THE EFFECT OF EFFLUENT FROM TIGER PRAWN (*Penaeus monodon*) FARM ON THE WATER QUALITY OF SUNGAI BAKO, SARAWAK

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ABSTRACT

This study was carried out to determine the effect of effluent from tiger prawn (*Penaeus monodon*) farm towards water quality of Sungai Bako, Sarawak. Eight sampling stations were selected in this study; four stations at Sungai Bako (S1, S2, S3 and S4), three stations within the culture ponds (K8, K9 and K10) and one station at sedimentation pond (SP). The effectiveness of effluent treatment system was assessed based on the results of the water samples analysis at the sedimentation pond during prawn harvesting and after three days of retention period. The performance of sedimentation pond was considered good as the value of these parameters: total suspended solids (TSS), phosphorus, nitrate and total nitrogen decreased from 353 mg/L to 141 mg/L, 10.5 mg/L to 1.6 mg/L, 0.9 mg/L to 0.09 mg/L and 0.5 mg/L to 0.4 mg/L, respectively. There were not much difference changes for the value of pH, dissolved oxygen (DO), total nitrogen and phosphorus in Sg. Bako before and after the effluent was discharged into the river from the sedimentation pond. However, the value of TSS, ammoniacal nitrogen (N-NH_3) and biological oxygen demand (BOD) were increased after the effluent was discharged. When all these parameters were compared to National Water Quality Standard (NWQS) for Malaysia, three parameters pH, nitrate and phosphorus fall in Class I, ammoniacal nitrogen and BOD in Class II while DO and TSS in Class III. According to NWQS, the result of the water quality at cultural pond is within the recommended value for *P. monodon* farming except for ammoniacal nitrogen which was above the recommended value.

ABSTRAK

Kajian ini dijalankan untuk menentukan kesan pengaliran efluen dari kolam ternakan udang harimau (*Penaeus monodon*) terhadap kualiti air Sg. Bako, Sarawak. Lapan stesen persampelan telah dipilih untuk kajian ini iaitu empat stesen di Sg. Bako (S1, S2, S3 dan S4), tiga stesen di kolam ternakan (K8, K9 dan K10) dan satu stesen di kolam sedimentasi. Keberkesanan sistem rawatan efluen dinilai berdasarkan keputusan analisis sampel air di kolam sedimentasi pada hari penuaian serta hari ketiga selepas penuaian. Kolam sedimentasi didapati berfungsi dengan baik berdasarkan penurunan nilai TSS daripada 353 mg/L kepada 141 mg/L, fosforus daripada 10.5 mg/L kepada 1.6 mg/L, nitrat daripada 0.9 mg/L kepada 0.09 mg/L dan jumlah nitrogen daripada 0.5 mg/L kepada 0.4 mg/L. Tiada perbezaan yang ketara pada nilai pH, DO, jumlah nitrogen dan fosforus sebelum dan selepas efluen dari kolam sedimentasi dialirkan ke dalam Sg. Bako. Walau bagaimanapun, nilai TSS, amonia nitrogen dan BOD di Sg. Bako menunjukkan peningkatan selepas efluen dibuang. Apabila kesemua parameter ini dibandingkan dengan Piawai Kualiti Air Kebangsaan (NWQS), tiga parameter (pH, nitrat dan fosforus) berada dalam Kelas I, amonia nitrogen dan BOD berada dalam Kelas II manakala DO dan TSS dalam Kelas III. Berdasarkan NWQS, nilai kualiti air di kolam ternakan adalah di dalam nilai yang bersesuaian untuk penternakan *P. monodon* kecuali nilai amonia nitrogen yang melebihi nilai yang dicadangkan.

Key words: *Penaeus monodon*, tiger prawn farm, effluent, water quality

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INTRODUCTION

Shrimp has been farmed for centuries in Asia, using traditional low-density methods (Wikipedia, 2007). Shrimp were farmed on a small scale in ponds, in monocultures or together with other species such as milkfish, or in rotation with rice, using the paddy fields for shrimp cultures during the dry season, when no rice could be grown. Such traditional cultures often were small operations in coastal areas on river banks. Mangroves are favorable area because of their naturally abundant supply of brackish water for shrimp pond (Braaten and Flaherty, 2000).

