Laboratory Scale Evaluation of a Treatment System for Effluents from Hybrid Catfish Ponds

Dusit Aue-umneoy[1] and Yont Musig[2]

ABSTRACT

Results from laboratory scale investigation indicated that treatment of hybrid catfish pond effluent in a treatment system consisting of one day sedimentation followed by four days aeration and nine days absorption by water hyacinth was very effective in removing pollutants from the effluent. Initial concentrations of pollutants in the effluents used for the experiments were between 9.58 and 40.14 mg-N/l for ammonia, 0.02 and 1.67 mg-N/l for nitrite, 12.35 and 56.59 mg-N/l for total kjeldahl nitrogen, 1.50 and 2.15 mg/l for total phosphorus, 0.001 and 0.022 mg-S/l for hydrogen sulfide, 41.5 and 61.7 mg/l BOD_5, and 568.3 and 826.7 mg/l for total suspended solids. Average removal rates of 1 day sedimentation were 81.2% for total suspended solids, 54.7% for BOD_5, 72.7% for total phosphorus, 26.5% for total ammonia nitrogen, 33.3% for total kjeldahl nitrogen, and 100% for hydrogen sulfide while 4 days aeration removed 6.5% of total suspended solids, 6.9% of BOD_5, 6.2% of total phosphorus, 51.2% of total ammonia nitrogen, and 14.1% of total kjeldahl nitrogen, by average. Treatment by water hyacinth for 9 days removed 9.9% of total suspended solids, 28.4% of BOD_5, 11.7% of total phosphorus, 22.2% of total ammonia nitrogen, and 32.9% of total kjeldahl nitrogen. The whole treatment system was able to reduce 97.6% of total suspended solids, 90.0% of BOD_5, 90.6% of total phosphorus, 99.9% of total ammonia nitrogen, 80.3% of total kjeldahl nitrogen, and 100% of hydrogen sulfide.

INTRODUCTION

Effluents from hybrid catfish ponds contain very high concentrations of total suspended solids and nutrient elements. Reported concentrations of total suspended solids, total kjeldahl nitrogen, total ammonia nitrogen and total phosphorus in hybrid catfish effluents were 699.2, 51.293, 31.790 and 2.710 mg/l, respectively (Musig and Aue-unneoy, 2008). Usually, the effluents from fish ponds were released to public waters without any treatment. This practice created a lot of problems concerning water pollution and the deterioration of aquatic ecosystem in receiving waters. Sedimentation and aeration were reported to be very effective in treating shrimp pond effluents (Teichert-Coddington *et al*, 1999; Faculty of Fisheries, 2002; Engle and Valderrama, 2003). Water

[1] Faculty of Agicultural Technoogy, King Mongkut's Institute of Technoogy Ladkrabang, Bangkok 10502, Thailand.
[2] Faculty of Fisheries, Kasetsart University, Bangkok 10900, Thailand.

hyacinth was also reported to be very effective in nutrient removal (Sooknah and Wilkie, 2004; Jianbo *et al*, 2008). In this study, the effects of sedimentation and aeration on the quality of hybrid catfish pond effluents were investigated and the efficiency of the treatment system for hybrid catfish ponds consisting of sedimentation, aeration and water hyacinth unit, was developed and evaluated in laboratory scale.

MATERIALS AND METHODS

Primary study of effluent characteristics and the effect of aeration on effluent quality

Primary studies of effluent characteristics and the effect of aeration on effluent quality were conducted in 40 liter aquaria. The studyon characteristics of effluent was done by putting 30 liters of hybrid catfish pond effluent into 40 liter aquaria and let stand without any disturbance for 96 h. Effluent samples were taken initially and at 1,3, 6, 12, 24, 48, 72, and 96 h and were analyzed for pH, dissolved oxygen, total suspended solids, BOD_5, total ammonia, nitrite, total Kjeldahl nitrogen, total phosphorus, and hydrogen sulfide.

The study on the effect of aeration on effluent quality was also done in 40 liter aquaria containing 30 liters hybrid catfish pond effluent. Aeration was provided throughout the 96 h experiment. Effluent samples were taken initially and at 1,3, 6, 12, 24, 48, 72, and 96 h, and were analyzed for pH, dissolved oxygen, total suspended solids, BOD_5, total ammonia, nitrite, total Kjeldahl nitrogen, total phosphorus, and hydrogen sulfide. Three replications were set for each experiment.

