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Particle Size Distribution in the Bottom Sediments of the Kemaman River Estuarine System, Terengganu, Malaysia

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ABSTRAK

Sedimen permukaan daripada sistem muara Sungai Kemaman dianalisis bentuk butiran saiz bagi memahami dengan jelas proses sedimentasi di muara dan sepanjang Sungai Kemaman. Nilai-nilai statistik tidak menunjukkan perubahan signifikan mengikut musim tetapi hanya memberi nilai phi (Ø) yang rendah semasa musim luar monsun berbanding musim monsun. Ciri-ciri pemendakan sedimen bagi setiap stesen adalah banyak bergantung kepada gabungan daya fizikal seperti aliran air tawar, arus pasang surut and ombak.

ABSTRACT

Surface sediment samples from the Kemaman River estuarine system were analysed for the grain size in order to understand better the sedimentation processes in the estuary and along the Kemaman river. Their statistical values do not vary significantly according to the seasonal changes but show some relatively lower phi (Ø) values during the non-monsoon season compared to the monsoon season. The characteristics of deposited sediments at each station are very dependent upon the combination of physical forces such as freshwater runoffs, tidal currents and waves.

INTRODUCTION

Estuaries and rivers are often regions of high sedimentation, serving as traps for minerals from inland sources transported seaward by rivers, and materials from the coastal ocean transported landward. Determinations of the relative contributions of inland and marine sources of sediments in estuaries are necessary for predicting and controlling sedimentation in harbours, and becoming the sites of major discharges of urban and industrial pollutants. Sediment transport in estuaries and along the river can be important for maintaining navigation channels, dredging harbours, maintaining fish stocks, managing water quality and preventing coastal erosion. These sediments exhibit a considerable degree of variability in terms of mineral type, size range and organic content.

It has been well established that estuaries trap particles and some dissolved materials transported in rivers (Martin *et al.* 1981; Fox 1981; Kennedy 1984). Consequently, estuarine sediments are considered to be important sinks for nutrients, organic matter, trace substances and contaminants derived from inland sources (Simpson *et al.* 1976; Bopp *et al.* 1982). In riverine estuaries, as freshwater mixes with seawater, material transport and deposition can be affected by river flow, tidal flow, wave activity, currents and non-tidal circulation patterns (Dyer 1979). Along submergent coastline estuarine circulation is often characterized by a lower salinity surface layer with a net seaward flow and a denser, more saline bottom layer with a landward flow. This upstream or landward flow along the bottom causes the estuaries to trap particles and particle-associated substances from both riverine and marine sources (Meade 1969; Goldberg *et al.* 1979). In Malaysia, there is little research done regarding spatial and temporal variation of bottom sedimentation along the river. The information about sedimentation rate or erosion aspects is very limited. Nevertheless, detailed investigation concerning both spatial and temporal variability are required in order to better understand the sedimentation processes in the estuaries and along the Kemaman river.

MATERIALS AND METHODS

Description of the Study Area

The study site is located in the Chukai district (04 14.46 N Latitude 103 26.45 E Longitude) which is about 160 km south of Kuala Terengganu, the capital state of Terengganu (*Fig. 1*). In this district flows two major rivers, the Kemaman and Chukai rivers. Although the two rivers diverge upstream, they converge downstream to share a common estuary known as the Kemaman estuary. The Kemaman river is the larger of the two and comparatively has larger drainage and larger discharge and mean annual outflow compared to the Chukai river. The Kemaman river has a fresh water discharge of about 80 m^3/s during the non-monsoon season and 500 m^3/s during the monsoon season. Their river catchment areas, rapidly affected by the industrialization and human activities, has the sea water intrusion limited to a distance of 10 km upstream from the mouth. According to the accumulated data from 1968 to 1987, obtained from the Malaysian Meteorological Service, the monsoon seasons with strong winds and long frequency periods with mean annual rainfall of 3064 mm occurred from November to January. (*Fig. 2*). Meanwhile the non-monsoon seasons with low rainfall occurred during April, May and June.

