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EVALUATION OF NATURAL RADIOACTIVITY IN SOIL IN DISTRICT OF KUALA KRAI, KELANTAN

(Penilaian Radioaktiviti Semulajadi Tanah Daerah Kuala Krai, Kelantan)

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Abstract

Granitic rocks as in the case of Kelantan, contribute higher natural background activity than usual in environment. Moreover, the mining activities of mineral resources in Kelantan may responsible for the uranium mobility in the surrounding environment. Radiation from the radioactive element may cause health risk to human health through the external and internal exposure. In this study, a radiological monitoring was done on soils in the area where based on geological map of Kelantan containing uranium deposits. Soil was taken at various locations along the Kelantan river to measure activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K . Soil samples were taken from surface up to 45 cm depth with three separate layers. The samples were measured using Gamma Spectrometer. ^{226}Ra in soil for first layer, second layer and third layer are ranging from 47.1 – 251.1, 48.6 - 426.7 and 43.0 – 430.3 Bq/kg, respectively. ^{228}Ra is ranging from 54.2-284.4 for first layer, 50.4-457.1 for second layer and 44.5-441.1 Bq/kg for the third layer, respectively. The activity concentration of ^{40}K in soil ranging from 491.1-2495.6, 473.4-2615.9 and 488.8-2632.2 Bq/kg for first, second and third layer, respectively. These results were then used to calculate in order to estimate External Hazard Index, Absorbed Dose Rate, Radium Equivalent and Annual Effective Dose at sampling locations. It was found from this study that the exposure risk to radiation for those living and drinking water from the area is very significant.

Keywords: gamma spectrometer, Kelantan River, radium, uranium, granite

Abstrak

Batu granit seperti dalam kes di Kelantan, menyumbang kepada aktiviti yang lebih tinggi pada latar belakang semula jadi daripada biasa pada alam sekitar. Tambahan pula, aktiviti perlombongan sumber galian secara aktif yang dijalankan di Kelantan menyebabkan uranium yang jauh di dalam kerak bumi terangkut keluar ke alam sekitar. Unsur radioaktif boleh membahayakan kesihatan manusia pada pendedahan luar sama ada melalui rantai makanan atau kegunaan harian. Dalam kajian ini, pemantauan radiologi dilakukan ke atas tanah di kawasan itu kerana dipercayai mempunyai simpanan uranium. Kuala Krai telah dipilih untuk pensampelan kerana kewujudan kawasan deposit uranium berdasarkan peta geologi Kelantan. Sampel tanah yang diambil dari pelbagai lokasi sepanjang sungai untuk mengukur kepekatan aktiviti ^{226}Ra, ^{228}Ra dan ^{40}K dalam tanah. Sampel tanah diambil sehingga 45 cm dengan kedalaman tiga lapisan yang berasingan dan air pada kedalaman pertengahan paras sungai. Sampel-sampel diukur menggunakan Spektrometer Gamma. Kepekatan aktiviti ^{226}Ra dalam lapisan tanah untuk lapisan pertama, kedua dan ketiga adalah lapisan antara 47.1 – 251.1, 48.6 - 426.7 and 43.0 – 430.3 Bq/kg masing-masing. Kepekatan aktiviti ^{228}Ra adalah antara 54.2-284.4 untuk lapisan pertama, 50.4-457.1 untuk lapisan kedua dan 44.5-441.1 Bq/kg untuk lapisan ketiga. Kepekatan aktiviti ^{40}K dalam tanah antara 491.1-2.495.6, 473.4-2.615.9 dan 488.8-2.632.2 Bq/kg untuk lapisan pertama, kedua dan ketiga masing-masing. Keputusan ini dikira untuk menganggarkan Indeks Bahaya Luar, Kadar Penyerapan Dos, Dos Tahunan Berkesan dan Radium Setaraf di lokasi pensampelan.

Kata kunci: spectrometer gamma, sungai Kelantan, radium, uranium, granit

Introduction

In Kuala Krai, the ganitic region that is sitting on Olak Jeram, Kuala Krai is called as '*Granit Banjaran Sempadan*' [1]. It is biotite granite porfiri with pink medium-grained. The types of the rocks in that granites are k-feldspar phenocryst that is red and slightly grey, the creamy white plagioclase matrix with quartz and mafic mineral that presents is biotite [2]. The area of Olak Jeram that were shown in the Geological Map of Kelantan, have the characteristics of intrusive and extrusive rocks. Usually, volcanic rocks (extrusive) are 1.5 to 2 times higher in uranium content than their intrusive equivalents [3].

