SURFACE RADIATION DOSE AND RADIONUCLIDE MEASUREMENT IN EX-TIN MINING AREA, KG GAJAH, PERAK

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Abstract

The amount of natural radionuclide present in environment, especially soils, sediment and water in the abundance tin mining area are varies depending on the amount of heavy minerals left over in that particular place. If the place used to be the processing area for tin ores, the left over known as 'amang' contains heavy minerals. This study was carried out in UiTM Training Center, Kg Gajah, within Kinta Valley Perak which used to be the active tin mine area in the past. Surface doses were measured using Ludlum dose rate meter, at the surface and 1 meter above the surface. The radionuclides content were measured by collecting soil samples, dried, ground, sieved using 250 μm sieve, packed in a container and counted after 4 weeks using gamma spectrometer with HPGe detector. The level of surface dose varies from one location to another, but there is a critical area which has a significantly high surface dose approaching 30 μSv/hr. The mean activity concentrations in the critical area for ^{40}K, ^{226}Ra and ^{228}Ra are 2521±298 Bq/kg, 3798±419 Bq/kg and 12896±1533 Bq/kg respectively. The hazard index for the critical area seems to be extremely high and is not safe for people to be there.

Keywords: surface radiation dose, tin mine, heavy minerals, natural radionuclide.

Introduction

Malaysia has long been known as one of the world's leading tin producers. The number of operating tin mines decreased to 38 in 1998. This has left behind more than 2000 mined-out ponds. The lengths of the ponds are up to 500 and 1000 m for gravel pump and dredge mines, respectively. Most of the ponds have thick layers of slurry slime at the bottom. The slurry contains heavy minerals such as ilmenite, monazite, zircon and xenotime. 'Amang' contains tin ores, quartz sand, monazite, zircon, xenotime, ilmenite, struverite and other minerals, including those containing uranium and thorium (TED, 2007).

Mining generally has a very high impact on man and environment, which results on one side in an increase of employment and economic profit for the community and the operators, but also represents a threat to natural reserves due to landscape changes and pollution. This often results in destroyed ecosystems and polluted environments, which represents a hazard to the local population. Processing of by-product-heavy minerals from tin mining and also from tin mining areas is rich in uranium and thorium. External exposures occur when workers or persons are close to stockpiles of radioactive minerals, soils and tailings. Abandoned dumping sites (tailings) are usually subject to leaching of uranium and thorium when they come into contact with an aqueous medium (Ibeanu, 2003).

Acknowledged by Ibeanu (2003), tin ore is a radioactive mineral, which is rich in monazite and zircon components. During the tin ore processing operations, uranium and thorium concentrate and are responsible for the observed high concentrations levels measured in the tailing dump and contaminated soil samples. Funtua (2005) stated that several years of mining and processing of casseterite (tin ore) and columbite (niobium ore) in Jos Plateau have generated large quantities of tailing that are rich in these radioactive minerals and are mostly dumped haphazardly in the environment. Furthermore, there is a growing concern over the radiological impact of these tailings since it has been established that these ores are associated with accessory minerals like zircon, monazite, xenotime and thorite, which have high concentrations of thorium and uranium. Tin mining activities are usually carried out in populated areas like Klang Valley and the Kinta Valley in Malaysia. The main problems caused by mining are namely formation of wasteland, damage to natural drainage, pollution and the destruction of natural habitats.

Monazite is considered to be one of the most important geological materials. This may be due to the presence of uranium and thorium elements in it which are the main fissile elements used in nuclear projects (Hassan, 1997).

Monazite forms in phosphatic pegmatites but is actually a standard trace constituent in many ordinary igneous, metamorphic and vein filling rocks. Notable occurrences in monazite are widespread and diverse. In Malaysia the minerals are also by-products of 'amang' processing plants.

Ilmenite is a weakly magnetic titanium-iron oxide mineral which is iron-black or steel-gray. It is a crystalline iron titanium oxide ($FeTiO_3$). Ilmenite most often contains appreciable quantities of magnesium and manganese and the full chemical formula can be expressed as $(Fe,Mg,Mn,Ti)O_3$. The potential health effect when swallowed is non-toxic and there are not known hazards resulting from accidental ingestion of ilmenite sand as may occur during normal handling. However, swallowing a large amount may result in irritation to the digestive system due to abrasiveness. It gives low hazard to the skin. By inhaled the normal grain size of the product precludes it from being an inhalation hazard. Handling can however fracture grains, and in the dry state this can generate dust. This is normally regarded as general nuisance dust, but can be irritating if inhaled at high concentration. This may cause symptoms such as coughing or sneezing.

The external hazard index (H_{ex}) can be calculated from the following criterion

$$H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_K/4810 < 1 \quad (1)$$

where C_{Ra}, C_{Th} and C_K are the activities concentrations of ^{226}Ra, ^{232}Th and ^{40}K (in Bq/kg) respectively. The value of this index must be less than unity in order to keep the radiation hazard to be insignificant. The maximum values of H_{ex} equal to unity correspond to the upper limit of Ra_{eq} (370 Bq/kg).

