ABSTRACT

Aquaculture plays an important role in Thailand, contributing a very high portion of the total export product and national income. In the last two decades, the technology of intensive farming has expanded significantly in 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 reviews the pollution created by freshwater aquaculture and also cage culture with their effluent management. Preventive measures through proper healthy environment and food security, government regulation, and policies are also described.

Key words: aquaculture development, effluent management, environmental management, Thailand

CURRENT SITUATION OF AQUACULTURE IN THE NATIONAL ECONOMY

Brief Historical Development of Aquaculture

It is believed that aquaculture in Thailand has been practiced in the country for about 300 years, as shown by the historical record of the Thai carp species 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 related with both socioeconomic and technical development. Aquaculture development has been through three stages. First, it 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. Second, with the development of technical and 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 is its present transition stage to becoming more harmonious with the natural environment and more consistent with socioeconomic development. The present trend in technical development has been to go toward the improvement of the cultural environment by using technological development and preventive 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, the total aquaculture production reached 703,300 tons for coastal aquaculture and 361,125 tons for freshwater aquaculture.

AQUACULTURE STRUCTURE AND PRODUCTION

The total fisheries production of Thailand in 2003 totalled 3,914,073 tons, of which 27.2 percent come from aquaculture. Freshwater aquaculture production was 9.2 percent, and 18 percent from the coastal aquaculture. Production from inland fisheries was 198,447 tons, composed of striped snakehead fish (12.1 percent), common silver barb (19.6
percent), and walking catfish (7 percent). Shrimp production from marine capture was only 3.2 percent of the total captured production of 2,651,223 tons.

**FRESHWATER CULTURE**

Total yield from freshwater culture was 89,800 tons in 1986 and gradually increased to 361,100 tons in 2003. Tilapia production was the highest (123,600 tons or 34.2 percent of total freshwater culture production) followed by catfish (*Clarias* species) (115,400 tons or 31.9 percent), prawn (28,500 tons or 7.89 percent) and carp (*Puntius gonionotus*) (88,000 tons or 24.3 percent). Those species with yields of about 10 percent of total freshwater culture yield were striped snakehead, catfish (*Pungasius*), and snake headed fish (*Channa striata*).

The ratio of the export value for the freshwater aquaculture are as follows: nile tilapia, 69.9 percent; hybrid Thai tilapia (*tab tim*), 16.7 percent; and carp, 6.7 percent. The export volume in 2003 was 15,773 tons which is equivalent to US$28.5 million. The giant freshwater prawn is also an export commodity with a high demand in the world market. In 2004, Thailand's export of this prawn reached up to 3,942.6 tons with a value of US$ 20.1 million.

**COASTAL AQUACULTURE**

Total yield volume from coastal aquaculture was 61,900 tons in 2003, a slight increase compared with that in 2000. Of this, 58 percent were yield from prawn culture, and 2.4 percent from fish culture. The rate of increase was the highest for white shrimp culture. Production from tiger shrimp culture had been decreasing through the years.

By species, the largest share in coastal culture yield volume was shellfish culture, green mussel (11.8 percent), followed by oyster and blood clam. Yield from shrimp culture was 47 percent of the total production. The rate of increase was now the highest for white shrimp (*Litopenaeus vannamei*), followed by sea bass (*Lates calcarifer*) and grouper.

The total production area of shrimp in Thailand was 75,000 ha involving 30,800 farmers, and a 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 percent, while 11 percent uses an area of more than 4.8 ha (National Statistical Office, 2000). In the last five 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 the salinity intrusion in the 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 follows:

1) Impact on 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. It has an 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.

3) Salinity intrusion to freshwater area or agricultural areas.

**GOVERNMENT ORGANIZATION AND SUPPORT SERVICES FOR AQUACULTURE**

In order to sustain the food industry (farming through processing plant) and to maintain consumer confidence in product safety, 2004 has been declared as the “Food Safety Year” by the Thai Government. It generally aimed 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 overseas markets.

The Department of Fisheries has adopted an Action Plan on Food Safety from Farm to Table to ensure that 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 GAP for marine shrimp certification has been done in Thailand since late 2002, followed by the GAP for giant freshwater prawn certification in 2003. By the year 2005, the government has moved forward to implement GAP for all aquatic farm animals and hatchery in both inland and brackishwater aquaculture. The work steps follow farm registration,
training and farm improvement. Then, farm auditing by DOF agencies would be done for GAP certification. At present, about 20,000 marine shrimp and giant freshwater farms have been certified under GAP 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 be able to trace back the origin of aquaculture products and to adopt the Quality Mark for Fishery Commodity and Food Standards (Q mark) to assure that Thai aquaculture, especially for shrimp and fishery products, are always at international standards.

