Aquaculture development toward the sustainable and environmental management in Thailand

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Abstract

Aquaculture plays an important role in Thailand with a very high portion of total export products and national income. In the last two decades, the technology of intensive farming has expanded significantly with freshwater and marine farming. At present the marine shrimp farming area is approximately 70,000 ha. along the coastal area and also some inland area. The environmental problems faced by the intensive farming are a major constraint to its future growth. This paper review the pollution created by the freshwater aquaculture and also cage culture with their effluent management. Preventive measures through proper healthy environment and food security, government regulation and policies are described.

Current Situation of Aquaculture in the National Economy

A Brief Historical Development of Aquaculture

It is believed that aquaculture in Thailand has been practiced in Thailand for about 300 years, i.e., the historical record on the Thai carp specie culture in Ayudhaya Royal Palace . Looking back to the evolution of the aquaculture in Thailand in just the past two decades would show that it has gone through several changes or reforms that have been closely interacted with both socioeconomic and technical development. Aquaculture development has been through three stages, first served to fulfill the domestic food demand as the basic purpose of a primary industry and to stabilize social security by ensuring employment in rural areas. With the development of technical and the government support under the policy on agricultural sectors and rural development, aquaculture then gradually played an important role in producing commodities for export. The third stage of aquaculture development presently is in a transition stage to adjust itself to be more harmony with the natural environment and more consistent with socio-economic development. The present trend in technical development has been to go toward the improvement of the culture environment by using technological development and preventative measures, such as farm management technology and effluent management.

Aquaculture plays an important role in the national economy, foreign exchange earning, food production and employment for the rural population. Inland and coastal aquaculture makes a significant contribution .In 2003, total aquaculture production reached 703,300 tones for coastal aquaculture and 361,125 tones for freshwater aquaculture.

Aquaculture Structure and Production

Fisheries production of Thailand in 2003 totally was 3,914,073 ton, of which 27.2 % was come from aquaculture. Freshwater aquaculture production was 9.2 %, and 18.0 % from the coastal aquaculture. Production from inland fisheries was 198,447 ton, which were striped snake-head fish 12.1 %, common silver barb 19.6%, walking catfish 7.o%. Shrimp production from marine capture was only 3.2 % of total fisheries capture production 2,651,223 tons.

Freshwater Culture

Total yield from freshwater culture was 89.8 thousand tons in 1986 and gradually increased to be 361.1 thousand tones in 2003. Tilapia production was the highest (123.6 thousand tons or 34.2% of total freshwater culture production) followed by catfish (*Clarias* specie) (115.4 thousand tons or 31.9%),prawn (28.5 thousand tons or 7.89%) and carp *Puntius gonionotus* (88 thousand tons or 24.3%). Those species with yield about 10% of total freshwater culture yield were striped snakehead, catfish (*Pungasius*) , and snake headed fish (*Channa striat*a)

The ratio of the export value for the freshwater aquaculture are; nile tilapia 69.9 %, hybrid thai red tilapia 16.7%, and carp 6.7 %. The export volume in 2003 are 15,773 tons, 28.5 million US$. The giant freshwater prawn(*Macrobrachium rosenbergii*) is also one export commodity with a high inclination in the world market. In 2004, Thailand has exported this prawn up to 3,942.6 ton with the US$ 20.1 million, which is increased in high production.

Coastal Aquaculture.

Total yield volume from coastal aquaculture was 61.9 thousand tons in 2003, a slightly increase compare with that in 2000. Of this, 58 % were yield from prawn culture, and 2.4 % from fish culture. The rate of increase was highest for white shrimp culture. Production from tiger shrimp culture had been decreasing through the year.

By species, the largest share in coastal culture yield volume was shellfish culture, green mussel (11.8 %) followed by oyster and blood clam . Yield from shrimp culture was 47.0 % of the total production. The rate of increase was now greatest for white shrimp (*Litopeneaus vannamei*) , followed by sea bass*(Lates calcarife*r) and grouper .

Shrimp production area in Thailand , with a total production area of 75,000 ha and 30,800 farmers and production of 330,000 tons in 2003,, recent statistics show that 37 % percent of shrimp farmers are small operators utilizing a farming area less than 0.8 %, and 11% an area more than 4.8 ha.(National Statistical Office, 2000). In the last 5 years, some farmers in the Inner Gulf of Thailand moved to culture marine shrimp in inner inland area, culture by low water salinities and the zero discharge technique. The Royal Thai Government, through the Ministry of Science, Technology and Environment has banned such practice by enacting The Environment Act 1992. This is due to aware of salinities intrusion in rice field, agricultural area and underground freshwater.