Tiger prawn farming based on modern technology was introduced in Malaysia since 1970. This industry is developing very rapidly after the successes experienced in neighboring countries such as Thailand, Indonesia and Philippines and generating about 1,260 ton metric of tiger prawn in 1987 and 3,937 ton metric in 1993 (National Report Malaysia, 1997). However, Malaysia is not one of the major producers of cultured marine prawn in the world and the area for marine prawn culture is about 5,100 hectares (2,627 hectares in 1995) (Eurocbc, 2007). In year 2000, almost all aquaculture entrepreneurs were using tiger prawn (*Penaeus monodon*) in their farming because of high demand from Japan, Singapore, Hong Kong and West Asia (Eurocbc, 2007).

While extensive farms mainly rely on the natural productivity of the pond, more intensively managed farms rely on artificial shrimp feeds either exclusively or as a supplement to the organisms that naturally occur in a pond. A food chain is established in the ponds based on the growth of phytoplankton. Fertilizer and mineral conditioners are used to boost the growth of the phytoplankton to accelerate the growth of shrimps. Food for the *P. monodon* which consist of protein was served every four hours based on age of the prawn. The effluent from the farming pond was released directly into the sedimentation pond which mainly consists of organic wastes such as prawn faeces, extra food and shells. After retention time, the effluent was released into the river and this water contains organic substances, suspended solids, pathogen, ammonia, phosphorus, nitrate and chemical substances that used as pesticide and shrimp treatment (Flaherty et al., 2000). Nutrient was important for the phytoplankton growth but if the concentration is above the recommendation limit for fertilization and feeding, pollution could occur (Trott and Alongi, 2000).

Waste from the artificial food pellets and excrements of the shrimp can lead to the eutrophication of the ponds. Eutrophication is nutrient enrichment with e.g. nitrogen and phosphorus and will occur in the pond if the extra nutrient was not released from pond. Green algae such as *Enteromorpha, Cladophora* and *Ulva* will grow rapidly because of the presence of extra nutrient. The algae will effect on growth of invertebrate in the sediment (Ismail et al., 1999). Eutrophication can occur in stagnant water when the nitrate-nitrogen value is higher than 0.9 mg/L (Setiarto and Suradi, 1999).

All the data obtained was compared to National Water Quality Standard (NWQS) for Malaysia (DOE 2007) as a reference.

The purpose of this study was:

(i) to obtain information on the water quality in the tiger prawn aquaculture ponds before and after harvesting

(ii) to study the relationship between the water quality of the aquaculture pond and the estuary of Sungai Bako.

MATERIALS AND METHODS

Sample collection

The tiger prawn farm, AS Sdn. Bhd, was selected in this study and it was located nearby estuary of Sg. Bako, Kuching, Sarawak. The size of the farm was 19.2 hectare which included 16 farming ponds, water storage ponds, effluent treatment ponds, pump house, generator, office, quarters and store. In each cycle, the prawn was first rearing in February and will be harvested in May.

Water sampling was conducted at eight sampling stations. Four stations were located at Sungai Bako (S1, S2, S3 and S4) meanwhile three stations were within prawn pond (K8, K9 and K10) and one station at sedimentation pond (SP) (Fig. 1). Samples were collected and stored in polyethylene and glass bottles. All the samples were stored in an icebox and transported to the laboratory for analysis.

Water Quality Measurement

The *in situ* measurement was carried out for pH using YSI 30, dissolved oxygen (DO) using YSI 55 and salinity using ultrameter Myron. Other parameters were analyzed by using Standard Methods (SM) (APHA 1995). Total suspended solid (TSS) was analyzed by method APHA 2540 D. Typically 1000 mL of sample was filtered on a pre-weighed pre-combusted Whatman GF/F filter. The filter was placed in an aluminum dish and dried at 105ºC under vacuum to constant weight. After drying, the filter and

