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Research paper

Study on Vertical Profile of ^{210}Pb and Sedimentation Rate at Pantai Remis Coastal Area and Kuala Selangor Estuary

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Abstract

Two sediment cores in Kuala Selangor estuary and Pantai Remis coastal area were obtained using gravity corer and then were analyzed using Alpha Spectrometry System. In order to estimate the sedimentation rate in the area, ^{210}Pb dating technique and Constant Rate & Supply (CRS) model were used. From the study, the vertical profile of ^{210}Pb shows a decreasing trend with depth and finally achieving a constant level. Based on the vertical profile of ^{210}Pb, activity of excess ^{210}Pb was obtained and was used to determine the sedimentation rate in the study area. Pantai Remis coastal area shows high sedimentation rate than Kuala Selangor estuary which may due to high sediment input in the area. Besides, the differences in sedimentation rate might be attributed to highly variable sedimentary and hydrodynamic conditions in the estuary and coastal area.

Keywords: *Coastal Area, CRS model, Estuary, ^{210}Pb dating technique, Sedimentation Rate*

1. Introduction

^{210}Pb (half-life 22.3 years) is a naturally occurring radioactive material. ^{210}Pb in sediment is generated *in-situ* by the decay of ^{226}Ra which also known as supported ^{210}Pb (^{210}Pb$_{supp}$). Upward diffusion of a small portion of ^{222}Rn produced in soil and sediments is known to introduce ^{210}Pb into the atmosphere. The subsequent fallout of ^{210}Pb provides an input of this isotope to surface soil and sediments. This additional or fallout ^{210}Pb is called excess ^{210}Pb (^{210}Pb$_{excs}$) which is delivered to estuarine waters through several routes including atmospheric wet and dry deposition, oceanic input, and catchment runoff [1].

The activity of ^{210}Pb$_{excs}$ in the sediments can be calculated as the difference between the ^{210}Pb$_{supp}$ and the total ^{210}Pb (^{210}Pb$_{total}$) activities [2][3]. The data of ^{210}Pb$_{excs}$ can then be used to estimate the age and sedimentation rates over 100 years [4]. In this study, the estimation of sediment age and sedimentation rate was calculated using CRS model as it is widely used for the lakes, coastal zones or estuaries, where sedimentation processes are intensified by anthropogenic actions [5]. Using CRS model calculation, the supply of ^{210}Pb$_{excs}$ to the sediment surface is assumed to be constant and without variable sediment compaction and sediment deposition [6].

^{210}Pb dating of coastal sediments have been extensively conducted over the past 40 years for historical pollution reconstruction studies, sediment focusing, sediment accumulation and mixing rate determination [7]. In addition, the evaluation of sedimentation rate is a tool that can be used to check for sediment delivery and sedimentation patterns [8]. Past studies have proven that sedimentation rate is affected by factors including proliferation of small scale mining [2], different in topographic setting [9], water depth [10] and sediment texture [11].

In Malaysia, considerable works have been done to determine the sedimentation rate using ^{210}Pb dating technique. Studies include the application of this method to assess sedimentation rate in Terengganu coastal waters [9], vertical profiling of ^{210}Pb in sediment core from Kuala Selangor [11], assessment of sedimentation of As and Zn in ex-mining lakes [12, 13] and to study sedimentation rate in Terengganu mangrove forests [14]. This present study aims to determine the vertical profile of ^{210}Pb and sedimentation rate at Pantai Remis coastal area and Kuala Selangor estuary. In addition, the differences in sedimentation rate for these two areas will be thoroughly discussed.

2. Method

2.1 Site Description

Pantai Remis coastal area and Kuala Selangor estuary are located in the northern districts of Selangor in the west coast of Peninsular Malaysia. Sungai Selangor is one of the main rivers in the state of Selangor and act as an important source of water supply for domestic and agricultural uses. Extensive developments were carried out along the Sungai Selangor and most of the ex –mining pond are located near to this river. Its coastal area is enriched with mangrove forests and the land in mainly use for agricultural activities particularly coconut, paddy and oil palm plantations.

