VERIFICATION AND REFINEMENT OF INTENSIVE SHRIMP CULTURE TECHNIQUES: THAILAND

Integrated Physical and Biological Technologies for Water Recycling in Shrimp Farms

Putth Songsangjinda
Coastal Aquaculture Research Institute
Office of Coastal Fisheries and Development Bureau
Department of Fisheries
Muang District, Songkhla 90000, Thailand

Project Site: Marine Shrimp Research and Development Center, Department of Fisheries, Songkhla, Thailand

BACKGROUND

Environment-friendly shrimp culture system has been an issue for improving shrimp farming and making it sustainable. In the past decade, Thailand adopted the open shrimp culture system, which consumed a lot of coastal and estuarine waters. The huge amount of nutrients and organic matter are dumped into the water receiving areas, resulting in eutrophication of the natural resource. A strategy developed to solve the problem was to reduce the water consumption in shrimp farms by recycling the water and re-using it for succeeding culture operations. The technologies that have been adopted for water treatment in recycling included physical, biological and chemical treatments. Since the effluent from shrimp farms is turbid, in high volume, and enriched with organic nutrients, the integration of physical and biological treatment was considered a potential treatment system that can be used extensively in recycling the effluents from shrimp farms.

The objectives of the activity are:

(1) to develop the suitable application of integrating the physical and biological treatment system in recycling the effluents from shrimp farms; and

(2) to demonstrate and transfer the successful treatment technique to the shrimp farmers.

PROJECT ACTIVITIES

Efficiency of Physical Treatment for Recycling Effluents from Shrimp Farms

Water quality management is a basic practice for the success in intensive tiger shrimp farming. Many reports indicated that heavy feeding during the grow-out period results in the accumulation of uneaten feeds and metabolic wastes in the water and in the bottom of the shrimp pond. Shrimp feed is the main source of nitrogen and phosphorus loading in shrimp ponds and is discharged to the water receiving area during water exchange. This is primarily because of eutrophication in the water body surrounding the shrimp farming area.

Thus, water treatment process for shrimp farm effluents is potentially considered as a means to reduce the impacts of intensive shrimp culture on the surrounding environment. In the past two decades, many water treatment systems were tested and demonstrated in aquaculture farms including the biological filtration in shrimp farms using bivalves and seaweed, chemical treatment trials in laboratory integrating the biological treatment for shrimp farm effluents, and the recirculating system for *P. monodon* culture using submerged biofilter.

Intensive shrimp farming consumes a lot of organic enriched feeds in order to produce the expected large production. Shrimp feed is the main source of nitrogen and phosphorus loading in shrimp ponds resulting in water deterioration during the shrimp grow-out period. Thus, water quality management should be the main concern of shrimp farmers. The open system for shrimp farming uses a lot of clean water to maintain water quality in the pond by means of toxic dilution. In the open system shrimp pond culture, about 45% of nitrogen and 26% of phosphorus are dissolved and suspended in the water column (Table 1), with a total water discharged of 194,328 m^3/ha/crop, which is 3–13% of the daily average pond volume (Muthuwan and Lin, 1996). With the open system technique, a lot of organic and nutrients are discharged to the surrounding areas.

Table 1. Nitrogen and phosphorus budget in the open shrimp farming system (Muthuwan and Lin, 1996)

Items	Nitrogen budget (kg/ha/crop)	Phosphorus budget (kg/ha/crop)
Input		
Feed	502.9 (82.4%)	165.4 (86.5%)
Inflow	84.3 (14.0%)	7.8 (4.2%)
Fertilizer	19.2 (3.2%)	17.4 (9.2%)
Rain	2.2 (0.37%)	0.14 (0.07%)
Teaseed	0.14 (0.03%)	0.21 (0.10%)
Shrimp	0.07 (0.01%)	negligible
Total	608.81 (100%)	190.95 (100%)
Output		
Shrimp	151.7 (24.7%)	17.5 (9.1%)
Discharged	275.4 (45.0%)	50.3 (26.2%)
Sediment	161.3 (26.4%)	45.5 (23.5%)
Unaccounted	20.5 (3.9%)	77.9 (41.2%)
Total	608.9 (100 %)	191.2 (100%)

The investigation on pollution loading of Songsangjinda et al. (1993) indicated that pollution loading includes total suspended solids, organic matter (indicated by BOD) and nitrogenous compound (Table 2).

Table 2. Pollution loading measured at the outflow of the drain canal as differentiated from the inflow loading of the open system shrimp farm (size of 80 ha, 94 ponds, water exchange = 2737.5 m^3/ha/d and the average daily standing stock of shrimp biomass = 2790 kg/ha). Negative value indicates the retaining or consumption in the shrimp farm (Songsangjinda et al, 1993)

Variable	Inflow (kg/ha/d)	Outflow (kg/ha/d)	Out flow Loading (kg/ha/d)
Dissolved Oxygen	18.13	13.13	-5.000
Total Ammonia Nitrogen	0.19	0.59	0.406
Total Nitrogen	1.38	1.88	0.500
Phosphate	0.03	0.03	-0.001
Total Phosphorus	0.35	0.31	-0.039
BOD_5^{20}	6.38	12.44	6.063
Total Suspended Solid	525.63	532.50	6.875

The low water exchange system is one of shrimp pond management systems that farmers used to protect themselves from the negative feedback of the deteriorated shrimp farming area, i.e., outbreak of shrimp diseases and poor water quality. In the low water exchange system, a farmer is able to reduce the consumption of water from 194,328 m^3/ha/crop to 21,084 m^3/ha/crop. In this system, most of the waste tends to accumulate in the bottom of the pond. Songsangjinda and Koolkaew (in press) reported that the nitrogen accumulated in the pond bottom was about 65% of the total Nitrogen input that mainly comes from shrimp feeds (Fig 1). This is about 2.5 times higher than the nitrogen accumulation in the shrimp pond using the open culture system.

