Analysis of radiological hazards from surface soils in Khong Chiam and Sirinthon districts, Ubon Ratchathani province

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Abstract. The radiological hazards from natural radionuclides in soil at the border area between the northeast of Thailand and Laos were studied and evaluated. The 33 surface soil samples from Khong Chiam and Sirinthon districts in Ubon Ratchathani province were collected and measured the specific radioactivity (²²⁶Ra, ²³²Th and ⁴⁰K). The radioactivity of all soil samples was analyzed from gamma ray spectrums using hyper-pure germanium detector. The results applied for calculating the radiological hazards which were radium equivalent activity (Ra(eq)), absorbed dose rate (D), annual effective dose equivalent (AEDE(out)) and external hazard index (H(ex)). The experimental results obtained the radioactivity concentrations in a range of 10.64 to 46.67 Bq kg⁻¹ with average value of 22.82 ± 3.59 Bq kg⁻¹, 6.35 to 44.72 Bq kg⁻¹ with average value of 15.49 ± 3.57 Bq kg⁻¹ and 31.22 to 521.57 Bq kg⁻¹ with average value of 130.44 ± 28.46 Bq kg⁻¹ for ²²⁶Ra, ²³²Th and ⁴⁰K, respectively. The calculation results of Ra(eq), D, AEDE(out) and H(ex) showed significantly lower than the radiological hazard levels which are recommended by the United Nations Scientific Committee on the Effects of Atomic Radiation. The results of this study reveal that people can live and travel along the border area in the northeast of Thailand.

1. Introduction
Natural radioactive elements (Naturally Occurring Radioactive Materials), referred to as (NORM) occur and are common in various components of the crust. The human's daily life is mainly obtained from the radioactive elements available in nature [1]. The background is already in radiation, based on the location and nature of the landscape, whether it is soil. The sand, rocks or foods that we eat are in the radioactive elements. Even with small amounts but in a level that can be measured by the radiation detector. Natural radioactive elements that humans receive mainly from uranium (uranium-series) series, such as Radium-226 (²²⁶Ra), Radon-222 (²²²Rn) and thorium (thorium series), such as thorium-232 (²³²Th), radium-228 (²²⁸Ra), as well as decay products resulting from decay in various radioactive series. It also contains a naturally existing radioactive element since the birth of the human world. But it is not the radioactive element in the series mentioned above, namely potassium-40 (⁴⁰K). The radioactive elements that man-made are built in the soil. The water and vegetable plants such as caesium-137 (¹³⁷Cs)
are radioactive elements, which are caused by radioactive dust of nuclear weapons testing or nuclear power plants.

A group of radiation protection in Thailand and foreign countries are interested in measuring the natural radiation dose in the soil. Milk, dairy, fruit, food imported from abroad, to be the basic information of natural radiation and to assess the safety of exposure to the people's rays. In many countries [2-15], including Thailand, the information on the natural radiation is in the soil sample. Most of the water sand and vegetable plants are located in the southern part of Thailand. A section of Office of Atoms for Peace, which is a direct measurement of radiation in the surrounding environment. In most parts of the office, it is a random operation from across the country, thus making the basic information a system of radiation available in nature in many areas. In particular, the natural radiation information of the northeast is relatively low.

There is additionally the Sirinthon dam which is the water maintenance and power creating in the city. It is likewise a diversion region to the general population of the dam. The city likewise has a famous tourism spot where the large river territory is should visit the two locales area. Statistically, the radiation on the earth has not yet official existing. Regarding the primer on the two local areas (Khong Chiam and Sirinthon district) for instances, the type $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ soil put away in the second local of Ubon Ratchathani province. Moreover, according to the UNSCEAR 2000 observational data examined that the dirt of remote scientists and specialists around the globe are keen on surveying and breaking down the particular radiation esteems on the pollution, which is become the main resources of characteristic radioactive sort as mentioned above. Regarding the northeast district of Thailand, a fringe zone of the Mekong River has been frontier between Thai land and Laos. There is a vacationer or shopping in the Chong Mek showcase, which is the open market in the two regions. It is likewise utilized as a reason for evaluating the danger of presentation to the normal radiation of the neighbourhood populace. Eventually it conveys the outcomes contrasted on research in Thailand that could elaborate the information around the universe.

