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ASSESSMENT OF NATURALLY OCCURING RADIONUCLIDE IN THE SEDIMENT CORE IN SOUTHERN OF KUALA SELANGOR COASTAL AREA

(Kajian Radionuklida Tabii di dalam Teras Sedimen di Kawasan Pesisir Pantai Selatan Kuala Selangor)

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Abstract

This study is to determine naturally occurring radionuclide activity concentrations of ^{226}Ra, ^{228}Ra and ^{40}K in sediment core using gamma-ray spectrometry with a high-purity germanium (HPGe) detector. Sediment core was taken from 14 locations in two areas in Kuala Selangor which are Pantai Remis and Pantai Jeram. Samples were taken during Northeast Monsoon in January and March 2011. ^{40}K was measured via its 1460 keV energy peak, ^{226}Ra (of the ^{238}U) and ^{228}Ra (of the ^{232}Th) through their γ-ray lines 609.3 keV (^{214}Bi) and 911.1 keV (^{228}Ac). The mean activity concentration of ^{226}Ra in Pantai Remis is 37.49±1.38 Bq/kg and ranged between 19.44-55.74 Bq/kg. For ^{228}Ra the activity concentration ranged between 40.75-82.23 Bq/kg with a mean value of 58.64±2.60 Bq/kg; and that of ^{40}K from 206.53-398.30Bq/kg with a mean of 316.95 ± 10.88 Bq/kg. Meanwhile the mean activity concentration of ^{226}Ra in Pantai Jeram is 32.35±1.27 Bq/kg and ranged between 21.28-38.67 Bq/kg. For ^{228}Ra the activity concentration ranged between 34.25-106.72 Bq/kg with a mean value of 57.96±2.55Bq/kg; and that of ^{40}K from 246.12-394.53 Bq/kg with a mean of 325.14±10.87 Bq/kg. Different vertical profile of ^{226}Ra, ^{228}Ra and ^{40}K activity concentration observed between sampling locations might due to the sediment mineralogy, source of radioactivity, geochemistry of the area and oceanic process. Plus, smaller ^{228}Ra/^{226}Ra activity ratio range suggests that interaction on these two series with the surrounding were very similar. Value of study radionuclides in present study were almost comparable with study done in other part in Malaysia. Moreover, world mean value of ^{226}Ra, ^{228}Ra and ^{40}K provided by UNSCEAR (1993) fall within the value range of radionuclides in present study.

Keywords: Natural radionuclides, activity concentration, sediment core, coastal area, gamma spectrometer

Abstrak

Kajian ini adalah untuk menentukan aras radionuklid tabii (^{226}Ra, ^{228}Ra dan ^{40}K) di dalam teras sedimen menggunakan spektrometer gama yang dilengkapkan dengan pengesan germanium lampau tulen (HPGe). Teras sedimen telah di ambil daripada 14 lokasi di dua kawasan di Kuala Selangor iaitu Pantai Remis dan Pantai Jeram. Sampel telah di ambil semasa monsun timur laut pada Januari dan Mac 2011. Radionuklid ^{40}K diukur melalui puncak tenaga 1460 keV. Untuk ^{226}Ra (daripada ^{238}U) dan ^{228}Ra (daripada ^{232}Th) garisan sinar gama 609.3 keV (^{214}Bi) dan 911.1 keV (^{228}Ac) digunakan. Purata kepekatan aktiviti ^{226}Ra di Pantai Remis ialah 37.49±1.38 Bq/kg dan julat di antara 19.44-55.74 Bq/kg. Untuk ^{228}Ra, kepekatan aktiviti julat diantara 40.75-82.23Bq/kg dengan purata 58.64±2.60 Bq/kg; dan bagi ^{40}K julat di antara 206.53-398.30Bq/kg dengan purata 316.95 ± 10.88 Bq/kg. Sementara itu purata kepekatan aktiviti ^{226}Ra di Pantai Jeram ialah is 32.35±1.27 Bq/kg dan julat diantara 21.28-38.67 Bq/kg. Untuk ^{228}Ra kepekatan aktiviti berjulat diantara 34.25-106.72 Bq/kg dengan purata bernilai 57.96±2.55Bq/kg; dan bagi ^{40}K julat diantara 246.12-394.53 Bq/kg dengan purata 325.14±10.87 Bq/kg. Terdapat perbezaan profil mencangcang bagi kepekatan aktiviti untuk ^{226}Ra, ^{228}Ra and ^{40}K, yang mugkin disebabkan oleh mineralogi sedimen, punca radioaktif, geokimia kawasan tersebut serta proses lautan. Tambahan pula, nilai lingkungan kecil bagi nisbah activiti untuk ^{228}Ra/^{226}Ra mengcadangkan bahawa interaksi di antara dua siri ini dengan persekitaran adalah sama. Nilai radionuklida yang dikaji di dalam kajian ini adalah sebanding dengan kajian yang dijalankan di kawasan lain di Malaysia. Nilai purata dunia bagi ^{226}Ra, ^{228}Ra and ^{40}K yang dinyatakan oleh UNSCEAR (1993) jatuh di dalam lingkungan nilai radionuklida di dalam kawasan kajian ini.

Kata kunci: Radionuklid tabii, kepekatan aktiviti, teras sedimen, kawasan pesisir pantai, spektrometer gama

Introduction

Kuala Selangor is located in the Sungai Selangor estuary in the west coast of Peninsular Malaysia. Its coastal zone is characterized by semi diurnal, micro tidal regime with the mean spring tidal range of about 4.0 m [1]. Pantai Remis and Pantai Jeram coastal area which are located in the southern part of Kuala Selangor is enriched with mangrove forest which play an important role in coastal protection and sustaining local fisheries. Land in the area is used primarily for forestry; fishing and harvesting of mangrove products; housing estates, industry and agriculture including mixed cropping, coconut and palm plantations in adjacent areas.

A wide range of radionuclides has been released into the oceans. Their distribution in space and time can be quite complex, but is always related to four general processes: the input function/source, radioactive decay, biogeochemistry, and oceanic processes [2]. Meanwhile, coastal area acts as deposition areas for washed-out materials due to human activities occurring around the catchment area. Those materials include radionuclide contaminants due to naturally occurring radioactive materials (NORM) and/or technologically enhanced NORM (TENORM) [3]. Examples of NORM and/or TENORM are ^{226}Ra, ^{228}Ra and ^{40}K. The movement of these radionuclides into the coastal area is affected by geographical characteristic, tidal forces and physical characteristics of the sediment particles itself. Sediment which is one of the components in marine environment is vital in determining the concentration and dispersion of radionuclide as its offers large surface areas for adsorption [4].