The behavior of uranium and thorium during the formation of igneous rocks indicate higher concentrations in the youngest and most felsic and silicic members. Granitic rocks contain higher uranium than the crustal average, thereby making them a potential source. In all type of uranium mineralization, it was believed that the granite, in view of its higher uranium content was considered to be the prime source for uranium, which due to lateral geological processes in the quartz pebble conglomerate type and sandstone hosted uranium deposits [3].

There were several studies on uranium, thorium and potassium in several parts in Malaysia for examples in Taman Negara, Pahang, Kota Tinggi, Johor and Jengka, Pahang. The concentration of U and Th in soil samples at Taman Negara, Kuala Keniam, Pahang are ranging 0.46 μg/g to 0.75 μg/g and from 2.02 μg/g to 3.19 μg/g respectively [4]. Radioactivity in water resources from river at Kota Tinggi district for U, Th and K are (7.93 ± 0.13) mBq/L, (3.12 ± 0.04) mBq/L and (10,381 ± 354) mBq/L respectively [5]. The soil samples collected from an oil palm cultivated area of Jengka 15, in Maran District, Pahang and results show the level of K-40 activities at various locations are in the range of 52.9-150.5 Bq/kg [6].

Due to high uranium content in the granite rock that dominated the area, there is strong possibility of higher radiation level in the study area [7]. . This study is to evaluate the radioactivity content in the soil then estimate the radiation internal and external radiation exposureto the general public that are living or entering the study area.. Therefore step can be taken to limit exposure to the general public, particularly if the exposure level is found to be significant. It is important to note that exposure to radiation may occurred through inhalation of radon and its progeny or ingestion of radioactive food that has been contaminated through food chain. Besides, the level of the activity concentration of radionuclides in the soil sample may provide general idea e on the concentration of the uranium in that area.

The objectives of the present studies, are to measure the activity concentration of ^{226}Ra, ^{228}Ra dan ^{40}K in soil samples of three different depth collected from district of Kuala Krai in Kelantan; the data then will be applied to estimate the radium equivalent activity (Ra_{eq}), total absorbed dose rate (D), external hazard index (H_{ex}) and annual effective dose (AED).

Materials and Methods

Sampling site

The soil samples and the river water were collected along Sungai Kelantan and its tributaries in the district of Kuala Krai. Three layers of soil were sampled for this study. The first layer samples were collected from surface to 15 cm depth and the second layer from 15 cm to 30 cm. The third layer samples were from 30 cm to 45 cm depth. The water were also sampled and analyzed in this study. Table 1 shows the coordinates of the sampling point, while Figure 1 shows a map of sampling points in the study area.

There are two types of sampling locations, the location type one were at hilly part of the river valley and the other were along the river bank. The study area was chosen with believe of its potential of having uranium deposit and as well rich with other minerals. The coordinates of the sampling points are given in the Table 1.

Table 1. Sample code, description and the coordinates of the area.

Sample Code	Description	Coordinates
S1	Small Rivers	N05°22.231' , E102°15.042'
S2		
S3		N05°22.262' , E102°14.984'
S4		
S5		N05°22.311' , E102°15.184'
H1	Hilly Areas	N05°21.372' , E102°17.554'
H2		N05°21.379' , E102°17.339'
T1	Small Rivers	N05°22.514' , E102°16.605'
T2		N05°22.486' , E102°14.141'
M1	Main Rivers	N05°21.253' , E102°14.532'
M2		N05°22.680' , E102°14.332'
M3		N05°23.253' , E102°14.195'

