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Analysis of Natural Radioactivity of Soil Samples using NaI (Tl) Detector from Fault Regions of Kolasib, Mizoram, India

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***Abstract*— Measurement of natural radioactivity in soil samples collected from Fault regions of Kolasib District, Mizoram has been carried out using 5"x 4" NaI (Tl) Detector. The purpose of this study is to examine the safety levels of activity concentrations in soil.The average activity concentrations collected from the soil samples for ^{238}U, ^{232}Th and ^{40}K were found to be 37 Bq/kg, 102 Bq/kg and 678 Bq/kg which are higher than worldwide values of 35 Bq/kg, 30 Bq/kg and 400 Bq/kg respectively. The average radium equivalent activity concentrations levels obtained from the soil samples were found to be of 237 Bq/kg and were found to be within the safe limit of 370 Bq/kg recommended by UNSCEAR. The average values of the external and internal hazard indices were 0.63 and 0.74 and are less than unity and are therefore considered safe and can be used for construction materials.**

Keywords*—NaI (Tl) detector,Activity concentration, Radium equivalent activty, Hazard indices

I. INTRODUCTION

The study of radiation distribution and radiation levels is significant for assessing the exposure to human beings. Human beings have always been exposed to natural radiations from terrestrial and extraterrestrial radiations. Due to different geological features, absorbed dose rate from cosmic radiation varies with them. Natural radionuclides can be categorised as Cosmogenic and Primordial sources. The main difference between them is that cosmogenic comes from cosmic ray particles from the Sun and stars interacting with the earth's atmosphere and undergoing nuclear reactions while Primodial are those which are in existence since the origin of Earth. The higher levels of terrestrial background radiation are mainly associated with igneous rocks [1-2]. The main source of gamma radiations on earth are usually radionuclides of 238U, 232Th and 40K and their corresponding daughter elements [3]. Rocks, soil present on earth, in water and in building materials used for construction purposes may be the sources of primordial long-lived radionuclides such as 238U, 226Ra, 232Th and 40K. Radionuclides and their radioactive isotopes present in air, water and food, from which they are mainly exposed by outdoor natural terrestrial radiations are inhaled by human beings [4].

The main aim of this study is to examine the activity concentrations in soil. Analysis of radioactivity of soil samples is significant for acquiring data for dose estimation. The Gamma radiation resulting from the Primordial radionuclides of 238U, 232Th and 40K and their daughter elements are the main source of irridation of the human body. Data regarding natural radioactivity of soil samples around fault regions of Kolasib District has not been acquired by other researchers and this is the first time for this particular study in the areas. The objective of this is to get a base line data for the regions and to determine whether the average activity concentrations are well within the recommended maximum activity concentration as recommended by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

In this study soil samples collected from the various fault regions of Kolasib District are studied using thallium (Tl) activated 5"x4"Sodium Iodide (NaI) detector. The activity concentrations of radionuclides of 238U, 232Th and 40K as well as Radium equivalent (Raeq) activity are measured. External and internal hazard indices were also measured so as to ensure that the soils from the areas of study are safe for construction purposes. Radium equivalent activity is most widely used index to assess radiation hazards and is weighted sum of activities or radiological effect of materials that contain different natural radionuclides 238U, 232Th and 40K [5].

Radon and Thoron concentration measurements have been carried out in other areas of Mizoram using other devices by other scholars in the past. These studies have been done in areas of Mat Fault [6-7].Apart from this continuous measurements of radon concentration have also been carried out in Chite Fault [8-9]. The present study has been carried out for the first time in different fault regions of Kolasib.

II. STUDY AREA

Mizoram lies in the seismic zone V of seismic zonation map of India located between 22º19'N and 24º19'N latitude and 92º 16'E and 93º 26' E longitude. The state of Mizoram is a hilly area with an average elevation of about 1000 meters to 1300 meters from sea level. It is a tropical region with moderate climate and the temperature varies from 11ºC to 24 ºC during the winter season and 18 ºC to 29 ºC during summer. The study area of Kolasib lies in the northern parts of Mizoram sharing its borders with Assam and the geographical map of the studied region is shown in figure 1. The study area extends 23º53'29.57''to 24º28'16.1'' latitude and 92º39'33.97'' to 92º48'40.71'' longitude.

