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The determination of ^{210}Pb in the sediments: Sedimentation rates from the Terengganu coastal waters, Malaysia

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ABSTRACT

Detail ^{210}Pb analysis of two core samples collected with a gravity corer from the coastal water of Terengganu South China Sea has provided a chronology of the sediments identifying the subtle yet distinct variations in recent sedimentation. This investigation of recent sedimentation with the use of ^{210}Pb analyses is a part of an overall study to examine and quantify past and present patterns and rates of sedimentation, revealing how deposition environments and their morphological structure transform. To assess the recent to sub-recent depositional processes in the Terengganu coastal water, a detailed sediment analysis was conducted. The activities of natural radionuclide ^{210}Pb along with the ^{208}Po tracer were measured by Alpha Spectrometry to estimate sedimentation rate and mass accumulation rate. The highest accumulation rates were recorded near the Terengganu river estuary, seem to be controlled by several addition factors that modulate the settling particles, such as onshore precipitation and river runoff and the lower rates near the island.

Key words: ^{210}pbm Sedimentation, Alpha Spectrometry.

INTRODUCTION

Continental margins from a link between the ocean and land is an important areas for understanding the biogeochemical cycles of heavy metals, carbon and other materials (Anderson *et al.,* 1994; Yamada and Aono, 2003; Masuzawa *et al.,* 2003). In addition to land-derived materials, a large quantity of particles are produced in situ by high primary production and transported away from the land to the sea through river and estuary (Kato *et al.,* 2003). Mechanisms that promote sedimentation lead to the sequestration of large amounts of organic matter as well as mad-made heavy metals and other contaminants.

Sedimentation rate and mass accumulation rate are useful to understand sediment-transport processes and the flux of the major constituents of the sediments, as lithogenic and organic components, both important for geochemical studies (Alperin *et al.,* 2002; Borole, 2002; Gorgas and Wilkens, 2002). Aelian transport of lithogenic particles could constitute an important input to the deep sea sediments. Size, shape and composition of settling particles are important factors that determine transport and preservation in the sediments. Moreover, morphologic characteristic of the seafloor, such as the presence of canyons, slope terraces and govern sediment accumulation patterns (Masqué *et al.,* 2002; Muñoz *et al.,* 2004).

Naturally occurring radioisotope ^{210}Pb has been widely utilized to determine sedimentation rates in coastal continental margin sediments and despite some limitations of the methodology, it has demonstrated to be a useful tool to estimate recent

sedimentation rates (White *et al.,* 2002; Moon *et al.,* 2003; Shotyk *et al.,* 2005; Crusius *et al.,* 2004; Huh and Chen, 1999; Oguri *et al.,* 2003; Masque*et al.,* 2003). ^{210}Pb is a natural product of the ^{238}U decay series with a half-life of 22.3 years. Basically, ^{210}Pb content in seawater is supplied from the insitu decay of ^{226}Ra in seawater and ^{222}Rn in the atmospheric and subsequent rainout to the ocean surface. ^{210}Pb is efficiently scavenged by suspended fine particles and thus actively removed from seawater on timescales comparable to its half-life (Henderson and Maier-Reimer, 2002); it is deposited on the seafloor, producing an excess with respect to ^{226}Ra decay within the sediments. This allows the estimation of sedimentation rate where productivity and adjective processes are considered to be important aspects in the distribution and removal of ^{210}Pb in the water column (Nozaki *et al.,* 1997; Thomson and Turekian, 1976).

South China Sea Terengganu waters are located in eastern peninsular Malaysia. The surrounding community of Terengganu waters is mainly depends on the sea as the source of income particularly the fisherman. In recently year, the coastal area of Terengganu was rapidly developed in order to maximize the employment of natural resources in the marine environment. Importance of this coastal area as a fishing area yet is exposed to large different of sediment transportation pattern as the great development is carrying out along the Terengganu river, Marang river, Merchang river and Paka river.

MATERIAL AND METHOD

Collection and sampling of sediments

Core sample was collected in Terengganu waters in August 2004 using gravity corer (Fig. 1). Samples was then stored in the PVC pipe and keep in freezer in order to minimize contamination. In the laboratory, sediment cores were sliced into 2cm intervals and were dried at 60^{o}C to a constant weight and homogenized to analyses the ^{210}Pb activities, determined mainly by alpha spectrometry of its daughter, ^{210}Po.

Chemical analysis

For the chemical analysis, 2g of dried sample was placed in a beaker and digested with HNO_3 with a spike of 0.275ml of ^{209}Po. The solution was heat on the hot plate in the temperature of less that 60°C (^{209}Po will be lost in temperature above 60°C) for 24 hours. Time and date are necessarily to be recorded. Each additive of acid required 24 hours for digesting such as $HClO_4$, HCl, and 6M of HCl. After that, sample solution was centrifuged and plated onto the silver foil with the presence of ascorbic acid for 24 hours.

