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Coastal Erosion Measurement Along Tanjung Lumpur to Cherok Paloh, Pahang During the Northeast Monsoon Season

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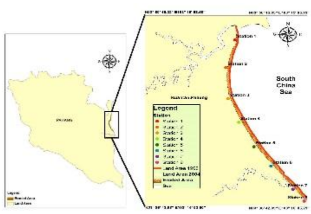
Graphical abstract



Abstract

The map of Tanjung Lumpur to Cherok Paloh from 1996 to 2004 revealed that there were significant changes on coastal profiles. If the problem remains unsolved within 5 to 10 years, the beaches in the area might be fully eroded. The main objective of this study is to measure erosion of the coastline along Tanjung Lumpur to Cherok Paloh, Pahang during the northeast monsoon (December 2013 to February 2014). Transit set and dry sieving method were used for beach profile and grain size characteristics measurement. GRADISTAT v8 program is used for sedimentological analysis. Cluster analysis was used to show the group of higher eroded, medium eroded and lower eroded. The study found that almost all of the beach profiles had increased in length and the beach slopes were steeper; meanwhile the sedimentological analysis indicated that all the stations were dominated by sandy type during the period of study. The action of higher waves, tides and currents were the biggest contribution to erosion during northeast monsoon. From this study, it can be concluded that almost all stations have undergone erosion during the northeast season.

Keywords: Coastal profile; erosion; sedimentological analysis; cluster analysis; northeast monsoon

Abstrak

Peta Tanjung Lumpur hingga ke Cherok Paloh dari tahun 1996-2004 menunjukkan bahawa terdapat perubahan ketara pada profil pantai. Jika masalah ini tidak dapat diselesaikan dalam tempoh 5 hingga 10 tahun, pantai-pantai di kawasan tersebut mungkin akan terhakis sepenuhnya. Objektif utama kajian ini adalah untuk mengukur hakisan pantai di sepanjang Tanjung Lumpur ke Cherok Paloh, Pahang semasa berlakunya monsun timur laut (Disember 2013-Februari 2014). Kaedah Set Transit dan pengayakkan kering telah digunakan untuk mengkaji profil pantai dan pengukuran ciri-ciri saiz bagi butiran pasir. Program GRADISTAT v8 digunakan untuk analisis sedimentologi. Analisis kluster digunakan untuk menunjukkan kumpulan yang lebih tinggi, sederhana dan rendah terhakis. Kajian ini mendapati bahawa hampir semua profil pantai menunjukkan peningkatan dari segi panjang dan cerun pantai yang lebih curam; manakala analisis sedimentologi menunjukkan bahawa semua stesen telah didominasi oleh butiran jenis berpasir. Keadaan dimana ombak, pasang surut dan arus adalah sumbangan terbesar kepada hakisan semasa berlakunya monsun timur laut. Daripada kajian ini, dapatlah disimpulkan bahawa hampir semua stesen kajian telah mengalami hakisan tanah semasa berlakunya monsun timur laut.

Kata kunci: Profil pantai; hakisan; analisis sedimentologi; analisis kluster; monsun timur laut

1.0 INTRODUCTION

Pahang is the largest state and located at the east coast of Peninsular Malaysia. Kuantan is the capital of Pahang, which situated in the center of the state and located on the banks of the Kuantan River mouth. Pahang has a lot of beautiful beaches with fascinating landscape and scenery, which can capture the attention of visitors to the beaches. Cherating, Teluk Chempedak, Tanjung Lumpur and Pantai Sepat are the examples of the most captivating beaches in Pahang, which attract people for recreational activities. Pahang coastlines have immense social, environmental, and economic value, especially for the population that resides in the area.

However, these areas underwent recession due to erosion problem. Measurement of coastal erosion is needed in order to prevent the situation from becoming worst in the long term period. According to the report from National Coastal Erosion Study[1], approximately 46.3% of Pahang's coastlines have undergone erosion which accounts for 125.4 km of its length. The effect of coastal erosion caused the total number of visitors to that area was decreasing due to safety problems.

Coastal erosion can be defined as the physical wearing of surface materials by currents, wave action, and tidal currents.[2] Commonly, the coastal erosion was caused by waves generated via storms, wind or fast moving motor craft and these shall make a long term losses of sediments at that area. Coastal erosion occurs when the shore loses their materials (sediments) which resulting in depletion of sediment budget.[3] Coastline change their shape and size from time to time as a response to waves, currents and tides.[4] Human activities such as beach construction, land reclamation, port construction, shrimp farming, and offshore activities also play their role in these processes.[5] The coastal erosion activity normally occurs when the sand are washed off from the coastline and gets smaller, and the opposite process, in which accretion, starts to take place when sand or other materials are accumulated to the coastline and becomes bigger.