The main reason of this research work is to study the level of radioactivity in the UiTM training center, ex-tin mine area. The area is about 600 acres and one third of it is the land area. About two third of the area is a water body from the tin mine activity. There is also area used for tin smelting during those day.The objectives of this study are to determine the surface dose in the study area, to determine the activity concentration and profile of ^{226}Ra, ^{228}Ra and ^{40}K in the soil using gamma spectrometry and to determine the external hazard index and annual effective dose in the study area.

Experimental

This study was conducted in the UiTM Training Center in Kg Gajah, Perak. The location is shown in Figure 1 .

Radiation doses were measured (in-situ) at the selected points at the surface and 1 meter height in the study area. The measurements were conducted using radiation dose digital rate meter detector. Portable radiation survey instrumentation used for measuring environmental radiations is survey meter Model 2241 from LUDLUM Measurement Incorporations.

The samples for radionuclides activity concentration were collected in the study area. The sampling points were determined by using a global positioning system (GPS). The topsoil from each point at the sampling location, at 10 cm depth was taken and mixed together to obtain a representative sample of about 2 kg mass. Then, the samples were dried in an oven at 100^{o}C for 24 hour (until dry), then ground to fine powder and homogenized by passing through a 250 μm test sieve. Finally, the sample were sealed in plastic containers and left for at least one month before counting. The soils samples for profile were collected using hand auger to the depth of 10 cm in the area of highest surface radiation dose. The samples were sliced every 2 cm and all the samples kept in plastic bags. The samples were processes similar to the previous samples.

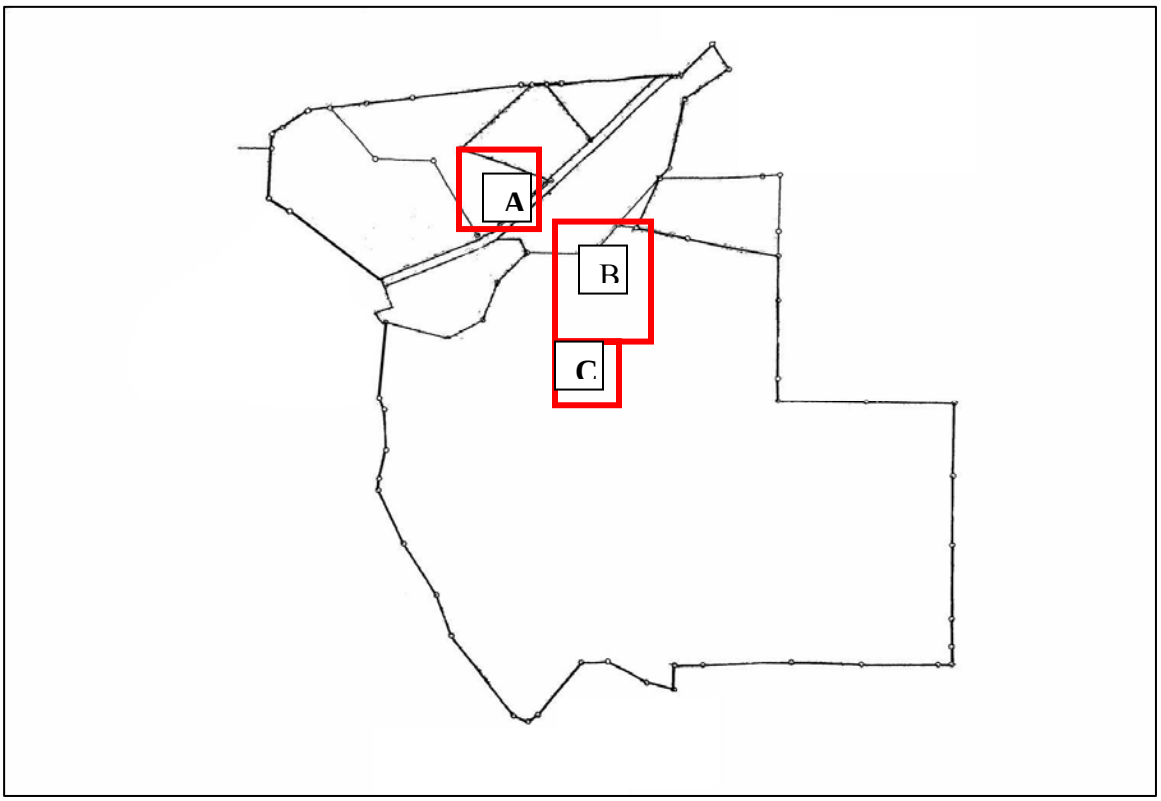

Fig. 1: The map of UiTM Training Center in Kg Gajah, Perak.

The activity concentrations of ^{226}Ra, ^{228}Ra and ^{40}K for all collected samples were measured for a counting time of 7200 s using a γ-ray spectrometry with a p-type coaxial high purity Ge (HPGe). The full energy peak efficiency was determined by using the reference sources (Soil-6). The size of the standard source was the same as that of the studied samples. For the measurement of ^{226}Ra activity concentration, the γ-ray energies of 295.21 and 351.92 keV of ^{214}Pb, 609.31 and 1120.29 keV of ^{214}Bi were used. The activity concentration of ^{228}Ra was determined at the γ-ray energies 911.07 keV and ^{40}K was measured directly from the 1460.8 keV.

Results and Discussion

The surface radiation doses measured in three different locations are shown in Figures 2 – 5 below. In Figures 2a and 2b show the radiation surface dose measured on the surface and 1 meter above the surface in the location A. It reaches 1.11 μSv/hr.

