Carbonaceous biochemical oxygen demand and nitrification oxygen demand of the effluents of *Penaeus monodon* culture ponds

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Abstract

Five-day carbonaceous biochemical oxygen demand ($CBOD_5$) of *Penaeus monodon* pond effluents varied between 9.3 and 34.0 mg/l and ultimate carbonaceous BOD of the effluent varied between 10.7 and 42.0 mg/l. $CBOD_5$ of the effluents were 51-2 to 86.9 percent of ultimate CBOD. Rate of biochemical oxidation (k) of shrimp pond effluents varied between 0.06 and 0.18 per day with an average k value of 0.12. Nitrification oxygen demand of shrimp pond effluents varied between 0 and 1.0 mg/l at 5 days, 0.4 and 22.9 mg/l at 10 days and 13.4 and 38.2 mg/l at 20 days. Combined oxygen demand of shrimp pond effluents varied between 9.3 and 34.0 mg/l at 5 days, 20.4 and 64.6 mg/l at 10 days, and 28.0 and 80.0 mg/l at 20 days. At 20 days, nitrification oxygen demand were 29.0 to 61.8 percent of combined oxygen demand. Results of laboratory scale investigation indicated that aeration can significantly increase reduction rate of BOD_5 of shrimp pond effluents.

Introduction

The biochemical oxygen demand (BOD) test is a bioassay procedure involving the measurement of oxygen consumed by living organisms, mainly bacteria, while utilizing the organic matter present in a waste, under conditions as similar as possible to those that occur in nature. The BOD test may be considered as a wet oxidation procedure in which the living organisms serve as the medium for oxidation of the organic matter to carbon dioxide and water. A quantitative relationship exists between the amount of any given organic compound to carbon dioxide, water, and ammonia.
On the basis of this relationship, it is possible to interpret BOD data in terms of organic matter, as well as the amount of oxygen used during its oxidation.

The nitrifying bacteria, which oxidize non-carbonaceous matter for energy, are usually present in relative small numbers in untreated domestic sewage, and their reproductive rate at 20°C is such that the populations do not become sufficiently large to exert an appreciable demand of oxygen until about 8 to 10 days have elapsed in the regular BOD test(Sawyer et al, 1994). Once the organisms become established, they oxidize nitr ogen in the form of ammonia to nitrite and nitrate in the amount that introduce serious error into BOD work.

In intensive culture of shrimp, large amount of feed is introduced into culture ponds. Part of the feed is consumed and utilized for growth and energy source by shrimp. However, large amount of feed is also left in the ponds as uneaten feed. Shrimp feces also contain organic matter that is not utilized by shrimp. It is calculated that only small portion, 11.7 to 13.5 percent, of given feed are converted to shrimp fresh and large portion, 61.7 to

68.1 percent, are leftover in the ponds as feces and shrimp molt. Some parts of the feed, 18.4 to 25.0 percent, is utilized for energy through respiration(Ruttanagosrigit, 1997). Feed conversion ratio (FCR) of the intensive culture of *Penaeus monodon* are between 1.5-1.8 (Lie, 1983; Chen et al, 1989; Muthuwan, 1991). However, if high stocking density is used, feed conversion ratio may increase to the level of 2.0-3.0 (Boyd, 1989). Nutrient released from decomposed feed will trigger phytoplankton bloom and add up organic matter into the pond system(Boyd, 1992). The built up of organic matter in shrimp ponds result in pond environmental problem which directly affect shrimp. Organic matter released from shrimp ponds in the effluents also can create environmental problem in surrounding water. Results from the investigation by Musig et al (1995) indicated that BOD_5 of the effluent from shrimp ponds, utilizing water exchange system, releasing during culturing period, were between 2.5 and 10.7 mg/l and most of them were less than 10 mg/l. The highest BOD_5 of the effluents were detected during the last two week of grow-out period and also during harvest with the BOD_5 values varried between 19.0-60.5 mg/l. Shrimp pond effluents contained 11.6 to 251.0 mg/l of total suspended solids, 0 to 0.1018 mg/l of total phosphorus, and 0.0104 to 0.5398 mg/l of inorganic nitrogen (Musig et al, 1995).

