Evaluation of the Effect of Sediment Resuspension on Water Quality and Cultured Shrimp

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ABSTRACT

The effects of sediment resuspension on water quality, sediment property, and shrimp were investigated in a closed culture system for black tiger shrimp (*Penaeus monodon* Fabricius) using 5 m^3 rectangular concrete ponds lined with sandy clay loam. Sediment resuspension was done by supplying air from an air compressor through porous PVC pipes positioned 10 cm above the pond bottom. Two rows of small pores were drilled on the underside of the pipe to direct air stream to bottom sediment. Aeration for control units were done through air stones hanging 10 cm above pond bottom. Results of this study showed that sediment resuspension significantly improved pond water quality by inhibiting phytoplankton growth, decreasing daily fluctuation of dissolved oxygen and pH, and decreasing water COD. Weekly averages of phytoplankton number and chlorophyll *a* content in sediment resuspension treatment were significantly lower ($P<0.05$) than that of the control from week 11 till the end of the experiment. Significantly lower COD values ($P<0.05$) were also observed in sediment resuspension treatment compared to that of the control during the fourth month. Average concentrations of ammonia, nitrite, and sulfide in the sediment resuspension treatment were not significantly different ($P>0.05$) from the control. Significantly higher ($P<0.05$) values of redox potential of bottom soil in sediment resuspension treatment were also observed at 28% of sampling date. No significant differences ($P>0.05$) were found among average body weight, average survival rate and average feed conversion ratio of shrimp in sediment resuspension treatments and in the control.

INTRODUCTION

Conditions in the pond bottom are very important to the success of aquaculture production systems. The accumulation of organic sediments in pond bottom soil limits pond intensification due to intensive organic matter degradation and high sediment oxygen demand resulting in deteriorating conditions in the pond bottom. This leads to the development of anoxic conditions in the sediment and at the sediment–water interface. As a series of anaerobic processes, affected by the redox potential of the system,

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are taking place, a large number of potentially toxic materials such as organic acids, reduced organic sulfur compounds, reduced manganese and sulfides are generated (Avnimelech and Ritvo, 2003; Hopkins, *et al*.,1994). Exposure to toxic substances endangers the well-being of the cultured shrimp resulting in reduced feeding, slower growth, mortality and possibly higher susceptibility to disease. Boyd (1990) noted that aerobic and anaerobic degradation of organic matter progresses in pond bottom, but water-logged conditions do not favor rapid or complete oxidation. Management mostly used by shrimp farmers include the use of aerators to minimize and periodically removal of bottom sediment. Sediment resuspension is also suggested as a means of pond bottom soil management (Avnimelech and Ritvo, 2003; McIntosh, 2000). In this experiment the effects of sediment resuspension on pond water quality and some properties of pond bottom soil were evaluated as well as its effect on survival rate and growth rate of cultured shrimp.

MATERIALS AND METHODS

The experiment was done in concrete ponds with a volume of 5 m^3 and depth of 1 m, at Samutsongkram Coastal Aquaculture Station in the Inner Gulf of Thailand. The pond bottom was lined with 10 cm thick bottom soil from shrimp ponds and filled with 20 ppt saltwater. Post-larvae (3.7 g PL 20) of giant tiger shrimp (*Penaeus monodon* Fabricius) were then stocked at 30 shrimp/m^2 (150 shrimp/pond). Shrimp were fed 3 times a day with pellet feed based on recommended feeding rates. The experimental ponds were aerated by 1.5 kW air compressor. In control ponds, air stones were used for air distribution. Air stones were hung at 10 cm above the pond bottom. In sediment resuspension treatment ponds, air was distributed through two PVC pipes hanging in parallel at 10 cm above pond bottom. Two rows of small holes (2 mm in diameter) were drilled at 5 cm interval on the underside of the pipes to allow the air to directly go to the surface of the bottom soil. Three replications were set for each treatment with experimental period of 17 weeks. Water quality parameters such as salinity, sechi disc visibility, ammonia, nitrite, sulfide and chlorophyll *a* were analyzed daily. Temperature, pH and dissolved oxygen concentrations were measured twice a day at 06:00 and 15:00 hours. Water COD and the number of phytoplankton were analyzed weekly. Pond bottom soil samples were also collected and analyzed for texture prior to the experiment. Soil organicmatter and soil pH were analyzed initially and at the end of the experiment. Soil redox potential was analyzed every three days. Dissolved oxygen was measured by DO meter YSI model 57, pH of water was measured by pH meter Cyber Scan pH-100, and soil redox potential was measured by Ion Analyzer Orion model EA920. Ammonia was analyzed by phenatemethod and nitrite was analyzed by colorimetric method (APHA *et al*., 1992). Chlorophyll *a* content was analyzed by methods recommended by APHA, *et.al*. (1992). Sulfide was analyzed by method recommended by Grasshoff (1976). Soil was analyzed for texture prior to the experiment. Soil pH and soil organic matter content were analyze every two month and soil redox potential was measured every three days. Soil texture was analyzed by hydrometer method (Day, 1964). Soil organic matter content was analyzed by Walkley and Black method (Jackson, 1958). Soil pH was measured in 1:1 mixture of soil and distilled water. Shrimp were weighted and counted at the end of second month and at the end of the experiment.

