Minimum Requirement to Improve Quality before Discharging from Hybrid Red Tilapia Intensive Cage-Culture in Earthen Ponds to the Environment

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ARTICLE INFO

Received: 29 Nov 2021
Received in revised: 2 Mar 2022
Accepted: 14 Mar 2022
Published online: 27 Apr 2022
DOI: 10.32526/ennrj/20/202100208

Keywords:
Hybrid red tilapia/ Water level/ Sedimentation/ Reducing environmental pollution

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ABSTRACT

This study determined a practical method to reduce environmental pollution by wastewater from fish ponds. Water quality in three hybrid red tilapia ponds (0.24 ha) was examined before and during harvest at five water depths of 10, 20, 50, 100, and 150 cm, as well as at the water surface and pond bottom. All water samples were analyzed for BOD, TN, TP, TAN, TS, TSS, and SS, with results compared with the Thailand control standard for freshwater aquaculture effluent. All quality parameters of the seven water samples showed statistical significance ($p<0.05$) that increased with water depth. Degradation was highest in the bottom 50 cm of the fish pond. Limiting drainage to a depth of 50 cm was achieved by tilting the drainage pipe, and the resulting effluent met all water quality parameter standards. At a water depth of 50 cm, the remaining water was drained using a water pump, and all water quality parameters failed to meet the required standards. When this water was allowed to settle for 24 h, BOD, TN, TP, TAN, and TSS reduced to 21.06%, 2.42%, 11.68%, 5.47%, and 43.36% of full pond values, respectively. Results suggested sedimentation as a practical technique requiring a smaller pond area to reduce environmental pollution.

1. INTRODUCTION

Aquaculture farms release discharge water from fish ponds to 1) improve water quality during the culture period and 2) drain water during harvesting. The main inputs to aquaculture systems are feed and seston. These are transformed to fish biomass or released in the water as feed waste and excreta in the form of suspended organic solids or dissolved nutrients, including nitrogen and phosphorus (Feng et al., 2004; Li et al., 2011), and are often discharged without treatment (Li et al., 2011). Dissolved inorganic nutrients such as ammonia, urea and phosphate are readily taken up by phytoplankton and macroalgae to stimulate their growth (Troell et al., 2003; Feng et al., 2004; Newell, 2004), leading to hypoxia and harmful algal blooms (Alonso-Rodríguez et al., 2003; Troell et al., 2003; Feng et al., 2004; Cao et al., 2007; Mohamed and Al-Shehri, 2012). In many countries, aquaculture farm effluents cause major ecological impacts on the environment through habitat destruction and water pollution (Teichert-Coddington, 1995; Coldebella et al., 2018; Sampantamit et al., 2020).

In 2007, the Thailand Pollution Control Department enacted a wastewater control standard to reduce water pollution from aquaculture ponds impacting the environment. This standard suggested a requirement for sedimentation ponds of the same size as the cultivation ponds; however, farmers considered this to be a burden on production. Reducing the amount of discharge wastewater requiring treatment would reduce sedimentation pond size and lessen the burden on farmers. This research assessed the minimum water level sedimentation requirement to improve wastewater quality before discharge from intensive cage-culture earthen ponds to the environment.

Citation: Taparhudee W, Is-haak J, Jongjaraunsuk R. Minimum requirement to improve quality before discharging from hybrid red tilapia intensive cage-culture in earthen ponds to the environment. Environ. Nat. Resour. J. 2022;20(4):340-347. (https://doi.org/10.32526/ennrj/20/202100208)

Two ways to reduce the impact of wastewater on the environment include reducing the amount of discharge wastewater or improving the discharge water quality. Intensive cultivation of hybrid red tilapia requires a large quantity of feed, leading to high accumulation of organic matter in ponds from left over feed and fish excretion. Cole and Boyd (1985) reported that excessive nutrients in fish ponds result in poor water quality and slow growth rate. Intensive culture ponds require frequent water changes. Therefore, improving discharge water quality is a more practical alternative to reducing discharge water quantity.