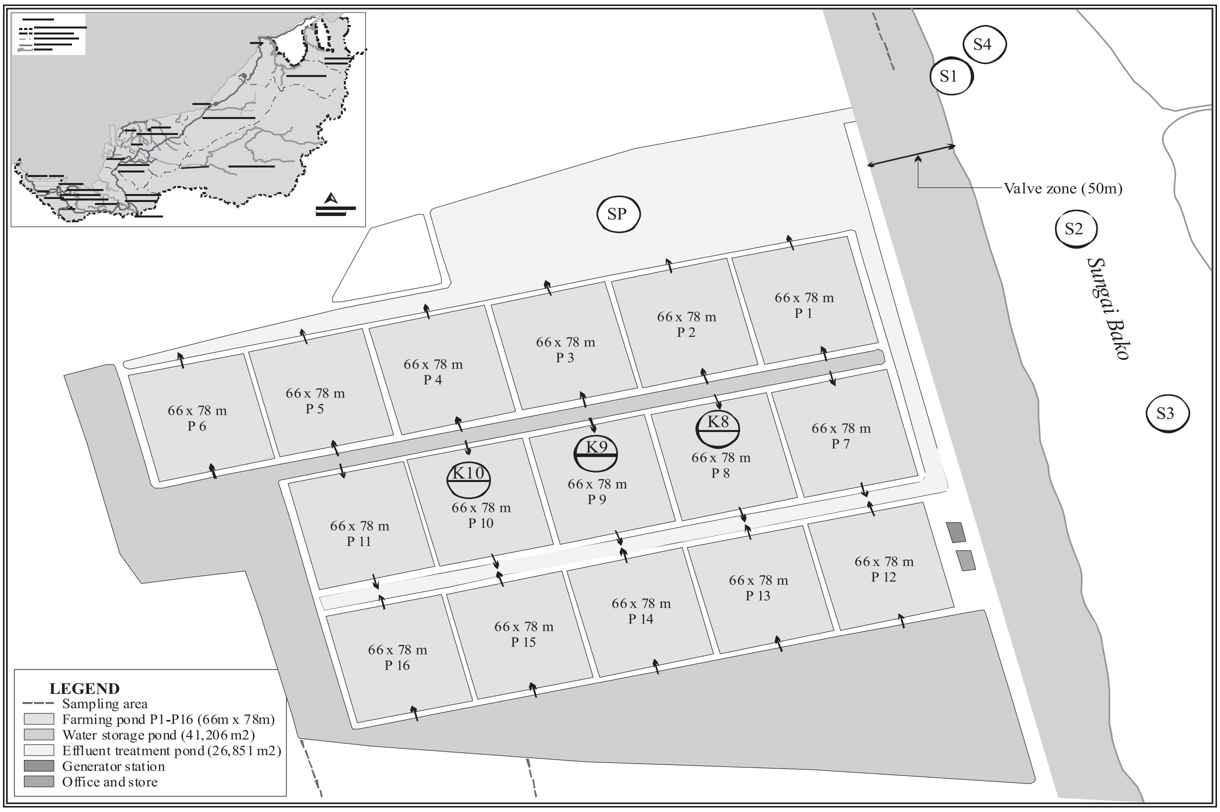

Fig. 1. Location for sampling sites.

dish were allowed to cool in a dessicator. The filters were weighed for TSS determination.

Unfiltered water samples were analyzed for biochemical oxygen demand (BOD) by SM APHA 5210 B (APHA, 1995) with measurement of oxygen demand at 5 days. Initial and final dissolved oxygen was measured using a calibrated YSI 5000 DO meter equipped with a YSI 5010 BOD probe (Yellow Springs, OH) and calibrated by Winkler titration according to SM 10200 H (APHA, 1995).

Total ammonia nitrogen (NH_3-N) was quantified with the Nessler method (SM 4500-NH3 C, APHA, 1995). The test was performed on unfiltered samples that were frozen within 24 hours of collection. After defrosting, 5 mL of sample was centrifuged at 3000 rpm for 5 minutes. Background interference from sample color was determined by measurement of 0.5 mL of the supernatant at 425 nm prior to the addition of reagent. HACH Nessler reagent (Loveland, CO) was then added to the remaining sample. The sample was vortexed thoroughly and re-centrifuged. The amount of ammonia was quantified by subtracting the absorbance of the sample without reagent from the sample with reagent at 425 nm.

Combined nitrate (NO_3-N) and nitrite (NO_2-N) were analyzed by the cadmium reduction method (Nitrate LR Hach Method 8192) using HACH NitraVer (Loveland, CO) reagents.