Pantai Remis coastal area is well known for its tourism activities. People come to this area to collect 'remis' – the local term for mussel. This area is characterized by its sandy beaches and mangroves forest along the coastal area which also act as a protection during high tide phenomenon. Meanwhile, Kuala Selangor estuary is well known for fishing activities and the sediment texture is much finer than the sediment in Pantai Remis coastal area.

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2.2 Samples Collection and Preparation

The sediment core samples were collected at two locations in Kuala Selangor coastal area. The first location is at Pantai Remis (PR) (03°11.995´N 101°18.397´E) and the second location is at Kuala Selangor (KS) estuary (03°18.266´N 101°13.032´E). Both locations are shown in Figure 1.

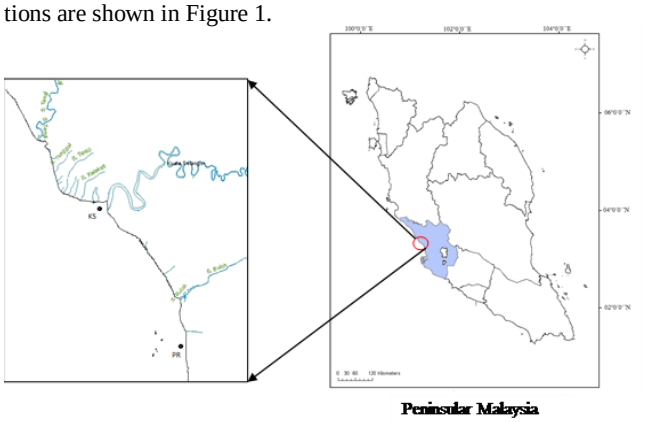


Fig. 1: Map of Peninsular Malaysia showing the Sampling Locations at Pantai Remis (PR) and Kuala Selangor (KS)

The sediment core sample were taken using small gravity corer. Internal PVC pipe with 4.5 cm in diameter and 45 cm in length was inserted into the gravity corer. About 6 to 8 sediments were sampled at each point and sediment cores obtained were about 32 cm in length. The cores were further sub-sampled by slicing them into 4 cm slices. Slices of identical depth of the 6 to 8 cores in each point were mixed to form homogeneous representative aggregate at that depth of the sediments. After that, all samples were oven-dried at 60°C until constant weight. The dry sediments were then grounded into fine powder and were sieved using 250 µm mesh sieve to get a homogenized sediment sample.

2.3 ^{210}Pb analysis

Approximately 2.0 g of dried and homogenized sediment core samples were weighted and 200 µl (23.2842 dpm/g) of ^{209}Po yield determinant tracer was spiked into the sample. Acid leaching using aqua regia, HCl 37%, HNO_3 (65%) and H_2O_2 (30%) was performed onto the sample on a hotplate. Then, the samples were evaporated until dryness at temperature not exceeding 90°C to avoid volatility losses. Dried sample were then cooled to get white residue. Subsequently, 5 ml of HCl (37%) was added to the sample to convert it into 0.5 M HCl medium. The solution was filtered to remove siliceous solid and the residue is washed several times with distilled water. The solution is then made up to 120 ml using distilled water. Glass jar was heated for a few minutes on hot plate and magnetic stirrer was inserted into solution. Approximately 0.2 g of ascorbic acid was added into the solution and measured with $KMnO_4$ until colour of the solution remained unchanged. Ascorbic acid is used to bind free Fe and reduce Fe^{3+} to Fe^{2+} in sample [15] [16]. Cleaned silver disc (2 cm x 2cm) with one side covered with adhesive glue was immersed into the solution in the glass jar. Plating was carried out for 24 hours while stirring. After 24 hours, the disc was rinsed with distilled water, labeled and then kept dried for further counting using alpha spectrometry.