RESULTS AND DISCUSSION

Water in sediment resuspension treatment was significantly more turbid than in the control treatment. Mean initial secchi disc visibility reading in the soil resuspension treatment was 48.5 cm compared to 79.9 cm of the control. Water turbidity in both treatments decreased continuously from weeks 1 to 17 as indicated by the reduction in secchi disc visibility readings, which were from 48.5 to 3.6 cm in soil resuspension treatment, and from 79.9 to 12.7 cm in the control. Thus from weekly average values of secchi disc visibility, water in sediment resuspension treatment was significantly more turbid ($P<0.05$) than that in the control (Table 1, Figure 1). Turbid conditions in the sediment resuspension treatment clearly affected phytoplankton growth indicated by significantly lower weekly average of phytoplankton number and chlorophyll *a* content, compared to that of the control from weeks 11 through 17. Average chlorophyll *a* content varied from 2.1 to 61.8 and 3.2 to 147.9 µg/L in sediment resuspension treatment and in control, respectively. Average density of phytoplankton in control and sediment resuspension treatment ranged from 28,703-196,400 and 20,857-89,864 per liter (Table 1, Figure 2). Water temperature varied between 27.3 and 28.5 ^{o}C in control and 27.2 and 28.1^{o}C in sediment resuspension treatment (Figure 3).

Dissolved oxygen at 06:00 a.m. varied between 6.3 and 6.7 mg/L in control and between 6.5 and 7.0 mg/L in sediment resuspension treatment. Average 6:00 a.m. dissolved oxygen concentration of sediment resuspension treatment were significantly higher ($P<0.05$) than those of control from weeks 10 to 17. At 1500 hours, the dissolved oxygen levels in the control varied between 7.0 and 8.3 and while that of sediment resuspension treatment varied between 6.7 and 7.1. Average 1500 hours dissolved oxygen concentration in the sediment resuspension treatment was significantly lower ($P<0.05$) than those of control beginning from week 5 until theend of the experiment (Table 2, Figure 4). Wider daily fluctuations of pH and dissolved oxygen were observed especially on the third and fourth months (Figure 4). Water pH at 0600 hours decreased from 8.8 to 8.6, and 8.8 to 8.4 from weeks 1 to 17 in sediment resuspension treatment and in the control, respectively. At 1500 hours, water pH in the control varied between 8.8 and 9.3 and while that in the sediment resuspension treatment varied between 8.6 and 8.9 (Table 3, Figure 5). Water COD varied between 331.0 and 562.3 mg/L for control and between 323 and 499.4 for sediment resuspension treatment (Figure 6). Significantly lower COD values were observed in sediment resuspension treatments compared to that of the control during the fourth month.

Table 1. Secchi disc visibility values, phytoplankton density and chlorophyll *a* content of water in the control and sediment resuspension treatment