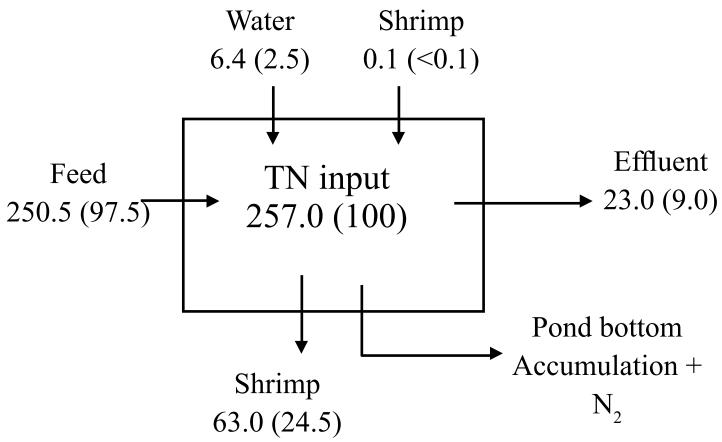

Fig 1. Illustration of the nitrogen budget from a shrimp pond using low water exchange system (Songsangjinda and Koolkaew, in press)

Although the low water exchange system is suitable for the prevention of negative effects from outside the pond, the waste accumulated in the pond often causes stress on the shrimps, which could result in infection from severe diseases. A recirculation system is therefore adopted to remove the organic wastes from the low water exchange system.

A demonstration using a large water treatment unit (WTU) for water recirculation in shrimp pond was tested in Songkhla, Thailand. The results from this demonstration showed that the average values of culture parameters (production, total feed, average daily growth, size and survival rate) of shrimps from WTU ponds were 12-15.1% better than those from the traditional ponds but did not have significant differences (Table 3). This was attributed to the seasonal variation of farm management (Songsangjinda and Koolkaew, in press).

Table 3. Comparison of the parameters of the WTU and traditional shrimp cultivation (number of pond = 6), average from 3 crops of shrimp culture

Shrimp growing parameters	Average overall 3 crops (SD)		% Improvement
	WTU ponds	Traditional ponds	
Growing period (d)	122 (14)	117 (21)	4.3
Production (kg/pond)	2456 (435)	2177 (574)	12.8
Total feed (kg/pond)	4042 (645)	3601 (810)	12.2
Weight (g)	19.8 (3.2)	17.2 (3.0)	15.1
Average daily growth (g/d)	0.17 (0.04)	0.15 (0.02)	13.3
Food Conversion Ratio	1.65 (0.11)	1.68 (0.24)	-1.8
Survival rate (%)	65 (10.6)	58 (12.4)	12.0

Water qualities and removal efficiency in a small-scale recycle shrimp pond using an integrated physical and biological technology

Shrimp farmers now aim not only for disease-free shrimps with high growth rate and high yield, but also resource conservation. By minimizing and avoiding altogether the discharge of organic matters and nutrients from the grow-out into the natural waters, the adverse environmental impacts often associated with intensive shrimp farming, is completely avoided. This can be achieved through a closed culture system where wastewater is treated and returned to the growing ponds.

For this system, a model shrimp farm in Thailand consists of a 2.0 rai (35x90 m^2) grow-out pond and a 0.5 rai (30x27 m^2) treatment pond. A third pond is required to serve as reservoir for new water during the initial filling as well as to compensate for losses due to evaporation and possible seepage. This system served as basis for the development of the closed culture system technology.

The grow-out pond and the treatment pond are connected in order to allow the water to circulate from one pond to the other as shown in Fig 2.

Fig 2. The recirculation shrimp culture using the integrated physical and biological technology demonstration in Marine Shrimp Research and Development Center

A filter box with a capacity of 0.7-1.0 ton is installed in the treatment pond (Fig 3). The filter box is perforated at the sides and bottom and filled with bags containing sand, shells or pieces of broken coral. The inlet of the water supply pump is set in the middle of the bags of filter media. During operation, the treated water is pumped through the filtered tray into the grow-out pond when refilling of water is required. The treatment pond should be efficient so that the sediment reduction and water quality improvement should be at least 20-50% better than that of an untreated pond.

Fig 3. Sand filter box as a physical filtration in the treatment pond

Water Quality

Low oxygen level:

- In case oxygen concentration is lower than 3.5 ppm, the number of paddle wheel aerators or the working duration of the aerators must be immediately increased.
- In case oxygen concentration is lower than 2.0 ppm, feeding must be stopped until the oxygen concentration is raised to more than 2.8 ppm.

pH and alkalinity:

- In case the pH and alkalinity are lower than the optimal level, carbonated lime must be added into the pond at 4 kg/rai (25 kg/ha) daily until the pH is raised to the desired range.
- If the pH and alkalinity in the pond are higher than the optimal level, stop the application of lime and water exchange.

Transparency:

- If the transparency is lower than 25 cm, the rate of water exchange should be increased to a level higher than in normal conditions.
- If the transparency is higher than 40 cm and the phosphate level is low, 0-46-0 formulated fertilizer should be added at 1.0 kg/rai (6.25 kg/ha).