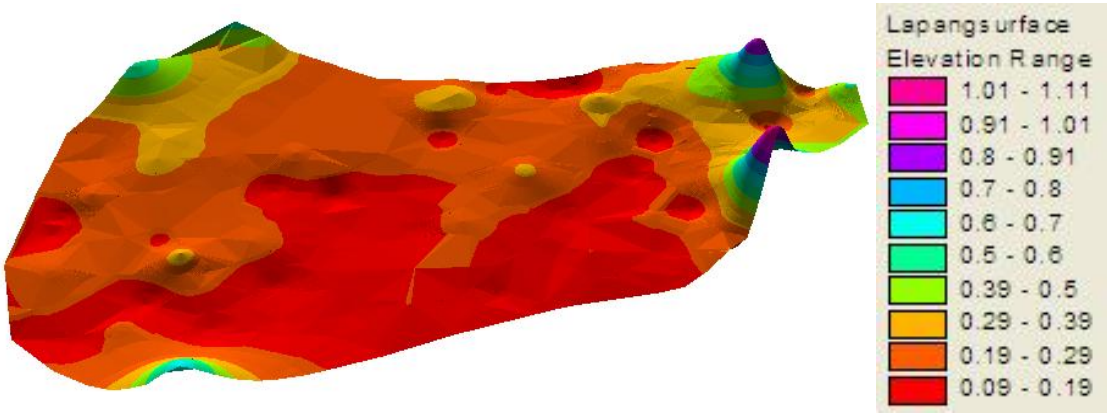

Fig. 2a: Radiation doses measured at the surface in location A

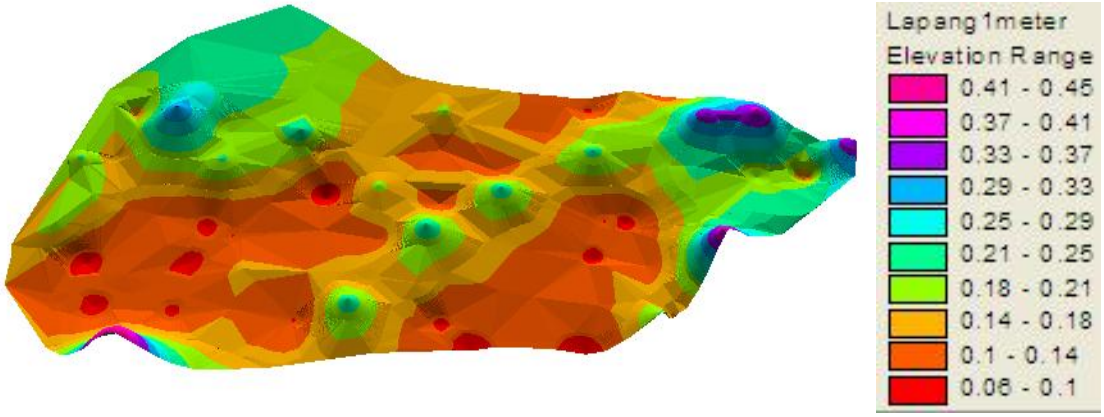

Fig. 2b: Radiation doses measured at 1 meter above the surface in location A

Figures 3a-3b show the radiation surface dose measured on the surface and 1 meter above the surface in the location B. It reaches 5.9 µSv/hr.