Dissolved ortho-phosphate (PO_4-P) was quantified in filtered samples by the ascorbic acid method (Hach Method 8048) using HACH PhosVer3 packets (Loveland, CO) and measured at 890 nm.

Total nitrogen was determined using persulfate digestion method (Hach Method 10071). Sodium metabisulfite is added after the digestion to eliminate halogen oxide interferences. Nitrate then reacts with chromotropic acid under strongly acidic conditions to form a yellow complex with an absorbance maximum at 410 nm.

Statistical Analysis

The statistical analysis was done using Minitab software at 95% level of significant.

RESULTS AND DISCUSSION

pH

pH is generally considered as one of the most important factors in shrimp farming pond. The values of pH from farming pond ranged from 8.6 to 8.7 (Table 1). This value was higher than previous study on assessment of brackish shrimp farming and impacts to the environment done by

Ting (2001) which was 7.39 to 8.29. This farming pond had the same system with the pond studied by Ting which was the half closed system or semi-intensive. Semi-intensive cultivation involves stocking densities beyond those that the natural environment can sustain without additional inputs. Consequently these systems depend on a reliable shrimp postlarval supply, and a greater management intervention in the pond's operation. Compared to intensive, "closed" hatchery and grow out systems enable the farmer to better control the farming environment. The re-circulation of water in "closed" systems reduces the amount of wastes discharged and provides an opportunity to locate the ponds away from coastal areas (Rönnbäck, 2001).

The increment of pH values was due to the addition of calcium or magnesium compound to the soil for the purpose of reducing soil acidity and CO_2 absorb by phytoplankton for photosynthesis (Boyd and Tucker, 1998). Meanwhile, the pH value at the sedimentation pond on day one was 7.6 and day three was 7.8 (Table 2). The value of pH at Sg. Bako was 7.98 and reduced to 7.48 (not significant at $p>0.05$) after receiving discharge from the prawn sedimentation pond (Table 3). In the sedimentation pond, decomposition processes occurred in the pond and this can cause decreasing in the alkalinity. The acidic condition remains at the bottom and normally did not mix with the top layer of the water. According to the NWQS, (DOE, 2007) the pH values for the farming pond, sedimentation pond and Sg. Bako were classified as Class I which was in range 6.5 to 8.5 (Table 4).

Total suspended solids (TSS)

At least 10% of the effluent released from the farming pond when the water was changed as scheduled and during the harvesting stage. The effluent released from the pond at the harvesting stage contains higher concentration of dissolved and suspended substances rather than the effluent from schedule changing water (Boyd and Tucker, 1998).

The value for TSS in the farming pond was from 58 to 77 mg/L which was not exceeding the limit for *P. monodon* farming. According to Alabaster and Lloyd (1980) the suitable value of TSS for *P. monodon* farming was from 25 to 80 mg/L. In the sedimentation pond, the TSS value was reduced from 353 mg/L to 141 mg/L after three days the shrimp were harvested. The mean value of TSS in Sg. Bako was 53 mg/L before the effluent was released into the river, and this value was increased to 110 mg/L after the effluent released into it (Table 3). There is a significant difference in TSS before and after its being discharged into the river at $P<0.05$. The increment of TSS value in Sg. Bako was not solely contributed by the discharge from the sedimentation pond, but also from the suspended materials carried by the river from the upstream. The location of S1 and S4 sampling sites was in the estuary where most of the suspended materials accumulated at this area. Based on TSS value, water in Sg. Bako was classified as Class III (51-150 mg/L) according to INWQS.

In recent years, a number of farms have started employing bottom aeration techniques to

Table 1. Physical parameters of water samples from the farming pond

Parameter \ Sites	Average value before harvesting		
	K8	K9	K10
pH	8.7	8.6	8.6
DO (mg/L)	6.5	7.2	6.0
TSS (mg/L)	58	77	68
BOD (mg/L)	6.7	6.3	5.4
Ammoniacal nitrogen (mg/L)	5.8	3.2	4.4
Total Nitrogen (mg/L)	52.6	19.9	41.1
Nitrate (mg/L)	0.6	1.0	0.7
Phosphorus (mg/L)	0.6	0.3	0.4