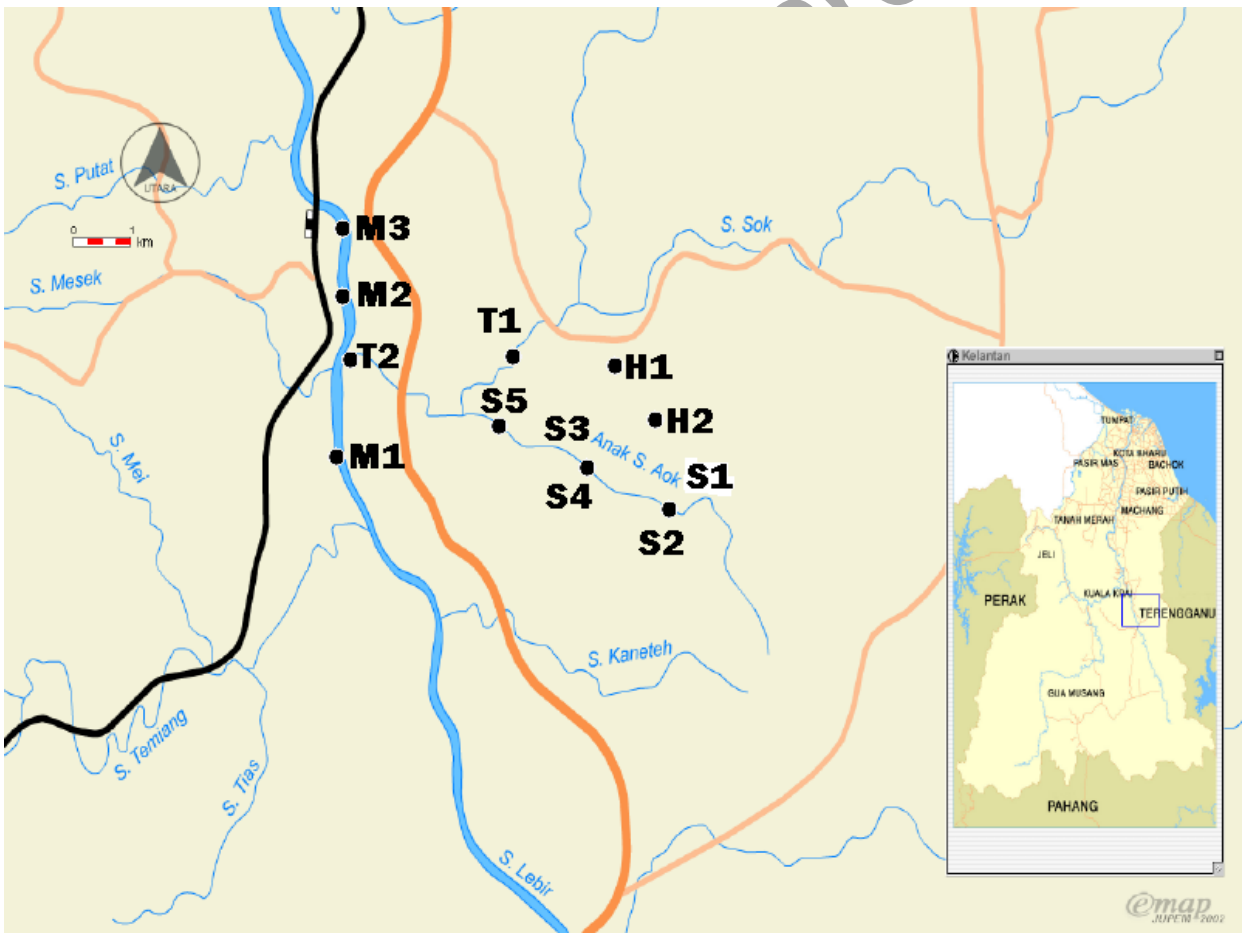

Figure 1. Map of Sampling Points

Sampling and samples preparation

Soil samples were taken from surface to 45 cm depth; the soil samples were subdivided into three layers 15 cm depth for each layer. The samplings were undertaken using hand auger at five different holes at each sampling point in order to collect statistically representative sample of the location. All debris such as stones, grass, root and the non-soil were taken out before transferred samples into the labeled plastic container.

In the laboratory, samples were dried at 60°C until reaching the constant mass. The dried samples were then ground using Agate bowl mill and sieved through 250 µm aperture mesh to homogenize them. After that, those samples were transferred into 500 ml plastic container and sealed for at least three weeks in order for the U and Th radioactive decay products to reach the secular equilibrium.

Instrumentation

All measurements were performed using gamma spectrometer; equipped with ORTEC coaxial HPGe detector having 1.85 keV energy resolution with a relative photo peak efficiency of 25%, at 1332 keV ^{60}Co gamma ray. The associated electronics consisted of a multi channel analyzer (MCA) allowing the determination of the uranium and thorium series radionuclide. For γ-analysis, the samples were placed directly over a coaxial HPGe detector. The sample counting time was 21600 seconds. The integrated counts for energy peaks of ^{226}Ra, ^{228}Ra and ^{40}K were analysed. Spectra analysis was done using Gamma Vision software. The efficiency calibration of the spectrometer was obtained using analytical grade UO_3 ore in KCl matrix prepared in UiTM laboratory [8].