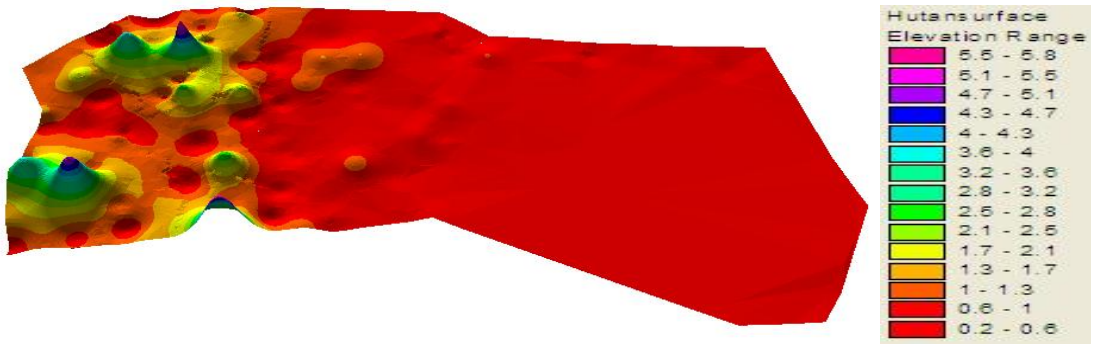

Fig. 3a: Radiation doses measured at the surface in location B

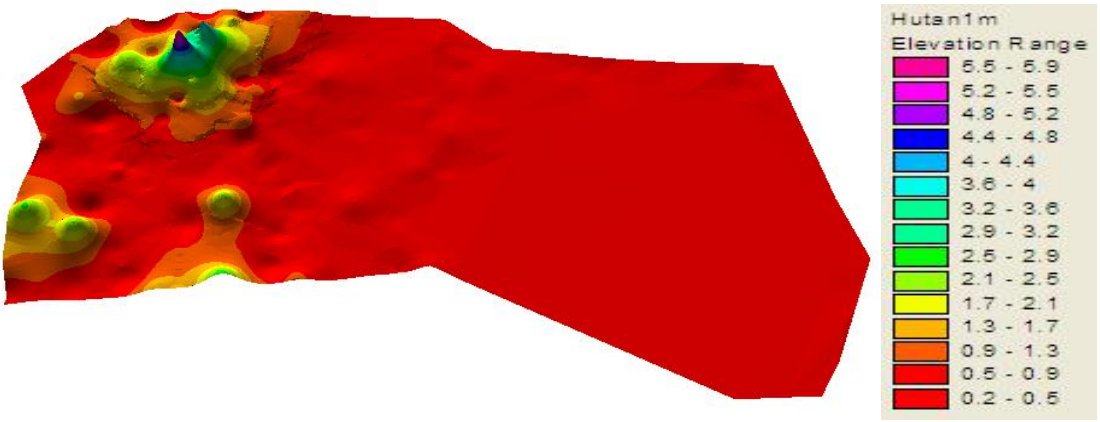

Fig. 3b: Radiation doses measured at 1 meter above the surface in location B

Figures 4a-4c show the radiation surface dose measured on the surface and 1 meter above the surface in the critical area of location B. It reaches 28 µSv/hr.

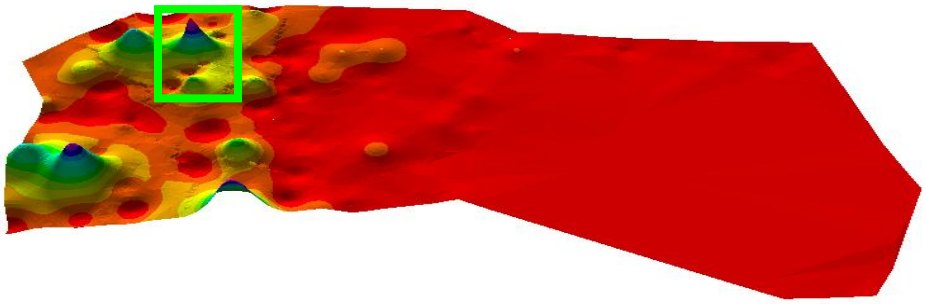

Fig. 4a: The critical area in location B

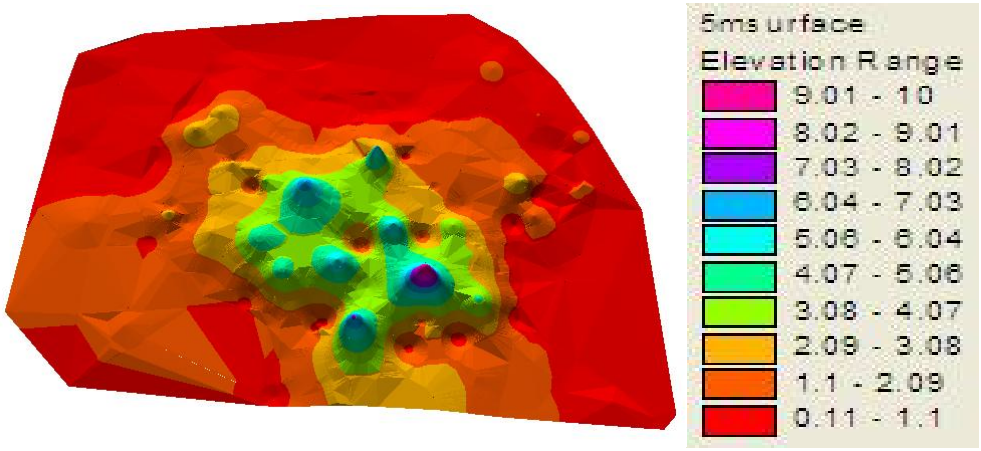

Fig. 4b: Radiation doses measured at the surface in critical area in the location B

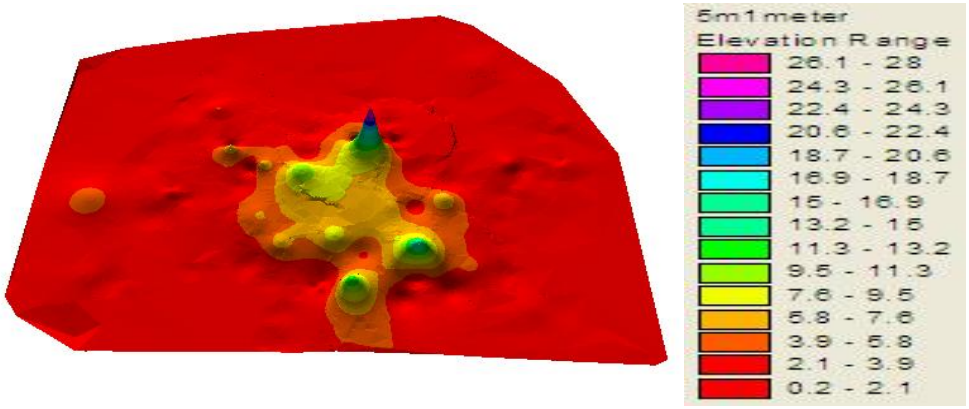

Fig. 4c: Radiation doses measured at 1 meter above the surface in critical area in the location B

Figures 5a-5b show the radiation surface dose measured on the surface and 1 meter above the surface in the critical area of location C. The values reach 5.7 µSv/hr.

