Study the effects of different media derived from palm shell for marine shrimp discharge filtration

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Abstract. Marine shrimp culture is important in agricultural sector which generates income for farmers. If marine shrimp culture is not proper management, it can cause environmental impacts on coastal ecosystem and water quality. Some areas use water spraying, washing and then flushing the pond bottom after shrimp harvesting and discharge water to receiving water which high nutrient and suspended solids exceeded the effluent standard. This research studied the marine shrimp discharge filtration using different media derived from palm shell. Three different media types for wastewater filtration were palm shell biochar (B), raw palm shell (R) and palm shell mixed with palm shell biochar (volume ratio of 1:1) (M). The simulated wastewater was daily fed via the top of the filter in semi-continuous mode (8 hours/day) at the hydraulic retention time of 4 h. During the 54 days of operation, water sample was collected to analyse SS, BOD, NH₃-N, TP and FCB. At day 54th of operation, the average suspended solids (SS) removal efficiencies of B, R and M were 84, 82 and 84%, respectively, and the average total phosphorus (TP) removal efficiencies were 33, 28 and 30%, respectively. All filters could remove ammonia on the first 30 days of operation in which the concentration met the standard requirement of <1.1 mg/L. The average influent biochemical oxygen demand (BOD) concentration of 27 mg/L can be reduced to less than 20 mg/L after 3 days of operation in all filters. In addition, all filters were able to reduce the fecal coliform bacteria (FCB) to a lower concentration. Thus, these three different media are environmentally friendly material that can be used for effluent water filtration in the small-scale shrimp farm.

Keywords: Palm shell, Shrimp farm, Wastewater treatment, Waste management

1. Introduction

Marine shrimp culture is important in agricultural sector which generates income for farmers. The increasing of shrimp demand in the market resulted in the continuing of aquatic resources degradation if marine shrimp culture is not proper management. For example, farmer removes the sediment after shrimp harvesting by spraying, washing and then flushing out of the pond. This method is time-saving and low cost, but the consequence of rich organics in the sediment could affect the receiving water quality and mangrove forest which is a nursery place of coastal animals. Bottom sediment of shrimp
pond composes of shrimp excretion, residual food, chemical residues and inorganic substances. The 27% of nitrogen in the intensive shrimp pond was found in the sediment, whereas 45% was found in dissolved and suspended in water [1].

Biological filtration is one of wastewater treatment processes that can effectively remove organic substance. The biofilter mainly relies on the activities of the microorganisms that are attached onto the filter media. Ideal media for filters should provide high specific surface area, high porosity, low cost and durability [2]. Plastic media have become more common use, however, they are expensive and can not or less decompose after used. Recently, biochar is a popular media due to its physical characteristics, sustainable production, and global availability which high effective COD and total nitrogen removal as same as granular activated carbon [3]. In addition, natural media such as wood chips from bamboo and eucalyptus [4], sea shells [5] were also used as filter media in biofilter. Palm oil is an economically important vegetable oil in Thailand, so a huge of palm shells waste was produced from palm mill every day. A few researches had used palm shell for filter media and there was no work investigate the using of raw palm shell mixed with biochar. Thus, this research tries to use this agricultural waste as an environmentally friendly filter media by directly use as raw materials, as biochar and mixed of raw materials and biochar for marine shrimp discharge treatment. In addition, the performance of reactor at different hydraulic retention times was also investigated.

2. Materials and Methods

2.1 Filter media
Palm shell residues from palm oil refining process at southern Thailand were used as a filter media in this study. There are 2 types of filter media, namely, raw material and biochar from palm shell. Palm shell was washed with tap water, then they were dried in the hot air-oven at 70 °C for 24 h before used. Palm shell biochar was prepared by carbonization of washed palm shell in a 200 liters steel drum kiln under the limitation of oxygen gas.

2.2 Reactor design
A column experiment was set up in order to test and compare the three different filter media, namely palm shell biochar (B), raw palm shell (R) and palm shell mixed with palm shell biochar (volume ratio of 1:1) (M) for treatment of marine shrimp discharge water. The cylindrical shaped-acrylic columns with inner diameter of 7 cm and height of 65 cm were used. The height of the filter media is 50 cm and the working volume of 1.925 liter. Three sampling outlets were placed at 20, 40 cm from the top and bottom of the reactor as shown in Figure 1.