The evaluation of the combined effects of sedimentation and aeration on hybrid catfish pond effluent quality

From the results of the primary investigation it was obvious that a short period of sedimentation combined with aeration should be affective for removing pollutants from hybrid catfish effluent. So the experiment was set up to evaluate the effluent treatment system combining the sedimentation and aeration units. Justifying from the results of primary investigation, a 12 h treatment period was selected for sedimentation while a 96 h treatment period was selected for aeration. The experiment was done in 40 liter aquaria. Thirty liters of hybrid catfish pond effluent were put into the sedimentation unit then left undisturbed for 12 h, after which the supernatant was pumped into the aeration unit and aerated for 96 h. Effluent qualities were analyzed initially and at the end of each treatment period for pH, dissolved oxygen, total suspended solids, BOD_5, total ammonia, nitrite, total Kjeldahl nitrogen, total phosphorus, and hydrogen sulfide. Three replications were set for the experiments.

Design and evaluation of effluent treatment system for hybrid catfish pond effluent

Considering the results of primary studies, an effluent treatment system for hybrid catfish pond effluents was designed to include three treatment units namely sedimentation, aeration and water hyacinth units. The sedimentation period was decided to be 1 day instead of 12 h to make it more practical for the farmers, while the aeration period was still 4 days. A treatment unit with water hyacinth was included because

the treatment systems with sedimentation and aeration unit still failed to reduce nutrient concentrations, especially ammonia, to a satisfactory level. It has been reported that water hyacinth is very effective in removing nutrients. Outdoor concrete tanks, 80X80 X20 cm, were used for each treatment unit. The initial biomass of water hyacinth per treatment unit was 20.4g dry weight. Hybrid catfish pond effluents used for this experiment were collected from three hybrid catfish farms. The effluent was put into sedimentation tanks and let stand for one day then the supernatant was pumped into the aeration unit. Then it was aerated for four days, after which it was pumped into the water hyacinth unit, and let stand for nine days. Effluent qualities were analyzed initially and at the end of each treatment period for pH, dissolved oxygen, total suspended solids, BOD_5, total ammonia, nitrite, total Kjeldahl nitrogen, total phosphorus, and hydrogen sulfide. Three separate experiments were set for each of the effluent from three hybrid catfish farms. Three replications were set for each experiment.

Dissolved oxygen and pH were measured by Dissolved Oxygen Meter YSI Model 95 and pH Meter YSI Model 63, respectively. The analysis of other effluent qualities was carried out using analytical methods recommended by APHA *et al* (1992).

RESULTS AND DISCUSSIONS

Sedimentation rate and the change in effluent quality during sedimentation period

When the effluents from hybrid catfish ponds were put into the aquaria and let stand for a period of time, changes in effluent quality were observed. Total suspended solids, BOD_5 and total phosphorus drastically decreased. Total suspended solids decreased from 331.7 to 85.0 mg/l within 12 h and decreased further to 63.3, 37.5, 30.8 and 28.7 mg/l within 24, 48, 72 and 96 h. BOD_5 decreased from 32.2 to 15.2 mg/l within 12 h and decreased further to 9.3, 7.1, 6.9 and 6.8 mg/l within 24, 48, 72 and 96 h, respectively. Total phosphorus decreased from 1.43 to 0.49 mg/l within 12 h and decreased further to 0.41, 0.38, 0.37 and 0.30 mg/l within 24, 48, 72 and 96 h. Slight decreases in total ammonia nitrogen were observed during sedimentation. Total ammonia nitrogen decreased from 39.85 to 38.63, 35.26, 34.61 and 33.42 mg-N/l within 24, 48, 72 and 96 h, respectively. Nitrate-nitrogen decreased from the initial concentration of 0.04 to 0.02 mg-N/l at 24 h, then remained at the same level till 96 h. Nitrite-nitrogen increased from 0 to 0.03 mg-N/l at 96 h. pH of the effluent increased from 7.2 to 7.5 at 12 h, then increased to 8.2 at 96 h. Dissolved oxygen decreased from 2.5 to 2.0 mg/l at 3 h, and then fluctuated between 2.1 and 2.3 mg/l. All hydrogen sulfide disappeared within 3 h (Table 1).