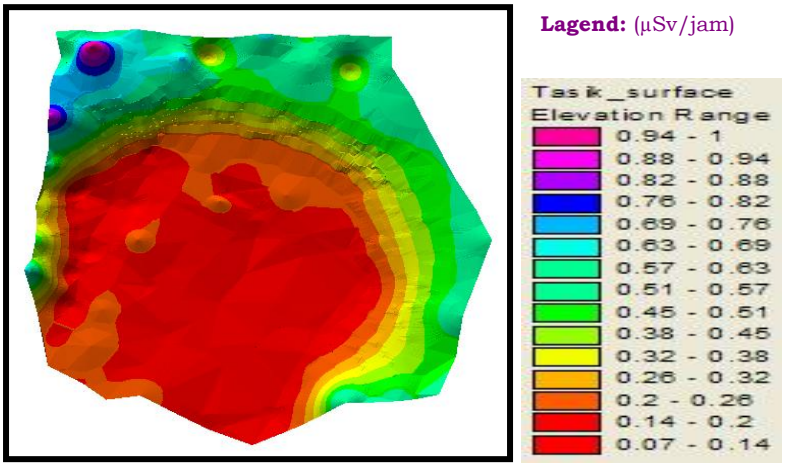

Fig. 5a: Radiation doses measured at the surface in the location C

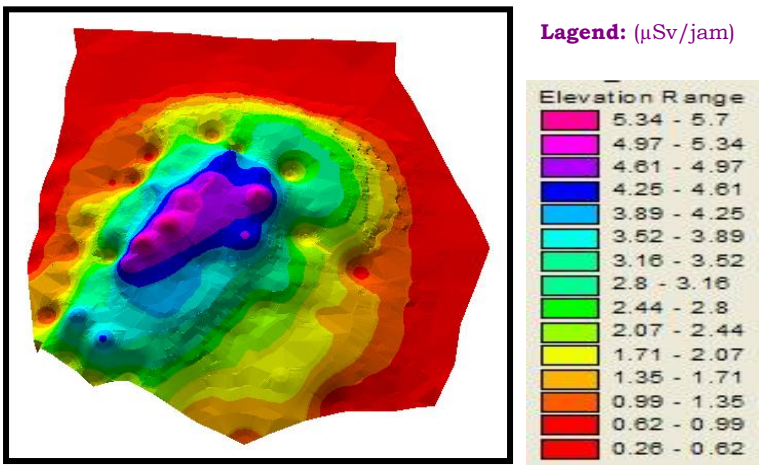

Fig. 5b: Radiation doses measured at 1 meter above the surface in the location C

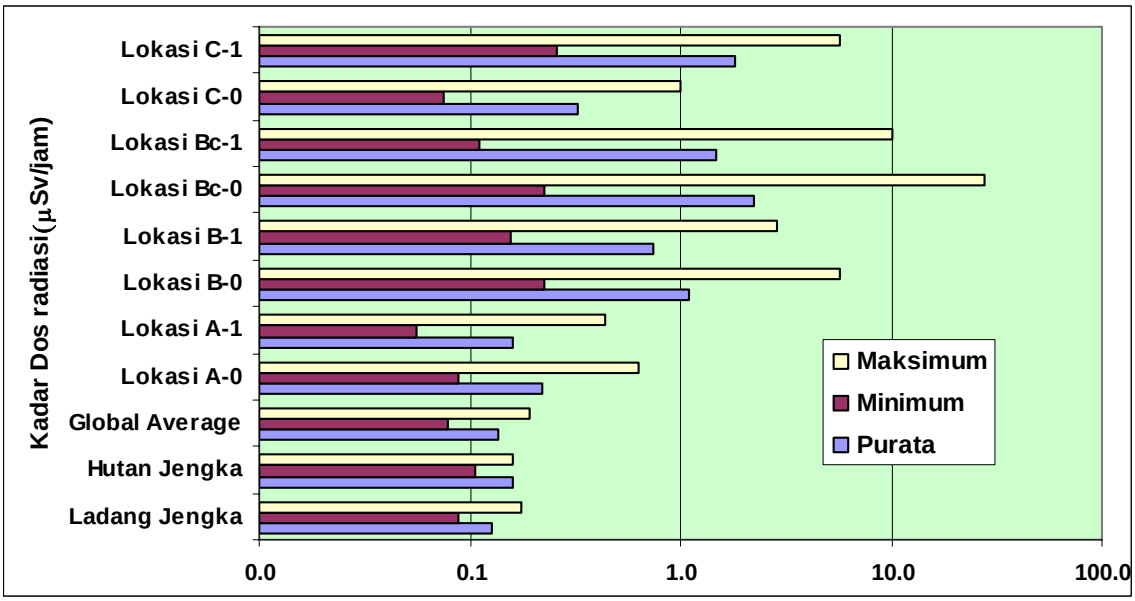

Fig. 6: Comparison with Jengka area and Global Range values: 0.079 – 0.190 mSv/hr

The radionuclide activity concentrations for ^{40}K, ^{226}Ra and ^{228}Ra measured in soil samples taken from various points in the critical area in location B is shown in Table 1 below. The energy peaks 295,352 and 609 keV were used to determine ^{226}Ra. Energy peak 911 keV was used to determine ^{228}Ra. Energy peak 1461 keV was used to determine ^{40}K.The mean activity concentration for ^{40}K is 2521±298 Bq/kg. The mean activity concentrations for ^{226}Ra and ^{228}Ra are 3798±419 Bq/kg and 12896±1533 Bq/kg respectively. From the ratio $^{228}Ra/^{226}Ra$ calculated it shows that ^{228}Ra is 3 times ^{226}Ra. Thus, the concentration of thorium is higher than the concentration of uranium in this area.

