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Accumulation of Settling Particles in Some Coral Reef Areas of Peninsular Malaysia

(Akumulasi Partikel Terampai di Beberapa Kawasan Terumbu Karang di Semenanjung Malaysia)

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ABSTRACT

The aim of this study was to determine the accumulation of settling particles in coral reefs of Peninsular Malaysia. Settling particles were collected from the coral reefs of Port Dickson, Pulau Langkawi, Pulau Tioman, Pulau Redang and Pulau Tinggi from 2005 to 2008. The average total settling particles in Pulau Langkawi and Port Dickson was 49.8 mg/cm^2/day, while for Pulau Tioman, Pulau Redang, and Pulau Tinggi was 3.5 mg/cm^2/day. The results showed that accumulations rate in west coast were higher than east coast of Peninsular Malaysia. However, Pulau Tioman in the east coast received high accumulations rate of settling particles in certain times of the year due to sediment resuspension at shallow reefs caused by high energy seasonal yearly wave and monsoon.

Keywords: Accumulations rate; coral reef; organic matter; Peninsular Malaysia; settling particles

ABSTRAK

Kajian ini adalah untuk menentukan kadar pemendakan partikel di kawasan terumbu karang Semananjung Malaysia. Sampel telah diambil dari kawasan terumbu karang Port Dickson, Pulau Langkawi, Pulau Tioman, Pulau Redang dan Pulau Tinggi dari tahun 2005 hingga 2008. Purata kadar pemendakan di Pulau Langkawi dan Port Dickson adalah 49.8 mg/cm^2/hari, manakala di Pulau Tioman, Pulau Redang and Pulau Tinggi adalah 3.5 mg/cm^2/hari. Hasil menunjukkan bahawa kadar sedimentasi di pantai barat adalah lebih tinggi dari pantai timur Semenanjung Malaysia. Namun, sesetengah kawasan dari pesisir barat menerima kadar pemendakan yang tinggi pada waktu tertentu kerana pemendakan semula sedimen pada terumbu cetek akibat tenaga ombak yang tinggi pada musim monsoon yang berlaku setiap tahun.

Kata kunci: Bahan organik; kadar akumulasi; partikel terampai; Semenanjung Malaysia; terumbu karang

INTRODUCTION

Coral reefs are relatively fragile ecosystems, highly susceptible to damage and degeneration when disturbed by some natural forces (Grigg & Dollar 1990). However, they are also robust, naturally resilient and can withstand multiple perturbations through time (Dahl & Salwat 1988). The major causes of coral degradation are sedimentation and eutrophication events. Discharge from rivers brings along soil, organic matter, inorganic matter and other pollutants into the coral reef area which will limit the growth of coral reefs. High deposition of settling particles onto the coral reefs is not only from the river and terrestrial, but also from re-suspended sediment in the water column or dredging of nearby areas.

High accumulation of settling particles in the water column will decrease the sunlight intensity and impede the zooxanthellae of corals from photosynthesizing effectively. At the same time, the settling particles will clog the polyps and eliminate the animal from feeding and respiring. Thus, the corals are unable to grow well. The settling coral recruitment is unable to attach to hard substrate as most substrate will be covered with particles. This will suppress the spreading and growth of new corals in the area. An extended period of sediment stress over a period of time can gradually wear down the reef's growth and defences. The effects of sediments as settling particles on coral reefs have been well documented for the Indo-Pacific and Caribbean regions (Hubbard 1986).

Peninsular Malaysia is located on the Sunda Shelf with relatively shallow water and the climate is influenced by the monsoonal wind system. Malaysian reefs and their coral fauna have been reasonably well studied and updated fairly. However, coral diversity is relatively low in the west coast of Peninsular Malaysia because of turbid conditions and muddy substrates (Chua & Charles 1980). The accumulation of settling particles in coastal waters of Malaysia varies between locations and seasons. The settling particles deposition in west coast of Peninsular Malaysia is not well documented because the coral reef communities in west coast are not well established compare in east coast of Peninsular Malaysia. The purpose of this study is to elucidate the accumulation of settling particles

in the coral reefs region of Peninsular Malaysia. The sites has been chosen for this research because the coral reef areas is being heavily developed for tourism and poses potential treats to the marine natural resources.

