

Water Hyacinth For Nutrient Removal

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INTRODUCTION

Never before in the history of this country has so much research been focused towards the ever-increasing enrichment problems in this nation's lakes and streams. The real problem is finding practical and economical means of removing these nutrients prior to the discharging of them into our waterways. In some areas, algal and aquatic plant growths have increased to such an extent that the waters have become unsuitable for recreation, industry, agriculture, municipal water supply, and other related uses.

Unfortunately, the problem of over-nutrication is being complicated by excessive drainage, population growth, and an ever-increasing demand for clean water for everyone's use.

Nitrogen and phosphorus have been implicated as the primary nutrients causing these excessive aquatic plant and algal growths. There are natural occurrences of these nutrients into the watercourses from decomposition of cellular material or gaseous exchanges from the atmosphere. The artificial introduction of nutrients is contributable mostly to discharges from domestic and industrial wastes. The runoff from well-fertilized farm lands, and street drainage is also increasing the eutrophication of our watercourses.

Removal of these nutrients from the various discharges is absolutely necessary if these algal and aquatic weed growths are to be controlled and possible eliminated. Examples of excessive algal and aquatic weed growths are numerous. To cite excessive algal growths, one only has to look at Lake Lawne, and for weed growths, the Little Econ west of Highway 420.

SUMMARY

The problems associated with nutrients entering our watercourses are increasing each year. The nutrients are the cause of obnoxious algal and aquatic weed growths. Nitrogen and phosphorus have been implicated as primary causes of eutrophication.

It was determined that a standard for degree of nutrient removal should be set by an algal pond treatment plant. Results of the algal pond showed removal up to 99% soluble ortho phosphates, (leaving 1.0 mg/L), 67% Nitrate-N, (leaving 5.0 mg/L), and 88% Ammonia-N, (leaving 7.0 mg/L).

The aquatic pond process, consisting of an aquatic plant pond, air stripping and coagulation unit, was devised having a total flow of 8.0 liters per day. This aquatic pond removed 99%+ ortho phosphates, (leaving 0.7 mg/L), 99% Nitrate-N, (leaving 0.2 mg/L), and 99%+ Ammonia-N (leaving 0.1 mg/L).

With the excellent 8.0 liters per day pond results, a 1,000 gallon per day pilot plant was enacted at the Orange County Northwest Sewage Treatment Plant. Data from this and other aquatic plant nutrient removal devices should be available in the near future.

This paper will be directed towards using hyacinths

as practical means of eliminating nitrogen and phosphorus compounds before they are effluented into the watercourses.

The object of the research work was to compare the results from an aquatic weed pond, air stripping, and coagulation process with an algal pond. This comparison was to determine if pond, air, and coagulation process was as efficient as algal ponds in removing nitrogen and phosphorus compounds and to determine design for such a process.

LITERATE REVIEW

Sources of Nutrients

There are many sources of nitrogen and phosphorus compounds. Nutrients effluented by conventional sewage treatment plants depend basically on the type of process and the plant's loading rate.

Rudolfs' (10) findings indicated that the average phosphate concentration in the effluent from a biological treatment system was 0.22 mg/L. McKinney (7) found little data readily available to indicate that trickling filters are capable of reducing phosphates in sewage. Moore (8) found that high rate trickling filters remove approximately 10% of the total nitrogen in sewage as ammonia nitrogen. Removal of nitrogen by conventional activated sludge can range from 10% to 90%, depending on the temperature and loading rates employed.

A sewage plant in Texas has reported up to 95% removal of phosphates with a modified activated system. Results of this magnitude are usually not the rule but normally the results of one particular plant receive no special attention.

Discharges from industries into lakes and streams depend primarily on the type, concentration, and volume of a particular waste. In general, most industrial wastes are high in carbonaceous and low in nitrogenous compounds.

Eck (2) related that runoff from a drainage basin can contribute 18 pounds of nitrogen and 0.5 pounds of phosphorus per acre. These figures could be two to three times higher from well-fertilized, improved marshland used for farming.

Sawyer (11) found in Madison, Wisconsin, that the street drainage carried about 0.22 mg/L soluble phosphorus and 0.3 mg/L organic nitrogen. Sylvester (12) observed a content of 0.22 mg/L of soluble phosphates and in nitrates, approximately 4.20 mg/L from urban street drainage. In Orlando, it has been observed that the soluble phosphate content averages 0.55 mg/L while nitrates average 0.52 mg/L from street drainage. These Orlando results are preliminary in nature and will be published at a later date when the survey is completed.