week	Secchi disc visibility (cm)		Phytoplankton (no./L)		Chlorophyll *a* (µg/L)	
	Control	Sediment resuspension	Control	Sediment resuspension	Control	Sediment resuspension
1	79.9±8.01[a]	48.6±10.98[b]	41,921±6,214[a]	40,439±1,973[a]	7.5±3.41[a]	6.2±2.44[a]
2	81.2±2.96[a]	38.0±5.08[b]	42,531±6,064[a]	30,049±3,413[a]	8.1±4.06[a]	3.6±2.26[a]
3	77.5±6.89[a]	42.3±2.87[b]	28,703±6,170[a]	20,239±4,903[a]	3.2±1.30[a]	2.1±1.01[a]
4	76.2±4.85[a]	47.1±4.27[b]	40,726±4,311[a]	21,894±2,148[b]	7.5±4.33[a]	3.3±1.71[b]
5	71.4±5.51[a]	45.3±2.67[b]	33,102±2,531[a]	20,857±4,566[b]	4.1±1.27[a]	3.2±0.96[a]
6	64.2±5.17[a]	42.4±7.53[b]	35,477±3,109[a]	22,375±3,253[b]	4.3±2.06[a]	2.4±1.68[a]
7	68.3±5.10[a]	43.7±3.35[b]	38,900±2,855[a]	32,210±4,819[a]	5.4±2.69[a]	3.6±1.40[a]
8	46.6±12.65[a]	30.9±11.34[b]	76,782±21,471[a]	40,061±6,724[b]	26.0±15.05[a]	10.1±6.99[a]
9	22.5±2.87[a]	13.1±3.73[b]	88,826±12,006[a]	77,182±1,423[a]	45.7±9.89[a]	29.3±11.76[b]
10	26.9±4.54[a]	7.4±1.65[b]	93,650±7,870[a]	84,213±9,681[a]	57.3±17.42[a]	43.1±13.71[a]
11	16.7±2.89[a]	4.3±0.65[b]	120,769±18,496[a]	82,813±13,149[b]	87.4±11.32[a]	61.8±4.39[b]
12	11.6±1.41[a]	4.1±2.65[b]	138,691±26,827[a]	89,864±4,665[b]	100.4±22.98[a]	55.2±9.84[b]
13	13.6±1.41[a]	3.5±1.14[b]	90,215±9,360[a]	69,860±9,631[a]	45.3±8.99[a]	21.5±11.35[b]
14	13.1±2.23[a]	3.8±0.18[b]	98,948±10,012[a]	46,590±2,516[b]	58.8±12.07[a]	9.4±2.35[b]
15	17.3±4.34[a]	3.5±0.26[b]	119,879±10,347[a]	34,071±9,915[b]	84.0±6.06[a]	5.1±3.71[b]
16	15.3±2.05[a]	3.4±0.17[b]	160,580±21,840[a]	21,565±4,082[b]	110.0±8.99[a]	2.9±1.89[b]
17	12.7±0.94[a]	3.6±0.13[b]	196,400±21,570[a]	35,016±8,420[b]	147.9±34.94[a]	3.9±1.36[b]

Remark: Average values with different superscripts in the same row are significantly different ($P<0.05$).

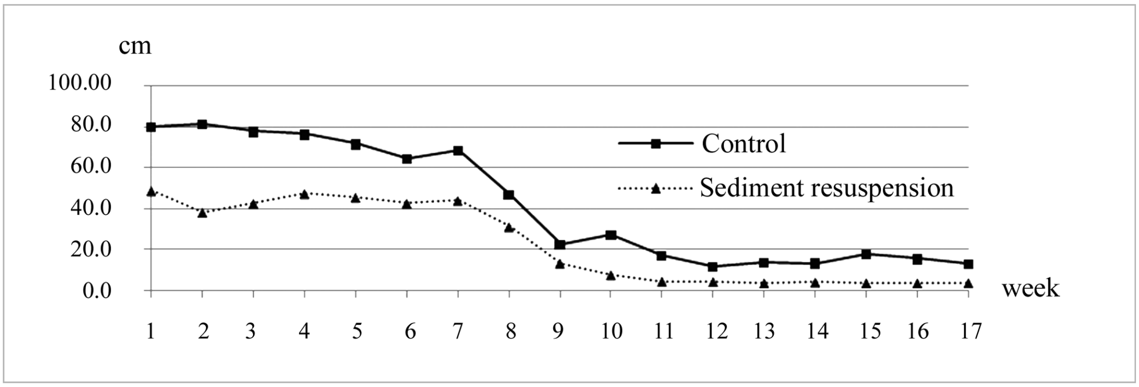
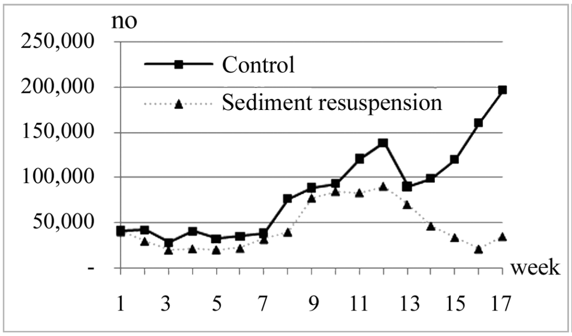


Figure 1. Secchi disc visibility of water in control and sediment resuspension treatment at 0600 and 1500 hours.



