USE OF WATER HYACINTHS TO UPGRADE WASTEWATER TREATMENT PLANT EFFLUENTS

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INTRODUCTION

Compliance requirements by the 1985 National Municipal Policy have resulted in a multitude of administrative orders to Alabama municipalities. Additional orders are expected throughout 1988 as waste load allocations are revised. Since most of the municipalities are small (less than 1.0 MGD) and unable to depend on grant assistance to meet the July 1, 1988, deadline, simple, low-cost systems need to be developed (1).

The concept of optimizing existing systems coupled with aquatic treatment systems has been determined as the most practical approach. The issuance of seasonal permits further increases the probability of success for these systems to be cost-effective as well as practical. The 1985 Alabama Legislature appropriated funds to the Department of Environmental Management for the purpose of environmental research. This project, one of several selected, was contracted with the Department of Civil Engineering at Auburn University.

The objectives of this research include:

(1) To determine design parameters that will enable prediction of process performance in water hyacinth systems in more temperate climates.
(2) To investigate the feasibility of upgrading wastewater treatment plant effluents utilizing water hyacinth treatment technology.

BACKGROUND

One of the primary differences between conventional and aquatic treatment systems is that in the conventional system wastewater is treated rapidly in a highly managed environment, but in the aquatic system treatment is relatively slow in an essentially unmanaged environment. Since the primary impetus for this research is to investigate the feasibility of employing water hyacinths to enhance previously treated wastewater, possibly by conventional means, the discussion will be mainly devoted to the treatment of wastewater which is of approximately secondary effluent quality. The parameters of concern in wastewater treatment include suspended solids, organic compounds, pathogens, nutrients, heavy metals and dissolved inorganic salts.

In brief, the water hyacinth treatment system (WHTS) employs the floating macrophyte with its dangling root structure to enhance the effluent quality after secondary treatment. The hyacinths are maintained in channels or ponds and the extensive root structure occupies the upper region of the water column.

Design Parameters for Aquatic Treatment Systems

The parameters which are used to design the WHTS's include hydraulic residence time (HRT), hydraulic loading rate (HLR), hydraulic application rate (HAR), organic loading rate (OLR), total-nitrogen loading rate (TNLR), ammonia loading rate (ALR) and total-phosphorus loading rate (TPLR).

System Dimensions

The design length to width ratios, baffling and other channel obstructions or devices can influence the flow characteristics. Another consideration that has been reported in past research efforts is the effect of the depth of the water column on the TSS, BOD, and TN removal efficiencies. Associated with this design parameter will be the water hyacinth root zone characteristics and the rate of the detrital layer accumulation and decomposition. Research has indicated that the lower the nutrient concentrations, the greater the root lengths develop (3).

Climatic Factors

The climate throughout the State of Alabama (especially the central and northern regions) will limit the time period of effective treatment particularly when considering more stringent advanced secondary levels. The seasonal permit can make allowances for this limitation or greenhouses can prevent or alleviate the problem. Systems in Alabama have been constructed which include greenhouse protection. The principal purpose of these greenhouses is for winter protection of a portion (seed stock) of the water hyacinths to accelerate the next year's crop establishment.

EXPERIMENTAL METHOD

In order to investigate the utility of the various design parameters, especially in a temperate climate such as middle Alabama, a pilot facility was constructed at a wastewater treatment plant in Union Springs, Alabama. Two parallel continuous flow systems and four batch reactors were utilized to collect information concerning the effects and relationships of HRT, HAR, OLR, ALR, water and air temperature, water column depth, root length of hyacinths, detritus accretion, evapotranspiration(ET) rate, and rainfall on the organic and nutrient treatment efficiency. Figure 1 illustrates the configuration of the two continuous flow treatment trains, each having two channels 8 ft x 32 ft x 2 ft. The water depth was maintained at approximately 20 inches. The channels were stocked with hyacinths from a swamp near Selma, Alabama. One treatment train (channels Cl and C2 in series) was harvested every one to two weeks while the other treatment train (channels C3 and C4 in series) was allowed to grow to maximum density.