BOD_5 has been included in parameters for shrimp pond effluent standard and BOD_5 measurement has been widely practice to determine pond water quality and pond effluent quality.

This investigation was carried out to study the nature of the decomposition of organic matter in the effluents of *Penaeus monodon* culture ponds by studying biochemical oxygen demand of shrimp pond effluents. Nitrification oxygen demand of the effluents were also investigated. The study was also done to investigate the possibility of using aeration to reduce BOD_5 of the effluents.

Materials and Methods

Biochemical oxygen demand of shrimp pond effluents were studied using effluents from intensive culture ponds from 5 shrimp farms in Trad and Chantaburi provinces. The effluents were collected and carbonaceous biochemical oxygen demand and combined oxygen demand of each effluent were measured at 1, 2, 3, 4, 5, 6, 7, 8, 10, 12, 14, 16, 18, and 20 days using dilution method (APHA, AWWA and WEF, 1998). Carbonaceous biochemical oxygen demand were measured by inhibiting nitrification by the application of a nitrification inhibitor, TCMP [2-chloro-6, (trichloromethyl) pyridine] (APHA, AWWA and WEF, 1998).

Nitrification oxygen demand was calculated by subtracting carbonaceous oxygen demand from combined oxygen demand. Ultimate carbonaceous BOD were estimated using Fujimoto methods(Fujimoto, 1961). Rate of biochemical oxidation were calculated from following equation(Hammer and Hammer, 1969);

$$y = L(1-10^{-kt})$$

where L = Ultimate carbonaceous BOD (mg/l)

y = BOD_5 (mg/l)

t = 5 days

k = rate of biochemical oxidation(per day)

The study of the effect of aeration on BOD_5 of shrimp pond effluents were conducted in laboratory scale experiments. The study was done in 61x42x20 cm. plastic containers containing 30 liters of shrimp pond effluent. Shrimp pond effluents from 2 shrimp farms in Chantaburi province were used for this study. Treatments included control without aeration and treatment unit with aeration. Aeration was provided by air-compressor through air-stone. Five replications were set for each treatment. BOD_5 of the effluent in each treatment unit were measured periodically for 7 days. Five replications were set for each treatment. Data were analyzed statistically to study the effect of aeration on BOD_5 of the effluents.

The analysis of the effluent quality were done according to the methods recommended by APHA, AWWA, and WEF (1998). BOD of the effluents were analyzed by dilution method. Carbonaceous oxygen demand was measured by inhibiting nitrification using 2-chloro-6-(trichloro methyl) pyridine (TCMP) (APHA, AWWA, and WEF, 1998).

Results

Five-day carbonaceous biochemical oxygen demand ($CBOD_5$) of shrimp pond effluents varied between 9.3 and 34.0 mg/l and ultimate carbonaceous biochemical oxygen demand of the effluent varied between 10.7 and 42.0 mg/l. Five- day biochemical oxygen demand were 51.2 - 86.9% of ultimate biochemical oxygen demand. Average BOD_5, BOD_{10} and BOD_{20} of shrimp pond effluents were 20.4, 28.0 and 28.5 mg/l, respectively. Ten-day Carbonaceous biochemical oxygen demand were 84.3 to 100 percent of ultimate CBOD and 20-day carbonaceous oxygen demand were 91.9 to 100 percent of ultimate BOD (Table 1).

The BOD_5 values of the effluents was 86.9% of ultimate BOD when k-value was 0.18 and decreased to 79.8-81.0, 61.1% and 51.2% of ultimate BOD when k-value was 0.14, 0.13, 0.08 and 0.06 . Average ultimate BOD of shrimp pond effluent was 30.6 mg/l. The rate of biochemical oxidation (k) of the effluents varied between 0.06 and 0.18 with average k value of 0.12 (Table 1).

