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# Estimation of Radon Mass Exhalation Rate and Radium Content in Soil Samples Collected from Kolasib District of Mizoram, India

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**Abstract:** Scintillation-based detector Smart RnDuo have been used for the measurement of radon mass exhalation rate in soil samples collected from Kolasib districts of Mizoram, which is located in the North-Eastern region of India. The state of Mizoram is considered to be one of the highest age adjusted lung cancer incidence rate area in India. The radon mass exhalation rate in these samples has been found to vary from 0.92 mBq/kg/hr to 51.97 mBq/kg/hr, with an average value of 26.57 mBq/kg/hr. For measurement of the radium activity concentration in the collected soil samples, 5"X 4" NaI (TI) gamma spectrometer was employed. It was found that the activity concentration of radium obtained in this study ranges from 12.90 Bq/kg to 43.39 Bq/kg, with an average value of 26.84 Bq/kg. From the data obtained, the radon emanation factor was also calculated. Correlation between radium activity concentration and radon mass exhalation rates obtained in this study shows that they have a positive correlation.

**Keywords:** Radionuclides, Radon mass exhalation rate, RnDuo, soil

## I. INTRODUCTION

Primordial radionuclides such as  $^{238}\text{U}$  and  $^{232}\text{Th}$  are found in traces almost in every soil, rocks and water on earth. They usually have a very long half-life and continuously decay into another radioactive element, hence forming a decay chain. Primordial radionuclides like  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  and their corresponding daughter elements are the main source of gamma radiations on earth[1], and their presence in the soil could lead us to identify their origin as well as abundance of their daughter elements like radon, thoron and their progenies.

Radon, a decay product of  $^{238}\text{U}$ , is a highly radioactive, colourless, chemically inert gas and is one of the main sources of radiation exposure to human beings[2]. Of the total radiation received by humans, the contribution of radon and its decay products is 51% through inhalation and 0.21% through ingestion[3-4]. Due to its short half-life, radon continuously disintegrates into its progeny, thereby releasing alpha particles. The three main progenies of radon, namely, polonium, lead and bismuth have extremely short half-life and this makes radon extremely hazardous [5-6].

Radon is being continuously formed in the soil and released in air. Radon formed in the soil enters into the pore spaces of soil grains by a process called emanation and then escapes into the environment by a process known as exhalation[7-8]. Exhalation mainly depends on the type of soil, its grain size distribution, porosity and the water content of the soil. Radon and its isotopes have been identified as the second leading cause of lung cancer after tobacco smoking [9-10]. Hence, estimation of radon mass exhalation rate is important to give a useful reference against radiation safety measures and to create a baseline for further studies.

## II. STUDY AREA

Figure 1 show the geographical sites where the soil samples were collected. The sampling area extends from from  $23^{\circ}58'56.5''$  to  $24^{\circ}30'43.5''$  latitude and from  $92^{\circ}35'54.4''$  to  $92^{\circ}46'23.7''$  longitude in Kolasib district of Mizoram, India. The soil samples were collected from 27 different locations within the study area. As Mizoram has one of the highest age rate for lung cancer incidence in males and females amongst all sites of India[11], it is important to study of the concentration of carcinogenic elements like radon and its parent element  $^{226}\text{Ra}$  in this area.

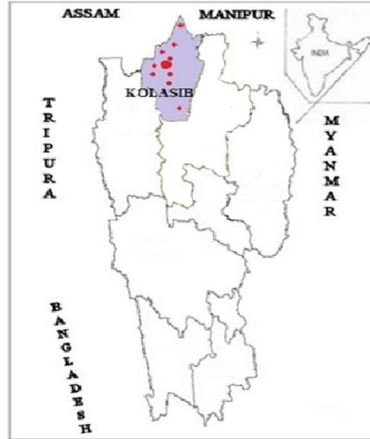


Fig. 1: Geographical Map of the studied region of Kolasib district, Mizoram.

### III. METHODOLOGY

#### A. Measurement of Radon Mass Exhalation Rate

The measurement of radon mass exhalation rate in collected soil samples was carried out by using a scintillation based radon monitor Smart RnDuo. RnDuo is an advanced portable continuous radon /thoron monitor, whose detection principle is based on detection of alpha emitted from radon and its decay products formed inside a scintillation cell volume, and has multiple applications in radon and thoron studies [12]. The instrument consists of a progeny filter and a thoron discriminator which eliminates radon/thoron progenies and thoron from entering the scintillation chamber.

