Status, problems and future trend on application of bioremediation technology for coastal zone development in Thailand

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SUMMARY: Despite economic crisis in Thailand, environmental degradation trends have not reversed. Several governmental sectors monitoring the status of natural resources are attempting to utilize organisms such as green mussel, red algae, Artemia and bacteria for waste water (shrimp farm effluent, in particular) biological treatment. Educational sectors are carrying out the researches on utilization of mangrove forests and vetiver grasses for domestic waste treatment. Moreover, studies on potential and application technique of benthic polychaetes, common seaweed, and other organisms for sustainable development of coastal shrimp culture are focused. On the whole, lack of integration of knowledge, cooperation among involving authorities and participation in environmental protection by the public were evident as major problems on effective application. Further progress on bioremediation technology in Thailand should deserve more response on the development of coastal culture and waste treatment technology. Social awareness and cooperation from the public should be simultaneously encouraged.

KEY WORDS: bioremediation, waste treatment, coastal zone, Thailand

INTRODUCTION

Coastal zone of Thailand consists with ca 2,614 km long of sea shore which can be divided simply into three sites; the eastern shore of 515 km long, the western shore of 1,248 km long, and the Andaman Sea shore of 710 km long. There are about 23 rivers that flow through the coastal zone into the Gulf of Thailand. The coastal land area accounts ca 35 % of the total land area of Thailand. In this area, there are 412 districts with different population densities and patterns of land using and there are about 1,400 small industrial factories. Recent data indicates that local people in the coastal area are likely to change their carrier to shrimp farmers and/or tourism concerns1). Thus, deterioration of nearshore mangrove forests is apparent. The natural mangrove forest is evident to be destroyed for shrimp culture and tourism purposes and remained only in 46 districts.

Thailand has included the watershed of the Chao Phraya and other major river system that drain into the Gulf of Thailand. The estuaries and marine areas around the river mouths of these rivers are subjected to pollution especially during May-July when the runoff is small2). Low oxygen, high BOD and high coliform counts result from the discharges of both domestic and industrial organic wastes. Trace and/or heavy metals have been found in high concentration in some rivers. Eutrophication resulting in algal blooms is also found especially in the upper gulf and river mouths because of nutrient inputs from the land.

DEGRADATION OF COASTAL RESOURCES

Most of the coastal areas of Thailand are considered sensitive in pollution aspect2). These areas are spawning grounds for several marine and brackish-water species and are also important small-scale local subsistence fisheries and numerous aquaculture farms. Many areas are also prime tourist spots that generate large revenues for local communities. Recent status of the coastal zone of Thailand is known that despite the economic crisis the environment degradation trend was not reversed. For instance, the depletion of Thai mangrove forests has continued despite the law enforced more than a decade ago. Examples of resource deterioration and their causes are as follows.

Mangrove forest: Recent information is evident that the mangrove forests are continuing destroyed. Area of the forest decreases from more than 3,200 million square kilometers in 1961 to ca 1,600 million square kilometers in 19963). Lost area is about 57 % of the total mangrove area. The mangrove area is largest in the Andaman Sea coast whereas the
smallest area is in the central part of Thailand. Main cause of deterioration is due to the cut for shrimp culture activity.

Erosion coast: There are many areas in the coast around the Gulf of Thailand that have extremely erosion problem. Those areas are situated around Ta Chin estuary to the Chao Phraya estuary and in some provinces in the Southern Thailand. The coast around the Andaman Sea has less erosion problem. Their stable coast is about 84.2 % and the extremely erosion area is only 2.4 %. Almost of their cause is due to natural process.

Coral reef: Coral reef in Thailand can be found both in the Gulf of Thailand and in the Andaman Sea with the total area of about 74.9 and 78.6 square kilometers, respectively. Condition analysis of the coral reef in the Gulf of Thailand indicates that very good reef condition is 16.4 % whereas poor to very poor reef condition is 24 %. The coral reef condition analysis of the Andaman Sea indicates that very good condition reef is 4.6 % whereas poor to very poor condition is 49.8 %. Causes of deterioration are normally due to over-destructive fishing method (e.g. push nets and trawling), tourism activities, sedimentation, and pollution associated with coastal development. In addition, recent information in the last 2-3 years depicted that dead of the coral reef in very large area (coral bleaching) could also be caused by dramatic changes in water quality.