Table 2. Physical parameters of water samples from sedimentation pond

Parameter	On harvesting day	Three days after harvesting	Percentage of decrement
pH	7.6	7.8	2.63*
DO (mg/L)	7.7	2.1	72.61
TSS (mg/L)	353	141	60.05
BOD (mg/L)	5.6	6.1	8.93*
Ammonia-nitrogen (mg/L)	0.7	0.3	56.76
Nitrate (mg/L)	0.5	0.4	14.29
Phosphorus (mg/L)	0.9	0.1	89.41
Total nitrogen (mg/L)	10.2	1.6	84.04

*Increment

Table 3. Physical parameters of Sg. Bako before and after released of effluent from farming pond

Sites Parameter	Before released of effluent					After released of effluent					Statistical analysis (P)
	S1	S2	S3	S4	Min±SD	S1	S2	S3	S4	Min±SD	
pH	7.1	8.2	8.4	8.2	7.98±0.59	7.5	7.5	7.5	7.4	7.48±0.05	0.148
DO (mg/l)	3.88	3.48	3.59	3.36	3.58±1.35	3.06	3.90	3.76	3.95	3.67±0.41	0.714
TSS (mg/l)	59	53	49	51	53±4.32	136	110	86	109	110±20.43	0.002
BOD (mg/l)	0.4	0.4	0.3	0.4	0.38±0.05	3.2	2.6	2.0	2.0	2.45±0.57	0.00
NH_3-N (mg/l)	0.16	0.19	0.08	0.09	0.13±0.05	0.90	0.76	0.63	0.35	0.66±0.22	0.005
Total nitrogen (mg/l)	1.23	1.21	1.13	1.18	1.19±0.04	1.29	0.98	0.99	1.15	1.10±0.15	0.311
Nitrate (mg/l)	0.70	0.55	0.43	0.49	0.53±0.12	0.37	0.19	0.32	0.33	0.3±0.08	0.014
Phosphorus (mg/l)	0.18	0.08	0.07	0.13	0.12±0.05	0.22	0.08	0.06	0.04	0.05±0.03	0.765

* SD- Standard Deviation

Table 4. Class of Sg. Bako based on NWQS

Parameter	Average value	Class based on NWQS
pH	7.48±0.05	I
DO	3.67±0.41	III
TSS	110±20.43	III
BOD	2.45±0.57	II
Nitrogen ammonium	0.66±0.22	II
Nitrate	0.30±0.08	I
Phosphorus	0.05±0.03	I

improve the quality of total suspended solids. Aeration is supplied by rotary type air blower powered either by electric motor or diesel engine. Since bottom aeration is provided from the beginning, most wastes are being digested aerobically and only a small portion of waste is deposited at the bottom after the harvesting (Latt 2002).

Dissolved oxygen (DO)

The lowest DO value in farming pond was 6.0 mg/L while the highest was 7.2 mg/L. These results showed that the farming pond had high DO level and it was suitable for *P. monodon* growth. The minimum oxygen level for growth of *P. monodon* was 3.5 mg/L (Zelaya et al., 2002). Nevertheless, in this study the DO level was decreased drastically from 7.7 mg/L on day one to 2.1 mg/L on day three in the sedimentation pond (Table 2). Reduction of DO value occurred because the microorganisms consumed oxygen during degradation of organic matter. Releasing the effluent from the sedimentation pond into Sg. Bako, was not significantly effected the DO value. The value of DO before the effluent released was 3.58 mg/L while after the effluent released was 3.67 mg/L. This is because the water that flows from upstream of the river able to dilute the discharge from the sedimentation pond to downstream. Sg. Bako was classified as Class III based on NWQS which was in the range 3 to 5 mg/L (Table 4).

Biological oxygen demand (BOD_5)

The pond had lower range of BOD value which was 5.4 to 6.7 mg/L compared to BOD value observed by Ting (2001) that showed a range of 3.66 to 12.93 mg/L. Meanwhile, the BOD value for sedimentation pond was 5.6 to 6.1 mg/L. High loading of nutrients in shrimp pond lead to increased in BOD. The BOD value is the total oxygen required by microbial decomposer to decompose the organic matter. BOD was used as indicator for the present of organic matter in the pond. Theoretically, the decrement of DO value was correlated with the increment of BOD value. The BOD value in Sg. Bako was increased at each sampling station from 0.38 mg/L (before released of effluent) to 2.45 mg/L (after released of effluent). The discharging of this effluent into the river had a significant different at $p<0.05$. However, the BOD value is still in the acceptable range and Sg. Bako was classified as Class I based on NWQS (1 to 3 mg/L).

