Trends in Sediment yield of the Kemaman River Estuary, Terengganu-Disember 2002-February 2004

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ABTRACT

The Kemaman River drains the southern half of Kemaman-Chendor coastal system and is the primary source of sediment to Kemaman estuary. In this paper, it is demonstrated that anthropogenic activity within a watershed, such as agriculture and urbanization were affect the sediment yield from the watershed. Over 26 month, the delivery of suspended sediment from the Kemaman River to The Kemaman Estuary has increase by about 25 percent. Using flow and suspended sediment discharge data provided by the Drainage and Irrigation Department (DID) revealed possible increasing trend on suspended sediment discharge and concentration. Temporal analysis indicates that the trend of sediment yield was increase during the monsoon season resulting over sediment supply closed to river mouth. This scenario has implication for nearshore fisherman's navigation due to seabed deposition. In a broader context, this study underscores the need to address the anthropogenic impacts and flood monsoon on sediment yield in the Kemaman-Chendor estuary system.

Keywords: Suspended sediment concentration, sediment yield, flow, discharge, river estuary

INTRODUCTION

Understanding sediment transport processes in a river estuary and coastal waters is important when studying sediment transport and mobility within the river coastal environment. Combination of data and modeling analyses can be used to evaluate sediment characteristics for short and long term periods. In a natural environment, river estuary and nearby coastal can be considered as the most dynamic system. Many important reactions controlling the transfer of elements from the continents to coastal waters and the oceans are taking place in estuaries. For many elements, river estuaries can act as filters, capable of reducing the river load of dissolved and particulate elements to the oceans. However, due to intensive human activities in the upstream as well as coastal development along the beach causing instability on process and respond within the system. As a result, some parts of the estuary registered beach and bank erosions while the other corner of the estuaries, sediment deposition occurred. In general, sediment mobility and its subsequent coastal erosion across the river estuary is one of a major concern around the world. It is well documented that most of the sediment sources are transported from the river itself and waves actioned through the seabed, beach and cliff erosions (Komar, 1976; Nielsen, 1992). The volumes of sediment yields from rivers are varied from 541, 000 t/km^2/y (Yangtse River), 120, 000 t/km^2/y (Mississippi River) to 92, 000 t/km^2/y (Kelantan River). Both sources generally provide sufficient sediment supply to develop beach profile along the coastal shoreline. However, problems may arise when wave rushed onto the beach causing beach drift and later creating littoral erosion. As a result, sediments in the surf zone are transported along the beach in a zig-zag pattern (Pethick, 2984). How do the sediment mobilized, where the sediment goes and how far the sediment travels are of the interesting subjects focused among the hydrogeomorphologists, geologists and oceanographers.

The specific aim of this paper is to study the behaviour of nearshore sediment mobility and migration of the Kemaman River estuary, Terengganu. In conjunction with the questions addressed above, this study sets three main objectives namely,

a) To study the sediment mobilization patterns due to wave actions during the severe monsoon seasons of December 2003-February 2004.

b) To relate the sediment mobility with sediment properties and suspended sediment concentration in the study area.

MATERIALS AND METHODS

The fingerprint technique has been widely used to trace the sediments mobility in river channels. However, the use of tracers in river estuary research is, however, relatively scarce. In general, different methods for tracing and quantifying sediment mobilization in the river estuary have been developed over the last 40 years. Most of the techniques used are focused on the *in-situ* survey, sediment sampling and airborne remote sensing. All of these methods have advantages but also potential problems and limitations. This study used multiple fingerprints to quantify the pattern of sediment mobility namely the use of environmental radionuclide *Caesium-137* and sediment properties analysis. Both techniques found to be satisfactory to define the two objectives listed above. Meanwhile, the equilibrium beach profile modeling was applied for estimating volume of sand to be created along the Kuala Kemaman beach after the eroding episode.

To date, most studies involving sediment mobility have focused on the use of radionucliders such as *Caesium-137* (^{137}Cs), *Beryllium-7* (^{7}Be) and *Excess lead-210* ($^{210}Pb_{ex}$). Since that early work by Rogowski and Tamura (1965), the ^{137}Cs have been successfully used in tracing sediment sources in many areas of the world (He and Walling, 1996; Walling and Woodward, 1995).

