Sediment Quality in Cockle Culture and Non-Cultured Area at Bandon Bay, Thailand

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***Abstract*—** The indispensability of sediment for blood cockle is the sources of food, habitat, refuge and reproduction. Aside from water quality, sediment properties can be used to determine survival and growth as well as the estimation of the yield of the cockle culture. Cultured repeatedly in the same area for a long time will be impacted the soil quality is interesting to investigate. This study was aimed to compare the amount of total acid volatile sulfides (AVS), pH and water content of the sediment in the cockle culture and non-cultured area in the west coast of Bandon Bay, Thailand. Sampling sediments from 3 stations of culture area and 2 stations of non-cultured area collected with hand corer were cut into 4 levels, 0-2, 2-4, 4-6 and 6-8 cm before analyzed. Results showed that the AVS content in cockle culture areas (0.0124 ± 0.01 to 0.054 ± 0.01 mg / g) was higher than those in non-culture areas (0.0084 ± 0.00 to 0.0230 ± 0.01 mg / g) as well as the water content in soil of culture areas (41.22 ± 3.63 to 54.71 ± 1.84%) and non-cultured areas (39.97 ± 5.50 to 45.20 ± 14.54%). The pH of the both areas was expressed in weak acid to neutral (6.02 to 7.63). It was clearly demonstrated that cockle culture repeated in the same area influenced the accumulation of AVS content and the porosity of the sediment.

***Keywords*—** sediment, cockle culture, AVS, Bandon Bay

I. Introduction

BANDON Bay, a large bay located in the southeast of Thailand, consists of special ecosystems of sandy beaches, coral reefs, sea grass beds, mangrove forest, and other types of wetlands. The fertility of the area is influenced by the southwest monsoon and the northeast monsoon and plenty of rivers, mainly Tapi river, drained organic matter and minerals into the Bay. The amount of freshwater discharged to the Bay resulted the area become famous in many ways; tourism, recreation, coastal aquaculture and fisheries. Bandon Bay was classified as one of the best place suitable for spawning, nursery, and feeding grounds for various kinds of shellfish such as oysters, blood cockles, pearls, green mussels, surf clam, and crabs including shrimp culture [1]. The estimated productivity showed the greater comparing to the culture area in Malaysia and Ha long Bay in Vietnam [2]. Among shellfish culture, blood cockles became the most widely distribution around the east and west coast of the Bay.

Cockle is widely known high nutritional value and vital to the economy. Cockle farming in Bandon Bay has been done over 40 years cause of a less duration of culture, suitable characteristics of the area, easy management and high revenue. It was reported that total production of cockle in Thailand was 40,978 tons (in 2010), which was the part of Bandon Bay as high as 31.8 percent (13,049 tons) [3]. The culture was started by scattering young cockles (2,500 ind. per kg) at the ratio of 300-3,000 kg per hectare into the mud flat and left for 1 or 2 years until became the appropriate size (80-120 ind. per kg) without feeding. The products were yielded using rakes clam boat. Cockles are always buried under the sediment around 1-12 inches depth noticed from 2 holes at the surface, which is a channel for water in and out. They use foot movement to find food, avoid enemies and find the appropriate environment and also embed in the sediment to prevent the loss of water outside the shells [4]. After harvesting the shells, the surface of the sediment was disturbed by bamboo rake in order to remove the dead shells and residues. Then the next piles of young cockles will be started again and continue to culture sequences over and over like this.

A large-scale of cockles probably had the potential to change the delivery of biological and physical activities such as acting as a store of organic carbon, disturbance to sediments by movement the cycling of nutrients within sediment pore water through excretion, feeding and oxygenation within the upper sediment layers and will impact on the micro-benthic, macro-faunal communities and also microorganisms. Not only amount of cockles, but also lots of drain from community, industrial factory and farming areas discharged to the bay may affect the sediment quality. In addition, high nutrients inputs brought the increasing rates of organic matter produced by phytoplankton. After the death of plankton sinking to the bottom, they were consumed by microorganisms which decomposed organic materials. This process would reduce the limited oxygen in the sediments. Sulfur-reducing and sulfate-reducing bacteria generated usable energy under low-oxygen conditions by using sulfates to oxidize organic compounds or hydrogen and produced hydrogen sulfide as a waste product [5]. Hydrogen sulfide