Materials and Methods

Samplings were conducted at Port Dickson, Pulau Langkawi, Pulau Tioman, Pulau Redang and Pulau Tinggi (Figure 1). Specific localities of each sampling locations were Blue Lagoon from Port Dickson; Terumbu Kili, Pulau Ekor Tebu and Mak Simpan from Pulau Redang; Kg. Sebirah, Buloh Kasap and Pulau Mentinggi from Pulau Tinggi; and Teluk Yu and Datai from Pulau Langkawi. The sampling in Port Dickson, Pulau Langkawi, Pulau Redang and Pulau Tinggi were carried out once for each site between 2006 to 2008. The samplings in Pulau Tioman were conducted at Pulau Tulai and Pulau Renggis, and carried out a few times in September 2005, May 2006, April 2007 and September 2007.

The sampling was conducted by SCUBA diving. Sample traps were placed at different depth according to the average depth of coral reef (Figure 2). Samples traps were modified from Gardner (1980) where each sample trap consisting of three plastic jars was attached to a central stake which was fixed to the substratum. The sample traps of 7.6 cm diameter were fixed with the mouths of the plastic jars approximately 45.6 cm above the sediment surface. This set-up resulted in a height to width ratio of 1:6 which minimized the capture of sediment re-suspended from the bottom and maximized the collection efficiency. After 3 days, the plastic jars were capped and then removed. The calculation of accumulation of settling particles was measured by mass/cm^2/time (Gardner 1980). The samples were taken back to the laboratory and filtered with 0.45 μm filter papers to obtain the total settling particles. The samples were dried in the oven at 60°C until their weight was constant. The total accumulation rate (AR) was calculated by dividing the collected sample weight by the total volume of the plastic jar (45.36 cm^2) and the number of sampling days (3 days):

$$\text{Accumulation rate (AR)} = \text{Sample (g)} / 45.36\ \text{cm}^2 / 3\ \text{days} \quad (1)$$

The accumulated particles were then heated in furnace at 500°C for about 4 h to obtain the organic and inorganic matter contents with

$$\text{Total organic matter} = [\text{Sample weight (g)} - \text{Sample weight after furnace (g)}] \times 100\ \% \quad (2)$$

and

$$\text{Total inorganic matter} = [\text{Sample weight after furnace (g)}/\text{Sample weight (g)}] \times 100\ \% \quad (3)$$

