Pertanika J. Trop. Agric. Sci. 18(1): 71-76(1995)

ISSN: 0126-6128

Grain-size Distribution of Sediment in the Vicinity of Setiu Lagoon-estuary System

ROSNAN YAACOB, MOHD LOKMAN HUSAIN and NOOR AZHAR MOHD SHAZILI
Faculty of Fisheries and Marine Science
Universiti Pertanian Malaysia
Mengabang Telipot, 21030 Kuala Terengganu, Malaysia

Keywords: sediment grain-size distribution, statistical measures, lagoon and estuary

ABSTRAK

Enapan di sistem lagun-muara di Setiu, pantai timur Malaysia kebanyakkannya adalah terdiri dari puin kasar hingga ke sangat halus dengan nilai kepencongan yang kebanyakkannya negatif. Kawasan muara sungai adalah dipengaruhi oleh daya pengangkut dan hakisan. Tiada terdapat kelodak dan tanah liat di muara sungai ini adalah kerana kurang terdapatnya faktor pemendapan yang dipengaruhi oleh arus yang kuat berbanding dengan kawasan lagun. Enapan di kawasan pantai adalah pasir kasar ke halus. Saiz butiran min berkurang ke arah barat-laut pantai itu. Nilai kepencongan pasir pantai kebanyakkannya negatif yang mana menunjukkan kawasan kajian dipengaruhi oleh ombak dan arus yang agak kuat.

ABSTRACT

The sediments in the Setiu Lagoon-estuary system on the east coast of Malaysia consist mostly of coarse to very fine particles. The major portions of the sediment are negatively skewed. The estuary area is under the influence of transportative and erosive forces. The lack of silt and clay in the estuary is attributable to less depositional factor under the influence of stronger currents than in the lagoon area. The beach sediment ranges from coarse to fine sand. Generally, the mean grain-size decreases towards the north-west sector. The skewness value of the beach sand area is mostly negative, indicating that the study area is under the influence of rather strong wave and current action.

INTRODUCTION

An understanding of the distribution pattern of sediments is fundamental to the successful design and operation of coastal structures such as jetties, breakwaters and groins and to effective management of coastal zones. The estuary and lagoon areas are constantly undergoing physical changes. The causative factors of sediment distribution are cyclic in nature, and include wind, wave, tide and current (Pethick 1984). Man-induced activities are equally important factors affecting sediment distribution. In the past, especially in Malaysia, the major interest in estuaries and lagoons has been primarily biological, resulting in a notable lack of literature on specific coastal, physical and geological processes. No study of physical and sedimentation processes on Setiu Lagoon-estuary system exists. The Malaysian Drainage and Irrigation Department (Jabatan Parit dan Taliair Malaysia 1977) conducted river discharge measurements for a few selected points on the Setiu and Chalok rivers but did not describe physical processes within the estuary. Salleh and Hussain (1986) collected temperature and salinity data for a feasibility study for a mariculture project in the Setiu estuary but did not explain the circulation or other physical processes. The purpose of this study is to describe the general distribution of the beach and estuarine sediment along the coastline of a Setiu Lagoon-estuary system.

STUDY AREA

The lagoon-estuary system investigated extends from latitude 5° 35'N to 5° 45'N and from longitude 102° 40'E to 102° 49'E and is located on the east coast of Peninsular Malaysia about 60 km north-west of Kuala Terengganu (*Fig.1*). The system forms one of the principal water resources of north-west Terengganu. The Setiu lagoon-estuary is of primary oceanographic interest since it is one of the large estuaries on the Terengganu coast into which two major river systems empty. The major sources of freshwater are the Setiu and Chalok rivers that drain the southern-eastern part of the study area. The estuary area is the region along the south-eastern side of the study area from the bridge at Kampung Penarik to Kampung Payang (Stations 1-13). The lagoon area is the section from Kampung Che Buis to Kampung Benting Lintang (Stations 14-25). One striking topographical feature within the estuary and lagoon area is a series of small islands that act as sediment traps and prevent migration of sediment. In general, the estuary area is deeper than the lagoon area.

High rainfall is recorded during the monsoon season. The north-east monsoon prevails between November and March, and the rest of the year is the transition and south-west monsoon periods. The mean annual temperature lies in the range of 25.6 °C to 27.8 °C. The temperature of surface water is typical of tropical waters, being 27 °C to 28 °C and belongs to the surface type with warm temperatures of more than 25 °C (Leong 1974) and low salinity of less than 34 ppt. Phillips (1985) described the tides along the Terengganu coast as having mean spring tide in the range of 1.8 m. The tidal ranges in the study area nowhere exceeded 2m and the area conforms to the low mesotidal coastal type (Hayes 1979). The coastal current usually flows parallel to the coastline in a southerly direction during the north-east monsoon but is reversed for the rest of the year (Dale 1956). Current in the south-eastern region of the estuary (i.e. near the head of the estuary) is mainly a combination of tide and river outflow. In the lagoon area, tides seem to be the major force in the water movement. The current speed is greater at the estuary area, indicating that it is more active in terms of hydraulic energy level than the lagoon area (Rosnan 1988). NNE-NE waves predominate during NE monsoon seasons whereas NE-SEE waves predominate dur-

