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Measurement of natural radioactivity level in surface sediment in southern Kuala Selangor coastal area

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ABSTRACT

Kuala Selangor is located in Sungai Selangor estuary in the west coast of Peninsular Malaysia. Kuala Selangor coastal area is susceptible to pollution load as a lot of industrial and human activities are located in the west coast of Peninsular Malaysia and along Sungai Selangor. Surface sediment was taken from 14 points at two locations in southern Kuala Selangor that are in ‘Pantai Remis’ and ‘Pantai Jeram’. This study focused on radioactivity level of naturally occurring radionuclide (mainly ^{226}Ra, ^{228}Ra and ^{40}K) in surface sediment using gamma-ray spectrometry with a high-purity germanium (HPGe) detector. For ^{40}K, the presence of this was measured directly via its 1460 keV energy peak. For ^{226}Ra (of the ^{238}U) and ^{228}Ra (of the ^{232}Th) the γ-ray lines 609.3 keV (^{214}Bi) and 911.1 keV (^{228}Ac) were used. The concentration of ^{226}Ra, ^{228}Ra and ^{40}K in samples obtained from Pantai Remis coastal area ranged between 42.9±1.4-60.0±1.6 (mean 47.6±1.5) Bq/kg, 61.9±2.8-79.3±2.9 (mean 69.5±2.7) Bq/kg and 324.5±10.6-455.8±13.2 (mean 422.2±12.2) Bq/kg, respectively. Meanwhile, the concentration of ^{226}Ra, ^{228}Ra and ^{40}K in samples obtained from Pantai Jeram coastal area ranged between 45.1±1.6-50.4±1.5 (mean 47.2±1.6) Bq/kg, 62.5±2.8-75.9±3.0 (mean 69.2±2.9) Bq/kg and 338.7±10.7-490.6±14.0 (mean 428.2±12.4) Bq/kg, respectively. The mean external hazard index due to these radionuclides is 0.484 for ‘Pantai Remis’ and ‘Pantai Jeram’ (less than unity). Thus, it is expected that no radiation hazard attributed to the radiation from the study radionuclides will be experience by people in the areas.

| Natural radionuclide| Surface sediment| Activity concentration | Gamma spectrometer | Coastal area |

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1. INTRODUCTION

The two prominent sources of external radiation are cosmic rays and terrestrial gamma-rays which are derived mainly from naturally occurring radioactive materials (NORM) [1]. ^{226}Ra, ^{228}Ra, and ^{40}K is NORM that present almost everywhere in the water, land and air. These radionuclides when deposited on the surface soil is washed and drained through rivers transport and finally ended in the estuary and entering the marine environment and also through several pathways such as weathering, erosion, fallout, rainwater and human activities [2].

Sediments which one of the component of marine environment represents the major sink for many radionuclides [3]. It is widely known that the activities of these radionuclides in the sediment depend on the geological information, human activities and industries along the area. Thus, accumulation of these radionuclides in the sediment may raise many problems concerning safety of biotic life, food chain and ultimately humans [4].

Kuala Selangor is located in the Sungai Selangor estuary in the west coast of Peninsular Malaysia. Great development and various human activities in the west coast of Peninsular and along the river of Sungai Selangor released certain amount of radionuclide that will enter waterways and finally end up in the coastal area and marine environment.

A number of researches had been done at Kuala Selangor coastal area concerning of radionuclide concentration in water [5], sediment [6] and biota [7]. However, no such data available that determine the activity concentration of natural radionuclide ^{226}Ra, ^{228}Ra and ^{40}K in surface sediment.

Hence, this study embark on determination of the activity concentration of natural radionuclide ^{226}Ra, ^{228}Ra and ^{40}K in surface sediment in southern Kuala Selangor coastal area specifically at ‘Pantai Remis’ and ‘Pantai Jeram’ area. Besides, this paper will also evaluate the radiological hazard due to this radionuclide by calculating the radium equivalent, absorbed dose rate, annual effective dose rate and external hazard index. This study is important to provide data on current radiation hazard and assessment of potential hazard in the future.

2. EXPERIMENTAL

2.1 Sample collection

Sediment sample was taken manually using grab method at a depth of 10 centimetres from the surface along the coastal area and from the coastal area toward the sea during low tide on 13 January 2011 and 16-17 March 2011.

