NATURAL RADIONUCLIDES IN AGRICULTURAL SOIL IN MANDALAY AREA

Thet Thet Cho[1], Kalyar Thwe[2], Kathi Nwe[3]

Abstract

Natural radionuclides are present in every human environment such as earth crust, water, air, foods and even our own body contains naturally occurring radioactive materials. In this study, the radioactivity levels of ^{226}Ra,^{232}Thand ^{40}K in the agriculturalsoil samples in Mandalay area were determined by using HPGe detector at Department of Physics, University of Mandalay. The activity concentration were found in the range of 8.329 Bq/kg to 33.42 Bq/kg for ^{226}Ra, 16.25Bq/kg to 72.38Bq/ kg for ^{232}Th and 363.4 Bq/kg to 488.3 Bq/kg for ^{40}K, respectively. The radiological hazard parameters for ^{226}Ra, ^{232}Th and ^{40}K in were also evaluated. The radium equivalents activity (Ra_{eq}) and the absorbed dose rate (D) are 107.9Bq/kg and 50.72nGy/h. Obtained results were compared and discussed with internationally recommend values.

Keywords: Radionuclides, Soil, Gamma Ray Spectroscopy, radiological hazard parameters.

Introduction

Radioactive elements occur naturally in the earth's rocks, soils, and water in varying concentrations. Naturally occurring radionuclides contribute to a major portion to the effective dose of the worldwide population. Natural radionuclides in soil generate a significant component of the background radiation exposure of the population. The natural radioactivity in soil mainly comes from the uranium and thorium decay series and potassium. Radiation has always been present and is all around us in many forms. Life has evolved in a world with significant levels of ionizing radiation, and our bodies have adapted to it.

Many radioisotopes are naturally occurring, and originated during the formation of the solar system and through the interaction of cosmic rays with molecules in the atmosphere. The earth's outer atmosphere is continually bombarded by cosmic radiation. Usually, cosmic radiation consists of fast moving particles that exist in space and originate from a variety of sources, including the sun and other celestial events in the universe. Some ionizing radiation will penetrate the earth's atmosphere and become absorbed by humans which results in natural radiation exposure. The composition of the earth's crust is a major source of natural radiation. The main contributors are natural deposits of uranium, potassium and thorium which, in the process of natural decay, will release small amounts of ionizing radiation. Uranium and thorium are found essentially everywhere. Trace amounts of radioactive minerals are naturally found in the contents of food and drinking water. For instance, vegetables are typically cultivated in soil and ground water which contains radioactive minerals. Once ingested, these minerals result in internal exposure to natural radiation.

Detection of radioactivity, analysis of radioactive samples, and deciphering data require sophisticated devices and techniques. One of the popular techniques being used today for low-background radio-analysis is the gamma-ray spectrometry. Three types of gamma ray detectors can be used for gamma ray analysis: thallium doped sodium iodide crystal NaI(Tl) scintillation

[1] Dr, Assistant Lecturer, Department of Physics, University of Mandalay
[2] Dr, Professor, Department of Physics, University of Mandalay
[3] Dr, Professor, Department of Physics, Mandalay University of Distance Education.

detector, lithium drifted crystal of purified germanium detector, and High-Purity Germanium (HPGe) detector. Among them, HPGe- detector is the most sensitive and efficient device which is widely used in determining activity of radionuclides from higher order down to pCi level. Assessing the effects of radiation exposure based on the knowledge of radionuclide distribution and radiation levels in the environment is important for public health protection. M. S. Jaffar *et al.*, were studied the specific activities of different natural radio nuclides in the soil samples from different locations in the middle and northern parts of Iraq by using gamma-ray spectrometry. In 2016, G. Alzubaidi *et al* .,were determined the activity concentrations of naturally occurring radio nuclides ^{226}Ra, ^{232}Th, and ^{40}K in agricultural and virgin soil samples randomly collected from Kedah, north of Malaysia. In this study, the radioactivity levels and radiation hazard of ^{226}Ra, ^{232}Th and ^{40}K in the agricultural soil samples in Mandalay area were determined by using aHPGe detector at Department of Physics, University of Mandalay.