Seagrass bed: Among coastal habitats, seagrass beds are the least studied compared to coral reefs and mangrove system. In Thailand, from 20-30 % of seagrass areas are damaged. Waste disposal from domestic use and aquaculture, destructive fishing method and coastal development and land reclamation that release sediments are among the major threats.

Coastal water: Water qualities in the coastal zone around the Gulf of Thailand are in moderate condition, which suitable for agricultural purpose, except some area near estuaries. The water qualities in the zone around the Andaman Sea are commonly in good condition, which could be utilized either for aquatic animal conservation, fisheries, swimming or water sports.

The highest loads of domestic wastewater from nearshore provinces can be found at Bangkok, the capital city of Thailand (1,163,450 m³/day or ca 2x10⁵ kg BOD/day). Total amounts of domestic wastewater from the nearshore provinces, which can be divided into the central part, the eastern part, and the southern part, are 1,685,002 m³/day, 601,473 m³/day, and 1,438,188 m³/day, respectively. Great amounts of BOD are generated each year by the coastal population. Of these, only about 13 % are removed by sewage treatment.

BIOREMEDIATION TECHNOLOGY

It is well known that among major problems facing the coastal zone today, the contamination of coastal water with organic pollutants is quite important. While regulatory steps have been implemented to reduce or eliminate the production and release to the environment, significant environmental deterioration has occurred in the past and will probably continue to occur in the future.

The need to remediate these sites has led to the development of new technologies called "Bioremediation" that emphasize the detoxification and destruction of the contaminants. Although bioremediation in the former time has focused on the use of microorganisms for routine treatment and transformation of waste products for more than 100 years, the new bioremediation technology here attempts to initiate broad focus on biological processes for the remediation of water, sediment, and similar environmental media.

The bioremediation technology involving the coastal zone development in Thailand has not long been utilized. There are some instances of bioremediation which have been attempted under several purposes as follows.

UTILIZATION OF MANGROVE FOREST FOR DOMESTIC WASTE TREATMENT

Replantation of mangroves

Mangrove is one of the most important natural resources in the coastal zone of Thailand. Utilization of the mangroves for local people has long been recognized. Nevertheless, only few researches on their potential on wastewater treatment have been conducted. Among these researches, some of them attempted to clarify mangrove potential on improvement of effluent from intensive shrimp culture farms and some has studied relationship between organically contaminated water and sediment, loaded
from the shrimp farms, and mangrove structure and growth.8) A promising study on application of mangroves for polluted water treatment has been carrying on from 1997 at Lam Pak Bia, Petchaburi Province in the Southern Thailand9). In this research, the potential of natural mangroves is compared to those of mixed specie, newly planted mangroves. Such experiments have been done both in the field area and the large concrete tank system. The species used for the experiments are Rhizophora apiculata, Avicennia spp., Bruguiera cylindrica, and Ceriops tagal. Among these, Rhizophora apiculata and Avicennia spp indicate most effective potential of wastewater treatment due to their tolerance and high growth rate. Although natural mangroves show the highest efficiency, the newly planted mangrove have revealed its remarkable potentials on BOD elimination and DO increment.

In addition, since the research is in preliminary step of work, more details on other nutrient modification technology will be further developed. Moreover, rate of the polluted water treatment by the natural mangrove should be clarified so as to determine the necessary areas of the mangrove, both of the natural and the planted ones, for the treatment purpose. Researches on long-term monitoring and assessment and those related biotic and non-biotic components in the ecosystem are suggested to deserve more depth study.

UTILIZATION OF SEAWEED FOR AQUACULTURE WATER TREATMENT

Realizing the importance of seaweed, research project on Algal Culture and Transferring Technology had been initiated since 1985. Accordingly, knowledge on seaweed distribution and culture have been gradually developed. Red algae in the genus of Gracilaria has been primarily focused since it can provide agar which is the economically important and broadly-used substance. Culture of Gracilaria in shrimp culture ponds and in effluent stocking ponds has been first conducted in 199010). At that time the problems on culture technique and pond condition were great so that result on roles of the seaweed on water quality could not be illustrated.