Table 1. Change in quality of hybrid catfish pond effluent after left settling for a period of time

hours	DO mg/l	pH	BOD_5 mg/l	TAN mg-N/l	NO_2^--N mg-N/l	NO_3^--N mg-N/l	H_2S mg-S/l	TP mg-P/l	TSS mg/l
0	2.5	7.2	32.2	39.85	0	0.04	0.001	1.43	1.43
3	2.0	7.2	18.2	39.77	0.01	0.04	0	0.66	0.66
6	2.3	7.3	17.1	39.52	0.01	0.04	0	0.63	0.63
12	2.1	7.5	15.2	39.30	0.01	0.03	0	0.49	0.49
24	2.2	7.5	9.3	38.63	0.01	0.02	0	0.41	0.41
48	2.3	8.0	7.1	35.26	0.01	0.02	0	0.38	0.38
72	2.3	8.0	6.9	34.61	0.01	0.02	0	0.37	0.37
96	2.2	8.2	6.8	33.42	0.03	0.02	0	0.30	0.30

According to the results of this study, most of the suspended solids in the hybrid catfish pond effluent had a high settling velocity. Most of the suspended solids, 74.4-80.9%, settled down within 12-24 hrs. Sedimentation rates of suspended solids were 46.7, 57.6, 74.4, 80.9, 90.7 and 91.3% at 3, 6, 12, 24, 48, 72 and 96 h, respectively. High decreasing rates of BOD_5 and phosphorus content indicated that organic matter and phosphorus in the effluent were mostly in particulate form of settleable suspended solids. Removal rates were 43.5, 46.9, 52.8, 71.1, 78.0, 78.6 and 78.9% for BOD_5 and 53.8, 55.7, 65.6, 71.3, 73.4, 73.9 and 79.1% for total phosphorus at 3, 6, 12, 24, 48, 72 and 96 h, respectively. The same trend was observed in marine shrimp pond effluents by Teichert-Coddington *et al.* (1999), who reported that settling removed 100% of settleable solids, 88% of total suspended solids, 71% of volatile solids, 63% of BOD_5, 31% of total nitrogen and 55% of total phosphorus, within 6 h. Faculty of Fisheries (2002) also reported that within 6 h, settling removed 71.5-89.5% of total suspended solids, 66.7-88.3% of BOD_5, 9.4-58.3% of total nitrogen and 13.3-70.3% of total phosphorus.

The accumulation of nitrite during sedimentation period indicated that nitrification process occurred during sedimentation. Ammonification, nitrification and volatilization were factors controlling the change in ammonia concentration in the effluent which slightly decreased during settling period. The reduction of 24.4, 48.8 and 56.1% of nitrate nitrogen in the effluent indicated that denitrification process also occurred during sedimentation.

Effect of aeration on effluent quality

Aeration resulted in the increase in dissolved oxygen in the effluent from the initial concentration of 2.5 to 6.1 mg/l within 3 h and then fluctuated between 6.1 and 6.6 mg/l. Lesser degree of the decrease in total suspended solids, BOD_5 and total phosphorus were observed compared to the first experiment. Total suspended solids

decreased from 331.7 to 212.5 mg/l within 12 h and decreased to 174.2, 129.2, 94.2 and 82.5 mg/l within 24, 48, 72 and 96 h. BOD_5 decreased from 32.2 to 22.4 mg/l within 12 h and decreased to 22.1, 18.0, 18.1 and 17.6 mg/l within 24, 48, 72 and 96 h. Total phosphorus decreased from 1.43 to 0.81 mg/l within 12 h and decreased to 0.62, 0.60, 0.59 and 0.57 mg/l within 24, 48, 72 and 96 h. A slight decrease in total ammonia nitrogen was observed, where it decreased from 39.85 to 36.99 mg/l within 12 h and to 34.03, 31.20, 30.47 and 29.62 mg-N/l within 24, 48, 72 and 96 h, respectively. Nitrate nitrogen increased from an initial concentration of 0.04 to 0.05 mg-N/l at 3 h and fluctuated between 0.03 and 0.06 mg-N/l during 6 to 72 h then increased to 0.14 mg-N/l at 96 h. Nitrite nitrogen increased from 0 to 0.03 mg/l within 48 h and then to 0.13 and 0.59 mg/l within 48, 72 and 96 h. pH of the effluent increased from 7.2 to 8.5 at 3 h and increased to 8.7 at 96 h. All hydrogen sulfide disappeared within 3 h of aeration (Table 2).