Material and Method

2.1 Sample Collection and Preparation

Soil is not only the key nutrient bearing environment for plant life but also a supplier of many pollutants to plants because plants can uptake toxic substances through their roots from soils. In this experiment twelve samples of soil samples were collected from different agricultural fields in Mandalay Division. All soil samples were collected from top 0 to 5cm deep soil layer. Collected soil samples were purified by removing all contaminants such as rocks, woods, metals, dry roots, grasses, vegetation residual parts. The map of sampling area was shown in Fig. (1). Table (1) shows the sample codes and location of analyzed soil samples. The collected samples were put in vacuum black plastic bags directly after collection to prevent from atmospheric humidity. And then all these samples were dried at room temperature about two weeks. After drying all collected soil samples were powdered by using a pestle and mortar prior to analysis. Fine quality of the sample is obtained by using 200 mesh sieves. Then 500 grams of each sample were weighed and transferred in sealed cylindrical containers to analysis.

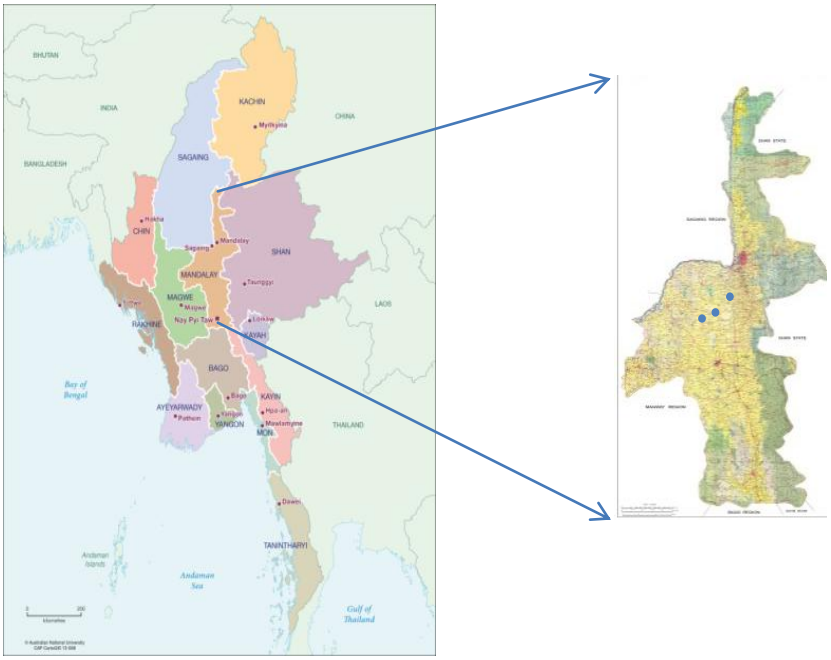

Figure 1 The photograph of map of sampling area.

Table 1 The sample codes and sample location of analyzed soil samples

Sr No	Sample Code	Sample Name
1	RSS1	Soil sample from rice field near Myotha
2	RSS2	Soil sample from rice field near Shan Lay Kyun
3	RSS3	Soil sample from rice field near Latt Kaung
4	BSS1	Soil sample from bean field near Myotha
5	BSS2	Soil sample from bean field near Shan Lay Kyun
6	BSS3	Soil sample from bean field near Latt Kaung
7	SSS1	Soil sample from spinach field near Myotha
8	SSS2	Soil sample from spinach field near Shan Lay Kyun
9	SSS3	Soil sample from spinach field near Latt Kaung
10	PSS1	Soil sample from peanut field near Myotha
11	PSS2	Soil sample from peanut field near Shan Lay Kyun
12	PSS3	Soil sample from peanut field near Latt Kaung

