Advances in Engineering Research, volume 178
Mizoram Science Congress 2018 (MSC 2018)

Measurement of natural radioactivity using NaI (Tl) detector in soil samples collected from Aizawl, Mizoram, India

Vanramlawma[1], Hmingchungnunga[1], Remlalsiama[1], Laldingngheta[1], L.Z. Chhangte[1], Z. Pachuau[1], B. Zoliana[2*], Rosangliana[2], B.K. Sahoo[3], B.K. Sapra[3]

[1]Department of Physics, Mizoram University, Tanhril 796004, Mizoram, India
[2]Department of Physics, Government Zirtiri Residential Science College, Aizawl 796007, Mizoram, India
[3]Radiological Physics and Advisory Division, Bhabha Atomic Research Centre, Mumbai 400085, India

*Corresponding author: bzoliana@gmail.com

Measurement of natural radioactivity in soil samples collected from Aizawl district, Mizoram, was carried out using gamma spectrometer 5"X 4" NaI (Tl) detector. Soil samples were collected from 15 different sites located in various parts of Aizawl district. The activity concentrations were measured for three specific radionuclides, *viz.* ^{238}U, ^{232}Th and ^{40}K. The activity concentration of ^{238}U nuclides was found to be in the range of 20.13 Bq/kg to 60.4 Bq/kg, with an average value of 34.03 Bq/kg. For ^{232}Th nuclides, the activity concentration ranges between 53.68 Bq/kg to 161.03 Bq/kg, with an average value of 90.71 Bq/kg. For ^{40}K nuclides, it ranges from 279.58 Bq/kg to 964.62 Bq/kg, with an average value of 765.35 Bq/kg. To assess the uniformity of natural radioactivity in soil with respect to exposure, the radium equivalent activity was calculated and was found to be in the range of 135.62 Bq/kg to 350 Bq/kg, with an average value of 217.32 Bq/kg. Except for ^{238}U nuclides, the overall average activity concentrations of ^{232}Th and ^{40}K nuclides in collected soil samples were found to be higher than world average, but lower than the critical value set by IAEA. The radium equivalent activity value in all the samples was found to be lower than the critical value of 370 Bq/kg. Hence, no radiological hazards were observed within the specified study area.

Keywords: Radionuclide, activity concentration, NaI (Tl) detector, soil.

INTRODUCTION

Natural radioactivity is a common occurrence in nature. Natural radionuclide can be broadly classified into two types – cosmogenic (which comes from cosmic ray particles undergoing nuclear reactions), and Primordial (which are in existence since the origin of Earth) (Radenkovic *et al.*, 2009; Tzortzis *et al.*, 2003). Primordial radionuclide such as ^{238}U and ^{232}Th usually has a very long half-life and are found in the earth's crust. They are important sources of naturally occurring radionuclides (NORM) because they continuously decay into another radioactive element. This process of decaying continues on and on, thereby forming a decay chain. Radionuclide of ^{238}U, ^{232}Th and ^{40}K and their corresponding daughter elements are the main source of gamma radiations on earth (Ya-Xin *et al.*, 2005). Their distribution on the terrestrial surface mainly depends on the distribution of rocks or soil from which they originate and on the processes through which they are concentrated (Mahur *et al.*, 2008; Kabir *et al.*, 2009).

Measurement of natural radioactivity in soil is extremely important because gamma radiations emitted from NORM represents the main external source of irradiation of the human body (Alaamer, 2008; UNSCEAR, 1993). Human beings inhale or ingest many radionuclide and their radioactive isotopes present all around us, from which they are mainly exposed by outdoor natural terrestrial radiations that originates predominantly from upper 30 cm layer of soil present on earth (Chikasawa *et al.*, 2001). Estimation of gamma radiation level is needed to give a useful reference against radiation safety meas-

ures and protection (Harb *et al.*, 2008). The presence of ^{238}U, ^{232}Th and ^{40}K radionuclide in soil also leads us to identify the origin and abundance of their daughter elements like radon, thoron and their progenies.

The present work aims at measuring the natural radioactivity in soil samples collected from Aizawl, Mizoram which is located in the North- Eastern region of India, by utilizing NaI (Tl) gamma spectrometry.

Materials and Methods

Figure 1 shows the geographical sites from where the soil samples were collected. The sampling area extends from 23°34'23.6''N to 23°48'49.6''N latitude and from 92°39'51.9''E to 92°51'28.2''E longitude. Soil samples were collected from 15 different locations within the study area and background gamma radiation levels were taken using gamma survey meter PM-1050 at the time of sampling.