The erosion of beach can be accelerated based on the result of runoff during the period of heavy rain, in which at this period, the beach sediments are swept into the sea by heavy runoff issuing from a stream.[6] In Malaysia, the eastern coast of Peninsular Malaysia will facing the maximum rainfall during northeast monsoon.[7] However, the sediments that found on beach are dependent on the nature of the waves.[8] Figure 1 shows the size of the land area in 2004 (yellow), where it became decrease compared to the size of the land area in 1996 (red). This is because the land underwent recession due to erosion problem. Observation made in the area shows that most of the study area has been eroded. The presence of tourists and traders at that area also were decreased due to coastal erosion and safety problems. If the problem remains unsolved immediately within 5 to 10 years, the beaches area will becoming fully eroded and might cause a huge impact on ecotourism and the local residents' income.

The main objective of this study is to measure the coastal erosion along Tanjung Lumpur to Cherok Paloh, Pahang during the northeast monsoon (December 2013–February 2014). The specific objectives are to determine changes of beach profile, to determine sedimentological characteristics, and to determine the causes of coastal erosion along the study area during the northeast monsoon.

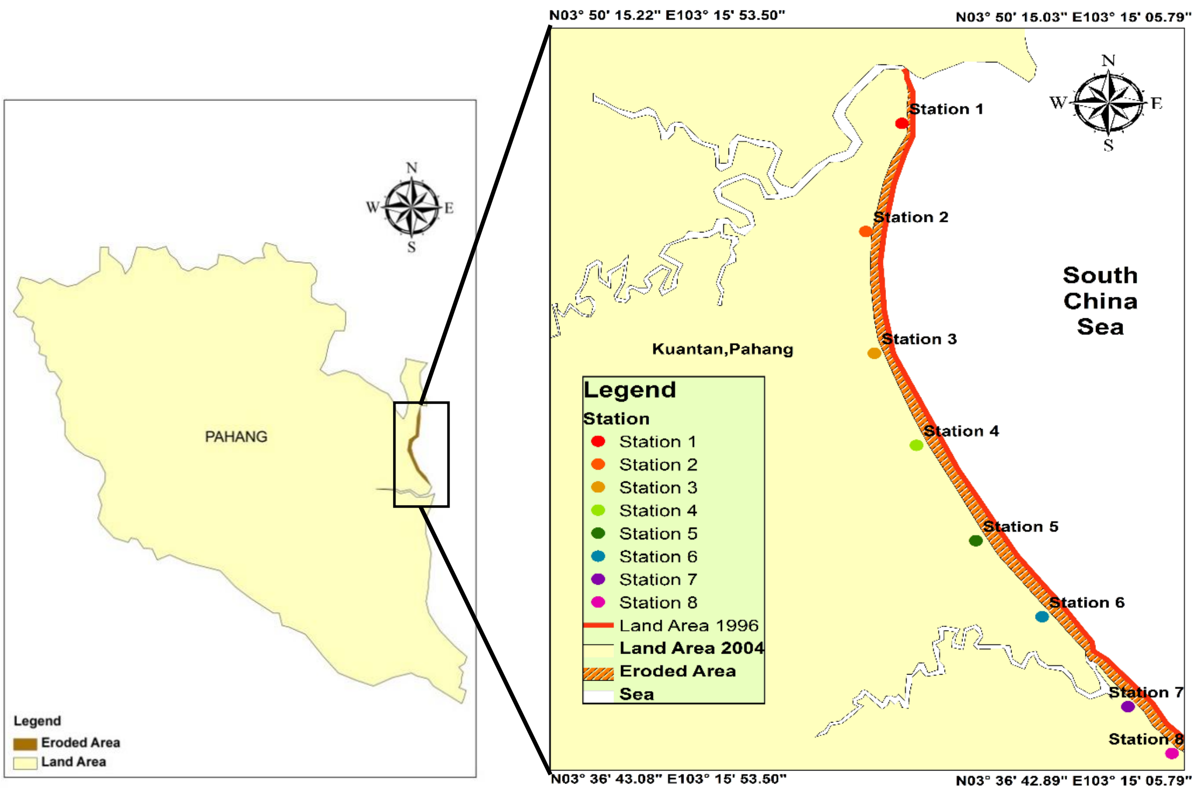


Figure 1 Map of the study area (*Source*: Faizan[9])

2.0 EXPERIMENTAL

Sites Description

Tanjung Lumpur to Cherok Paloh is located along the eastern coast of Peninsular Malaysia, which in Pahang State. The study area covers approximately 25 km in length of the Pahang coastline area starting from Pantai Tanjung Lumpur (latitude 03° 48' North and longitude 103° 20' East) to Pantai Cherok Paloh (latitude 03° 38' North and longitude 103° 23' East). Figure 1 shows the study area locations. The area is almost fully exposed to the attacks of waves from the South of China Sea.