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can react with metal ions in the water and produce metal sulfides, which are not water soluble. These metal sulfides, such as ferrous sulfide (FeS), are often black or brown, lead to the dark color of sludge [6]. It is mentioned as the dangerous substance for the environment. High concentrations of sulfide can affect the respiratory and metabolic depression of organisms in the ground such as various types of shells [7]. Due to growth of the shellfish relies on many factors, especially the suitable conditions and abundance of sediment. It is possible that the polluted will affect the quality of the sediment which is the substrate for cockle. In addition, the long term of culture in the same area may affect the sediment quality and directly due to the growth and survival of cockle.

Thus, it is necessary to study the characteristics and the composition of each layer of the sediment depth that is, however, expected to have an impact on the productivity of cockles. It will be made awareness of the relations between the characteristics of the sediment and the cockle yield and can be used as basic data for guidance in finding a way to increase the cockles in the future.

II. Materials And Methods

Sediment Sampling and analysis

The study sites were located at the west coast of Bandon Bay, Thailand, including three stations of culture area (station 1, 2 and 3) and two stations of non-cultured area (station 4 and 5). Sediment samples were collected at the cockle culture area by hand corer with three replicates and cut into 4 layers, each 2 cm depth, 0-2, 2-4, 4-6 and 6-8 cm, kept in plastic bags and analyzed as quickly as possible. Total acid volatile sulfides (AVS), pH and water content of the sediment were analyzed. AVS was assayed by changing sulfide in various forms (HS-, S_2- and FeS_2) into hydrogen sulfide (H_2S) using 18N sulfuric acid (H_2SO_4). The amount of hydrogen sulfide in the sediment was then measured using Hedrotek column (AVS test column). The analysis of pH was done according to [8]. 10 g of wet sediment was filled with 1N KCI 20-25 ml, mixed well and left for 30 min. The clear supernatant was measured with pH meter. Water content was analyzed according to [9].

III. Results And Discussion

Hydrogen sulfides in the sediment

The results showed that the amount of sulfides accumulated in the sediments collected from the cockle farms were 0.0430±0.002, 0.0315±0.011, 0.0345±0.030 and 0.0281±0.009 mg/g (station1), 0.0207±0.002, 0.0301±0.014, 0.0308±0.013 and 0.0541±0.012 mg/g (station2) and 0.0291±0.009, 0.0321±0.013, 0.0169±0.010 and 0.0124± 0.008 mg/g for station 3 at the depth of 0-2, 2-4, 4-6 and 6-8 cm, respectively. While the amount of sulfides accumulated in sediments from non-cultured area were 0.0092±0.008, 0.0159±0.014, 0.0116±0.005 and 0.0211±0.005 mg/g (station 4) and 0.0113±0.005, 0.0084±0.001, 0.0088±0.002 and 0.0230±0.011 mg/g (station 5) at the depth of 0-2, 2-4, 4-6 and 6-8 cm, respectively (Fig.1). It indicated that hydrogen sulfide content in sediment of cockle culture area was exactly higher than the area of non-cultured in total levels of depth. However, the results showed no significant difference ($p>0.05$) of the content in each layer.

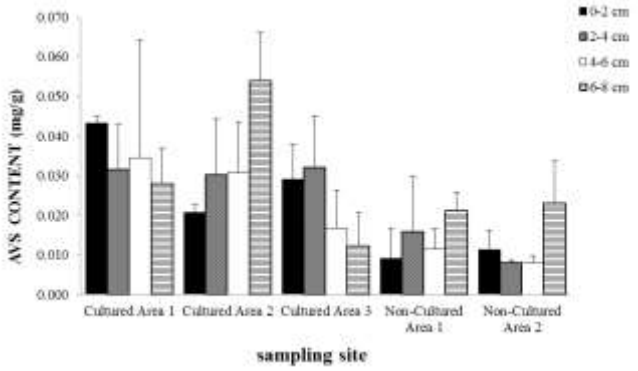

Fig.1 Hydrogen sulfide contents in layers of sediments collected from cockle culture and non-cultured area at Bandon Bay, Surat Thani Province