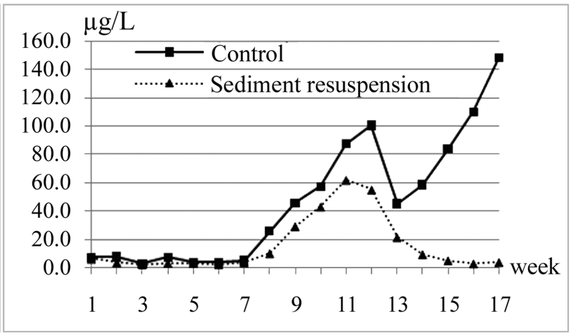
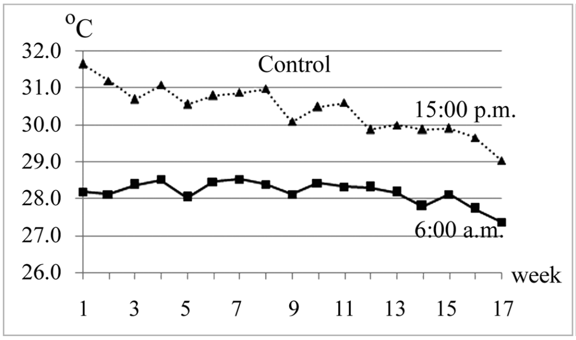


Figure 2. Phytoplankton number and chlorophyll *a* content in control and sediment resuspension treatment at 0600 and 1500 hours.



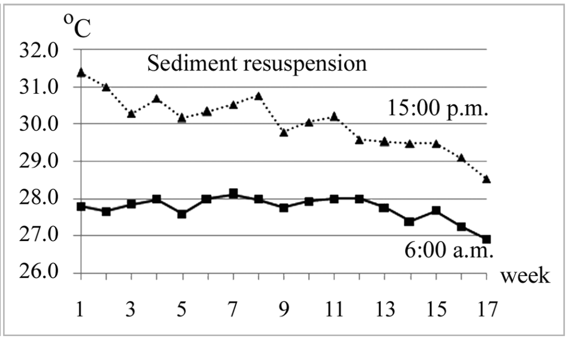


Figure 3. Water temperature in control and sediment resuspension treatment at 0600 and 1500 hours.

Table 2. Dissolved oxygen concentration in control and sediment resuspension treatment (mg/L)

	0600 hours		1500 hours	
week	**Control**	**Sediment resuspension**	**Control**	**Sediment resuspension**
1	6.7±0.28 [a]	6.8±0.30 [a]	7.2±0.61 [a]	7.0±0.53 [a]
2	6.4±0.08 [a]	6.6±0.08 [b]	7.2±0.38 [a]	6.9±0.40 [a]
3	6.4±0.26 [a]	6.5±0.25 [a]	7.0±0.24 [a]	6.7±0.23 [a]
4	6.6±0.35 [a]	6.8±0.35 [a]	7.0±0.30 [a]	6.7±0.28 [a]
5	6.4±0.20 [a]	6.6±0.20 [a]	7.3±0.30 [a]	7.0±0.29 [b]
6	6.5±0.15 [a]	6.6±0.20 [a]	7.2±0.34 [a]	6.8±0.30 [b]
7	6.5±0.17 [a]	6.7±0.16 [a]	7.6±0.29 [a]	7.1±0.22 [b]
8	6.6±0.20 [a]	6.8±0.20 [b]	7.7±0.38 [a]	7.1±0.31 [a]
9	6.6±0.18 [a]	6.8±0.25 [a]	7.6±0.32 [a]	7.1±0.22 [b]
10	6.4±0.17 [a]	6.7±0.17 [b]	7.6±0.40 [a]	7.0±0.23 [b]
11	6.5±0.12 [a]	6.7±0.18 [b]	7.8±0.41 [a]	7.1±0.36 [a]
12	6.6±0.15 [a]	6.8±0.14 [b]	7.6±0.33 [a]	7.1±0.44 [a]
13	6.5±0.09 [a]	6.8±0.10 [b]	7.6±0.22 [a]	6.9±0.32 [b]
14	6.5±0.09 [a]	6.8±0.09 [b]	7.7±0.47 [a]	6.9±0.26 [b]
15	6.4±0.10 [a]	6.9±0.12 [b]	8.2±0.46 [a]	7.0±0.53 [b]
16	6.4±0.20 [a]	6.9±0.18 [b]	8.3±0.45 [a]	6.7±0.35 [b]
17	6.3±0.11 [a]	7.0±0.09 [b]	8.2±0.32 [a]	6.7±0.25 [b]

Remark: Average values with different superscripts in the same row are significantly different ($P<0.05$).