The climatic condition in this area is the monsoon season's type, which known as the southwest monsoon (May to September), northeast monsoon (November to March) and two shorter periods of inter-monsoon seasons which bring an annual rainfall between 1488 to 3071 mm per year.[10] These areas are influenced by the semidiurnal tides with two high tides and two low tides, within a lunar day. The prevailing wind flow in the southwest monsoon season is light and south-westerly, which is below of 15 knots; and in the northeast monsoon, the prevailing wind is north-easterly or easterly in the range of 10 to 20 knots and sometimes may reach to 30 knots or more during periods of strong surges of cold air from the north (cold surges).[7] Meanwhile, the winds are light and variable during the two inter-monsoon seasons.

Data Collection

Eight stations were identified, which the longitude and latitude coordinates of each station were recorded using Global Positioning System (GPS) (Table 1). Data for three months were collected in northeast monsoon (December 2013, January 2014, and February 2014) and used for comparison. The study area covered approximately 25 km of length with each station consists of 2 km apart.

Table 1 GPS Locations of sampling stations 1 to 8

STA	GPS Coordinate	Location
1	N 03◦ 47.844 E 103◦ 20.451	Pantai Tanjung Lumpur
2	N 03◦ 46.533 E 103◦ 19.856	Pantai Kg Anak Air
3	N 03◦ 44.905 E 103◦ 19.529	Pantai Kg Kuala Baharu
4	N 03◦ 43.507 E 103◦ 19.730	Pantai Kg Rhu Bongkok
5	N 03◦ 41.917 E 103◦ 20.286	Pantai Kg Ketapang
6	N 03◦ 40.628 E 103◦ 20.923	Pantai Kg Sepat
7	N 03◦ 37.750 E 103◦ 22.858	Pantai Kg Hijrah
8	N 03◦ 37.513 E 103◦ 23.026	Pantai Cherok Paloh

Three types of analysis were applied, known as beach profiles, sedimentological characteristics measurement, and cluster analysis. These analysis are able to explain the beach behaviour and its morphologic variation along the times.[11] Beach profile measurement was conducted *in-situ* using transit set; meanwhile the sediment grain size measurement was collected on-site; and analysed in the laboratory using dry sieving method. The CA method was analysed using XLSTAT software.

Profile Data

The measurement of beach profiles is important in order to get the information of erosion and sand deposition, in which delineate the shape of the beach surface along the study location by comparing profiles of the same transect taken over time, and it is possible to determine gains and losses of sand at that area. Meanwhile, the measurement of sediment characteristics is an important technique for studying sediment movements, which it can be an indication of erosion or accretion at the study area.[11] It also can be used to identify the seasonal textural behaviour along coastlines.[12]

In this study, the beach profiles measurement was executed using a set of transit set, which consisting of theodolite and measuring pole and run *in-situ* following the method described by Azfar *et al.*[13], Rosnan *et al.*[11], and Saravanan and Chandrasekar[14]. Beach profiles using transit set is the most traditional, easy, and very adequate methods used in performing beach profiling surveys and its capability of providing highly accurate readings on survey data.[13] Then, the beach profiles were generated by calculating distance and elevation of the beach.

Sedimentological Data

In this study, dry sieving method was used. This method has been widely used by sedimentologist in order to classify sedimentary and explain the transport dynamics in the certain area.[15] The analysis of sedimentological characteristic using dry sieving method is important as it provides an indication that the area is becoming erosion or accretion, to classify sedimentary environments and elucidate transport dynamic at coastal area.[16] The surface sediment samples were collected at high tide, mid tide and low tide along eight stations using a plastic hand scoop for 5 cm depth during the beach profile survey. The sediment samples were stored in plastic bags and transferred into the laboratory. All foreign materials (leaves and shell fragments) in the samples were removed and dry out in the oven at a temperature of 105ºC for overnight. 100 g of the sample was transferred to the coarsest of the stacked series of sieve with mesh diameters of 4 mm, 2.8 mm, 2 mm, 1.4 mm, 1 mm, 710 µm, 500 µm, 355 µm, 250 µm, 180 µm, 125 µm, 90 µm and 63 µm; and shake for 10-15 minutes using mechanical shaker. The materials that trapped in each sieves were transferred onto a piece of paper, weighed, and recorded. This method was referring to the method described by Abuodha[16], Rosnan and Zaini[15], and Dora *et al.*[12].