It was found by Hutchinson (3) that rain falling in temperate regions contains 0.64 mg/L Ammonia-N and approximately 0.196 mg/L Nitrate-N. Chalupa (1) found that the atmosphere will supply inorganic phosphorus as (P_2O_5) and he found that the Sedlice Reservoir in Cze-

hoslovakia, over a seven month period, received approximately 1.87 pounds of inorganic phosphorus as P_2O_5 . Many bacteria and algae are capable of fixing or obtaining their prime source of nitrogen from the air.

Removal of Nutrients

There are many ways to remove nutrients to a safe level prior to their release into the receiving waters. It has been assumed that removal of phosphorus is most likely the key to success in controlling nutrients to where they do not cause obnoxious algal or weed growths. It has been estimated that 0.015 mg/L soluble phosphorus content in a lake at the beginning of a growing season will result in a nuisance algal bloom (5). Sawyer (11) indicated in studies of several Wisconsin lakes that a concentration of 0.3 mg/L of inorganic nitrogen and 0.01 mg/L of soluble phosphates at the start of an active growing season will result in algal blooms. Also, it was reported in a Federal Water Pollution Control Administration report, *Fertilization and Algae in Lake Sebasticook, Maine*, that the soluble phosphates content should be reduced to 0.02 mg/L to eliminate nuisance algal and weed growth conditions. Realizing that these reported mg/L figures on nitrogen and phosphorus are extremely difficult to relate to actual field conditions.

MacKenthum (5) has put these limiting figures of nitrogen and phosphorus compounds into pounds per acre foot. He indicated that the upper limits of inorganic nitrogen ($NH_3 + NO_2 + NO_3$) should be 0.8 lb/A.F. and the soluble phosphorus to be 0.4 lb/A.F. at the start of early spring growth.

Armed with these limiting values, the literature was reviewed to find economical means of removing these nutrients.

The Lake Tahoe Report (6) suggested nitrate removal by biological means. This means to convert nitrogen into organic cell material, and then remove the nitrogen by microbial denitrification. One of the essential conditions for denitrification (when nitrates are reduced to gaseous nitrogen) is anaerobiosis. Realizing anaerobic conditions occur under large hyacinth masses, the literature was reviewed to determine if such aquatic plants would be satisfactory and would they be capable of removing a sufficient amount of phosphorus to warrant their use? This review did indicate that anaerobiosis did occur at the Sun City, Florida Project, but most all projects using hyacinths were raised in quiescent waters which are excellent breeding and hiding habitats for mosquitoes.

On the question of phosphate removal, only a limited amount of field data is available. Van Vuran (13) stated that hyacinths are especially suitable for removal of nutrients from effluent lakes. He found that one acre of hyacinths, grown under ideal climatic conditions, with cropping could remove 3,075 lbs. of nitrogen per year.

Realizing the nitrogen compounds might not be removed to a satisfactory limit within the aquatic plant tank. Also, re-aeration of the pond effluent is needed to add oxygen prior to releasing it to the receiving stream. Air stripping methods were reviewed for their merits. Kuhn (4) found air stripping could remove 92% of the ammonia content. An air to liquid loading of 520 to 550 cf/gal. of waste flow was required as compared to 0.2 to 2.5 cf/gal. treated waste required in conventional activated sludge sewage treatment plants.

To assure the removal of phosphorus compounds with-

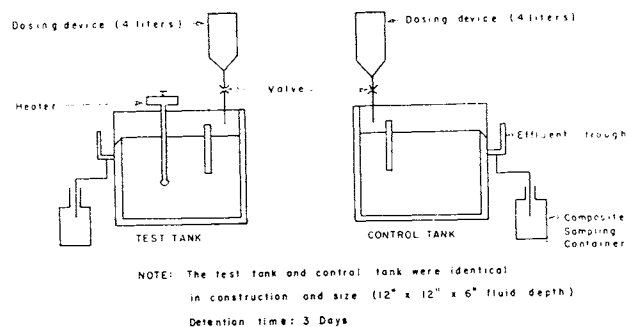


Figure 1. Laboratory algae test apparatus.

in limits, the literature was reviewed to determine the most practical means of removal. The theory that soluble phosphates can be precipitated as insoluble salt was explored to its fullest. Owen (9) used unslaked lime ($Ca(OH)_2$) to raise the pH to 11.0. Also, alum at a pH of 5.57 ± 0.25 at a dosage of 250 mg/L could remove 95% of the total phosphates.

