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SOLAR POWERED WASTEWATER TREATMENT

by
Ray Dinges

Wastewater Technology and Surveillance Division
Texas Department of Health
1100 West 49th Street
Austin, Texas 78756

Summary

Results obtained from pilot studies and operation of a plant scale facility located at the Williamson Creek Wastewater Treatment Plant at Austin, Texas demonstrate that culture of the water hyacinth (Eichhornia crassipes) in shallow basins is effective in the removal of algae, fecal coliform bacteria and other deleterious impurities from stabilization pond effluent. Stabilization ponds followed by hyacinth culture constitute an economical, low energy wastewater treatment system. Hyacinths represent a useful product which may be converted into fuels, compost or used for livestock feed.

Introduction

Conventional secondary biological wastewater treatment plants, with the exception of simple stabilization ponds, require substantial capital outlay for construction, maintenance and operation. A significant portion of the operational costs is due to the input of external energy required.

Wastewaters contain abundant potential energy. There has been an increasing interest in recent years among the scientific and engineering communities concerning development of natural treatment systems which will function on gravity, the energy stored in wastewaters and that available from sunlight.

Since 1975, the Wastewater Technology and Surveillance Division of the Texas Department of Health, in cooperation with the City of Austin, has been studying the use of controlled culture of the water hyacinth Eichhornia crassipes to improve stabilization pond effluent quality at the Williamson Creek Wastewater Treatment Plant (1,2,3,4,5).

The Hyacinth

A European botanist discovered hyacinths floating upon the surface of backwaters in the Amazon River Basin of South America in the early 1800's (6). These benign-appearing plants with their beautiful bluish-purple flowers were transported to other warm regions of the world where they now flourish (7).

The prodigious productivity of the hyacinth has given it an almost legendary status. It is quite likely that the hyacinth is the most productive macrophyte upon this planet. This productive capability, it should be noted, occurred without selection, or genetic manipulation by man. In fact, man has waged incessant warfare upon this species ever since it began to invade the inviting habitats afforded by man-made reservoirs and canal systems decades ago. Efforts to destroy the plant using mechanical, chemical and biological weapons have cost millions of dollars. The relentless struggle is well documented in a considerable body of literature.

Hyacinth reproduction is essentially vegetative. A "mother" plant extends stolons forming "daughter" plantlets. The daughter plants, in turn, produce offspring. A "family" of plants may remain connected for some time by stolons in still waters if left undisturbed. Mat formation will continue throughout the growing season unless a confined space becomes filled. Hyacinths may also reproduce from seed. A bloom is ephemeral, lasting less than one day. Flower stalks bend towards the surface and enter the water within a matter of hours. The encapsulated seeds do not mature for 18-20 days, at which time they sink to the bottom. The seed is the only part of the plant which is not buoyant. Seed germination is most often associated with a decayed hyacinth mat from a previous growing season. Tiny seedlings are rooted in the debris for a period of time before they assume the floating form. It takes about 3 months for the plants to become mature. Late seasonal germination and the long maturity period required is perhaps one reason why wild hyacinth populations in the United States are restricted to the lower Southern States, and to Southern Arizona and California.

Hyacinths normally float upon the water surface, but will become rooted in mud if left stranded. Their rounded, dark green leaves act as sails. Therefore, they do not persist in large open bodies of water and even may be driven before the wind and blown up onto the shore. Leaf petioles (stems) have egg-shaped swellings of spongy air filled tissue which serve as floats. They have fine, feathery root systems.

Morphology of plants in nutrient-limited waters is strikingly different from those in enriched waters. Hyacinths in clean waters have a compact form, small leaves and grow to a height of only a few centimeters (inches). They bloom profusely and the root systems approach a length of 0.6 m (2 feet). Hyacinths growing in enriched waters become very crowded and have large leaves. Searching for adequate light, the leaves and stems grow to a height of up to 1.2 m (4 feet) above the water surface. Petiole floats are absent, root systems abbreviated and blooming is sparse and sporadic.

Hyacinths will not tolerate brackish waters and are cold sensitive. They are very hardy otherwise.