Results and Discussion

Activity concentration of three radionuclides which are ^{226}Ra, ^{228}Ra and ^{40}K have been analyzed using gamma energy of 609, 911.2 and 1460 keV respectively..These energy peaks were chosen because of its high intensity which is 0.461, 0.29 and 0.107 respectively. Activity concentrations of ^{226}Ra, ^{228}Ra and ^{40}K in samples were calculated in Bq/kg. It is important to note that the 609 keV is the gamma line of ^{214}Bi, and the 911 keV is the gamma line for ^{228}Ac. At secular equilibrium the ^{214}Bi is equivalent to activity concentration of ^{226}Ra and the ^{228}Ac is equivalent to ^{228}Ra.

Table 2. The activity concentrations of ^{226}Ra at 609 keV energy peak

Location	Activity concentrations of ^{226}Ra (Bq/kg)						
	1st layer	±	2nd layer	±	3rd layer	±	Mean
S1	124.7	11.2	248.3	15.8	105.4	10.3	159.5
S2	159.6	12.6	292.8	17.1	279.4	16.7	243.9
S3	120.6	11.0	278.0	16.7	165.5	12.9	188.0
S4	162.9	12.8	339.8	18.4	344.8	18.6	284.2
S5	130.5	11.4	272.0	16.5	257.5	16.0	220.0
H1	143.4	12.0	290.4	17.0	177.4	13.3	203.7
H2	251.1	15.8	426.7	20.7	430.3	20.7	369.4
T1	122.7	11.1	114.8	10.7	85.6	9.3	107.7
T2	47.1	6.9	48.6	7.0	43.0	6.6	46.2
M1	220.2	14.8	158.2	12.6	159.9	12.6	179.4
M2	75.0	8.7	235.2	15.3	65.2	8.1	125.1
M3	179.2	13.4	172.3	13.1	145.8	12.1	165.8

Tables 2, 3 and 4 list the activity concentrations of ^{226}Ra, ^{228}Ra and ^{40}K measured in the 12 soil samples from Olak Jeram Kuala Kerai, Kelantan; samples collected at three consecutive depth (3 x15cm). Overall, most of second layer gives higher activity concentrations than the first layer except for T1, M1 and M3. This may due to the surface runoff when the rain falls down as the sampling points chosen are at the water pathways. The range of activity concentrations of ^{226}Ra (uranium series) for first layer is 47.1 – 251.1, second layer is 48.6 - 426.7 and third layer is 43.0 – 430.3 Bq/kg. The mean value for activity concentrations of ^{226}Ra at 609 keV energy peak in three different layers range from 46.2 – 369.4 Bq/kg.

Table 3. The activity concentrations of ^{228}Ra at 911 keV energy peak

Location	Activity concentrations of ^{228}Ra (Bq/kg)						
	1st layer	±	2nd layer	±	3rd layer	±	Mean
S1	168.6	13.0	295.6	17.2	171.8	13.1	212.0
S2	192.6	13.9	344.3	18.6	307.4	17.5	281.4
S3	160.0	12.6	324.9	18.0	352.6	18.8	279.2
S4	213.2	14.6	396.8	19.9	382.6	19.6	330.8
S5	199.1	14.1	352.4	18.8	354.5	18.8	302.0
H1	166.8	12.9	321.9	17.9	179.0	13.4	222.6
H2	273.6	16.5	457.1	21.4	441.1	21.0	390.6
T1	148.5	12.2	135.2	11.6	97.4	9.9	127.1
T2	54.2	7.4	50.4	7.1	44.5	6.7	49.7
M1	252.8	15.9	166.5	12.9	170.4	13.1	196.6
M2	100.4	10.0	242.7	15.6	91.1	9.5	144.7
M3	284.4	16.9	251.0	15.8	243.0	15.6	259.5

Table 3 shows the activity concentrations of ^{228}Ra (thorium series). The range of the activity concentrations of ^{228}Ra in soil for first layer are 54.2-284.4, second layer 50.4-457.1 and third layer 44.5-441.1 Bq/kg. The pattern of activity concentrations of ^{228}Ra as it goes deeper into soil is not much different from the activity concentrations of ^{226}Ra and most of the second layer is higher than first layer except for T1, T2, M1 and M3. The mean value for activity concentrations of ^{228}Ra at 911 keV energy peak in three different layers range from 49.7 – 390.6 Bq/kg.

