratus*, *Typha latifolia*, and *Brachiaria purpurascens* invaded the system with varying degrees of success (see figure 3). Other plants were present in very small numbers at different times during the season. The system never reached the stage of complete cover by *P. repens* that was evident during late summer of the first year.

Brachiaria purpurascens (formerly *Panicum purpurascens*), a naturalized species (19,21), probably entered the system through seed deposition. Initially, this plant was restricted to the edges of the constructed wetland area with little penetration into the inundated areas. Our replanting efforts augmented the spread of this plant to other parts of the system, but it did not persist. It appeared that *B. purpurascens* was incapable of tolerating inundation in mill effluent. It quickly died when flooded. As this grass is also a marsh grass, we assume that it was unable to tolerate the chemical stresses imposed by the effluent. *Brachiaria purpurascens* will probably persist as a marginal plant along the edges of the system but is unlikely to be a major component of a full-scale system.

Cyperus odoratus, a sedge, grew best during the second year of the study, although it never reached coverage levels equal to those obtained by *P. repens*. This plant exhibited several complete generations during the course of the year. We were aware of at least five generations with a generation time of approximately five weeks during summer. There was very little overlap between generations. The plants would grow to maturity, set seed, and die as the next generation was beginning to establish itself. Pond coverage by *C. odoratus* dropped sharply in September (see figure 3) and recovered in October. The September coverage sample coincided with the changeover period between generations. *Cyperus odoratus* normally grew from floating mats of dead vegetation or anchored in the substrate. This plant continued to cycle and set seed during the December die-off. Vigor of *C. odoratus* was reduced late in the year. We do not know if exposure to the effluent contributed to this, but we do not believe that it did. This species is found growing along the ledges of the secondary clarifiers at the mill all year. The reduced vigor most likely resulted from reductions in photoperiod and ambient temperatures. Competitively, *C. odoratus* was able to maintain itself during summer when *P. repens* grew best. *Cyperus odoratus* is native to the southeastern United States (21). Because of its rapid generation time, ability to complete its life cycle in mill effluent, and the abundance of local sources, *C. odoratus* will most likely be present in fairly large quantities in any large-scale tertiary treatment system developed.

Typha latifolia, cattail, is also native to the region (21). This plant was actively suppressed during the early part of the 1990. When suppression was stopped, cattail slowly established itself and grew well until a freeze in mid-December killed the standing crop. This plant is found growing in drainage ditches containing effluent every year so it is expected that the plant will regenerate in the ponds during the coming year. Of all the plants that were found in quantity in the ponds during this year, *T. latifolia* demonstrated the best ability to tolerate continued inundation at the desired depths. Its late-year growth exceeded that of *C. odoratus*. This late season vigor, coupled with the height of the plant, may make cattail a superior competitor in the long run.

Conclusions

The torpedo grass monoculture tertiary treatment system originally designed for the Leaf River Pulp Operations mill demonstrated some qualities that would be beneficial to a full-scale tertiary treatment system, but its overall efficacy should be questioned. The plant does not appear to tolerate water column depths necessary for full-scale operation. Its annual growth pattern and sensitivity to subfreezing temperatures may be detrimental to systems which must operate all year. The development of the floating mat left a significant portion of the effluent column without attachment sites for microorganisms. Additionally, in a full-scale system, it will be difficult to maintain a monoculture without extensive effort. Any native plants that tolerate the effluent and enter the system through natural succession could provide a structural base for microorganisms. As has been suggested elsewhere (23), native plants may reduce the cost and effort of long term maintenance of such a system.