A wetlands technique is widely used for improving wastewater quality. Plants in wetlands absorb soluble nutrients and filter solids, thereby improving polluted wastewater quality (Turcios and Papenbrock, 2014). This technique is very effective but limitations include a large land area for water treatment of 0.7-2.7 times the size of the culture ponds (Schwartz and Boyd, 1995). Shpigel et al. (2013) applied 10,000 m^2 of wetland with *Salicornia* spp. for the removal of nitrogen and total suspended solids produced from 900 kg of 45% crude protein fish feed (11 m^2/kg of feed) during one year. However, biotreatment investment costs are high (Gutierrez-Wing and Malone, 2006). Solid precipitation is another technique commonly used in aquaculture farms, with wastewater drained to sedimentation ponds, dried under the sun and removed as fertilizer in solid form. This method requires a smaller area than the wetland technique but is more labor-intensive.

Recently, reports have shown that the nutrients and solids in aquaculture ponds are highly concentrated in the last 5-20% of the discharge volume (Schwartz and Boyd, 1994; Teichert-Coddington et al., 1995; Teichert-Coddington et al., 1999; Coldebella et al., 2018). Thus, the quality of the upper water pond layers may qualify for discharge into the environment, and the common process of treatment of all drained water after harvest may not be necessary. Precipitation treatment performed only on the lower pond layers would reduce sedimentation pond size and treatment costs, while increasing land efficiency. Previous research investigated channel catfish and shrimp in the USA and Honduras under lower temperatures and humidity values than experienced in Thailand. A tropical environment stimulates biological activity and increases the concentration of sewage; therefore, volumes of discharge water needing treatment will be different. If farmers know the level of sewage in the pond that does not meet the water quality standard, then this will reduce the volume of water requiring treatment. Hybrid red tilapia in Thailand are raised in highly intensive systems that create large amounts of nutrients and wastewater.

This research studied the quality of water at different depths in hybrid red tilapia ponds before and during harvesting, and compared water quality parameters at each depth to the Thailand control standard of wastewater from freshwater aquaculture farms. The Thai standard requires biochemical oxygen demand (BOD) <20 mg/L, total nitrogen (TN) <4.0 mg/L, total phosphorus (TP) <0.5 mg/L, total ammonia nitrogen (TAN) <1.1 mg/L, and total suspended solids (TSS) <80.0 mg/L (TECAC, 2008). The first drained water level that did not reach all the standard parameters was considered as the minimum water level required to improve water quality before discharge into the environment.

2. METHODOLOGY

2.1 Ponds cultivation and water management

The commercial hybrid red tilapia culture ponds used in this study were located at Jittiporn Farm, Klong 13, Pathum Thani Province in the central region of Thailand. Three rectangular ponds (0.24 ha, 150 cm deep and 1:1 inner dike slope) were tested for the experiment. In each pond, fish were raised in six 7.5×15×1.2 m^3 cages. The fish (weight 100 g) were stocked at 1,200 fish per cage (9 fish/m^3) and fed at 2-3% of their body weight per day with 30% protein pellet feed divided into three meals at 07:00, 11:30, and 17:00 h. Two 3-h.p. aerators were operated to maintain water circulation. These were turned off during each feeding time for about 45 min. The fish were raised for four months to reach a harvestable size of 800 to 1,000 g. Fish harvesting was performed by lifting the cage out of the water. The out-cage fish were seined when the water was drained to a depth of 50 cm.

Water exchange at a rate of 10 to 20% of total pond water volume began three weeks after stocking by adding fresh water and draining the wastewater through a ten-inch diameter PVC drain pipe installed 50 cm above the bottom of the pond (Figure 1). The pond was drained by lowering this pipe to reduce the water level to 50 cm depth. Wastewater was pumped out by a twelve-inch diameter pump installed at the bottom of the pond.

Figure 1. PVC pipe installed

Most of the wastewater and sewage from the pond are discharged during fish harvesting. This creates an environmental problem. Fortunately, the lifting cage harvest method does not disturb the sewage at the bottom of the pond. The upper drained water does not mix with the sewage and may qualify under Thai control standards to allow discharge into the environment. However, this has not yet been scientifically proven. The lower part of the wastewater, with high concentrations of organic matter, becomes disturbed during the seining of the out-cage fish and electrical pumping. Research to determine the required time for the solids to precipitate and the water to qualify for discharge was therefore undertaken, comprising three experiments.