Table 4 shows the activity concentrations of ^{40}K and the values are much higher compared to Jengka, Pahang [6]. The range for first layer is 491.1-2495.6, second layer is 473.4-2615.9 and third layer is 488.8-2632.2 Bq/kg. As it mentioned before, the geological conditions of the place is granitic area that have k-feldspar. Feldspar is main component of mineral to form rocks in aluminosilicate group and can be divided by three which is potassium, sodium and calcium [9]. It is an explanation to the big value of ^{40}K in that area that has the source from the type of rocks. The mean value for activity concentrations of ^{40}K at 1460 keV energy peak in three different layers range from 741.3 – 3053.3 Bq/kg.

Table 4. The activity concentrations of ^{40}K at 1460 keV energy peak

Location	Activity concentrations of ^{40}K (Bq/kg)						
	1st layer	±	2nd layer	±	3rd layer	±	Mean
S1	1005.4	31.7	2479.7	49.8	934.7	30.6	2228.6
S2	932.8	30.5	2610.8	51.1	2496.7	50.0	3042.1
S3	988.6	31.4	2489.7	49.9	1018.0	31.9	2267.0
S4	820.7	28.6	2615.9	51.1	2626.3	51.2	3053.3
S5	646.1	25.4	2610.9	51.1	2632.2	51.3	2965.9
H1	559.9	23.7	2151.9	46.4	551.1	23.5	1647.1
H2	491.1	22.2	2254.4	47.5	2297.5	47.9	2541.1
T1	1184.2	34.4	1196.9	34.6	1127.6	33.6	1771.4
T2	498.4	22.3	473.4	21.8	488.8	22.1	741.3
M1	2495.6	50.0	1014.4	31.8	1270.1	35.6	2409.6
M2	599.9	24.5	2533.4	50.3	580.5	24.1	1873.4
M3	671.6	25.9	691.3	26.3	748.4	27.4	1068.9

Tables 5 to 8 shows the corresponding total absorbed dose rate (D), radium equivalent activity (Ra_{eq}), external hazard index (H_{ex}) and annual effective dose for each samples. The calculation was done using the reviewed equations below.

Table 5. External Hazard Index (H_{ex}) at points of sampling

Location	H_{ex}			
	1st layer	2nd layer	3rd layer	Mean
S1	2.20	3.33	1.14	2.22
S2	1.37	2.66	2.46	2.16
S3	1.15	2.52	2.02	1.90
S4	1.43	3.01	2.96	2.47
S5	1.26	2.64	2.61	2.17
H1	1.15	3.48	1.29	1.97
H2	1.84	3.39	3.34	2.86
T1	1.15	1.08	0.84	1.02
T2	0.44	0.42	0.39	0.42
M1	2.09	1.28	1.35	1.57
M2	0.71	2.10	0.65	1.15
M3	1.72	1.58	1.49	1.60

External hazard index were calculated using the activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K. From Table 5, the sampling area of S and H gives higher indicated the existence of extrusive/intrusive rocks beneath the soils. H is hilly area, thus it is believe that the surface runoff accumulate in the S area which is small river. The range of H_{ex} for first later is 0.44-2.20, second layer is 0.42-3.48 and third layer is 0.39-3.34. The mean value for External Hazard Index (H_{ex}) at points of sampling in three different layers are range from 0.42 – 2.86. There is certain

average value that is greater than the acceptable average value of unity [10]. The H_{ex} is calculated using the equation (1)[11].

$$\text{External Hazard Index} = C_{Ra}/370 + C_{Th}/259 + C_K/4810 \quad (1)$$

The absorbed dose rate were estimated using the equation (2). The range for absorbed dose rate in area of sampling for first layer is 76.1-362.4 nGy/hr, second layer is 73.4-574.8 nGy/hr and third layer is 67.80-568.3 nGy/hr. The mean value for Absorbed Dose Rate (D) at points of sampling in three different layers range from 72.4 – 483.2 nGy/hr. Based on the table 6, all values have exceeded the international recommended value which is 55 nGy/hr [11].

$$\text{Absorbed Dose Rate} = 0.461C_{Ra} + 0.623C_{Th} + 0.0414C_K \quad (2)$$

Table 6. Absorbed Dose Rate (D) at points of sampling

Location	D (nGy/hr)			
	1st layer	2nd layer	3rd layer	Mean
S1	204.1	401.3	194.3	266.6
S2	232.2	457.6	423.7	371.2
S3	196.2	433.6	338.1	322.6
S4	241.9	514.5	506.0	420.8
S5	211.0	453.0	448.5	370.8
H1	193.2	423.5	216.1	277.6
H2	306.5	574.8	568.3	483.2
T1	198.1	186.7	146.8	177.2
T2	76.10	73.40	67.80	72.4
M1	362.4	218.6	232.5	271.2
M2	121.9	364.5	110.9	199.1
M3	287.6	264.5	249.6	267.2