Then, a computer program namely GRADISTATv8 that created by Blott and Pye[17] was used for statistical calculation in order to get mean, sorting, skewness, and kurtosis values. GRADISTAT program is extremely versatile, accepting standard and non-standard size data, and producing a range of graphical outputs including frequency and ternary plots.[12] The GRADISTAT program calculation was considering the logarithmic method (*phi*-scale, Ø) that proposed by Folk and Wards[18] as follows:

$$\text{Mean } (X_{\emptyset}) = \frac{\emptyset_{16} + \emptyset_{50} + \emptyset_{84}}{3}$$

$$\text{Sorting } (Sd_{\emptyset} \text{ or } \sigma_{\emptyset}) = \frac{\emptyset_{84} - \emptyset_{16}}{3} + \frac{\emptyset_{95} - \emptyset_{5}}{6.6}$$

$$\text{Skewness } (Sk_{\emptyset}) = \frac{\emptyset_{16} + \emptyset_{84} - 2\emptyset_{50}}{2(\emptyset_{84} - \emptyset_{16})} + \frac{\emptyset_{5} + \emptyset_{95} - 2\emptyset_{50}}{2(\emptyset_{95} - \emptyset_{5})}$$

$$\text{Kurtosis } (K_{\emptyset}) = \frac{\emptyset_{95} - \emptyset_{5}}{2.44(\emptyset_{75} - \emptyset_{25})}$$

Wentworth scale proposed by Wentworth[19] was used to express the size of the sediment (mean Ø value). According to Bird[6], a $\log_2$ can be used to provide integers for each of the Wentworth class limits, which can be expressed as:

$$D_{\emptyset} = -\log_2 (D\text{mm})$$

where $D_{\emptyset}$ is the sediment/grain diameter in phi units (Ø), and D is the corresponding diameter in millimetre.

Cluster Analysis

Cluster analysis (CA) classifies objects (cases) into classes (clusters), so that each object is similar to the others within a class but different from those in other classes with respect to a predetermined selection criterion.[20] In this study, CA was used to classify the area of higher eroded (HE), medium eroded (ME), and lower eroded (LE). Ward's method was applied to the data from beaches distance. Dendrogram is a result and illustrated based on the most common approach in hierarchical agglomerative clustering.[21]

3.0 RESULTS AND DISCUSSION

Beach profiles were recorded started from December 2013 to February 2014 during the northeast monsoon, where during this period the weather was rainy, strong waves and high tides. The data was recorded using a set of transit set via *in-situ* measurement. The findings of this study shows the average length of beaches in December 2013 was shorter compared to January and February 2014 with the values of 15.5m, 16.3m, and 17.2m, respectively, and this situation occurred in all of the stations. Figure 2 depicts the changes of beach's length from the station 1 to 8. The distance of beaches in February 2014 appears to be longer compared to December 2013 due to the end of rainy season. This is because beach erosion or accretion can be accelerated as a result of runoff during heavy rain periods, in which beach sediments are swept into the sea by strong runoff issuing from a stream.[6] The stability of beach length depended on the sediment volume entering and leaving this section due to the net cross-shore and longshore transport.[22] Strong waves during the northeast monsoon also play a vital role in shaping of a coastline especially to make it eroded or accretion.[22]