Table 2. The change in effluent quality after aeration for a period of time

hours	DO mg/l	pH	BOD_5 mg/l	TAN mg-N/l	NO_2^--N mg-N/l	NO_3^--N mg-N/l	H_2S mg-S/l	TP mg/l	TSS mg/l
0	2.5	7.2	32.2	39.85	0	0.04	0.001	1.43	331.7
3	6.1	8.5	27.8	38.51	0.01	0.05	0	0.98	254.0
6	6.3	8.5	23.8	37.39	0.01	0.04	0	0.84	226.7
12	6.3	8.5	22.4	36.99	0.01	0.03	0	0.81	212.5
24	6.4	8.5	22.1	34.03	0.01	0.03	0	0.62	174.2
48	6.6	8.7	18.0	31.20	0.03	0.04	0	0.60	129.2
72	6.5	8.7	18.1	30.47	0.13	0.06	0	0.59	94.2
96	6.6	8.7	17.6	29.62	0.59	0.14	0	0.57	82.5

Continuous aeration of effluents from hybrid catfish ponds resulted in less sedimentation rate of total suspended solids compared to that of effluents not disturbed, due to the re-suspension of some of the solids from turbulence generated by aeration. Re-suspension of the solids also resulted in the decrease in rate of removal of BOD_5 and total phosphorus of the effluent. However, increased dissolved oxygen concentration of the effluent to 6.1-6.6 mg/l from aeration resulted in a greater rate of nitrification. Aeration for 4 days resulted in a decrease in ammonia nitrogen concentration, from 39.85 to 29.62 mg-N/l and resulted in the accumulation of nitrite and nitrate. This resulted in increased concentrations from 0 and 0.04mg/l to 0.59 and 0.14 mg/l of nitrite and nitrate, respectively. Aeration increased effluent pH from the initial value of pH 7.2 to 8.5-8.7. The increase in pH of the effluent after aeration resulted from the dispersion of supersaturated carbon dioxide in the effluent. High pH value of the effluent resulted in a higher degree of accumulation of nitrite because the ability

of *Nitrobacter* in converting nitrite to nitrate decreases in high pH environments. Nitrite oxidation is reduced at alkaline pH through competitive inhibition between NO_2^- and OH^- (Keen an Prosser, 1987).

Combined effect of sedimentation and aeration on hybrid catfish pond effluent quality

When sedimentation for a period of 12 h and aeration for a period of 96 h are combined to treat hybrid catfish effluent, total suspended solids decreased from 331.7 to 75.0 mg/l, while BOD_5 decreased from 32.2 to 6.3 mg/l, total phosphorus from 1.435 to 0.303 mg/l, and total ammonia nitrogen from 39.85 to 20.40 mg-N/l. Nitrite nitrogen increased from 0.003 to 0.332 mg-N/l. Nitrate concentration did not change while all hydrogen sulfide (0.001 mg-S/l initial concentration) disappeared within 12 h of sedimentation (Table 3).

Table 3. The change in effluent quality after 12 h sedimentation and 96 h aeration

Treatment period	DO mg/l	pH	BOD_5 mg/l	TAN mg-N/l	NO_2^--N mg-N/l	NO_3^--N mg-N/l	H_2S mg-S/l	TP mg/l	TSS mg/l
Initial	2.5	7.2	32.2	39.85	0	0.04	0.001	1.43	331.7
Sedimentation									
12 h	-	7.7	16.0	38.57	0.01	0.04	0	0.38	111.7
Aeration									
96 h	6.8	8.7	6.3	20.40	0.33	0.04	0	0.30	75.0

Removal rate of pollutants from hybrid catfish pond effluent subjected to 12 h sedimentation followed by 96 h aeration were 80.4, 100.0, 79.0 and 77.4% for BOD_5, hydrogen sulfide, total phosphorus and total suspended solids, respectively. All hydrogen sulfide and nitrate, and most portions of other pollutants i.e. 50.3% BOD_5, 73.4% total phosphorus and 66.3% total suspended solids, were removed during the 12 h sedimentation. The concentration of total ammonia decreased by 48.8% after 12 h of sedimentation and 46 h aeration (Table 4). The combination of 6 h sedimentation and 46 h aeration was reported to remove 88.2% of total suspended solids, 91.1% of BOD_5, 35.2% of total nitrogen, 64.2% of total ammonia nitrogen, and 25.7% of total phosphorus from shrimp pond effluents (Faculty of Fisheries, 2002)