2. Experimental
2.1. Sample collection and preparation
All of the surface soil samples (33) were collected from Sirinthon District (18) and Khong Chiam (15), each of which is kept soil in the 2,500 cm² area at a depth into the soil 10 cm, and then store in a plastic bag with a weight of about 1kg, then record the geographical coordinates with GPS and then bring the soil sample into the tray was dried up at room temperature. After that, take a sample of the soil in the oven at a temperature of 100 °C for 10 hours to keep the soil dry and without moisture and pulverized the sample into a fine powder sieved through a 2 mm mesh size. It is packed in a cylindrical plastic container (diameter 7.5 cm and height 5.5 cm) and sealed with a PVC tape to prevent radon gas emissions. All samples kept for about 1 month in order to radioactive equilibrium between the $^{226}\text{Ra}$, $^{222}\text{Rn}$ and their decay products. The detection of $^{226}\text{Ra}$ needs a secular equilibrium between the mother nuclide and its daughters. This can be reached when the sample is packed gas tight for at least the sevenfold half-life of the corresponding radon nuclide prior to the gamma analysis. This equates to 28 days in the case of $^{226}\text{Ra}$. After one month, it brought the soil sample to measure gamma ray spectrum using hyper-pure germanium (HPGe) detector.

2.2. Analysis
The analysis of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ natural radionuclides using gamma spectrometry techniques by hyper-pure germanium probe (HPGe) model GR 2519 of the Canberra. The energy resolution is 1.9 keV at the energy 1.332 MeV of cobalt-60 ($^{60}\text{Co}$) and relative efficiency of 25%. The detector was contained in a cylindrical lead shield with a thickness of 10 cm in order to prevent the gamma rays from the environment into interference. The detector is connected to the DSA-1000, which is built with an electrical supply and multichannel analyzer by using the program Genie-2000 to analyze of gamma radiation. The calibrations of energy and resolution of the detector were performed using multi-nuclide source produced by Eckert and Ziegler Isotope Products. The source was obtained in a 500 ml Marinelli
beaker and activity is 1.027 μCi or 38.00 kBq. The radio nuclides used were Cd-109, Co-57, Te-123 m, Cr-51, Sn-113, Sr-85, Y-88, Cs-137 and Co-60. In addition, the efficiency calibrations of the detector were carried out using three different IAEA standard reference materials: IAEA-RGU-1, IAEA-RGTh-1, and IAEA-RGK-1. The efficiency corrected intensities of the measured discrete gamma ray at energies 351.92 keV (214Pb) and 609.32 keV (214Bi) were used to determine the activity concentrations of the 226Ra, 232Th activity concentration was determined from the gamma ray 583.19 keV (208Tl) and 911.20 keV (228Ac). The emission line 1460.82 keV was used to estimate the 40K concentration. All samples were counted via gamma detector for 10,800 s.

2.3. Radiation dose estimation

2.3.1. Radium equivalent activity (Ra_eq). The soil contains radioactive elements that are the natural radiation, including 226Ra, 232Th, and 40K, which emit external gamma radiation. Analyzing concentration in units of the Radium equivalent activity of Ra_eq to find out what the material is appropriate to take advantage of any side, as the weighted sum of the rays of 3, nuclides is 226Ra, 232Th and 40K in the following equation [16, 17]:

$$Ra_{eq} (\text{Bq kg}^{-1}) = A_{Ra} + 1.43A_{Th} + 0.077A_{K} \quad (1)$$

where $A_{Ra}$, $A_{Th}$, and $A_{K}$ are the specific activities of 226Ra, 232Th, and 40K in Bq kg$^{-1}$, respectively.

2.3.2. Absorbed dose rate in air $(D)$. The external gamma absorbed dose rate in the air $(D)$ at 1 m above the ground was calculated from specific activity of 226Ra, 232Th and 40K in the soil. The calculations were performed according to the following relation below [16, 17]:

$$D \ (\text{nGyh}^{-1}) = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_{K} \quad (2)$$

2.3.3. Annual effective dose equivalent (AEDE_{out}). The annual effective dose equivalent was estimated can be obtained from the conversion coefficient from absorbed dose rate in air using the 0.7 SvGy$^{-1}$ and the opportunity to time spent outdoor about 20% (0.2) with a total of 8,760 hours. The AEDE was calculated from the following equation [16]:

$$AEDE_{out} \ (\text{mSvy}^{-1}) = [D \ (\text{nGyh}^{-1}) \times 8,760 \text{hy}^{-1} \times 0.2 \times 0.7(\text{SvGy}^{-1})] / 10^6 \quad (3)$$

2.3.4. External hazard index $(H_{ex})$. The external hazard index was estimated by the following equation [17]:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_{K}}{4810} \quad (4)$$

The value of this index must be less than unity for the radiation hazard to be negligible.