The growth of shrimp production from culture system has increased the national income, but at the same time it has an impact on public areas and the environment. This can be summarized as follow;

1) Impact of Mangroves. A satellite image (Landsat band 4 and 5) from 1992 shows that actually only 11.31 percent of the mangroves has been

removed for marine shrimp farming Effect on coastal environment and resources, through the organic waste, chemical and silt sediments.

2) Chemical and drugs. Such as antibiotic, pesticides, etc. lead to rejection of the products in the export markets.

4) Salinity intrusion to the freshwater area or agricultural areas.

Government Organization and Support Services for Aquaculture

In order to sustain the food industry (including farmer through processing plant) and to maintain consumer confidence in product safety, Year 2004 has been declared as the "Food Safety Year" by the Thai Government. The general aims are to apply standard practices to all sectors of the value chain from primary production to the market place and apply a single standard for products whether destined for domestic or oversea markets.

The main key issues in Code of conduct for responsible aquaculture and related business is food safety are as follow:

1) The culture site would be out of conservation area

2) Aquaculture farming would be conducted using environmental friendly culture technology

3) The product would be free from chemical drug to meet international standards.

4) The effluents need to be treated to comply with the regulation before being discharged out.

5) Farm sanitation would meet the standard while farm operation should be friendly to the nearby community's other activities.

6) The farm should record for every activity needed to be done in order to be granted a farm certification.

Principles in environmental policy on the aquaculture practices

Leading principles are " precautionary principles" and " producing more out of less". Consequences are the application of best available technology concerning pollution and the use of resources. In a longer perspective this will have the following consequences for fish farming:

- Suitable farming site , appropriate farm design and better farm management would be primary factors for success in the intensive aquaculture production.
- No discharge of toxicants and antibiotics
- The discharge of nutrients and other non-accumulating matter has to be as low as possible by application of best available technology
- The small discharge that have to take place anyway must be sited to such recipients where they cannot pollution effects of any significances

Environmental goals for the fish farming management

- Prevent that the growing of the fish farm industry cause new or contribute to existing eutrophication problems
- The discharge of micro-pollutants must be reduced to a levels on which only non significant and reversible effects can be observed.
- Stop of any sedimentation from the aquaculture discharge in a natural bodies
- The release of antibiotics be limited so much that no residues can be traced in wild fish, shellfish and sediments. The risk for resistance in bacteria must be significantly reduced.

- All slaughter wastes and dead fish must be handled without causing a risk for pollution or infection.

The effluent water quality standards and the system of wastes treatment are required with the reasonable cost of investment and realistic for compliance.

LEGAL FRAMEWORK

Marine shrimp farm along the coastal area of Thailand play an importance role in the national income and provide employment. The Department of Fisheries has developed very strong policies to promote shrimp farming as a sustainable profession. Their plans and policies can be summarized as follows:

1. Marine shrimp farming area across the country would not exceed 76,000 ha.
2. Regulations for shrimp farming in Thailand announced by the Department of Fisheries in November 1991 Under Fisheries Act 1947 are
   - Shrimp farmers are to be registered with the Department of Fisheries at the district offices
   - Shrimp farm over 8 ha. are to be equip with wastewater treatment or sedimentation ponds not covering less than 10 % of the pond area
   - Water released from the shrimp pond area are to contain a BOD not exceeding 20 mg./L
   - Saltwater is not to be pumped into public freshwater resources or other pumped into public areas
   - Sludge or bottom mud sediment are to be kept in suitable areas and not to discharge to natural water body.

Action Plan on Food Safety

The Department of Fisheries has adopted an Action Plan on Food Safety from Farm to table to ensure that the aquaculture productions are safe and comply with international standards. In addition to that, procedures have been improved in all sectors of the food supply chain. The implementation of GAPs for marine shrimp certification has been done in Thailand since late 2002, and followed by the GAP for giant freshwater prawn certification in 2003. By the year 2005, the government has moved forward to implement GAPs for all aquatic animals farm and hatchery in which both inland and brackish water aquaculture. The steps of work are following farm registration, training and farm improvement. Then, farm auditing by DOF agencies would be done for GAPs certification. At present, about 20,000 marine shrimp and giant freshwater farmers have been certified under GAPs criteria.