Table 4. Percentage removal of pollutants in the effluent of hybrid catfish pond subjected to 12-h sedimentation and 96-h aeration

Treatment	BOD_5	TAN	NO_3^--N	H_2S	TP	TSS
Initial concentration(mg/l)	32.2	39.85	0.04	0.001	1.43	331.7
12 h sedimentation(%)	50.3	3.2	0	100.0	73.4	66.3
96 h aeration(%)	30.1	45.6	0	0	5.6	11.1
Total	80.4	48.8	0	100.0	79.0	77.4

The efficiency of effluent treatment system combining sedimentation, aeration, and water hyacinth treatment units

The treatment of hybrid catfish pond effluent in a system consisting of 1 day sedimentation followed by 4 days aeration and 9 days absorption by water hyacinth proved to be very effective in removing pollutants from the effluent. The treatment system was able to reduce 97.6% of total suspended solids, 90.0% of BOD_5, 90.6% of total phosphorus, 99.9% of total ammonia nitrogen, 80.3% of total kjeldahl nitrogen, and 100% of hydrogen sulfide, by average (Tables 5 and 6). In the first trial, total suspended solids, BOD_5, total phosphorus, total ammonia nitrogen, total kjeldahl nitrogen, and hydrogen sulfide were reduced to 9.9, 6.5, 0.16, 0.05, 16.80, and 0 mg/l from the initial concentrations of 826.7, 61.7, 2.15, 40.14, 56.59 and 0.022 mg/l, respectively. In the second trial, total suspended solids, BOD_5, total phosphorus, total ammonia nitrogen, total kjeldahl nitrogen, and hydrogen sulfide were reduced to 30.8, 5.2, 0.18, 0.02, 3.09 and 0 mg/l from the initial concentrations of 765.0, 41.5, 1.50, 9.58, 12.35 and 0.001 mg/l, respectively. In the third trial, total suspended solids, BOD_5, total phosphorus, total ammonia nitrogen, total kjeldahl nitrogen, and hydrogen sulfide were reduced to 10.5, 3.8, 0.14, 0, 0.99 and 0 mg/l from the initial concentrations of 568.3, 52.0, 1.60, 15.40, 22.05 and 0.002 mg/l, respectively. Nitrite concentration decreased from the initial concentrations of 0.67 and 1.67 mg-N/l to 0.524 and 0.01 mg-N/l in the first and second trials, but increased from the initial concentration of 0.02 mg-N/l to 0.54 mg-N/l in the third trial. In the first trial, concentration of nitrate increased from initial concentration of 0.29 mg-N/l to 14.94 mg-N/l but in the second and third trials, concentrations of nitrate decreased from initial concentrations of 0.28 and 0.05 mg-N/l to 0.01 and 0.04 mg-N/l (Table 5).

Sedimentation for 1 day resulted in the removal of 81.2% of total suspended solids, 54.7% of BOD_5, 72.7% of total phosphorus, 26.5% of total ammonia nitrogen, 33.3% of total kjeldahl nitrogen, and 100% of hydrogen sulfide, by average while aeration for 4 days resulted in the decrease of 6.5% of total suspended solids, 6.9% of BOD_5, 6.2% of total phosphorus, 51.2% of total ammonia nitrogen, and 14.1% of total kjeldahl nitrogen, by average. Treatment by water hyacinth for 9 days resulted in the decrease in 9.9% of total suspended solids, 28.4% of BOD_5, 11.7% of total phosphorus, 22.2% of total ammonia nitrogen, and 32.9% of total kjeldahl nitrogen, by average (Tables 6).

Treatment of shrimp pond effluent through settling for 6 h was reported to remove 88% of total suspended solids, 63% of BOD_5, 31% of total nitrogen, and 14% of total phosphorus (Teichert-Coddington, 1999). The average removal rates in sedimentation ponds (12 h sedimentation period) for shrimp pond effluents were 69.1% for total suspended solids, 50.3% for BOD_5, 28.8% for total nitrogen, 35.4% for total phosphorus, and 38.0% for hydrogen sulfide. Whereas the average removal rates in effluent treatment system for shrimp pond effluent consisting of 12 h sedimentation and 7 days aeration were 83.5% for total suspended solids, 57.8% for BOD_5, 90.9%

for total ammonia, 58.5% for total nitrogen, 49.2% for total phosphorus, and 94.0% for hydrogen sulfide (Faculty of Fisheries, 2002). Wastewater treatment systems using water hyacinth have been reported with removal efficiency of 37-91% for BOD_5 and 21-92% for total suspended solids (USEPA, 1988). Zimmels *et al* (2006) also reported that water hyacinth is effective for sewage purification. According to Brix (1977) macrophytes mediated transfer of oxygen to the rhizosphere, by leakage of roots, and increased aerobic degradation of organic matter and nitrification.