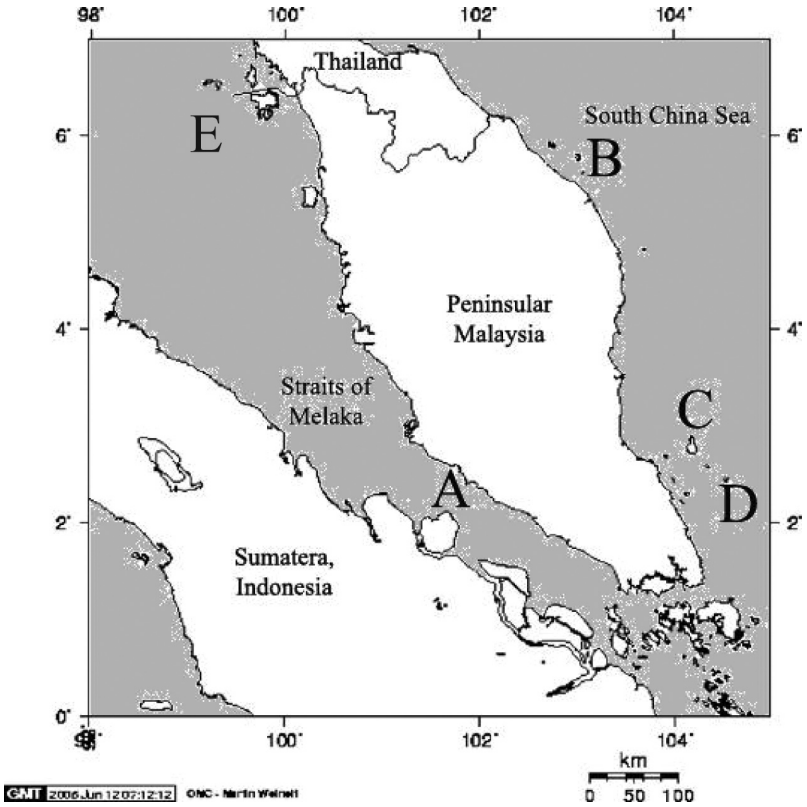

FIGURE 1. Sampling location (A) Port Dickson, (B) Pulau Redang, (C) Pulau Tioman, (D) Pulau Tinggi and (E) Pulau Langkawi

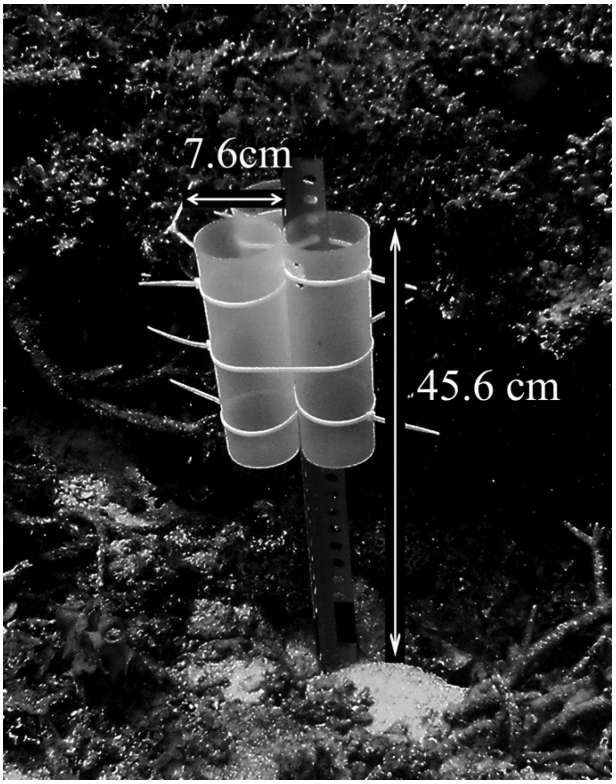

FIGURE 2. Sample trap set up in the field

RESULTS

Accumulation rate of settling particles were calculated using (1) for each sampling locations except Pulau Tulai and Pulau Renggis which were carried out four times (Table 1). The study indicated that sampling sites located in the west coast had higher accumulation rate than locations in the east coast. The only exception was Pulai Tulai during September 2005 sampled at depths between 1 m and 3 m that had an extraordinary accumulation rate compared to the sampling sites located in east coast. The samples from Port Dickson in the west coast during September 2006 at 3 m depth showed the highest accumulation rate with 76.83 mg/cm^2/day. But, the accumulation rate at 2 m depth was three times smaller with 22.78 mg/cm^2/day. Teluk Yu in Pulau Langkawi had a higher accumulation rate compared to Datai at 49.92 and 6.64 mg/cm^2/day, respectively. Port Dickson and Pulau Langkawi were widely separated locations in the west coast of Peninsular Malaysia and the settling particles in their coral reefs were extremely high.