Ammonia and nitrite:

- In case ammonia and nitrite concentrations are too high, the farmer must increase the efficiency and accuracy of the feed quantity estimate, increase the oxygen to more than 4 mg/1 to accelerate treatment process, and consider a decrease in the feeding quantity by 10 to 40% as needed.

Biological oxygen demand (BOD):

- In case the oxygen concentration is too high, paddle wheel aeration must be increased and that the oxygen concentration must not be lower than 3.5 ppm.
- In case the oxygen demand is too high, the efficiency and accurateness of the feeding quantity estimation and the aeration must be increased, while the feeding quantity should be considerably reduced by 10-40% as necessary.

Bacteria and Vibrio *spp.*:

- In case the total bacteria and *Vibrio* spp. is too high, consider decreasing the feeding rate and increasing the water exchange rate, as necessary.
- In case other related problems occur, immediate action must be taken and continued until the problem is solved. Chemical should not be used, especially those with strong action and with long lasting residue. When problems are encountered, one must consider increasing the oxygen and changing the water as necessary.

Water quality in the treatment pond:

- In case oxygen is lower than 3.5 ppm, aeration should be considerably increased through the operation of aerators.
- In case of low pH or low alkalinity, lime should be added to increase the alkalinity of the water.
- In case sand bags are clogged, these must be changed and cleaned. During the cleaning of the sand bags, recirculate the water into the treatment pond.
- When the efficiency of ammonia removal is decreased, increase the oxygen concentration in the grow-out pond.

- In case the concentration of the total bacteria and *Vibrio* spp. is too high, increase the aeration in the treatment pond should be increased and sand bags should be changed as necessary.
- When the treatment pond is highly loaded and the oxygen concentration is low, aeration should be increased.
- If mortality of the fish or seaweeds occurs, increase the water circulation. If the water quality in the grow-out pond is in the optimal range or no problem has been encountered, stop adding water from the treatment pond into the grow-out pond. When the problem is solved, additional fishes or seaweeds should be restocked at the required amount.

The water quality in grow-out pond varied depending on the day of culture. The pH of water should be slightly decreased from about 9.0 at the beginning to the level of 7.8 at the day of harvest. The levels of DO at 0900 AM should vary between 4.3 to 8.4 mg/l all throughout the grow-out period. Transparency in the grow-out pond stabilizes when the water recycle program starts after the first month of shrimp culture. Ammonia level varies in a stable range between 0.1-1 mg/l, while nitrite showing accumulation should range from 0.6 to 1.0 mg/l after the second month of culture period, which probably indicates a slow process of transforming nitrite to nitrate. The BOD fluctuates in a stable range of 9 to 16 mg/l from the period two weeks after the water recycling until harvest. Results of the water recycling experiments indicated that the water quality in a small-scale shrimp pond stabilizes after water recycling is performed (Fig 4).

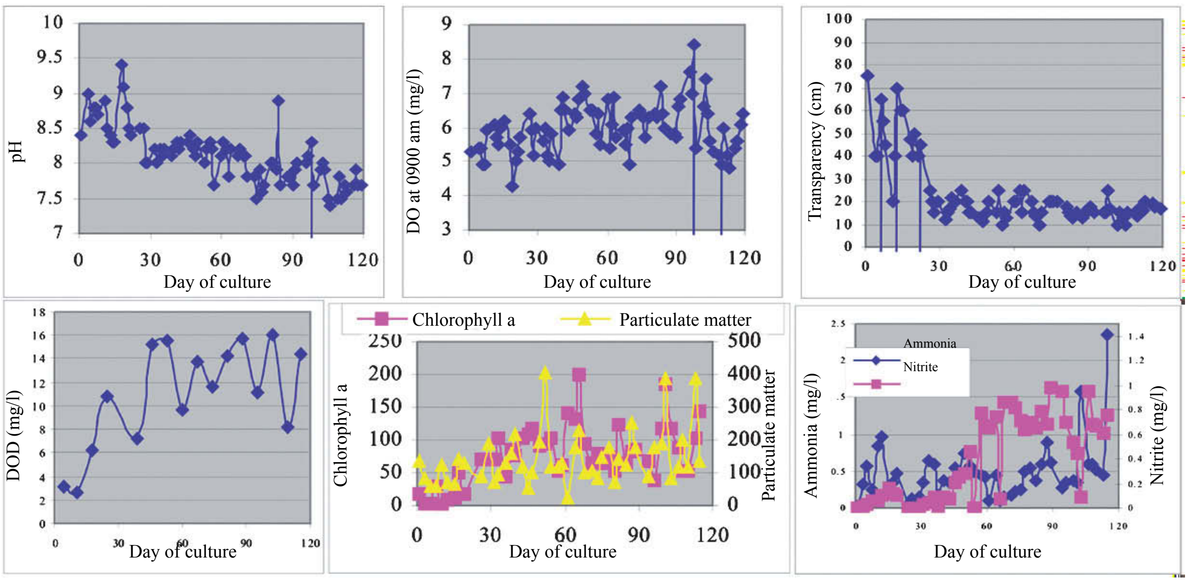

Fig 4. **Water quality parameters in a small-scale shrimp pond with water recycling using integrated biological and physical technology**