Alpha spectrometry system was used to determine the sediment layer age and sedimentation rate. The alpha spectrometry system facilities used in this study is provided by Malaysian Nuclear Agency. Energy and efficiency calibration were done periodically by the agency themselves. The sediment samples were analyzed together with standard reference material (SRM) IAEA-368 that act as a quality control for every batch of experiment.

The analysis of ^{209}Po (yield tracer) and ^{210}Po was counted by using 450 mm^2 area alpha spectrometry, releases an alpha particle, approximately at 4843 keV and 5264 keV respectively. These alpha particles were then identified by alpha spectrometer with Si PIPS detector (silicon surface barrier detectors). The outputs from the silicon detectors are amplified and transmitted through a multiplexer system into a computer based multi-channel analyzer. Using the alpha spectrometer two count numbers were obtained for each measurement, namely for ^{209}Po and ^{210}Po. During the process of plating until the counting of the sample, ^{209}Po tracer will decay. Hence, plating date correction (PDC) was made and were calculated based on Equation 1.

$$PDC = A^{-\lambda(\Delta t)} \quad (1)$$

Where,
A = ^{209}Po activity at the time it was added during the plating process
$\lambda = 1.86 \times 10^{-5}$ days
Δt = date counted – date plated.

The activity of ^{210}Pb was then determined from the peak area of ^{210}Po, based on the yield of ^{209}Po tracer after plating date correction. Using CRS model calculation, the supply of $^{210}Pb_{excs}$ to the sediment is assumed to be the same for each time interval. Hence, the initial activity concentration (A_o (t)) of $^{210}Pb_{excs}$ in sediment of age, t years must satisfy $A_o(t).r(t) = \lambda$, where r(t) is the dry mass sedimentation rate at time t and λ is the ^{210}Pb radioactive decay constant. Letting x be the present depth of sediment at age t, the present concentration of $^{210}Pb_{excs}$ at depth x is $A(x) = A_o$ (t).e-$^{\lambda t}$. A and A_o are calculated by direct numerical integration of the ^{210}Pb profile [4]. The age of sediments of depth x is then given by equation 2.

$$t_x = \left(\frac{1}{\lambda}\right)\left[\ln\left(\frac{A_o}{A_x}\right)\right] \quad (2)$$

Where;
Λ = The decay constant of ^{210}Pb
A_o = Total inventory of $^{210}Pb_{excs}$ in the sediment column
A_x = Inventory of $^{210}Pb_{excs}$ below depth x.

The activities of $^{210}Pb_{excs}$ were calculated by subtracting the activity of $^{210}Pb_{supp}$ from the activity of $^{210}Pb_{total}$ measured in each sample [17]. Activity units were in bequerel per kilogram (Bq/kg) of sediment. Inventories of $^{210}Pb_{excs}$ activities were calculated by summing its concentration in each layer of sediment (IAEA-TECDOC-1429, 2005) as shown in equation 3.

$$I_S = \sum_{i=1}^{M} S_i D_i (U_i - L_i) \quad (3)$$

Where I_s is the radionuclide inventory in a sediment core (Bq/m^2), M is the number of sediment layers (the layer number is counted downward from the surface to the deeper layer), S_i is the radionuclide concentration in layer i (Bq/kg-dry), D_i is the density of layer i (kg dry/m^3), U_i is the upper boundary of layer i (m), and L_i is the lower boundary of layer i (m). Finally, the sedimentation rate at certain depth was calculated using the following equation:

$$S = z/t \quad (4)$$

Where;
S = Sedimentation rate (cm/year)
z = Distance between A_o and A_z in cm
t = The age of sediment at depth of z cm

3. Results and Discussion

3.1 Vertical profile of ^{210}Pb

Figure 2 shows the vertical profile of $^{210}Pb_{total}$ for location PR and location KS. Based on the vertical profile of $^{210}Pb_{total}$, the value of $^{210}Pb_{supp}$ and $^{210}Pb_{excs}$ were determined. $^{210}Pb_{supp}$ activity at each site was determined as the average of the bottom segments that

had exhibited a relatively constant activity [18] and $^{210}Pb_{excs}$ was determined as the difference between $^{210}Pb_{supp}$ and $^{210}Pb_{total}$ activities.