PROCEDURE

The primary object of this study was to find an economical means of removing nitrogen and phosphorus compounds from sewage plant effluent. It has been estimated that the average secondary sewage plant effluents approximately 10 to 60 mg/L soluble ortho phosphates, 5 to 20 mg/L Nitrate-N, and 1 to 30 mg/L Ammonia-N. It was concluded at the start of this experiment that an aquatic plant pond using hyacinths would be used, followed by aeration and coagulation to remove these compounds within acceptable limits.

For comparison with the aquatic pond process, various experiments using algae as means of nutrient removal were conducted (figure 1). These algal studies were conducted under ideal conditions in the laboratory, and it was concluded that the optimum for maximum nutrient removal was at 30° C., completely mixed, and then allowed to be coagulated with lime for phosphate removal (Table I).

With the standards set from the algal pond study, the aquatic plant pond tests were started. The primary object of this laboratory study was to demonstrate that the process would be equal to or attain greater removal of nutrients over the algal pond studies. This system consisted of an aquatic plant pond with a detention time of ten days, an air stripping unit which had a detention time of 1.6 hours, and a flocculation and settling unit with a combined detention time of 7.4 hours (figure 2). Feed for this experiment was obtained from the effluent of a well-treated extended aeration sewage treatment plant, (99% of the total phosphates were converted to ortho.) Feed rate into

TABLE I. SUMMARY OF MAXIMUM REMOVAL FROM ALGAL POND STUDIES—30° C. POND MIXED—COAGULATED WITH LIME

Type of Process	Nitrate-N		Ammonia-N		Phosphate	
	Final Effluent Conc.	Percent Removal	Final Effluent Conc.	Percent Removal	Final Effluent Conc.	Percent Removal
Algal Pond Effluent	5.0 mg/L	67	7.0 mg/L	88	1.0 mg/L	99

RESULTS AND DISCUSSION

The results of the aquatic plant pond investigation, (Tables 2 and 3), indicated that when the dissolved oxygen content within the pond reached zero, after 42 days denitrification occurred from this point (figure 3). After denitrification occurred in the aquatic pond, the ammonia plus nitrate concentration leaving the pond was 1.8 mg/L at an air rate of 0.5 cfm, (2,547 liters air per liter of influent feed into the plant pond.) the air stripping unit. The Nitrate-N plus Ammonia-N content in the coagulation tank effluent was 0.04 mg/L.

The ortho phosphates within the plant pond at first were removed by 50% or better. Then, as more and more bottom settlements occurred within the pond, the phosphates seemed to recycle back into the waters above, resulting in only 10% to 15% removal of ortho PO₄ within the pond at the conclusion of the study.

The air stripping-coagulation process following the pond removed approximately 99% of the ortho phosphates to a final effluent concentration of 0.4 mg/L.

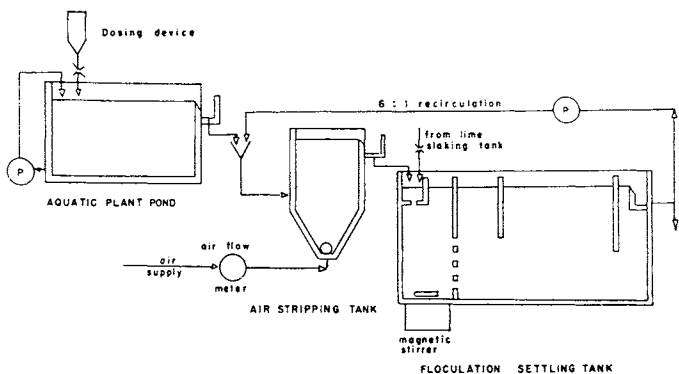


Figure 2. Laboratory aquatic plant pond process.

the aquatic plant pond was 4,000 ml., twice per day, given a ten day detention time. The air stripping rate was varied from .006 cfm to 0.5 cfm. The chemical feed rate into the flocculation tank was 300 mg. lime added per liter of influent feed into the aquatic plant pond. The effluent from the settling tank was recirculated back to the air stripping tank at a 6:1 recirculation influent feed rate.

