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Analysis of Radon Mass Exhalation in Soil Samples from Fault Regions of Kolasib District Mizoram, India

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Abstract: In order to identify the distribution of radon mass exhalation soil samples from fault regions of Kolasib District were obtained. These were measured and analysed using scintillation based smart RnDuo device. The soil samples were collected from three different points in each selected fault. The exhalation rates from different locations ranges from 2.3 mBq/kg/hr – 54.19 mBq/kg/hr with an average of 20.42 mBq/kg/hr. Gamma survey measurement was also carried out which ranges between 89 nSv/hr – 157 nSv/hr with an average of 117.13 nSv/hr. The correlation graph between mass exhalation and gamma survey was plotted and a very weak correlation was obtained.
Keywords: Radon, mass exhalation, soil samples, RnDuo, fault

I. INTRODUCTION

The main source of radiation comes from cosmic rays, solar radiation and radioactive elements from the earth. The atmosphere prevents a majority of radiations from cosmic and solar radiations from reaching the earth but decay of radioisotopes like uranium, thoron, radium and radon. Radon is gas formed on the fourteenth step of sequence of ^{238}U radioactive decay series and is being continuously formed in the soil and released in air. This radon gas released in the air occupies 43% of radiation received by human beings and is usually the reason of lung cancer[1-2].

The movement of radon inside the soil is called emanation where radon is released into small air or water contained in pores between soil and rock particles and when it arrives at the soil surface it exhales into the atmosphere. The movement of radon is achieved by means of diffusion, advection and by means of gas transport[3]. The concentration of radon in soil is influenced by soil moisture content, barometric pressure variations, temperature and structure of soil. Radon becomes environmental hazards when it remains concentrated in enclosed places such as houses, caves and mines. Indoor radon and its influence on health has been studied by many researchers and the main contributor to these indoor concentration are radon from the soil and its exhalation[4-5]. Therefore radon and its exhalation from the soil are significant in obtaining data to be used in indoor concentration as well as for baseline data for further studies.

The purpose of this study is to obtain data for exhalation rates from soil samples collected from fault regions of Kolasib district, Mizoram, India. The fault regions are selected because faults are also responsible for movement of radon through rocks inside the earth[6]. This is the first investigation done regarding mass exhalation in soil samples on fault regions of Kolasib district. The results from this investigation will provide data for further studies in the future.

In this work, the radon exhalation from soil samples collected from various fault regions of Kolasib District, Mizoram are measured along with gamma survey of each region. The results are compared with the exhalation of radon in some parts of India.

II. MATERIALS AND METHODOLOGY

The study area is located at north-east of India on Kolasib district in the state of Mizoram which lies in the seismic zone V of seismic zonation map of India. The geographical sites where the soil samples were collected from the fault lines are as shown in Fig 1. Kolasib district is located on the north of Aizawl, which is the capital of the state Mizoram. It is a tropical region with moderate climate and the temperature varies from 11℃ to 24 ℃ during the winter season and 18 ℃ to 29 ℃ during summer. The sampling area extends from N 23° 53' 29.57" to N 24° 28' 16.1’’ latitude and E 092° 39'33.97" to E 092° 47'41.09" longitude.