2.2 Sampling and testing

2.2.1 Water quality at different water depths before harvesting

This experiment was conducted on the day of harvesting. After shutting down all the aerators for 30 min and before draining water out of the pond, a technician collected water samples using a 20 cm diameter PVC water sampling pipe. Three water samples were taken at five water depths of 10, 20, 50, 100, and 150 cm and also from the water surface and the pond bottom.

All water samples were analyzed for BOD, TN, TP, TAN, total solids (TS), TSS, and settleable solids (SS) by the methods shown in (Table 1). Water volume in the pond is shown in Table 2 and calculated using equation 1.

$$\text{Water volume } (m^3) = \left(\frac{1}{2} \times (\text{water surface area} + \text{pond bottom area}, m^2)\right) \times \text{water depth (m)} \quad (1)$$

- *Data analysis*

Water quality parameters from the three experimental ponds were averaged, with water quality data at different water depths analyzed for variance by one-way ANOVA. Comparison of mean differences between treatments was performed using Duncan's New Multiple Range Test at 95% confidence interval ($p<0.05$). Each parameter was averaged, with results reported as standard deviation by SPSS 24.0. Water quality data at different depths were then compared with the Thai standards of wastewater drainage from freshwater aquaculture farms (TECAC, 2008), as shown in Table 1.

Table 1. Water quality analysis methods and Thailand control standards.

Water quality parameter (mg/L)	Analysis method	Thailand standard
BOD	APHA et al. (2005)	<20.0 mg/L
TN	Raveh and Avnimelech (1979)	<4.0 mg/L
TP	Raveh and Avnimelech (1979)	<0.5 mg/L
TAN	APHA et al. (2005)	<1.1 mg/L
TS	APHA et al. (2005)	-
TSS	APHA et al. (2005)	<80.0 mg/L
SS	APHA et al. (2005)	-

2.2.2 Water quality at different water depths during harvesting

This experiment investigated water quality discharge from red tilapia ponds during harvesting using two steps of draining according to pond depth. First, water was drained by lowering the drainage pipe from the surface (150 cm total water depth) until the water depth was 50 cm. The remaining water was then pumped out by a 20 cm diameter water pump. Three water samples were collected at the tip of the drainage pipe or the pump outlet at 0, 50, 100, 130, 140, and 150 cm water depths and at the pond bottom.

Before water quality analysis, the three samples taken at each water depth were mixed and measured using the method shown in Table 1. Data analysis was performed as followed in experiment 1.

2.2.3 Wastewater quality changes after settling for different times

This experiment investigated the precipitation of solids and nutrients inside the ponds. From the results of the second experiment, only water samples that did not pass the control standard were studied for sedimentation. The substandard samples were allowed to stand in test tubes at room temperature, with samples taken at sedimentation times 1, 3, 6, 12, 24, 48, 72, and 96 h. Water quality analysis methods are shown in Table 1. Changes in sedimentation percentages were recorded from 0 h.

Before water quality analysis, the three samples taken at each sedimentation time were mixed and measured using the methods shown in Table 1. Data analysis followed the procedures used in experiment 1.

3. RESULTS

3.1 Water quality at different water depths before harvesting

Results of calculated water volume and analyzed water quality at different water depths before the discharge was drained from the pond are shown in Tables 2 and 3. The total volume of the water in the pond was 3,097 m^3 and 50 cm of the last part of pumped water was 31% of that volume. All water quality parameters of the seven water samples were statistically significant ($p<0.05$) and increased at each water depth.