Figure 1. Diagram of the filter columns for this study.
2.3 Simulated marine shrimp discharge water

Sediment and water samples of three shrimp ponds after pond preparation were taken from 3 shrimp farms at Phang Nga province and were kept in ice box at a temperature of 4 °C before analysis at environmental laboratory, KMUTT, Bangkok, Thailand. The samples were analyzed for pH, suspended solids (SS), biochemical oxygen demand (BOD), ammonia (NH₃), total phosphorus (TP), total coliform bacteria (TCB) and fecal coliform bacteria (FCB). The simulated wastewater was prepared by mixing 6 kg of sediment with 40 L of simulated seawater solution and adjusted the property to similar the water samples (see Table 1). The simulated seawater solution was prepared by dissolving 6 kg natural seawater powder (produced by Phetchaburi aquacultic demonstration farm, Thailand) in 200 L of tap water and then aerate continuously for 3 days.

| Table 1 | The property of shrimp discharge water. |
|---------|----------------------------------------|
| pH      | SS (mg/L) | BOD (mg/L) | NH₃ (mg-N/L) | TP (mg-P/L) | TCB (CFU/100 mL) | FCB (CFU/100 mL) |
|         | 7.08 ± 0.02 | 341 ± 60 | 28.70 ± 1.5 | 1.54 ± 0.80 | 0.43 ± 0.03 | 20967 ± 1401 | 4800 ± 600 |

2.4 Start-up and operation of the filter

All filter media were soaked in tap water for 24 hours to allow the media adsorbed water. Then, they were packed into the columns and were gradually filled with simulated wastewater for 8 hours and left overnight. After that, the operation at the hydraulic retention time (HRT) of 4 hours was started. The operation time of the filter was imitated the real water discharge by farmer’s work at 8 hours/day (semi-continuous mode). The simulated wastewater was daily fed via the top of the filter at 9 a.m. Effluent samples were collected and analyzed for pH, SS, NH₃-N, TP, BOD and FCB at 5 p.m. After 30 days of operation, the influent was adjusted to give the average NH₃-N concentration from 0.45 to 1.2 mg/L for study performance. During 57 day of operation, the samples were collected at 20, 40 and 50 cm along the depth of the filter.

3. Results and discussion

3.1 Operational filter performances

In this study, the main constituents of the influent contain high levels of pollutants which did not meet effluent quality standard for coastal aquaculture (see Table 2) by the government of Thailand [6].

| Table 2 | The influent for study and the effluent quality standard for coastal aquaculture. |
|---------|----------------------------------------|
| pH      | SS (mg/L) | BOD (mg/L) | NH₃ (mg-N/L) | TP (mg-P/L) |
| Influent | 6.7-7.8 | 110-390 | 21-38 | 0.35-1.2 | 0.40-0.52 |
| Standard | 6.5-8.5 | < 70 | < 20 | < 1.1 | < 0.4 |

3.1.1 Suspended solids, ammonia, and total phosphorus concentration and treatment efficiency

Figure 2 shows the variation of SS in the effluent of the three filters over the entire operational period lasting 54 days. The effluent suspended solids concentration of all filters decreased continuously on the first 20 days, then decreased slowly and stable. The effluent SS concentration from B filter was lower than from R and M filter. This SS removal may due to adsorption in the biochar. Although the influent SS concentrations was increased after 30 days of operation, it was found that effluent SS concentration from all filter media was not exceed the effluent quality standard for coastal aquaculture. No clogging problem was observed throughout this study, this may be due to the short-term study. The average SS removal efficiencies of 84, 82 and 84% were found for B, R and M filters, respectively.
It can be seen in Figure 3 that all filters showed the increment of ammonia (NH$_3$-N) concentration in the effluent on the first 25 days of operation. The effluent NH$_3$-N concentrations of all filter were even higher than that of influent which implies that all media release nitrogen with the effluent in the first phase of operation. The NH$_3$-N concentration in effluent were 0.47, 0.50 and 0.56 mg/L for B, R and M filters, respectively. After 25 days of operation, biofilm was observed on the surface of the media and the effluent NH$_3$-N concentrations of all filters slowly decreased. The gradually low NH$_3$-N concentrations in the effluent showed that a period of 20-30 days is required for nitrifying community to stabilize under these loadings [7]. At this time, occurrence of biological processes due to coverage by the biofilm layer, biofilm growth and nitrifying bacteria were able to utilize NH$_3$-N as nutrient sources, resulted in enhanced nitrogen removal. After 30 days of operation, it was found that all filter media could treat ammonia although the influent NH$_3$-N concentrations was increased. The average removal efficiencies of 13, 13 and 12% were found for the B, R and M filters, respectively.