Analytical Methods

Sampling was carried out twice: the first sampling during the dry season (May 1993) and the second during the rainy season (January 1993). A total of 14 stations (Table 1) were collected during both samplings using the ekman grab. Out of that, 3 surface sediment samples were collected across the mouth of the estuary. Another 11 water samples were collected at one km interval inside the Kemaman rivers commencing from the mouth of the rivers (*Fig. 1*). Stations 1, 2 and 3 in the estuary represent the most seaward while Stations 12, 13 and 14 along the Kemaman river, represent the most landward fresh water point. Since neither texture nor the grain size of the sediments in the Kemaman river varied significantly ($P>0.05$) by the seasonal changes, the data used in this study was the average of both samplings during the dry and rainy seasons.

The grain size of the sediments was determined using the standard dry and wet sieving techniques (Folk 1974). Samples which consist of more than 90% sand were analysed using the dry sieving method, while samples having more than 90% fine sediments were analysed using the laser diffraction method. The median grain size of the sediment was estimated by linear interpolation of the distribution curve. Both median and mean grain size were used in the preliminary data analysis, although only the mean is presented in this study because both parameters show equivalent results. Sedimentological characteristics are reported in phi (ø) units using the conversion factor of Folk (1974) as below. By using the negative value, coarse grain size will have a lower phi (Ø) value which tends to increase when the particle size becomes finer.

$$\varnothing = -\log_2 D$$

where D is diameter of particle in mm.

The mean, standard deviation and skewness of each sample were calculated by the moments method using equations defined by McBride (1971). The method of moments uses data from every grain plot data to obtain statistical information concerning the sedimentary population. The formula proposed by McBride (1971) used to calculate the sedimentological characteristics of mean, skewness and sorting are as follows:

$$X\,\varnothing = \frac{\Sigma fm}{n} \tag{1}$$

$$\sigma_{\varnothing} = \frac{\sqrt{\Sigma f\left(m - X_{\varnothing}\right)^2}}{100} \tag{2}$$

$$Sk_{\varnothing} = \frac{\Sigma f(m - X_{\varnothing})^3}{100\sigma_{\varnothing}{}^3} \tag{3}$$

where ;