2.2 Radioactive Measurement

Radioactivity in soil samples were measured by gamma ray spectrometry system from University of Research Center in Mandalay University. Gamma-ray spectrometry is one of the most accepted and widely used techniques for the detection and analysis of radioactive materials for a wide range of activity. The gamma ray spectrometry system consists of a High Purity Germanium (ORTEC model GMX10P4-70-RB-SMN) detector, detector shield with lead, high voltage power supply, cooling system (electrically cooled by X COOLER 3), a preamplifier, digital signal processor, a multichannel analyzer system with Gamma Vision-32 software installed in PC and data readout devices. Before the measurement, the energy calibration for the detection system was done using the standard sources (^{133}Ba, ^{60}Co, ^{22}Na and ^{137}Cs) of known energies. The energy calibration for the HPGE detector is shown in Table (2) and the energy calibration curve is also shown in Fig.(3).The efficiency calibration curve was used by using standard reference material IAEA 448 in this measurement. All each samples and background measurements were taken 10800 s for analysis measurements. The photograph of HPGe detector was shown in Fig.(3).

Table 2 Energy calibration for HPGE detector.

Radionuclides	Channel No.	Energy (keV)
^{133}Ba	427.8	81
^{133}Ba	1459.84	276.39
^{133}Ba	1599.6	302.73
^{133}Ba	1880.78	356.02
^{133}Ba	2028.2	383.85
^{22}Na	2700.82	511
^{137}Cs	3497.26	661.66
^{60}Co	6201.54	1173.23
^{22}Na	6737.18	1274.54
^{60}Co	7043.38	1332.5