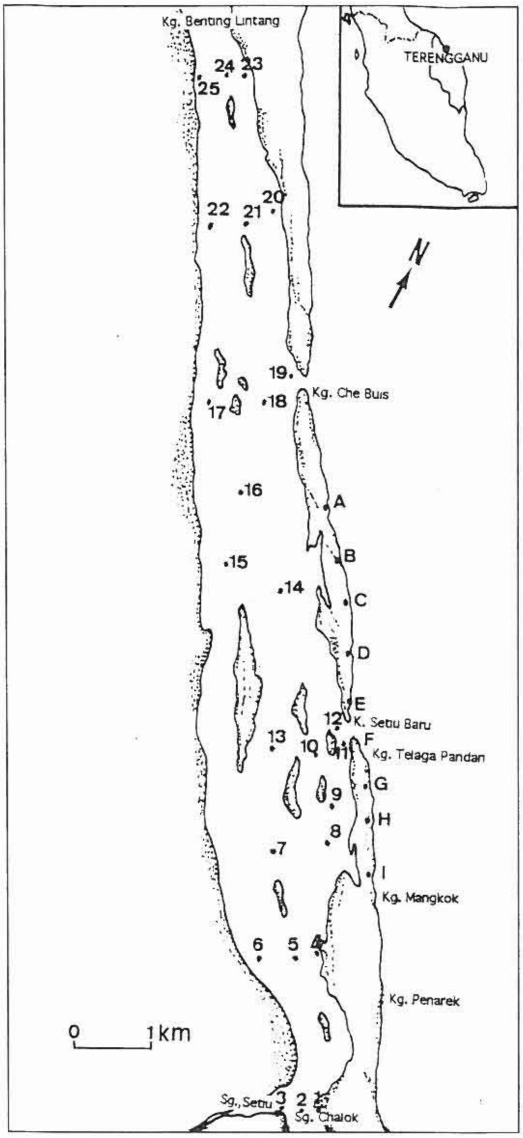

Fig 1: Location of the sampling stations

ing the other seasons. The most frequent wave height is between 1.0 to 1.5m. The most prominant winds come from N-NE and SE-S direction. Winds stronger than 20 km/h are mainly from NE-ENE directions. NE-E wind occupies about 70% of the wind frequency from the sea. Raj (1982) stated that there are two net directions of present-day beach sediment transport by littoral drift along the Terengganu coastline, a north-westward transport, to the north-west and a southward transport, south of Kuala Terengganu. The average annual rates of sediment transport for the Setiu area are 30 to 75 m/year and are considered moderate. The longshore drift in both directions probably contributes the quartz sand making up the beach.

MATERIALS AND METHODS

Sampling Technique

Thirty-four samples were collected with an Ekman grab sampler in May 1990 in the estuary and lagoon areas (*Fig. 1*). At every sampling station sediment sub-samples were taken from the centre of the grab with a plastic corer (diameter 4.6 cm and length 25 cm). The physical appearance of the sediment (such as colour and observed textural classes) were recorded on site. The beach samples were collected in plastic bags from the foreshore area at each station in October 1990.

Analytical Technique

The sediment samples were air dried and quartered by hand (Krumbein and Pettijohn 1938). A small portion of the samples (50 - 100 g) was used for textural analysis by the wet sieving and pipette method as described by Buller and McManus (1979). The coarse fraction (particles with diameter greater than 4 phi or 63 µn) were analysed using the dry sieving technique. Based on the data obtained, statistical measures were calculated according to the graphical measures of Folk and Ward (1957) as follows:-

$$\text{Mean } (M_z) = \frac{\text{Ø}16 + \text{Ø}50 + \text{Ø}84}{3}$$

$$\text{Sorting Coefficient } (\sigma_I) = \frac{\text{Ø}84 - \text{Ø}16}{4} + \frac{\text{Ø}95 - \text{Ø}5}{6.1}$$

$$\text{Skewness } (S_k) = \frac{\text{Ø}16 + 2\,\text{Ø}84 - 2\text{Ø}50}{2(\text{Ø}84 - \text{Ø}16)} + \frac{\text{Ø}5 + \text{Ø}95 - 2\text{Ø}50}{2(\text{Ø}95 - \text{Ø}5)}$$