After the deposition process, deposited silver plate will be dried in room temperature before detect by Alpha Spectrometry, Canberra model. The activities ^{209}Po and ^{210}Po will be appeared in a peak form which will be assisting in the calculation of ^{210}Pb (dpm/g). The duration of counting will takes for at least 3 days

Data analysis

The activity of ^{210}Pb is obtained by the formula below:

Activity ^{210}Po (^{210}Pb) = A (dpm/g)

$$= \frac{\text{Actual } ^{210}\text{Po } (^{210}\text{Pb})}{\text{Actual } ^{209}\text{Po}} \times ^{209}\text{Po (24.74 dpm/g)} \times \frac{\text{tracer weight } ^{209}\text{Pb (g)}}{\text{sample weight (g)}}$$

$A = A_o\, e^{-\lambda t}$ (equal to the accumulative residual unsupported ^{210}Pb below the sediment age of t).
$A_o = A / e^{-\lambda t}$ (equal to the total unsupported Pb in the sediment column).
$\lambda = \ln 2 / t_{1/2} = 0.639$ (decay constant of ^{210}Pb)
$T_{1/2}$ = half-life (22.3 years)
t = depth (cm) / sedimentation rate in years.

Inventories (I) of ^{210}Pb (unsupported) are expressed in dpm-2 and were calculated according to Muñoz (2004):

$$I = \Sigma A_i \rho_i h_i$$

Where A_i is the $^{210}Pb_{xs}$ (dpm g^{-1}), ρ represented the bulk density interval i (g cm^{-3}), and h represented the thickness of the interval (cm).

Sedimentation rates were estimated directly from:

$$A = A_o e^{-\lambda t}$$

Neither estimation considers the mixing effect. Since other radionuclides are not available for this study, we worked with the ^{210}Pb activities below the mixing layer (Lewis *et al.,* 2002; Oguri *et al.,* 2003). Thus our estimates on sedimentation rate assume that mixing is negligible below the mixed layer, where sedimentation is the dominant process. On the other hand, the use of a constant value to estimate the unsupported ^{210}Pb (in excess) where no ^{226}Ra data are available does not greatly affect sedimentation rate estimations; ^{226}Ra is usually constant with depth and ^{226}Ra value agree well with ^{210}Pb values at the base of the sediment cores (Radakovitch and Heussner, 1999; Oguri *et al.,* 2003).

RESULTS AND DISCUSSION

Figure 2 shows the activities of ^{210}Pb$_{xs}$ was decreasing exponentially with depth from 0 – 8cm depth. The activities were later increased from 8cm onwards to 18cm and finally reaching constant values at ~18cm to 26cm. A higher value of ^{210}Pb activity on the surface might be caused by the fresh deposition particle which basically derived from the