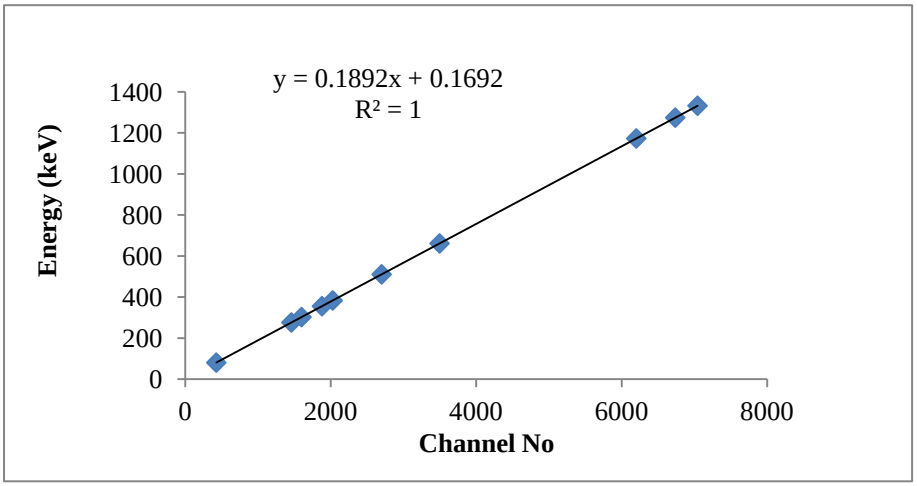

Figure 2 Energy calibration curve for HPGe detector

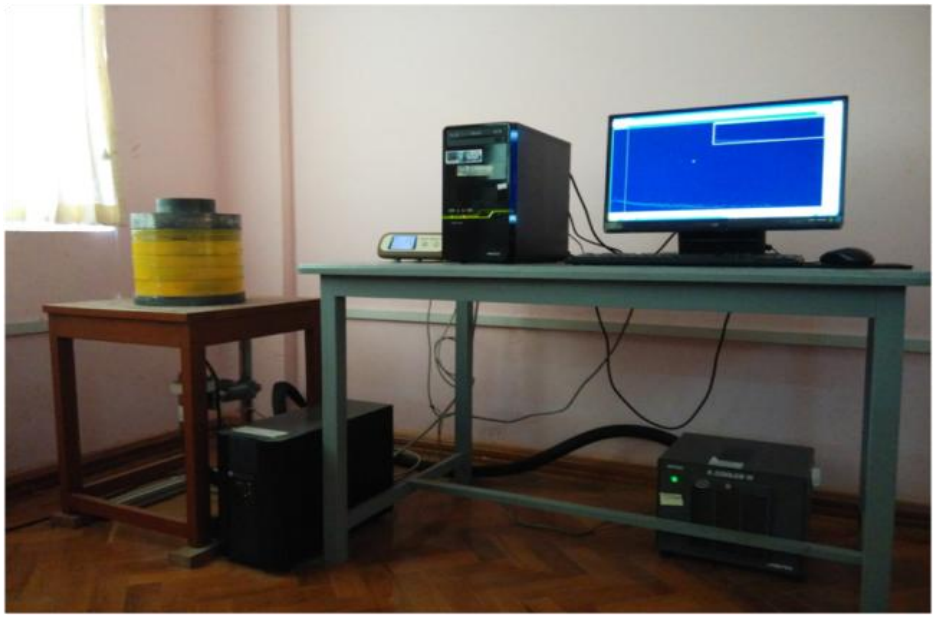

Figure 3 The photograph of HPGe detector

2.2.1 Analytical Methods

The gamma activity was calculated based on the measured efficiency of the detector from the following equation.

$$A = \frac{C}{\varepsilon(E) \times P_{\gamma} \times W}$$

where, A is the activity in $Bqkg^{-1}$; C is the net gamma counting rate in countper second (cps); ε(E) is the efficiency of the detector at energy E (keV); Pγ is the photon emission probability at energy E (keV) intensity of the radionuclide and W is the dry mass of the sample.

2.2.2 Radium Equivalent Activity

It is significant to evaluate the gamma-ray radiation hazards of soil to human beings. The gamma-ray radiation hazards due to the natural radionuclides ^{226}Ra, ^{232}Th, and ^{40}K were assessed

by various radiation hazard indices. Uniformity with respect to exposure to radiation has been defined in terms of radium equivalent activity (Ra_{eq}) in Bq kg^{-1} to compare the specific activity of materials containing different amounts of ^{226}Ra,^{232}Th and ^{40}K. It is calculated through the following relation

$$Ra_{eq} = A_{Ra} + 1.43\ A_{Th} + 0.077A_K$$

where, A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1}, respectively.

2.2.3 Absorbed Dose Rates

The external outdoor absorbed gamma dose rates due to terrestrial γ- rays from the nuclides ^{226}Ra, ^{232}Th and ^{40}K at 1 m above the ground level was calculated as

$$D= 0.461\ A_{Ra}+0.623\ A_{Th}+0.0414\ A_K$$

where, A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1}, respectively[4].

Result and Discussion

