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The Determination of Sediment Acceration Rate Using ^{210}Pb in Johore Coastal Water, Malaysia

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ABSTRACT

Ocean sediments give information on the paleoclimatic evolution in the geological past which gives detailed information on both the age of the sediments and both paleoceanographic and paleoclimatic conditions during sedimentation. One possible way to date sediments is with ^{210}Pb method which can be used to date sediments up to 100 years. In this study, two core samples labelled as JB15 and JB17 were collected using pledging corer, analysed and measured for the activity of ^{209}Po and ^{210}Po using the alpha spectrometer. Applying the methods, average sedimentation rates for JB15 and JB17 were calculated as 0.38 cmyr^{-1} and 0.43 cmyr^{-1}, respectively. Assuming that the sedimentation rate values are accurate, this might imply that the sediments at the depth of 30 cm were deposited 70 years ago.

Keywords: Johore coastal water, ^{210}Pb, sedimentation rate

INTRODUCTION

The outfall of radionuclide in the marine environment has become a tool for tracing the history of the marine environment since 1960s. Several radionuclide such as ^{14}C, ^{230}Th and ^{137}Cs (Ritchie *et al*., 1990), ^{239}Pu, ^{240}Pu (Price, 1991), ^{230}Th (Kamaruzzaman and Willison, 2005) and ^{7}Be (Burch *et al*., 1988; Walling *et al*., 1999) were probably the most extensive elements which have been employed to trace the past of marine environment. Since these environments represent important commercial, residential and recreational importance, it is imperative to understand the processes operating in these coastal regions so as to determine the most suitable management practices in the surrounding areas. One such method used to obtain chronologies of deposition over the past 150 years is ^{210}Pb analysis. The ^{210}Pb method has successfully been applied to sediments from lagoons, estuaries and coastal environments (Jones and Chenhall, 2001; Kate, 2002; Krishnaswamy *et al.,* 1971) with sedimentation rates ranging from mm to cm per year. In more specific, the ^{210}Pb method is used as a dating method because ^{210}Pb is concentrated in a stratified manner and decays at a known rate (Wei and Murray, 1994).

In Malaysia, studies related to the characteristics of sediments and heavy metals of the coastal waters are well documented, but only little information is known about the accumulation rate of sediments. Furthermore, studies on accumulation rate using radinuclides from the Malaysian coastal areas have received little attention and therefore, only limited studies have been done regarding to their roles in the process of sedimentation. In view of potential importance of

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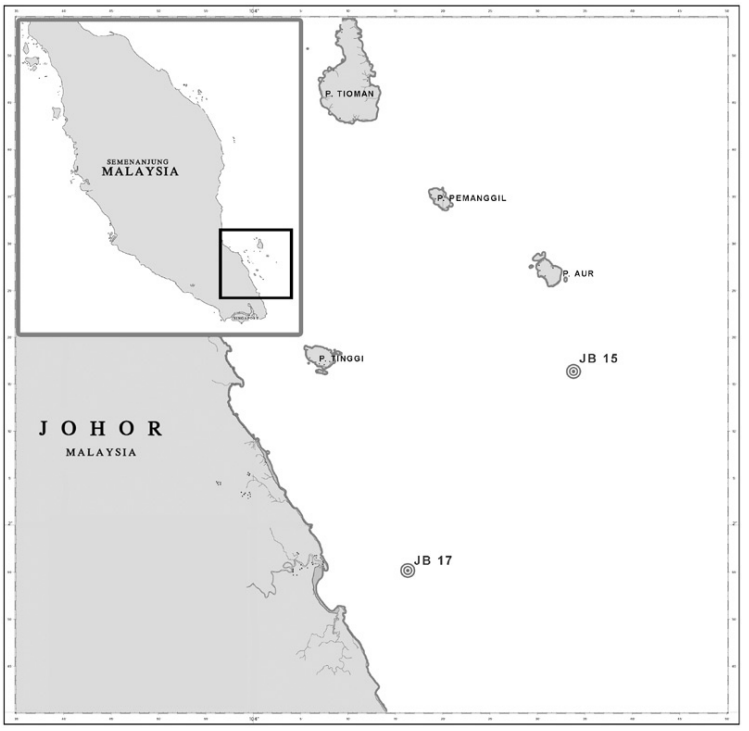


Fig. 1: Location of the core samples, JB15 (2° 16.250'N; 104° 33.850'E) and JB17 (1° 55.173'N; 104° 16.385'E) obtained in the study area

accumulation rate to various aspects of the environment, a research on the use of radionuclide (^{210}Pb) vertical profiles to determine the sedimentation rate was carried out.