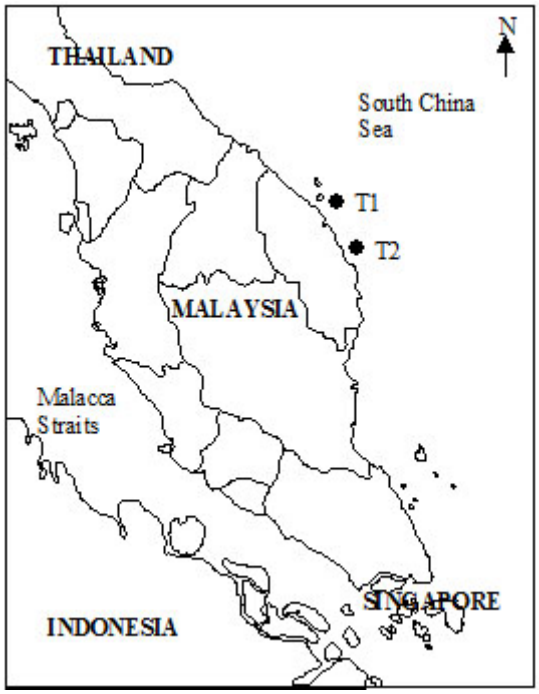

Fig. 1: Map showing sampling location T1 and T2 off the Terengganu waters

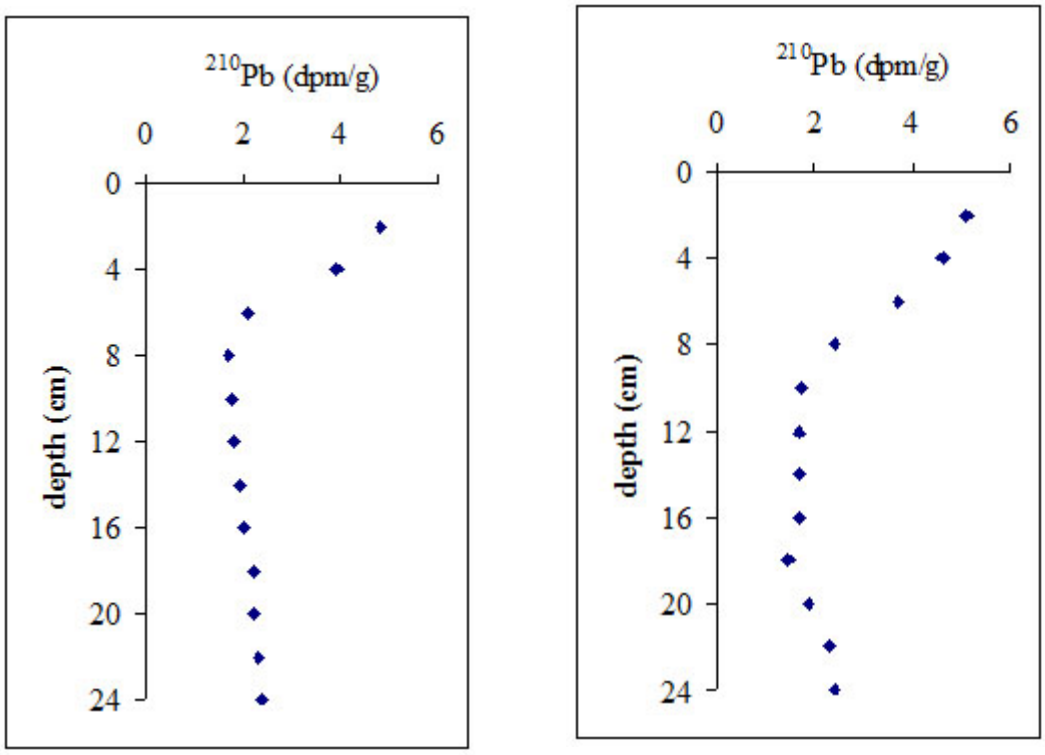

Fig. 2: ^{210}Pb$_{xs}$ distribution with depth in Terengganu South China Sea

atmosphere and land. Besides that, this might be also resulting from ^{210}Pb initial activity of settling particles and additional scavenging in the water column, or from older sediment issued from resuspension (Miralles et al. 2005). It is clear that ^{210}Pb increases monotonically with depth, suggesting of the particulate scavenging (Chung et al. 2004). Thus, the scavenging of ^{210}Pb from the sediment and water column might be a reason to the increases of ^{210}Pb value from 8 cm to 18 cm depth.

The established method of ^{210}Pb indicates the sedimentation rate of Terengganu South China Sea was 0.30 cm year^{-1}. Reading was obtained by selecting the 'best-curve' from the establishment ^{210}Pb (dpm g^{-1}) distribution with depth. Study discovered the mixing layer and bioturbation in the top core layer was insignificant which displayed the $R^2 \geq 0.9$ (0 to 8 cm). The influences of sedimentation rate in South China Sea is mainly depends on the seasonal current movement particularly northeast monsoon and southeast monsoon. Sediment accumulation rate might be more significant during the northeast monsoon which leads to the increases of river input in the coastal area. Besides that, sediment size and portion was also interfered the sedimentation rates in most area of South China Sea particularly Terengganu water.

In general, sedimentation rate along the Terengganu coastal water show no significant different. Since mass accumulation rate is related to the density of the sediments, changes in particle composition could somewhat complicate data interpretation. Strong precipitation and river discharges along the Terengganu coastal transport terrigenous matter and sediment to the ocean. This constitutes an additional source of particle, increasing sedimentation rate with a predominance of siliciclastic material over organic particles. It is evident that the different topographic settings of the study area also contribute to the differences in sedimentation rate. Low sedimentation are comparable to low values reported for northern South China Sea, 0.23 cm/year (Chung *et al.,* 2004), Peru shelf, 0.07-0.32 cm/year (Koide and Goldberg, 1982: Kim and Burnett, 1988), Bay of Biscay, 0.2-0.5 cm/year (Lesueur *et al.,* 2001) and East China Sea, 0.3-1.0 cm/year (Huh and Chen, 1999), where erosive processes plan an important role in the distribution of the sediment (Froelich *et al.,* 1988).

CONCLUSION

^{210}Pb established method deployed in the Terengganu South China Sea water indicates the distribution of ^{210}Pb activities was varies according to depth. Core sample did not indicate a significant of mixing layer as well as bioturbation activities. The sedimentation rate in Terengganu South China Sea was mainly influenced by the ambient forces such as current motion (lateral transport) and river input especially during the northeast monsoon season. Top core layer experiencing the freshly deposition of ^{210}Pb sources from terrestrial and atmosphere. Meanwhile the increases of ^{210}Pb activity in the deep core were suggested due to the particulate scavenging from the water column and the deeper sediment pore.

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