3. Results and discussion

For the specific activity of natural radionuclide 226Ra, 232Th, and 40K in 33 samples collected from the Sirinthon district and the Khong Chiam district, Ubon Ratchathani province are shown in table 1. The specific activity (226Ra, 232Th and 40K) in the Sirinthon district with a range of 10.64 to 46.07 Bq kg$^{-1}$, 6.35 to 40.74 Bq kg$^{-1}$ and 31.22 to 351.23 Bq kg$^{-1}$, with average value of 23.59, 15.88 and 129.65 Bq kg$^{-1}$, respectively. The specific activity (226Ra, 232Th and 40K) in the Khong Chiam district with a range of 15.06 to 46.67 Bq kg$^{-1}$, 6.90 to 44.72 Bq kg$^{-1}$ and 32.45 to 521.57 Bq kg$^{-1}$, with the average value of
21.89, 15.02 and 131.40 Bq kg\(^{-1}\), respectively. It is also observed that the activities of \(^{40}\)K were higher than those of both \(^{226}\)Ra and \(^{232}\)Th in all of the soil-samples.

**Table 1.** The specific activity of \(^{226}\)Ra, \(^{232}\)Th, and \(^{40}\)K in the soil samples in Sirinthon and Khong Chiam districts.

| District      | Sample code | \(^{226}\)Ra (Bq kg\(^{-1}\)) | \(^{232}\)Th (Bq kg\(^{-1}\)) | \(^{40}\)K (Bq kg\(^{-1}\)) |
|---------------|-------------|-------------------------------|------------------------------|-----------------------------|
| Sirinthon     | S1          | 20.04 ± 3.11                  | 7.40 ± 4.13                  | 72.32 ± 18.08               |
|               | S2          | 20.13 ± 2.50                  | 18.20 ± 2.85                 | 88.70 ± 20.48               |
|               | S3          | 22.52 ± 4.01                  | 19.68 ± 3.89                 | 64.99 ± 22.57               |
|               | S4          | 24.31 ± 3.42                  | 13.27 ± 3.97                 | 100.92 ± 46.87              |
|               | S5          | 46.07 ± 5.16                  | 40.74 ± 5.89                 | 351.23 ± 56.23              |
|               | S6          | 21.32 ± 4.28                  | 16.74 ± 3.80                 | 105.74 ± 24.67              |
|               | S7          | 11.02 ± 2.49                  | 7.04 ± 2.27                  | 76.99 ± 20.56               |
|               | S8          | 21.10 ± 3.33                  | 11.36 ± 3.59                 | 67.26 ± 17.62               |
|               | S9          | 19.27 ± 3.48                  | 6.35 ± 5.34                  | 41.22 ± 16.83               |
|               | S10         | 24.34 ± 3.72                  | 15.07 ± 2.90                 | 107.73 ± 23.39              |
|               | S11         | 37.67 ± 5.08                  | 20.25 ± 4.74                 | 319.58 ± 58.75              |
|               | S12         | 20.26 ± 3.49                  | 6.75 ± 3.03                  | 129.65 ± 29.86              |
|               | S13         | 18.97 ± 4.07                  | 14.12 ± 4.64                 | 132.25 ± 27.26              |
|               | S14         | 10.64 ± 1.84                  | 8.79 ± 1.86                  | 68.45 ± 12.26               |
|               | S15         | 18.92 ± 3.73                  | 11.29 ± 2.73                 | 95.89 ± 28.30               |
|               | S16         | 29.18 ± 4.31                  | 24.10 ± 4.15                 | 297.01 ± 51.32              |
|               | S17         | 27.16 ± 4.26                  | 19.46 ± 3.75                 | 115.12 ± 27.24              |
|               | S18         | 14.44 ± 2.74                  | 7.41 ± 2.54                  | 31.22 ± 15.56               |
|               | **Average** |                          | 23.59 ± 3.66                  | 129.65 ± 29.86              |
| Khong Chiam   | S19         | 28.49 ± 2.83                  | 18.50 ± 3.10                 | 161.10 ± 23.28              |
|               | S20         | 46.67 ± 6.42                  | 44.72 ± 6.98                 | 521.57 ± 82.88              |
|               | S21         | 19.00 ± 3.07                  | 13.26 ± 3.02                 | 75.12 ± 21.37               |
|               | S22         | 17.82 ± 3.12                  | 9.02 ± 4.72                  | 202.91 ± 36.44              |
|               | S23         | 18.61 ± 2.34                  | 8.23 ± 1.73                  | 85.28 ± 15.13               |
|               | S24         | 19.19 ± 3.53                  | 18.19 ± 4.45                 | 195.50 ± 38.51              |
|               | S25         | 15.06 ± 3.03                  | 16.20 ± 4.09                 | 82.56 ± 23.63               |
|               | S26         | 27.68 ± 4.07                  | 16.32 ± 3.87                 | 179.11 ± 36.10              |
|               | S27         | 17.96 ± 3.69                  | 10.60 ± 3.04                 | 32.45 ± 14.58               |
|               | S28         | 16.92 ± 2.11                  | 12.47 ± 2.48                 | 102.34 ± 16.41              |
|               | S29         | 26.69 ± 6.35                  | 16.01 ± 3.65                 | 88.51 ± 22.28               |
|               | S30         | 17.79 ± 3.25                  | 8.95 ± 3.32                  | 90.35 ± 20.20               |
|               | S31         | 15.92 ± 2.98                  | 11.42 ± 0.91                 | 32.61 ± 15.76               |
|               | S32         | 15.41 ± 2.99                  | 6.90 ± 2.92                  | 37.27 ± 19.57               |
|               | S33         | 25.20 ± 2.89                  | 14.45 ± 2.53                 | 84.31 ± 15.59               |
|               | **Average** |                          | 21.89 ± 3.51                  | 131.40 ± 26.78              |
|               | **Ranges (33)** |                | 10.64 – 46.67                | 31.22 – 521.57              |
|               | **Mean (33)** |                          | 22.82 ± 3.59                  | 130.44 ± 28.46              |
Table 2. The radium equivalent activity (Ra_{eq}), absorbed dose rate (D), annual effective dose equivalent (AEDE_{out}) and external hazard index (H_{ex}).