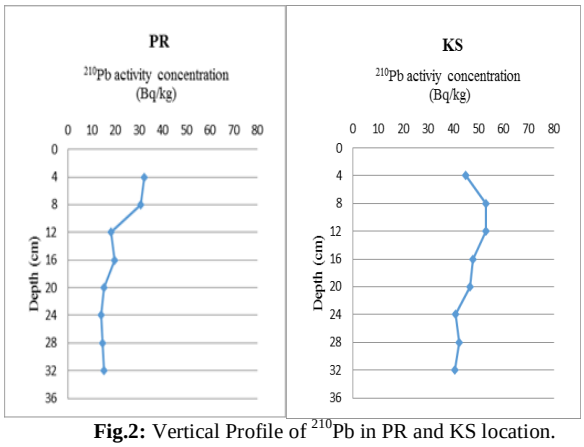


Fig.2: Vertical Profile of ^{210}Pb in PR and KS location.

The ^{210}Pb profile shows relatively high concentrations in the surface sediment caused by natural fallout. There is decreasing trend with depth; eventually achieving constant level which is inherent in the sediment itself. The decreasing trend is caused by radioactive decay of fallout ^{210}Pb with time. Deeper levels in a core correspond to earlier times, so that radioactive decay is manifested as decreasing concentration with depth [19] [12].

Activity concentration of ^{210}Pb in location PR is higher in the upper layer of the sediment and generally decreased and started to achieve constant value at 20 cm depth and onwards. Meanwhile, activity concentration of ^{210}Pb in location KS started to show a decreasing trend at 8 cm depth and finally achieve a constant value at 24 cm depth. Fluctuation occurs at 4 cm depth in location KS may due to the nature of the coring method compaction which usually takes place in the top section of the core samples [12]. Besides, location KS show higher inventory of $^{210}Pb_{excs}$ with a value of 3433178 ± 2055 Bq/m^2 as compared to location PR with a value of 2433 ± 67 Bq/m^2. As mentioned earlier, possible sources of ^{210}Pb are atmospheric input, oceanic input, and catchment runoff. Hence, higher $^{210}Pb^{excs}$ inventory observed in location KS may due to its location which is located at the mouth of Selangor River. A lot of anthropogenic activities located near and along the Selangor River such as mining activities, agricultural activities, land clearing for development and industrial activities which may contribute to the higher inventory of $^{210}Pb_{excs}$ in the area. Furthermore, higher inventory in location KS may due to its sediment texture which is much finer than the sediment texture in location PR. In line with a study done by Choy et al. [11], ^{210}Pb inventory is commonly higher in fine sediment due to the higher scavenging efficiency by clays.

3.2 Sedimentation Rate

Based on the $^{210}Pb_{excs}$ data, estimation of sediment age and sedimentation rate in each layer in the core were made. Then, mean sedimentation rate throughout the core in location PR and KS were determined from the slope of graph as shown in Fig.3 and Fig.4. Based on the figure, both of the cores show R^2 value about 90%. This showed that the sedimentation in the cores occurs linearly. The high R^2 values also mean that the results obtained are a good fit of CRS model used.