There was no nitrification oxygen demand in three shrimp pond effluents at day 5 but in the other two shrimp pond effluents, nitrification oxygen demand were detected at low level of 0.4 and 1.0 mg/l or about 0.02-0.06% of combined oxygen demand (Table2,4). Nitrification oxygen demand of shrimp pond effluents were detected beginning from day 5 and day 6 (Fig. 1-5). At day five, nitrification oxygen demand were between 0 and 1.0 mg/l. At day 10, nitrification oxygen demand of the effluent were between 0.4 and 22.9 mg/l and nitrification oxygen demand at day 20 were between 13.4 and 38.2 mg/l (Table 2). Significant level of nitrification oxygen demand of the effluents were mostly detected starting from day 7 and day 10. In one effluent significant level of nitrification oxygen demand was not observed until day 16 (Fig.1-5).

Five days combined oxygen demand of the effluents were between 9.3-34.0 mg/l then increased to 20.4-64.6 mg/l on day 10. Twenty days combined oxygen demand were between 28.0-80.0 mg/l(Table 3). Carbonaceous BOD increased rapidly during the first 5-7 days and then leveled off while combined oxygen demand still rising as the result of nitrification processes (Fig. 1-5).

Table 1. Carbonaceous biochemical oxygen demand of the effluents from shrimp ponds (mg/l)

Days	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Average
5	34.0 (81.0%)*	9.3 (86.9%)	16.6 (79.8%)	25.3 (61.1%)	17.0 (51.2%)	20.4 (67.6%)
10	41.7 (99.3%)	10.7 (100.0%)	20.0 (96.2%)	39.4 (95.2%)	28.4 (84.3%)	28.0 (94.6%)
20	41.8 (99.5%)	10.7 (100.0%)	20.4 (98.1%)	39.4 (95.2%)	30.5 (91.9%)	28.5 (96.3%)
Ultimate BOD	42.0	10.7	20.8	41.4	33.2	29.6
k value (per day)	0.14	0.18	0.14	0.08	0.06	0.12

Remark: * = percent of ultimate BOD exerted

Table 2. Nitrification oxygen demand of the effluents from shrimp ponds (mg/l)

Days	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Average
5	0	0	0	0.4	1.0	0.3
10	22.9	12.6	0.4	11.8	10.1	11.6
20	38.2	17.3	13.4	16.1	20.7	21.1

Table 3. Combined oxygen demand of the effluents from shrimp ponds(mg/l)

Days	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Average
5	34.0	9.3	16.6	25.7	18.0	20.7
10	64.6	23.3	20.4	51.2	38.5	39.6
20	80.0	28.0	33.4	55.5	51.2	49.6

Table 4. Percentage of nitrification oxygen demand in combined oxygen demand of shrimp pond effluents(%).

Days	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Average
5	0	0	0	0.02	0.06	0.02
10	35.4	54.1	0.02	23.1	26.2	27.8
20	47.7	61.8	40.1	29.0	40.4	43.8

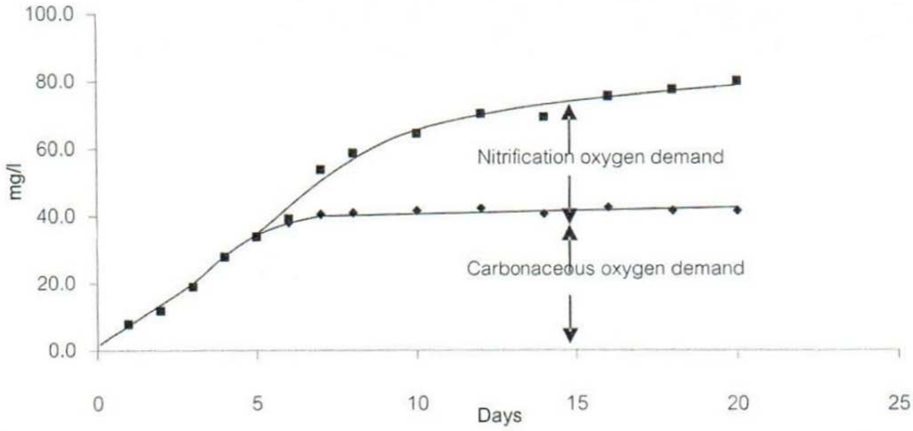

Fig. 1. Carbonaceous and nitrification oxygen demand of the effluent from shrimp pond in Klong Khud, Tamai district, Chantaburi province (Farm 1).