Total phosphorus (TP) concentration in the effluent of B, R and M filters decreased throughout the operation period (see Figure 4). The effluent TP concentration from B filter was lower than in R and M filter, this was assumed to be due to adsorption. Bali and Gueddari [8] presented that the phosphorus removal is not attributed to microbial uptake, but it is mainly due to physical–chemical mechanisms such as adsorption and precipitation. In another research reported that the most of TP was removed by the adsorption [7]. The average TP removal efficiencies of 34, 27 and 29% were found for B, R and M filters, respectively.

![Figure 2. Variation of SS concentration during operation.](image1)

![Figure 3. Variation of NH$_3$-N concentration during operation.](image2)

![Figure 4. Variation of TP concentration during operation.](image3)
3.1.2 BOD and FCB and treatment efficiency

Biochar filter had the most removal of BOD, the effluent BOD concentration less than 10 mg/L was obtained in the first 24 days of operation (see Figure 5). The decreased of effluent BOD concentration on the first phase may due to adsorption since biochar filters are characterised by specific surface and high porosity, which provides better absorption and reduce of organic matter [9]. However, all filters can remove BOD concentration from average influent concentration of 27 mg/L to less than 20 mg/L (follow Std.) after the first 3 days of the operation from filtration processes and biological activities due to development of a biofilm.

The R and M filters could remove FCB in the influent from approximately 3,900 CFU/100 mL to less than 2,500 CFU/100 mL after the first 10 days of the operation (Figure 6). Meanwhile, biochar gave higher effluent FCB concentration than raw palm shell and mixed media. The decreased of effluent FCB differs between materials due to filtration processes, inappropriate conditions for growth and different characteristics. Raw palm shell composed nearly 54% of lignin [10] and lignin can inhibit the growth of gram-negative bacteria (E. coli, S. typhimurium and V. cholera) [11]. The structure of biochar, which is characterized by large specific surface and high proportions of micro- and macropores, provides a good environment for shelter, protection and growth of bacteria [9].

3.2 Performance along the depth of the biochar filter

Table 3 showed the variation of SS, NH₃-N, TP, BOD and FCB in the effluent at different depths of the biochar filter. The pollutants removal increased with the increasing depth. Long contact time of wastewater with the active biofilm on media promotes better biological degradation of organic pollutants and enhancing the chances of adsorption [12].

| Filter | Depth (cm) | SS (mg/L) | NH₃ (mg-N/L) | TP (mg-P/L) | BOD (mg/L) | FCB (CFU/100 mL) |
|--------|------------|-----------|--------------|-------------|-------------|-----------------|
| Influent | -          | 304       | 1.130        | 0.458       | 28.0        | 4100            |
|         | 20         | 101       | 1.020        | 0.375       | 16.0        | 3500            |
| B       | 40         | 47        | 0.966        | 0.314       | 9.0         | 2500            |
| Eff     | 42         |           | 0.927        | 0.281       | 7.5         | 2000            |

Figure 5. Variation of BOD concentration during operation.

Figure 6. Variation of FCB concentration during operation.

Table 3 The pollutant concentrations along different depths of biofilter on day 57 of operation.
4. Conclusion

It can be concluded from the present study that palm shell, a low-cost agricultural residue, can be successfully used as filter media for treatment shrimp discharge wastewater. Palm shell biochar showed more efficient pollutants removal than raw palm shell and mixed media when operating in long term. Scale-up of design and operation of filter system can be applied for marine shrimp discharge.

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