Stabilization Ponds

Stabilization ponds are shallow earthen basins used to treat wastewaters. Algae (single celled plants) proliferate in the enriched waters and the long detention periods provided facilitate significant reductions in deleterious chemical compounds and adverse biological agents. Algae produce oxygen necessary for the bacteria responsible for the dissimulation and mineralization of organic materials. Mineralization of organics, in turn, furnishes the nutrients necessary for algae growth. Such solar-powered systems are economical and simple to operate and maintain.

Unfortunately, algae-filled effluents from ponds constitute a burden on receiving waters as the algae themselves are organic and biodegradable. Effluents also still contain nutrients and fecal organisms. They do, however, represent an effective preliminary phase in cleansing wastewaters (8).

Pilot Studies

Facilities

Two wastewater treatment plants are located at the Williamson Creek facility. Plant A consists of an aerated basin equipped with a surface aerator, a clarifier and three stabilization ponds. Sludge is returned to the aerated basin with excess sludge and clarified effluent being discharged to the ponds. The three ponds, which are about 1.2 ha (3 acres) in size, are operated in series and at a depth of about 2.44 m (8 ft). There is no discharge from the system and excess water is pumped to a large pond of Plant B by an electric driven pump rated at 31.54 l/sec (500 gal/min) that is activated by a float switch. Design capacity of Plant A is 757 m^3/d (0.2 mgd) and it receives controlled flows of 1,325 to 1,438 m^3/d (0.35 to 0.38 mgd).

Plant B receives the remainder of daily flow, which averages 12,500 m^3/d (3.3 mgd). This plant consists of two aerated basins operated in parallel and three stabilization ponds. The three ponds are 18.2 ha (45 acres), 15.4 ha (38 acres) and 13.0 (32 acres) in size and are 2.7 m (9 ft) deep.

An excavation 9.1 m (30 ft) wide and 64 m (210 ft) long (585 m^2) was constructed between Pond 3 of Plant A and Pond 1 of Plant B and divided into four sections by barriers of crushed stone 10 to 15 cm (4 to 6 in.) in diameter. Section 1 was 30.5 m (100 ft) in length and 0.6 m (2 ft) in depth. One half of the second section, which was 18.3 m (60 ft) long, was 0.6 m (2 ft) deep, and the other half was 3 m (10 ft) deep. Both of the remaining sections were 7.6 m (25 ft) long and 0.8 m (2.5 ft) deep.

During the first study phase (June 1975 to February 1976), the experimental system was furnished with water obtained from Pond 3 of Plant A using an electrically-driven centrifugal pump rated at 3.15 l/sec (50 gal/min). A 5 cm (2 in.) diameter steel pipe was used for water delivery. A waste line with a gate valve was provided to regulate inflow by discharging excess water back to the stabilization pond.

A more enriched water was acquired from Pond 1 (18.2 ha) of Plant B in the second study phase, which extended from May through August, 1976. Water was provided to the experimental facility by gravity flow through a 6.4 cm (2.5 in.) diameter steel pipe equipped with a gate valve for flow control.

A rectangular plastic (polyethylene) container 35.5 cm x 12.7 cm (14 in. x 16 in. x 5 in.) was placed in each section to serve as a sedimentation pan.

Mean water depth in the experimental system during the first study phase was 1 m (3.3 ft). At a flow rate of 1.26 l/sec (20 gal/min), theoretical system detention time was 5.3 days. Operational mean water depth was maintained at 85 cm (2.8 ft) in the second study phase and the detention period was 4.5 days at a flow rate of 1.26 l/sec (20 gal/min). A 1.26 l/sec (20 gal/min) rate of flow was found to be about the maximum hyraulic loading that could be accepted without causing breakthrough of solids. Flow introduced into the system amounted to 109 m^3/d (28,800 gal/day), or the wastewater contribution of a community of about 300 people.

Surface organic loading on the experimental system was 4.34 $g/m^2 \cdot d$ BOD_5 (38.7 lbs/acre/day) in the first study phase and 8.93 $g/m^2 \cdot d$ (79.7 lbs/acre/day) in the second study phase.

Influent-effluent samples were collected weekly and analyzed by accepted procedures.

Results

Numerous parameters used in the characterization of water quality were evaluated in order to document changes which occurred in the waters passing through the pilot hyacinth culture unit. Results of some of the more common water quality tests are presented in Table 1.

Levels of contaminants found in the leaves and stems of hyacinths and in the basin sediment are presented in Table 2.