Hence, the objective of this study is to determine the activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K in the sediment core in southern of Kuala Selangor coastal area specifically at 'Pantai Remis' and 'Pantai Jeram' area.

Materials and Methods

Sampling location

Sediment core samples were taken from 14 locations in southern part of Kuala Selangor coastal area where 7 locations are from Pantai Remis and another 7 locations are from Pantai Jeram, Kuala Selangor as shown in Figure 1.

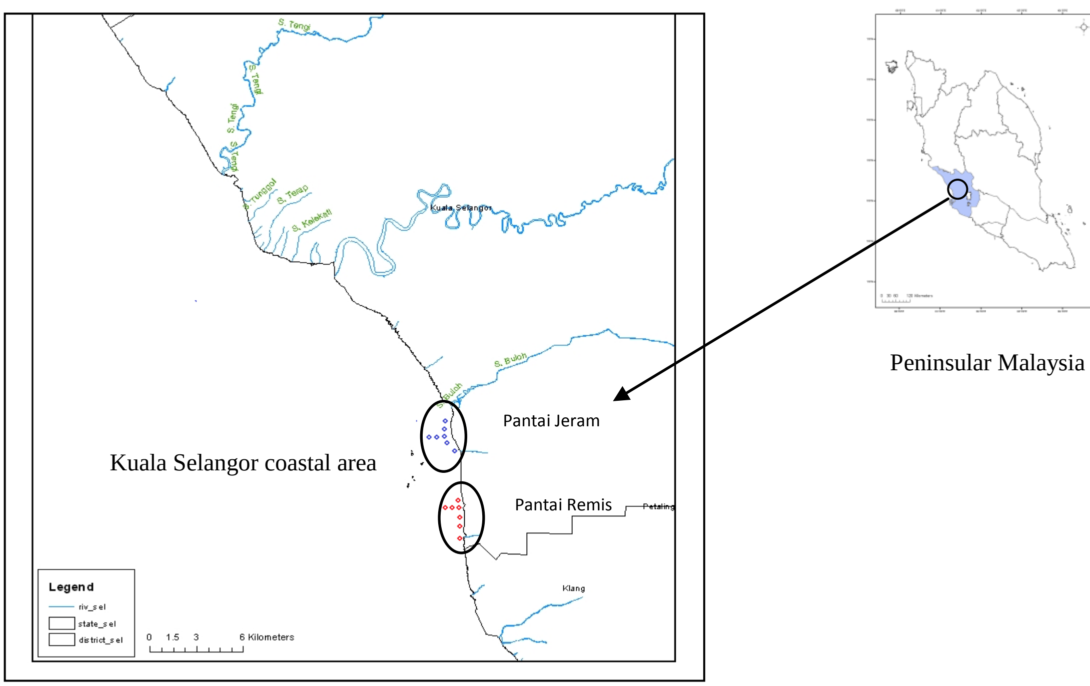

Figure 1. Map of sampling location

The samples were taken in the intertidal zone which is along the coastal area and 200 to 300 m away from land (toward the sea) as shown in Figure 2a and Figure 2b.

Figure 2a. Sampling point in Pantai Remis

Figure 2b. Sampling point in Pantai Jeram

Distance between each consecutive point is about 100 meters to 300 meters. The position of sampling points was determined using Global Positioning System (GPS). Table 1 shows the GPS coordinate and sampling location of the study area.

Table 1. Coordinates and sampling locations for collecting sediment in the study area

Area	Sample code	GPS Coordinate		Location
		Longitude	Latitude	
Pantai Remis	PR1	101°18.422´	03°12.074´	Along the coastal
	PR2A	101°18.419´	03°11.994´	Along the coastal
	PR2B	101°18.397´	03°11.995´	Toward the sea
	PR2C	101°18.255´	03°11.999´	Toward the sea
	PR3	101°18.347´	03°11.850´	Along the coastal
	PR4	101°18.335´	03°11.701´	Along the coastal
	PR5	101°18.379´	03°11.565´	Along the coastal
Pantai Jeram	PJ1	101°18.364´	03°13.261´	Along the coastal
	PJ2	101°18.285´	03°13.542´	Along the coastal
	PJ3A	101°18.265´	03°13.599´	Along the coastal
	PJ3B	101°18.247´	03°13.680´	Toward the sea
	PJ3C	101°18.226´	03°13.711´	Toward the sea
	PJ4	101°18.238´	03°13.762´	Along the coastal
	PJ5	101°18.074´	03°30.905´	Along the coastal

Sample collection

Sediment core samples were taken manually using 42 cm length PVC pipe. Each sediment core was sliced into 4 cm and dried in the oven at 60^{o}C until constant weight. The dried sample was then grounded into fine particle and pass through 250 mesh sieve. About 100 - 150 g of surface sediment was packed into polyethylene container and were carefully sealed using cellophane tape to avoid the escape of gaseous radon and thoron from the sample [5]. Then, it is allowed to achieve equilibrium for at least 3 weeks.

Sample analysis

The activity concentration ^{226}Ra, ^{228}Ra, and ^{40}K in the sediment core samples were counted for 14400 seconds using gamma spectrometry system with ORTEC p-type HPGe coaxial detector coupled to a spectrum processing system. The HPGe has a resolution of 1.85 keV and 25 % relative efficiency at 1332 keV ^{60}Co gamma-ray. The background radiation was also measured to carry out the necessary correction. Efficiency calibration of the spectrometer was carried out by using analytical grade UO_3 ore in KCl matrix prepared in the laboratory using identical container geometry as the samples. The spectrum processing and analysis were done using ORTEC Gamma Vision^{TM} Version 6.07 [6].

^{226}Ra activities were determined by measuring the photo peaks of its daughter nuclides; ^{214}Bi at 609.3 keV. The ^{228}Ra activities in the samples were determined by measuring the intensity of ^{228}Ac at 911.1 keV. Meanwhile, the activity concentration of ^{40}K was determined directly via its 1460 keV energy peak [7].