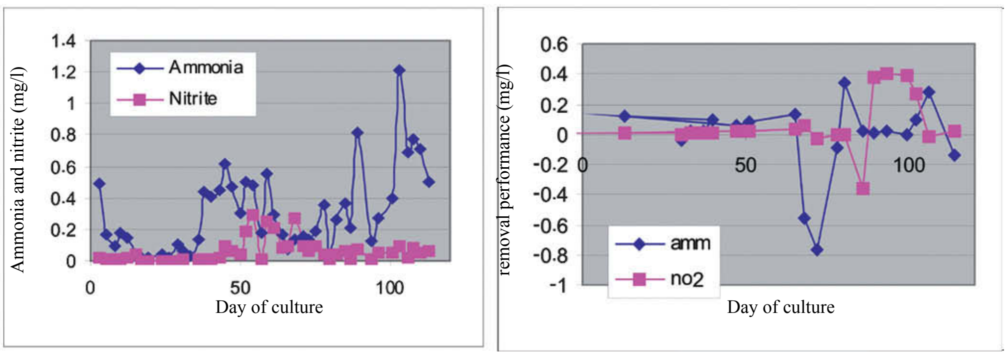

Fig 5. **Ammonia and nitrite variation in the treatment pond (left) and the removal performance of ammonia and nitrite in the treatment pond (right)**

The water qualities in the grow-out and treatment ponds are shown in the Table 4. Results indicated that ammonia and nitrite in water had a lower average concentration after being kept in the treatment pond compared to the average concentration in the grow-out pond. The removal performance of ammonia and nitrite by the treatment pond (Fig 5) varied from about 0.4 to –0.8 mg/l (negative value indicates the release from treatment to the grow-out pond).

Table 4. The minimum, maximum, and average concentration of water quality investigated in the grow-out and treatment ponds

Water quality variables	Growing pond			Treatment pond		
	min	max	average	min	max	average
pH	7.4	9.4	8.1	7.4	8.4	8.0
DO at 0900 am (mg/l)	4.3	8.4	6.0	3.5	8.1	6.0
Transparency (cm)	10	75	23	10	30	17
Ammonia (mg/l)	0.03	2.35	0.47	0.02	1.21	0.31
Nitrite (mg/l)	0.00	0.97	0.40	0.00	0.29	0.06
Nitrate (mg/l)	0.00	0.62	0.09	0.01	0.41	0.13
TDN(mg/l)	0.94	4.38	2.08	0.24	6.74	2.45
PO4-P(mg/l)	0.00	0.05	0.02	0.00	0.10	0.03
TDP(mg/l)	0.03	0.15	0.08	0.03	0.12	0.06
Chlorophyll (µg/l)	1.2	200.9	77.2	4.4	164.0	60.7
Particulate matter (mg/l)	23	403	144	45	311	151
BOD (mg/l)	2.61	16.1	11.0	3.9	16.5	9.6

Evaluation of the efficiency of oyster (*Crassostrea lugubris*), green mussel (*Perna viridis*) and seaweed (*Gracillaria fisheri*) on improvement of the quality of effluents from shrimp ponds

This study was designed to understand the efficiency of aquatic organisms used in a biological treatment unit, i.e., oyster (*Crassostrea lugubris*), mussel (*Perna viridis*) and seaweeds (*Gracillaria fisheri*), on water quality improvement. A study was carried out using an outdoor experimental tank equipped with water recirculation trays (control and experimental trays), which were floated at the water surface of the tank. The evaluation of the improvement efficiency was conducted under the continuous flow through system (Fig 6.).

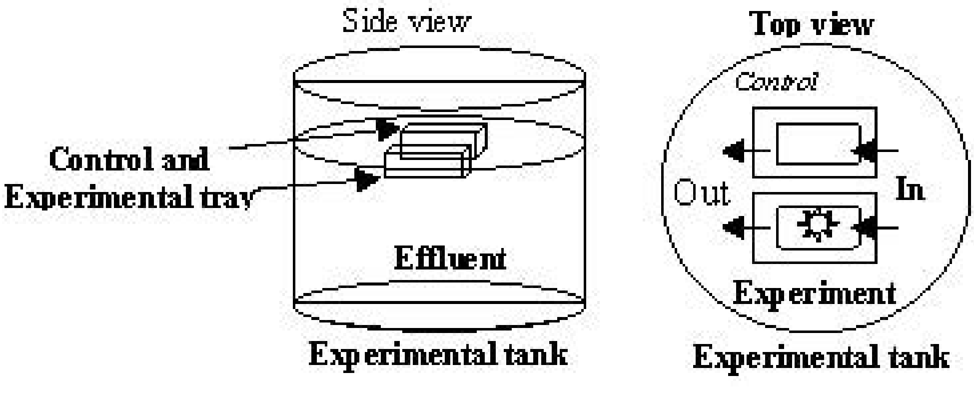

Fig 6. The experimental tank used for the evaluation on the efficiency of quality improvement of shrimp farm effluents by oyster *(Crassostrea lugubris)*, green mussel (*Perna viridis*) and seaweed *(Gracillaria fisheri)*

During the experiment, the effluents from shrimp farms were pumped into the tanks where the experimental trays were set (Fig. 6). Airlift siphon was used to circulate the effluent water between the trays and the experimental tank. The flow rate of the water through the experimental and control trays was adjusted to be constant at the same flow rate.

The water quality parameters, i.e., nitrogenous and phosphorus compounds, particulate organic nitrogen (PON), particulate organic carbon (POC), and particulate organic phosphorus (PP), BOD, particulate matters (PM), and chlorophyll *a* were measured from the inlet and outlet of the trays.

Total ammonia nitrogen (TAN) was analyzed according to the Modified Indophenol (Sasaki and Sawada, 1980). Nitrite-Nitrogen (NO_2^-) was analyzed using the Diazotization (Bendschneider and Robinson, 1952). Nitrate-Nitrogen (NO_3^-) was analyzed using cadmium reduction column (APHA, 1980) and the Diazotization method as mentioned above. Total Dissolved Nitrogen (TDN) was analyzed according to the persulphate digestion (Koroleff, 1983). The PON and POC were analyzed using CN analyzer (LECO CHN900). The calculation of the PON was made by subtracting the TAN components, while the TAN was the sum of the nitrogen compounds analyzed in the same water sample.