Following the successful conclusion of the pilot studies, a full-scale facility treating an amount of wastewater which might be expected from a population of about 3,500 people was provided and placed into operation. The experimental hyacinth culture basin is being operated as if it were an integral unit of the Williamson Creek Wastewater Treatment Plant in order to learn more about operational-management procedures. Routine effluent quality evaluation is restricted to those parameters commonly included in discharge permit requirements.

TABLE 1—PILOT STUDIES—INDICATED MEAN REDUCTIONS IN WASTEWATER QUALITY PARAMETERS

	First Study Phase June 1975-February 1976			Second Study Phase May 1976-August 1976		
	Influent	Effluent	%Reduction	Influent	Effluent	%Reduction
BOD_5, mg/l	22.6	5.2	77	46.5	5.7	87
TSS, mg/l	43.3	7.0	84	117	7.5	93
COD, mg/l	84	40	52	184	51	72
MBAS, mg/l	0.17	0.03	82	0.13	0.04	66
Fecal Coliform Bacteria/100 ml	2895	31	98	27423	363	98

Full Scale Study

The three stabilization ponds of Plant A are about 1.2 ha (3.0 acres) each in size and are usually operated in series at a depth of 2.4 m (8 ft). Actual depths are less due to sludge accumulation. The last stabilization pond was drained, cleaned, and converted into a hyacinth culture basin. A crushed stone barrier approximately 2.4 m (8 ft) in height and 9 x 9m (30ft x 30ft) in size was constructed at the lower end of the basin to prevent escape of the plants and to create a clear outlet zone. Influent is admitted to the basin from the second stabilization pond by an adjustable gate. A water depth of .9 m (3 ft) is maintained in the hyacinth culture basin. System effluent is transferred to a nearby 18.2 ha (45 acres) stabilization pond by an electrically driven pump rated at 31.5 l/sec (500 gal/min). Flow to the wastewater treatment plant varies between 1,325 (.35 mgd) and 1,445 m^3/d (.38 mgd). A somewhat lesser amount of water passes through the hyacinth basin due to seepage and evaporation losses.

Test results from October, 1977 until March, 1979 are presented in Table 3.

Comment

These studies have revealed that marked improvement in stabilization pond effluent quality may be obtained by the controlled culture of the water hyacinth. Hyacinth treatment systems may be operated on a year-round basis in tropical, or frost-free sub-tropical climates. Elsewhere, they can be grown seasonally. Wastewaters would require storage during the late winter-early spring period.

Greenhoused culture basins supplied with heat would permit year-round operation in temperate climates. Hyacinth treatment systems would probably be best suited for communities having populations up to 5,000 people.

TABLE 2—Pilot Studies—Contaminant Accumulation by Hyacinths and Contaminants in Basin Sediment

	Means, mg/kg (dry weight)	
	Hyacinths (Stems and Leaves)	Sediment (Plant Debris)
As	2.63	8.4
Ag	—	3.3
Cr	8.96	170
Cu	8.3	52
Fe	470	13000
Hg	0.18	0.47
Mg	4300	6100
Mn	153	260
Ni	9.7	164
Pb	6.5	16
Zn	24	490
PCB*	39.6	—
Chloride	63533	—
Nitrogen-Kjel.	1900	25000
Phosphorus-P	7821	5200
Potassium	65133	—
Sodium	1490	—

*Micrograms

Hyacinths can be used for the generation of methane and as a portion (25%) of livestock feeds (9,10,11). Large-scale crop production of hyacinths in shallow paddies would entail the input of significant amounts of enriched waters. Wastewaters produced by large cities could serve this need. Small communities would likely opt to convert harvested hyacinths and basin sediment into compost, or use the material directly as a soil amendment for agricultural land.

TABLE 3—Plant Scale Study—Indicated Mean Reductions in Wastewater Quality Parameters Obtained during the Period from October 1977—March 1979, at the Williamson Creek Experimental Hyacinth Treatment System

	Population Served—3,500+		
	Influent	Effluent	% Reduction
BOD_5, mg/l	44.5	12.3	72.3
TSS, mg/l	41.3	9.0	78.2
Fecal Coliform/100ml	6471*	356	94.4

*One test result of 6 X 10^6 organisms not used in calculation of mean

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