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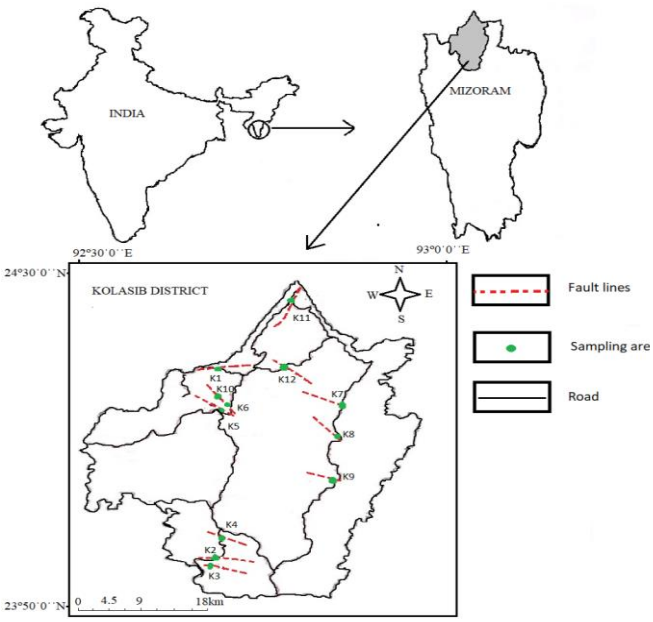

Fig 1: Geographical Map of the studied region of Kolasib

III. METHODOLOGY

Thallium (Tl) activated 5"x 4"Sodium Iodide (NaI) detector was used for measurement of activity concentration of ^{238}U, ^{232}Th and ^{40}K in the soil samples collected which was connected to a PC based multi-channel analyzer also known as GSPEC-SA (Version 2.5 X) as shown in figure 2. To overcome background radiation, the detector is enclosed in a cylindrical lead and iron shield. The concentrations of ^{238}U were determined using a photo peak of photo peak of 295 keV (19%) from ^{214}Pb, ^{232}Th concentration were determined using a photo peak of 270 keV (4%) from ^{228}Ac. ^{40}K concentration were determined from its 1460 keV (11%) photo peak.

The soil samples were collected from 12 selected fault regions of Kolasib District as shown in figure 1. The samples were dried and heated using a heater at a temperature of about 110°C. The collected samples were then grinded into powder size and were sieved using a 500 µm mesh.The grinded samples were then sealed inside an air-tight plastic container of 250ml and were kept undisturbed for a minimum period of 30 days to attain radioactive equilibrium. The weights of the samples were also measured and recorded.

Before measuring the natural radioactivity in the sample, a three-point energy calibration is carried out using sources containing a mixture of several radionuclides [10]. In this present study, IAEA standard source of ^{60}Co and ^{137}Cs 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 [11].

For efficiency calibration, IAEA standard source of ^{238}U, ^{232}Th and ^{40}K were analyzed using the multichannel analyzer for a period of 10800 sec. For the gamma energy peak obtained, the efficiency was calculated using the formula:

$$\eta(\%) = \frac{Area/_{Sec}}{Dps} \times \frac{100}{Ab\%} \times 100 \quad (1)$$

Where,
η (%) = Percent Efficiency
Area/Sec= Net peak area per second (background subtracted)
dps = Source strength
Ab% = Gamma ray abundance factor

Background subtracted net photo peak data for ^{232}Th, ^{238}U and ^{40}K are shown in table 1. The Multichannel Analyzer was then used for determination of radioactivity content of the samples for a period of 50,000 seconds. Since radioactive equilibrium was established, the ^{238}U and ^{232}Th concentrations were determined from the concentrations of their daughter elements, namely ^{214}Pb and ^{228}Ac respectively. The activity concentrations were expressed in terms of Becquerel per kilogram (Bq/kg). The formula for activity concentration (A) was for each sample is given by:

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

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

The radium equivalent activity provides a guideline for regulation of safety standards against radiation protection for the general public and it is calculated by using following equation

$$Ra_{eq}\,(Bq/kg) = C_U + 1.43\,C_{Th} + 0.077\,C_K \quad (3)$$

Where, C_U, C_{Th} and C_K represents activity concentrations in Bq/kg of ^{238}U, ^{232}Th and ^{40}K respectively.The formula for External hazard index is given by [12]:

$$H_{ex} = \frac{C_U}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad (4)$$

And the formula for Internal Hazard Index is given by [13]:

$$H_{in} = \frac{C_U}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad (5)$$

Fig 2: NaI Detector

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IV. Result And Discussion

The calculation for Efficiency Calibration of NaI Detector was done based on equation 2 using ^{232}Th, ^{238}U and ^{40}K standard sources is given in the table 1. The efficiency measured was found to be 13% for ^{232}Th, 7% for ^{238}U and 2% for ^{40}K.

Table 1: Efficiency Calibration of NaI Detector using ^{232}Th, ^{238}U and ^{40}K standard source.

Sl.no	*Element*	*Counting Time (Sec)*	*Activity (Bq)*	*Net Area*	*Branching Intensity (%)*	*Counts per second*	*Efficiency (η) (%)*
1	232Th	10800	3854	229392	4	21	13
2	238U	10800	1636	267803	19	24	7
3	40K	10800	4557	195742	11	18	2

The measurement of Activity Concentrations of ^{238}U, ^{232}Th and ^{40}K radionuclide in soil samples collected from 12 different fault regions of Kolasib District are given in table 2. These values show different variations when compared with each other as shown in figure 3. The activity concentrations collected from the soil samples were found to be in the range of 12 Bq/kg to 58 Bq/kg for ^{238}U, 34 Bq/kg to 161 Bq/kg for ^{232}Th and 175 Bq/kg to 1190 Bq/kg for ^{40}K with an average of 37 Bq/kg, 102 Bq/kg and 678 Bq/kg for ^{238}U, ^{232}Th and ^{40}K respectively.

Table 2. Activity Concentrations, Radium equivalent activity, External and internal hazard indices of ^{238}U, ^{232}Th and ^{40}K radionuclide in soil samples collected from fault regions of Kolasib District

SAMPLE CODE	ACTIVITY CONCENTRATION (Bq/kg)			Radium equivalent Activity (Bq/kg)	External Hazard Index (Hex)	Internal Hazard Index (Hin)
	^{238}U	^{232}Th	^{40}K			
K-1	12	34	615	108	0.29	0.32
K-2	32	89	774	220	0.59	0.68
K-3	36	101	858	247	0.66	0.76
K-4	51	141	1190	344	0.93	1.06
K-5	43	119	885	282	0.76	0.88
K-6	58	161	736	346	0.93	1.09
K-7	25	68	765	182	0.49	0.56
K-8	22	62	221	129	0.34	0.40
K-9	53	147	175	277	0.74	0.89
K-10	29	82	660	197	0.53	0.61
K-11	50	138	642	297	0.80	0.93
K-12	32	88	619	206	0.55	0.64

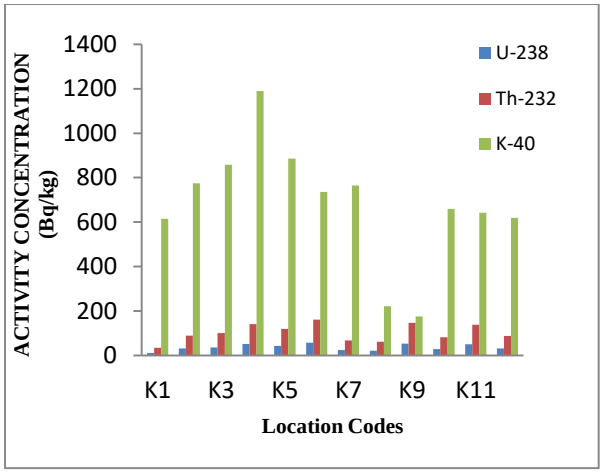

Fig 3: Activity Concentrations of ^{238}U, ^{232}Th and ^{40}K radionuclide in soil samples collected from fault regions of Kolasib District

The Radium equivalent activity concentrations were also determined and shown in table 2. The measured values of Radium equivalent activity concentrations are within the range of 108 Bq/kg to 346 Bq/kg with an average of 237 Bq/kg. Figure 4 shows the various ranges of Radium equivalent activity concentrations of the different regions.