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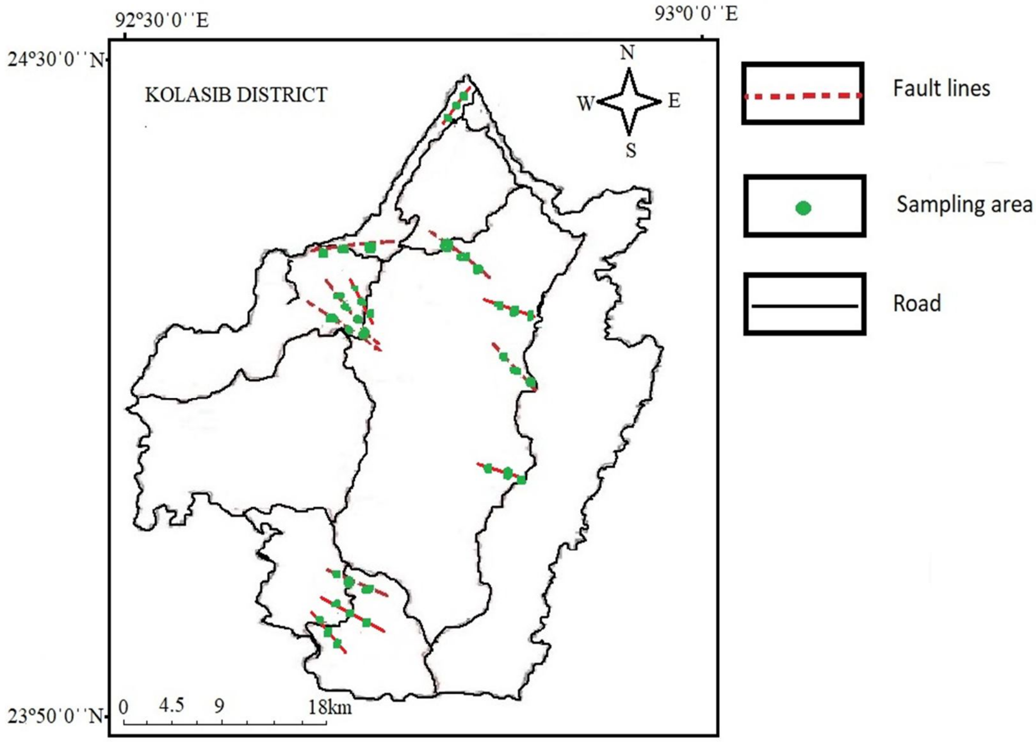

Fig 1: Study area of Kolasib district with sampling areas

Soil samples were collected from 36 different locations within the study area as shown in Fig 1. The soil samples were collected in such a way that for each fault line on the area, three samples were collected by means of gardening tools. The soil is burrowed a few centimeters deep depending on the structure of soil and the top most soil is avoided when sampling the soil. The samples are then brought back to the lab where they are analysed.

The Radon content in soil was obtained by means of scintillation cell method using Smart RnDuo. It is a technologically advanced portable radon /thoron monitor, designed for multiple applications in radon and thoron studies. By diffusion process, sample gas is collected into a scintillation cell and passes through a progeny filter and thoron discriminator eliminating the progenies. The thoron discriminator does not allow the short lived thoron to pass thorough. The radon measurements in RnDuo are based on detection of alpha emitted from radon and its decay products formed inside a scintillation cell volume and are continuously counted by the PMT and the associated counting electronics.

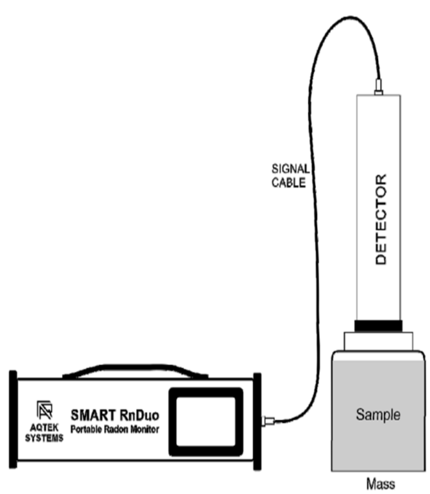

Fig 2: Smart RnDuo

When measuring radon, the volume and mass are taken before placing them on the exhalation chamber. The sample is then placed in the chamber and fitted with the detector connected by signal cable to the main device. The samples are then measured for a cycle of 60 minutes for a minimum of period of 8 hours. Build up data of radon with elapsed time can be retrieved and least square fitting can be carried out using the equation:

$$C(t) = \left(\frac{J_m M}{V}\right) t + C_o \qquad \rightarrow (1)$$

Where $C(t)$ is ^{222}Rn concentration $(Bq\,m^{-3})$ at time t, C_o is the ^{222}Rn concentration $(Bq\,m^{-3})$ present in the chamber volume at $t = 0$, M is the total mass of the dry sample (*Kg*). V is the effective volume (volume of detector + porous volume of sample + residual air volume of mass exhalation chamber) (m^3). The porous volume (V_P) can be estimated using the following Eqn. (2)

$$V_P = V_s - \left(\frac{M}{\rho_g}\right) \qquad \rightarrow (2)$$

Where V_s is the sample volume in the mass exhalation chamber. ρ_g is the specific gravity of the sample which can be taken as 2.77 *gm/cc* for clay type soil material. t is the measurement time (*hr*).
Upon least square fitting of the data to the above equations one may obtain the rate of radon exhalation per unit mass of the sample J_m from the fitted parameters with the information of the mass M of the sample.