Table 3. Water pH in control and sediment resuspension treatment

	0600 hours		1500 hours	
week	**Control**	**Sediment resuspension**	**Control**	**Sediment resuspension**
1	8.8±0.06 [a]	8.8±0.05 [a]	8.8±0.04 [a]	8.9±0.04 [b]
2	8.8±0.02 [a]	8.8±0.02 [a]	8.9±0.03 [a]	8.9±0.03 [a]
3	8.8±0.02 [a]	8.8±0.0 [a]	8.9±0.03 [a]	9.0±0.04 [b]
4	8.8±0.02 [a]	8.7±0.01 [a]	8.9±0.02 [a]	8.9±0.16 [a]
5	8.8±0.02 [a]	8.7±0.05 [a]	8.9±0.03 [a]	8.9±0.04 [a]
6	8.8±0.05 [a]	8.7±0.03 [a]	9.0±0.09 [a]	8.9±0.06 [b]
7	8.7±0.14 [a]	8.7±0.12 [a]	9.0±0.04 [a]	8.9±0.05 [b]
8	8.7±0.04 [a]	8.7±0.02 [a]	9.0±0.04 [a]	8.9±0.05 [a]
9	8.7±0.06 [a]	8.7±0.05 [a]	8.9±0.11 [a]	8.9±0.12 [a]
10	8.8±0.05 [a]	8.7±0.03 [b]	9.1±0.05 [a]	8.9±0.05 [b]
11	8.7±0.07 [a]	8.7±0.03 [a]	9.1±0.07 [a]	8.8±0.06 [b]
12	8.6±0.14 [a]	8.7±0.04 [a]	8.9±0.22 [a]	8.7±0.08 [b]
13	8.5±0.14 [a]	8.6±0.02 [b]	8.9±0.14 [a]	8.7±0.02 [b]
14	8.5±0.04 [a]	8.6±0.02 [b]	9.0±0.16 [a]	8.6±0.03 [b]
15	8.6±0.16 [a]	8.6±0.02 [a]	9.2±0.14 [a]	8.7±0.01 [b]
16	8.5±0.07 [a]	8.6±0.01[b]	9.3±0.13 [a]	8.6±0.02 [b]
17	8.4±0.05 [a]	8.6±0.01 [b]	9.1±0.12 [a]	8.6±0.02 [b]

Remark: Average values with different superscripts in the same row are significantly different (P<0.05).

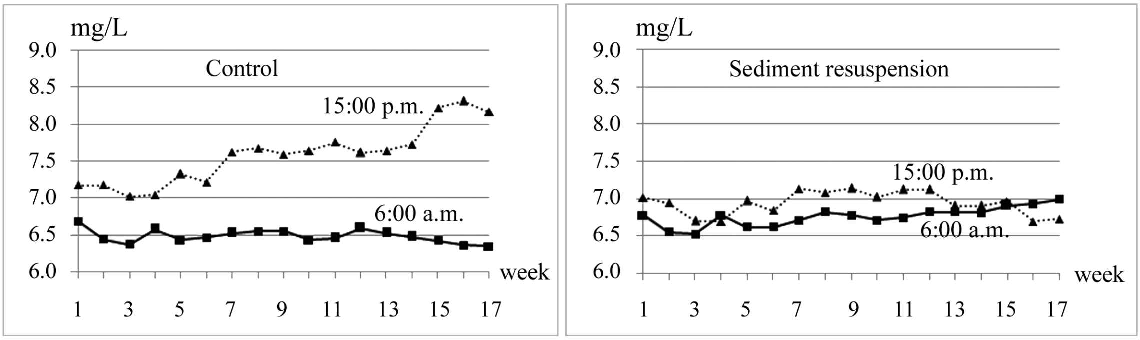


Figure 4. Dissolved oxygen concentration in water in control and sediment resuspension treatment at 0600 and 1500 hours.