The Ministry of Agriculture and cooperatives declared the Quality Mark for Agricultural Commodity and Food Standards (Q Mark).

The main key issues in the code of conduct for responsible aquaculture and related business in food safety are as follows:
1) The culture site would be out of conservation area.
2) Aquaculture farming would be conducted using environment-friendly culture technology.
3) The product would be free from chemical drugs 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 every activity needed to be done in order to be granted a farm certification.

**PRINCIPLES IN ENVIRONMENTAL POLICY ON AQUACULTURE PRACTICES**

Leading principles are “precautionary principles” and “producing more out of less.” Its 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 the success of intensive aquaculture production.
- No discharge of toxicants and antibiotics
- The discharge of nutrients and other non-accumulating matter has to be at as low as possible by application of best available technology
- The minimal discharge that has to take place anyway must be directed to such recipients where they cannot cause pollution of any significance.

**ENVIRONMENTAL GOALS FOR THE FISH FARMING MANAGEMENT**

- Prevent that the growth of the fish farm industry causes new or contribute to existing eutrophication problems.
- The discharge of micro-pollutants must be reduced to levels on which only nonsignificant and reversible effects can be observed.
- Stop any sedimentation from the aquaculture discharge in natural bodies
- The release of antibiotics be limited such 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 the risk of pollution or infection.

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

**LEGAL FRAMEWORK**

Marine shrimp farm along the coastal area of Thailand plays an important role in the national income and provides 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 should not exceed 76,000 ha.
2) Regulations for shrimp farming in Thailand announced by the Department of Fisheries in November 1991 Under the Fisheries Act 1947 are as follows:
   • Shrimp farmers are to be registered with the Department of Fisheries at the district offices.
   • Shrimp farms over 8 ha are to be equipped with wastewater treatment or sedimentation ponds not covering less than 10 percent 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 public areas.
   • Sludge or bottom mud sediment are to be kept in suitable areas and not to be discharged to natural water body.

TECHNOLOGICAL DEVELOPMENT FOR FISH FARM MANAGEMENT AND PRODUCTION OF SAFE AQUACULTURE FOODS

Today, aquaculture is facing increasingly tight restrictions in many areas, as concern over environmental impact and competition for resource grows. Aquaculture wastes that are discharged to receiving water have a determined impact to the environment. Thus, aquaculture activity is focusing its attention on development of technologies for improvement of effluent quality and pollution loading.

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

In aquaculture, waste loading comes from two 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 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 percent feed N is retained by fish fed on most commercial feed, even if they consumed all of the feed fed. Feed N not retained by the fish (70 percent) is excreted, of which 87 percent is dissolved form and 13 percent is solid form. In a comprehensive study of intensive ponds, an average of 78-79 percent N added to the ponds directly loaded the environment. A major portion of N (31 percent) is retained in the sediment, while the waterborne nutrients are 35 percent.

In an evaluation of waste load in intensive culture, approximately 88 percent of nitrogen content in the pond comes from feed, 13-33 percent of this comes from excretion.

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

TECHNOLOGICAL DEVELOPMENT FOR FISH FARM MANAGEMENT

Marine Shrimp Culture Effluent

The effluent’s water quality and quantity produced by marine shrimp farms has been studied comprehensively in Thailand. In 1993, the 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 of 2.02 kg/ha/day; total suspended solid of 532.2 kg/ha/day; and chlorophyll, 0.11 kg/ha/day. For the farm with a semi-zero water discharge system, the study in the Chantaburi province 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, Tookvinas et al. (1995) reported that the effluent of shrimp farm loaded into this bay during 1995 was about 16,697 ton/pond (pond area 2,479 sq m). This effluent contained loading of biological oxygen demand (BOD) and total ammonia nitrogen (TAN) of about 5,989 kg/yr and 3,497 kg/yr, respectively.

The sludge, or bottom sediment in a shrimp pond after 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 percent organic matter. When the sludge was drained directly to receiving water bodies, it could cause a significant effect on the environment, such as nutrient enrichment of natural water resources encouraging a plankton bloom and eutrophication.

The zero discharged culture system is now mostly being practiced, and the sludge must be kept inside the sludge pond. GAP certification and COC practice covering the international criteria are used to promote better production for export market.

DOF-related associations and exporters are providing the technical, monitoring and audit services for the food safety production.