Ammoniacal nitrogen (N- NH_3)

Ammoniacal nitrogen at the study farming pond showed higher value which was 3.2 to 5.8 mg/L than the value reported by Ting (2001) which was in range of 0.45 to 3.63 mg/L. However, the value for the sedimentation pond showed decreasing from 0.7 mg/L to 0.3 mg/L. The highest concentration of ammonia was excreted by shrimps fed with artificial diet compared to phytoplankton and chironomid larvae (benthos) through protein catabolism (Shishehchian et al., 1999). Ammonium is continuously transforming into ammonia and hydrogen ions and vice versa. Changing the situation by changing pH or temperature will disturb the old equilibrium and create a new one. Ammonia is poisonous compared to ammonium. At a pH of 7 or less only ammonium is present, at pH of about 8 around 5% is ammonia and 95% ammonium, and at pH of 9 then 50% is ammonia and 50% is ammonium.

In Sg. Bako, after the effluent from the sedimentation pond was released into the river, the mean value of ammonia-nitrogen was increased from 0.13±0.05 mg/L to 0.66±0.22 mg/L which is significant at $p<0.05$. The artificial feed or pellet for the prawn contains high protein content and as it degrades ammonium was released which may add ammonium-nitrogen value in the river. Based on NH_3-N, the river was classified as Class II compared to NWQS which was in range 0.3 to 0.9 mg/L (Table 4).

Nitrate (NO_3)

In the farming pond, the nitrate value was in the range of 0.5 to 1.0 mg/L which was suitable for *P. monodon* growth except at K9 which was 1.0 mg/L. Boyd and Tucker (1998) had reported that the suitable value for growth was less than 1.0 mg/L. The nitrate value for the sedimentation pond was between 0.4 to 0.5 mg/L. Meanwhile, the average value of nitrate in Sg. Bako was 0.53 mg/L and after receiving discharge from the sedimentation pond, the water in Sg. Bako managed to dilute the nitrate content to 0.3 mg/L (not significant at $p<0.05$). Nitrate was produced from nitrification process where the microorganism oxidizes ammonia compounds. Nitrate was less toxic compared to nitrite. According to the NWQS, Sg. Bako was classified as Class I which means the value was in natural level.

Total nitrogen

Total nitrogen at the sedimentation pond showed decrement value from 10.1 mg/L to 1.6 mg/L after day three of retention time, while at farming pond total nitrogen value was higher, in the range of 19.9 to 52.6 mg/L. The majority of the nutrients added to shrimp ponds are not incorporated into the shrimp but end up being deposited in pond sediments or discharged in effluent (Tookwinas, 1998). In Sg. Bako, the total nitrogen value was slightly decreased from 1.19 mg/L to 1.10 mg/L, (not significant at $p<0.05$) probably due to dilution effect from the river and the absorption of this nutrient by mangrove plants at the estuary of this river. McCarthy (1980) reported the present of phytoplankton can absorb nitrogen from 1 to 2 µg/L from the environment.

Phosphorus

The value of total phosphorus dissolved in the water should less than 0.1 mg/L even though phosphorus was important for metabolism. Phosphorus was produced by phosphate fertilizer which was used for phytoplankton growth. The phosphorus value in the farming pond was 0.3 to 0.6 mg/L meanwhile in the sedimentation pond; the phosphorus value was decreased from 0.9 to 0.1 mg/L. The decrement of phosphorus in Sg. Bako ranged from 0.12 mg/L to 0.05 mg/L (by 58.3%) (not significant at $p<0.05$) showed no threat of excess phosphorus in the river. This value was in Class I according to the NWQS.

CONCLUSION

AS Aquaculture Sdn. Bhd. had run a proper management of an aquaculture system for *P. monodon* farming. The decreased in TSS, nitrate, phosphorus, total nitrogen and ammoniacal nitrogen value in the final effluent showed that the system in the sedimentation pond was efficient to reduce these parameters. Effluent from the sedimentation pond that released into Sg. Bako had no significant effect towards pH, DO, total nitrogen and phosphorus.

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