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All 14 surface sediment samples were collected from 14 sampling point. Seven sampling point was from 'Pantai Remis' area and another seven sampling point was from 'Pantai Jeram' area in sourthern Kuala Selangor coastal area as shown in Figure 1. Distance between each point is about 300-500 meter. The sampling point positions were determined using Global Positioning System (GPS). Table 1 shows the GPS coordinate and sampling location of the study area.

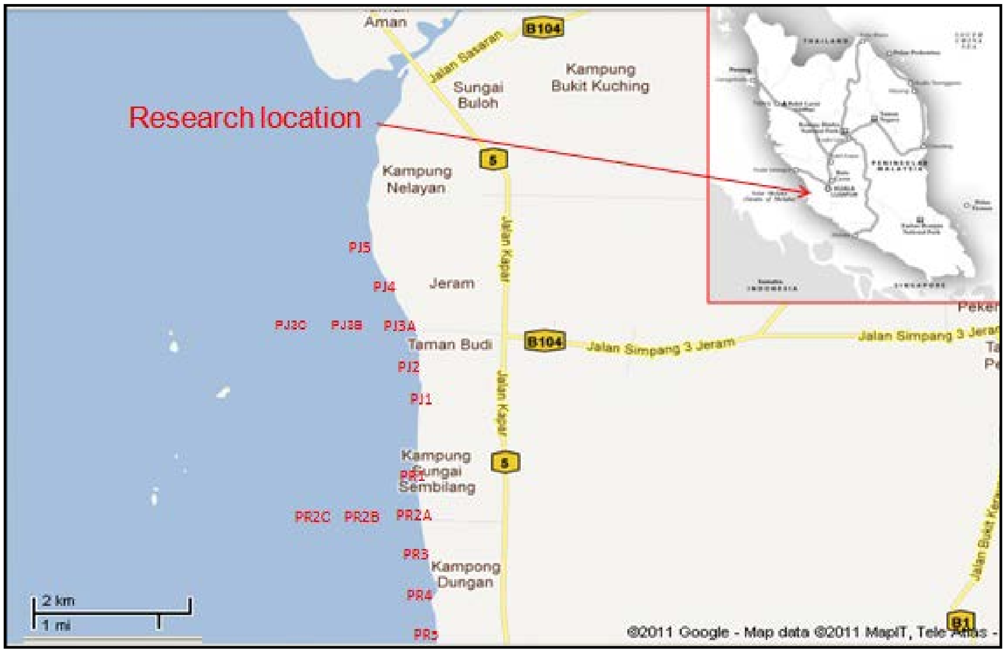

Fig. 1 Map showing sampling locations.

Table 1 GPS coordinate and sampling location of the study area.

Sample code	GPS Coordinate		Location
	Longitude	Latitude	
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
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°13.905′	Along the coastal

PR = Pantai remis PJ = Pantai Jeram

2.2 Sample preparation

The surface sediment samples were brought to the lab and dried in the oven at 60°C until constant weight. Then, it was grinded to fine powder using agate ball mill and sieve using 250 µm mesh-sieve. About 300-400 g of surface sediment was packed into polyethylene container and allowed the radionuclides to achieve secular equilibrium for at least 3 weeks prior to measurement using gamma spectrometry system.

2.3 Gamma spectrometry system

The activity concentration ^{226}Ra, ^{228}Ra, and ^{40}K were counted for 14400 s econds life time using gamma spectrometry system with ORTEC p-type HPGe coaxial detector coupled to a spectrum processing system. The

HPGe has a r esolution 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 GammaVision™ Version 6.07 software [8].

^{226}Ra activities were determined by taking the photopeaks 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 activities of ^{40}K were determined directly via its 1460 keV energy peak [9].