Measurement of natural radioactivity using NaI (Tl) detector

The measurement of activity concentration of ^{238}U, ^{232}Th and ^{40}K in the soil samples collected was carried out by using thallium (Tl) activated 5" X 4" sodium iodide (NaI) detector. The detector was connected to a GSPEC-SA (version 2.5 X), which is simply a PC-based multichannel analyzer. To overcome background radiation, the detector is enclosed inside a cylindrical lead and iron shield. For efficiency calibration, standard source of ^{238}U, ^{232}Th and ^{40}K were analyzed using the GSPEC-SA multichannel analyzer for a period of 10800 seconds (3 hours). For the gamma energy peak obtained, the efficiency was calculated using the formula:

Figure 1: Geographical Map of the study area of Aizawl.

$$\eta(\%) = \frac{Area/_{sec}}{dps} X \frac{100}{Ab\%} X100 \quad (1)$$

Where,

η(%) = Percent efficiency

Area/sec= Net peak area per second (background subtracted)

dps = Source strength

Ab% = Gamma ray abundance factor

To measure the activity concentration of soil, the soil samples were first dried and heated using a heater at a temperature of about 110°C. The collected samples were ground into powdered size and sieved using a 500 µmmesh. It was then sealed inside an air-tight container of 250 ml and was kept undisturbed for a minimum period of 30 days to attain radioactive equilibrium.

Before measuring the natural radioactivity in the sample, a three-point energy calibration was carried out using sources containing a mixture of several radionuclides (ISO, 2007). In this present study, ^{60}Co and ^{137}Cs sources were used for energy calibration. This calibration allows the establishment of the relationship between the channel numbers of the analyzer and the known energy of the photons (BIPM, 2004).

The radioactivity content of the samples was then obtained by analyzing with GSPEC-SA Multichannel Analyzer for a period of 50,000 seconds. In this analysis, the activity concentrations were determined for ^{238}U, ^{232}Th and ^{40}K after removing the background radiation content. Since secular equilibrium was reached between ^{238}U and ^{232}Th and their decay products, the ^{238}U concentration was determined from the average concentrations of ^{226}Ra and that of ^{232}Th was determined from the average concentrations of the ^{228}Ac. The activity concentrations of ^{238}U-series (^{226}Ra), ^{232}Th- series (^{228}Ac), as well as ^{40}K, was expressed in Bq/kg. The weights of the samples were measured and the activity concentration (A) was obtained (in Bq/kg) for each samples using the formula:

$$A = \frac{N}{T} X \frac{100}{\gamma\%} X \frac{100}{\eta\%} X \frac{1}{Wt} \quad (2)$$

where,

N/T = Background subtracted net photo peak counts in time 'T'.

γ = abundance of gamma ray under consideration.

η = absolute detection efficiency obtained from the energy efficiency calibration.

Wt = weight of the sample

Determination of radium equivalent activity

Uniformity of natural radioactivity in soil with respect to exposure to radiation has been defined in terms of radium equivalent activity (Ra_{eq}) to compare the specific activity of materials containing different amounts of ^{226}Ra, ^{232}Th and ^{40}K (Kansal and Mehra, 2015).

$Ra_{eq} = C_{Ra} + 1.43\ C_{Th} + 0.07\ C_{K-}$ -------- (3)

Where C_{Ra}, C_{Th} and C_K represents the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K (in Bq/kg) respectively.

Classification of soil type using USDA triangle

Sample soil classification was carried out by adapting the United States Department of Agriculture (USDA) textural soil classification system. It consists of three main primary classifications, namely, sand, silt and clay. These three classifications are further divided into 12 classes. A triangular plot, called the USDA triangle was employed for this purpose (García-Gaines *et al.*, 2015).

Sample soils were first dried and then sieved using a mechanical sieve shaker for a period of 20-30 minutes. Five different sieves of sieve mesh number, namely, 60 (grain size 0.25 mm which corresponds to medium sand), 120 (grain size 0.125 mm which corresponds to fine sand), 230 (grain size 0.0625 mm which corresponds to very fine sand), 325 (grain size 0.044 mm which corresponds to silt/mud) and >325 (grain size smaller than 0.044 mm which corresponds to clay) was used to identify the grain size distribution. Percentage of the grain size distribution obtained was then plotted using USDA triangular plot.