Technically speaking, the ^{137}Cs is an artificial radionuclide, a group 1 in chemical series with half-life time 2.05 years. It behaves as a conservative element in seawater, similar to other alkali element (e.g. *K* and *Na*). In an original form, the ^{137}Cs is a soft silvery-gold which is one of the three metals (gallium and mercury) that are liquid at room temperature. In this study, the *in-situ* measurements were applied to trace the sediment mobility within the estuary system. Two plots from backshore and foreshore of Kuala Kemaman river estuary were selected and labelled with the radioactive tracer ^{137}Cs. These plots were subjects to highly potential eroded as reported by local villagers and the Drainage and Irrigation Department (DID) (Figure 1).Tracer solution of ^{134}Cs with specific activity of 37 x 10^3 kBq mg^{-1} Cs was diluted with water and spread over the plots using two-wheel manual spraying equipment. On 17 November 2003, a total of 15.5 x 10^3 kBq was sprayed over the plots yielding a mean activity level of 65.3 kBq m^{-2}. The site was re-visited twice during the pick monsoon season on 12 December 2003 and the last once on 7 February 2004. The *in situ* NaI detector measurements (resolution of 1.95 keV at 1.33 MeV equipped with multichannel analyzer-Serie 10 plus 1004) were performed randomly along the estuary up to Pantai Chendoh, some 7 km southern to the Kuala Kemaman. The measurement time was 30 second.

Meanwhile, two samples 100 g each were collected at the zones which subject to sediment particle size analysis. The wet seiving technique was used to separate between coarse, sand and silts. The results then were compared with the samples taken randomly during the ^{137}Cs distribution measurement. Individual suspended sediment concentration (SSC) was also collected frequently to relate with sediment mobility during the study period. In this study, direct measurement of the SSC in a stream is the most reliable method to investigate their formation and patterns of the flow and sediment characteristics. For marked, each sample locations were fixed using the Geographical Positioning System (GPS).

The distribution of the tracer within the backshore and foreshore based on the day of application (17 November 2003) is shown in Table 1. The pattern shows higher ^{137}Cs activity in the backshore zone compared with foreshore. It is believed happened due to ^{137}Cs is strongly adsorbed on fine sands and silts.

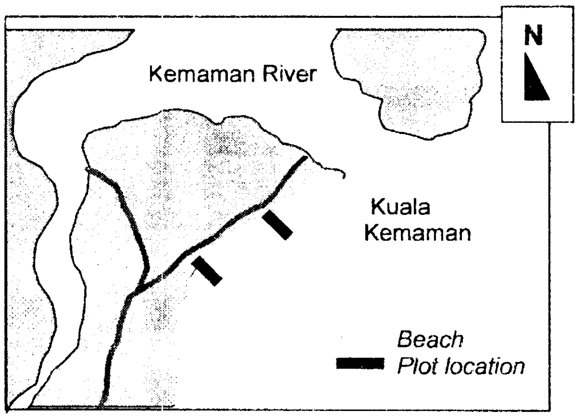

Figure 1: Location of the study plots

Table 1: Spatial distribution on ^{137}Cs activity (cpm) for backshore and foreshore zone on 17 November 2004

Ref. Points*	Backshore	Foreshore
1	7845	5334
2	5638	2655
3	8873	5422
4	9577	7344
5	16465	10945
6	19675	13354
7	20744	6744
8	22421	5236
9	18745	5574
10	21544	4655
Maximum	22421 (8)	13354 (6)
Minimum	5638 (2)	2655 (2)
Average	15153	6261
f factor	0.013	0.018

**Reference points were choosed randomly*

Based on the in-situ measurement of ^{137}Cs activity. The measure activity ranged between 5638 cpm to 22421 cpm for backshore while for foreshore is between 2655 cpm to 13354 cpm. The mean values for backshore and foreshore were 15153 and 6261 cpm respectively. The counting efficiency (*f* factor) for the instrument (cpm Bq^{-1}) then was computed using the equation below:

$$f = R_t D_t^{-1} \qquad (1)$$

Where *f* is counting efficiency, R_t = in situ measured ^{134}Cs activity in counts per minute (cpm) at time *t*, when the measurement is performed and D_t = disintegration rate of ^{134}Cs in *Bq* (1 *Bq* = 1 disintegration per second, *dps*) at time *t*, when the measurement is performed. The *f* factor for backshore was 0.013 while for foreshore was 0.018.

The sediment particle analyses were also carried out for both zones. The results are presented in Table 2.