Pulau Redang in the east coast of Peninsular Malaysia had the lowest accumulation rate. All sites in Pulau Redang were sampled at different depths had almost similar accumulation rates at between 0.20 and 0.54 mg/cm^2/day. Pulau Tinggi during July 2007 and Pulau Mentinggi had twice the accumulation rate of Kampung Sebirah and Buloh Kasap with an average of 4.56 mg/cm^2/day. The accumulation rates obtain in Kampung Sebirah and Buloh Kasap were almost the same at between 1.47 to 2.11 mg/cm^2/day. Pulau Renggis during May 2006 had low accumulation rates at between 0.25 to 0.49 mg/cm^2/day except at 8 m depth with 1.58 mg/cm^2/day. During the four sampling periods, all sites sampled at depths between 5 m to 12 m showed that the accumulation rate was not more than 2.50 mg/cm^2/day. Pulau Tulai had a higher accumulation rate compare to Pulau Renggis. However, the amount of settling particles varied greatly throughout the sampling period from as low as 1.11 to 32.84 mg/cm^2/day. During April 2007, Pulau Tulai received the lowest settling particles with 1.11 to 1.49 mg/cm^2/day.

Organic and inorganic matters of settling particles were calculated using (2) and (3) (Table 1). The sampling sites in the west coast had almost 90% inorganic matter except Port Dickson samples at 3 m depth containing 93.92% inorganic matter. Although Datai had a lower accumulation rate compared to other sites in the west coast the percentage of inorganic matter was in the same range. In the east coast, Pulau Tulai during the first two sampling showed the highest accumulation rate among the other sites and had the highest percentage of inorganic matter, 95.14 to 96.30%. The results showed that lowest accumulation rate was from Pulau Redang and Pulau Renggis during May 2006 with a high percentage of organic matter, 11.94 to 26.45% and low percentage of inorganic matter, 73.55 to 88.06%. Pulau Tinggi had a higher percentage of inorganic matter compare to Pulau Redang, although it had a similar accumulation rate. In general, this study showed that low accumulation rate had high percentage of organic matter and vice-versa. The relationship between accumulation rate and percentage of organic matter was conducted using Spearman's Rank Order correlation coefficient. There was a large negative correlation between the two continuous variables ($n=65$; $r = -0743$; $p<0.005$), with the higher accumulation rate associated with a high percentage of organic matter (Figure 3).

DISCUSSION

The high accumulations of settling particles in the west coast of Peninsular Malaysia as noted in this study are higher than the east coast of Peninsular Malaysia. This study showed the first record of accumulation rates in Pulau Langkawi and Port Dickson. Both locations in the west coast of Peninsular Malaysia are shallow at less than 3 m depth and the accumulation rates between the depths are different. Port Dickson and Teluk Yu showed high accumulation rates except in Datai. The sandy beach in Port Dickson is flat and coral reefs are exposed to air during low tide. These would increase the re-suspended sediment during changes of tides. If the wave energy is low, the suspended sediment settles out of the water column will deposit on the sea floor (Philipp & Fabricius 2003). At the shallower depths, the wave energy becomes high and causes the re-suspended sediment to settle in the sediment trap.