Freshwater Fish Culture Effluent

Water quality in freshwater aquaculture has different concentrations or mass-based which varies depending on the species cultured and the feed used. The water in the culture pond normally is the proper quality for living aquatic animals (Table 1). The development of techniques for effluent management should consider, in general, effluent management procedures involving issuing a permit to discharge effluents, and maximum and minimum levels of individual substances that may be allowed in the effluents.

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

Trash fish, still commonly used for feeding carnivorous fish, composed of 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 unprocessed animal ingredient. Low-pollution diets for the intensive carnivorous fishes in Thailand are unpopular. Control of effluent during harvesting is only practiced by draining the large integrated fish pond, but not draining directly to the natural water body or agricultural area.

In formulating legislation and regulation for effluent from aquaculture, information is needed on the characteristics of effluent water so that water quality criteria can be set up permit. The permit also requires specific management practice 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 an ongoing study by the Department of Pollution Control before implementation of the standard and basic treatment system.

**EFFLUENT FROM CAGE CULTURE**

Cage culture plays an important role in the main water sources of the country. This has several advantages over other methods of culture. Because

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Snakehead fish</th>
<th>Catfish</th>
<th>Tilapia</th>
<th>Giant freshwater prawn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total suspended solid (mg/l)</td>
<td>79.6</td>
<td>142.8</td>
<td>35.7</td>
<td>26.9</td>
</tr>
<tr>
<td>Ammonia-nitrogen (mg/l)</td>
<td>1.906</td>
<td>0.543</td>
<td>0.231</td>
<td>0.431</td>
</tr>
<tr>
<td>Total nitrogen (mg/l)</td>
<td>3.974</td>
<td>1.614</td>
<td>0.624</td>
<td>1.212</td>
</tr>
<tr>
<td>Total phosphorus (mg/l)</td>
<td>0.641</td>
<td>0.300</td>
<td>0.579</td>
<td>0.081</td>
</tr>
<tr>
<td>BOD (mg/l)</td>
<td>15.1</td>
<td>15.6</td>
<td>12.7</td>
<td>8.9</td>
</tr>
<tr>
<td>COD (mg/l)</td>
<td>84.8</td>
<td>114.5</td>
<td>106.6</td>
<td>44.0</td>
</tr>
</tbody>
</table>
they use existing water bodies, cage culture is a profitable activity contributing significantly to natural food production, employment and economy 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. This type of culture depends entirely on an external feed input, which 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 results 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 have shown that feeds for young fish were less water stable than feeds for grow-out fish. After 10 minutes in the water as feed for fish, the losses in feed nutrients and particles of ingredients were dissolved. Lipids 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. Aquafeeds take most of the blame for aquaculture pollution, but poor feeding management is often the greater culprit. The waste components from uneaten feed are undigested feed (fecal waste) and excretion products from the catabolized protein, such as total ammonia nitrogen. Excreted minerals, especially phosphorous, are also present.

Based on feed contribution to the culture system of tilapia and giant gourami, estimated waste production is shown in Table 3.

The growth and survival rate of red tilapia (*Oreochromis*) and giant gourami (*Osphronemus gourami*) in cage culture were recorded with the feed efficiency values. Based on the results from extensive study (Department of Pollution Control, 2002), it can be concluded that during environmental changes such as the rise of water temperature, the fluctuation of water qualities especially during the early rainy season, or when the temperature varies during the change from rainy season to cold season, reducing the risk could be done by lowering the adjustment of 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 of the 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 as well as 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 THE PRODUCTION OF SAFE AQUACULTURE FOODS**

According to the Thai national policy, the potential aquaculturist must be familiar with local, state and national legal requirements. Special permits are
usually required to operate in the reservoir. Some provinces have prohibited the use of any water enclosure (cages, pens, rafts) in navigable waters. Local zoning may prohibit aquaculture operations in certain areas. Restriction has also prohibited the culture of marine or brackishwater species in the freshwater area. Permits are required before certain species may be transported into or/and across certain area. The potential aquaculturists 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 criteria that the farmer wants to meet. Feed quality is the operating cost that the farmer tries to reduce. High protein, lipid and phosphorus cause high feed cost and high waste load in fish pond due to the leaching of nutrient from feed and feces. Consequently, optimum nutrient feed for each species can solve these problems. In addition, feeding practices also cause high waste load in fish pond. The nutrient leaching from feed when fed to fish and uneaten feed are primary wastes in fish pond. The standard of aquatic animal feed quality with different stages 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 with 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 stakeholders in 1999 with support from the World Bank. Guidelines for shrimp farms and shrimp hatcheries were documented in 2000.