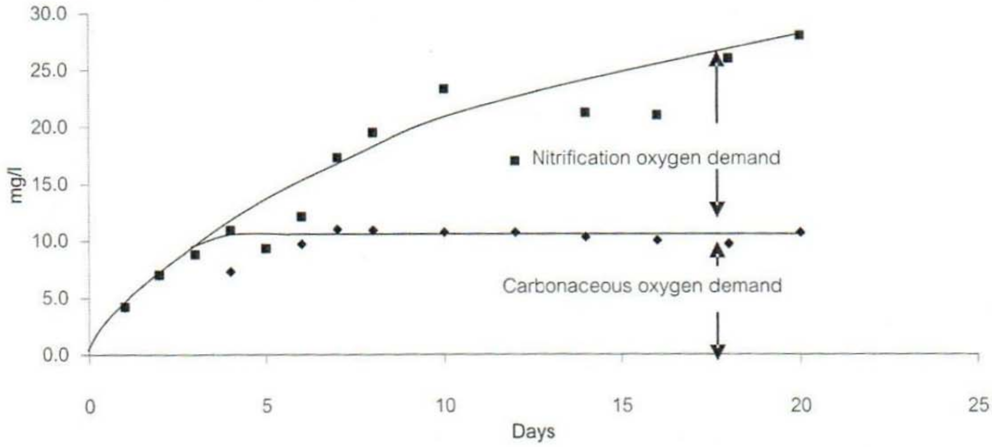

Fig. 2. Carbonaceous and nitrification oxygen demand of the effluent from shrimp pond in Kung Kaben, Tamai district, Chantaburi province (Farm 2).

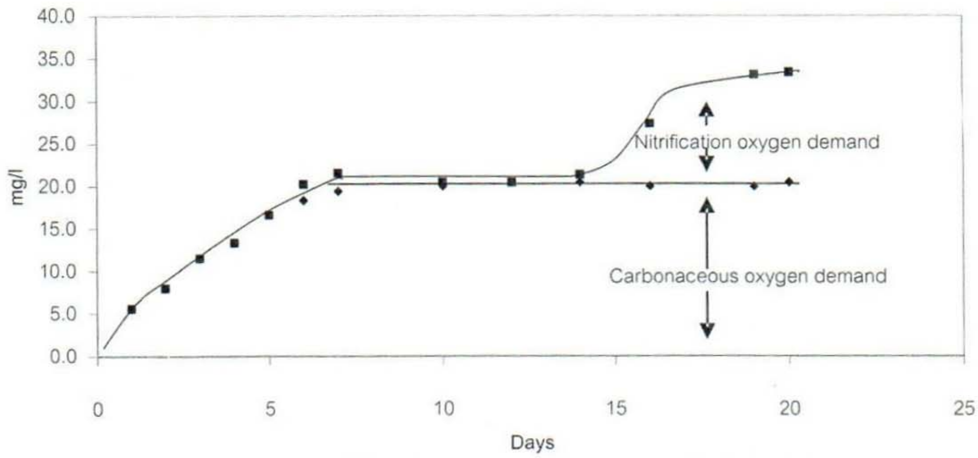

Fig. 3. Carbonaceous and nitrification oxygen demand of efluent from shrimp farm in Laen Ngob district, Chantaburi province (Farm 3).