Results and Discussion

Sediment dry bulk density

Dry bulk density in sediment is the mass of dry sediment in a given bulk volume of sediment [8]. Dry bulk density in the sediment core along the coastal and toward the sea in Pantai Remis and Pantai Jeram were shown in Figures 3a - 4b respectively.

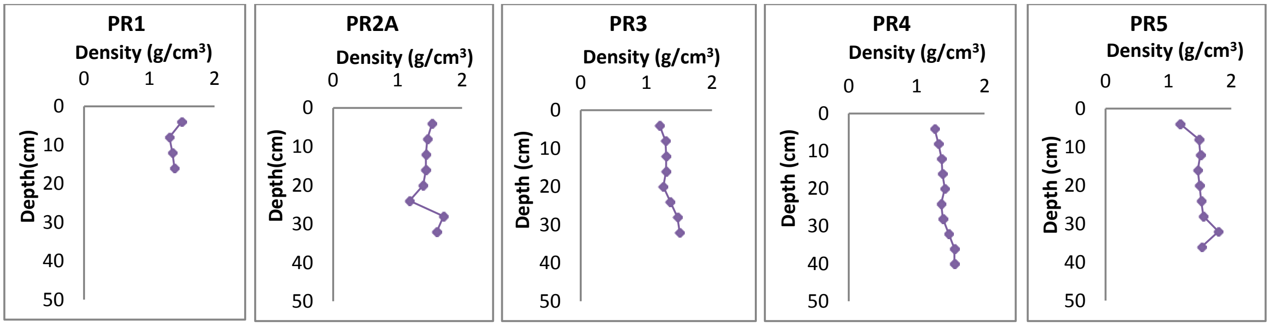

Figure 3a. Density in the sediment core along coastal area in Pantai Remis

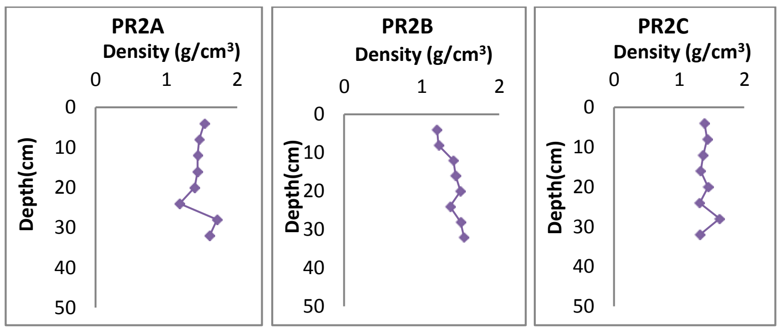

Figure 3b. Density in the sediment core toward the sea in Pantai Remis

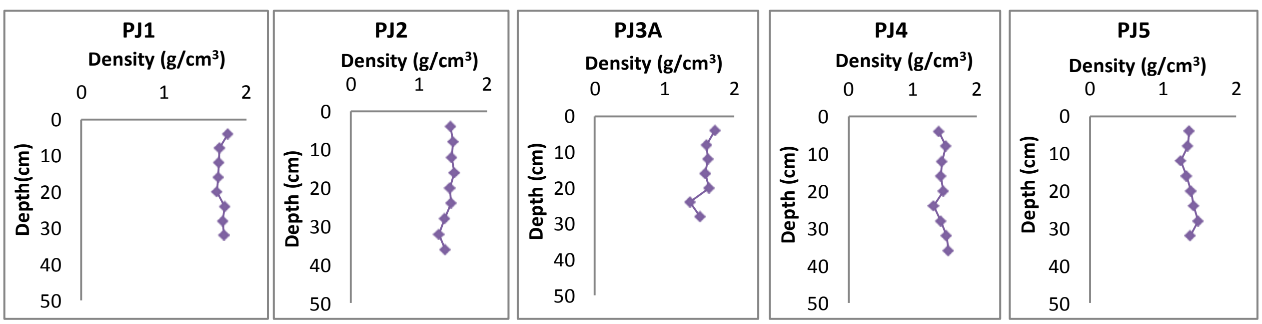

Figure 4a. Density in the sediment core along the coastal area in Pantai Jeram

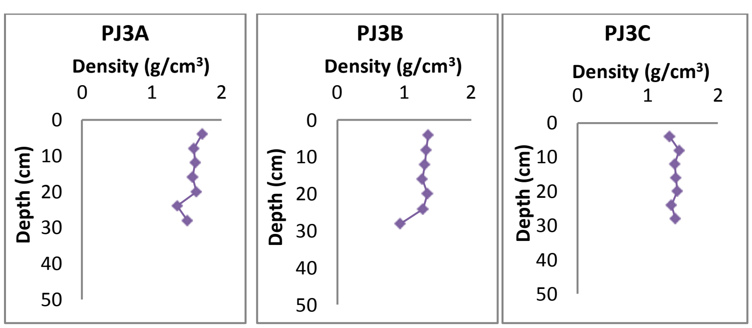

Figure 4b. Density in the sediment core toward the sea Pantai Jeram

The depth distribution of density the sediment core along coastal area and toward the sea in Pantai Remis was characterized by generally increase down the core. However, a spike was observed at 24 cm and 28 cm depth in PR2A sample as well as at 32 cm depth in PR5 sample. Meanwhile, densities of the sediment core along the coastal and toward the sea in Pantai Jeram were also increasing from the top layer to the bottom layer except in PJ3A and PJ3B samples. Pantai Remis and Pantai Jeram area can be classified as mudflat area located in the intertidal zone. Sediment mineralogy in the mudflat area may largely consist of silt and clay. Meanwhile, sand was also presence in the top layer of the core for location located along the coastal area. Some sea shells were also observed attach to the sediment in some location in Pantai Remis and Pantai Jeram. According to [9], dry bulk density is related, directly or indirectly to the softness (or hardness) of the sediment, its vulnerability to erosion, re-suspension and other mechanical properties. Hence, sediment mineralogy and sediment characterization as well as interaction with the coastal ecosystem may affect the dry bulk density of the sediment. Furthermore, removal of sediment cores from in situ conditions results in changes in porosity and saturated bulk in particular, not only as a result of disturbance during the penetration of the gravity corer in the sediment but also because the cores are removed from in situ temperature conditions to surface conditions [10].