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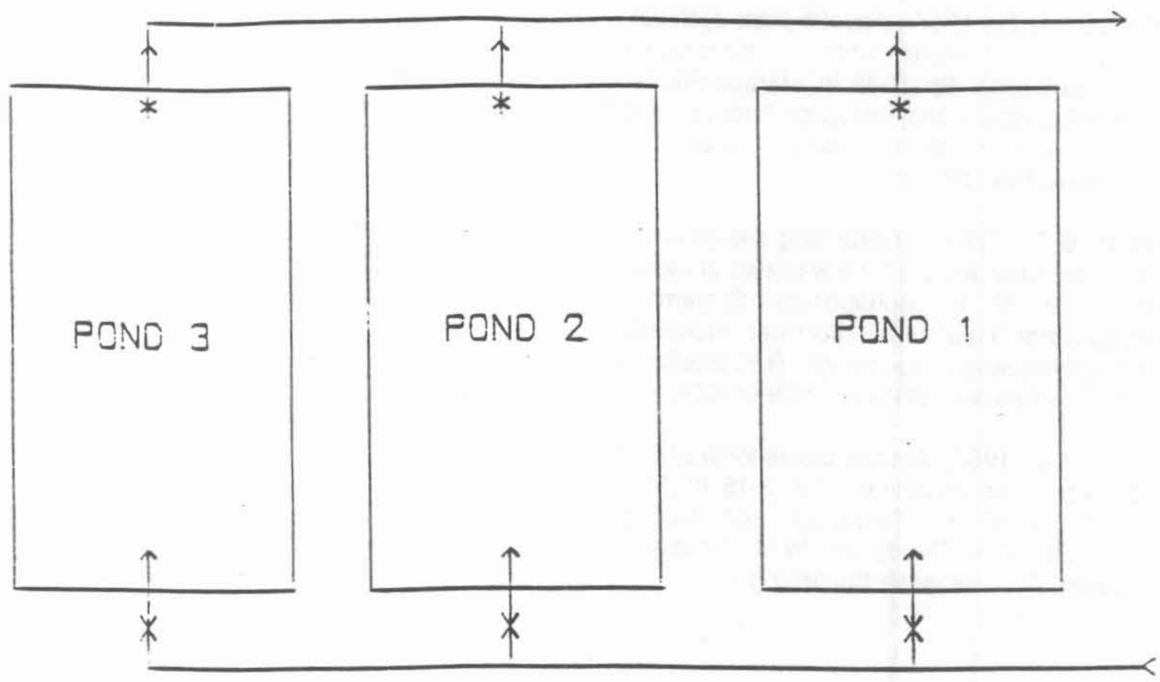