Thereafter, research on efficiencies of Gracilaria fisheri on reduction of ammonia, nitrite, nitrate and phosphate in shrimp pond effluents has been conducted11). The results indicate the importance of density used in the pond (suitable density 1 kg biomass/m²) and the necessary of development in culture method (insert-line method) and maintenance technique. Continued report on seaweed utilization during 1995 has concerned the absorption potential of nitrogen compounds in shrimp pond effluents by culturing green algae (Caulerpa macrophysa), brown algae (Sargassum polycystum), and red algae (Gracilaria salicornia)12). In the report, nutrient absorption capacity can be enhance by the ambient concentration in the effluents and the density 1g/l of effluent gave the highest rate of absorption.

There are also some studies concerning seaweed growth rates and some attempts to utilize mixed culture of red algae and other aquatic animals to treat the culture water. Most of them focus on the wastes from shrimp culture and related media. The important problems emphasized are the difficulties in species selection and preparation for the treatment and in handling of practical culture techniques. Limitation of application in high turbid effluent should also be carefully considered. Thus, for continuous and effective treatment, the needs of particular cares and depth study on related circumstances should be deserved.

UTILIZATION OF BRINE SHRIMP FOR AQUACULTURE EFFLUENT TREATMENT

Brine shrimp (Artemia salina) is well known as important shrimp feed which has been used widely in the shrimp culture system of Thailand. Primarily study on the utilization of Artemia sp. to control the quality of wastewater from intensive shrimp farming has depicted that the Artemia can apparently decrease the levels of BOD and chlorophyll in the treated samples within one week of experimental runs13).
More concrete study carried out later in 1991 has focused on the treatment efficiency of *Artemia* \(^{14}\). Major aim of this study was to treat the effluent water to the normal level compared to those of nearby aquatic ecosystem before the discharge. Results have revealed that this organism has maximum treatment efficiencies of BOD and chlorophyll of 0.1 mg BOD/individual/day and 4.8 mg chlorophyll/individual/day, respectively. Recent information indicates that adult stage of *Artemia* has higher treatment efficiencies.

Major problems of long-term treatment are caused by infections by other organisms, especially phytoplankton and protozoa species to *Artemia* filtering organ, and the increment of dissolved ammonium and phosphate concentrations in the treated water. Thus, high mortality rate can be observed during the late period of the experiments. From these findings, development of continuous circulation system and next-step water treatment should be carefully considered further.

**UTILIZATION OF OTHER ORGANISMS**

There are also other organisms utilized for wastewater and contaminated deposit treatments. An application of "green mussel" (*Perna viridis*) for biological treatment of effluents from intensive shrimp farm has been carried out by exposure of the organisms to the effluent for a study period\(^ {15}\).

![Green mussel (*Perna viridis*)](image)

Varying the mussel stocking density and monitoring of water quality and mussel survival rates, the results indicate potential of the mussel in water improvement. The density of 1 kg mussel/1 ton of stagnant water is recommend.

Case study of utilization of "bacteria" in coastal culture development focuses mainly on the improvement of water quality and enhancement of harvesting products. Common bacterial species used are *Bacillus subtilis*, *Enterobacter aerogenes*, and *Pseudomonas stutzeri*. The results show that production and survival rate of treated pond could increase more than 100 %\(^ {16}\).

Utilization of "vetiver grass" from different ecotypes for wastewater treatment is also one of interesting researches. The vetiver is a perennial, tropical grass and widely distributed throughout Thailand. Some report has revealed its possibility to be used as biological wastewater treatment since its well response as higher growth rate in the experiment with domestic waste treatment\(^ {17}\).

In addition, study on remediation techniques for the application of a deposit-feeding polychaete (Family Capitellidae) for treatment of organically polluted sediment of recent shrimp culture system of Thailand has been recently carrying on (Meksumpun C, unpublished data).

![Deposit-feeding polychaete (Capitella sp.)](image)

High possibility in effective use is expected since the polychaete has revealed its high efficiencies in organic elimination, sulfide detoxification, and re-oxygenation of the bottom deposit\(^ {18}\). Pilot-scale mass culture technique and application technique for field area is carefully developed.

**CONCLUSIONS AND RECOMMENDATIONS**

Similarly to the suggestion of Baker and Herson (1994), the authors believe that all bioremediation techniques depend on having the right organisms in the right place with the right environmental conditions for degradation to occur. Nevertheless, like any treatment technology, bioremediation has its limitation and disadvantage. Because of its complexity, successful bioremediation is dependent on an interdisciplinary approach involving such disciplines as microbiology, ecology, chemistry, geology, and engineering. Integration of knowledge is therefore necessary. Moreover, promotion of the potential for positive public participation is needed for broad utilization and achievement.

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