Vertical profile of natural radioactivity in sediment core

Vertical profile of ^{226}Ra, ^{228}Ra and ^{40}K in sediment core were discussed in two parts which is "along the coastal" and "towards the sea" for both Pantai Remis and Pantai Jeram respectively.

Along the coastal area in Pantai Remis

Vertical profiles of ^{226}Ra and ^{228}Ra along the coastal area in Pantai Remis were shown in Figures 5a. Generally, the activity concentration of ^{226}Ra and ^{228}Ra in all samples shows almost similar trend. However, activity concentration of ^{228}Ra is higher than ^{226}Ra in all samples.^{228}Ra is a daughter product of ^{232}Th which comes from Thorium (Th) decay series meanwhile ^{226}Ra is a daughter product of 230Th which comes from Uranium (U) decay series. According to [11], concentration of Th is higher than U in sedimentary rock. Hence, activity concentration of ^{228}Ra is higher than ^{226}Ra because their activity concentration is in accordance with their respective parent nuclides.

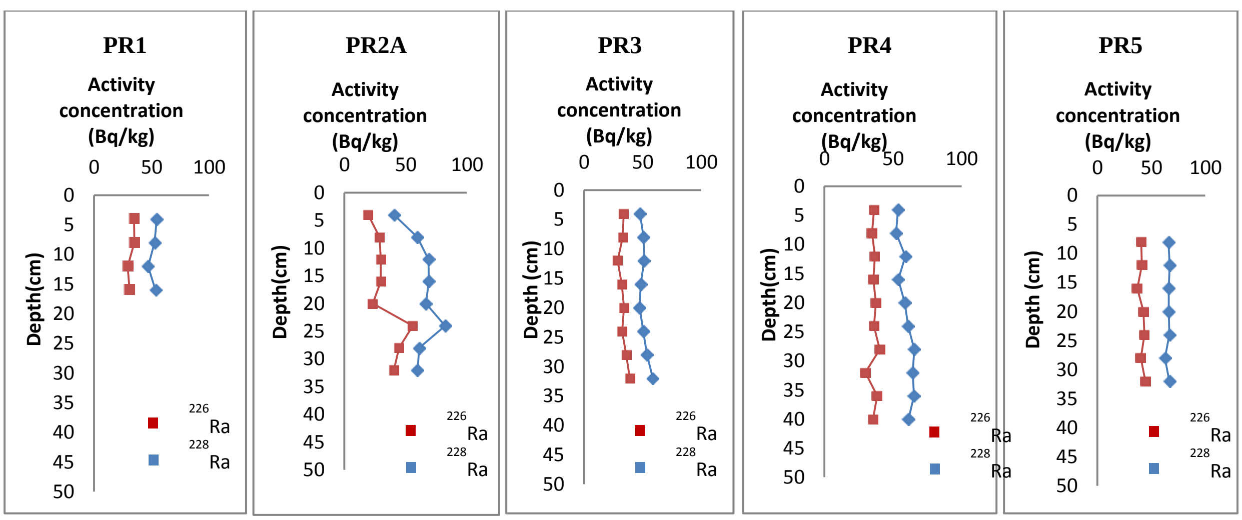

Figure 5a. Vertical profile of ^{226}Ra and ^{228}Ra activity concentration along coastal area in Pantai Remis

In PR1 sample, the vertical distribution of study radionuclides is up to 16 cm depth because the sampling point is characterized as a rocky shores area. The sediment core mainly dominated by *barnacles species* that inhabit on the rock surface. Hence, the sediment core which taken manually using PVC pipe experience difficulty to penetrate into deeper level. The activity concentration for ^{226}Ra and ^{228}Ra were ranged from 29.29-35.16 Bq/kg (mean = 32.51±1.30 Bq/kg) and 47.01-54.42 Bq/kg (mean = 51.89±2.47 Bq/kg) respectively. Activity concentration of the study radionuclides show inconsistent pattern which might because of bioturbation. The bioturbation normally affects only the top few cm of the core. The assumption that biological and physical mixing was restricted to the surface mixed layer (SML) [12].

However, PR2A sample shows an increasing trend of ^{226}Ra activity concentration until 24 cm depth and decreasing back until 32 cm, similar trends were also observed in activity concentration of ^{228}Ra. A spike at 24 cm is probably related to its density as at 24 cm the density is lower, and density is closely related to the mineralogy composition of the sediment. According to villagers in the area, our sampling location used to be a village but because of the coastal erosion, the coastal area had moved inward. Thus, probably the presence of building materials and other materials embedded in the old sediment increase the amount of radioactivity due to the human activities in that area long time ago.

PR3 sample shows generally consistent trend throughout the core ranging from 28.60 - 39.01 Bq/kg (mean = 33.66 ± 1.35 Bq/kg) for ^{226}Ra and 47.39-58.59 Bq/kg (mean = 51.01±2.50 Bq/kg) for ^{228}Ra. In PR4, ^{226}Ra and ^{228}Ra activity concentration show the trend of decreasing after 30 cm depth. Constant variation of vertical profile in PR5 sample was observed. The activity concentration of ^{226}Ra ranging from 37.02 - 44.69 Bq/kg (mean = 41.00±1.39) and activity concentration of ^{228}Ra ranging from 56.34 - 67.02 Bq/kg (mean = 64.82 ± 2.65). Deeper levels in a core correspond to earlier times, so that radioactive decay is manifested as decreasing concentration with depth [13]. Besides, the constant value of radionuclides activity concentration in the bottom sediment can act as a natural background level as proposed by [14, 15]. Natural background may be non-homogenous in the analyzed area because several factors determine the distribution pattern of minerals and elements in an estuary (e.g. the sediment grain size and the physical-chemical conditions of waters and hydrology). For that reason, an accurate determination of the natural background levels could be achieved by taking deep sediment distributed across the estuary as a reference.