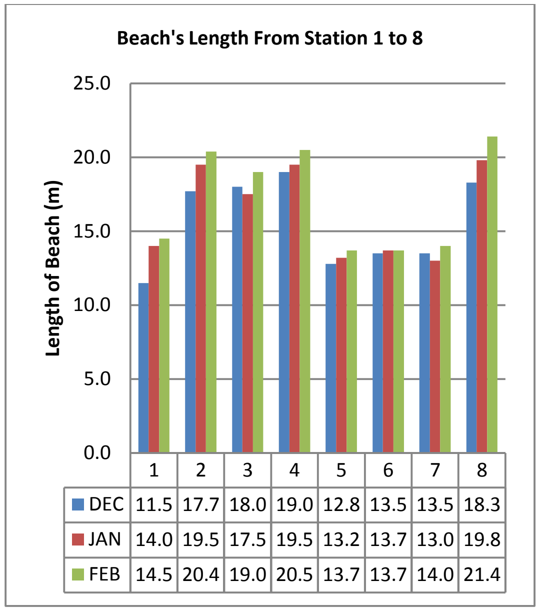


Figure 2 Distance of beaches from station 1 to 8

Referring to Figure 3, it shows that station 1, 5, 6, and 7 had tendency of erosion. This is because the east coast of Peninsular Malaysia, especially in the study area is facing the maximum of rainfall during northeast monsoon.[7] Some of the station showed slightly accretion at the high tide especially in station 1 and 8 due to their location closely to the mouth of Kuantan River (Station 1) and Pahang Tua River (Station 8), which means it is plausible to receive a continuous supply of fluvial sediment from the river. In station 1, 5, 6, and 7, it shows progressively eroded due to these stations were located at the middle of the hooked shaped bay which it is constantly faces the waves from South China Sea.

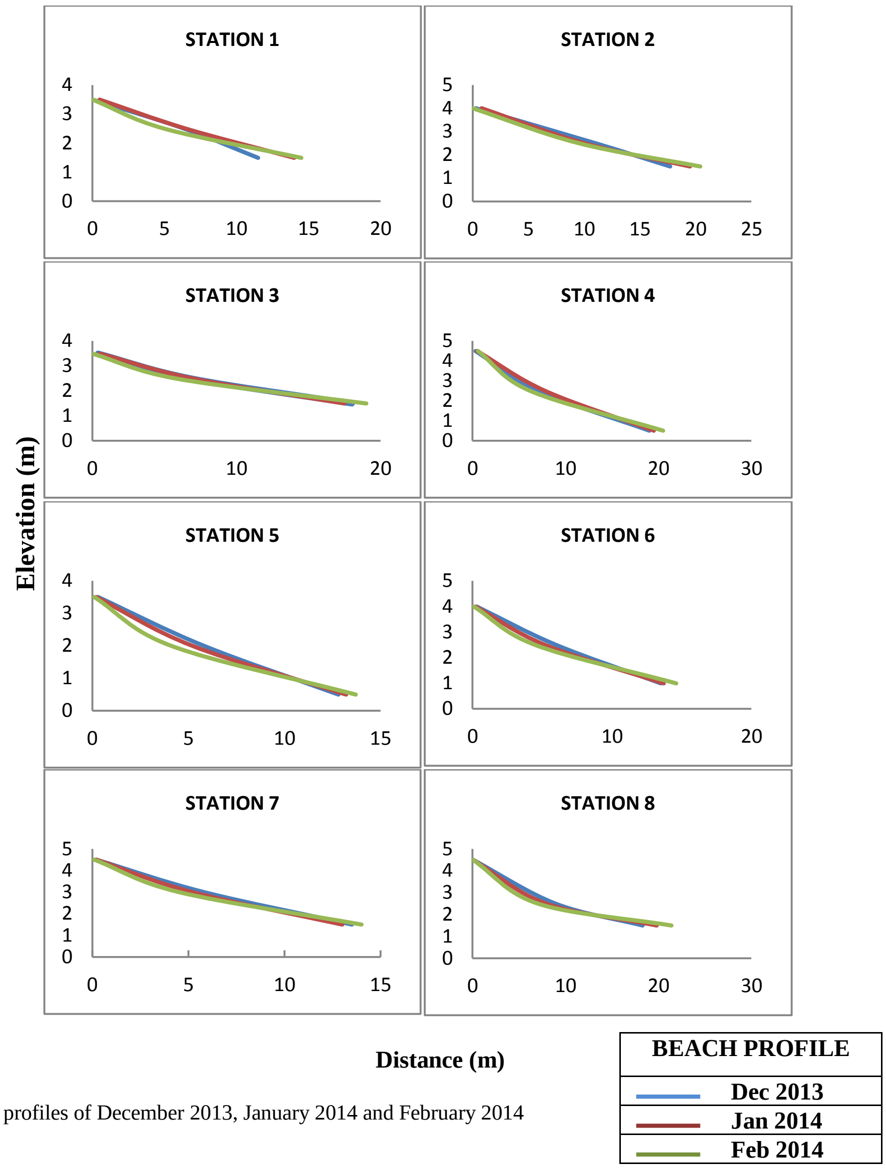


Figure 3 Beach profiles of December 2013, January 2014 and February 2014

During the measurement of beach's length, the beach's slope was run and recorded using a transit set. From Table 2, almost all the stations showed decrease of the beach slopes for the month of December 2013, January 2014 and February 2014.