| Sample code | Ra_{eq} (Bq kg^{-1}) | D (nGy h^{-1}) | AEDE_{out} (mSv y^{-1}) | H_{ex} |
|-------------|----------------------|---------------|------------------------|--------|
| S1          | 36.19                | 16.74         | 0.02                   | 0.10   |
| S2          | 52.99                | 23.99         | 0.03                   | 0.14   |
| S3          | 55.67                | 25.00         | 0.03                   | 0.15   |
| S4          | 51.06                | 23.45         | 0.03                   | 0.14   |
| S5          | 131.37               | 60.54         | 0.07                   | 0.35   |
| S6          | 53.40                | 24.37         | 0.03                   | 0.14   |
| S7          | 27.02                | 12.55         | 0.02                   | 0.07   |
| S8          | 42.52                | 19.41         | 0.02                   | 0.11   |
| S9          | 33.59                | 15.58         | 0.02                   | 0.09   |
| S10         | 54.19                | 24.84         | 0.03                   | 0.15   |
| S11         | 91.24                | 42.96         | 0.05                   | 0.25   |
| S12         | 33.09                | 15.16         | 0.02                   | 0.09   |
| S13         | 49.34                | 22.81         | 0.03                   | 0.13   |
| S14         | 28.48                | 13.08         | 0.02                   | 0.08   |
| S15         | 42.45                | 19.56         | 0.02                   | 0.11   |
| S16         | 86.51                | 40.42         | 0.05                   | 0.23   |
| S17         | 63.85                | 29.10         | 0.04                   | 0.17   |
| S18         | 27.44                | 12.45         | 0.02                   | 0.07   |
| S19         | 67.35                | 31.05         | 0.04                   | 0.18   |
| S20         | 150.78               | 70.32         | 0.09                   | 0.41   |
| S21         | 43.75                | 19.92         | 0.02                   | 0.12   |
| S22         | 46.34                | 22.14         | 0.03                   | 0.13   |
| S23         | 36.95                | 17.12         | 0.02                   | 0.10   |
| S24         | 60.26                | 28.00         | 0.03                   | 0.16   |
| S25         | 44.58                | 20.19         | 0.02                   | 0.12   |
| S26         | 64.81                | 30.11         | 0.04                   | 0.18   |
| S27         | 35.62                | 16.05         | 0.02                   | 0.10   |
| S28         | 42.63                | 19.62         | 0.02                   | 0.12   |
| S29         | 56.40                | 25.69         | 0.03                   | 0.15   |
| S30         | 37.55                | 17.39         | 0.02                   | 0.10   |
| S31         | 34.76                | 15.61         | 0.02                   | 0.09   |
| S32         | 28.15                | 12.84         | 0.02                   | 0.08   |
| S33         | 52.36                | 23.89         | 0.03                   | 0.14   |
| Ranges      | 27.02 – 150.78       | 12.45 – 70.32 | 0.02 – 0.09            | 0.07 – 0.41 |
| Mean        | 54.89                | 25.28         | 0.03                   | 0.15   |