Table 1**:** Radionuclide ^{40}K, ^{226}Ra and ^{228}Ra activity concentrations in soil from the critical area in Location B

No	^{40}K (Bq/kg)	^{226}Ra(Bq/kg)	^{228}Ra(Bq/kg)	Ratio $^{228}Ra/^{226}Ra$
1	997±138	2405 ± 292	6520±970	2.71
2	21±3	715 ± 87	1797±268	2.51
3	7629±994	10143 ±1085	32330±3556	3.19
4	119±25	375 ± 47	1215±183	3.24
5	90±12	199 ± 24	743±110	3.72
6	9304±963	12932 ± 1348	47518±5084	3.67
7	2410±311	3172 ± 392	16730±2404	5.27
8	3205±424	4515 ± 484	13718±1510	3.04
9	898± 126	2299 ± 281	5803±857	2.52
10	534± 80	1224 ± 150	2590±384	2.11
Range 21 – 9304		**199 – 12932**	**1215 – 32330**	
Means 2521 ± 308		**3798 ± 419**	**12996 ±1533**	

The profile of these radionuclides ^{40}K, ^{226}Ra and ^{228}Ra activity concentrations are showing the same trend where the concentrations decrease as we go deeper (see Table 2 and Figures 7 and 8). The radionuclides concentrated more on the surface. From the results, the first 2 cm may have been washed by the rain; therefore it shows lower activity concentration. There is a possibility that the monazite deposit in this study area is predominant in the upper 0-10 cm depth.

Table 2: Radionuclides profile ^{40}K, ^{226}Ra and ^{228}Ra activity concentrations in soils samples

Code sample	^{40}K (Bq/kg)	^{226}Ra(Bq/kg)	^{228}Ra(Bq/kg)	Ratio $^{228}Ra/^{226}Ra$
Soil A0	90±12	199±24	743±110	3.72
Soil A1	340±55	816±101	2130±317	2.61
Soil A2	373±60	671±83	1948±291	2.90
Soil A3	362±51	483±53	930±105	1.92
Soil A4	165±33	282±36	607±92	2.15
Soil A5	164±32	209±27	451±69	2.16
Range	**90– 373**	**199– 816**	**451- 2130**	
Mean	**249±40**	**444±54**	**1135±164**	
Soil Do	2410±311	3172±392	16730±2404	5.27
Soil D1	19600±2533	20097±2150	77764±8545	3.87
Soil D2	8928±1162	13484±1642	71507±10516	5.30
Soil D3	4958± 663	8045±991	42155±6152	5.24
Soil D4	3713± 491	4711±505	16908±1861	3.59
Soil D5	1241± 169	1530±165	5426±600	3.54
Range	**1241-19600**	**1530-20097**	**5426– 77764**	
Mean	**6808±888**	**8506±974.**	**38415±3260**	