The certification for production process starts from the upstream level such as hatcheries, grow out farm, chemical and control, feed factory and feed quality control, monitoring on drug residues and water qualities around the cultivation area. The midstream and downstream level include Standard of Sanitation and Post Harvest Handling and Transportation, and Standard of Cold storage and Packing house. Furthermore, The Department of Fisheries has developed the traceability system to trace back to the origin of aquaculture products and adopted the Quality Mark for Fishery Commodity and Food Standards (Q mark) to assure that Thai aquacultures, especially for shrimp and fishery products are always at international standard. The Ministry of Agriculture and cooperatives declared for the Quality Mark for Agricultural Commodity and Food Standards (Q Mark).

II Technological Development for fish Farm management and Production of Safe Aquaculture Foods

Today, aquaculture has to face increasingly tight restrictions over development in many areas, as concern over environmental impact and competition for resource grows. Aquaculture waste that discharged to receiving water has a determination impact to environment. Thus, aquaculture activity could have focusing attention on development of technologies for improve of effluent quality and pollution loading.

In most case, a significant fraction of the biological oxygen demand (BOD) and organic nitrogen waste can be removed with simple settling technology. On the contrary, re-circulating water systems produce wastes and cannot in themselves reduce environmental impact. Consequently, the system requires treatment processes. Re-circulating system can mitigate environmental impact by dramatically reducing the volume of water discharge and control the water quality via control some environmental factors and reducing waste loading.

In aquaculture, waste loading comes from 2 sources fish feed and fish excretion. These organic wastes and nutrients consist of solid matter (mainly uneaten feed, feces, and phytoplankton) and dissolved metabolites (mainly ammonia, urea and carbon dioxide). Uneaten feed and excretory products sinking directly onto the pond bottom, can have a significant effect on the sediment quality and thus on the health of animal living there.

The primary source of wastes in aquaculture comes from excretory products and uneaten feed. Generally, nutrient loading in aquaculture is evaluated by focusing on nitrogen loading and BOD. The concepts are total nitrogen input (consumed) equal to total nitrogen retention in fish body including total nitrogen in excretion (feces and urine). Only around 30% feed N is retained by fish fed most commercial feed, even if they consumed all of the feed fed. Feed N not retained by the fish (70%) is excreted, which 87% is dissolved form and 13% is solid form. Comprehensive study of intensive ponds, the average of 78-79% N added to the ponds directly loaded the environment. A major portion of N (31%) is retained in the sediment, while the water-borne nutrient is 35%.

Evaluation of waste load in intensive culture, approximately 88% of nitrogen content in the pond comes from feed, 13-33% of this comes from excretion.

In the case of organic matter expressed as energy and BOD, 35% of energy is utilized for fish growth, 47% for respiration and the remaining amount 18% goes as feces. The fish incorporates about 25% of the nitrogen, 15% is lost in feces and 60% is excreted as ammonia from the gills.

Technological development for fish farm management

1) Marine shrimp culture effluent

The effluent's water quality and quantity produced by marine shrimps farms has been studied comprehensive in Thailand. In 1993, Department of Fisheries (Songsangjinda and Tunvilai 1993) stated that the pollution loading from an intensive tiger shrimp practicing an open water exchange system in the southern province of Thailand, comprised of total nitrogen 2.02 kg/ha/day, total suspended solid 532.2 kg/ha/day and chlorophyll a 0.11 kg/ha/day. For the farm mange with semi-zero water discharged system, the studied in the Chantaburi province(eastern part of Thailand) was conducted by Tookwinas et al 1995 . The water discharged was 67,400 ton/ha/crop, with a total nitrogen of 5.1 kg/ha/crop, a total organic carbon of 89.6 kg/ha/crop and a BOD of 1,821 kg/ha/crop.

In an estuarine like Kungkrabaen Bay, Chantaburi province, Tookvinas , et al.(1995) reported that the effluent of shrimp farm loaded in to this bay during 1995 was about 16,697 ton/pond (pond area 2,479 square m.). This effluent contained loading of biological oxygen demand (BOD) and Total ammonia nitrogen (TAN) about 5,989 kg/yr. and 3,497 kg/yr., in respectively.