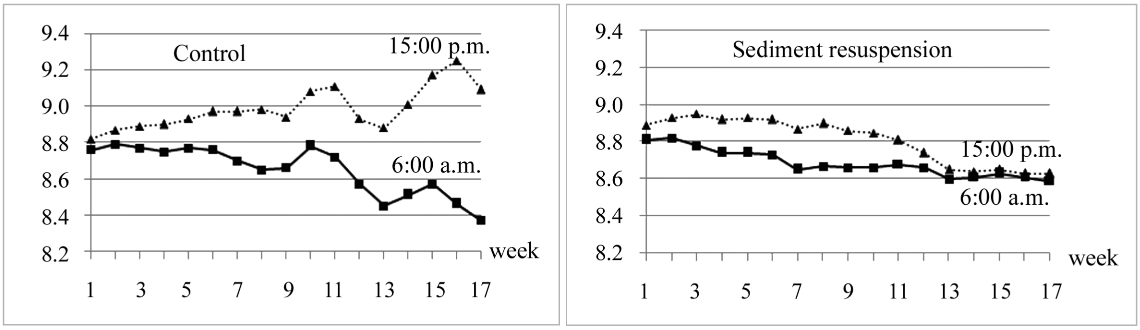


Figure 5. Water pH in control and sediment resuspension treatment at 0600 and 1500 hours.

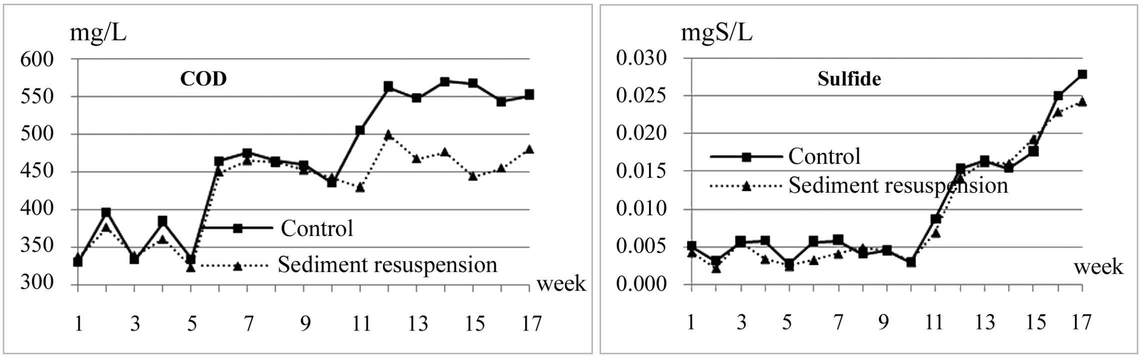


Figure 6. COD and sulfide concentration in water in control and sediment resuspension treatment.

Weekly average concentrations of ammonia, nitrite and sulfide in pond water of both treatments were not significantly different (P>0.05). Concentration of sulfide in control ponds varied between 0.003 and 0.028 mgS/L while the concentration in sediment resuspension ponds varied between 0.002 and 0.024 mgS/L (Figure 6). Ammonia concentration in control ponds varied between 0.002 and 0.015 mgN/L while the concentration in sediment resuspension ponds varied between 0.001 and 0.012 mgN/L. Nitrite concentration in control ponds varied between 0.001 and 0.196 mgN/L while the concentration in sediment resuspension ponds varied between 0.001 and 0.251 mgN/L (Figure 7). Pond bottom soil is sandy clay loam consisting of 25% clay, 23% silt, and 52% sand. Average initial soil pH and initial soil organic matter content of control and sediment resuspension treatment are 7.5 and 7.3, and 1.8 and 1.7%, respectively. There was no significant different between average values of soil pH and soil organic matter content in control and in sediment resuspension treatment at 2 months and at the end of the experiment (P>0.05). Soil organic matter increased from initial value of 1.8% to 2.7% at the end of the experiment in control and from 1.7% to 2.1% in sediment resuspension treatment (Table 4). Redox potential of bottom soil of sediment resuspension treatment decreased from initial value of +60.1 mv to -171.4 and -168.0 mv at day 114 and day 117 comparing to redox potential of bottom soil in control which decreased from initial value of +60.9 mv to -206.6 and 195.4 mv at day 114 and day 117. Significantly higher (P<0.05) values of redox potential of bottom soilin sediment resuspension treatment were observed at 28% of sampling date comparing to control (Figure 8).