RESULTS AND DISCUSSION

The sediments at the sampling sites ranged from sand to sandy loam. The sample colour was mostly yellowish brown in the estuary area and dark grey in the lagoon area. In the estuary region all the samples were found to have a range in the sand classes. Visual examination of the coarse fraction (larger than two millimetres) shows that it is composed almost exclusively of carbonate detritus, mostly shell fragments. Sand percentages within the sampling sites range from 93.6 to 97.80%, silt between 0 and 22.36% and clay between zero and 9.30% (Table 1). Results showed higher percentages of sand in the estuary area, especially at the inlet. At the outer inlet of lagoon and adjacent beach, the sediment consisted of 100% sand. Silt content was higher at the central part and lower in the mid-channel of the lagoon. The silt percentage generally decreased toward the inlet and there is lower clay content in the area away from the inlet. There is little mixing of gravel and mud.

Plots of the graphic mean, sorting and skewness values show estuary-lagoon sediment populations which can be related to spatial variation. The range of mean grain size is 0.15 - 1.58 phi. The mean diameter also indicates that most of the sediment in the system consists of coarse to very fine sand, with greater prevalence of very fine sand size according to the classification of Wentworth (1922). The few samples with a mean grain-size coarser than sand are unequally distributed but always occur at the inlet area. However mean grain-size values at Stations 11 and 12 are in the medium to coarse sand range and showed great variation in space and time.

Sediments in the lagoon-estuary system have a range of sorting coefficient of 0.82 - 2.11 phi. There was a large group of samples with a sorting coefficient between 1 - 2 phi (poorly sorted). Most of the remaining samples showed sorting coefficient near 0.90 phi (moderately sorted). The sediments for the most part are poorly sorted, but a significant portion of the area is influenced by moderately sorted sediment. The lowest values (best sorting) were confined to the region at Stations 1 and 6, near the head of the estuary and lagoon respectively. The highest value (poorest sorting) occurred at Station 12. In general, sorting of sediment improves as grain size decreases.

Skewness values in the estuary and lagoon system range from -0.46 to -0.22. Positive values of skewness indicate that the normal size distribution is influenced by finer sizes. Most of the sediments were negatively skewed and these

TABLE 1
Particle size distribution and the statistical parameters of sediments in the estuary-lagoon area.

Station No.	Gravel %	Sand %	Silt %	Clay %	Mean M_z	Sorting Coefficient	Skewness S_k
	> - 1 Phi	-1 to 4 Phi	8 - 4 Phi	< 8 Phi			
1	8.10	91.9	None	None	0.25	1.38	0.07
2	16.20	93.8	None	None	0.59	1.04	-0.04
3	17.10	82.9	None	None	0.26	1.39	0.07
4	3.70	96.3	None	None	0.48	0.93	-0.01
5	10.00	90.0	None	None	0.63	1.21	-0.18
6	18.90	81.1	None	None	0.20	1.17	-0.09
7	3.20	96.8	None	None	2.27	2.00	0.24
8	2.90	97.1	None	None	1.27	1.40	0.06
9	4.40	95.6	None	None	0.70	1.00	-0.11
10	3.50	96.5	None	None	0.96	0.82	-0.21
11	2.20	97.8	None	None	0.31	0.85	0.22
12	3.70	96.3	None	None	1.58	2.11	0.19
13	8.60	91.4	None	None	1.40	0.83	-0.11
14	1.50	97.3	None	None	1.48	1.09	0.05
15	6.10	93.3	None	None	0.70	1.07	-0.13
16	1.10	97.5	None	None	0.32	0.70	-0.46
17	-	86.7	8.40	5.60	0.52	1.08	-0.09
18	-	88.3	7.12	7.12	0.98	1.02	-0.11
19	-	73.6	19.10	7.30	0.60	1.01	0.01
20	-	94.6	5.37	0.03	0.58	1.15	0.04
21	-	95.3	4.61	0.03	0.27	1.96	-0.34
22	-	93.5	4.00	3.00	0.17	1.93	-0.23
23	-	94.1	1.40	4.40	0.15	1.87	-0.20
24	-	82.0	14.90	3.10	0.80	1.98	-0.29
25	-	94.2	1.30	4.60	0.90	1.45	-0.31

Estuary (Stations 1-13)
Lagoon (Stations 14-25)

areas are probably associated with sediments deposited in an environment dominated by strong current action or might be due to the accumulation of coarse grains at these areas (Buller and McManus, 1979). Skewness values decrease as the grain size increases. Following Visher (1969), it is suspected that the coarser sediment (less than 1 phi) transport mechanism is by means of bedload, while the remaining fraction in the size range of 2 to 1 phi is by saltation and fraction of sizes beyond 2 phi is by means of suspension.