The annual effective dose is calculated based on the absorbed dose and the occupancy factor of 20% for outdoor 0.7 Sv/Gy is the conversion coefficient from gamma absorbed dose rate in air outdoors. The range of the annual effective dose for first layer is 0.09-0.44 mSv/yr, second layer is 0.09-0.70 mSv/yr and 0.08-0.70 mSv/yr. The mean value for Annual Effective Dose (AED) at points of sampling in three different layers are range from 0.09 – 0.59 mSv/yr. The world average range is between 0.3-0.6 mSv/yr and the limit is 1 mSv/yr [12]. The annual effective dose is calculated using the equation (3) below [13].

$$\text{Annual Effective Dose} = D\ (\text{nGy/h}) \times 8760\ (\text{h/year}) \times 0.2 \times 0.7\ (\text{Sv/Gy}) \times 10^{-6} \quad (3)$$

Radium equivalent is common index to compare the total activity concentration of ^{226}Ra, ^{228}Ra dan ^{40}K in soil samples. It is assume that 370 Bq/kg of ^{226}Ra, 259 Bq/kg of ^{228}Ra and 4810 Bq/kg of ^{40}K emits equal gamma rays. The significance of this index is to represent the gamma ray output from different radionuclides in certain material like building block or soil as a single number, rather than put a limit on each radionuclide. The world average value for Radium equivalent is 370 Bq/kg. The equation used by [14] used to calculate radium equivalent as represent below. Based on table 8, the range of radium equivalent for the first layer is 163.0-774.0 Bq/kg, second layer is 157.1-1253.9 Bq/kg and third layer 144.3-1238.0 Bq/kg. The mean value for Radium Equivalent (Ra_{eq}) at points of sampling in three different layers range from 154.8 - 1057.4 Bq/kg.

$$\text{Radium equivalent} = C_{Ra} + 1.43C_{Th} + 0.077C_K \quad (4)$$

Table 7. Annual Effective Dose (AED) at points of sampling

Location	AED (mSv/yr)			
	1st layer	2nd layer	3rd layer	Mean
S1	0.25	0.49	0.24	0.33
S2	0.28	0.56	0.52	0.45
S3	0.24	0.53	0.41	0.39
S4	0.30	0.63	0.62	0.52
S5	0.26	0.56	0.55	0.46
H1	0.24	0.52	0.27	0.34
H2	0.38	0.70	0.70	0.59
T1	0.24	0.23	0.18	0.22
T2	0.09	0.09	0.08	0.09
M1	0.44	0.27	0.29	0.33
M2	0.15	0.45	0.14	0.25
M3	0.35	0.32	0.31	0.33

Table 8. Radium Equivalent (Ra_{eq}) at points of sampling

Location	Ra_{eq} (Bq/kg)			
	1st layer	2nd layer	3rd layer	Mean
S1	443.2	862.0	423.0	576.1
S2	506.8	986.2	911.2	801.4
S3	425.5	934.3	748.1	702.6
S4	530.9	1113.7	1094.1	912.9
S5	465.0	976.9	967.1	803.0
H1	425.1	916.4	475.9	605.8
H2	680.2	1253.9	1238.0	1057.4
T1	426.3	400.3	311.7	379.4
T2	163.0	157.1	144.3	154.8
M1	774.0	474.3	501.4	583.2
M2	264.7	777.4	240.2	427.4
M3	637.6	584.6	550.9	591.0

Table 9 shows the activity concentrations of ^{222}Rn and ^{226}Ra in water [1]. The measurement of radioactivity in water is important as an indicator high level of radioactivity from the study area as the surface runoff from the hilly area is going into the river basin. Moreover, the interaction between water and rocks can affect the releasing of minerals into the water [15]. The range of the activity concentrations of ^{222}Rn and ^{226}Ra in water is 0.88-4.43 Bq/L and 0.11-0.55 Bq/L, respectively [1]. The limit for the activity concentrations of ^{222}Rn in water is 0.2 Bq/L [15] and based on INTERIM National Water Quality Index for Malaysia, the activity concentrations of ^{226}Ra cannot exceed 0.1 Bq/L. Thus, based on table 9, all value have exceeded the limit and if consumed more than 2 L/day, the consumer may receive radiation dose exposure of more than 0.1 mSv/year.