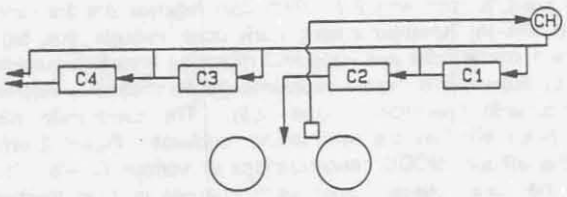

Figure 1. Configuration of the Continuous Flow Water Hyacinth Treatment System.

The systems were loaded with polishing pond wastewater which had been diluted with tap water to approximate a secondary effluent. The HRT's ranged from 0.8 to 4.0 days per channel over four separate testing periods in 1987. The HLR for each individual channel ranged from 130,000 to 680,000 gal/ac/d. Therefore, the HLR based on the entire treatment train ranged from 65,000 to 340,000 gal/ac/d. Table 1 presents design criteria based on existing systems across the U.S. which utilize water hyacinths to upgrade secondary effluents.

Table 1

Design Criteria for Water Hyacinth Treatment to Upgrade Secondary Effluents

Parameter	Range	Optimum	Units
HRT	1-15	4-10	d
HLR	5,000-500,000	<80,000	gal/ac/d
OLR	<45	<30	lb/ac/d
ALR	5-20	<15	lb/ac/d
Depth	0.75-4	<2	ft
Surface Area	–	<1	acre
Length:Width	1:1-15:1	>10:1	–

RESULTS AND DISCUSSION

The data presented in this report have been reduced and analyzed at four time periods which represent HLR's (per channel) of 130,000, 290,000, 450,000 and 675,000 gal/ac/d, respectively. The date ranges represented by each period are as follows: period 1 - 9/17/87 to 9/30/87, period 2 - 6/15/87 to 9/30/87, period 3 - 9/8/87 to 9/16/87, and period 4 - 7/10/87 to 8/8/87. The values represented are averages over each treatment period. Since the purpose of this research is to determine the suitability of these systems to meet the compliance requirements only the data from the period of May to December is included since this was the seasonal period of effective treatment at the Union Springs pilot facility (based on NH_4^+-N removal). The contaminants of primary concern with the state of Alabama include TSS, BOD 5 and ammonia-nitrogen (NH_4^+-N). The TSS concentrations for both systems (harvested and unharvested) ranged from 2 mg/L to 15 mg/L. Typically, the TSS were 7 mg/L or less indicating the effectiveness of these systems to remove algae and colloidal solids as well as settleable solids. The harvested system was slightly less efficient due to the weekly disturbance of the harvesting procedure.

The 5-day BOD concentrations ranged from 2-18 mg/L but typically were less than 10 mg/L. The systems had a comparable treatment effectiveness with most of the removal occurring in the first channel of each treatment train. It should be noted that these systems responded hydraulically as completely mixed reactors even though the L:W ratio was 3:1. Plug flow regimes are the recommended design; however recent work does indicate that higher OLR's will create odor problems and mosquito breeding problems. These systems might require supplemental aeration or a step-feed or recirculation operational mode (2,3). The completely mixed regime helps alleviate the overloading problems. Figure 2 represents the effluent BODS concentrations at various OLR's. It includes the data collected from each channel in both treatment trains. The linear regression reveals a high degree of variability. However, on-going analysis indicates that the following multiple regression equation: BOD_5(effluent) = f[BOD_5(influent), NH_4^+-N (influent), and HLR] will predict the effluent BOD_5 with a high degree of precision. The equation is developed based on data from all tanks in the harvested and unharvested treatment trains.