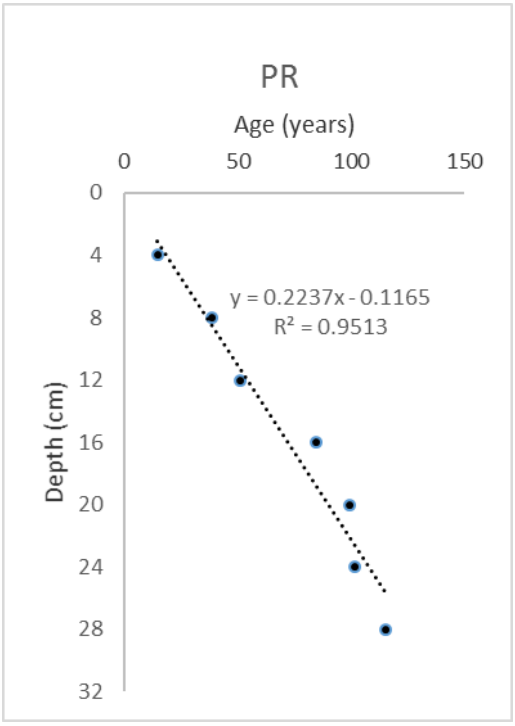


Fig.3: Profile of Sedimentation Rate in PR Location

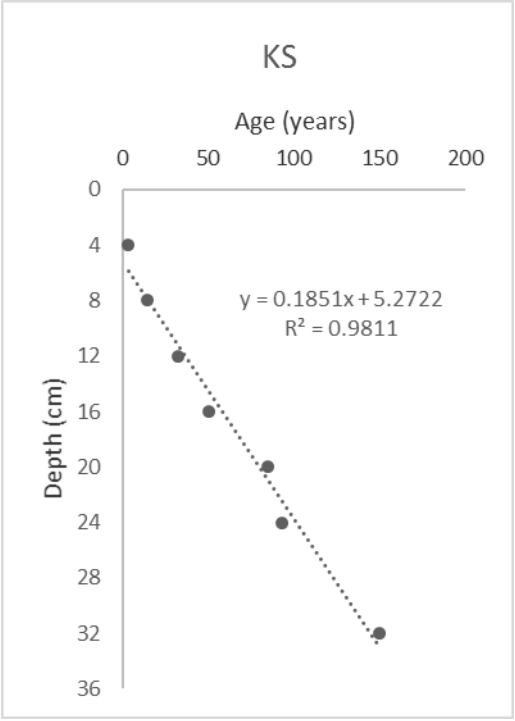


Fig.4: Profile of Sedimentation Rate in KS Location

Mean sedimentation rate in PR and KS location is 0.2237 cm/year and 0.1815 cm/year respectively. Slightly higher sedimentation rate observed in location PR may due to the increase in the sediment input caused by mangrove forest destruction for development purposes in some parts of the area. Additionally, the differences in sedimentation rate might be attributed to highly variable sedimentary and hydrodynamic conditions in the estuary and coastal area [20]. Sedimentation rate in the study area was also compared with other study as shown in Table 1.

Table 1: Comparison of Sedimentation Rate in the Study Area with Other Study

Area	Sedimentation rate (cm/year)	References
PR	0.2237	Present study
KS	0.1851	Present study
Kuala Selangor	0.10 – 0.20	[11]
Terengganu South China Sea	0.30	[10]
Eastern Coast of Thailand	0.46 – 0.69	[21]

By comparing with the study done by Choy et al. [11], generally sedimentation rate in location PR and KS were comparable with the sedimentation rate data in Kuala Selangor. Besides, sedimentation rate values in Terengganu South China Sea and Eastern Coast of Thailand show higher values as compared to the study area. This may due to the different topographic setting in the area.

4. Conclusion

The vertical profile of ^{210}Pb and sedimentation rate in the study area has been successfully determined. The vertical profile of ^{210}Pb shows a decreasing trend with depth and finally achieving a constant level. Location KS show higher inventory of $^{210}Pb_{excs}$ which may due to its location that is near to Selangor River and its sediment texture which contained high fine sediment. Besides, high sedimentation rate observed in location PR may due to high sediment input in the area. Meanwhile, mean sedimentation rate in location PR and KS were generally comparable sedimentation rate data in Kuala Selangor and lower than the sedimentation rate in Terengganu South China Sea and Eastern Coast of Thailand which may due to the different topographic setting in the area.

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