Table 5. Effect of effluent treatment system on hybrid catfish pond effluent quality

	pH	DO	TAN	NO_2^--N	NO_3^--N	TKN	TP	H_2S	BOD_5	TSS
		mg/l								
First										
trial										
Initial	8.5	4.2	40.14	0.67	0.29	56.59	2.15	0.022	61.7	826.7
Sedimentation (1day)	8.6	-	36.77	0.68	0.28	41.11	0.36	0	38.0	77.5
Aeration (4 days)	8.6	4.6	19.16	4.37	1.14	32.49	0.30	0	32.0	37.1
Water hyacinth (9 days)	6.9	5.0	0.05	0.52	14.94	16.80	0.16	0	6.5	9.9
Second										
trial										
Initial	6.7	3.9	9.58	1.67	0.28	12.35	1.50	0.001	41.5	765.0
Sedimentation (1day)	7.0	-	4.60	2.82	0.48	8.45	0.64	0	18.5	282.0
Aeration (4 days)	7.7	7.6	0.39	2.81	3.75	7.54	0.48	0	16.0	220.8
Water hyacinth (9 days)	6.0	6.1	0.02	0.01	0.01	3.09	0.18	0	5.2	30.8
Third										
trial										
Initial	8.2	3.1	15.40	0.02	0.06	22.05	1.60	0.002	52.0	568.3
Sedimentation (1day)	8.5	-	12.46	0.10	0.06	13.03	0.36	0	15.5	57.8
Aeration (4 days)	8.3	6.6	2.34	1.82	0.34	8.69	0.28	0	13.0	20.4
Water hyacinth (9 days)	6.8	4.4	0	0.54	0.04	0.99	0.14	0	3.8	10.5

Table 6. Percentage of pollutants removed by the effluent treatment system (average values and ranges)

Treatment	BOD_5	TSS	TKN	TP	TAN	H_2S
Sedimentation	54.7	81.2	33.3	72.7	26.5	100
(1 day)	38.4-70.2	63.1-90.6	27.4-40.9	57.3-83.3	8.4-52.0	-
Aeration	6.9	6.5	14.1	6.2	51.2	-
(4 days)	4.8-9.7	4.9-8.0	7.4-19.7	2.8-10.7	43.9-65.7	
Water hyacinth	28.4	9.9	32.9	11.7	22.2	-
(9 days)	17.6-41.4	1.7-24.8	27.7-36.0	6.5-20.0	3.9-47.6	
Total	90.0	97.6	80.3	90.6	99.9	100
	87.7-92.6	95.9-98.8	70.3-95.5	88.0-92.6	99.8-100	-

CONCLUSION

Results from the laboratory scale investigation indicated that treatment of hybrid catfish pond effluent in a treatment system consisting of 1 day sedimentation followed by 4 days aeration and 9 days absorption by water hyacinth was very effective in removing pollutants from the effluent. The treatment system was able to reduce 97.6% of total suspended solids, 90.0% of BOD_5, 90.6% of total phosphorus, 99.9% of total ammonia nitrogen, 80.3% of total kjeldahl nitrogen, and 100% of hydrogen sulfide, by average. Sedimentation for 1 day resulted in the removal of 81.2% of total suspended solids, 54.7% of BOD_5, 72.7% of total phosphorus, 26.5% of total ammonia nitrogen, 33.3% of total kjeldahl nitrogen, and 100% of hydrogen sulfide, by average. Removal rates with 4 days aeration were 6.5% for total suspended solids, 6.9% for BOD_5, 6.2% for total phosphorus, 51.2% for total ammonia nitrogen, and 14.1% for total kjeldahl nitrogen, by average. Treatment by water hyacinth for 9 days removed 9.9% of total suspended solids, 28.4% of BOD_5, 11.7% of total phosphorus, 22.2% of total ammonia nitrogen, and 32.9% of total kjeldahl nitrogen, by average.

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