Sulfide in various forms occurred in the sediments had caused by biological and chemical processes. A direct role in the occurrence of sulfide is available bacterial decomposition of organic matter in the soil in anaerobic condition (anaerobic decomposition), using sulfate (SO_4^{2-}) as an electron acceptor in the reaction. The main group of bacteria is called "sulfate reducing bacteria" and the reactions of organic matter decomposition known as the "sulfate reduction" [7]. Clean sandy soil generally undetected amounts of sulfide. [10] reported that sediment at the level of 0-2 cm depth in the Gulf of Thailand and the east coast of Malaysia Peninsular was lower than 0.001 mg/ g dry wt.

Our results showed the content of hydrogen sulfide accumulated in sediment in culture area and non-cultured area in the same range of the other reports. [11] reported that the area of cockle culture at the coast of Samut Sakorn Province accumulated the content of hydrogen sulfide about 0.024 to 0.059 mg/g. [12] studied the distribution of hydrogen sulfide in sediment at shrimp culture area and reported the content of 0.058-3.149 mg/g dry wt. While the study of dynamics of the organic content and quality of the sediment at the mussel (*Perna viridis*) in Sriracha Bay was found that the amount of organic matter was 12-74 mg/g and the rate of precipitation in the culture area were higher than those of non-cultured area [13].

While some area that had unique characteristics such as the area crowded with tourists at Koh Samui, the mouth of Ban Prakong river during the bloom of red tide and the intensive area of oyster farm at the mouth of Welu river could find the amount of sulfide up to 0.3, 1.7 and 2.0 mg/g dry wt. of sediment, respectively [14]; [15]; [16]. It was reported that shrimp farm may cause the accumulation of nitrogen and hydrogen sulfide in sediment. Hydrogen sulfide at the area

nearby shrimp farm at Tha Thong canal (41.8±49.2 mg-S/kg) and Klong Ram (41.6±40.3 mg-S/kg) at Surat Thani Province, was higher than the far place at Bandon Bay (27.8±26.9 mg-S/kg) [17].

The accumulation of hydrogen sulfide depended on type of ground or floor. Mud or clay filled with organic matter had ability to sorb hydrogen sulfide better than sand. It is the reason that why the cockle area was appropriate to contain hydrogen sulfide much more than the non-cultured area. [18] proved that hydrogen sulfide produced from moist soils (50% water-holding capacity) was higher than those produced from air-dried soil. [19] studied the seasonal variation of nitrogen in the oyster farm in Thau Lagoon, France, and found that total organic content in culture area (49.6 mg/g) was higher than non-cultured area (13.3 mg/g). The character of soil in culture area was silt which was appropriated to the accumulation of organic matter and showed the high precipitation of sediment compared to the non-cultured area. However, our study took place in the west coast of Bandon Bay which consisted of sandy soil and sandy loam crumbly, so the difference of accumulation of hydrogen sulfide in sediment wasn't showed distinctively.

Hydrogen sulfide accumulation corresponded to the depth levels, soil character and composition of organic compound in the sediment. Normally, it would increase when the soil became deeper. In nature, the maximum hydrogen sulfide accumulation in sandy soil appeared at 6-8 cm depth, while at 2-3 cm depth from the surface belonged to mud or clay [7]. However, our results showed that the amount of sulfide was not related to the depth layer may be due to the influence of wind and water circulation in the bay. Since, there were many activities such as transportation of fright, fishing boats, collecting shells and recreation, and the area was exactly influenced by tidal. It may cause the spread up of the sediment to the surface water before settling down and some sediment may be moved.