The sludge, or bottom sediment in a shrimp pond after the harvest, is composed of polluted organic matter. Songsangjinda and Tunvilai, et al., (1993) stated that each kilogram of sludge was composed of 13.6 mg hydrogen sulfide, 45.9 mg ammonia nitrogen, 1.2 mg orthophosphate, and 16.0 percent organic matter. When the sludge was drained directly to receiving water bodies, it could cause a significant effect on the environment, cause nutrient enrichment of natural water resources, encouraging a plankton bloom and eutrophication.

The zero discharged culture system are now mostly being practiced, and the sludge must be kept inside the sludge pond. GAP certification and COC practiced cover the international criteria are used to promote the farmer to produce the better production for exporting market. Department of Fisheries, related associations and the exporters are servicing for the technical , monitoring and audited for the food safety production.

2) Freshwater fish culture effluent

The water quality in the freshwater aquaculture has different concentration or mass based varying to the culture species and feed used. The water in the culture pond normally are in the proper quality for aquatic animals living.(Table 1) The developing techniques for effluent management should be considered , in general, effluent management procedures involving issuing a permit to discharge effluents, maximum and minimum levels of individual substances that may be allowed in the effluents.

Table 1 . Water quality in culture pond during culture period of some freshwater fish and giant freshwater prawn

Parameter	Snake head fish	Catfish	Tilapia	Giant freshwater prawn
Total suspended solid (mg/l)	79.6	142.8	35.7	26.9
Ammonia-nitrogen (mg/l)	1.906	0.543	0.231	0.431
Total nitrogen (mg/l)	3.974	1.614	0.624	1.212
Total phosphorus (mg/l)	0.641	0.300	0.579	0.081
BOD(mg/l)	15.1	15.6	12.7	8.9
COD (mg/l)	84.8	114.5	106.6	44.0

The effluents during harvesting period are characterized as high waste loading relatively low volume. (Table 2) , this show that the most problem of effluent from intensive fish culture are in the harvesting period, particular the sludge or sediment from the bottom pond.

Table 2. Water quality in effluent during harvesting of some freshwater fish and giant freshwater prawn

Parameter	Snake head fish	Catfish	Tilapia	Giant freshwater prawn
Total suspended solid (mg/l)	528.3	282.5	196.7	151.7
Ammonia-nitrogen (mg/l)	5.493	0.860	0.650	0.788
Total Kjeldahl nitrogen (mg/l)	7.611	2.937	1.866	1.264
Total nitrogen (mg/l)	8.060	4.714	2.600	1.498
Total phosphorus (mg/l)	1.269	0.390	0.164	0.088
BOD (mg/l)	21.4	13.6	20.8	17.1
%Organic matter in bottom soil	4.9	2.3	7.3	3.2
%Organic carbon in bottom soil	2.8	1.3	4.2	1.8

Trash fish, still commonly used for feeding carnivorous fish, chicken viscera, and waste from chicken slaughter house are also used. Moist feed generally incur severe criticism because they are thought to be more polluting than dry feeds and because of the risk of disease transfer through of unprocessed animal ingredient. Low –pollution diets for the intensive carnivorous fishes in Thailand are not appearing. Control on the effluent during harvesting is the only way in practiced by draining to the large integrated fish pond, not to drain directly to the natural water body or agricultural area .

The legislation and regulation for the effluent from aquaculture needs the information on the characteristics of effluent water to set up the water quality criteria for permit . The permit are also requires the specific management practiced for the effluent and often requires a monitoring program to verify that the effluent characteristics fall within the restrictions of the permit. So, the standard of permit for the freshwater culture effluent is now ongoing study by The Department of Pollution Control before implementation the standard and basic treatment system.

3) Effluent from Cage culture.

Cage culture plays an important role in the main water sources of country , there have several advantages over other methods of culture. Because they use existing water bodies, cage culture is a profitable activities contributing significantly to natural food production, employment and economic in agricultural sectors. However, it is subject to competition for all its resources, particularly space and water, which will inevitably increase particularly in natural water resources.

Direct influence of fish cage culture is through its effluent discharge. As this type of culture depends entirely on an external feed input results in the deterioration of the water qualities from uneaten feed, fecal discharge and that from nitrogenous metabolism.

Cage cultured fish are entirely dependent on formulated diet, and the waste products from the consumption is released directly to the water body. This resulted in cage contributing nutrients, organic matter (BOD), and turbidity that causes deterioration of water quality and biota downstream.