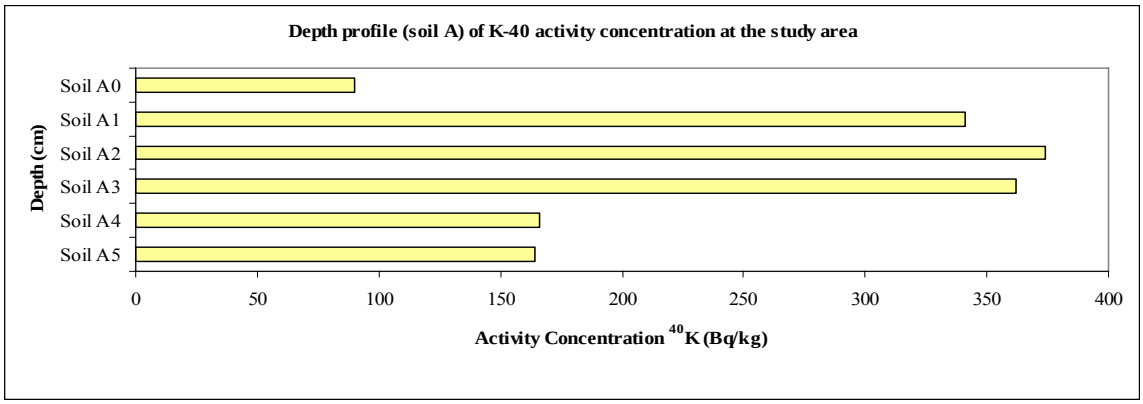

Fig. 7a: Depth profile of ^{40}K activity concentrations in soil Point A samples

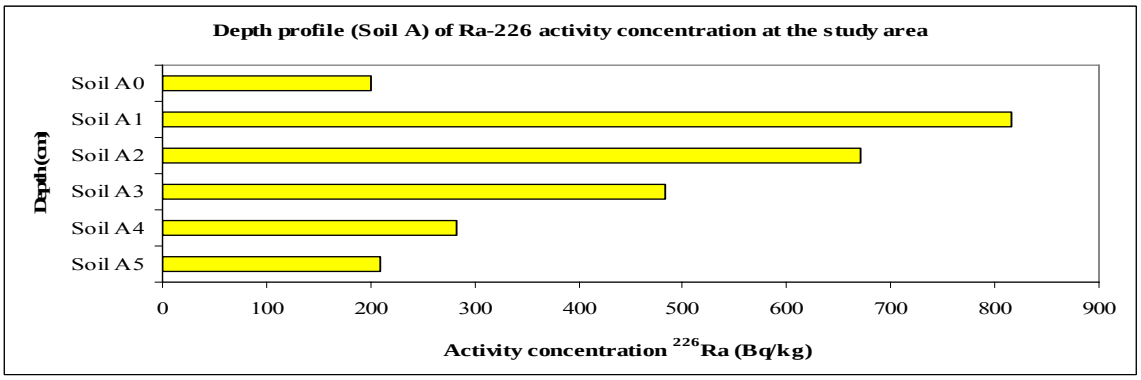

Fig. 7b**:** Depth profile of ^{226}Ra activity concentrations in soil Point A samples

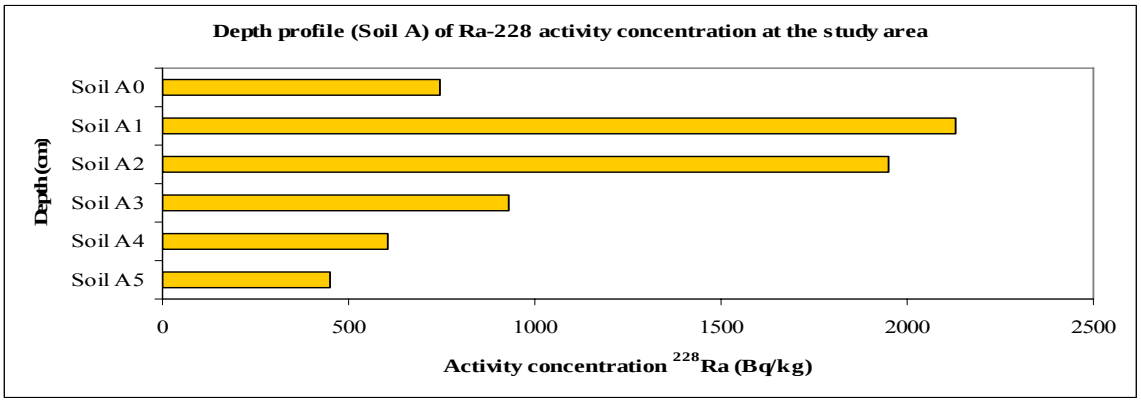

Fig. 7**c:** Depth profile of ^{228}Ra activity concentrations in soil Point A samples

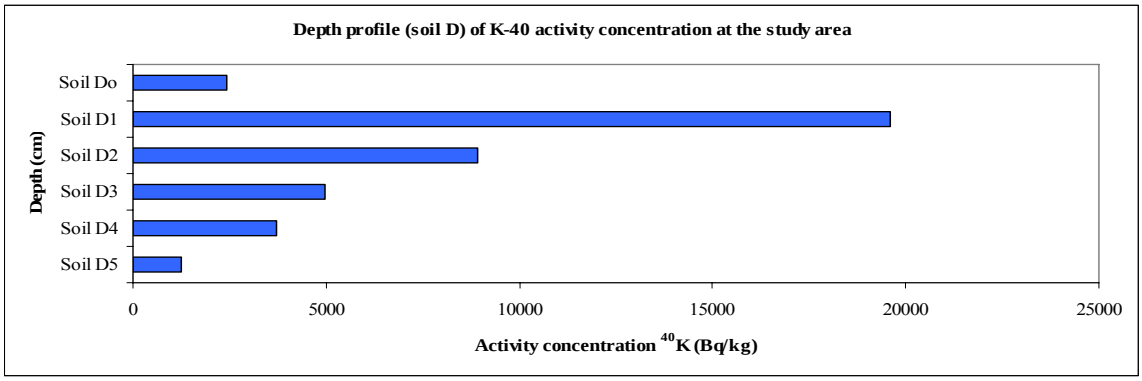

Fig. 8a**:** Depth profile of ^{40}K activity concentrations in soil Point D samples