Along with soil samples collected, gamma survey was done in each region where samples were collected. This is carried out with Survey Meter PM 1405 by detection block on the basis of Geiger-Muller counter by transformation of photon to electropulses. The detection and transfer of measured data to the main microprocessor controller are carried out by the embedded microprocessor controller. The instrument's output information is obtained on the LCD of the device. The measurement range for γ radiations is between the ranges of 0.1 $\mu Sv/hr$ – 100 mSv/hr. The measurements of gamma readings were detected using the survey meter at a distance of 1*m* above the ground.

III. RESULTS

The results of the mass exhalation from soil samples collected from different fault lines calculated using Eqn. (1) are shown in table 1. The exhalation rate varies as seen from the data with minimum value of 2.3 at K25 and maximum of 54.19 $mBq/Kg/hr$ at K36. The mass exhalation rates ranges from 2.3 $mBq/Kg/hr$ – 54.19 $mBq/Kg/hr$ with an average of 20.42 $mBq/Kg/hr$. This is comparable with fault regions of Aizawl District, in which the values of radon exhalation range between 11.2 $mBq/Kg/hr$ - 72.2 $mBq/Kg/hr$ with an average of 39.92 $mBq/Kg/hr$ [7]. The variation may be due to rainfall and moisture content in the soil as soil moisture content plays a significant role in exhalation [8]. The results obtained from this are also comparable to work done in Northern Rajasthan (14.96 $mBq/Kg/hr$), Kangra District, Himachal Pradesh (19.91 $mBq/Kg/hr$) and Kathmandu Valley, Nepal (6.4 $mBq/Kg/hr$)[9-11]. We can see that there are variations in different places when compared with each other. This may be due to differences in geology of the areas of study. The differences in structure of the land and soils play an important part in exhalation process. The presences of uranium in rocks underneath the earth are also the cause of high radon exhalation.
The gamma readings from soil samples collected from different fault lines are shown in table 1. The result ranges from 89 nSv/hr – 157 nSv/hr with an average of 117.13 nSv/hr. The maximum gamma reading is at K27 with a reading of 157 nSv/hr and minimum at K8 and K16 with both having values of 89 nSv/hr is shown in Fig. 4
The correlation graph between mass exhalation and gamma survey is shown in Fig 5. A very weak correlation was obtained and we can see that the correlation value R^2 = 0.086 which shows that the negative correlation.

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Table 1: Measurement of radon mass exhalation rate and gamma survey from fault regions of Kolasib district

Location code	*GPS Coordinate*	*Gamma Survey meter readings (nSv/hr)*	*Radon mass exhalation rate (mBq/kg/hr)*	*Error Percentage (%)*
K1	Elevation 23 m N 24° 20' 45.23" E 092° 40'08.88"	106	8.2	15
K2	Elevation 36 m N 24° 20' 51.39" E 092° 40'17.69"	101	11.9	15
K3	Elevation 44 m N 24° 20' 58.15" E 092° 40'32.85"	107	24.6	15
K4	Elevation 260 m N 24° 15' 27.80" E 092° 40'36.50"	141	35.5	15
K5	Elevation 351 m N 24° 15' 11.15" E 092° 40'37.48"	127	25.4	11
K6	Elevation 431 m N 24° 14' 49.92" E 092° 40'56.08"	119	35.9	16
K7	Elevation 385 m N 24° 14' 52.80" E 092° 41'36.26"	127	45.0	15
K8	Elevation 410 m N 24° 14' 59.27" E 092° 41'34.60"	89	12.8	13
K9	Elevation 403 m N 24° 14' 41.37" E 092° 41'24.56"	119	10.0	15
K10	Elevation 474 m N 23° 53' 29.57" E 092° 40'23.97"	98	11.0	15
K11	Elevation 468 m N 23° 53' 39.61" E 092° 40'25.25"	135	7.6	15
K12	Elevation 447 m N 23° 54' 14.22" E 092° 40'26.09"	110	5.6	16
K13	Elevation 186 m N 23° 55' 59.81" E 092° 40'19.32"	132	27.7	13
K14	Elevation 138 m N 23° 56' 04.76" E 092° 39'46.88"	108	28.4	15
K15	Elevation 152 m N 23° 56' 00.50" E 092° 39'33.97"	102	6.7	15
K16	Elevation 271 m N 23° 57' 59.14" E 092° 40'54.97"	89	28.8	10
K17	Elevation 313 m N 23° 57' 19.59" E 092° 41'04.06"	109	35.7	16
K18	Elevation 311 m N 23° 57' 11.55" E 092° 41'06.12"	118	32.7	16
K19	Elevation 48 m N 24° 20' 58.1" E 092° 45' 32.0"	129	9.9	15
K20	Elevation 38 m N 24° 20' 57.5" E 092° 45' 23.5"	130	11.5	15
K21	Elevation 37m N 24° 20' 59.0" E 092° 45' 16.6"	105	6.5	15
	Elevation 49 m	142	45.3	