TABLE 1. Accumulation rates, organic and inorganic matters from all locations

Place	Location	Date	Depth (m)	Accumulation rate (mg/cm^2/day)	Organic matter (%)	Inorganic matter (%)
Port Dickson	Blue Lagoon	Sep-06	2.0	22.78	9.56	90.44
			3.0	76.83	6.08	93.92
Pulau Redang	Terumbu Kili	May-06	3.0	0.48	14.00	86.00
			6.0	0.54	13.58	86.42
			9.0	0.37	11.94	88.06
	P. Ekor Tebu	May-06	3.0	0.33	16.29	83.71
			4.0	0.37	20.08	79.92
			6.0	0.20	26.45	73.55
	Mak Simpan	May-06	5.0	0.35	15.67	84.33
			7.0	0.41	17.08	82.92
			9.0	0.29	19.86	80.14
Pulau Tinggi	Kg. Sebirah	Jul-07	3.7	1.47	4.65	95.35
			4.7	1.83	6.20	93.80
			5.9	2.05	5.83	94.17
	Buloh Kasap	Jul-07	5.4	2.11	6.34	93.66
			6.0	1.97	5.13	94.87
			6.5	1.75	6.83	93.17
			7.0	1.78	7.20	92.80
			8.0	2.04	7.15	92.85
	P. Mentinggi	Jul-07	3.9	5.13	6.78	93.22
			4.1	4.10	6.86	93.14
			4.3	4.57	6.67	93.33
			4.6	4.42	6.22	93.78
Pulau Langkawi	Teluk Yu	Jan-08	1.0	49.92	9.76	90.24
	Datai	Jan-08	2.0	6.64	9.58	90.42
Pulau Tioman	Pulau Tulai	Sep-05	1.0	26.15	4.52	95.48
			2.0	32.84	3.70	96.30
			3.0	17.49	3.96	96.04
		May-06	3.0	14.22	4.08	95.92
			4.0	10.04	4.62	95.38
			5.0	12.95	4.86	95.14
		Apr-07	4.0	1.11	11.33	88.67
			4.5	1.49	10.46	89.54
			5.0	1.32	11.03	88.97
		Sep-07	2.0	4.75	11.29	88.71
			3.0	4.69	12.30	87.70
			4.0	5.32	11.48	88.52
	Pulau Renggis	Sep-05	5.0	0.93	11.74	88.26
			7.0	1.62	11.63	88.37
			8.0	1.84	12.12	87.88
			9.5	1.37	12.23	87.77
			11.0	1.45	10.57	89.43
			12.0	1.51	9.12	90.88
		May-06	7.0	0.29	19.87	80.13
			8.0	1.58	6.73	93.27
			9.0	0.25	24.70	75.30
			10.0	0.49	17.21	82.88
			11.0	0.42	20.86	79.14
			12.0	0.41	17.70	82.30
		Apr-07	8.0	1.52	15.73	84.27
			9.0	2.50	12.77	87.23
			10.0	0.99	19.43	80.57
			11.0	1.00	16.79	83.21
			11.5	1.04	17.42	82.58
			12.0	1.04	14.10	85.90
		Sep-07	8.0	1.62	12.12	87.88
			9.0	2.02	14.83	85.17
			10.0	1.94	13.45	86.55
			11.0	1.82	12.58	87.42
			11.5	1.97	12.65	87.35
			12.0	2.22	13.83	86.17

• standard deviation is less than 5%

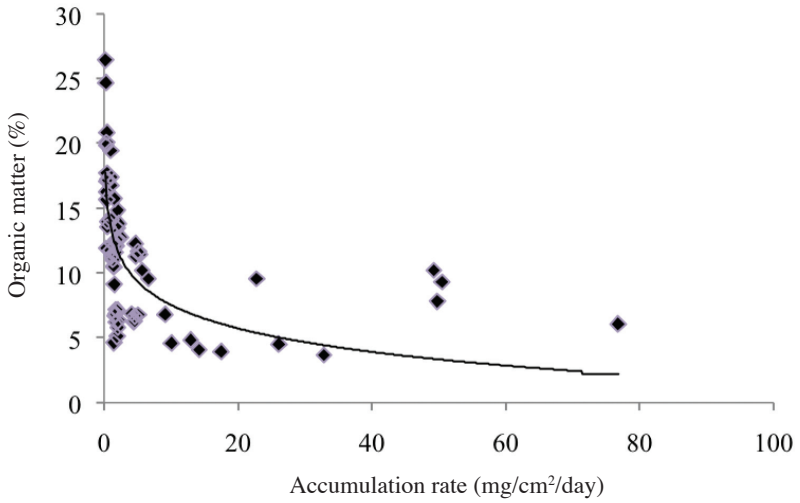

FIGURE 3. Correlation of accumulation rates and organic matter

The domination of *Porites* species in the Straits of Malacca is because it has a high tolerance to sediment and particle deposition probably due to their cleaning mechanism to remove sediments through their mucus secretions or ciliary action (Goh & Sasekumar 1980; Hendry & McWilliams 2001). The high accumulation of settling particles and large dead coral coverage in the west coast compared to the east coast of Peninsular Malaysia has proven that high input of sediment from the shore has a big impact to the coral reef. Chua & Charles (1980) also noted that coral diversity is low in the west coast of Peninsular Malaysia relatively related to the turbid and muddy conditions of seabed.

