Journal of Agricultural Technology 2011 Vol. 7(2): 215-224
Available online http://www.ijat-aatsea.com
ISSN 1686-9141

Design and operation of a biological integrated system for wastewater of cattle farm treatment and utilization in circulated water fish culture

Rittiruk, U., Kangpanich, C.* and Rakseree, S.

Rajammangala University of Technology Tawan-ok, Bangpra, Cholburi, Thailand.

Rittiruk, U., Kangpanich, C. and Rakseree, S. (2011). Design and operation of a biological integrated system for wastewater of cattle farm treatment and utilization in circulated water fish culture. Journal of Agricultural Technology 7(2): 215-224.

The bio-integrated (intensive) system is used for treated waste water from cattle farms rearing in fish pond with recirculation system. This study consisted of 2 experiments as hybrid facultative pond, constructed in wetland oxidation pond and elephant grass grower ponds that reduced BOD, ammonia, nitrate and phosphate at the concentrations of 80.81, 76.60, 79.56 and 77.89%, respectively. The second experiment consisted of hybrid facultative pond, constructed in wetland, oxidation pond, elephant grass grower ponds and water milfoil grower ponds that reduced BOD, ammonia, nitrate and phosphate concentrations of 82.86, 88.16, 82.82, 82.27%, respectively. The result revealed that the fish rearing experiment with recirculation system exhibited higher water quality, growth rate and production than the second experiment.

Key words: biological integrated system, constructed wetland, cattle farm

Introduction

Aquaculture production and intensive animal farms are important source of pollution such as wastewater from animal husbandry, water tab which causes water surface and groundwater contamination with nutrient. Wastewater from these processes causes water pollution including organic, nutrient, parasite, bacteria and viruses. Water pollution causes a broad impact on activities related to water use, creature survival, biodiversity, and health of people and pets. Furthermore, they affect agricultural ecosystem and destroy the sustainability of food production. The impact of that processes need to change how animal farm from the same old manufacturer style to produce in the new friendly environmental way. Human tries to discover and develop technology in the appropriate ways for treatment wastewater from manufacturing and animals over the past 2-3 decades. Those technologies have many characteristics from

*Corresponding Author: Kangpanich, C.; e-mail: chanpimk@gmail.com

the different of wastewater treatment technology from the community and industry. In order to prevent the high cost, the most appropriate technology is biotechnology which coordinates perfectly with the ecosystem (Wang, 1987, 1991). In addition to the rehabilitation of the water back to the good quality, organic substances and nutrient from the waste water are transformed from the waste to be the advantage substances for plant usage. Moreover, they are transfered through the food chain to be increasing value agricultural productions such as production from herbivore fish and plankton, chicken, duck and goose, aquatic plants and vegetables cultivated in non-soil environment. Wastewater treatment system for agriculture that hacome b popular in many countries are dry wells, ponds fill weather and artificial lagoon. The limitation of each water treatment system leads to a limitation performing effective task in small water treatment system. The ecosystem integration of multiple treatment systems can increase the effective of wastewater treatment from the more complex process of wastewater treatment. Miller and Semmens (2002) stated that high effective treatment in wastewater treatment system from fish pond requires 3 steps of treatment process including separate sediment, decaying suspend and reduction of nutrient in water, and eliminate parasite and viruses. Wang *et al.* (2006) designed wastewater treatment system methodology using combination several ecosystems to increase the effective treatment including advanced hybrid facultative pond, aeration pond, fish pond, duck weed pond and constructed wetland by measurement COD BOD suspended solid ammonium million and triple phosphate at 69.1 78.3 76.4 62.1 and 52.9%, respectively.

Materials and methods

General condition of research location

The experiment was conducted in wastewater ponds receiving wastewater from dairy cattle shed with 30 milk cattle and pasteurization plant with a milk production capacity of 100-200 liters per day. Size of pond for wastewater was an area of 800 square meters, 1.50 meters deep, average wastewater volume 5-50 cubic meters per day depending on season. Wastewater quality was simple sampling collected every 2 times per month at 8:00 oxygen dissolve 0 mg/liter, Alkaline conditions was 204-296 mg per liter. Acidity and alkaline were 7.04-7.32 BOD 5 day 126-182 mg per liter. Total ammonia was 3.4241-4.3392 mg/liter, Nitrate 2.4652-3.2278 mg./liter, Phosphate 2.8733-3.0173 mg. per liter. Quality water overflowing from the tank waste was oxygen dissolve 0.2-0.5 mg per liter, Alkaline conditions was 248-280 mg per liter. Acidity and alkaline was 6-99-7.46, BOD 5 days 21.3-36.7 mg. per liter, total ammonia

2.0558-2.8377 Mg/liter, Nitrate 1.0942-1.3291 mg./liter, Phosphate 1.2832-1.7405 mg./liter. Average time of water contamination in the pond was 30 days.