The stability of the feed in water is an important factor determining nutrient leakage to the environment. The results from water stability and losses of feed within 0, 5 10,20 30 and 60 minutes in water has shown that feeds for young fish were less water stability than feed for grow-out fish. After 10 minutes in the water as feed for fish, the losses of feed nutrients and particles of ingredients were dissolved . Lipid can be considered highest lost within 10 minutes.

Much of the nitrogen and phosphorus added to natural water where fish cage are cultured is also wasted. Aquaculture feeds take most of the blame for aquaculture pollution, but poor feeding management is often the greater culprit. The waste components from un eaten feed are undigested feed (fecal waste) and excretion products from the digested protein, such as total ammonia nitrogen. Also excreted minerals, especially phosphorous, are present.

Based on feed contribute to the culture system of tilapia (*Oreochromis niloticus*)and giant gourami,*(Osphronemus gourami*) estimated waste production was shown in the table 3;

Table 3 Waste production form red tilapia and giant gourami cage culture

Waste production	**% of Body weight/day**		**% of feed/day**	
	Red tilapia	Giant gourami	Red tilapia	Giant gourami
Fecal wast				
Fecal weight	0.175	0.37	6.587	11.53
Fecal nitrogen	0.0026	0.007	0.107	0.194
Fecal phosphorous	0.0026	0.008	0.099	0.228
Fecal BOD	0.13	0.329	4.697	9.31
Excretion waste in water				
Nitrogen	0.069	0.102	1.436	2.163
Phosphorous	0.002	0.0001	0.032	0.005
Nutrient loss within ten minutes in water*				
Feed loss in weight**	3.726	1.634	3.726	1.634
Feed nitrogen**	0.112	0.065	0.112	0.065
Feed phosphorous**	0.033	0.046	0.033	0.046
Feed BOD loss in water**	6.16	2.155	6.16	2.155
Total waste in water				
Organic matter increased	3.901	2.004	10.313	13.164
Nitrogen increased	0.184	0.174	1.655	2.422
Phosphorous increased	0.038	0.054	0.164	0.279
BOD	6.290	2.484	10.857	11.465

* average from feed derived (young fish : grow out feed = 2 : 1)

** % of feed ingested (based on percentage of fish body weight and percentage of feed distributed)

Source: SUMFISH (2003)

The growth and survival rate of red tilapia (*Oreochromis*) and giant gourami (*Osphronemus gourami*) in cage culture were recorded with the feed efficiency values. The results from extensive study (Department of Pollution Control, 2003) can be concluded that during the environmental changes such as the rise of water temperature, the fluctuation of water qualities especially during the early rainy season, or when the temperature varied during the change of rainy season to cold season, to reduce the risk could be done by adjusting lower the stocking density of fish in the cage.

The quantity of wastes discharged from a fish cage depends on the quantity and quality of feed input. As a result on rapid expansion in cage culture in freshwater water sources, the potential effects on the environment would be on the increase of suspended solids and nutrients, impacts on aquatic living organisms, species composition, diversity and abundance and changes in natural fish community and genetic pools and also concerns on the polluted water problem in the culture areas. Though fish cage culture is a profitable activity and economic in agricultural sectors, studies on the measures and mitigation to reduce impact of freshwater fish cage culture should be taken into account for sustainable healthy environment.

Technological Development in Production of Safe Aquaculture Foods

According the Thai national policy, the potential aquaculture must be familiar with local, state and national legal requirements. Special permits are usually required to operate in the reservoir. Some province, have prohibiting the use of any water enclosures(cage, pen, rafts) in navigable waters. Local zoning may prohibit aquaculture operations in certain areas. Restriction has also prohibit the culture of marine or brackish water species in the freshwater area . Permits are required before certain species may be transported into or/and across certain area. The potential aquaculture must be prepared to abide by all local laws if he wishes to be welcomed into a given area.

The goal of aquaculture is maximum production at the appropriate cost. Feed and feeding practices are the main criterion that the farmer emphasizes to work for this objective. Feed quality is the operating cost that farmer trys to reduce. The high protein, lipid and phosphorus cause the high feed cost and high waste load in fish pond due to the leaching of nutrient from feed and feces. Consequently, the optimum nutrient feed for each species can solve these problems. In addition, feeding practices also cause of high waste load in fish pond. The nutrient leaching from feed when feed to fish and uneaten feed are primary waste in fish pond. The standard of aquatic animals feed quality with different stage of life were set up for freshwater fish, freshwater giant prawn, marine shrimp.