Figure 1: Pond Schematic. Each pond 65m by 25m. x = inlet flow gauge. * = weir

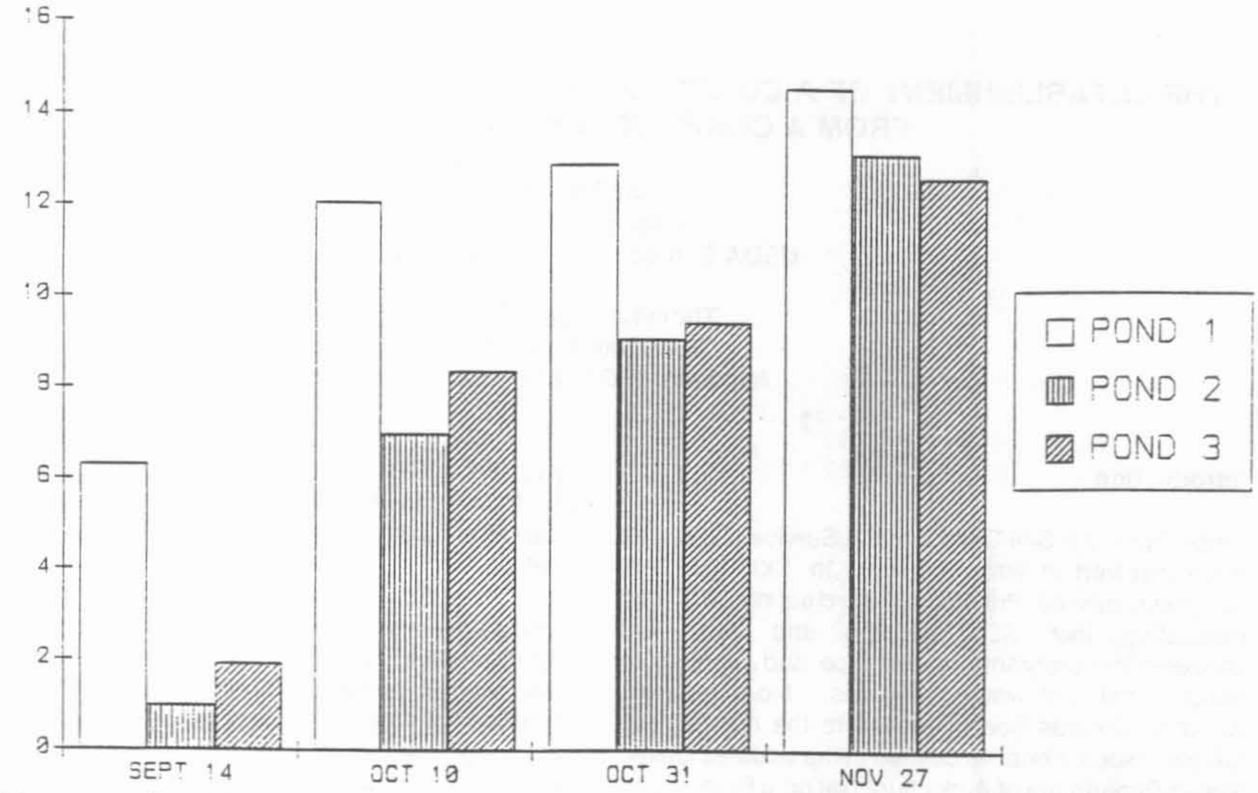

Figure 2. Wet-weight biomass for each pond in 1989.
Biomass expressed in KG/square meter

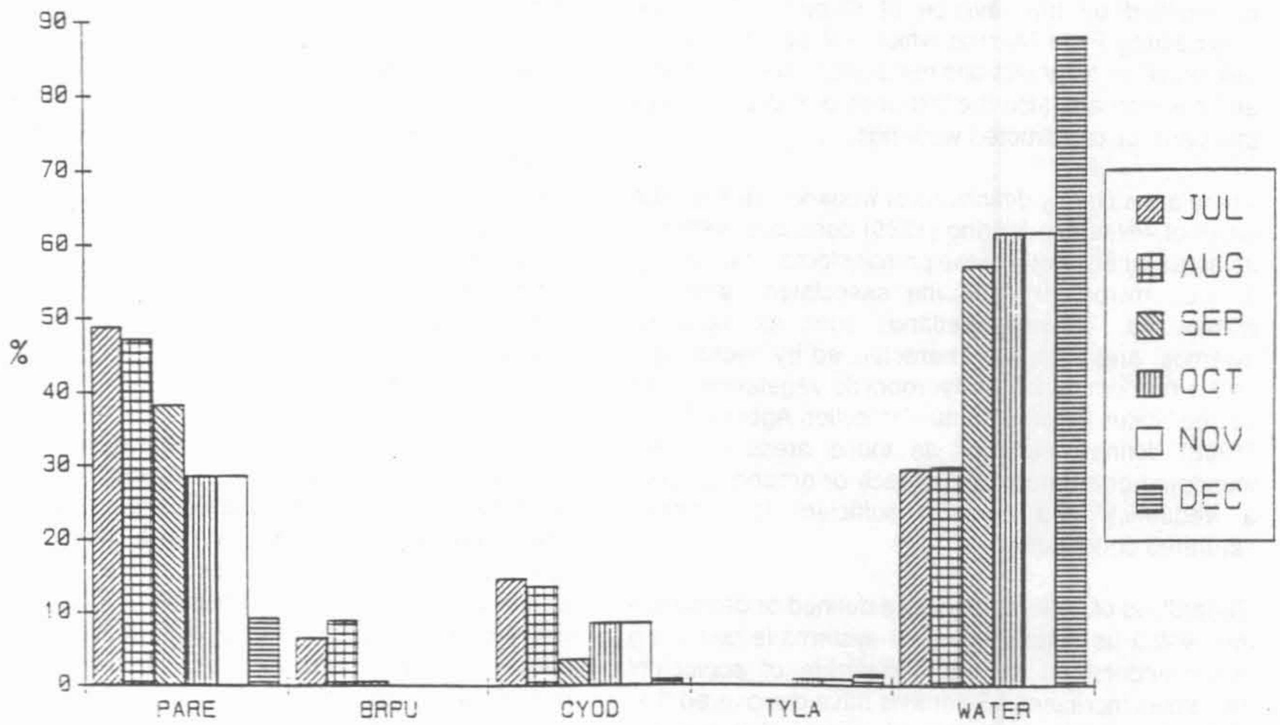

Figure 3. Composite monthly coverage of ponds for 1990.
PARE = Panicum repens, BRPU = Brachiaria purpurascens
CYOD = Cyperus odoratus, TYLA = Typha latifolia