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

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

<table>
<thead>
<tr>
<th>Waste production</th>
<th>% of Body weight/day</th>
<th>% of feed/day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Red tilapia</td>
<td>Giant gourami</td>
</tr>
<tr>
<td>Fecal waste</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fecal weight</td>
<td>0.175 0.37</td>
<td></td>
</tr>
<tr>
<td>Fecal nitrogen</td>
<td>0.0026 0.007</td>
<td></td>
</tr>
<tr>
<td>Fecal phosphorous</td>
<td>0.0026 0.008</td>
<td></td>
</tr>
<tr>
<td>Fecal BOD</td>
<td>0.13 0.329</td>
<td></td>
</tr>
<tr>
<td>Excretion waste in water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.069 0.102</td>
<td></td>
</tr>
<tr>
<td>Phosphorous</td>
<td>0.002 0.0001</td>
<td></td>
</tr>
<tr>
<td>Nutrient loss within 10 minutes in water*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feed loss in weight**</td>
<td>3.726 1.634</td>
<td>3.726 1.634</td>
</tr>
<tr>
<td>Feed nitrogen**</td>
<td>0.112 0.065</td>
<td></td>
</tr>
<tr>
<td>Feed phosphorous**</td>
<td>0.033 0.046</td>
<td></td>
</tr>
<tr>
<td>Feed BOD loss in water**</td>
<td>6.16 2.155</td>
<td></td>
</tr>
<tr>
<td>Total waste in water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic matter increased</td>
<td>3.901 2.004</td>
<td>10.313 13.164</td>
</tr>
<tr>
<td>Nitrogen increased</td>
<td>0.184 0.174</td>
<td>1.655 2.422</td>
</tr>
<tr>
<td>Phosphorous increased</td>
<td>0.038 0.054</td>
<td>0.164 0.279</td>
</tr>
<tr>
<td>BOD</td>
<td>6.29 2.484</td>
<td></td>
</tr>
</tbody>
</table>

* 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)

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 is the intensive culture of the carnivorous fish such as snaked headed fish (Channa), and catfish (Clarias). The effluent from these intensive culture needs to be improved before being discharge outside.

The treatment system for reducing waste load from aquaculture activity is typically present in four systems: oxidation pond, aerated lagoon, wetland, and wetland with fish culture. The design of farm system for culture of intensive carnivorous fish was studied and practiced in the central part of Thailand, such 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 carrying the major loss of particulate nutrients in the form of heterotrophic and autotrophic microplankton and also bottom deposition of 10-15 percent 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 that there are several ways to improve the effluent quality (Department of Pollution Control, 2003, 2004, and 2005)

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

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

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

Therefore, the water system for freshwater culture in earthen pond has two designs.
Design 1. Small treatment system; Aerated lagoon + Wetland+ Sludge lagoon
Design 2. Large scale treatment system; Wetland and fish culture + Sludge lagoon.

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

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 of more than 50 percent in one day and reduce total phosphorus of around 34 percent in one day. For Design 2 (Wetland and fish culture + Sludge lagoon), the system presents the efficiency to reduce BOD and TSS of more than 50 percent in three days and reduce ammonia, total nitrogen, and phosphorus of around 25-30 percent in three days.

The decision point for selecting treatment system is cost and benefit. Design 1 requires some machine for generating oxygen in aerated lagoon and needs electricity or gasoline for machine operations. Although the area for treatment system is small (hydraulic resident time: HRT 1 day), it does not get any production from treatment system. Whereas, Design 2 needs more area than Design 1 of around 30 percent (hydraulic resident time: HRT 3 days) but the system produces fish every year and at low operating cost.

In conclusion, the appropriate effluent water treatment for aquaculture has to consider waste loading from culture pond, amount of water flow in culture system, area for constructing 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 permit 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 needs to be set up in the farm, not only to follow the standard permit, but for the good of all...
Fig. 1. Small treatment system (aerated lagoon + wetland + sludge lagoon).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerated lagoon and wetland</td>
<td>Hydraulic residence time (HRT) 1 day</td>
</tr>
<tr>
<td>Sludge lagoon</td>
<td>200% of total sludge</td>
</tr>
</tbody>
</table>

Fig 2. Large scale treatment system (wetland + fish culture + sludge lagoon)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetland with fish culture and</td>
<td>Hydraulic residence time (HRT) 3 days</td>
</tr>
<tr>
<td>sludge lagoon</td>
<td>200% of total sludge</td>
</tr>
</tbody>
</table>
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 systems have been set up. Local administration 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 percent of aquaculture farmers are small-scale farmers. There is a 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 regards to the development of the coastal area is also required.

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