Biochemical oxygen demand (BOD) was analyzed according to APHA (1985). Dissolved organic phosphorus (DIP), and total dissolved phosphorus were analyzed according to the methods described in Strickland and Parsons (1972) and Koroleff (1983). Particulate phosphorus (PP) was analyzed using microwave digestion (GEM model MAR5) for 10 min at the pressure of 120 PSI in the solution of which the Nitric: Perchloric acid ratio was about 0.3: 0.9 ml. The phosphorus content in digested samples was analyzed using the DIP mentioned above. Particulate matter was determined according to the dry weight difference of the unfiltered and filtered paper. Chlorophyll *a* was analyzed by the acetone extraction according to the method in Strickland and Parsons (1972).

The efficiency of effluent quality improvement (unit per g dry weight per hour) was calculated based on the difference of water quality parameters between inlet and outlet of the control and experimental trays as shown in the following equation.

$$\text{Efficicien cy(mg/gdw/ h)} = \frac{\left(\frac{\text{Concentrat ion inflow} - \text{outflow}}{\text{Flow rate}}\right)\text{Exp} - \left(\frac{\text{Concentrat ion inflow} - \text{outflow}}{\text{Flow rate}}\right)\text{Con}}{\text{Organism Weight (dry weight)}}$$

The positive result from the equation indicates the efficiency of the organism on the quality improvement of the effluent water. The negative result indicates the inefficiency of the organism. The average efficiency on effluent quality improvement is shown in Table 5 for oysters, Table 6 for mussels and Table 7 for seaweeds.

Results from this experiment showed that mussel has the best efficiency among the experimented organisms. The average efficiencies were 50.14 mg/gDW/h, 0.190 mgN/gDW/h, 0.507 mgC/ gDW/h, 0.009 mgP/gDW/h and 26 µg/gDW/h in the improvement of PM, PON, POC, PP and phytoplankton in terms of chlorophyll *a,* respectively. These efficiencies were 2-57 folds higher than the efficiencies of effluent improvement by the oysters.

On the other hand, the use of mussels could produce metabolic waste (Total ammonia: TAN) and dissolved inorganic phosphorus (DIP) at the average rates of -0.036 mgN/gDW/hand -0.002 mgP/gDW/h, respectively, which was 3-17 folds higher than those produced by the oysters.

Table 5. Average and standard deviation of the efficiency on quality improvement of the effluent from shrimp farm using oyster (*Crassostrea lugubris*) (n=10)

	Water quality variables	Efficiency on quality improvement (mg/g dry wt/h)			
		Average	(SD)	Imrpovement	
				Positive	Negative
Dissolved inorganic nutrients	Total ammonia nitrogen (TAN)	-0.002	(0.007)		⊗
	Nitrite (NO_2^-)	0.000	(0.001)	⊗	
	Nitrate (NO_3^-)	0.003	(0.007)	⊗	
	Dissolved inorganic phosphorus (DIP)	-0.0005	(0.002)		⊗
Dissolved organic nutrients	Dissolved organic nitrogen (DON)	-0.164	(0.297)		⊗
	Dissolved organic phosphorus (DOP)	-0.004	(0.023)		⊗
	Biochemical Oxygen Demand BOD (20 C, 5 days)	-0.739 0.057	(1.508) (0.245)	⊗	
Suspended matters	Particulate organic nitrogen (PON)	0.004	(0.026)	⊗	
	Particulate Phosphorus (PP)	0.084	(0.413)	⊗	
	Particulate organic carbon (POC)	1.585	(6.426)	⊗	
	Particulate matter (PM)	0.46	(0.96)	⊗	
	Chlorophyll *a* (Chl.*a*)				

[1] unit of chlorophyll a improvement = µg/g dry wt/h

Table 6. Average and standard deviation of the efficiency on quality improvement of the effluent from shrimp farm using mussel (*Perna viridis*) (n=10)

	Water quality variables	Efficiency on quality improvement (mg/g dry wt/h)			
		Average	(SD)	Imrpovement	
				Positive	Negative
Dissolved inorganic nutrients	Total ammonia nitrogen (TAN)	-0.036	(0.079)		⊗
	Nitrite (NO_2^-)	0.001	(0.005)	⊗	
	Nitrate (NO_3^-)	0.029	(0.033)	⊗	
	Dissolved inorganic phosphorus (DIP)	-0.002	(0.010)		⊗
Dissolved organic nutrients	Dissolved organic nitrogen (DON)	-1.124	(2.426)		⊗
	Dissolved organic phosphorus (DOP)	-0.013	(0.084)		⊗
	Biochemical Oxygen Demand BOD (20 C, 5 days)	-1.769	(8.565)		⊗
Suspended matters	Particulate organic nitrogen (PON)	0.190	(0.397)	⊗	
	Particulate Phosphorus (PP)	0.009	(0.051)	⊗	
	Particulate organic carbon (POC)	0.507	(0.995)	⊗	
	Particulate matter (PM)	50.14	(156.0)	⊗	
	Chlorophyll *a* (Chl.*a*)	26.00	(84.92)		

[1] unit of chlorophyll a improvement = µg/g dry wt/h

In addition, the seaweeds showed a low efficiency on the improvement of TAN and DIP and slight sedimentation effect of the particulate matters. The results of this study indicated that the biological treatment unit probably had some limitation in applying to all water treatment requirements. The use of bivalves could improve the effluent water on the suspended matter especially particulate organic matter but the fecal pellet produced by bivalves accumulates and be decomposed thus, deteriorating the water quality in water treatment system. Seaweeds have the potential ability to absorb nutrients.