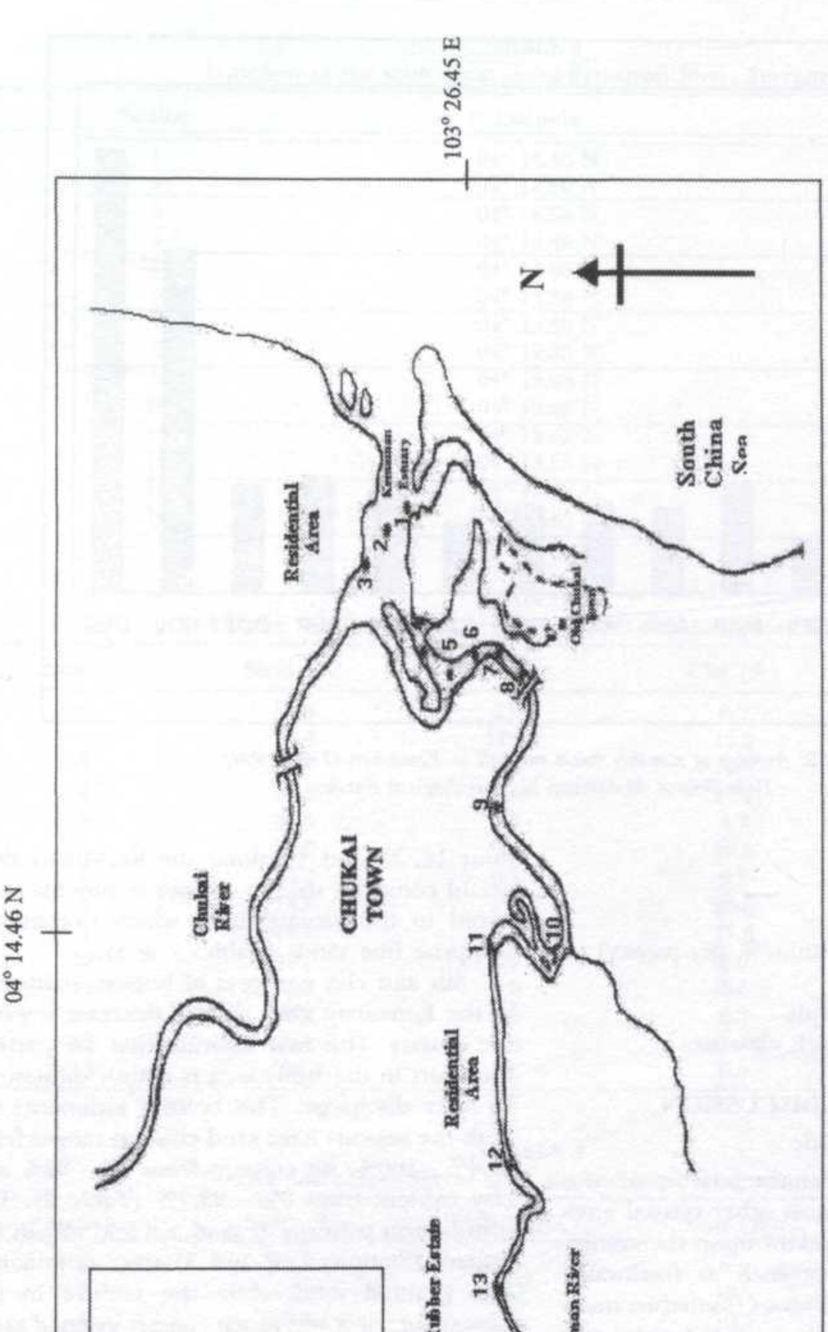

Fig. 1: Location of study area showing the sampling site along Kemaman River, Terengganu, Malaysia

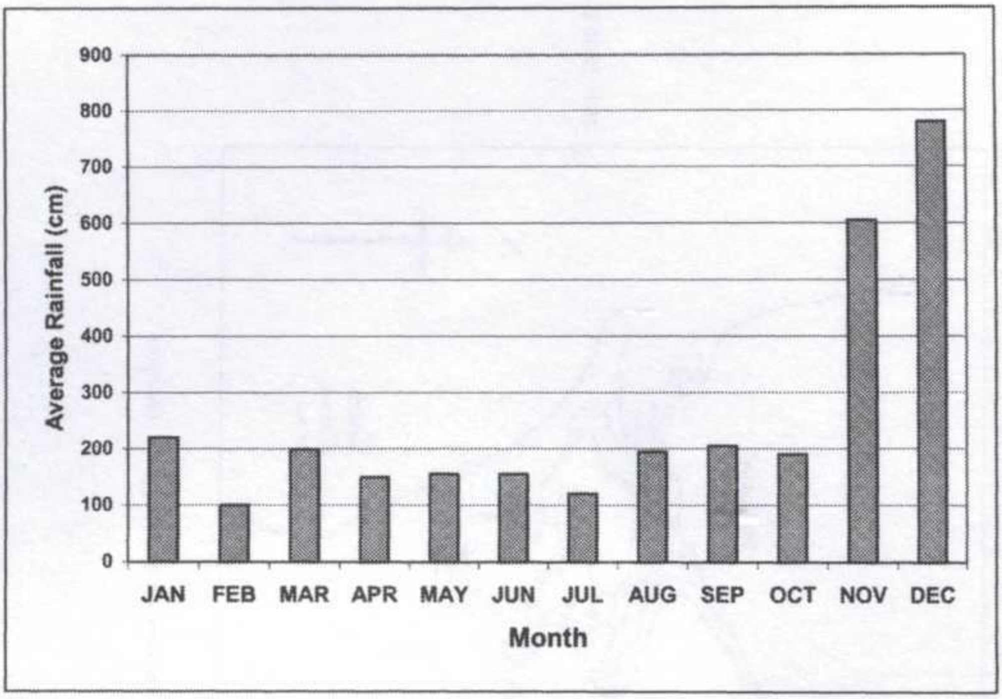

Fig. 2: Average of monthly mean rainfall at Kemaman (1981-1994).
Data Source: Malaysian Meteorological Service