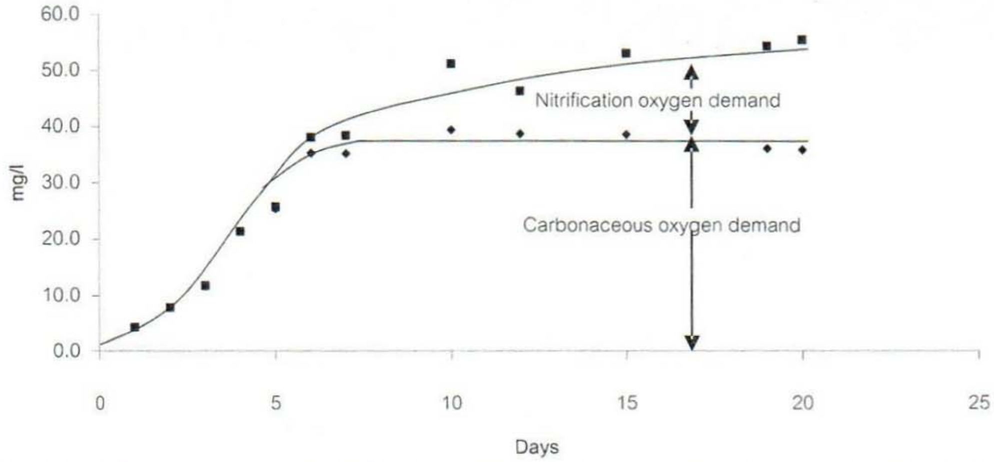

Fig. 4. Carbonaceous and nitrification oxygen demand of shrimp pond effluent from shrimp farm in Charngkharm, Na Yai Arm district, Chantaburi province (Farm 4).

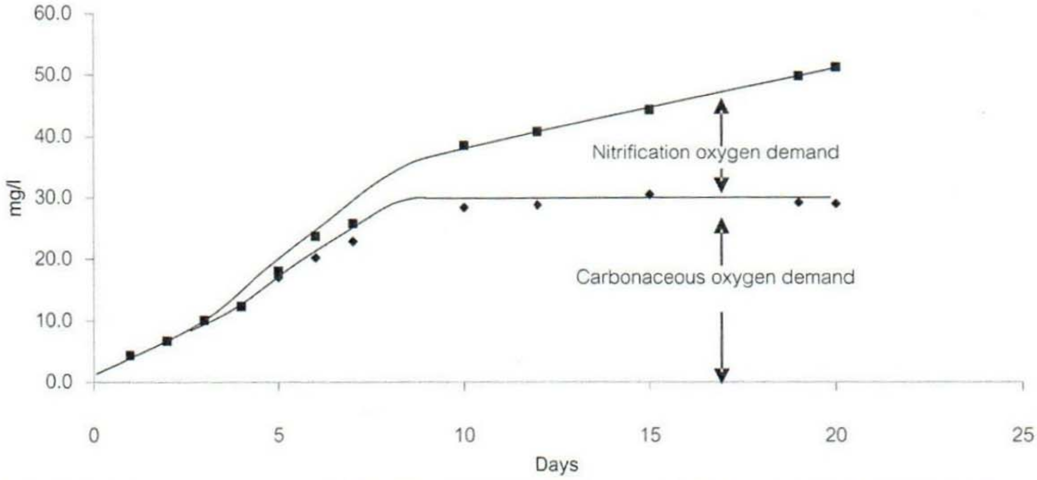

Fig. 5. Carbonaceous and nitrification oxygen demand of the efluent from shrimp pond in Bang Chan, Khlung district, Chantaburi province (Farm 5).

Results of laboratory scale investigation indicated that aeration can significantly increase reduction rate of BOD_5 of shrimp pond effluents. In the experiment with the effluent from farm 1, BOD_5 of shrimp pond decreased 38.7, 54.3, 67.2, and 73.7 percent at day 1, 3, 5, and 7, in control with no aeration. In treatment with aeration, BOD_5 of the effluent decreased 44.0, 66.4, 81.9, and 83.6 percent at day 1, 3, 5, and 7 which were significantly higher than the decreasing rate of control($P<0.5$).

In the experiment with the effluent from farm 2, BOD_5 of shrimp pond decreased 30.5, 43.3, 52.9, and 72.7 percent at day 1, 3, 5, and 7, in control without aeration. While in treatment with aeration, BOD_5 of the effluent decreased 59.4, 61.5, 80.2, and 88.2 percent at day 1, 3, 5, and 7 which were significantly higher than the decreasing rate of control($P<0.5$). Average decreasing rate of BOD_5 of the effluent in control and in treatment units with aeration were 34.6 and 51.7 percent on day 1, 48.8 and 68.9 percent on day 3, 60.0 and 81.0 percent on day 5, and 71.7 and 85.9 percent on day 6 (Table 5,6, Fig.6,7).