Soil samples collected from the different agricultural soil were analyzed by using aHPGe-gamma-ray spectrometer to determine the activity concentration for natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K.The background spectrum and gamma ray spectrum were shown in Fig. (4) to Fig. (7).The average activity concentrations of natural radionuclides in the soil samples in different location are shown in Table (3).The average concentrations in the soil samples in different crop soil sample were shown in Fig. (8) to Fig. (11). According our results, the activity concentration values are (8.329, 8.532, 10.55, 12.47, 12.69, 14,20, 17,69, 26.95, 27.72, 28,02, 28.12 and 33.42) $Bqkg^{-1}$ for ^{226} Ra, (16.25, 20.00, 23.87, 28.22, 35.11, 36.49, 36.82, 43.35, 44.17, 57.88, 65.30 and 72.38) $Bqkg^{-1}$ for ^{232}Th and (363.4, 367.8, 370.9, 379.4, 400.1, 406.7, 408.7,408.7, 439.0 447.9, 453.0 and 488.3) $Bqkg^{-1}$ for ^{40}K in rice soil, bean soil, spinach soil and peanut soil samples, respectively. The average activity concentrations are 19.06± 9.11 $Bqkg^{-1}$ for ^{226}Ra, 39.98 ± 17.70$Bqkg^{-1}$ for^{232}Th, 411.2 ± 39.04$Bqkg^{-1}$ for^{40}K, respectively. The variation of activity concentration with location was presented in Table (4). The variation of average activity concentration with location was presented in Fig. (12). In order to assess the health effects, the radiation hazards such as radium equivalent activity (Ra_{eq}), absorbed dose rate (D), have been calculated from the activity of nuclides ^{226}Ra, ^{232}Th, ^{40}K. The calculated radium equivalent activity data and the absorbed dose rates values are shown in Table (5). The radium equivalent values for the soil samples varied in the range from 72.32$Bqkg^{-1}$ to 165.43$Bqkg^{-1}$. The radium equivalent values in different soil sample were shown in Fig. (13). The absorbed dose rate in different soil samples were shown in Fig. (14).In the present study, the absorbed dose rates due to ^{226}Ra, ^{232}Th and ^{40}K in the soil samples varied from 35.13 $nGyh^{-1}$ to 76.23$nGyh^{-1}$. Comparison of absorbed dose rate in different location are shown in Table (6).