K22	N 24° 28' 11.5" E 092° 46' 54.9"			13
K23	Elevation 53 m N 24° 28' 16.1" E 092° 46' 53.4"	130	45.7	15
K24	Elevation 58 m N 24° 28' 15.7" E 092° 46' 56.6"	157	26.2	15
K25	Elevation 350 m N 24° 14' 56.4" E 092° 41' 12.3"	120	2.3	15
K26	Elevation 360 m N 24° 14' 55.2" E 092° 41' 12.6"	127	9.8	13
K27	Elevation 365 m N 24° 14' 52.3" E 092° 41' 11.8"	145	21.6	14
K28	Elevation 679 m N 24° 14' 12.85" E 092° 48' 26.37"	127	18.95	16
K29	Elevation 695 m N 24° 13' 55.04" E 092° 48'24.42"	92	15.27	15
K30	Elevation 683 m N 24° 13' 44.86" E 092° 48'17.95"	112	8.76	16
K31	Elevation 582 m N 24° 12' 06.28" E 092° 48'30.34"	106	17.68	16
K32	Elevation 587 m N 24° 12' 08.93" E 092° 48'34.25"	111	21.80	14
K33	Elevation 665 m N 24° 12' 23.88" E 092° 48'04.52"	114	9.50	16
K34	Elevation 717 m N 24° 06' 18.61" E 092° 48'40.71"	115	11.46	13
K35	Elevation 668 m N 24° 05' 41.82" E 092° 48'15.32"	110	4.05	16
K36	Elevation 834 m N 24° 06' 09.95" E 092° 47'41.09"	112	54.19	14

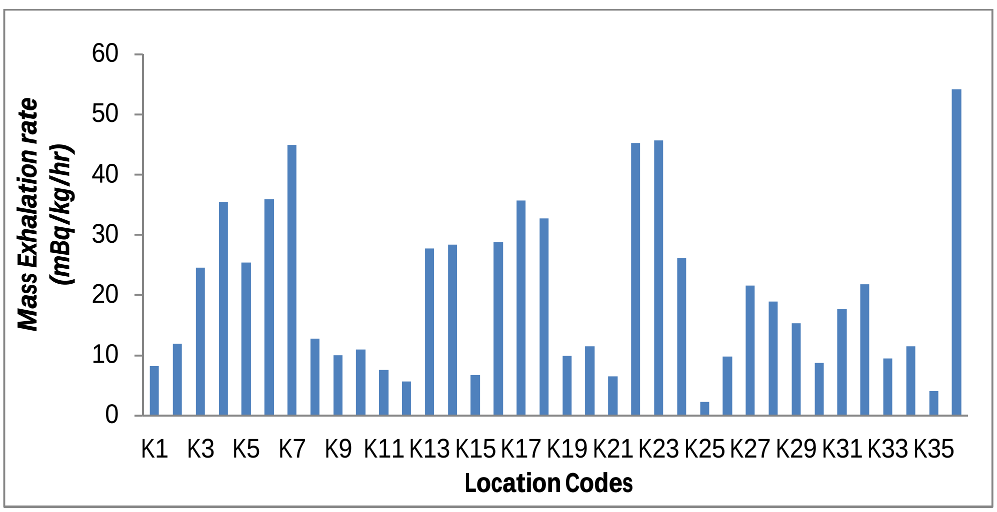

Fig 3: Radon mass exhaltion from fault regions of Kolasib District.