Table 2. Water volume in the hybrid red tilapia pond at different water depths

Water depth (cm)	Water volume (m^3)	Water volume (%)
150	3,097	100.0
100	2,017	65.1
50	985	31.8
20	389	12.5
10	193	6.2
5	96	3.1

Table 3. Water quality in the hybrid red tilapia pond before drainage

Water depth (cm from surface)	BOD (mg/L)	TN (mg/L)	TP (mg/L)	TAN (mg/L)	TS (mg/L)	TSS (mg/L)	SS (mg/L)
10	7.80 ± 0.29^{e}	0.26 ± 0.04^{e}	0.156 ± 0.021^{d}	0.051 ± 0.013^{d}	204.50 ± 6.36^{e}	57.50 ± 0.71^{d}	0^{d}
20	11.40 ± 0.28^{d}	0.61 ± 0.02^{d}	0.220 ± 0.028^{c}	0.085 ± 0.007^{d}	225.50 ± 2.12^{d}	63.10 ± 0.57^{cd}	0.15 ± 0.04^{cd}
50	12.60 ± 0.34^{c}	0.73 ± 0.08^{cd}	0.265 ± 0.007^{c}	0.120 ± 0.014^{d}	233.00 ± 4.24^{d}	67.00 ± 0.85^{cd}	0.24 ± 0.07^{bcd}
100	15.00 ± 0.28^{b}	0.89 ± 0.06^{bc}	0.320 ± 0.014^{b}	0.245 ± 0.007^{c}	246.50 ± 2.12^{c}	75.55 ± 1.34^{c}	0.36 ± 0.04^{bc}
150	15.80 ± 0.28^{b}	0.97 ± 0.01^{b}	0.360 ± 0.014^{b}	0.525 ± 0.064^{b}	278.00 ± 2.83^{b}	97.90 ± 1.63^{b}	0.47 ± 0.04^{b}
Pond bottom	28.80 ± 0.57^{a}	1.48 ± 0.16^{a}	0.425 ± 0.035^{a}	2.486 ± 0.014^{a}	1309.50 ± 113.40^{a}	369.50 ± 12.02^{a}	3.38 ± 0.23^{a}

Mean±standard deviations with different superscript letters in the same column are significantly different ($p<0.05$).

3.2 Water quality at different water depths during harvesting

All water quality parameters in the three ponds sampled at different water depths during harvest draining were statistically significantly different ($p<0.05$). Results in Table 4 showed that at a depth of 100 cm from the surface BOD, TN, TP, TAN, and TSS contents in the water were lower than the control standard. However, at over 100 cm depth, the BOD, TP, and TSS contents exceeded the control standard, while the TN and TAN contents exceeded the standard at the pond bottom and at depths over 150 cm.

During the harvest period, water quality in the ponds deteriorated with increasing depth. The last 50 cm of water recorded the highest deterioration (31.80% of the final volume of water in the pond), as shown in Table 4. Using the PVC drain pipe to reduce the pond water level did not stir up the sediment at the pond bottom. When the water depth reduced to 50 cm, the water was drained using the pump head placed on the bottom of the pond. When pumping started, the sediment at the bottom of the pond was disturbed. During this period the remaining fish in the ponds were also harvested by seining.

Table 4. Water quality parameters at different water depths during pond drainage

Water depth (cm from surface)	BOD (mg/L)	TN (mg/L)	TP (mg/L)	TAN (mg/L)	TS (mg/L)	TSS (mg/L)	SS (mg/L)
Surface	8.20±0.49^{f}	0.38±0.04^{f}	0.160±0.014^{d}	0.052±0.012^{d}	191.50±2.12^{e}	65.70±0.71^{f}	0.13±0.02^{d}
50	11.10±0.42^{e}	0.83±0.04^{e}	0.205±0.007^{d}	0.088±0.011^{c}	224.50±4.95^{d}	66.80±1.06^{f}	0.17±0.02^{d}
100	12.70±0.28^{d}	1.06±0.03^{d}	0.240±0.014^{d}	0.096±0.010^{bc}	238.00±2.83^{d}	79.00±1.41^{e}	0.53±0.05^{d}
130	23.70±0.42^{c}	1.73±0.04^{c}	0.560±0.014^{c}	0.110±0.019^{b}	474.00±2.83^{c}	264.80±5.91^{d}	57.05±2.69^{c}
140	27.80±1.56^{c}	1.85±0.04^{c}	0.605±0.007^{c}	0.144±0.017^{b}	487.50±12.02^{c}	282.20±2.35^{c}	60.14±7.88^{c}
150	48.60±6.79^{b}	2.16±0.09^{b}	0.730±0.042^{b}	0.206±0.011^{b}	633.00±8.49^{b}	448.20±2.35^{b}	140.34±1.07^{b}
Pond bottom	94.10±4.81^{a}	4.89±0.16^{a}	2.130±0.099^{a}	4.150±0.410^{a}	1324.50±16.36^{a}	1027.40±12.02^{a}	403.40±1.61^{a}
Average (mg/L)	32.31±30.53	1.84±1.48	0.660±0.680	0.690±1.530	510.43±395.24	319.16±343.56	94.54±145.34

Mean±standard deviations with different superscript letters in the same column are significantly different ($p<0.05$).