Table 9. Activity concentrations of ^{222}Rn and ^{226}Ra in water

Location	**Activity concentrations in water (Bq/L)**	
	^{222}Rn	**^{226}Ra**
S1/S2	1.21	0.15
S3/S4	2.89	0.36
S5	2.27	0.28
H1	2.84	0.35
H2	2.82	0.35
T1	0.88	0.11
T2	3.04	0.37
M2	4.16	0.50
M3	4.43	0.55
Range	0.88-4.43	0.11-0.55

Table 10. Comparison soil samples with the other studies in the granitic region and non-granitic region

Location	**^{226}Ra Bq/kg**	**^{228}Ra Bq/kg**	**^{40}K Bq/kg**	**Ra_{eq} Bq/kg**	**D nGy/hr**	**AED mSv/yr**	**H_{ex}**	**^{226}Ra in water Bq/L**	**^{222}Rn in water Bq/L**	**References**
Kuala Krai, Kelantan (Granitic region)	43.0-430.3	50.4-457.1	473.4-2632.2	144.3-1253.9	67.8-574.8	0.08-0.7	0.39-3.48	0.11-0.55	0.88-4.43	Present study
Upper Siwaliks, Northern India (Non-granitic region)	28.3-81.0	61.2-140.3	363.4-1002.	149.4-351.8	71.1-162.0	0.09-0.21	0.40-0.95	-	-	Joga Singh *et. a.,l* 2009
Northern Jordan (Non-granitic region)	25.6-213.9	20.9-29.5	226.3-350.2	85.1-268.5	43.2-135.1	0.053-0.165	0.23-0.73	-	-	Ibrahim *et. al.*, 2009
*Eskisehir, Turkey (Granitic region) *Rock	43.59-651.8	51.16-351.94	418.5-1694.9	183.31-1187.3	87.14-531.81	0.107-0.652	0.5-3.21	-	0.06-0.557	Orgun *et. al.*, 2005
Xiazhuang, China (Granitic region)	40.2-442	32.6-88.1	441.8-913	121-624	57.6-280	0.070-0.344	0.3-1.7	-	-	Yang *et al.*, 2005
World average	35	30	400	370	55					UNSCEAR 2000
Malaysia average	38-94	63-110	170-430							UNSCEAR 2008
Limit for public exposure						1	1			ICRP 2000

Table 10 shows the comparison soil samples of the present study with the other study around the world in the granitic region [15;16] and non-granitic region [13;17]. Clearly, the granitic region shows higher value than non-granitic region. Based on the Malaysia average for activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K value by [18], the value of the Kuala Krai have exceeded the given range thus proves the existence of radioelement in that area. The Ra_{eq} in granitic region have the range of 121-1253.9 Bq/kg while at non-granitic region is ranging from 85.1- 351.8 Bq/kg.

The value for the Absorbed Dose Rate for granitic region range from 57.6-574.8 nGy/hr whereas for non-granitic region range from 43.2-162.0 nGy/hr, about three times lower than granitic region. AED for granitic region range 0.07-0.7 mSv/yr and non-granitic region, about three times higher as well range from 0.053-0.21 mSv/yr. same goes to $H_{ex,}$ range at granitic region is 0.3-3.48 and at non-granitic region is 0.23-0.95. Overall, the granitic region has three times higher value than the non-granitic region and as compare among granitic regions, the value in Kuala Krai, Malaysia having not much different from Eskisehir, Turkey even though the sample from Turkey is rock.

Conclusion

The activity concentration in the area of Kuala Krai is higher than the Malaysia average value and two times higher than the non-granitic region from other places in the world. The H_{ex} is ranging from 0.42 to 2.86 and the annual effective dose is ranging from 0.09 to 0.59 mSv/year. These results provide a risk assessment due to the existence of some radioelement in the granitic rocks in that area.