Implementation of the Code of Conduct for responsible marine shrimp farming and related business in Thailand has been conducted along the FAO code of conduct for responsible fisheries, Codex alimentarius and Environment Management System (EMS). The environment statement was initiated and signed by the various concerned stakeholder in 1999 with a world bank support. Guideline for shrimp farms and shrimp hatcheries were documented in 2000.

The goal of the action plan to ensure the aquaculture products are safe and reach or exceed national and international standard. All stakeholders include hatcheries, farms, feed supplies, drug and chemical agent suppliers, handler, broker and fish markets, primary processors, processors, importer and exporters have to involved. In addition, process improvement has been emphasized on using good aquaculture practice (GAPs), good manufacturing practice (GMP) and hazard analysis critical control point (HACCP) systems in all sectors of the food supply chains.
Following the plan, the strategies are ;

Good aquaculture practices for hatchery and farm
Good practices for feed, drug and chemical supplier
Good practices for harvesting and marketing
Good manufacturing practices and HACCP controls for processing plants
Import and export control

Successful Cases of Technology Utilization and adoption in Fish Farms

The most serious problem for freshwater aquaculture are the intensive culture of the carnivorous fish as *Channa* snaked headed fish, *Clarias* catfish. The effluent from these intensive culture are needs to improve before discharge to out side .

The treatment system for reducing waste load from aquaculture activity typically presents in 4 system : oxidation pond, aerated lagoon, wetland and wetland with fish culture. The design of farm system for culture of intensive carnivorous fish were studied and practiced in the central part of Thailand, as Supanburi province. The oxidation pond can reduce waste load in effluent from an intensive fish pond with a water retention of two days by carried the major loss of particulate nutrients in the form of heterotrophic and autotrophic micro-plankton and also bottom deposition of 10-15% particulate nutrients . The study on the intensive culture of freshwater fish culture(snakehead fish *Channa striata* , walking catfish Hybrid Clarias (*Clarias macrocephalus X C. gariepinus*) in Thailand showed the culture system with several ways to improve the effluent quality.(Department of Pollution Control, 2003,2004,and 2005)

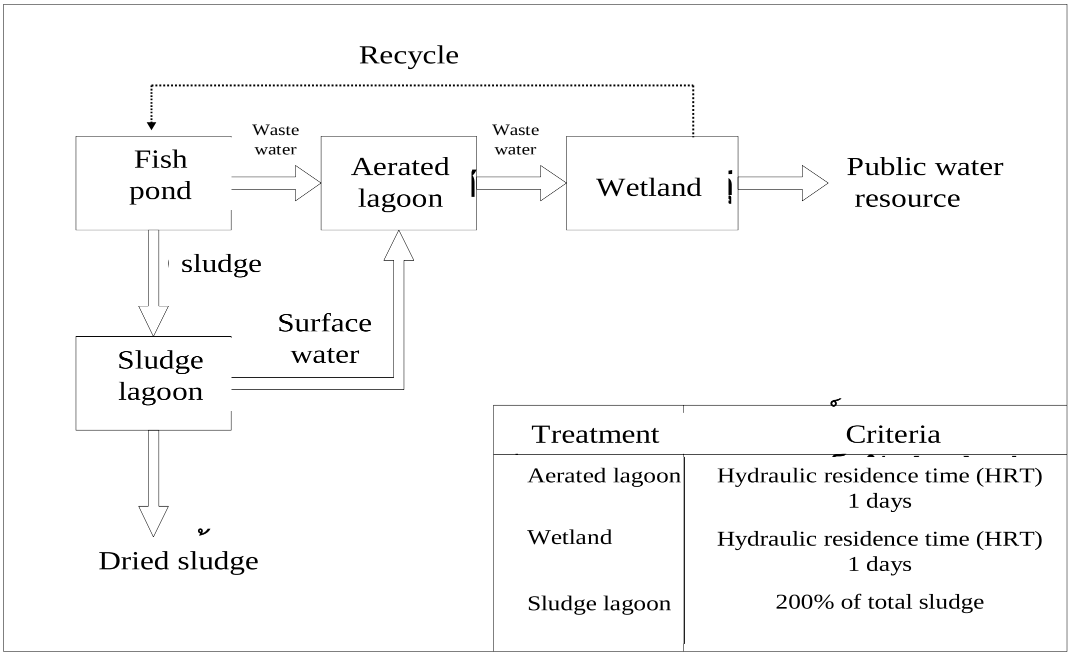
Aerated lagoon presents the high efficiency on reducing BOD and ammonia (>50%) and work effectively in a short period of one day.