3.3 Comparison of discharge quality changes in the hybrid red tilapia ponds at harvest and after settling at different times

Precipitation of the discharge from the hybrid red tilapia ponds during harvest resulted in significant differences in water quality parameters for all time periods ($p<0.05$), as shown in Table 5. Sedimentation times to meet the standard drainage controls for freshwater aquaculture ponds of BOD, TP and TSS in the water were 3 h, 1 h, and 24 h, respectively showing decreases of 37.4%, 38.5%, and 85.0%.

Table 5. Average concentrations of nutrients and solids from the last 50 cm of water left in the hybrid red tilapia ponds after sedimentation at different times compared with initial concentrations

Sedimentation time	BOD (mg/L)	TN (mg/L)	TP (mg/L)	TAN (mg/L)	TSS (mg/L)
Pumping	31.30±0.25^{a} (100%)	1.74±0.06^{a} (100%)	0.578±0.016^{a} (100%)	0.386±0.023^{a} (100%)	511.80±12.30^{a} (100%)
1 h	23.50±0.21^{b} (75.0%)	1.71±0.04^{ab} (98.0%)	0.355±0.008^{b} (61.5%)	0.292±0.013^{b} (75.6%)	258.10±9.80^{b} (50.4%)
3 h	19.60±0.29^{c} (62.6%)	1.70±0.04^{ab} (97.4%)	0.348±0.007^{bc} (60.3%)	0.286±0.005^{b} (74.0%)	194.80±12.11^{c} (38.1%)
6 h	14.70±0.23^{d} (47.0%)	1.64±0.06^{abc} (94.0%)	0.342±0.006^{bc} (59.2%)	0.281±0.004^{b} (72.7%)	123.50±8.50^{d} (24.1%)
12 h	11.40±0.11^{e} (36.5%)	1.62±0.08^{bc} (92.8%)	0.337±0.007^{bcd} (58.4%)	0.268±0.002^{bc} (69.3%)	115.70±4.60^{d} (22.6%)
24 h	9.90±0.18^{f} (31.7%)	1.60±0.06^{bcd} (91.7%)	0.335±0.011^{bcd} (57.9%)	0.267±0.004^{bc} (69.2%)	76.70±5.80^{e} (15.0%)
48 h	9.50±0.11^{f} (30.3%)	1.52±0.01^{cde} (87.4%)	0.322±0.016^{cde} (55.8%)	0.247±0.007^{cd} (64.0%)	48.40±10.20^{f} (9.5%)
72 h	6.30±0.17^{g} (20.3%)	1.49±0.03^{de} (85.6%)	0.314±0.008^{de} (54.3%)	0.236±0.010^{de} (61.1%)	22.60±6.70^{g} (%4.4)
96 h	3.90±0.30^{h} (12.6%)	1.47±0.05^{e} (84.5%)	0.303±0.015^{e} (52.4%)	0.212±0.015^{e} (54.8%)	15.00±4.70^{g} (2.9%)

Mean±standard deviations with different superscript letters in the same column are significantly different ($p<0.05$).

As shown in Table 6, average totals of BOD, TN, TP, TAN, and TSS in the full ponds were 100.08, 5.71, 2.05, 2.14, and 988.43 kg, respectively. When the final 50 cm of harvest effluent (31% of pond water volume, 985 m^3) was pumped and left to sediment for 24 h, BOD, TN, TP, TAN, and TSS reduced by 21.08, 0.14, 0.24, 0.12, and 428.57 kg or 68.37%, 8.05%, 42.04%, 30.83%, and 85.01%, respectively. This technique gave waste reduction in total pond water as 21.06% of BOD, 2.42% of TN, 11.68% of TP, 5.47% of TAN, and 43.36% of TSS.