MATERIALS AND METHODS

Sampling

The water circulation in Johore coastal water is strongly influenced by the East Asian monsoon system, where the circulation is predominantly cyclonic during the northeast monsoon (i.e. in the winter) and anti-cyclonic during the southeast monsoon in the summer (Wyrtki, 1961). The seasonal changes lead to significant variations in the mixed layer thickness, hydrographic properties and primary production (Gong *et al.,* 1992; Lui *et al*., 2002). Meteorologically, the Johore coastal water is influenced by the seasonal changes of monsoon which predominantly prevails from October to March each year. In this study, the sediment core sample was obtained from JB15, as shown in *Fig. 1*. Approximately 30 cm of the core sample was obtained and separated at 2 cm each. These samples were then dried in an oven and powdered before the chemical analysis was conducted.

Laboratory Analysis

^{210}Pb analysis was conducted based on the standard method (Carpenter *et al*., 1981). Briefly, 2g of the dried sample was placed in a beaker and digested with HNO_3 using a spike of 0.275ml of ^{209}Po. In order to maximize the detection of radioisotopes in the samples, both organic material and iron were removed with the treatment of H_2O_2 and HCL, respectively. The radioisotopes were concentrated into a solution by alternately heating it with acid $HClO_4$, HCl, and 6M of HCl on a hot plate at the temperature below 60°C for 24 hours. The sample solution was then centrifuged and plated onto a silver foil with the presence of ascorbic acid for 24 hours. Polonium-210 was also extracted using an auto deposition onto a silver plate and both the ^{210}Pb and ^{209}Po were analyzed using the alpha spectrometry counter known as the Canberra model.

Data Analysis

^{210}Pb was used to determine the sedimentation rates of the study areas (Krishnaswamy *et al*., 1971; Jones and Chenhall, 2001). The total ^{210}Pb activity was indirectly determined by the measurement of its alpha-emitting grand daughter nuclide, known as ^{210}Po (Kate, 2002). The measurement of ratio ^{210}Po and ^{209}Po activities will provide an adequate figure of supported ^{210}Pb as these two elements are assumed to be in equilibrium (Chung *et al*., 2004). Meanwhile, subtracting the supported ^{210}Pb from the total ^{210}Pb will determine the unsupported ^{210}Pb. The activity of ^{210}Pb is obtained using the formula proposed by Krishnaswamy *et al*. (1971), as follows:

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

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

Where:
$A = A_o e^{-\lambda t}$ (*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

Inventory (I) of ^{210}Pb (unsupported) is expressed in dpm^{-2} and is calculated according to Carpenter (1981):

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

Where:
A_i is the $^{210}Pb_{xs}$ (dpm g^{-1})
ρ_i represented the bulk density interval *i* (g cm^{-3})
h represented the thickness of the interval (cm)

Finally, the sedimentation rate is calculated using the following formula:

$A=A_o e^{-\lambda t}$
$A=A_o e^{-\lambda(x/S)}$
$\ln A=-(\lambda/S)x + \ln A_o$

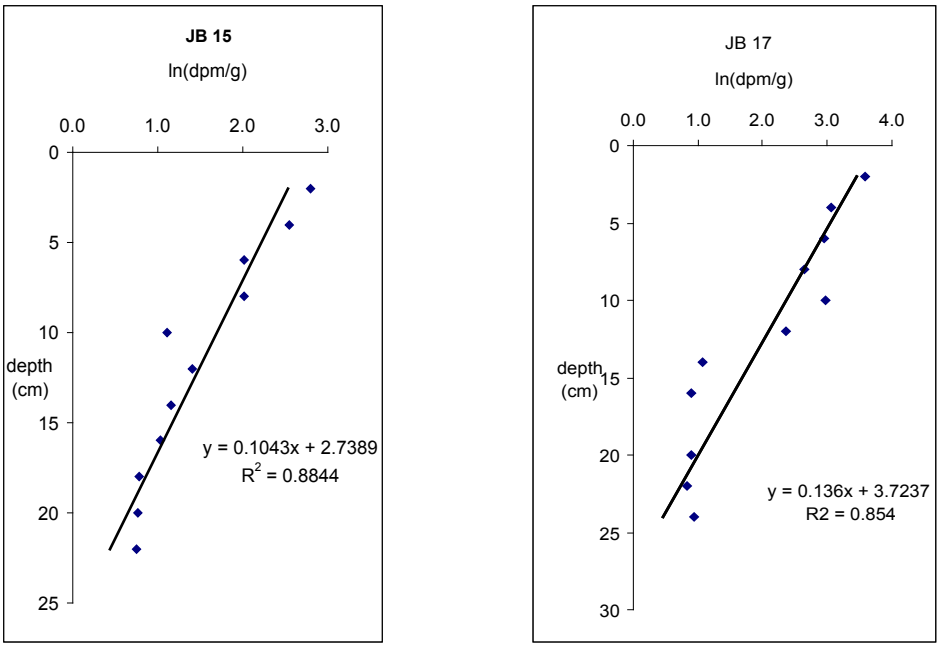


Fig. 2: The vertical distribution of ^{210}Pb in JB15 and JB17

Where:

A = Activity of excess ^{210}Pb in the sediment at any depth
A_o = Activity of excess ^{210}Pb in the freshly deposited sediment at depth=0 (the sediment-water interface)
S = Sedimentation rate in cm/year
λ = Radioactive decay constant (0.0311/year)
t = time in year

RESULTS AND DISCUSSION

Based on *Fig. 2*, the sedimentation rates in JB15 and JB17 were considered constant in the past 100 years, since the distribution of $^{210}Pb_{excess}$ was exponentially decreased according to depth (Tee *et al*., 2005). The bioturbation of the ^{210}Pb in both cores was shown as not significant as the R^2 value was higher than 0.80. However, JB17 which represented the activities of the ^{210}Pb was slightly uncertain compared to JB15, particularly at the depth of 10 cm to 16 cm.

The sedimentation rate of the study area was determined based on the assumption that the $^{210}Pb_{xs}$ was incorporated into the sediments at a constant rate (Chung *et al.,* 2004). Meanwhile, the "best curve" was identified based on the consideration of the graph vertical evenness of certain depth. As a result, the sedimentation rates of JB15 and JB17 of Johore coastal water was estimated as 0.38cmy^{-1} and 0.43cmy^{-1}, respectively. The sedimentation rate at JB17 was higher and this could be explained by the geographical position of the core, whereby their location is located near the estuary, or close to the mouth, providing it with 2 sediment sources known as fluvial and tidal. Greater water discharge from the river also brings much more suspended sediment to settle down to the sea bed. Assuming that the sedimentation rate values are accurate, this may imply that the sediments at the depth of 30 cm were deposited during the last 70 years.

The average sedimentation rate of this study was relatively higher compared to the study obtained in the northern South China Sea, which was 0.23 cm year^{-1} (Chung *et al*., 2004) but was much lower than the ones obtained for Terengganu estuary and Paka mangrove area which were 0.6cm yr^{-1} and 0.9cm yr^{-1}, respectively (Kamaruzzaman and Willison, 2005; Tan *et al*., 2004). The influence of the sedimentation rate in the South China Sea is mainly determined by the seasonal current movement, particularly the northeast monsoon and southeast monsoon. It is important to note that the sediment accumulation rate may be more significant during the northeast monsoon which increases the input of river in the coastal area.

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