Treatment system design

The average of wastewater from dairy cattle shed, plants and fish pond was 300 cubic meters per day and 90% majority comes from the fish pond. Treatment system consists of a set of stability adjustment for pond wetland component. Aquatic plants were totally grown in the area 200 square meters, average depth 75 cm and a series of concrete pond size 3 x 16 x 1.0 cubic meters was divided into 4 channels. Within each box of the pond have 4 floors camouflage light net horizontal distance the water flow for keeping bacteria that decomposed the organic substances and mineral liberation. A constructed wetland system was 200 square meters that comprise with 3 parts. The beginning and end of the constructed wetland was deep 60 cm pond planting Cyperaceae family. The central of the wetland was deep 100 cm planting floating plants and water lily. The size of earthern facultative pond was 600 square meters average depth 150 centimeters. The air was filled in this pond by photosynthesis of plants plankton. The pond was located along the wind blow direction to increase the water recirculation rate.

Experimental design

The efficiency treatment of wastewater was studied by comparative wastewater quality draining in treatment systems and after treatment. The data were collected as reduction of BOD, total ammonia values, nitrate and phosphate in water samples collected at 15.00 pm.

The suitable marginal plants species was studied by using water filtration systems first step by comparative of water quality treatment from fish pond through the 3 types planting system including Elephant grass, Sedge and Cyperus corymbosus. The wastewater from fish pond worked as the control group. All 3 types of marginal plants system consisted with whole-rock 35 cm thick cement as a pond. Area planted Screen was 4.8 square-meter concrete pond. This area was used to drain wastewater from fish ponds to planting crops at the rate of flow 12.5 liters per minute. The wastewater was passed through the treatment system to absorb through plant root and penetration filtering layer material and flow out from the pond. The control group drained water through the same size pond. Effective treatment measured from comparative of water quality through the water treatment system via plant. Completely randomized design (CRD) eas used in the experiment with 3 replications with 10 weeks of comparative trial period.

The experiment was studied the suitable submerged plant species for using in biological filtration the second step by comparative of water quality through the process of growing 4 types of submerged plants including water cabomba, Water milfoil, Tapegrass and Ambulia. The wastewater from the fish pond filtered through Elephant grass planting system as a control group by planting system that working as in the second items. Water flowing in rate was at 9.0 liters per minute. The experiment was used as CRD with 3 replications 10 weeks as comparative period.

The rexperiment was studied to compare the result of recirculation aquaculture system which was used wastewater treatment system in 2 types. The first type included the facultative pond, constructed wetland, oxidative ponds and biological filters from the first step using Elephant grass plant to absorb nutrients for 18 fields. The second type included the facultative pond, constructed wetland, oxidation ponds and biological filters from the first step planting for 9 fields. The biological filtering system the second type used water milfoil for absorbing the nutrient in 9 ponds. The flow rate of both type was 150 liter per minute. The water from each water treatment system was flown into the fish pond with the size of 800 square meters. 3200 of red Nile tilapia and 5000 of hybrid walking catfish are rearing and feed with the food with no less than 28% of protein. 16-week trial period in the fish pond used the air lift system. From after 10 weeks, the effective in recirculation system 2 types and quality of water in fish pond were compared throughout the 16 weeks by using statistics value. The statistics value was used to compare each independent experimental group and the growth of the fish via an average value and standard deviation.

Results and discussion

Each average water quality of wastewater and water treatment in treatment system are shown in Table 1 along with the decrease rates (percent) of water quality parameters at all stages of treatment are shown in Table 2.

Wastewater treatment system design has 3 important key components; facultative pond, constructed wetland, oxidative pond. Working principle of these systems were filtering sediments and decomposition as a suspendible and solution in the oxidation pond. In the pond consisted of wetlands and decomposition ponds that reduced BOD values lower than 50% and also reduced nutrients, total ammonia, nitrate and phosphate. Moreover, the pond was reduced the remaining BOD in constructed wetland, and it was added more oxygen, adjusted the pH and rebalance alkaline level within the oxidation pond. The result from these wastewater treatment system showed that the treatment water through this system gave better quality than wastewater within the mixing effluent ponds (Table 1). The study from the effective of this wastewater treatment system showed the potential to reduce BOD for 5 days, total ammonia, Nitrate and Phosphate at 80.55, 72.95, 74.44, and 73.16%, respectively (Table 2). The results of this treatment were consisted with Wang *et al.* (2006)'s treatment system which used a similar treatment system. However, the reduction of the Nitrate and Phosphate through constructed wetland that effective at 36.50 and 31.37%, respectively which was different from the result from Reed *et al.* (1995). Constructed wetlands, which were effective in absorbing nutrients about 80-90% showed that the average size was designed in the area of 200 square meters to treat the wastewater 300 cubic meters per day, that was still too low. There were 2 solutions about this problem. First, increasing constructed wetland size to 300% or more. The other was to increase the biological filtration system and used aquatic plants to absorb more nutrients.