TABLE 2
The statistical parameters of the sediment at the Setiu beach

Station No.	Mean M_z	Sorting Coefficient (C_1)	Skewness S_k	Type of Sorting
A	0.49	0.59	-0.06	Moderately well sorted
B	0.19	0.63	-0.34	Moderately well sorted
C	0.58	0.84	-0.26	Moderately sorted
D	1.13	0.88	-0.04	Moderately sorted
E	0.88	0.67	-0.16	Moderately well sorted
F	0.32	0.69	-0.08	Moderately well sorted
G	0.87	0.84	-0.10	Moderately sorted
H	0.90	0.63	-0.24	Moderately sorted
I	0.98	0.78	0.11	Moderately sorted

The data obtained by the dry sieving technique for all the composite beach sand are summarized in Table 2. Mean diameter ranged from 0.19 to 1.13 phi. It was found that Station D had the smallest grain size of all stations. The mean diameters also indicate that most of the beach sand consists of medium and fine-grained sand. Beach sand generally increased towards the South. In areas near the river inlet, the sediment had a relatively coarser grain size with coarser sand found to the south-west of the river mouth.

The sorting coefficient ranged from 0.59 to 0.88. All stations had either moderately well-sorted or moderately sorted sediment. Stations A and B at the extremity away from the river mouth had moderately well-sorted sediment. The skewness value was highest at Station I. Most of the beach sand was negatively skewed. This indicates that the beach sand has excess coarse fraction and the area is subjected to high wave energy or is under the influence of strong currents.

CONCLUSION

The estuary area is composed of poorly sorted coarse sediment and the lagoon area is of moderately sorted fine sediment. This shows that the estuary area is more active in terms of hydraulic energy level than the lagoon area. Furthermore, lack of silt and clay in the estuary area is attributable to a lack of depositional processes under the influence of relatively stronger currents compared to the lagoon area where depositional processes are active.

ACKNOWLEDGMENTS

The authors would like to thank Mr. Nazuki Sulong, Mr. Shahabudin Saad, Mr. Sukiman Sengat and Mr. Hamin Jusoh for the technical assistance and Norshimah Ahmad for typing the manuscript. This project was supported by Majlis Penyelidikan dan Kemajuan Sains Negara (MPKSN) under the Intensified Research Programme for Priority areas (IRPA), Grant No: 1-07-06 50260 through Universiti Pertanian Malaysia.

REFERENCES

BULLER, A.T. and J. MCMANUS. 1979. Sediment sampling and analysis. In *Estuarine Hydrography and Sedimentation. A Handbook.*, ed. K.R. Dyer p. 87-130. Cambridge: Cambridge University Press.

DALE, W.L. 1956. Wind and drift currents in the South China Sea. *Tropical Geography Journal* **8**: 1-31.

FOLK, R.L. and W.C. WARD. 1957. Brazos river bar: a study in the significance of grain size parameter. *Sedimentary Petrology Journal* **27**: 3-26.

HAYES, M.O. 1979. Barrier island morphology as a function of tidal and wave regime. In *Barrier Islands*, ed. S.P. Leatherman, p. 1-29. New York: Academic Press.

HJULSTROM, F. 1935. Studies of the morphological activity of rivers as illustrated by the River Fyris. *University of Upsala. Geology Bulletin* **25**: 221-227.

JABATAN PARIT DAN TALIAIR MALAYSIA. 1977. *Hydrological Data-rainfall Records for Peninsular Malaysia 1970-1975.* Kuala Lumpur: Kementerian Pertanian.

KRUMBEIN, W.C. and F.J. PETTIJOHN. 1938. *Manual of Sedimentary Petrography.* New York: Appleton-Century-Crofts.

LEONG, P.C. 1974. Hydrographic conditions off the East Coast of Peninsular Malaysia during August 1972. *Malaysian Agricultural Journal* **49(4):** 492-503.

PETHICK, J. 1984. *An Introduction to Coastal Geomorphology.* London: Edward Arnold.

PHILLIPS, R.P. 1985. Longshore transport of sediment during August and September on the Terengganu Coast. *Pertanika* **8(2):** 273-279.

RAJ, J.K. 1982. Net directions and rates of the present-day beach sediment transport by littoral drift along the east coast of Peninsular Malaysia. *Geological Society Malaysia Bulletin* **15**: 57-70.

ROSNAN YAACOB. 1988. Geophysical studies in Setiu lagoon-estuary system. M.S. thesis. Universiti Pertanian Malaysia.

SALLEH, U. and M.L. HUSAIN. 1986. Laporan Kajian Awal Kesesuaian Mutu Air dan Dasar bagi Sungai Merang dan Setiu, Kuala Terengganu. Universiti Pertanian Malaysia.

VISHER, G.S. 1969. Grain-size distribution and depositional process. *Sedimentary Petrology Journal* **39**: 1074-1108.

WENTWORTH, C.K. 1922. A scale of grade and class terms for clastic sediments. *Geology Journal* **30**: 377-392.

(Received 23 June 1993)