Habitat of cockle mainly located in mud or loamy soil and the environment suitable for cockle farming should be settled at the coastal area near the mouth of the river or bay and character of the area was smooth mudflats with a thickness of 40-50 cm and slight slope, not so strong current. Water depth is approximately 0.5-1.0 m and salinity of water should be about 10-30 ppt. Excretion of the shells was buried in the mud and also mixed with the debris from the column water and other organic matter drained from the land. All matters were the great sources for anaerobic bacteria to produce by product, hydrogen sulfide. Hayakawa et al. (2001) studied the deposition of sediments from two sources of the oyster culture (*Crassostrea gigas*) at the mouth of Ofunato river, Japan, and found that the accumulations of organic matter were 49.12 mg/g and 50.45 mg/g and the sediments were mostly waste from the excretion of shellfish. In addition, [16] found that the amount of sulfides in the surface layer of the sediment collected from oyster farm and the accumulated waste mainly was from the excretion of the shell.

Water content in sediment

Water contents of sediments collected from the cockle culture area at Bandon Bay were 53.22±2.25, 46.74±2.89, 41.22±3.63 and 51.74±14.11% at the depth of 0-2, 2-4, 4-6 and 6-8 cm, respectively for station 1 (Figure 2), and 50.70±3.57, 54.71±1.84, 43.44±5.55 and 53.04±1.26% for station 2 and 43.24±3.37, 45.67±6.82, 44.54±7.01 and 42.68±5.68% for station 3. While water content of the sediments from non-cultured area were 40.80±1.04, 45.20±14.54, 42.76±2.30 and 44.74±4.18% at the depth of 0-2, 2-4, 4-6 and 6-8 cm (station 4) and 40.20±1.44, 39.97±5.50, 40.97±10.87 and 40.82±2.56% belonging to the depths of station 5 (Figure 2). It indicated that water contents in sediment of culture area were exactly higher than those of non-cultured area in total levels of depth, but not significantly difference ($p>0.05$) in different levels.

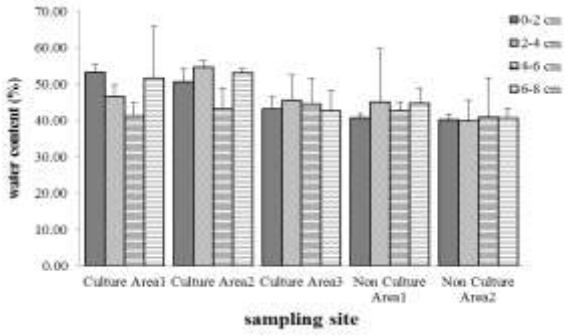

Fig. 2 Water content in layers of sediment collected from cockle culture and non-cultured area at Bandon Bay, Surat Thani Province

It was found that no relations between water content and the depth. The content did not show the significant difference in each layer of the sediment. However, water content in station 2 showed the high amount comparison to station 1 and 3, but the rest 2 stations of non-cultured area (station 4 and 5) expressed quantitatively similar for the depths.

Soil water content had a direct relationship to the amount of organic matter in the sediment [20]. Hence, the organic sediment could absorb too much water inside and caused sediment particles arranged loosely [21], so the high organic content in the sediment, the high capability of water content absorption as well. [22] examined sediment qualities in the Gulf of Santa Barbara and found that the amount of organic carbon increased 1% resulted the increase 9-28% of water content in soil. The result showed the high water content of sediment from culture area than those of non-cultured area. It seemed to explain that cockles are naturally located in the sediment around 1-12 inches depth and build holes at the surface as channels for water in and out. They come up to the water surface to find food, avoid enemies and find the appropriate environment before embed on the sediment to prevent the loss of water outside the shells. The frequent movement of the shells made the hole in sediment result the ability to absorb more water. Concentration of suspended particles in the water had a direct effect on the rate of feeding

for filter feeder like blood cockles [23]. They gained microbe, organic matter suspended in water and embed in mud, including phytoplankton in water volume [24]. Water content of the soil was the physical property indicated the nature of the arrangement of the particles and the hardness or soft of the sediments on the floor. It related to the particles, density and the porosity of the sediment [25]; [26]; [27]). In general, the fine soil is composed of high nutrients and large amount of organic matter deposited between space of particles. The deeper depth contained the high amount of nutrient, however, the nutrients were decreased at the level that the degradation by microorganisms occurred. Our results showed that the collected sediment was mud sandy soils, which could not store the amount of water and soluble nutrients, but provided the easily flow through and absorbed in the depth. So the surface layer composed of less concentration of nutrients and chemical and biological processes consumed those nutrients for the reaction would be occurred in the deeper. It is possible that to achieve the completion of the study and clearly explain, should be collected the soil samples in the longer depth.