Table 2 Beach slope for station 1-8

Station	Beach slope (°)		
	Dec 2013	Jan 2014	Feb 2014
1	4.9	4.8	4.8
2	5.0	5.0	4.9
3	7.2	6.9	6.7
4	5.4	5.2	5.0
5	7.4	6.8	6.9
6	7.0	6.7	6.8
7	7.6	7.0	6.8
8	5.6	5.0	5.1

For sedimentological data analysis, the statistical values of mean (Ø), sorting (Ø), skewness (Ø), and kurtosis (Ø) were calculated using GRADISTATv8 and the findings can be referred in Table 3. Then, pie charts were plotted to get the percentage of sedimentological class characteristics during the period of study.

Table 3 The average values of sedimentological characteristics for the months of December 2013, January 2014 and February 2014

STA	MEAN Ø						SORTING Ø						SKEWNESS Ø						KURTOSIS Ø					
	DEC		JAN		FEB		DEC		JAN		FEB		DEC		JAN		FEB		DEC		JAN		FEB	
1	2.08	FS	2.18	FS	2.18	FS	1.38	PS	1.29	PS	1.32	PS	-0.20	CS	-0.26	CS	-0.30	SCS	0.82	P	0.89	P	0.94	M
2	1.36	MS	1.85	MS	1.85	MS	1.37	PS	1.31	PS	1.33	PS	-0.14	CS	-0.25	CS	-0.19	CS	0.91	M	0.90	P	0.89	P
3	1.51	MS	1.63	MS	1.84	MS	1.25	PS	1.26	PS	1.34	PS	-0.10	S	-0.20	CS	-0.23	CS	0.97	M	1.02	M	0.96	M
4	1.63	MS	1.59	MS	1.89	MS	1.31	PS	1.26	PS	1.32	PS	-0.14	CS	-0.13	CS	-0.21	CS	0.92	M	0.93	M	0.96	M
5	1.25	MS	1.55	MS	1.71	MS	1.30	PS	1.29	PS	1.46	PS	-0.08	S	-0.23	CS	-0.18	CS	0.98	M	0.98	M	0.90	P
6	1.65	MS	2.09	FS	2.02	FS	1.38	PS	1.33	PS	1.37	PS	-0.16	CS	-0.21	CS	-0.23	CS	0.91	M	0.88	P	0.90	P
7	0.93	CS	1.34	MS	1.32	MS	1.42	PS	1.48	PS	1.35	PS	-0.05	S	-0.19	CS	-0.10	S	0.99	M	0.94	M	0.99	M
8	1.70	MS	1.38	MS	2.06	FS	1.41	PS	1.34	PS	1.47	PS	-0.16	CS	-0.16	CS	-0.28	CS	0.86	P	0.95	M	0.89	P

Where;

Mean Ø:
S = Fine Sand
MS = Medium Sand
CS = Coarse Sand

Sorting Ø:
PS = Poorly Sorted

Skewness Ø:
CS = Coarse Skewed
S = Symmetrical
SCS = Strong Coarse Skewed

Kurtosis Ø:
P = Platykurtic
M = Mesokurtic

Figure 4a-4b show the overall percentage of sedimentological class characteristics along the study area during the northeast monsoon. From the sediment samples, the majority of the sand during the study periods was categorized as medium sand, follows with fine sand, and coarse sand with the values of 71%, 25%, and 4%, respectively (Figure 4a). This result is an evidence of the finding, in which the east coast of Malaysia was dominated by coarse and medium sand due to high energy wave and current transports.[23] Abuodha[16] noted that during northeast monsoon the majority of beaches were dominated with smaller-phi coarser. However, Rosnan *et al*.[22] in their study along Cherating to Nenasi mentioned that almost all of the grain size analysis at that area is medium to fine sediment.

The analysis of skewness was used for indicating either the sediment consisted in fine or coarse fractions, in which the positive skewed, indicate the grain size under fine particles while the negative skewed associated to coarser particles.[15] Skewness (Ø) result indicates the sand categorized as coarse skewed (negatively skewed), symmetrical, and strongly coarse skewed with the values of 79%, 17%, and 4%, respectively (Figure 4b). Although the results of skewness for this research were dominated with coarse skewed (negatively skewed) and the majority of the particles along the study locations have medium sand category, but it was considered valid because of there are other physical factors such as rate of waves and currents action that act on beach. This evidence can be proved when the negative skewed can be dominated by rate of current action.[24]