Vertical profile of ^{40}K along coastal area in Pantai Remis was shown in Figure 5b. The vertical profile of ^{40}K is variable in PR1 indicating that the core up to 16 cm depth is in the mixing layer. PR2, PR3 and PR4 samples generally show a decreasing pattern of activity concentration of ^{40}K with a near surface enrichment. Meanwhile, PR5 sample shows an increase in activity concentration of ^{40}K from surface until 12 cm depth with a value of 350.92 Bq/kg. Then, it decrease and reach a constant value at the deeper part of the core. The higher values in PR5 samples may be attributed to the presence small water irrigation into the area. The point source of the water irrigation is from the terrestrial area that passed through the oil palm plantation. Hence, the water irrigation might carry fertilize agricultural soil which may increase the concentration of ^{40}K in the area.

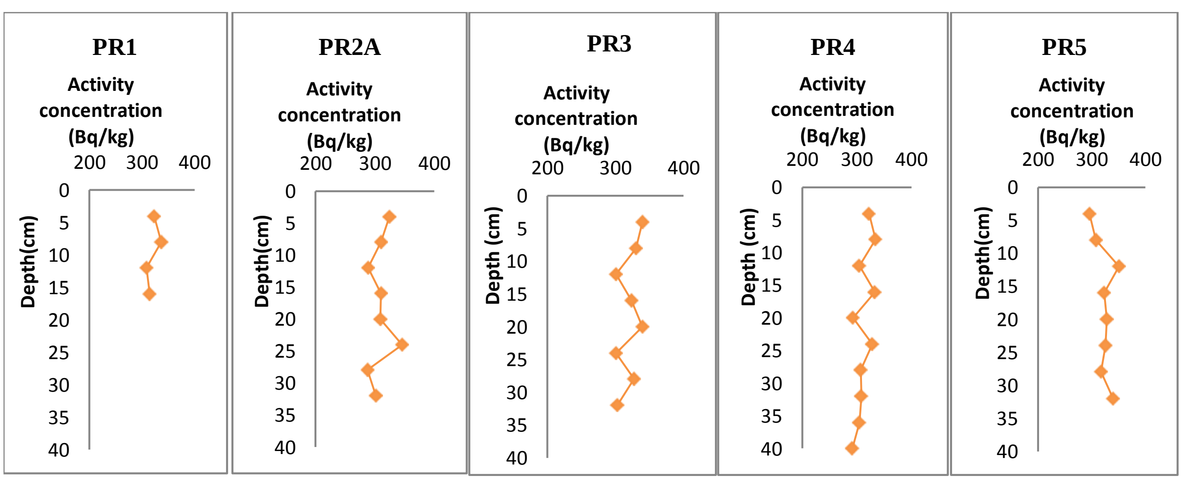

Figure 5b. Vertical profile of ^{40}K activity concentration along coastal area in Pantai Remis

Toward the coastal area in Pantai Remis

The vertical profile of ^{226}Ra and ^{228}Ra towards the sea in Pantai Remis were shown in Figure 6a. Almost similar trend of ^{226}Ra and ^{228}Ra vertical profile in PR2B and PR2C samples were observed. The activity concentrations initially decrease from the surface to 8 cm depth. The activity concentrations were then generally constant throughout the core until 28 cm depth and fluctuate at 32 cm depth. This trend may due to the effect of water current during high tide and sediment mineral composition in the area. Figure 6b. shows the vertical profile of ^{40}K towards the sea in Pantai Remis.

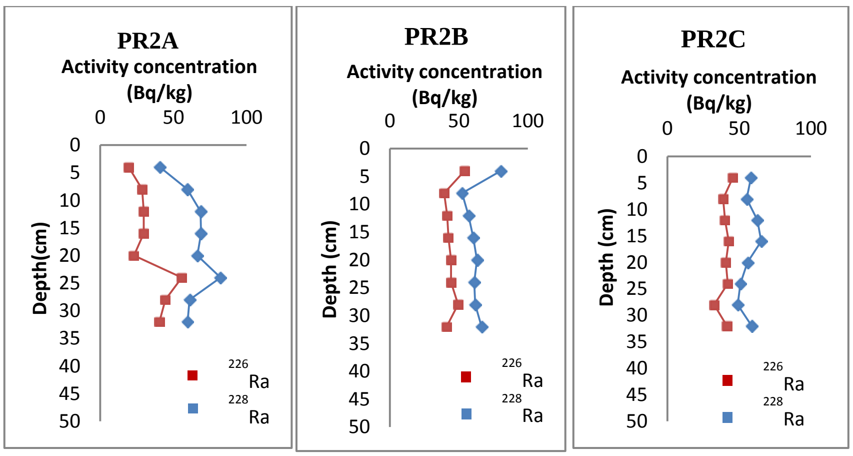

Figure 6a. Vertical profile of ^{226}Ra and ^{228}Ra activity concentrations towards the sea in Pantai Remis

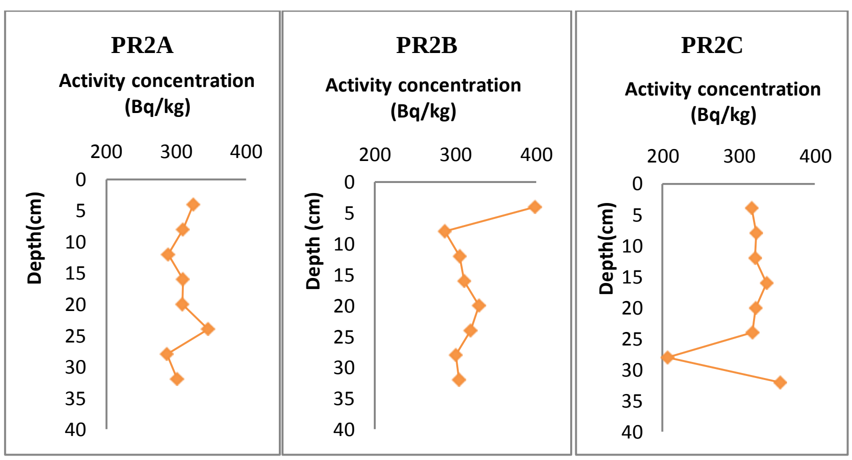

Figure 6b. Vertical profile of ^{40}K activity concentration towards the sea in Pantai Remis

Vertical profile of ^{40}K for PR2A and PR2B is varied but with generally decreasing down the core. Conversely, PR2C samples show roughly constant trend throughout the core but with a spike observed at 28 cm depth. The spike with a value of 206.53 ± 8.22 Bq/kg may indicate different particle size observed in the core [16].