$X_\varnothing$ = mean size
$\sigma_\varnothing$ = sorting
$Sk_\varnothing$ = skewness
f = weight % or volume % (frequency) of each class size
n = number of sample
m = mid-point of each class size

RESULTS AND DISCUSSION

Sedimentological Characteristic

The sedimentological characteristic of the Kemaman estuary, like most other coastal environments, are very dependent upon the combination of physical forces such as freshwater runoffs, tidal currents and waves (Kamaruzzaman 1994). However, statistically, neither texture nor the grain size of the sediments in the Kemaman river varied significantly (P>0.05) according to the seasonal changes (Tables 2 & 3). They only show some relatively lower phi (Ø) values during the non-monsoon season compared to the monsoon season. During the monsoon season which is associated with heavy rain and high water current, the water will transport a high concentration of suspended and fine sediments to the estuary areas. Therefore, areas which have strong currents (Kamaruzzaman 1994) as in Stations 12, 13 and 14 along the Kemaman river would comprise mainly coarser sediments compared to the estuary areas which dominantly comprise fine sands (Tables 2 & 3).

Silt and clay contents of bottom sediments in the Kemaman river show a decrease towards the estuary. This may indicate that the particle transport in the study area is mainly influenced by river discharge. The bottom sediments for both the seasons have sand content ranges from 42.4% - 100%, silt content from 0% - 32% and clay content from 0% - 23.7% (Table 2). The distribution patterns of sand, silt and clay in the estuary (Stations 1, 2 and 3) were dominantly fine grained sand while the texture in the Kemaman river was much coarser grained sand. The percentages of sand were higher (> 80%) within the freshwater region compared to within the estuary. Two probable causes may be forwarded to explain this difference. First, the swift river flow allows fine sediment to deposit but this flow is reduced drastically upon reaching the larger estuary, thus allowing more fine sediment to be deposited. Secondly, as hypothesized earlier, the tides also play a significant role in transporting sediments offshore into the estuary, thus the offshore materials consisting of

TABLE 1
Locations of the study areas along Kemaman River, Terengganu

Station	Latitude	Longitude
1	04° 14.46 N	103° 26.45 E
2	04° 14.50 N	103° 26.40 E
3	04° 14.58 N	103° 26.48 E
4	04° 14.49 N	103° 26.15 E
5	04° 14.05 N	103° 25.84 E
6	04° 13.38 N	103° 26.18 E
7	04° 13.35 N	103° 26.25 E
8	04° 12.85 N	103° 25.75 E
9	04° 13.25 N	103° 24.80 E
10	04° 12.65 N	103° 24.65 E
11	04° 13.42 N	103° 24.70 E
12	04° 13.25 N	103° 23.15 E
13	04° 13.27 N	103° 21.00 E
14	04° 12.85 N	103° 20.25 E

TABLE 2
Texture and percentage of sand, silt and clay during dry season

Station	Sand (%)	Silt (%)	Clay (%)	Texture
1	88.8	4.5	6.7	Very fine sand
2	76.0	11.7	12.3	Moderate sand
3	83.1	6.4	10.5	Fine sand
4	44.3	32.0	23.7	Moderate sand
5	91.9	3.4	4.7	Fine sand
6	80.0	9.5	10.5	Moderate sand
7	85.5	6.3	8.2	Coarse sand
8	73.8	5.6	20.6	Coarse sand
9	74.6	9.8	15.6	Coarse sand
10	96.5	1.5	2.0	Coarse sand
11	93.8	3.6	3.6	Very coarse sand
12	96.2	1.6	2.2	Very coarse sand
13	98.2	0.0	1.1	Very coarse sand
14	100.0	0.0	0.0	Very coarse sand