The study of sorting was important to measure due to it can be an indicator of the erosion and accretion at certain area. Sorting (Ø) analysis explains 100% of the sand along the study areas has poorly sorted (Figure 4c). Rosnan *et al.*[11] mentioned that poorly sorted sediment indicates the process of erosion, while well sorted sediment shows the accretion occurred at that area. According to Dyer[25], he noted that if the beaches are poorly sorted, sorting indicated the range of forces that determined the sediment size distribution. Based on that statement, logically the poorly sorted sediment has coarser in sediment size. However for this study, it was opposite. This is likely due to the factor of an environment formed where fluctuation of energy was happening over the spectrum. Rosnan *et al.*[11] mentioned that the presence of this energy will regulate the sediment transportation and sedimentation.

The kurtosis analysis was used in order to measure the peakedness or flatness of samples. The findings from the study showed that the sediment collected during December 2013 to February 2014 were 63% under mesokurtic and 37% under platykurtic category (Figure 4d). According to Abuodha[16], during the northeast monsoon, the distribution of beaches was more platykurtic and bimodal. However, the result from this research showed that most of the sediments along the study area were under mesokurtic and platykurtic classes.

During the study periods, observation made along the study area showed that the beach erosion or accretion was caused by the large waves, tides and currents during the northeast monsoon. This statement can be proved from the research done by Rosnan *et al.*[22], who made a research regarding on "Beach cycle and sediment characteristics along Pahang coastline" for a whole year, started from Cherating to Nenasi. They also found that among 12 sampling stations, most of them experienced erosion during the northeast monsoon season due to physical forces such as wind, wave, currents, and water level, which acted upon the coast. While, Rosnan and Zaini[15] noted that the finding from their study at the Setiu wetlands, Terengganu; waves, tides, currents, and monsoon season effects are the natural activities that influence the changes of beach profiles and sediment size distribution at beach area.

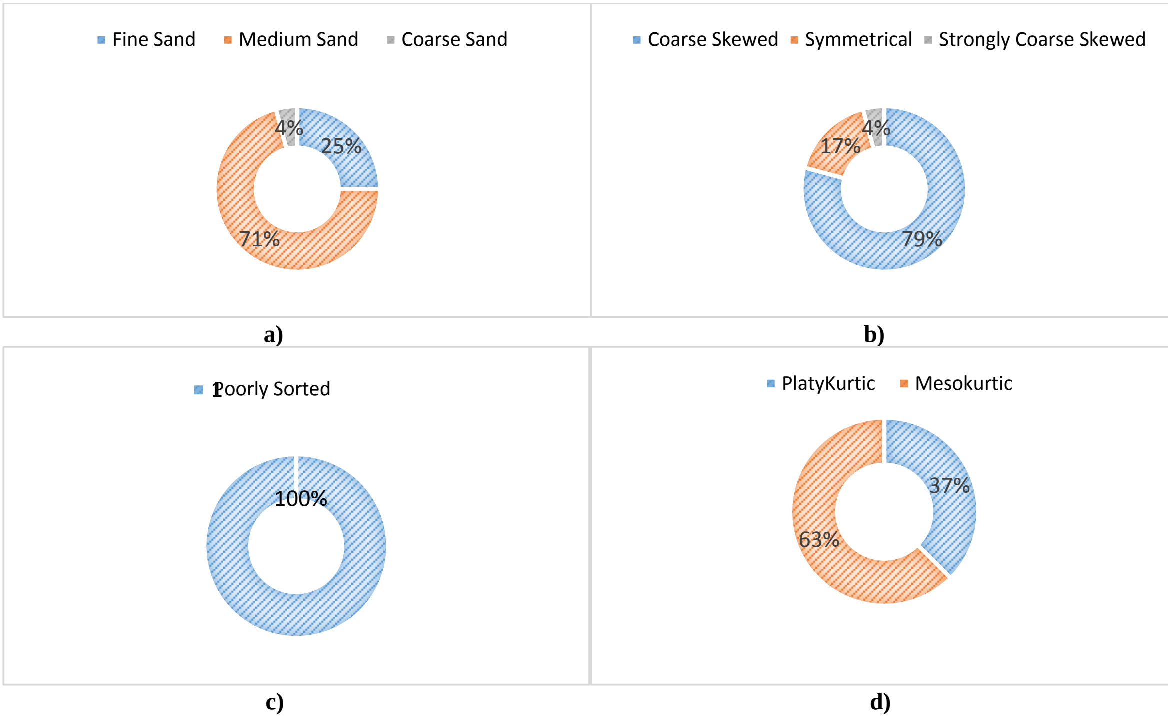


Figure 4 Overall percentages of sedimentological class characteristics along the study area during the northeast monsoon for a) mean, b) skewness, c) sorting, and d) kurtosis