Along the coastal area in Pantai Jeram
Vertical profiles of ^{226}Ra and ^{228}Ra activity concentrations along coastal Pantai Jeram were shown in Figure 7a. The activity concentration of ^{226}Ra in the sediment core show generally uniform trend from the surface up to the deeper level.

Meanwhile, vertical profile of ^{228}Ra activity concentration in PJ1, PJ2, PJ3A, PJ4 and PJ5 show almost similar trend as it is increasing from top layer to the bottom layer. Owing to its soluble and mobile nature, ^{228}Ra is supplied to the ocean mainly by released from coastal sediment near to the land ocean interface where its produces [17]. There are two small rivers channel into the Pantai Jeram area which is "Sungai Buloh" and "Sungai Jeram". The interaction between the rivers and tidal effect may reduce the ^{228}Ra activity in the surface sediment by active release of ^{228}Ra from coastal sediment in the surface layer to the seawater.

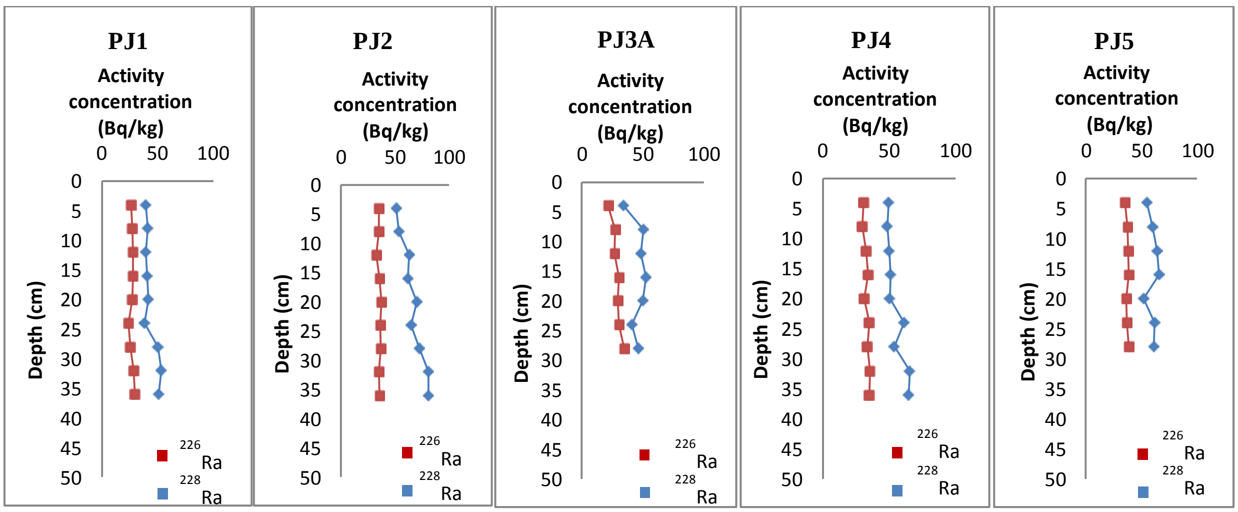

Figure 7a. Vertical profile of ^{226}Ra and ^{228}Ra activity concentrations along coastal area in Pantai Jeram

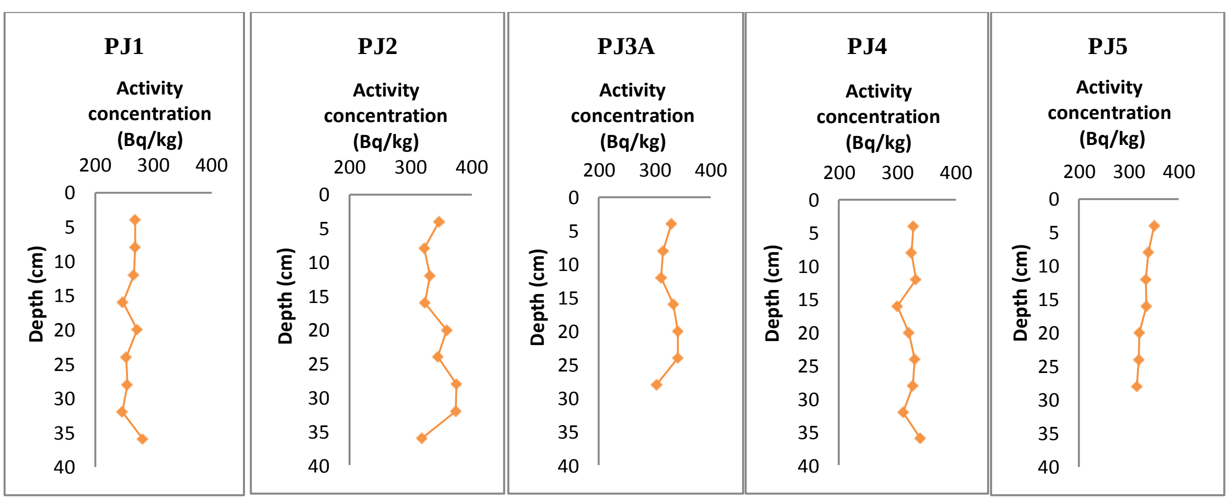

Figure 7b. Vertical profile of ^{40}K activity concentration along coastal area in Pantai Jeram

Vertical profiles of ^{40}K along coastal area in Pantai Jeram were shown in Figure 7b. Vertical profiles of ^{40}K in PJ1 and PJ4 samples show almost similar trend. However, activity concentration of ^{40}K in PJ4 is higher than PJ1 which ranging from 299.89 - 339.15 Bq/kg (mean= 323.07 ± 10.82) for PJ4 and 246.12 - 281.60 Bq/kg (mean = 261.84 ± 9.04 Bq/kg) for PJ1 respectively. PJ1 has the lowest activity of ^{40}K down the core, this probably due to its location that far from 'Sungai Selangor' as the river that flows into the area might carry fertilized agricultural soil. On the other hand PJ2 and PJ3A samples show a mixing pattern in the upper layer and the activity of ^{40}K start to decrease at depth of 36 cm and 28 cm respectively. However, PJ5 sample shows no discernible mixing pattern in the upper layer suggesting that minimal sediment reworking exist by decreasing the water dynamic energy and providing enough time for fine grain size to sink and deposit [18].