Table 2: Sediment particle size analyses based on wet sieving technique for backshore and foreshore zones (g)

Ref. Points	**Backshore**			**Foreshore**		
	coarse (g)	sand (g)	silts (g)	coarse (g)	sand (g)	silts (g)
1	13	34	53	10	75	15
2	8	22	70	41	38	21
3	12	49	39	32	19	49
4	14	42	44	38	47	15
5	27	26	47	19	37	44
6	19	52	29	58	40	50
7	2	55	43	26	24	2
8	7	32	61	33	35	32
9	15	23	62	24	16	60
10	10	38	52	55	32	35

The backshore zone characterized by highest percentage of silts with average of 50 % compared with sand (37 %) and coarse (13 %). At the foreshore zone, the results were inversed. Coarse immerged to be dominant with 37 % followed by sand (36 %) and silts (32 %). When relates to ^{134}Cs activity, a good relation was found between the ^{134}Cs activity and the present of silts. Highest ^{134}Cs activity normally followed by highest present of silts as recorded at Ref.Plot No. 8 for backshore (22421 cpm and 61 % silts) and Ref.Plot No. 6 for foreshore zone (13354 cpm and 50 % silts). As been mentioned before, one of a major ^{134}Cs characteristic was their capability to rapidly and firmly fixed with the fine sand and silts deposits. It is strongly bound and can be only displaced by ions of similar size and charge (Volpe, et.al. 2002). The pattern obtained confirmed with other studies carried out (i.e Tamura, 1965; Salbu 2001).

Meanwhile, the SSC at the Kemaman River estuary ranged from 67.8 mg/l to 286 mg/l with CV of 152 %. The relationshiups between SSC and Discharge (Q) is presented in Figure 2. Good relationship can be seen in the figure with the fact that sediment supply increased during the periods of rainfall which normally occurred during the monsoon.

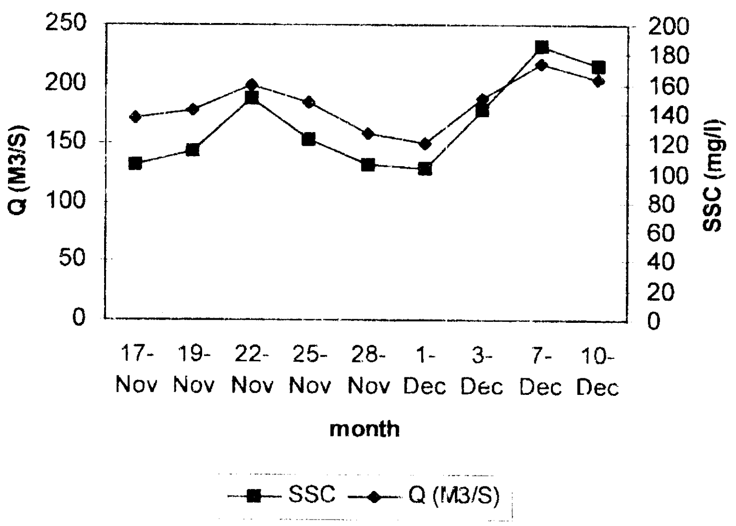

Figure 2: Relationship between Q and SSC

The study area was re-visited during the northeast monsoon on 12 December 2003. The results show tremendous change on ^{134}Cs activity. Over three weeks, there was a general decrease in the activity levels within the both backshore and foreshore zones (Figure 3). All the ref. points recorded ^{134}Cs activity less from 4.2 % (Ref. Plot No. 2) to 23.2 % (Ref. Plot No. 5) for backshore and minimum 26.5 % (Ref. Plot No.2) to 65.2 % (Ref. Plot. No. 1). Decrease in ^{134}Cs activity indicates that coastal erosion was occurred during the period. As reported by local villagers, severe erosion was occurred closely to the main road to jetty and up to 2 km stretching along the beach. As a result, The Kuala Kemaman District Office took a drastic action in conjunction with the DID to repaired the damage by installing the gabions about 200 meter along the beach.

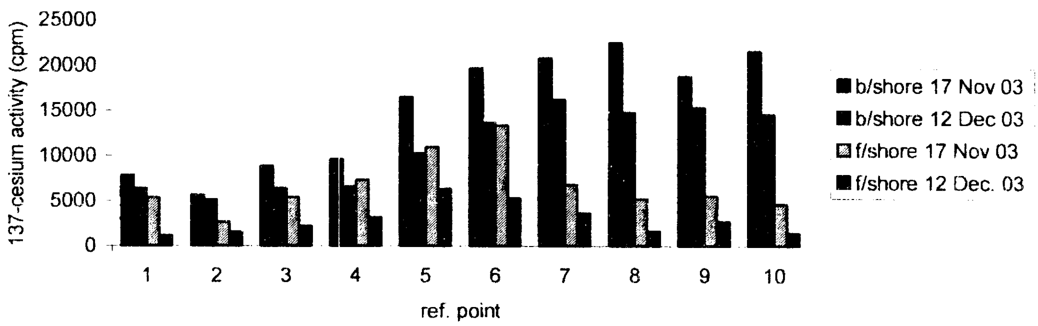

Figure 3: Changed on ^{134}Cs activity as measured in the study plots

By knowing the prevailing surface wave direction/pattern which is from the north-east (70 % as measured by direct observation). The *in-situ* NaI dectector measurement then was applied in order to trace the sediment fingerprints within the estuary system. Figure 4 illustrates the pattern of ^{134}Cs activity. Clearly, the mobility of ^{134}Cs depends on the migration/moving of bottom sediments which generally generated by wave and current energies.