3. RESULTS AND DISCUSSION

3.1 Activity concentration

The results for activity concentration of ^{226}Ra, ^{228}Ra, and ^{40}K in 'Pantai Remis' and 'Pantai Jeram' are presented in Table 2 and Table 3. The concentration of ^{226}Ra, ^{228}Ra and ^{40}K in samples obtained from 'Pantai Remis' coastal area ranged between 42.9±1.4 and 60.0±1.6 (mean 47.6±1.5) Bq/kg, 61.9±2.8 and 79.3±2.9 (mean 69.5±2.7) Bq/kg and 324.5±10.6 and 455.8±13.2 (mean 422.2±12.2) Bq/kg, respectively. Meanwhile, the concentration of ^{226}Ra, ^{228}Ra and ^{40}K in samples obtained from 'Pantai Jeram' coastal area ranged between 45.1±1.6 and 50.4±1.5 (mean 47.2±1.6) Bq/kg, 62.5±2.8 and 75.9±3.0 (mean 69.2±2.9) Bq/kg and 338.7±10.7 and 490.6±14.0 (mean 428.2±12.4) Bq/kg, respectively.

Generally, the mean activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K in 'Pantai Remis' and 'Pantai Jeram' are almost similar. Besides, the activity concentration of the study radionuclide is closely related to the human activities in the area as reported by many researchers [3], [10], [11], and [12]. Human activities such as agricultural activities, mining operation and industrial processing ores may contribute to the enhancement of elemental composition in sediments and, in some cases; also increase the radionuclide concentrations [13].

Besides, Kapar coal power plant that located near to the sampling area may release some natural radioactivity due to the combustion of coal through atmosphere and consequently being absorbed into the sediment. As reported in [14], it is assumed that the higher activity of natural radionuclide in coastal area of Kapar is affected by coal burning activity. Fly ash from the power plant will disperse and accumulate in the sediment through rainwater fallout.

Table 2 Activity concentration of ^{226}Ra, ^{228}Ra, and ^{40}K in Bq/kg in surface sediment sample taken from Pantai Remis, Kuala Selangor.

Sample code	^{226}Ra	^{228}Ra	^{40}K
PR1	42.9±1.4	64.6±2.7	439.2±12.3
PR2A	47.0±1.6	71.6±3.0	455.8±13.2
PR2B	46.0±1.5	63.7±2.8	434.1±12.5
PR2C	60.0±1.6	79.3±2.9	427.1±11.5
PR3	48.3±1.5	71.8±2.9	324.5±10.6
PR4	43.3±1.6	61.9±2.8	440.6±12.9
PR5	45.4±1.5	73.9±3.0	434.2±12.7
Mean	47.6±1.5	69.5±2.7	422.2±12.2
Range	42.9±1.4-60.0±1.6	61.9±2.8-79.3±2.9	324.5±10.6-455.8±13.2

Table 3 Activity concentration of ^{226}Ra, ^{228}Ra, and ^{40}K in Bq/kg in surface sediment sample taken from Pantai Jeram, Kuala Selangor.

Sample code	^{226}Ra	^{228}Ra	^{40}K
PJ1	50.4±1.5	67.2±2.7	338.7±10.7
PJ2	49.3±1.5	73.5±3.0	443.5±12.6
PJ3A	46.0±1.6	75.9±3.0	449.5±12.0
PJ3B	46.8±1.6	62.5±2.8	459.4±13.5
PJ3C	45.1±1.6	69.2±3.0	470.1±13.4
PJ4	45.6±1.6	64.5±3.0	490.6±14.0
PJ5	47.5±1.5	71.4±2.9	345.5±10.9
Mean	47.2±1.6	69.2±2.9	428.2±12.4
Range	45.1±1.6-50.4±1.5	62.5±2.8-75.9±3.0	338.7±10.7-490.6±14.0

The activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K were compared with other study in other region as shown in Table 4. The mean value of ^{226}Ra and ^{228}Ra in southern Kuala Selangor is higher than coastal Sabah and Sarawak but slightly lower for ^{40}K [15]. The mean value of ^{226}Ra is slightly higher than West Coast of Peninsular Malaysia (14.25–38.90) Bq/kg and the mean value of ^{228}Ra is within the range (16.91–97.18) Bq/kg as reported in [16]. On the other hand, the mean value of ^{40}K is comparable with the study done in the East Coast of Peninsular Malaysia Exclusive Economic Zone (EEZ) (420 Bq/kg) and slightly higher for ^{226}Ra and ^{228}Ra [2]. Nevertheless, mean concentration of ^{226}Ra and ^{228}Ra is comparable with the study done in Cubatao River, Brazil. In short, the activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K in the study is area is quite close and comparable with other region in Malaysia as well as outside Malaysia

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Table 4 Comparison of activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K (Bq/kg) in other region.