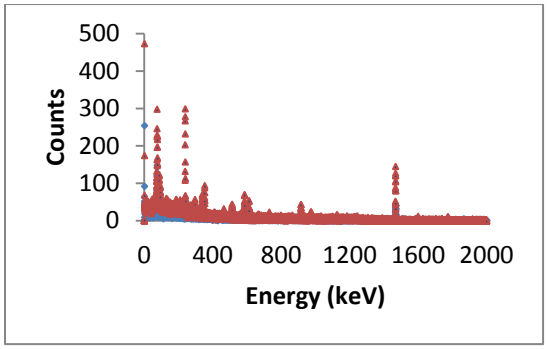

Figure 4 The gamma ray spectrum of soil RSS1 sample with background.

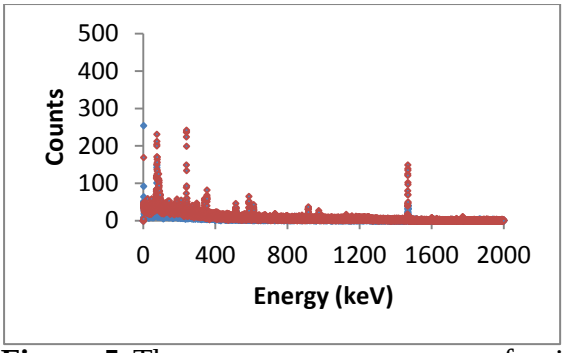

Figure 5 The gamma ray spectrum of soil BSS12 sample with background

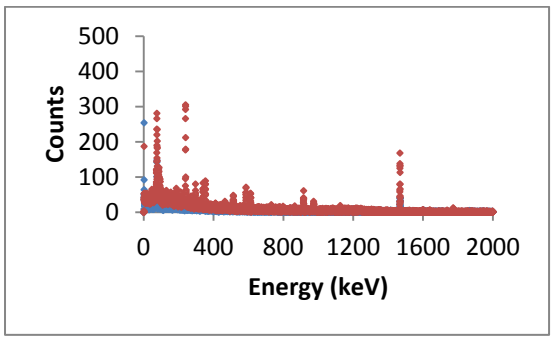

Figure 6 The gamma ray spectrum of soil SSS1sample with background

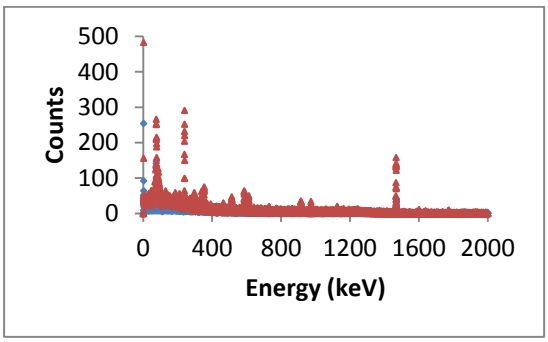

Figure 7 The gamma ray spectrum of soil PSS1 sample with background

Table 3 Activity concentration of natural radionuclide in the soil sample

Sample Name	Code	Activity Concentration (Bq/kg)		
		^{226}Ra	^{232}Th	^{40}K
Rice soil	RSS1	12.69	35.11	363.4
	RSS2	10.55	43.35	367.8
	RSS3	28.12	72.38	439
Bean soil	BSS1	8.329	28.22	370.9
	BSS2	28.02	57.88	488.3
	BSS3	12.47	20.00	408.7
Spanisch soil	SSS1	33.42	36.49	406.7
	SSS2	26.95	23.87	408.7
	SSS3	27.72	65.3	400.1
Peanut soil	PSS1	14.2	16.25	453.0
	PSS2	17.69	36.82	379.4
	PSS3	8.532	44.17	447.9

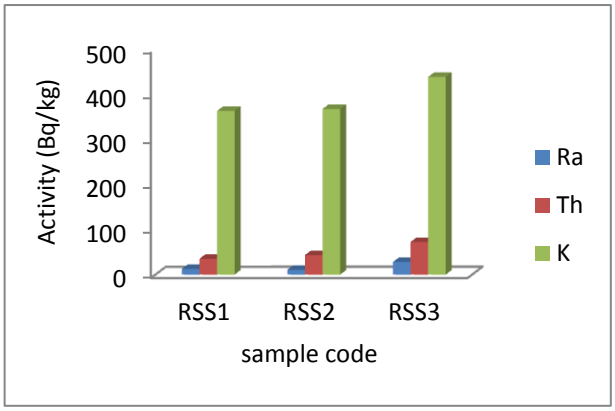

Figure 8 Activity concentration of radionuclide in the rice soil sample

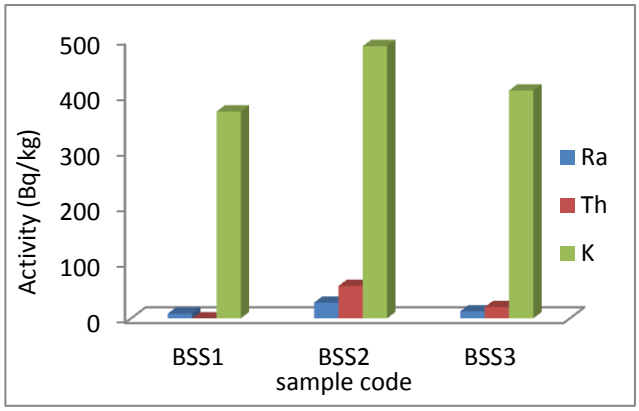

Figure 9 Activity concentration of radionuclide in the bean soil sample

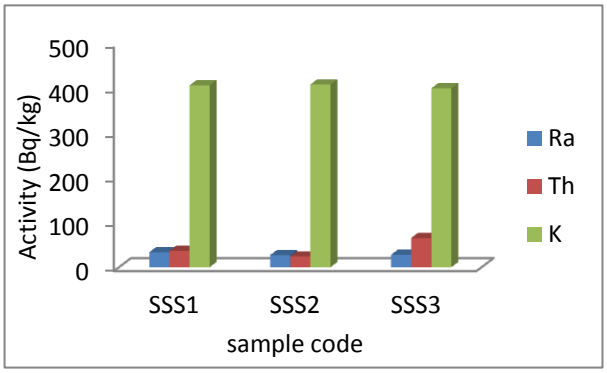

Figure 10 Activity concentration of radionuclide soil sample

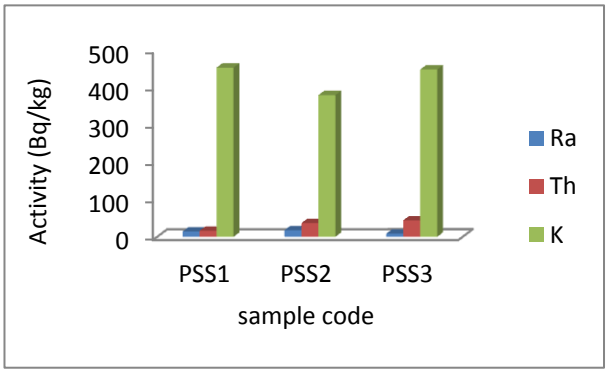

Figure 11 Activity concentration of in the spinach radionuclide in the peanut soil

Table 4 Average activity concentration in different location.