Many variables, such as aquatic plant pond temperature, bottom deposits, plant density, air stripping, and coagulation tank temperature were not controlled.

From a review of the literature and previous work on the subject, water hyacinth was selected as the aquatic plant. This plant was selected for a twofold purpose: (1) the literature indicated that the plant will take up tremendous amounts of nitrogen and phosphorus compounds in the water, and (2) this plant covers the water's surface; and consequently, prevents reoxygenation, setting up ideal conditions for anaerobiosis for nitrogen removal. From the literature review, it was ascertained only very limited work had been performed using plants other than water hyacinth.

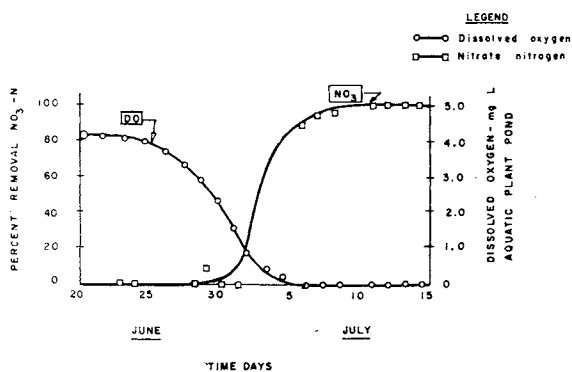


Figure 3. Laboratory aquatic plant process; overall nitrate-N reduction vs. dissolved oxygen concentration.

TABLE 2. AQUATIC PLANT, AIR STRIPPING & COAGULATION STUDIES FOR REMOVAL OF NUTRIENTS
ALL SAMPLES UNCENRIFUGED AND EXPRESSED IN MG/L

Date	Aquatic plant Influent			Aquatic plant Effluent			Air stripping Influent			Air stripping Effluent			Coagulation Effluent			Air Rate cfm
	NO ₃ -N	NH ₃ -N	PO ₄	NO ₃ -N	NH ₃ -N	PO ₄	NO ₃ -N	NH ₃ -N	PO ₄	NO ₃ -N	NH ₃ -N	PO ₄	NO ₃ -N	NH ₃ -N	PO ₄	
5-24-66	9.0	68	31	14	10	17	14	2	7	12	2	6	11	2	4	.006
5-26-66	9.0	68	31	13	10	17	12	3	5	12	2	5	10	2	2	.006
5-27-66	9.0	68	31	11	10	18	12	2	6	11	3	8	11	2	3	.006
5-31-66	9.0	68	31	15	10	19	13	2	8	12	2	8	12	2	2	.006
6- 3-66	9.0	68	31	15	12	7	13	2	7	13	2	4	13	.8	3	.006
6-23-66	9.2	7.6	72	24	4	31	14	3	5	14	3	5	13	2	2	.1
6-24-66	9.2	7.6	72	13	.4	28	12	.5	7	11	.3	5	11	.3	3	.1
6-28-66	9.2	7.6	72	12	.9	54	12	.5	14	11	.3	9	11	.2	4	.1
6-29-66	9.2	7.6	72	11	.9	60	11	.5	21	10	.3	5	8	.3	4	.1
6-30-66	9.2	7.6	72	13	1.1	57	11	.6	17	11	.3	5	10	.2	3	.1
7- 1-66	9.2	7.6	72	13	1.0	54	12	.7	9	10	.3	2	9	.2	2	.1
7- 4-66	12.0	7.3	68	13	6.7	59	6	.7	12	4	.2	12	1	.1	2	.5
7- 6-66	12.0	7.3	68	7	1.0	54	2	.7	14	1	.2	9	.4	.2	1	.5
7- 7-66	12.0	7.3	68	4	1.0	57	4	.7	12	.6	.2	5	.05	.2	1	.5
7- 8-66	12.0	7.3	68	3	1.0	55	2	.6	11	.5	.2	5	.05	.2	1	.5
7-11-66	11.4	7.8	72	2	1.0	53	2	.6	11	.5	.1	5	.05	.1	.9	.5
7-12-66	11.4	7.8	72	3	.9	54	2	.4	12	.3	.1	6	.04	.08	.8	.5
7-13-66	11.4	7.8	72	2	.9	57	2	.4	14	.3	.09	5	.03	.05	.8	.5
7-14-66	11.4	7.8	72	2	.8	56	1	.3	13	.2	.07	7	.03	.03	.6	.5
7-15-66	11.4	7.8	72	1	.8	60	1	.3	20	.2	.05	9	.02	.02	.4	.5

TABLE 3. PERCENT REDUCTION OF NUTRIENTS AQUATIC PLANT POND—AIR STRIPPING AND COAGULATION UNITS.