Table 6. Average mass nutrient and total suspended solids in full ponds and reduction after settling the last 50 cm of effluent for 24 h

Exposition	BOD	TN	TP	TAN	TSS
Average concentration of waste in the pond (mg/L)	32.31	1.84	0.66	0.69	319.16
Total water volume (m^3)	3,097	3,097	3,097	3,097	3,097
Total waste in the pond (kg)	100.08	5.71	2.05	2.14	988.43
Concentration of waste during pumping the last 50 cm (mg/L)	31.30	1.74	0.58	0.39	511.80
Concentration of waste after 24 h of settling (mg/L)	9.90	1.60	0.34	0.27	76.70
Water volume of the last 50 cm of effluent (m^3)	985	985	985	985	985
Total waste in the last 50 cm of effluent (kg)	30.80	1.70	0.60	0.40	504.10
Total waste after 24 h of settling (kg)	9.75	1.58	0.33	0.26	75.55
Total waste reduction after 24 h of settling (kg)	21.08	0.14	0.24	0.12	428.57
Total waste reduction after 24 h of settling (%)	68.37	8.05	42.04	30.83	85.01
Total waste reduction in total pond water (%)	21.06	2.42	11.68	5.47	43.36

4. DISCUSSION

4.1 Water quality at different water depths before harvesting

Comparing the results to the standard for wastewater drainage from freshwater aquaculture farms (TECAC, 2008) the BOD, TN, TP, and TAN values from all depths did not exceed the control levels, while only TSS exceeded the control standard at 150 cm depth. This one parameter exceeding the control standard made the water at 150 cm unqualified for discharge. Therefore, before harvesting, the caged tilapia pond water qualified for discharge into the environment to up to 100 cm depth from the surface. Boyd (1995), Teichert-Coddington et al. (1995) and Assan et al. (2021) reported that factors contributing to feed intake directly affected the concentration of nutrients in the pond as organic and inorganic substances derived from excess food and the release of fish waste in the form of feces and urine. These substances are deposited as sediment on the bottom of the pond, causing high BOD levels (Islam, 2005). Here, total nitrogen, total phosphorus and ammonia contents on the bottom of the pond were less than recorded by Teichert-Coddington et al. (1999) who studied intensive shrimp pond cultivation. In red tilapia ponds, total nitrogen, total phosphorus and total ammonia contents were 1.480, 0.425, and 2.486 mg/L, respectively while in shrimp ponds they were 4.15, 1.67, and 2.40 mg/L, respectively. The feed given to red tilapia in this study comprised only 30% protein, while shrimp farming uses a diet containing 40 to 45% protein. Higher protein feed results in higher organic and inorganic contents, particularly at the pond bottom (Halver and Hardy, 2002).

4.2 Water quality at different water depths during harvesting

During harvest, the fish are in a small volume of water. This increases density and encourages water agitation, leading to increased suspension of solids (Coldebella et al., 2018). Therefore, harvesting causes a significant increase in all water quality parameters. TN increased by 63.21% or 0.63 times, TP increased 133.33% or 1.33 times, TAN increased by 14.58% or 0.15 times, and TSS increased by 235.19% or 2.35 times. These concentrations were higher in water near the bottom of the pond. Schwartz and Boyd (1994) reported that pond nutrient concentration was inversely related to the depth of water within the pond. Concentrations of BOD, TN, TP, TAN, TSS, and TS in the water were significantly different ($p<0.05$) at different water depths. The concentration of nutrients was highest in the last 20 cm of water, or 12.5% of pond volume. This result concurred with Munsiri et al. (1996), Teichert-Coddington et al. (1999) and Coldebella et al. (2018) who reported that concentrations of nutrients and solids in the discharge increased, with highest values in the last 5 to 20% of discharge from the pond.