However, both organisms have low efficiency on the decomposed and transformation of organic matter. Thus, a new technique for the integration of a biological filter (Trickling Filter) is introduced, which have an advantage for the removal of organic wastes and dissolved nutrients in the water.

Table 7. Average and standard deviation of the efficiency on quality improvement of the effluent from shrimp farm using seaweeds (*Gracilaria fisheri*) (n=10)

	Water quality variables	Efficiency on quality improvement (mg/g dry wt/h)			
		Average	(SD)	Imrpovement	
				Positive	Negative
Dissolved inorganic nutrients	Total ammonia nitrogen (TAN)	0.007	(0.026)	⊗	
	Nitrite (NO_2^-)	-0.008	(0.011)		⊗
	Nitrate (NO_3^-)	0.004	(0.008)	⊗	
	Dissolved inorganic phosphorus (DIP)	0.0008	(0.001)	⊗	
Dissolved organic nutrients	Dissolved organic nitrogen (DON)	0.083	(1.216)	⊗	
	Dissolved organic phosphorus (DOP)	0.005	(0.026)	⊗	
	Biochemical Oxygen Demand BOD (20 C, 5 days)	-0.122	(0.622)		⊗
Suspended matters	Particulate organic nitrogen (PON)	0.023	(0.109)	⊗	
	Particulate Phosphorus (PP)	0.002	(0.010)	⊗	
	Particulate organic carbon (POC)	0.060	(0.225)	⊗	
	Particulate matter (PM)	0.361	(3.506)	⊗	
	Chlorophyll *a* (Chl.*a*)	0.396	(2.934)	⊗	

[1] unit of chlorophyll a improvement = mg/g dry wt/h

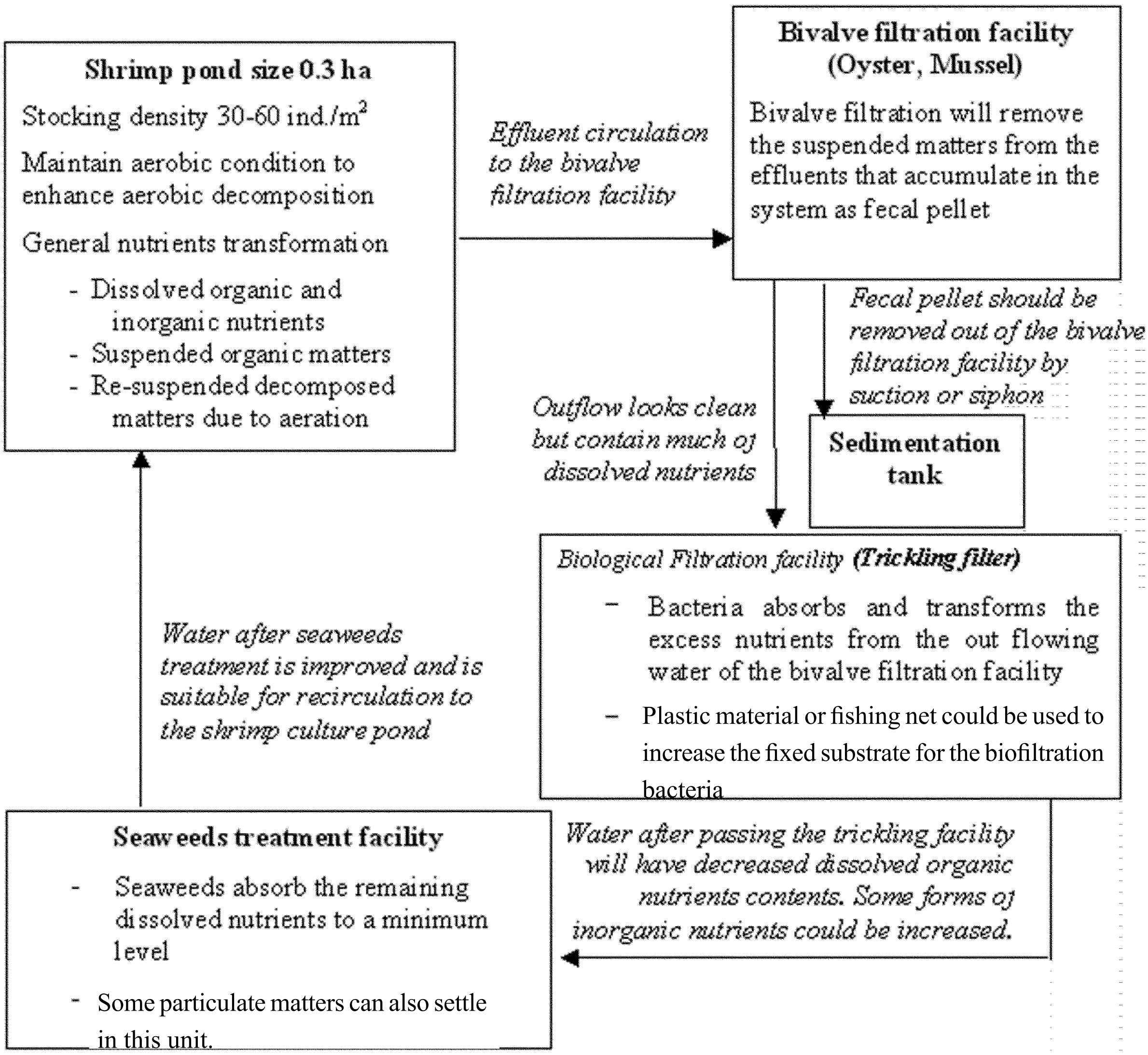

Fig. 7. Conceptual illustration of trickling filter using bivalves and seaweeds for water treatment of effluents from marine shrimp culture for water recycling