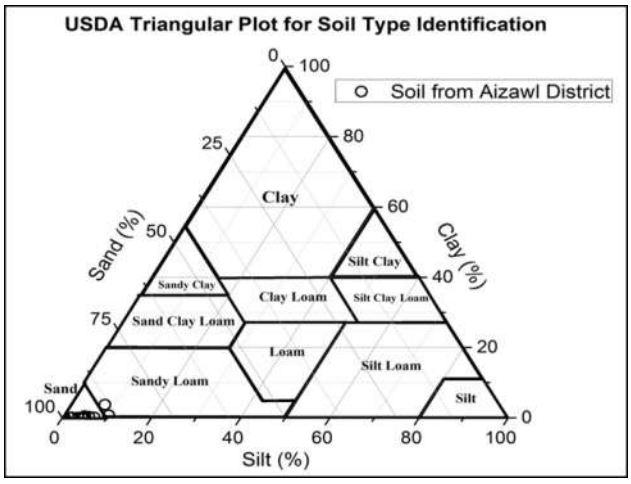

Figure 2: USDA triangular plot determining the soil type of Aizawl district.

RESULTS

Table 1 gives the results of measurement of efficiency calculation of the detector with respect to the given standard source of ^{238}U, ^{232}Th and ^{40}K nuclides. The efficiency was found to be 15.8%, 8.87% and 3.48% for ^{232}Th, ^{238}U and ^{40}K respectively.

Table 2 gives the results of measurement of natural radioactivity concentration of ^{238}U, ^{232}Th and ^{40}K radionuclides in soil samples collected from 15 different locations within the study area. The activity concentration of ^{238}U was estimated on the basis of ^{226}Ra activity concentrations. Also, the activity concentration of ^{232}Th was estimated on the basis of ^{228}Ac activity concentrations. The measured values of activity concentration for ^{238}U ranged from 20.13 Bq/kg to 60.4 Bq/kg, with an average value of 34.03 Bq/kg. For ^{232}Th, the activity concentration ranged from 53.68 Bq/kg to 161.03 Bq/kg, with an average value of 90.71 Bq/kg. For ^{40}K, activity content ranged from 279.58 Bq/kg to 964.62 Bq/kg, with an average value of 765.35 Bq/kg. It had been found that in all of the soil samples measured, ^{40}K was the most abundant of the three natural radionuclides which was taken into account. To assess the radiation hazards associated with these radionuclides, the radium equivalent activity was calculated and was found to be in the range of 135.62 Bq/kg to 350 Bq/kg, with an average value of 217.32 Bq/kg.

Figure 2 shows the triangular plot employed by United States Department of Agriculture for determining soil type of collected samples. Most of the soil samples collected was found to be of sandy type, while a few of them are found to be of sandy loam type.

DISCUSSION

The level of natural radioactivity for soil samples was measured using NaI (Tl) gamma spectrometry. The measured average activity concentrations of ^{238}U, ^{232}Th and ^{40}K in this study were found to be 34.03 Bq/kg, 90.71 Bq/kg and 765.35 Bq/kg respectively. The radium equivalent activity was calculated from the observed activity concentrations and the average value was found to be 217.32 Bq/kg, and was found to be lower than the critical value of 370 Bq/kg (OECD, 1979).

Except for ^{238}U nuclides, the overall average activity concentrations of ^{232}Th and ^{40}K nuclides in collected soil samples were found to be higher than the corresponding worldwide average values of 35, 30 and 400 Bq/kg respectively (UNSCEAR, 2000). The results obtained in this report was found to be much lower than the critical values of 10,000 Bq/kg for ^{40}K, 1000 Bq/kg for ^{238}U and ^{232}Th radionuclide, set by IAEA (IAEA, 2004). Hence, no radiological hazards were observed in this study.

ACKNOWLEDGEMENT

The authors would like to acknowledge the Board of Research in Nuclear Sciences, Department of Atomic Energy, Government of India, for providing financial assis-

Table 1: Efficiency calibration of NaI (Tl) detector using ^{232}Th, ^{238}U & ^{40}K standard sources.

Sl. No.	Element	Counting Time (Sec)	Activity (Bq)	Net Area	Abundance Factor (%)	Efficiency (η) (%)
1	^{232}Th	10800	3854.21	263134	4	15.80
2.	^{238}U	10800	1636	297805	19	8.87
3.	^{40}K	10800	4557.59	188600.3	11	3.48

Table 2: Activity concentrations of ^{238}U, ^{232}Th & ^{40}K radionuclides, radium equivalent activity, background gamma and soil grain size distribution.