Table 4. pH and organic matter content of bottomsoil in control and sediment resuspension treatment.

Month	initial		2		4	
	Control	**Sediment resuspension**	**Control**	**Sediment resuspension**	**Control**	**Sediment resuspension**
pH	7.5±0.07[a]	7.3±0.26[a]	8.0±0.19[a]	8.0±0.37[a]	7.9±0.74[a]	8.1±0.05[a]
Organic matter (%)	1.8±0.18[a]	1.7±0.03[a]	2.1±0.19[a]	1.8±0.02[a]	2.7±0.08[a]	2.1±0.21[a]

Remark: Average values with different superscripts in the same row are significantly different (P<0.05).

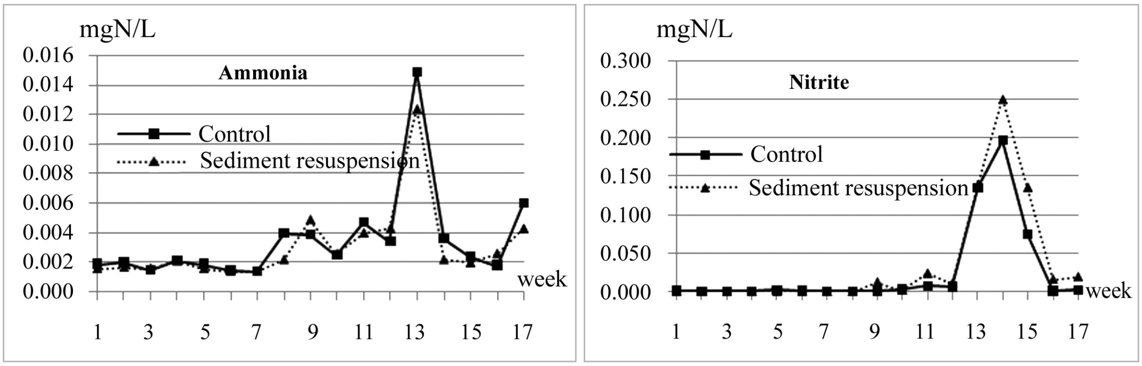


Figure 7. Ammonia and nitrite concentrations in water in control and sediment resuspension treatment.

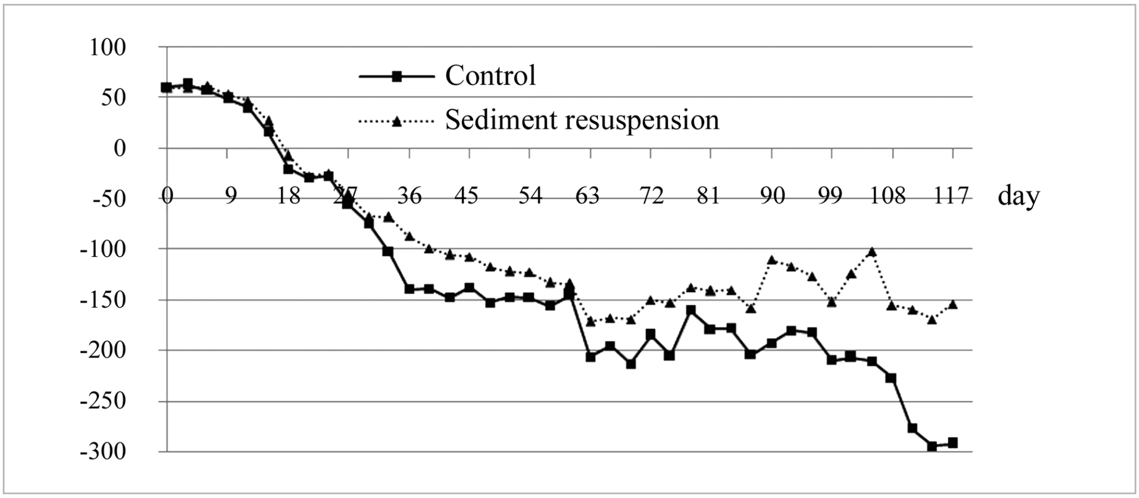


Figure 8. Soil redox potential in control and sediment resuspension treatment.