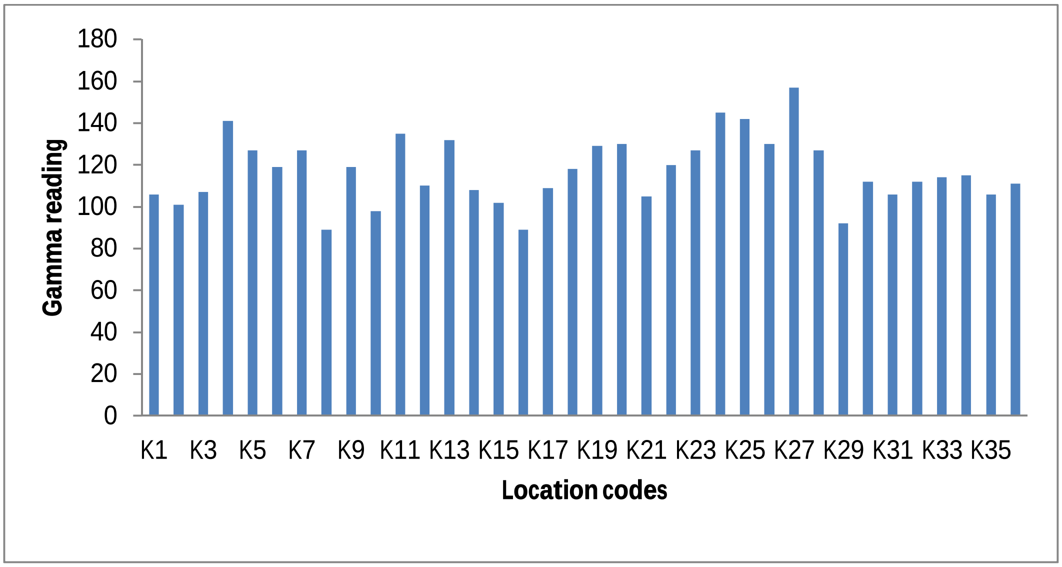

Fig 4: Gamma survey from fault regions of Kolasib District

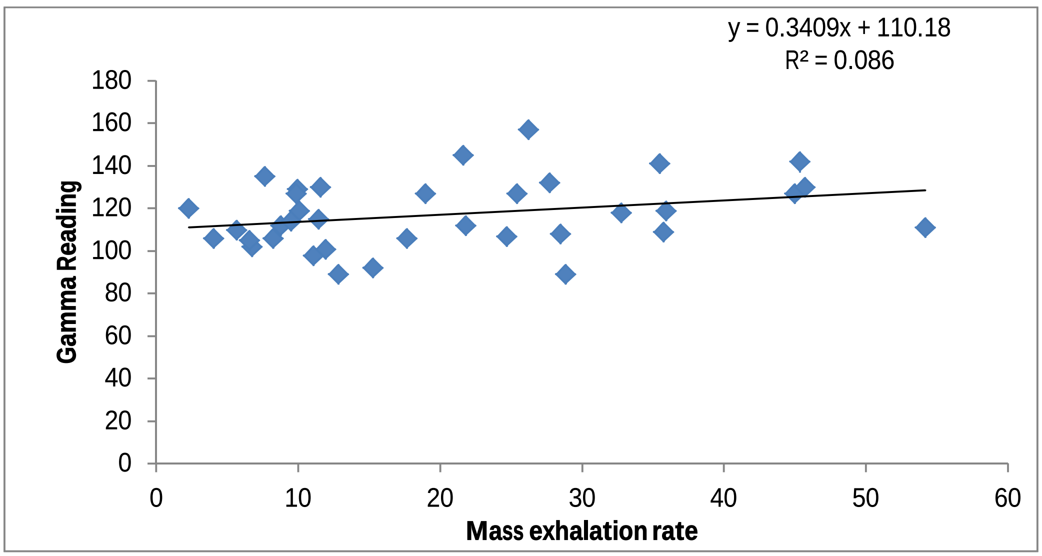

Fig 5: Correlation graph between mass exhalation rate and gamma survey.

IV. CONCLUSIONS

The averages of mass exhalation from fault regions of Kolasib district were obtained and comparable to other regions. The average values were higher than other regions due to differences in geology of the areas of study and due to the proximity of the fault lines. Gamma readings obtained shows slight variations on different regions and the correlation between mass exhalation and gamma survey shows negative correlation.

V. ACKNOWLEDGEMENT

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