From Table 2, the index of radiation risk is the radium equivalent activity (Ra_{eq}), absorbed dose rate in air (D), annual effective dose equivalent (AEDE_{out}) and external hazard index (H_{ex}) were calculated using the activity concentration of $^{226}$Ra, $^{232}$Th, and $^{40}$K in the soil. They include range and average values compared to global values. The Ra_{eq} activity in the soil for two locations ranges from 27.02 – 150.78 Bq kg^{-1} with the average 54.89 Bq kg^{-1} which is lower than the recommended maximum value of 370 Bq kg^{-1} [1, 17]. The absorbed dose rate in air ranges from 12.45 – 70.32 nGy h^{-1} with the average value of 25.28 nGy h^{-1} in the study area is lower than the worldwide average limit value. The values of AEDE_{out} ranges from 0.02 – 0.09 mSv y^{-1} with average value of 0.03 mSv y^{-1}. The world average annual effective dose rate is 0.07 mSv y^{-1} reported by UNSCEAR and external hazard index (H_{ex}) has a range
of 0.07 – 0.41 with the average value of 0.15 which is lower than unity is seen that the soil samples collected from the Sirinthon district and Khong Chiam district, Ubon Ratchathani province. In this study, it talks about the safety of radiation to people of the residents. For both Thailand and neighboring countries in these both districts. From table 3 when the comparison of the average activity concentration of 226Ra, 232Th, and 40K in 33 samples collected from the Sirinthon district and the Khong Chiam district with some research in Thailand and the world average. It was found that average activity concentration of 226Ra, 232Th, and 40K in this study was lower than every research in Thailand and the global average values (35 Bq kg\(^{-1}\) for 226Ra, 30 Bq kg\(^{-1}\) for 232Th and 400 Bq kg\(^{-1}\) for 40K)[1]. The values of activity concentration are much more or less, it depends on geographic conditions the properties of the chemical and physical soil of each type of soil in the area, which is another factor that causes different radiation[18-20].

Table 3. Comparison of specific activity of 226Ra, 232Th and 40K in soil samples with some research in Thailand and the world average.

| Locations     | 226Ra Specific Activity (Bg kg\(^{-1}\)) | 232Th Specific Activity (Bg kg\(^{-1}\)) | 40K Specific Activity (Bg kg\(^{-1}\)) | References |
|---------------|----------------------------------------|-----------------------------------------|--------------------------------------|------------|
| Thailand      | (10.64 – 46.67)                         | (6.35 – 44.72)                         | (31.22 – 521.57)                    | Present study |
| (Southern)    | 29                                     | 49                                      | 344                                  | [13]       |
| (Songkhla)    | (4 – 122)                              | (6 – 170)                              | (5 – 1,422)                         | [20]       |
| Thailand      | 68                                     | 45                                      | 213                                  |            |
| (Songkhla)    | (26 – 156)                             | (7 – 91)                               | (62 – 949)                          |            |
| Thailand      | 48                                     | 51                                      | 230                                  | [1]        |
| (11 – 78)     | (7 – 120)                              | (7 – 712)                              |                                      |            |
| Worldwide     | 35                                     | 30                                      | 400                                  | [1]        |
| (17 - 60)     | (11 - 64)                              | (140 - 850)                            |                                      |            |

4. Conclusions
In this study, the measurement and analysis specific radioactivity of 226Ra, 232Th and 40K in 33 soil samples collected from the Sirinthon district and the Khong Chiam district. The experimental results obtained the radioactivity concentrations in a range of 10.64 to 46.67 Bq kg\(^{-1}\) with average value of 22.82 ± 3.59 Bq kg\(^{-1}\), 6.35 to 44.72 Bq kg\(^{-1}\) with average value of 15.49 ± 3.57 Bq kg\(^{-1}\) and 31.22 to 521.57 Bq kg\(^{-1}\) with average value of 130.44 ± 28.46 Bq kg\(^{-1}\) for 226Ra, 232Th and 40K, respectively. The calculation results of RAeq, D, AEDE\(_{eq}\) and H\(_{eq}\) showed significantly lower than the radiological hazard levels which are recommended by UNSCEAR. This research data can be used as basic activity concentration in the surface soil of Sirinthon district and Khong Chiam District, Ubonratcathani province, Thailand. As a result of all soil samples in this study, it is safe for people of the residents, for both Thailand and Laos countries.

5. References
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Acknowledgments
The authors wish to gratefully acknowledge the Office of the National Research Council of Thailand (NRCT) and Roi Et Rajabhat University. The authors are thankful to the Department of Applied Radiation and Isotopes, Faculty of Science, Kasetsart University for measurement and analysis some parts of these research data.