pH of the sediment

pH in the soil will affect the absorption of minerals and the reaction of microbial degradation of organic matter. This is the reason why pH related to the occurrence of hydrogen sulfide. Our results showed that pH of sediments collected from the cockle culture area were 7.13±0.05, 7.24±0.02, 7.33±0.01 and 7.39±0.02 at the depth of 0-2, 2-4, 4-6 and 6-8 cm, respectively for station 1 (Figure 3), and 7.42±0.07, 7.61±0.10, 7.62±0.03 and 7.63±0.03 for station 2 and 7.30±0.11, 7.46±0.01, 7.57±0.03 and 7.63±0.01for station 3. While pH of the sediments from non-cultured area were expressed at 7.38+0.02, 7.35+0.01, 6.02+2.30 and 7.35+0.01% at the depth of 0-2, 2-4, 4-6 and 6-8 cm (station 4) and 7.21+0.01, 7.24+0.02, 7.29+0.01 and 7.30+0.01 for the depths of station 5 (Figure 3). It is indicated that pH in cockle culture area and non-cultured area in levels of depth were quite similar and both showed neutral, except at the level of 4-6 cm of non-cultured area seemed to be mild acid.

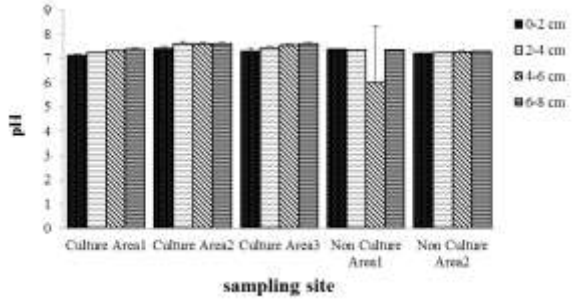

Fig. 3 pH in layers of sediment collected from cockle culture and non-cultured area at Bandon Bay, Surat Thani Province

pH acted as the environmental factors that influenced the growth of benthic organisms. It controlled the breakdown of the elements such as phosphorus and nitrogen in water which will be affected the phytoplankton to use those elements for growth [28]. The appropriate pH for aquatic animal was in the range of 6.5 to 9.0. The higher or lower pH would be harmful to the living, mostly be dangerous when pH<4 or pH>11 [29]. pH of sediment affected the distribution and activities of marine organisms. Low acidity condition restricted the shell synthesis and decomposition. Normally, pH of seawater occurred at 7.5-8.4[30]. It seemed depend on the topography and several environments such as soil and rocks characters. In the acidic soil, the water surrounding became acid and the microbial activity in the soil was affected. In addition, phytoplankton and microorganisms in aquatic area may cause the change of pH in water and soil. However, if water had high alkalinity, the change of pH was quite low [31].

Our results corresponded to [32] which reported that pH of sediment in cockle farms at Pattani Bay occurred in the range of 7.0-7.5. And pH at the mouth of Bangpakong river and Chonburi Bay (in 1995) was reported at 6.0-8.5 [33]. [34] reported that the sediment character at cockle farm at Samut Songkram and Petchburi Province consisted of clay, sand or mud. Mostly (40%) is clay soil and the pH values ranging from 7.3 to 7.6. Mild acidic, neutral and alkaline condition in the soil may cause of depth and tend to change the sediment color according to bacterial activity and also type of soil particles [7].

Sediment is a vital habitat for organisms living in the bottom ground. Sediment characters expressed an important role in determining the population structure, abundance and distribution boundary of organisms. Many factors influenced sediment also affected organisms located in. Finally, our results showed that cockle culture in the same area for a long time could accumulate hydrogen sulfide, a soluble toxic gas, in sediment more than non-cultured area, but there was no relationship between the sulfide accumulation and the sediment layers. Water content of the culture area was quite higher due to the movement and activities of the cockles and no significant different of pH in sediment layer of both area. However, it could not be concluded at now that the amount of hydrogen sulfide occurred would directly affect growth and survival of cockle culture at Bandon Bay.

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