Region	Activity concentration (Bq/kg)			Reference
	^{226}Ra	^{228}Ra	^{40}K	
Pantai Remis	47.6±1.5	69.5±2.7	422.2±12.2	Present study
Pantai Jeram	47.2±1.6	69.2±2.9	428.2±12.4	Present study
Coastal Sabah	23	35	557	[15]
Coastal Sarawak	30	39	462	[15]
Peninsular Malaysia West Coast	14.25–38.90	16.91–97.18	-	[16]
EEZ Peninsular Malaysia	30	56	420	[2]
Cubatao River, Brazil	41.2	66	-	[13]

3.2 Radiological assessment

Table 5 and Table 6 show the radium equivalent, absorbed dose rate, annual effective dose and external hazard index for 'Pantai Remis' and 'Pantai Jeram' area.

Radium equivalent activity, Ra_{eq} is used to estimate the hazard posed by different concentrations of radionuclides in materials, and is a measure on the suitability of a material to be used as building materials. The mean Ra_{eq} for 'Pantai Remis' and 'Pantai Jeram' are 176.5 Bq/kg and 176.1 Bq/kg respectively. These values are lower than the adopted limit to avoid radiation hazard from the material that is 370 Bq/kg [17].

The mean absorbed dose rate for 'Pantai Remis' and 'Pantai Jeram' area are 82.72 nGy/h and 82.58 nGy/h. This value is higher than international recommended value which is 55 nGy/h [18].

The mean annual effective dose for 'Pantai Remis' and 'Pantai Jeram' are similar which is 0.101 mSv/y. The worldwide average annual effective dose is approximately 0.5 mSv/y [19]. Thus, these values are lower than worldwide average.

The external hazard index for both 'Pantai Remis' and 'Pantai Jeram' is 0.484 which is less than 1. However, these values are higher than EEZ Peninsular Malaysia (0.38) [2] and East Malaysian marine sediment which is ranging between 0.17-0.33 [18].

Table 5 Radium equivalent, absorbed dose rate, annual effective dose and external hazard index for Pantai Remis area.

Sample code	Ra_{eq} (Bq/kg)	Absorbed dose rate (nGy/h)	Annual effective dose (mSv/y)	External hazard index (H_{ex})
PR1	166.0	78.18	0.096	0.457
PR2A	181.3	85.13	0.104	0.498
PR2B	167.5	78.88	0.097	0.461
PR2C	203.2	94.72	0.116	0.557
PR3	173.6	80.41	0.099	0.475
PR4	162.7	76.77	0.094	0.448
PR5	181.5	84.95	0.104	0.498
Mean	176.5	82.72	0.101	0.484
Range	162.7-203.2	76.77-94.72	0.094-0.116	0.448-0.557

Table 6 Radium equivalent, absorbed dose rate, annual effective dose and external hazard index for Pantai Jeram area.

Sample code	Ra_{eq} (Bq/kg)	Absorbed dose rate (nGy/h)	Annual effective dose (mSv/y)	External hazard index (H_{ex})
PJ1	170.2	79.10	0.097	0.466
PJ2	185.4	86.83	0.106	0.509
PJ3A	186.0	87.10	0.107	0.511
PJ3B	168.3	79.54	0.098	0.463
PJ3C	176.9	83.34	0.102	0.487
PJ4	172.1	81.48	0.100	0.474
PJ5	173.7	80.66	0.099	0.476
Mean	176.1	82.58	0.101	0.484
Range	170.2-186.0	79.10-87.10	0.097-0.107	0.463-0.511

4. CONCLUSION

The mean activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K in 'Pantai Remis' and 'Pantai Jeram' are almost similar. The activity concentration of study radionuclide is related to human activities in the surrounding area.

For 'Pantai Remis', the mean Ra_{eq} is 176.5 Bq/kg. The absorbed dose rate is 82.72 nGy/h and annual effective dose is 0.101 mSv/y. For Pantai Jeram, the mean Ra_{eq} is 176.1 Bq/kg. The absorbed dose rate is 82.58 nGy/h and annual effective dose is 0.101 mSv/y.The external hazard index for both 'Pantai Remis' and 'Pantai Jeram' is 0.484 (less than unity). Thus, it i s expected that no radiation hazard attributed to the radiation from the study radionuclides will be experience by people in the areas.

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