Results showed that disturbance of the pond bottom by the water pump as the last process of harvesting mostly affected TSS in the water followed by TP, BOD, and TN. The bottom of the pond was a sink of accumulated sludge (Ayub et al., 1993). Phosphorus is usually accumulated at the pond bottom in the form of total phosphorus, thereby increasing BOD levels (Islam, 2005). TN level showed little increase as nitrogen in the pond evaporated into the atmosphere in the form of nitrogen and ammonia by nitrification and/or denitrification processes (Funge-Smith and Briggs, 1998).

4.3 Comparison of discharge water quality changes in hybrid red tilapia ponds at harvest and after settling for different times

Total nitrogen and total ammonia both passed the standard from the beginning of water precipitation. These results differed from Teichert-Coddington et al. (1999) who found that sedimentation time of total nitrogen and total phosphorus from shrimp ponds was about 6 h. In their experiment, water quality data were analyzed at 0, 6, 12, 24, and 48 h, while in our study the frequency of data collection was 1, 3, 6, 12, 24, 48, 72, and 96 h, giving more detailed sedimentation measurements. Sedimentation time for suspended solids in our study was 24 h, similar to Teichert-Coddington et al. (1999).

Our study results showed that sedimentation was most efficient for TSS reduction, while removal of nitrogen, BOD and phosphorus by sedimentation was less effective. Nitrogen loss in ponds occurs mainly by nitrification and denitrification processes. Most phosphorus was adsorbed by the pond bottom sediment. Sedimentation removes BOD in the short term but it may later increase because of autochthonous organic matter production in the settling ponds (Teichert-Coddington et al., 1999). Therefore, this technique is another option to reduce the waste from the lowest water levels of harvest effluent with high concentrations of BOD, TN, TP, and TSS that are generally greater than the Thailand control standard of wastewater from freshwater aquaculture farms. This technique removed 21.08 kg of BOD, 0.14 kg of TN, 0.24 kg of TP, 0.12 kg of TAN, and 428.57 kg of TSS in a 0.24 ha pond in one culture crop or 87.83 kg of BOD, 0.58 kg of TN, 1.0 kg of TP, 0.50 kg of TAN, and 1,785.71 kg of TSS in a 1 ha pond.

Numerous techniques have been applied to reduce waste from aquatic animal ponds including wetland establishment (Turcios and Papenbrock, 2014 and Marques et al., 2019), biological treatment with duckweed (*Lemna minor*) and *Bacillus* sp. (Omitoyin et al., 2017), green microalgae (*Coelastrum morum*) (Adekanmi et al., 2020), and a co-culture system (Attasat et al., 2013). Most of these methods treat all the wastewater and require time, large wastewater treatment areas and additional treatment systems to achieve satisfactory results.

The results of this study can be used as an effective discharge treatment from hybrid red tilapia ponds. Water quality in the ponds should be monitored according to depth ranges. Water depths that do not meet the standard of control for drainage from freshwater aquaculture should be settled in a sedimentation pond before release. This method reduces the size of sedimentation ponds. If it is not easy to measure water quality at depth periodically, farmers can apply the results of this study by settling water from a depth of 50 cm to the bottom of the pond for at least 24 h. The upper water can be released or recycled. This will reduce the environmental impact. Pond sediment contains high levels of organic matter, organic carbon and nitrogen as well as phosphorus and potassium. These can be used as fertilizers for many types of plants (Haque et al., 2016; Eymontt et al., 2017; Dróżdż et al., 2020) and for construction of dams, roads, embankments and landfills (Maj and Koszelnik, 2016).

5. CONCLUSION

Uncontrolled draining of fish ponds significantly impacts the environment. Drainage from the water surface to a depth of 100 cm by lowering a drainage pipe can meet the standard of wastewater drainage for freshwater aquaculture. When the water depth reaches 50 cm, a water pump is used and all water quality parameters do not meet the standard. If this water is allowed to settle for 24 hours, all parameters meet the standard. However, before finally draining the water, the quality should first be measured because different management techniques give diverse results.

ACKNOWLEDGEMENTS

The authors would like to thank Kasetsart University, Thailand for funding support and Jittiporn Farm, Pathum Thani, Thailand and the Water Quality Analysis Laboratory of the Department of Aquaculture, Faculty of Fisheries, Kasetsart University, Bangkok, Thailand for providing research facilities.

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