The suitable marginal plant species for biological filtration from step 1 was compared the parameters of water quality treatment by filtration through 3 types of marginal plant with the water quality of wastewater from the fish pond are shown in Table 3.

Table 1. Average water quality of waste water and water treatment in treatment system.

Parameters	Wastewater			Water treatment		
	Diary cattle shed	**Fish pond**	**Mixed effluent**	**Facultative pond**	**Constructed wetland**	**Oxidation pond**
DO (mg/l)	0	0	0	0.5	1.8	5.2
Alkalinity (mg/l)	256	201	228	182	176	154
pH	6.96	7.16	7.14	7.20	7.41	7.64
BOD (mg/l)	165	22	36	14	10	7
Ammonia (mg/l)	2.7898	0.9021	2.7570	1.0380	0.8875	0.7733
Nitrate (mg/l)	2.9660	1.5527	1.5877	0.9929	0.6305	0.4058
Phosphate (mg/l)	3.7849	0.6568	1.9219	1.1601	0.7962	0.5159

Table 2 The decrease rates (percents) of water quality parameters at all stage of treatment.

Parameter	Mixed effluent	Water treatment	Decrease rates (%)
BOD (mg/l)	36	7	80.55
Ammonia (mg/l)	2.7570	0.7733	72.95
Nitrate (mg/l)	1.5877	0.4058	74.44
Phosphate (mg/l)	1.9219	0.5159	73.16

Table 3. The comparison water quality of fish pond effluent and effluent treatment step 1 by filtration 3 type of marginal plants.

Parameters	Wastewater	Water treatment			Scheffe	Sig (2 tailed)
		Elephant grass	Sedge	Cyperus		
$BOD_{24\,hr}$ (mg/l)	3.73 [a]	2.16 [b]	2.36 [b]	2.58 [b]	1.52	.000**
Ammonia (mg/l)	1.0194 [a]	0.9002 [a]	0.9717 [a]	0.9377 [a]	.0545	.230 [ns]
Nitrate (mg/l)	0.9379 [a]	0.8986 [a]	0.7880 [a]	0.9039 [a]	0.863	.385 [ns]
Phosphate (mg/l)	0.1713 [a]	0.2254 [a]	0.2402 [a]	0.2381 [a]	.0541	.531 [ns]

The results showed that by planting system Elephant grass, Sedge and Cyperus corymbosus was the potential to reduce BOD for 24 hours of wastewater from the fish pond with the different in statistically at 4 (P <.01). Elephant grass was the highest potential to reduce BOD from 3.73 mg. per liter to 2.16 mg. per liter. In contrast, it could not decrease the total ammonia, nitrate and phosphate. The reason was the nutrients in the wastewater from recirculating fish ponds became mostly in the form of suspendible organic substances that absorbed to filter keeping in the planting system before decomposition. The decomposition of organic substances in planting system wereleft with only the nutrients that decomposed which the plants could not absorb it and all contaminants in the water flow from the cultivated plants.

The study of the suitable submerged plant species for biological filtration from step 2 was compared the parameters of water quality treatment by biological filtration through 4 types of submerged plant with the water quality of wastewater from the fish pond in the biological filtration in step 1 Elephant grass. The result is shown in Table 4.

Table 4. The comparison water quality of effluent treatment step 1 and effluent treatment step 2 by filtration through 4 types of submerged plants.