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References

1. Hamzah, Z., Abdul Rahman, S. A., Saat, A., Agos, S. S. and Ahmad, Z. (2011). Measurement of ^{226}Ra in River Water using Liquid Scintillation Counting Technique. *Journal of Nuclear and Related Technologies*. **7(2)**; 12-23.
2. Kajian Potensi Batuan Granit Sebagai Sumber Batu Dimensi di Negeri Kelantan, Jabatan Mineral dan Geosains, Malaysia. JMG.KLT (IMP) 4/2005.
3. Maithani, P. B and Srinivasan, S. (2011). Felsic Volcanic Rocks, a Potential Source of Uranium – An Indian Overview. Energy Procedia **7**; 163–168.
4. Saat, A., Kassim, N. Hamzah, Z. Farisz, A. (2010). Determination of Surface Radiation Dose and Concentrations of Uranium and Thorium in Soil at Uitm Perhilitan Research Station Kuala Keniam, Taman Negara, Pahang. *Journal of Nuclear and Related Technologies*, **7(2)**; 49-54.
5. Abdul Rahman, A. T., Ramli, A. T and Wood, A. K (2004). Analysis of the Concentrations of Natural Radionuclides in Rivers in Kota Tinggi district, Malaysia. *Journal of Nuclear and Related Technologies*. **1(1),** 34-45.
6. Alias, M., Hamzah, Z., Saat, A., Omar, M., Tajuddin, Z., Kadir, W. M. W. A and Solleh, M. R (2004). Level of Naturally Occurring Radioactive Material, K-40 in Oil Palm's Cultivated Soil. *Journal of Nuclear and Related Technologies*. **1(2);** 1-11
7. Pandey, O. P., Agrawal, P. K.., and Chetty, T. R. K (2002). Unusual lithospheric structure beneath the Hyderabad granitic region, eastern Dharwar craton, South India. *Physics of the Earth and Planetary Interiors*. **130**, 59–69.
8. Saat, A., Hamzah, Z., Yusop, M. F., Zainal, M. A (2010). Experimental Determination of the HPGe Spectrometer Efficiency Calibration Curves for Various Sample Geometry for Gamma Energy from 50 keV to 2000 keV. *Progress of Physics Research in Malaysia.* 39-42.
9. Tinjauan Sumber Feldspar di Gua Musang, Negeri Kelantan, Jabatan Mineral dan Geosains, Malaysia. JMG.KLT (IMP) 1/2003.
10. ICRP (2000). Protection of the public in situations of prolonged radiation exposure; ICRP Publication 82; Pergamon Press, Oxford. Ann. ICRP, **29**(1–2).
11. Singh, S., Rani, A., and Mahajan, R. K (2004). ^{226}Ra, ^{232}Th and ^{40}K analysis in soil samples from some areas of Punjab and Himachal Pradesh, India using gammaray spectrometry. *Radiation Measurements.* **39**; 431 – 439.

12. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). (2000). Sources, effects and risks of ionization radiation, Report to The General Assembly, with Scientific Annexes B: Exposures from Natural Radiation Sources (New York: UNSCEAR).
13. Singh, J., Singh, H., Singh, S., Bajwa, B. J., and Sonkawade, R. G (2009). Comparative study of natural radioactivity levels in soil samples from the Upper Siwaliks and Punjab, India using gamma-ray spectrometry. *Journal of Environmental Radioactivity.* **100**; 94–98.
14. Kurnaz, A., Kucukomeroglu, B., Keser, R., Okumusoglu, N. T., Korkmaz, F., Karahan, G., and Cevik, U. (2007). Determination of radioactivity levels and hazards of soil and sediment samples in Fırtına Valley (Rize, Turkey). *Applied Radiation and Isotopes*. **65**; 1281–1289.
15. Orgun, Y., Altınsoy, N., Gultekin, A. H., Karahan, G., and Celebi, N. (2005). Natural radioactivity levels in granitic plutons and groundwater in Southeast part of Eskisehir, Turkey. *Applied Radiation and Isotopes*. **63**; 267–275.
16. Yang, Y., Wu, X., Jiang, Z., Wang, W., Lu, J., Lin, J., Wang, L., and Hsia, Y. (2005). Radioactivity concentrations in soils of the Xiazhuang granite area, China. *Applied Radiation and Isotopes.* **63**; 255–259.
17. Al-Hamarneh, I. F and Awadallah, M. I. (2009). Soil radioactivity levels and radiation hazard assessment in the highlands of northern Jordan. *Radiation Measurements.* **44**; 102–110.
18. UNCSEAR, United Nations Scientific Committee on the Effect of Atomic Radiation, (2008). Global Survey on Exposures to Natural Radiation Sources, United Nations, New York.
19. UNCSEAR, United Nations Scientific Committee on the Effect of Atomic Radiation, (2000). Sources, effects and risk of Ionizing Radiation, United Nations, New York.
20. Hamzah, Z., Abdul Rahman, S. A, and Saat, A. (2011). Measurement of ^{226}Ra, ^{228}Ra and ^{40}K in Soil in District of Kuala Krai using Gamma Spectrometry. *Malaysian Journal of Analytical Sciences.* **15 (2)**; 159 – 166.