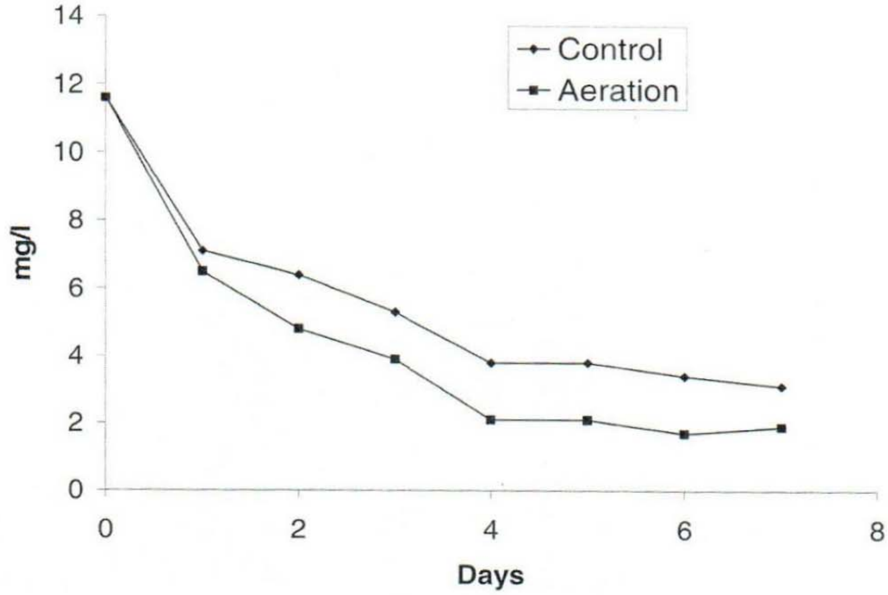

Fig. 6. Effect of aeration on BOD_5 of shrimp pond effluent from farm 1.

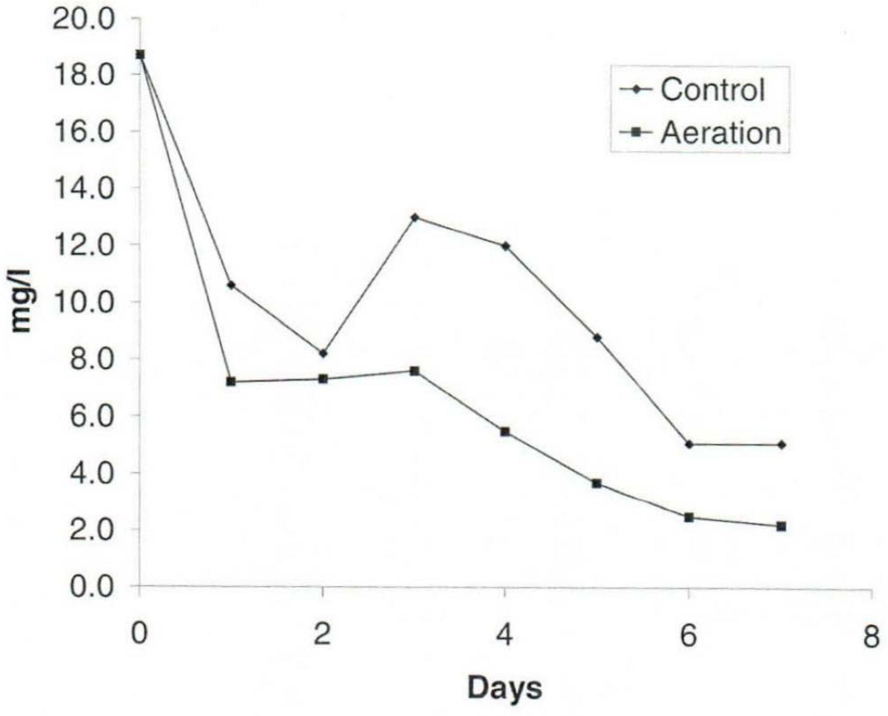

Fig. 7. Effect of aeration on BOD_5 of shrimp pond effluent from farm 2.