Parameters	Wastewater treatment step 1	Wastewater treatment step 2				Scheffe	Sig (2 tailed)
		Cabomba	Water milfoil	Tapegrass	Ambulia		
$BOD_{24\,hr}$ (mg/l)	2.68 [a]	1.59 [b]	1.37 [b]	1.60 [b]	1.72 [b]	.1477	.000**
Ammonia (mg/l)	0.9674 [a]	0.7461 [b]	0.5926 [c]	0.7043 [bc]	0.8814 [a]	.1274	.049*
Nitrate (mg/l)	0.7671 [a]	0.7804 [a]	0.5216 [a]	0.5589 [a]	0.7161 [a]	.1538	.489 [ns]
Phosphate (mg/l)	0.1894 [a]	0.1979 [a]	0.1876 [a]	0.2161 [a]	0.2265 [a]	.0328	.707 [ns]

The results showed that the planting of Water cabomba, Water milfoil, Tapegrass and Ambulia gave the potential to reduce BOD for 24 hours and total ammonia from all wastewater in the fish pond by the statistically ($P <.01$ and $P <.05$). The Water milfoil revealed the highest potential of reducing BOD 24 hours from 2.68 mg. to 1.37 mg. per liter and reduced total ammonia from 0.9674 mg. per liter to 0.5926 mg. per liter. However, it could not reduce Nitrate and Phosphate as the same reason as in item 2.

The fishing in recirculation water system was compared by using 2 types of wastewater treatment system, the quality of wastewater from cattle farm, milk facility and 2 types of water treatment in fish pond are shown in Table 5. The treatment performances in 2 types of treatment system were shown in Table 6. Finally, the average water quality in the fish pond that was used a 2 different types of treatment system in all 16 weeks are shown in Table 7.

Table 5. Water quality of mixed wastewater and 2 type of wastewater treatment.

Parameters	Mixed Wastewater	Type 1	Type 2
$BOD_{24\,hr}$ (mg/l)	5.37	1.03	0.92
Ammonia (mg/l)	2.7460	0.6426	0.3251
Nitrate (mg/l)	2.8174	0.5759	0.4840
Phosphate (mg/l)	2.6578	0.5876	0.4712

Table 6. Comparison of treatment performance in 2 types treatment system.

Parameters	Type 1 (%)	Type 2 (%)	Sig (2 tailed)
$BOD_{24\,hr}$	80.81^{a}	82.86^{a}	$.407^{ns}$
Ammonia	76.60^{b}	88.16^{a}	.015*
Nitrate	79.56^{a}	82.82^{a}	$.408^{ns}$
Phosphate	77.89^{b}	82.27^{a}	$.044^{ns}$

The average weight of the fish in the recirculation water system fish pond that was used 2 different types of treatment systems was shown in Table 8. The product, surviving rate and feed conversion were shown in Table 9.

The wastewater system from recirculation water system in the 2 types showed that the second type of wastewater treatment system can provide higher performance in treatment water than the first type. The second wastewater treatment system could reduce BOD 24 hours, total ammonia, Nitrate and phosphate at 82.86, 88.16, 82.82, and 82.27%, respectively. On the other hand, the first system decreased the wastewater quality parameters at 80.81, 76.60, 79.56, and 77.89%, respectively (Table 6). The second wastewater treatment system was better than the first wastewater treatment. Thus, the water quality in fish pond water circulation system that used the second wastewater treatment system gave better quality than the first one both in the water surface and the bottom of the pond for the whole 16 weeks (Table 7). Therefore, the better water quality made more growth rates, productive rates and survival rates of fish in the second system than in the first system (Table 8 and 9).

Table 7. Average water quality in the fish pond that is used 2 different types of treatment system in all 16 weeks.

Parameters	Level	Time	Type 1	Type 2	Sig (2 tailed)
DO (mg/l)	surface	06:00	1.91 [b]	3.15 [a]	.047*
		15:00	11.26 [a]	10.26 [b]	.000**
	bottom	06:00	1.67 [b]	2.29 [a]	.000**
		15:00	9.41 [a]	9.25 [b]	.000**
pH	surface	06:00	7.54 [b]	7.56 [a]	.000**
		15:00	8.36 [a]	8.26 [b]	.000**
	bottom	06:00	7.50 [b]	7.57 [a]	.000**
		15:00	8.24 [a]	8.19 [b]	.000**
Ammonia (mg/l)	surface	06:00	0.9641 [a]	0.8026 [b]	.000**
		15:00	0.7514 [a]	0.6812 [b]	.000**
	bottom	06:00	1.0905 [a]	0.8569 [b]	.000**
		15:00	0.8731 [a]	0.7044 [b]	.000**
Nitrate (mg/l)	surface	06:00	0.8957 [a]	0.6648 [b]	.000**
		15:00	0.7478 [a]	0.6056 [b]	.000**
	bottom	06:00	0.9718 [a]	0.7888 [b]	.000**
		15:00	0.9118 [a]	0.7637 [b]	.000**
Phosphate (mg/l)	surface	06:00	0.2008 [a]	0.1772 [b]	.000**
		15:00	0.1297 [a]	0.1213 [b]	.000**
	bottom	06:00	0.2318 [a]	0.2143 [b]	.000**
		15:00	0.1486 [a]	0.1470 [b]	.000**
CO_2 (mg/l)	surface	06:00	21.37 [a]	19.47 [b]	.000**
		15:00	2.86 [a]	3.02 [a]	.244 [ns]
	bottom	06:00	22.62 [a]	21.44 [b]	.000**
		15:00	3.21 [a]	4.04 [a]	.541 [ns]
$BOD_{24\,hr}$ (mg/l)	surface	06:00	2.90 [a]	2.15 [b]	.000**
	bottom	06:00	3.31 [a]	2.29 [b]	.002**
COD (mg/l)	surface	06:00	44.37 [a]	38.87 [b]	.000**
	bottom	06:00	59.75 [a]	45.62 [b]	.000**