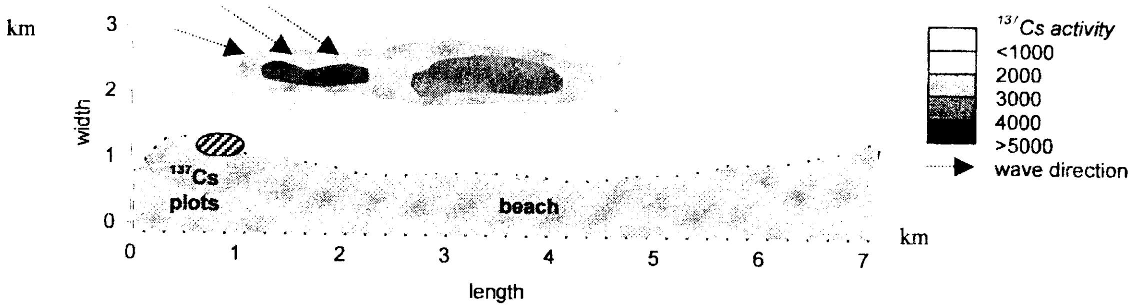

Figure 4: Schematic diagram of ^{134}Cs activity measured on 12 December 2003

As can be seen from the diagram, the ^{134}Cs fingerprints were inhomogeneously distributed within the estuary –coastal system. Higher activity levels were observed near to the study plots. The general pattern shows that most of the sediments were eroded and deposited along the foreshore lines to up to 4.6km from the study plots.

Meanwhile, the second *in-situ* NaI detector measurement was carried out on 17 February 2004. Over seven weeks since the last measurement on 12 December 2003, a whole study plot at backshore zone was washed away. Several local villagers claimed that strong waves occurred on 14-16 January 2004 resulting severe beach erosion. Damage on properties and infrastructures were also reported particularly towards the jetty complex. Figure 5 shows the sediment mobilization as detected by *in-situ* NaI detector.

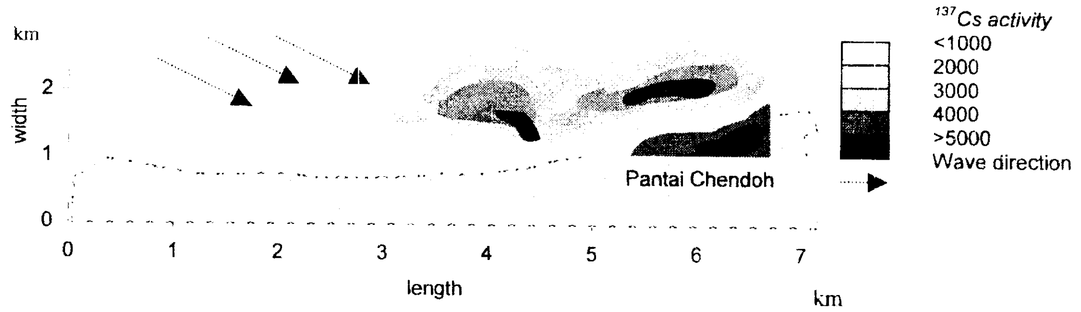

Figure 5: Schematic diagram of ^{134}Cs activity measured on 17 February 2004

Again, the spatial pattern of sediment mobilization follows the previous measurement which exhibit inhomogeneously distributed. Over seven weeks, the sediment fingerprints were travel as far as 6.4 km towards southern direction. Maximum ^{134}Cs activity was recorded accumulated adjacent to backshore and foreshore zones in Pantai Chendoh. As a result, the beach was reported highly sediment deposition and causing problematic to fisherman navigation.

CONCLUSION

At this stage, the use of ^{134}Cs activity as sediment tracer found to be satisfied to study the spatial pattern of sediment distribution and mobilization within the Kuala Kemaman estuary system. Although the study indicates several margin of error, i.e. difficulties in tracking sediment fingerprints dosed with Cs-137 in a random environment, sediment particles move in a stop and go pattern, etc, the Cs-137 proved useful in the identification of actively eroding beach sediment deposits during the study period. Meanwhile, severe erosion at the study plots and along the Kuala Kemaman beach required full attention from the government (DID, District Office, LKIM). Temporary and long term measures are required to protect the beach from erosion.

Coupled with good information on sediment characteristics, the problem perhaps can be minimized without further damaging on properties.

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