Thus, the integration of bivalves, trickling filter and seaweeds to the recirculation facility for shrimp farm effluent treatment, has been introduced. Here, the fluent is introduced to the bivalve (mussel or oyster) facility allowing the bivalves to filter the particulate matter. The fecal pellet should be removed frequently to prevent the deterioration of the environment of the bivalve compartments from the regenerated nutrients and organic matter. The dissolved organic and inorganic nutrients are filtered in the trickling by the microorganisms (including nitrifying bacteria). Since the inorganic nutrients in the water are absorbed by the seaweeds, the water can be recirculated to the shrimp pond (Fig 7).

Using this activity as a model, Thailand has developed a program for Thai Quality Shrimp following the "Code of Conduct for Responsible Shrimp Aquaculture". Known as "Code of Conduct" or "CoC", this program is aimed at producing shrimps meeting the three major standards and international concerns, such as:

1) The standard of shrimp culture practice should be guided by the CoC manual on shrimp/ hatchery management
2) The shrimp products should meet the international standard of quality shrimp (residual and contamination concerns)
3) The shrimp farms should practice the environmental-friendly manner.

Based on this program, the conceptual guidelines have been introduced to the shrimp farmers as follows:

1. Site selection: The farm's productivity must be increase while wastewater and environmental impacts must be minimized.
2. General management of the shrimp farms: The farms productivity must be increased while wastewater and all other environmental impacts must be minimized.
3. Stocking density: Good quality post larvae are released with consideration of suitable density specific for culture technique and pond capacity by checking the survival rate and shrimp size at harvest.
4. Food and Feeding: Good Management Practices (GMPs) for food and feeding are implemented to minimize excess feeds and decomposition at pond bottom, and water consumption.
5. Shrimp health management: GMPs in shrimp farming are used to reduce shrimp stress. Facilities for disease examination and protection must be provided.
6. Chemicals and therapeutic agents: Chemicals and therapeutic agents must be applied as necessary and in accordance with manufacturers' instructions.
7. Wastewater, solid wastes and farm hygiene: Farmers must properly manage effluents, solid wastes and farm hygiene in accordance with the GMPs to minimize contamination and environmental impacts.
8. Social responsibility: Farmers must communicate and contribute assistance to local communities to show their responsibility.
9. Group and training: Farmers must belong to a group or association to facilitate exchange of knowledge on shrimp culture development.
10. Data collection: Data on farm operation must be recorded for review purposes, improving shrimp culture techniques and for the auditing processes.

In this program, the concept of Integrated Physical and Biological Technology for the Mangrove-Friendly Shrimp Culture Project provides an application to make shrimp farming practices meet the standards of environment friendly. The CoC guidelines suggest that farmers should manage the model effluents to minimize environmental impacts. The demonstration model farm used to verify this technique was established at the farms of the Department of Fisheries at the Marine Shrimp Research and Development Center, Pawong, Songkhla, Thailand. The illustration of the environmental friendly farm is shown in the following project plan:

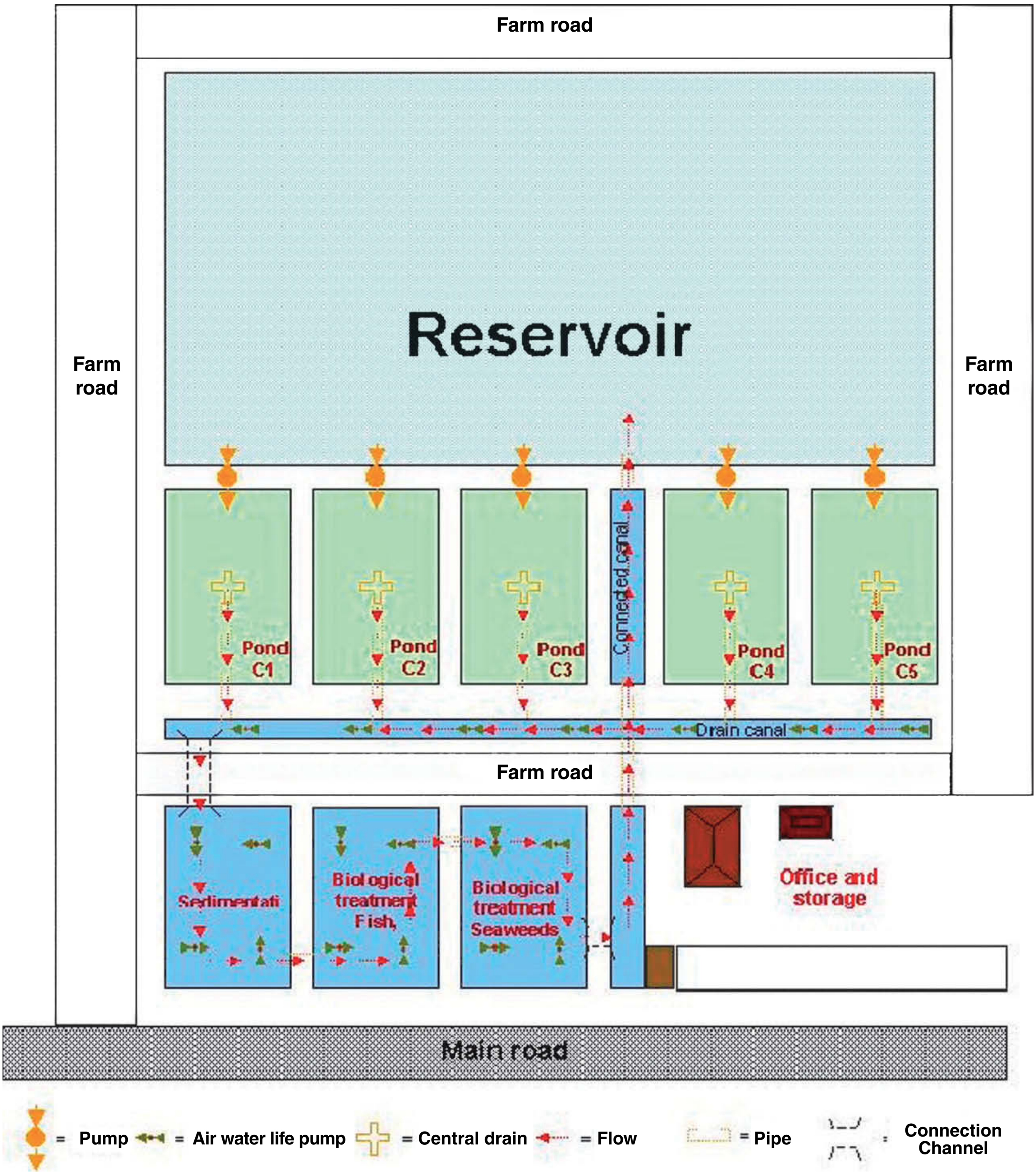

Fig 8. **Conceptual illustration of environment-friendly shrimp farming using the integrated physical and biological technology as effluent treatment system with treated water recirculated through the reservoir.**

The environment friendly shrimp farm (below):

The pond aeration system and circulation system in drain canal (above).

Effluent treatment system applied with the concept of integrated physical and biological technology, which is a series of sedimentation, fish and bivalve and seaweed treatment pond, respectively.

The general practices of this demonstration model farm are as follows:

1) Pond bottom is rehabilitated by enhancing organic decomposition directly at the bottom for about 1.5-2.0 months prior to stocking
2) Pond water preparation is made not more than 15 days prior to stocking
3) Larvae of *Penaeus monodon* (PL> 15) is stocked at density 50 ind/m^2
4) The PL is selected from CoC certified hatcheries for the best quality of PL
5) Best quality of feed and good feed management is used for good growth and good feed conversion ratio (FCR) to minimize degradation of the pond bottom and water
6) Aerobic condition is maintained by high DO (diurnal minimum > 4 mg/l) using paddlewheel and bottom aeration (air diffusion) for water and surface sediment of shrimp pond to enhance the aerobic decomposition of the remaining feed, feces and metabolic wastes
7) Sludge and sediments in the shrimp pond are disturbed by pulling a chain over the pond bottom, to break down/release the accumulated toxic metabolite and enhance oxygen transfer at the pond bottom
8) Water exchange is managed to be minimum in order to reduce the volume of effluents
9) Effluents are drained to the effluent treatment ponds to improve the water quality during the grow-out period through airlift pump circulation, for recycling to the reservoir for the next water exchange

BIBLIOGRAPHY

Enander M. and Hasselstrom M. 1994. An experimental wastewater treatment system for a shrimp farm. INFOFISH International, **4**: 56-61.

MaCintosh D.J. and Phillips M.J. 1992. Environmental issues in shrimp farming. In: *H. de Saram and T.Singh (ed).* Shrimp'92, INFOFISH and EUROFISH, Hong Kong. p 118-145.

Muthuwan V. and Lin C.K. 1996. Water quality and nutrient budget in intensive marine shrimp culture ponds. Technical paper 71, Inst. Mar. Sci., Burapa University, 28 p.

Rijin. J.V. 1996. The potential for integrated biological treatment systems in recirculating fish culture; A review. Aquaculture **139** :181-201.

Songsangjinda, P. and Koolkaew K. 2001. Effect of using water treatment unit on the production and nitrogen budget in the tiger shrimp, *Penaeus monodon* cultivation. In: *Proceeding of "70th Anniversary of The Japanese Society of Fisheries Science: International Commemorative Symposium*", Held in Oct.1-5, 2001. Yokohama, Japan. (in press).

Songsangjinda P., Tookwinas, S., Intramontreee, C. and La-ongsiriwong, L. 2000. Treatment of the water from close-recycled marine shrimp pond using oxidation pond and sand filtration. Technical report 2/2000. Marine Shrimp Research and Development Center, Department of Fisheries. 12 p.

Songsangjinda P and Tunvilai D.1993. Pollution loading from an intensive tiger shrimp farm. Technical report 15/1993. National Institute of Coastal Aquaculture, Department of Fisheries. 14 p.

Tookwinas S. 2000 Closed-recirculating shrimp farming system. State of the Art Series November 2000, SEAFDEC and Association of Southeast Asia Nation, Philippines 27 p.

Tookwinas S. and Neumhom, P. 1995. Experimental on coagulation of intensive marine shrimp farm effluent. In: *Wuthisiu P. and Otawa N. ed. International seminar on marine fisheries environment.* Held in March 1995, Rayong, Thailand. The Cosmic Pub. Com. Ltd. Bangkok Thailand p19-24.

Tseng K-F., Su H-M., Su M-S. 1998. Culture of *Penaeus monodon* in a recirculation system. *Aquaculture Engineering;* **17**: 138-147.