Pulau Redang shows the lowest accumulation of settling particles in all the sampling locations. There is minor variation of accumulation rates between the depths of samples taken. However, the organic matters content in the settling particles from Pulau Redang are the highest. The organic matter categories can be plankton or microorganisms. The high content of organic matter provides food to the coral colonies in Pulau Redang (Table 1). Meanwhile Pulau Tinggi shows high content of inorganic matter in the settling particles. It is believed to be due to re-suspended particles and runoff from the land or mainland of Peninsular Malaysia. Pulau Tinggi is located nearer the mainland of Peninsular Malaysia compare to Pulau Redang. The samples from Pulau Tinggi also show variations between the three locations. The accumulation of settling particles in the same area of coral reefs has differences because of the environmental condition such as sandy bottom for re-suspended sediment or between the coral reefs with low re-suspended sediment.

Samples obtained at Pulau Tulai of Pulau Tioman showed high accumulations of settling particles compare to Pulau Renggis. However the accumulation rates were extremely high during September 2005 and May 2006, due to the high rainfall between the sampling periods. The rainfall will cause high runoff from the shores. Pulau Tulai is also a mangrove island which can release more particles to flow from the mangrove area into surrounding seawater during the rainy period. There is no data obtained from the monsoon season at the sampling locations due to bad weather hindering diving activities. No differences were seen in this study between pre-monsoon and post-monsoon seasons. However, there would be a difference during the monsoon because high accumulation rates were noted during the rainy periods during sampling time in September 2005 and May 2006. The effects of rain were only seen in Pulau Tulai and not in Pulau Renggis. This is mainly due to the Pulau Renggis being small and rocky. The percentages of organic and inorganic matter in Pulau Tioman are similar to Pulau Redang. The reason why the coral reefs area in Pulau Redang and Pulau Tioman is high is because of low accumulation of settling particles which is high with organic matter. The high percentage of inorganic matter during September 2005 and May 2006 in Pulau Tulai, Pulau Langkawi and Pulau Tinggi are due to re-suspended particles caused by wave action. A few samples from different depths (September 2005 - 12 m and May 2006 - 8.0 m) of Pulau Renggis also show high total inorganic matter. This is can be due to the construction of the marina at Teluk Tekek which is near to Pulau Renggis (Teoh & Celesta 2004). The particles or inorganic matters from the construction site can possibly increase the inorganic matter of settling particles in Pulau Renggis. The marina is under construction from 2004 to 2006. The total inorganic matter in Pulau Renggis during 2007 is lower.

A negative correlation coefficient between accumulation rate and organic matter were noted at Pulau Tioman, while inorganic matter shows a positive correlation with accumulation rate. This study showed that the percentages of organic matters were constantly low at high accumulation of settling particles. At high accumulation of settling particles, there were high percentages of inorganic matter. The accumulation rates at various depths in the coral reef showed the significant influence of the organic and inorganic matters. The high accumulation is due to re-suspended sediment during

sampling periods. However, further investigation is needed to determine the influence of total re-suspended sediment at the shallow reef areas like Port Dickson, Pulau Langkawi and Pulau Tinggi. The coral reefs in the east coast need to be monitored and controlled before terrestrial input can degrade the condition of the reef areas. It is suggested that more sampling locations for further studies and; permanent sample traps be placed at each sampling site for long term monitoring together with according the coral coverage and health of coral reefs in both the coastal areas of Peninsular Malaysia and updated frequently.

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