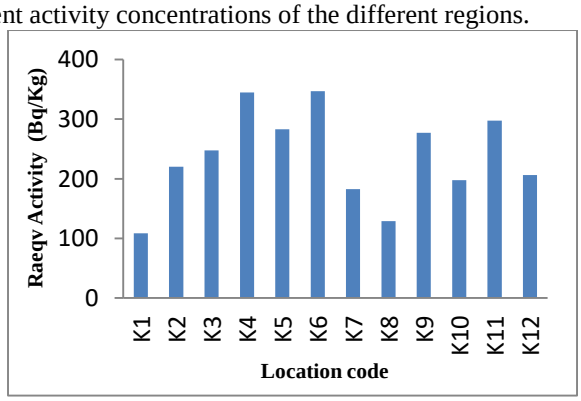

Fig 4: Radium Equivalent Activity Concentrations of ^{238}U, ^{232}Th and ^{40}K radionuclide in soil samples collected from fault regions of Kolasib District

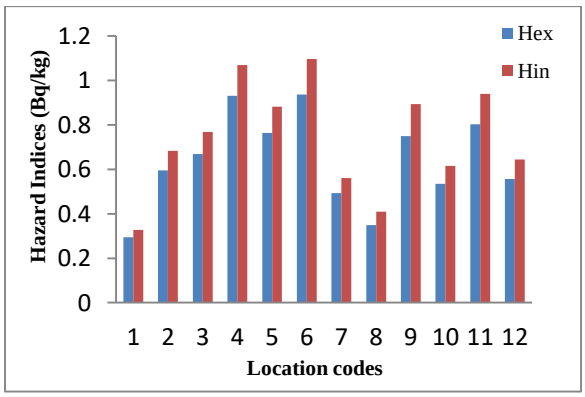

Fig 5: External and internal hazard indices of ^{238}U, ^{232}Th and ^{40}K radionuclide in soil samples collected from fault regions of Kolasib District

The external and internal hazard indices were also measured as given in table 2 and are within the range of 0.29

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to 0.93 with average value of 0.63 for H_{ex} and 0.32 to 1.09 with average value of 0.74 for H_{in}. The various ranges of external and internal indices are shown in figure 5.

V. CONCLUSIONS

The average natural activity concentrations of ^{238}U, ^{232}Th and ^{40}K collected from the soil samples are 37 Bq/kg, 102 Bq/kg and 678 Bq/kg which are higher than the corresponding worldwide values of 35 Bq/kg, 30 Bq/kg and 400 Bq/kg respectively, but these values are lower than IAEA critical values of 10,000 Bq/kg for ^{40}K and 1000 Bq/kg for all other radionuclides [14].

The Radium equivalent activity concentrations levels obtained from the soil samples are within the range of 108 Bq/kg to 346 Bq/kg with an average of 237 Bq/kg. Radium equivalent activity concentration levels for the different regions have been found to be within the safe limit of 370 Bq/kg recommended by UNSCEAR (2000) [15].

The values of the external hazard indices ranges from 0.29 to 0.93 with an average value of 0.63 and the values of internal hazard indices ranges from 0.32 to 1.09 with an average of 0.74. According to Radiation Protection 112, soil from the region is safe and is no threat to the population if the values of the corresponding external and internal indices are less than unity [16]. From the results we can see that the average values of both the external and internal hazard indices are less than unity but the values of K-4 and K-6 have values of 1.06 and 1.09 which is more than 1(unity). So soil from these areas excluding K-4 and K-6 are considered safe and can be used for construction materials.

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