The effluent NH_4^+-N concentrations ranged from 1-9 mg/L. These concentrations were highly dependent on the HLR and thus the ALR. Figure 3 illustrates this dependence and also the fact that the degree of variability is much less than that of the BOD regression. Again, this regression curve is based on data from the harvested and unharvested systems. A much higher degree of precision can be realized by separating the data for each system (as would be expected). The harvested system can be modeled with the following equation:

$$NH_4^+(\text{effluent}) = f(\text{ALR, GR, TWA, OLR}).$$

where

GR = Plant Growth Rate
TWA = Average Water Temperature

The plant growth rate plays a significant role in nutrient removal when operating in a harvesting mode. As expected the growth rate did not explain a high degree of variability in the non-harvesting mode. The multiple regression equation which best describes the effluent concentration in a non-harvesting mode is as follows:

$$NH_4^+(\text{effluent}) = f(\text{ALR, pH(influent), TWA, OLR}).$$

Most of the variability with this system can be explained with the ALR, pH(influent) and TWA terms. This is what we would expect in nitrifying systems which are not organically overloaded. Analysis of the NH_4^+-N removal models is continuing to estimate reaction rate constants for the harvested and unharvested systems.

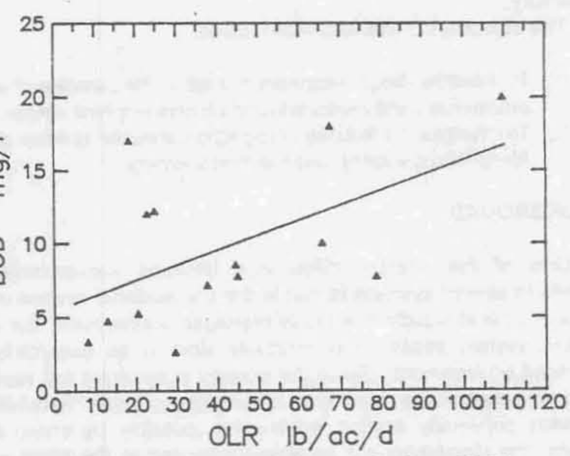

Figure 2. BOD Concentrations at Various OLR's.

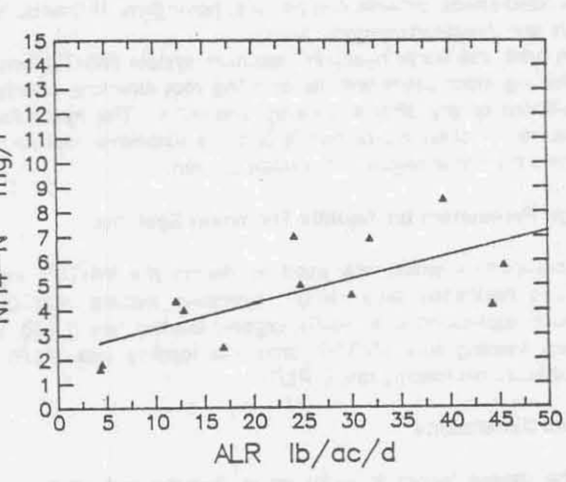

Figure 3. NH_4^+-N Concentrations at Various ALR's

CONCLUSIONS

The use of water hyacinth systems to upgrade secondary effluents in Alabama is a viable alternative throughout the state. The seasonal discharge allowances will definitely increase the attractiveness of this approach. Permanent greenhouse structures can also be considered for all or part of the treatment system. Another consideration would be an integrated approach to aquatic treatment. Wetlands are increasingly being investigated and constructed. Although these systems have a much higher tolerance for colder climates, they take longer to become established and may produce effluents higher in algae content. Water hyacinths could be placed at the effluent end of the treatment system to enhance solids removal.

Based on the research at Union Springs, HLR's as high as 300,000 - 400,000 gal/ac/d can produce advanced secondary effluent levels for BOD_5 and TSS. The NH_4^+-N effluent concentrations are more sensitive to the ALR (HLR). ALR's less than 10 lb/ac/d are indicated as appropriate loading rates to achieve effluent NH_4^+-N concentrations less than 2 mg/L.

Similar treatment efficiencies were obtained for BOD_5 and NH_4^+-N regardless of the operational mode. This indicates the systems can be operated with minimal maintenance harvesting and thus lower operational costs.

REFERENCES

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