The system of wetland demonstrates the efficiency on diminishing BOD and TSS (suspended solids) more than 50% via the sedimentation of sludge in wetland and relatively reduce ammonia, total nitrogen and total phosphorus due to the absorption of nutrient for aquatic plant growth.

On the other hands, wetland and fish culture system expresses the efficiency on mitigate BOD and TSS and sluggishly reduce ammonia, total nitrogen and total phosphorus but the efficiency is not as good as wetland system because of the herbivorous fish that culture in treatment system also excrete waste as feces and ammonia from gill excretion.

Therefore, the water system for freshwater culture in earthen pond has 2 design,
design 1 :small treatment system ; Aerated lagoon + Wetland+ Sludge lagoon
design 2 : large scale treatment system; Wetland and fish culture + Sludge lagoon.

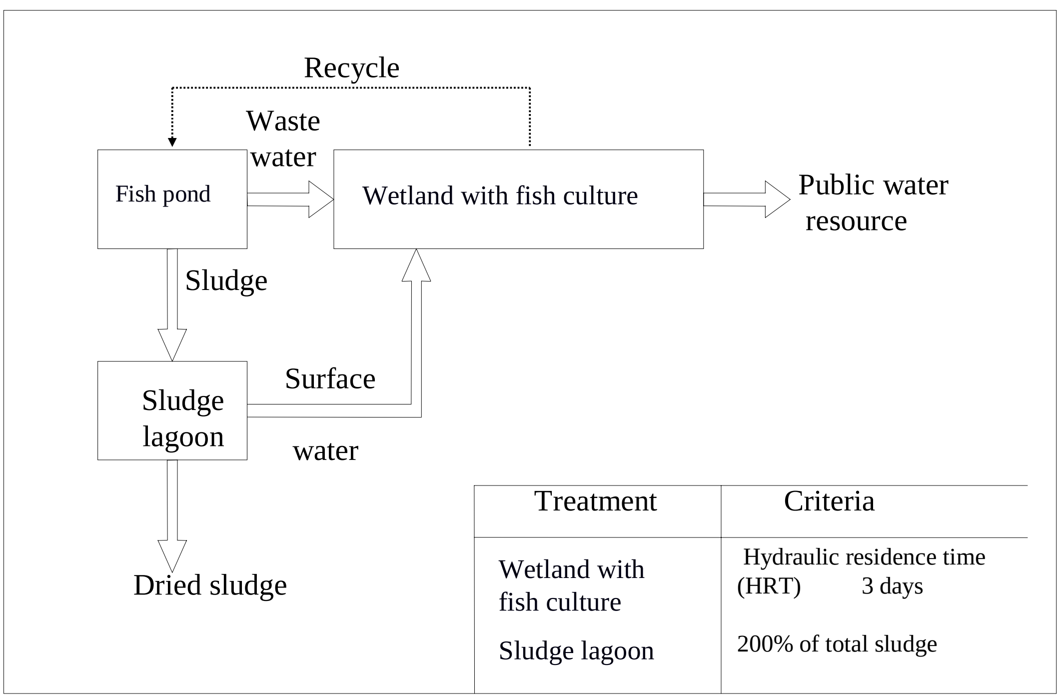
<u>Fig. 1:</u> Small treatment system (aerated lagoon + wetland + sludge lagoon)



Treatment	Criteria
Aerated lagoon	Hydraulic residence time (HRT) 1 days
Wetland	Hydraulic residence time (HRT) 1 days
Sludge lagoon	200% of total sludge

The effluent of pond culture quite differs from indoor and out door tank due to a large volume of water discharge from fish pond and the different waste load.