Table 8. Average weight of red tilapia and hybrid walking catfish in the recirculation water system fish pond 2 types.

Weeks	Type 1		Type 2	
	Red Tilapia	**Walking catfish**	**Red Tilapia**	**Walking catfish**
initial	35.55±13.69	26.88±9.63	31.27±12.30	24.49±7.60
2	72.00±23.63	60.89±22.14	65.97±21.00	58.22±15.53
4	98.48±35.55	124.48±35.69	108.92±33.71	126.92±29.79
6	179.30±49.04	152.08±61.52	195.82±39.36	161.85±59.09
8	194.42±56.31	204.65±69.44	218.23±40.92	217.08±60.38
10	229.40±63.33	223.15±79.24	271.52±45.35	258.00±89.30
12	282.75±67.80		327.50±53.49	
14	324.38±76.64		384.15±67.51	
16	392.58±83.32		448.57±91.06	

Table 9. The production, survival rate and feed conversion of the fish in the recirculation water system fish pond 2 types.

Parameters	Type 1			Type 2		
	Red Tilapia	**Walking catfish**	**Total**	**Red Tilapia**	**Walking catfish**	**Total**
Production (kg/rai)	1998	1584	3582	2358	2139	4497
Survival rate (%)	87.47	80.72	83.05	88.31	91.60	90.34
Feed conversion			1.32			1.35

In conclusion, the wastewater treatment system that consists of the facultative pond, constructed wetlands and oxidation pond gave a potential to reduce BOD for 5 days, total ammonia, Nitrate and Phosphate at 80.55, 72.95, 74.44, and 73.16% respectively.

Elephant grass planting in the non-soil environment system was suitable for biological filtration in step 1 and gave the potential to reduce BOD 24 hours of water in the fish pond from 3.73 mg. per liter to 2.16 mg per liter. However, this systemcould not reduce total ammonia, Nitrate and Phosphate due to the fact that the biological filtration per pond size was too small.

Water milfoil cultivated in non-soil environment was suitable for biological filtration system in step 2 and gave the potential to reduce BOD 24 hours and total ammonia of wastewater from the fish pond that using Elephant grass from 2.68 and 0.9674 mg. per liter to 1.37 and 0.5926 mg. per liter, respectively. In contrast, it could not reduce Nitrate and Phosphate from the limitation of the planting system size that was too small.

Wastewater treatment system was used to improve water quality in recirculation water system fishing by using the wastewater from the farm as a source in both types. The second type which consisted of facultative pond, constructed wetlands, oxidation pond, biological filtration system in step 1 and biological system in step 2 leaded to the suitable quality of the water in fish pond which increased more growth rates, productive rates and survival rates in the whole 16 weeks.

References

Miller, D. and Semmens, K. (2002). Waste management in aquaculture. Extension Service, West Virginia University, Morgantown.

Reed, S.C., R.W. Crites and E.T. Middlebrooks, (1995). Natural system for waste management and treatment, 2 ed edition, McGraw-Hill, Inc., New York.

Wang, B.Z. (1987). The development of ecological wastewater treatment an utilization system (EWTUS) in China. Wat Sci. & Tech. 19(1/2): 51–63.

Wang, B. (1991). Ecological wastewater treatment an utilization on low-cost, energy-saving/generating and resource recoverable technology for water pollution control in China. Wat Sci. & Tech. 24(5): 9–19.

Wang, L.J. Peng, B. Wang and Yang, L. (2006). Design and operation of and eco-system for municipal wastewater wastewater treatment and utilization. Wat Sci. & Tech. 54(1): 429–436.

(Received 14 January 2010; accepted 4 March 2011)