Towards the sea in Pantai Jeram

Vertical profile of ^{226}Ra, ^{228}Ra and 40K activity concentrations towards the sea in Pantai Jeram were shown in Figure 8a and 8b respectively.

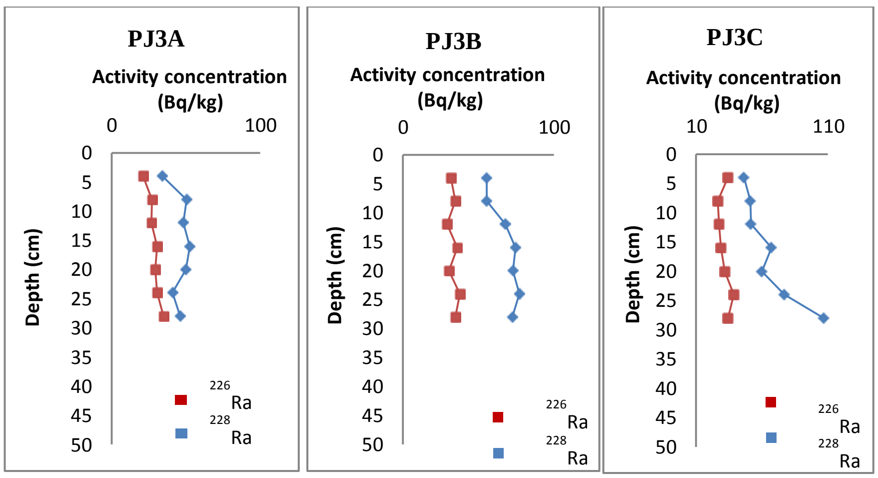

Figure 8a. Vertical profile of ^{226}Ra and ^{228}Ra activity concentrations towards the sea in Pantai Jeram

Vertical profiles of ^{226}Ra towards the sea in Pantai Jeram were not changing very much with depth. Meanwhile, vertical profile of ^{228}Ra in PJ3A, PJ3B and PJ3C shows a trend of increasing from top to the bottom layer. Lower activity concentration of ^{228}Ra in the top section of the core samples might due to the nature of the coring method compaction [19].

Vertical profile of ^{40}K activity concentrations towards the sea in Pantai Jeram show variable pattern mainly in PJ3C samples. PJ3C is located farthest away from the land. Input of ^{40}K in the area might come from adjacent land and sea as well.

The activity concentration of study radionuclides in all locations and $^{228}Ra/^{226}Ra$ activity ratio were tabulated in Table 2 and Table 3. $^{228}Ra/^{226}Ra$ activity ratio was calculated based on the mean value of ^{226}Ra and ^{228}Ra activity concentration respectively.

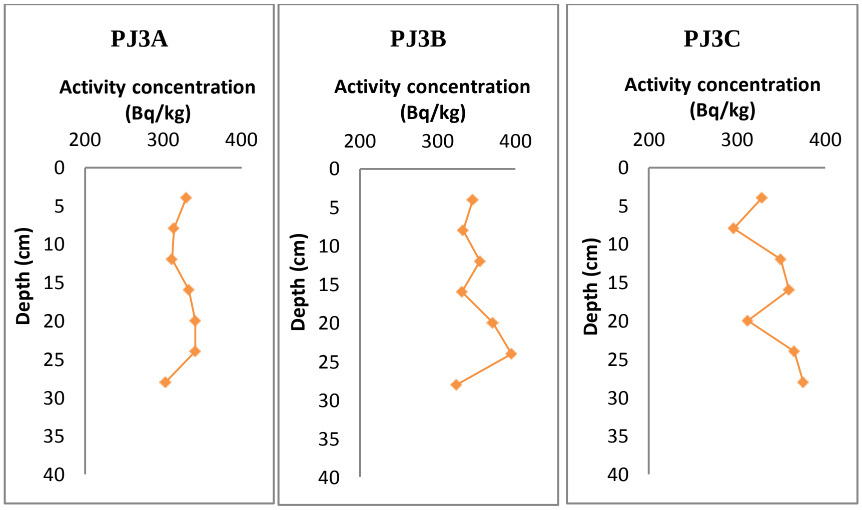

Figure 8b. Vertical profile of ^{40}K activity concentrations towards the sea in Pantai Jeram

Table 2. ^{226}Ra, ^{228}Ra and ^{40}K activity concentrations in sediment core at Pantai Remis in Bq/kg

Sample code	**Activity concentration (Bq/kg)**						**^{228}Ra/^{226}Ra activity ratio**
	^{226}Ra		**^{228}Ra**		**^{40}K**		
	Range	**Mean**	**Range**	**Mean**	**Range**	**Mean**	
PR1	29.29-35.16	32.51±1.30	47.01-54.42	51.89±2.47	308.76-335.87	320.43±11.08	1.60
PR2A	19.44-55.74	33.90±1.28	40.75-82.23	63.40±2.66	287.00-345.69	309.44±10.60	1.87
PR2B	39.39-54.19	44.60±1.52	52.32-80.48	62.87±2.72	286.99-398.30	319.24±11.04	1.41
PR2C	32.63-45.60	40.54±1.44	49.00-65.33	56.99±2.58	206.53-354.18	312.23±10.87	1.41
PR3	28.60-39.01	33.66±1.35	47.39-58.59	51.01±2.50	300.99-339.72	320.69±11.30	1.52
PR4	29.98-40.37	36.18±1.36	52.32-65.22	59.50±2.63	291.37-334.08	312.84±10.87	1.64
PR5	37.02-44.69	41.00±1.39	56.34-67.02	64.82±2.65	295.78-350.92	323.81±10.41	1.58
Average	19.44-55.74	37.49±1.38	40.75-82.23	58.64±2.60	206.53-398.30	316.95±10.88	1.56

Table 3. ^{226}Ra, ^{228}Ra and ^{40}K Activity concentrations in sediment core at Pantai Jeram in Bq/kg