Table 5. The change in BOD_5 of shrimp pond effluents with and without aeration(mg/l).

Farm 1			Farm 2		
Days	Control	Aeration	Days	Control	Aeration
0	11.6	11.6	0	18.7	18.7
1	7.1	6.5	1	13.0	7.6
3	5.3	3.9	3	10.6	7.2
5	3.8	2.1	5	8.8	3.7
7	3.1	1.9	7	5.1	2.2

Table 6. The decreasing rates of BOD_5 of shrimp pond effluents with and without aeration (%).

Farm 1			Farm 2			Average	
Days	Control	Aeration	Days	Control	Aeration	Control	Aeration
1	38.7	44.0	1	30.5	59.4	34.6	51.7
3	54.3	66.4	3	43.3	61.5	48.8	63.9
5	67.2	81.9	5	52.9	80.2	60.0	81.0
7	73.3	83.6	7	72.7	88.2	73.0	85.9

Discussion

The different among carbonaceous BOD_5 of the effluents from shrimp farms which varied between 9.3 – 34.0 mg/l resulted from several factors including culturing system, stocking density, feed and feeding, and pond management. Total or combined oxygen demand of the effluent at day 5 varied between 9.3- 34.0 mg/l. There was no nitrification oxygen demand in three shrimp pond effluents at day 5 but in the other two shrimp pond effluents nitrification oxygen demand were detected at low level of 0.4 and 1.0 mg/l or about 0.02-0.06% of combined oxygen demand (Table2,3,4). According to Sawyer et al(1994), the nitrifying bacteria, which oxidize noncarbonaceous matter for energy, are usually present in relative small numbers, and their reproductive rate at $20^{\circ}C$ is such that the populations do not become sufficiently large to exert an appreciable demand of oxygen until about 8 to 10 days have elapsed in the regular BOD test. Once the organisms become established, they oxidize nitrogen in the form of ammonia to nitrite and nitrate in the amount that introduce serious error into BOD work. Significant level of nitrification oxygen demand of the effluents in this study were detected starting from day 7 and day 10. In one effluent significant level of nitrification oxygen demand was not observed until day 16. Result from this study indicated that the use of nitrification inhibitor for routine BOD_5 measurement of shrimp pond effluent might not be necessary.

High value of nitrification oxygen demand, which were between 29.0 and 61.8 percent and 0.02 and 54.1 percent of 20-day and 10-day combined oxygen demand, indicated that ammonia was accumulated in the effluent. The accumulation of large amount of ammonia in shrimp ponds resulting from the decomposition of uneaten and undigested shrimp which is high in protein content.

The average rate of biochemical oxidation (k) of 0.12 per day is lower than average k value of domestic waste which is about 0.17 per day. For many years the BOD reaction was considered to have a rate constant k equal to 0.10 per day at 20°C. This value was established by extensive study of polluted river and domestic wastes in the United States and England. As the application of BOD test spread to the analysis of industrial wastes, and the use of synthetic dilution water become established, it was noted that k values considerably in excess of 0.10 per day were involved and that an appreciable variation occurred for different waste materials. It was also found that k values for domestic waste varied considerably from day to day and averaged about 0.17 per day rather than 0.10 per day as originally determined. Also the k values for effluents from biological waste treatment plants were found to be significantly lower than that of the raw wastes (Hammer and Hammer, 1996; Sawyer, et al, 1994).

Two major factors involving in the variation in k values are the nature of organic matter and the ability of the organisms present to utilize the organic matter. Organic matter occurring in domestic and industrial wastes varies greatly in chemical character and availability to microorganisms. That part which exists in true solution is readily available, but that part which occurs in colloidal and coarse suspension must await hydrolytic action before it can diffuse into the bacterial cells where oxidation can occur. The rate of hydrolysis and diffusion are probably the most important factors in controlling the rate of the reaction. It is well known that simple substrates, such as glucose, are removed from solution at very rapid rates, and k value are correspondingly high. More complex materials are removed much more slowly, and k values are lower. In a complex material such as domestic waste, reaction rates are modified greatly by the more complex substances, whereas in an industrial waste containing soluble compound of simple character, the reaction rate is usually very rapid (Sawyer, et al, 1994).