Sample location	Average activity concentration (Bq/kg)		
	^{226}Ra	^{232}Th	^{40}K
S1	17.16±11.10	29.02±9.248	398.5±40.95
S2	20.8±8.26	40.48±14.14	411.1±54.29
S3	19.21±10.18	50.46±23.58	423.9±23.10

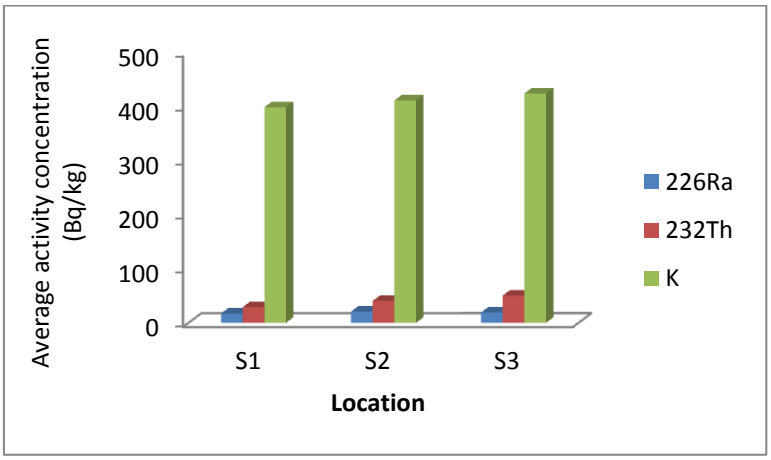

Figure 12 Average activity concentration in different location.

Table 5 Radium equivalent activities and absorbed dose rate in soil samples

Sample Name	Ra_{eq}(Bq/kg)	D (nGy/h)
RSS1	90.88	42.77
RSS2	100.86	47.10
RSS3	165.43	76.23
BSS1	77.24	36.78
BSS2	148.39	69.19
BSS3	72.54	35.13
SSS1	116.92	54.98
SSS2	92.55	44.22
SSS3	151.91	70.02
PSS1	72.32	35.42
PSS2	99.56	46.80
PSS3	106.18	49.99

Table 6 Comprison of absorbed dose rate in different location.

Countries	Absorbed dose rate ($nGyh^{-1}$)	Methodology
Romania[5]	81	Soil analysis using gamma spectrometry
Nigeria[6]	128	Analysis of rocks using gamma spectrometry
China[5]	69	Soil analysis using gamma spectrometry
Chittagong (Bangladesh)[7]	75	Soil analysis using gamma spectrometry
India[8]	95.2	Soil analysis using gamma spectrometry
World average[5]	55	-
Present Study	50.72	Soil analysis using gamma spectrometry