Sample code	Activity concentration (Bq/kg)						$^{228}Ra/^{226}Ra$ activity ratio
	^{226}Ra		^{228}Ra		^{40}K		
	Range	Mean	Range	Mean	Range	Mean	
PJ1	23.76-29.54	27.07±1.07	38.20-53.30	43.93±2.05	246.12-281.60	261.84±9.04	1.62
PJ2	32.82-37.24	35.60±1.34	50.96-81.20	66.64±2.75	318.50-374.92	343.75±11.27	1.87
PJ3A	21.28-34.92	28.71±1.14	34.25-52.51	46.13±2.18	303.46-341.41	324.88±10.35	1.61
PJ3B	29.50-38.01	33.67±1.39	55.52-74.78	68.09±2.98	324.36-394.53	350.34±12.16	2.02
PJ3C	26.25-38.67	31.55±1.28	46.19-106.72	65.65±2.75	296.54-374.99	340.84±11.11	2.08
PJ4	29.74-35.67	33.09±1.28	48.85-65.44	55.03±2.48	299.89-339.15	323.07±10.82	1.66
PJ5	33.41-38.63	36.75±1.39	51.99-65.82	60.23±2.68	316.39-351.89	331.26±11.35	1.64
Average	21.28-38.67	32.35±1.27	34.25-106.72	57.96±2.55	246.12-394.53	325.14±10.87	1.79

The mean activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K activity concentrations in sediment core at Pantai Remis and Pantai Jeram are almost similar. Thus, the radioactivity in the area might have similar biogeochemistry and oceanic process. However, the sources that contribute to the activity concentration of radionuclide in the area are different. As reported in [20], Kapar coal power plant that located near to Pantai Remis area may release some natural radioactivity due to the combustion of coal through atmosphere and consequently being absorbed into the sediment. Pantai Jeram is near to Sungai Selangor which is about, thus radioactivity in Pantai Jeram may largely due to human activities and plantation and development along Sungai Selangor.

The mean value of $^{228}Ra/^{226}Ra$ activity ratio was 1.56 and 1.79 in Pantai Remis and Pantai Jeram respectively. ^{238}U and ^{232}Th commonly occur together in nature. This frequently leads to a relatively constant $^{238}U/^{232}Th$ or $^{228}Ra/^{226}Ra$ ratio in many natural systems. This ratio may vary from the original value if the sample was subjected to physical or chemical interaction that may affect one series more or less than the other one. Smaller ratio range suggests that interaction on these two series with the surrounding were very similar [21].

Comparison to other studies

Normally, in coastal areas and on the continental shelf which are not very far from the land-based pollutants, it is reasonable to assume that the sediments have a range of concentration of natural radionuclides similar to that of terrestrial rocks, and the radioactive equilibrium is maintained [21]. For that reason, activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K in sediment core at Pantai Remis and Pantai Jeram were compared with the study done by [22] which determines the activity concentration of naturally occurring radionuclide in Selangor soil. Based on the study, the average activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K in Selangor soil is 66 ± 16 Bq/kg, 95 ± 32 Bq/kg and 204 ± 90 Bq/kg respectively. The activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K in Selangor soil are higher than the average activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K in the sediment core in Pantai Remis and Pantai Jeram. Possible reason is that the radionuclides determined in Selangor soil are near to the catchment area. Besides, radionuclides determined in the Selangor soil may enriched with igneous rock as compared to radionuclides determined in the present study which are enriched with shales and /or sedimentary rock. According to [23], igeneous rock contained higher concentration of uranium and thorium (parent of ^{226}Ra and ^{228}Ra respectively) than in shales and sedimentary rock. The activity concentrations of ^{226}Ra, ^{228}Ra and ^{40}K in study area were compared with other study and world mean value as shown in Table 4.

Table 4. Comparison of activity concentrations of ^{226}Ra, ^{228}Ra and ^{40}K in study area with study in other region and world mean value

Study area	**Activity concentration (Bq/kg)**			**Reference**
	^{226}Ra	**^{228}Ra**	**^{40}K**	
Pantai Remis	19.44-55.74	40.75-82.23	206.53-398.30	Present study
Pantai Jeram	21.28-38.67	34.25-106.72	246.12-394.53	Present study
EEZ Peninsular Malaysia	16-46	28-87	171-690	[21]
West Coast Peninsular Malaysia	14.25–38.90	16.91–97.18	-	[24]
Coastal sediment in Malacca Strait	16.4 – 81.8	23.8 – 113.1	-	[25]
Coastal of Sabah	16 -30	23–45	402–842	[26]
Coastal of Sarawak	23–41	27–45	142–680	[26]
Xinghua Bay mouth, Fujian, China	22.4–27.9	54.4–71.9	684–795	[27]
World mean value	25	25	373	[28]

Mainly, value of study radionuclides in present study were almost comparable with study done in EEZ Peninsular Malaysia, West Coast Peninsular Malaysia, coastal sediment in Malacca Strait, coastal of Sabah and Sarawak as well as Xinghua Bay mouth, Fujian China. Moreover, world mean value of ^{226}Ra, ^{228}Ra and ^{40}K provided by UNSCEAR (1993) fall within the value range of radionuclides in present study.

Conclusion

The mean activity concentration of ^{226}Ra in Pantai Remis is 37.49±1.38 Bq/kg and ranged between 19.44-55.74 Bq/kg. For ^{228}Ra the activity concentration ranged between 40.75-82.23Bq/kg with a mean value of 58.64±2.60 Bq/kg; and that of ^{40}K from 206.53-398.30 Bq/kg with a mean of 316.95 ± 10.88 Bq/kg. Meanwhile the mean activity concentration of ^{226}Ra in Pantai Jeram is 32.35 ± 1.27 Bq/kg and ranged between 21.28-38.67 Bq/kg. For ^{228}Ra the activity concentration ranged between 34.25-106.72 Bq/kg with a mean value of 57.96 ± 2.55Bq/kg; and that of ^{40}K from 246.12-394.53 Bq/kg with a mean of 325.14±10.87 Bq/kg. Different vertical profile of ^{226}Ra, ^{228}Ra and ^{40}K activity concentration observed between sampling locations might due to the sediment mineralogy, source of radioactivity, geochemistry of the area and oceanic process. Plus, smaller $^{228}Ra/^{226}Ra$ activity ratio range suggests that interaction on these two series with the surrounding were very similar. Value of study radionuclides in present study were almost comparable with study done in other part in Malaysia. Moreover, world mean value of ^{226}Ra, ^{228}Ra and ^{40}K provided by UNSCEAR (1993) fall within the value range of radionuclides in present study.

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