The different in the composition of organic matter in shrimp pond effluents resulted from different culturing system and different pond management techniques. Effluent discharge methods also influent effluent quality.

Results from laboratory scale experiment with effluents indicated that aeration can increase decomposition rate of organic matter in the effluent comparing to control without aeration. The decreasing in BOD_5 of the effluent in control partly resulted from the degradation of organic matter. However, large portion of the reduction of BOD_5 resulted from sedimentation of organic-rich suspended solids in the effluents. Several investigations indicated that suspended solids in shrimp pond effluents were quickly settle down to the bottom. Tiechert-Coddington et al (1998) reported that sedimentation can remove 88 percent of suspended solids, 63 percent of BOD_5, 31 percent of total nitrogen, and 55 percent of total phosphorus within 6 hours.

Conclusion

The BOD_5 values of shrimp pond effluents being studied were in the same range of those reported in previous studies. Five-days carbonaceous biochemical oxygen demand ($CBOD_5$) of shrimp pond effluents varied between 9.3 and 34.0 mg/l with average value of 20.4 mg/l. BOD_5 values of the effluents were 51.2-86.9% of ultimate carbonaceous BOD. At day 5 only

2 of the 5 shrimp pond effluents exerted nitrification oxygen demand at low level of 0.4 and 1.0 mg/l. Ultimate carbonaceous BOD varied between 10.7 and 42.0 mg/l with average value of 29.6 mg/l. Average rate of biochemical oxidation (k value) of shrimp pond effluents was 1.2. The k values varied between 0.06 and 0.18 per day. Twenty-day nitrification oxygen demand varied between 13.4 and 38.2 mg/l with average value of 21.1 mg/l. Results of laboratory scale investigation indicated that aeration can significantly increase reduction rate of BOD_5 of shrimp pond effluent. High nitrification oxygen demand of the effluents indicated high accumulation of inorganic nitrogen, especially ammonia and nitrite, in the effluents.

References

APHA, AWWA, and WEF. 1998. Standard Methods for the Examination of Water and Wastewater, 20th ed. APHA, Washington, D.C.,

Boyd, C.E. 1989. Water quality management and aeration in shrimp farming. Ala. Agr. Exp. Sta., Auburn Univ., Ala. Fisheries and Allied Aquacultures Dept. Ser. No.2.

Boyd, C.E. 1992. Shrimp pond bottom soil and sediment management in Proceeding of the Special Session on Shrimp Farming, J.A. Wyban, ed., World Aquaculture Society, Baton Rouge, La., pp. 166-181.

Chen, J., P.C. Liu and T.Y. Lin. 1989. Culture of *Penaeus monodon* in an intensified system in Taiwan. Aquaculture 77:319-328.

Fujimoto, Y. 1961. Graphical used of first-stage BOD equation. Journal WPCF, 36(1).

Hammer, M.J. and M.J.Hammer, Jr. 1996. Water and Wastewater Technology. Prentice Hall International, Inc., New York. 502 pp.

Musig, Y., W. Ruttanagosrigit and S. Sumpawapol. 1995. Effluents from Intensive Culture Ponds of Tiger Prawn (*Penaeus monodon* Fabricius). Kasetsart Univ. Fisheries Bull. No.21, pp. 1-9.

Muthuwan, V. 1991. Nutrient budget and water quality in intensive marine shrimp culture ponds. AIT Master Thesis, Asian Institute of Technology.

Ruttanagosrigit, W. 1997. Organic Matter Dynamics in a Closed, Intensive Culture System for Black Tiger Prawn (*Penaeus monodon*). AIT Doctoral Dissertation, Asian Institute of Technology.

Sawyer, C.W., P.L. McCarty and G.F. Parkin. 1994. Chemistry for Environmental Engineering. McGraw-Hill, Inc., New York. 658 pp.

Teichert – Coddington, D.R., D.B. Rouse, A. Potts and C.E. Boyd. 1999. Treatment of harvest discharge from intensive shrimp ponds by settling. Aquacult. Eng., 19:147-161.