TABLE 3
Texture and percentage of sand, silt and clay during rainy season

Station	Sand (%)	Silt (%)	Clay (%)	Texture
1	86.4	5.5	8.1	Very fine sand
2	73.8	12.7	13.5	Moderate sand
3	79.6	6.9	10.5	Fine sand
4	42.4	34.20	13.5	Moderate sand
5	89.3	3.9	6.8	Fine sand
6	78.9	10.9	10.2	Moderate sand
7	81.4	6.8	11.8	Coarse sand
8	72.6	6.8	20.6	Coarse sand
9	70.6	10.4	22.6	Coarse sand
10	96.7	2.2	1.1	Coarse sand
11	91.1	4.1	4.8	Very coarse sand
12	95.5	1.9	2.6	Very coarse sand
13	98.4	0.0	1.6	Very coarse sand
14	100.0	0.0	0.0	Very coarse sand

mostly fine sediments would also be transported into the estuary but only little would reach further upstream due to the opposing river currents. The lowest percentage of sand was observed at Station 4 and this can be explained by its geographical position, which is located close to the mouth of the estuary and where the 2 main rivers meet, providing it with 2 sediment sources, fluvial and tidal.

Mean (Xø)

Mean is an index of grain size measurement due to its weight. The obtainable mean values can determine the size of sediment grain. The increasing mean value indicates the decreasing of grain sizes and vice versa. The mean size gives a simple indication of the magnitude of the force, applied by water or wind which will move the grains. The mean value along the Kemaman river ranged from -0.7 to 3.4 Ø or ranging from the very coarse sand to a very fine sand (Table 2). The estuary area (Stations 1, 2 and 3) and some stations near the estuary (Stations 4, 5 and 6) are dominated by the finer sand. Meanwhile the sampling stations that are far away from the estuary (Stations 7 - 14) are more dominated by the coarser sandy texture. This can be explained by the high water velocity from the river inflow which may transport the fine sand and leave the heavier sand along Stations 7 to 14. The large amount of suspended and fine sand will be transported to the estuary, trapped and settle down during a period of slack water or during tidal.

Standard Deviation (sø)

Standard deviation is sometimes referred to as sorting and indicates the range of forces which determine the sediment size distribution (Briggs 1977; Dyer 1985). A large value standard deviation (a poor sorting) indicates that little selection of grain had taken place during transportation deposition. Good sorting, indicated by a small standard deviation, on the other hand, is produced by the selective action of energy which transports and deposits limited range of grain size. In this study, sorting does not show a significance within monsoons and has ranged values between 0.7 to 1.6 (Table 4), indicating that the sediments in general are moderately to poorly sorted. A moderate sorting was observed at Stations 1, 10 and 11 and these can be explained by their geographical position of the river with a slope curve which reduces the water flow and may allow more selection of grain to be deposited.

Skewness (Skø)

Skewness is the measure of the degree of symmetry to provide a measure of the tendency of the data to spread preferentially to one side of the average value. The skewness of each normal distribution refers to the slope distribution to the log scale whether symmetrical, positively or negatively skewed. The symmetrical distribution indicates that the different sizes of sediments are similarly distributed. A positive skewness indicates an excess of fine grain sizes which could be due either to the addition of fine sediment to the deposits or to the selective removal of the

TABLE 4
Average grain size statistical parameters for both sampling in the estuary and along the Kemaman River

Station	Mean (Ø)	Standard Deviation (Ø)	Skewness (Ø)	Sorting
1	3.4	0.7	-0.7	Moderately sorted
2	1.2	1.1	-0.4	Poorly sorted
3	2.2	1.1	-0.5	Poorly sorted
4	1.6	1.3	-0.1	Poorly sorted
5	2.2	1.5	-0.1	Poorly sorted
6	1.2	1.5	1.8	Poorly sorted
7	0.1	1.5	1.4	Poorly sorted
8	0.7	1.1	0.2	Poorly sorted
9	0.5	1.6	0.3	Poorly sorted
10	-0.4	0.9	0.3	Moderately sorted
11	-0.6	0.9	0.6	Moderately sorted
12	-0.7	1.1	1.2	Poorly sorted
13	-0.3	1.2	0.8	Poorly sorted
14	-0.2	1.1	0.1	Poorly sorted

coarser grain. In this study, as the mean values, skewness in the Kemaman river showed no variation between monsoons (P>0.05) and has a wide range from -0.7 to 1.8 which falls from a very positive skew to a very negative skew (Table 4). In general, the negative skewness was observed at the station near the estuary while the positive skewness was shown at the station away from the estuary. Station 6 has the highest skewness (1.8) and Station 1 has the lowest skewness (-0.7).

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