According to Garrison[4], the slope of the beach correlates positively with the grain size of the sediment particles, which depending on particle shape, wave energy, and the porosity of the packed sediments. For instance, the larger the sediment particle's size, the beach become steeper and vice versa. He also mentioned that the finer the grain, the less water soaked into the beach during a swash, while during the backwash, water will quickly run down the beach and carrying together the surface particles and generates more gradual slope.[4]

Table 4 The relationship between the particle sizes of beach material and the average slope of the beach
(*Source:* Garrison[4])

Type of beach material	Size (mm)	Average slope of beach
Very fine sand	0.0625 - 0.125	1°
Fine sand	0.125 - 0.25	3°
Medium sand	0.25 - 0.50	5°
Coarse sand	0.50 - 1.0	7°
Very coarse sand	1 - 2	9°
Granules	2 - 4	11°
Pebbles	4 - 6	17°
Cobbles	64 - 256	24°

Based on the findings, almost all of the readings tallied with the values given in Table 4. However, some of the stations were not tally to the values because of each stations received a different rate of the incoming action of wave energy. This reason can be supported by Beer[8], where he mentioned that the sediments of grain size that found on beaches is dependent on the nature of the incoming wave.

The CA was run using XLSTAT for clustering the area (Figure 5). From the dendrogram, it shows that the monitoring locations has been grouped into three main clusters. Cluster-I is formed by the monitoring sites of 1, 5, 6, and 7 and corresponds to the higher eroded (HE) sites. Cluster-II is formed by the monitoring sites of 2, 4 and 8 and corresponds to the medium eroded (ME) sites. Meanwhile, Cluster-III is formed by the monitoring sites of 3 and corresponds to the lower eroded (LE) site. From the result, it is evident that the CA technique is useful in offering reliable classification of coastal erosion measurement for the whole study area. The information from CA can be used for reducing the number of sampling sites without missing important information.

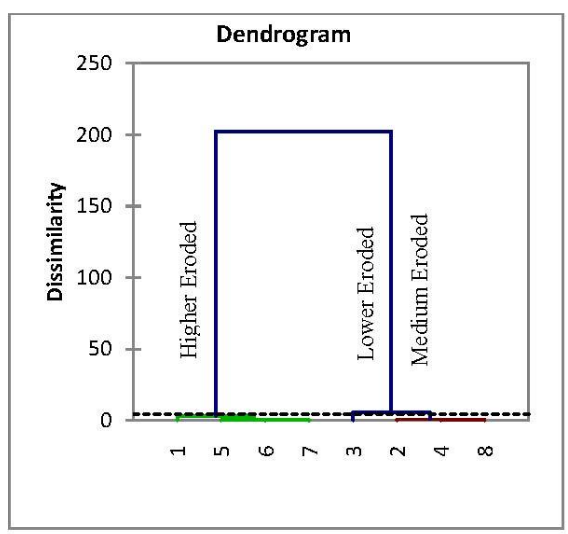


Figure 5 Dendrogram of clustering of sampling sites according to distance of beach profile along Tanjung Lumpur to Cherok Paloh using Ward's method

4.0 CONCLUSION

Coastal erosion measurement during the northeast monsoon generates information about the changes of beaches along the study area. Most of the stations have undergone erosion during the period of study. From the beach profiles, almost all stations get narrower and steeper during that time. The study showed that most of the locations were composed by medium sand, fine sand and coarse sand and it showed a dominance of poorly sorted sediment type. Meanwhile, most of the samples were distributed to coarse skewed (negatively skewed) followed by symmetrical and strongly coarse skewed (strongly negatively skewed); and the sediments were dominated by mesokurtic and platykurtic category. All these changes became evident that the areas are facing erosion. Based on the CA technique, three eroded area known as HE, ME, and LE has been generated successful, where it is obviously parallel to the results of beach profiles and sedimentological characteristics that found in the study area. The study also found that factors such as waves, tides and currents action rate are the biggest contribution for erosion, change of beach profiles and sediment size characteristics during northeast monsoon. This is because the east coast of Peninsular Malaysia facing higher energy wave and current transports during northeast monsoon. Therefore, it can be concluded that the northeast monsoon season affect the grain size distribution and also the beach profiles. The information from this study can be setbacks for the State Government or others public agencies in implementing coastal zone management, coastal development and coastal planning.

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