Sl. No.	Location Code	Background Gamma (nSv/hr)	U-238 (Bq/kg)	Th-232 (Bq/kg)	K-40 (Bq/kg)	Ra_{eq} (Bq/kg)	Grain Size Distribution (in %)		
							Sand	Silt	Clay
1	Azl 1	153	21.74	57.95	909.18	168.24	99.38	0.08	0.02
2	Azl 2	148	29.29	78.08	914.35	204.94	93.64	4.93	0.27
3	Azl 3	182	21.20	56.53	479.76	135.62	94.64	4.79	0.46
4	Azl 4	163	60.40	161.03	847.52	350.00	97.12	2.05	0.13
5	Azl 5	171	35.02	93.35	690.84	216.87	98.29	0.41	0.07
6	Azl 6	181	40.09	106.89	809.82	249.63	93.57	5.81	0.29
7	Azl 7	163	43.43	115.79	279.58	228.59	99.28	0.48	0.01
8	Azl 8	160	28.43	75.79	642.74	181.81	94.46	4.83	0.07
9	Azl 9	187	50.81	135.46	919.07	308.86	94.79	4.34	0.03
10	Azl 10	156	20.26	54.01	588.68	138.70	95.94	3.57	0.04
11	Azl 11	186	31.06	82.80	911.81	213.30	92.64	7.08	0.12
12	Azl 12	182	32.38	86.32	894.45	218.43	97.80	2.09	0.03
13	Azl 13	136	38.30	102.11	835.29	242.79	97.63	1.78	0.01
14	Azl 14	163	37.84	100.88	964.62	249.62	89.08	10.07	0.70
15	Azl 15	172	20.13	53.68	792.48	152.36	88.39	7.72	3.72

tance through research project.

REFERENCES

Alaamer, G.A.S. (2008). Assessment of Human Exposures to Natural Sources of Radiation in Soil of Riyadh, Saudi Arabia. *Turkish Journal of Engineering & Environmental Sciences*, **32**, pp. 229-234.

Bureau International des Poids et Mesures Table of Radionuclides (2004). Monographie BIPM-5.

Chikasawa, K., Ishii, T., Ugiyama, H. (2001). Terrestrial gamma radiation in Kochi Prefecture, Japan. *J Health Sci*, **47**, pp. 361–372.

García-Gaines, R. A., Frankenstein, S. (2015). *USCS and the USDA Soil Classification System: Development of a Mapping Scheme*. ERDC/CRREL TR-15-4. pp 5-7.

Harb, S., El-Kamel, A.H., El-Mageed, AI Abd, Abbady, A., Negm, H.H. (2008). Natural radioactivity measurements in soil and phosphate samples from El-Sabaea, Aswan, Egypt. *IX Radiation Physics & Protection Conference*, Nasr City, Cairo, Egypt.

IAEA (2004). Application of the concepts of exclusion, exemption and clearance. *Safety Standards Series No.* RS-G-1.7.

International Standard, ISO 18589-3:2007(E), 7.3.1. Energy calibration.

Kabir, K.A., Islam, S.M.A., Rahman, M.M. (2009). Distribution of radionuclides in surface soil and bottom sediment in the district of Jessore, Bangladesh and evaluation of radiation hazard. *Journal of Bangladesh Academy of Sciences*, **33**, pp. 117-130.

Kansal, S., Mehra, R. (2015). Evaluation and analysis of ^{226}Ra, ^{232}Th and ^{40}K and radon exhalation rate in the soil samples for health risk assessment. *Int. J. Low Radiation*, **10**, pp.1–13.

Mahur, A.K., Kumar, R., Sonkawade, R.G., Sengupta, D., Prasad, R. (2008). Measurement of natural radioactivity and radon exhalation rate from rock samples of Jaduguda uranium mines and its radiological implications. *Nuclear Instruments and Methods in Physics Research B*, **26**, pp. 1591–1597.

OECD (Organisation for Economic Co-Operation and Development) (1979). *Exposure to Radiation from the Natural Radioactivity in Building Materials.* Report by a Group of Experts of the OECD Nuclear Energy Agency, Paris.

Radenkovic, M.B., Alshikh, S.M., Andric, V.B., Miljanic, S.S. (2009). Radioactivity of sand from several renowned public beaches and assessment of the corresponding environmental risks. *Journal of the Serbian Chemical Society*, **74**, 461-470.

Tzortzis, M., Tsertos, H., Christofides, S., Christodoulides,

G. (2003). Gamma ray measurements of naturally occurring radioactive samples from Cyprus characteristic geological rocks. *Radiation Measurements*, **37**, pp. 221-229.

United Nations Scientific Committee on the Effects of Atomic Radiation (1993). *Sources and Effects of Ionizing Radiation*. UNSCEAR Report, New York.

United Nations Scientific Committee on the Effects of Atomic Radiation (2000). *Sources and Effects of Ionizing Radiation*. United Nations, New York.

Yang, X.I., Wu, X.M., Jiang, Z.Y., Wang, W.X., Lu, J.G., Lin, L., Wang, L.M., Hsia, Y.F. (2005). Radioactivity concentration in soil of the Xiazhuang granite area. *China Appl. Isot. Radiat*, **63**, 255-259.