Date	% red. in aquatic plant pond			% red. in air stripping tank			% red. in Coagulation tank			% red. for entire process		
	NO ₃ -N	NH ₃ -N	PO ₄	NO ₃ -N	NH ₃ -N	PO ₄	NO ₃ -N	NH ₃ -N	PO ₄	NO ₃ -N	NH ₃ -N	PO ₄
5-24-66	0	85	45	1	0	14	1	0	33	0	97	87
5-26-66	0	85	45	0	1	0	17	0	60	0	97	93
5-27-66	0	85	42	1	0	0	0	30	63	0	97	97
5-31-66	0	85	39	1	0	0	0	0	75	0	97	93
6- 3-66	0	82	77	0	0	43	0	25	25	0	99	90
6-23-66	0	47	57	0	0	0	7	33	85	0	97	97
6-24-66	0	95	61	1	40	29	0	0	40	0	99	96
6-28-66	0	88	22	1	40	36	0	0	56	0	99	96
6-29-66	0	88	17	1	40	76	20	0	20	13	99	94
6-30-66	0	85	21	0	50	70	9	33	40	0	99	96
7- 1-66	0	87	25	2	57	78	10	33	0	2	99	97
7- 4-66	0	8	10	30	71	0	75	50	83	92	99	97
7- 6-66	42	87	21	50	71	35	60	0	88	97	99	98
7- 7-66	67	87	16	85	71	58	92	0	80	80	99	98
7- 8-66	75	87	19	75	67	54	90	0	80	99	99	98
7-11-66	83	87	26	75	83	54	90	0	82	99	99	99
7-12-66	75	88	25	85	76	50	87	20	87	99	99	99
7-13-66	83	88	21	85	77	64	90	45	84	99	99	99
7-14-66	83	89	22	90	76	46	85	57	92	99	99	99
7-15-66	92	89	17	90	83	55	90	60	96	99	99	99
									Ave. —	43	99	99

A comparison of results with this study and the algal pond study is shown in Table 4. It can readily be seen that the aquatic plant pond, air and coagulation system is far superior to the algal pond in removing nitrogen and phosphorus compounds. There are still many unanswered questions regarding the aquatic plant system, such as, could 100% nitrogen compounds be removed under the water hyacinth mass if run long enough; or could another plant be used which would accomplish denitrification and take up more PO₄ than the water hyacinth? Also, the question of how to control mosquitoes within the water hyacinth mass still has to be answered.

These questions are very weighty, but realizing nutrition of our waterways in Central Florida is creating a tremendous problem, we have undertaken a 1,000 gpd pilot plant study using the same aquatic plant pond, air and coagulation process. Data from this pilot plant is proving to be very valuable. Also, like many other research projects, this one has opened the door to many other un-

answered questions regarding the controlled use of aquatic plants for removing nutrients. It is anticipated our pilot plant study using water hyacinth should be concluded in 1968, and this data will be available for publication and other researcher's use.

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TABLE 4. SUMMARY OF ALGAL AND AQUATIC PLANT STUDIES.

Type of process	Nitrate-N		Ammonia-N		Phosphate	
	Final Effluent Conc.	Per-cent Re-moval	Final Effluent Conc.	Per-cent Re-moval	Final Effluent Conc.	Per-cent Re-moval
Algal Pond* Effluent	5.0 mg/L	67	7.0 mg/L	88	1.0 mg/L	99
Aquatic Pond** Effluent	0.2 mg/L	99	0.1 mg/L	99+	0.7 mg/L	99+
Differences in Processes	4.8 mg/L	33	6.9 mg/L	11	0.3 mg/L	0

*Only maximum removal data for the algal pond.

**Average removal data for the aquatic plant pond.