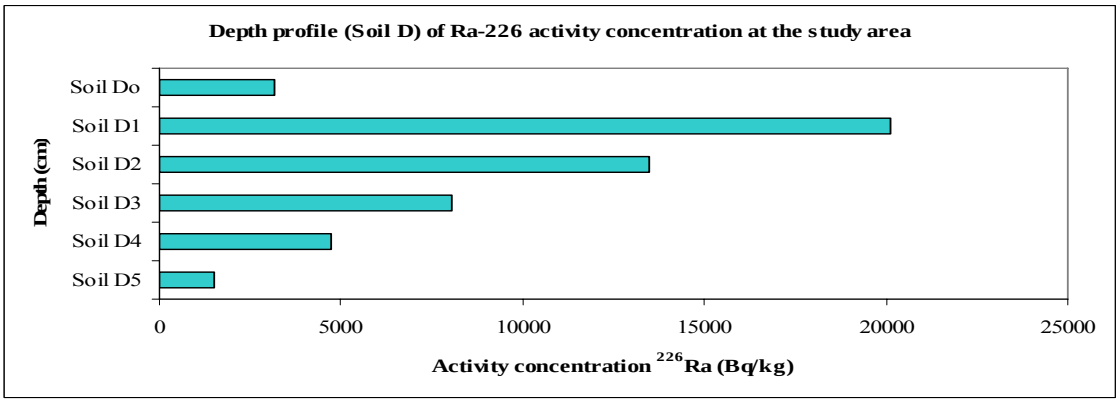

Fig. 8b**:** Depth profile of ^{226}Ra activity concentrations in soil Point D samples

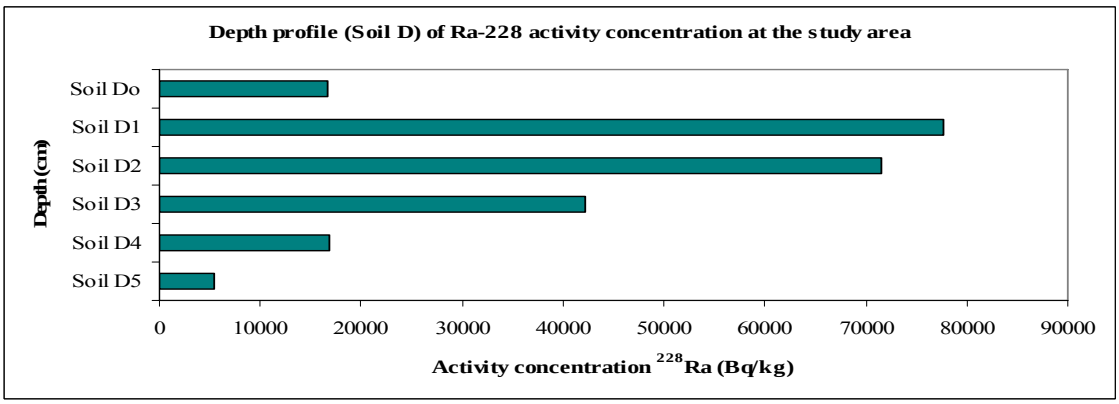

Fig. 8c**:** Depth profile of ^{228}Ra activity concentrations in soil Point D samples

From Table 3 also recorded the external radiation hazard index for the study area. The calculated values of H_{ex} for the soil samples in this studied are in range 3.43 – 220.36. Soil 9 and soil 5 show the highest H_{ex} which are 220.36 and 153.83. The lowest H_{ex} is 3.43. The value of this index must be less than unity in order to keep the radiation hazard to be insignificant. Since the values of the study area are higher than unity, therefore, according to Radiation Protection 112 report, this region is not safe and gives higher exposure to population. Taking into account that uranium and thorium are always presents in soil, their gamma radiation causes external exposures with the consequent absorbed dose.

Table 3**:** Summarized of calculated Air Absorbed Dose Rates, External Hazard Index (H_{ex}) and Annual Effective Doses

No	Absorbed dose rate (nGy/hr)				External hazard index (H_{ex})
	^{40}K	^{226}Ra	^{228}Ra	Total	
1	41.30	1109.15	4062.32	5212.77	31.89
2	0.88	329.72	1119.66	1450.26	8.88
3	315.84	4676.00	20141.84	25133.68	153.83
4	4.93	173.08	757.16	935.17	5.73
5	3.73	92.07	462.93	558.73	3.43
6	385.20	5961.94	29604.10	35951.24	220.36
7	99.78	1462.58	10422.94	11985.3	73.67
8	132.73	2081.78	8546.44	10760.95	65.84
9	37.19	1060.25	3615.79	4713.23	28.81
10	22.12	564.57	1613.73	2200.42	13.42
Range	**0.88 – 385.20**	**92.07 - 5961.94**	**462.93 - 29604.10**	**558.73 - 35951.24**	**3.43 - 220.36**

Conclusion

Surface radiation dose measured at 1m above the surface are in range between 0.313 – 13 μSv/hr for the whole area. The global range for surface radiation dose is 0.079 – 0.9 μSv/hr. Therefore, it can be concluded that the surface radiation dose for the study area are more than the global range.

It is found that the activity concentrations of ^{40}K is in the range of 21 - 9304 Bq/kg, 199–12932 Bq/kg for ^{226}Ra and 1215-32330 Bq/kg for ^{228}Ra. The mean activity concentrations for ^{40}K, ^{226}Ra and ^{228}Ra are 2521 ± 298 Bq/kg, 3798 ± 419 Bq/kg and 12896 ± 1533 Bq/kg respectively.

The mean activity concentrations in soils up to 10 cm depth for ^{40}K, ^{226}Ra and ^{228}Ra in Soil A are 249 ± 40 Bq/kg, 444 ± 54 Bq/kg and 31135 ± 164 Bq/kg respectively. Similarly, the mean activity concentrations for ^{40}K , ^{226}Ra and ^{228}Ra in Soil D are 6808 ± 888 Bq/kg, 8506 ± 974 Bq/kg and 38415 ± 3260 Bq/kg respectively.

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