<u>Fig 2:</u> Large scale treatment system (wetland + fish culture + sludge lagoon)



Treatment	Criteria
Wetland with fish culture	Hydraulic residence time (HRT) 3 days
Sludge lagoon	200% of total sludge

The overall efficiency of treatment system demonstrated in design 1 (Aerated lagoon + Wetland+ Sludge lagoon) shows that the system can reduce BOD, TSS, ammonia and total nitrogen more than 50% in one day and reduce total phosphorus around 34% in one day. For design 2 (Wetland and fish culture + Sludge lagoon), the system presents the efficiency to reduce BOD and TSS more than 50% in three day and reduce ammonia, total nitrogen total phosphorus around 25-30% in three day.

The decision point for selecting treatment system is cost and benefit. Design 1 requires some machine for generate oxygen in aerated lagoon and needs electric or gasoline for operating this machine. Although, the area for treatment system in small (hydraulic resident time: HRT 1 day) but do not get any production from treatment system. Where as design 2 needs more area than design 1 around 30% (hydraulic resident time: HRT 3 day) but the system produces fish production every year and low operating cost.

Table 3 Efficiency of water treatment system for reducing waste loading from aquaculture activity

Treatment system	parameter	Aerated lagoon (%)	Wet land (%)	Wetland and fish culture (%)	Sludge lagoon (%)	Over all efficiency (%)
Design 1:	BOD	75	50	-	40	87.5
	TSS	0	> 80	-	90	80.0
Aerated lagoon + Wetland + Sludge lagoon	Ammonia nitrogen	65	25	-	60	73.7
	Total nitrogen	30	45	-	80	61.5
	Total phosphorus	7	30	-	20	34.9
Design 2:	BOD	-	-	80	40	80
	TSS	-	-	85	90	85
Wetland and fish culture + Sludge lagoon	Ammonia nitrogen	-	-	25	60	25
	Total nitrogen	-	-	25	80	25
	Total phosphorus	-	-	30	20	30

On conclusion, the appropriate effluent water treatment for aquaculture have to consider on waste loading from culture pond, amount of water flow in culture system, area for construct treatment system and potential of investment in treatment system.

The art of settling limits requires knowledge of the effect of individual variables on aquatic ecosystems , individual organisms and also impact on different types and scale of receiving water body . The permits limits to be used by the regulation will vary according to classification and assimilation capacity of water bodies. The simple water treatment for the effluent need to be set up in the farm, so not only to follow the permit standard ,but to be good of all water users and make the aquaculture operation more sustainable and more profitable in the long term.

Emerging Needs and Future Direction

In the present legal system, the current and future importance of aquaculture is not fully reflected. So far, very few legal has set up.

Local administrative should become involved in the aquaculture pollution control, since new advances will be needed in water quality understanding, feeding technology, information, community facilitation and interactions.

In Thailand, about 78 % of aquaculture farmer are small-scale. There is need to improve the transfer of appropriate technology to the farmers , through government agencies and also involving aquaculture farmer associations.

Legislative needs.

Regulations issued by the Ministry of Agriculture and Cooperatives, including the coastal land use plan of the Department of Land Development, need to be strengthened to allow for the designation of zones for aquaculture. The clarification of responsibilities with regard to the development of the coastal area is also required.

References

Department of Pollution Control. 2003. Study on the measures and mitigation to reduce impacts of freshwater fish cage culture. Department of Pollution control, Ministry of natural resource and environment. Bangkok, Thailand.170 p.

Department of Pollution Control. 2004. Management of effluent from freshwater aquaculture. Department of pollution control, Ministry of natural resource and environment. Bangkok, Thailand. 325 p.

Department of Pollution Control. 2005. Development of management and water treatment system for freshwater aquaculture. Department of pollution control, Ministry of natural resource and environment. Bangkok, Thailand.275 p.

Siddiqui, A. Q. and A. H. Al-Harbi. 1999. Nutrient budgets in tanks with different stocking densities of hybrid tilapia. Aquaculture **.**170: 245-252

Songsangjinda,P. and D. Tunvilai. 1993. Pollution loading from an intensive tiger shrimp farm. Tech.paper No. 15/1993. NICA, Department of Fisheries, Thailand. 8 p.

SUMAFISH. 2003. Strategies for sustainable Management of Fisheries Resources in the Pasak Jolasid Reservoir, Thailand through Ecological and Socio-economic Assessment. ASEAN Reginal Center for Biodiversity and the European Commission. P 262-269.

Tookwinas,S., S. Dirakkait. W. Prompoj. C.E. Boyd and R.Show. 2000. Marine shrimp culture industry of Thailand operating guidelines for shrimp farms. Aquaculture Asia. 5(1): 25-28