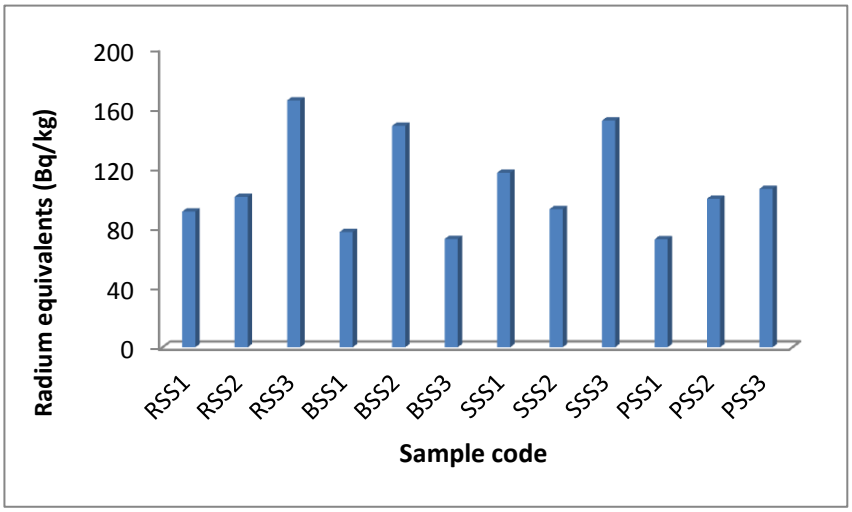

Figure 13 Radium equivalents activity in different soil samples.

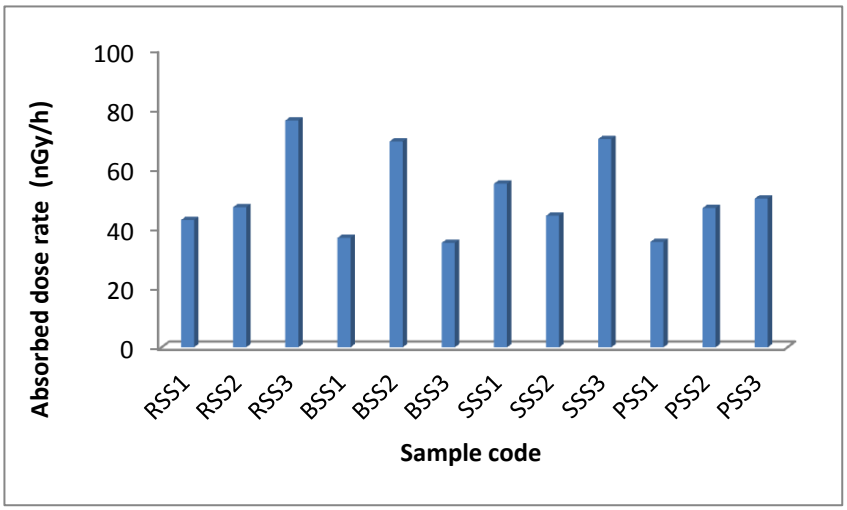

Figure 14 Absorbed dose rate in different soil samples.

Conclusion

In conclusion, the average activity concentrations are 19.06± 9.1 Bqkg^{-1} for ^{226}Ra, 37.64 ± 18.1 Bqkg^{-1} for ^{232}Th, 411.2 ± 39.0 Bqkg^{-1} for ^{40}K. This study observed that the average ^{40}K activity concentration obviously exceeds the values of ^{226}Ra and ^{232}Th in the study places. The average natural activity values of all analysis samples were less than the world average value for ^{226}Ra, ^{232}Th and ^{40}Kactivity. The calculated average radium equivalent activity value is 107.9 Bqkg^{-1}. This average value is below the allowable limit 370 Bqkg^{-1}recommended by the International Atomic Energy Agency (IAEA). The average absorbed dose rate value is 50.72 nGyh^{-1}in this study. These values are comparable to the world average of 55 nGyh^{-1}. The reported data in the present work can be considered as base values for distribution of natural radionuclides in the studied region.

Acknowledgements

We express our thanks to Dr Thida Win, Ractor, University of Mandalay, her permission and encouragement to conduct this research work.

References

Canadian Nuclear Safety commission " Introduction to Radiation ",2012.

G.Alzubaidi et al., J. Sci. World. **26**(2016)

M. I. Chowdhury et al., Appl. Radiat. Isot.,**51** (1999) 747-755.

M.S.Jaafar et al., Elixir Chem. Phys.**53** (2012) 12079-12081

O.S. jayi et al ., Health Phy.. **79** (2000)74-78.

S.Selvasekarapandian et al., J.Radional. Nucl. Chem., **252** (2002) 74-78

UNSCEAR, Explosure from natural sources of radiation. New York (1988)

UNSCER, Sources and Effects of Ionizing Radiation. (2000)