Shrimp grew from 0.02 g average body weight to 13.6 and 14.8 g in control and sediment resuspension treatment, respectively. In the control, the average survival rate, average production and average feed conversion ratio of shrimp were 61.1%, 1,236.0 g/m^2 and 1.7, respectively, while average survival rate, average production and average feed conversion ratio of shrimp in sediment resuspension were 61.1%, 1,236.0g /m^2 and 1.5, respectively. There were no significant differences (P>0.05) between average body weight, average survival rate, production rate, and feed conversion ratio of control shrimp and shrimp in sediment resuspension treatment (Table 5).

Table 5. Body weight, survival rate, production and feed conversion ratio of shrimp in control and sediment resuspension treatment.

	initial		**2**		**4**	
Month	**Control**	**Sediment resuspension**	**Control**	**Sediment resuspension**	**Control**	**Sediment resuspension**
weight (g)	0.02	0.02	2.94±0.19[a]	3.18±0.37[a]	13.58±1.46[a]	14.85±1.92[a]
Survival rate (%)	-	-	-	-	61.1±6.05[a]	64.22±3.42[a]
Production (g/m^2)	-	-	-	-	1,236.0±17.3[a]	1,426.4±135.7[a]
FCR	-	-	-	-	1.7±0.02[a]	1.5±0.14[a]

Remark: Average values with different superscripts in the same row are significantly different (P<0.05).

The most significant impact of sediment resuspension is the increase in water turbidity which directly affected phytoplankton growth by inhibiting light penetration into the water column. Significantly lower density of phytoplankton number and chlorophyll *a* content in sediment resuspension treatment from week 11 through the end of the experiment indicated the effect of water turbidity generated by sediment resuspension. According to the results of this study, sediment resuspension should be one of the effective means of controlling excessive phytoplankton growth in shrimp ponds with sandy clay loam bottom soil. In fed ponds, excessive phytoplankton blooms are the natural consequence of high feeding rates necessary for large yields of fish or shrimp. The die-offs or sudden death of all or a great portion of phytoplankton followed by rapid decomposition of dead algae can cause severe depletion of dissolved oxygen concentration in aquaculture ponds and may result in the death of cultured species (Alongso-Rodriguez and Paes-Osuna, 2003; Swingle, 1968; Boyd *et al.*, 1978). Shrimp diseases not specified in Chinese farms were preceded by a decrease in chlorophyll *a* and the increase in pheophytin which is a common degradation product of chlorophyll *a* (Hiu, *et al.*, 1998)

Other positive effects of sediment resuspension are higher redox potential of bottom soil and less diurnal fluctuation of dissolved oxygen and pH of water. Higher redox potential resulted from direct aeration to bottom soil while less diurnal fluctuation of dissolved oxygen and water pH resulting from less density of phytoplankton. Despite a lower density of phytoplankton, concentrations of ammonia and nitrite in water in the sediment resuspension treatment were not significantly different ($P>0.05$) from that of the control (Figure 7). Sulfide concentration in water in both treatments was also not significantly different ($P>0.05$). However, the improvement of pond conditions in sediment resuspension at this degree was still not enough to have a positive impact on cultured shrimp considering non-significant growth, survival rate, production rate, and feed conversion ratio compared to that of the control.

CONCLUSION

According to the results of this study, in ponds lined with sandy clay loam, resuspension of bottom sediment using modified aeration system generated a higher level of turbidity of water. This was indicated by the significantly lower ($P<0.05$) value of secchi disc visibility compared to that of the control. The increase in water turbidity resulted in less amount of light penetrating into the water column which resulted in limited phytoplankton growth especially in the third and fourth monthswith a high accumulation of nutrient which normally generates excessive phytoplankton bloom. Lower density of phytoplankton in sediment resuspension treatment resulted in anumber of positive effects on pond environment. Diurnal fluctuation of dissolved oxygen and pH were less as indicated by the difference between 0600 and 1500 hours readings. Lower water COD was also observed in sediment resuspension treatment compared to that of the control during the fourth month. Despite the less density of phytoplankton, concentrations of ammonia, nitrite, and sulfide in the water were still in the same level as that of the control. Higher redox potential of bottom soil in sediment resuspension treatment which was observed at 28% of sampling dates was a result of direct aeration of bottom sediment. The changes in soil pH and organic matter content were not different from control. Although sediment resuspension seems to have no positive effect on cultured shrimp as indicated from average body weight, survival rate, production rate, and feed conversion ratio, sediment resuspension seems to be an effective means for the prevention of excessive phytoplankton bloom in shrimp culture systems which will be very beneficial for shrimp farmer. However, field study is needed to confirm its potential in this matter.

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