The alpha scintillations from radon and its decay products formed inside the cell are continuously counted by the PMT and the associated counting electronics. The instrument has an in-built algorithm to continuously measure radon concentration. The measured radon concentration is then processed by a microprocessor unit as per the developed algorithm to display the concentration of radon (Fig. 2).

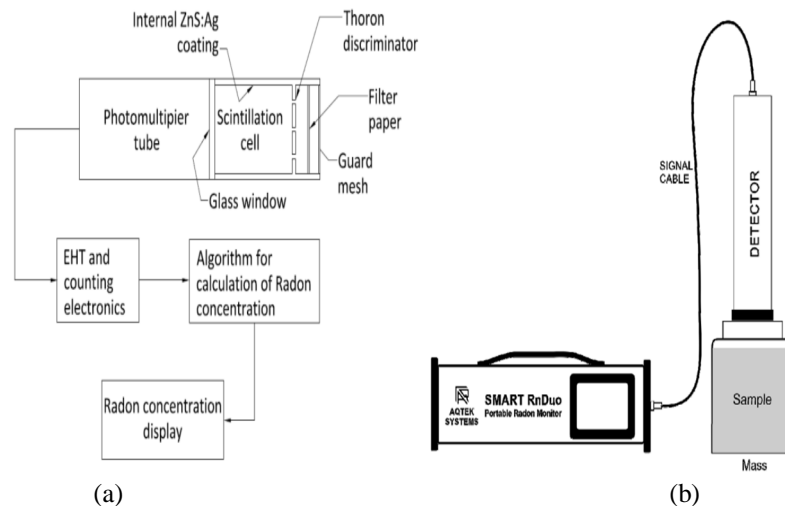


Fig. 2: (a) Schematics of radon measurement process in RnDuo.(b) Measurement of radon mass exhalation from soil.

For measuring radon mass exhalation rate, the sample was first weigh and its volume taken, and then put inside the radon mass exhalation chamber. The detector is then mounted on top of the exhalation chamber (Fig. 2b), and build up data of radon was retrieved every 60 minutes for a period of about 10- 24 hours. Least square fitting of the data obtained was carried out using the equation [13]:

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

Where  $C(t)$  is  $^{222}\text{Rn}$  concentration ( $\text{Bq m}^{-3}$ ) at time  $t$ ,  $C_0$  is the  $^{222}\text{Rn}$  concentration ( $\text{Bq m}^{-3}$ ) 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) ( $\text{m}^3$ ).

The porous volume ( $V_p$ ) can be estimated using the following equation

$$V_p = V_s - \left( \frac{M}{\rho_g} \right) \quad (2)$$

Where  $V_s$  is the sample volume in the mass exhalation chamber,  $\rho_g$  is the specific gravity of the sample and  $t$  is the measurement time (h).

On least square fitting of the data to the above equation, one may obtain  $J_M$  from the fitted parameters with the information of the mass  $M$  of the sample.

### B. Measurement of Natural Radioactivity Using NaI (Tl) Detector

The measurement of activity concentration of  $^{228}\text{Ra}$  in the soil samples collected was carried out by using Thallium (Tl) activated 5" X 4" Sodium Iodide (NaI) detector enclosed in a cylindrical lead and iron shield. The detector was coupled with a PC based multi-channel analyzer, GSPEC-SA (Ver. 2.5X). For efficiency calibration, standard source of  $^{238}\text{U}$  (provided by BARC, Mumbai) was analyzed for a period of 10800 sec (3 hours). From the gamma energy peak obtained, the efficiency was calculated using the formula:

$$\eta(\%) = \frac{\text{Area / sec}}{\text{dps}} \times \frac{100}{\text{Ab\%}} \times 100 \quad (3)$$

Where,  $\eta(\%)$  = Percent Efficiency

$\text{Area/sec}$  = Net peak area per second (background subtracted)

$\text{dps}$  = Source strength

$\text{Ab\%}$  = Gamma ray abundance factor

Before the start of the experiment, the collected samples were dried to a temperature of about  $110^\circ\text{C}$  and were then grinded and sieved using a  $500 \mu\text{m}$  mesh. Each sample were 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 measurement, a three-point energy calibration was carried out using sources containing a mixture of  $^{60}\text{Co}$  and  $^{137}\text{Cs}$  sources [14]. The energy calibration allows the establishment of the relationship between the channel numbers of the analyzer and the known energy of the photons [15].

The activity concentration of  $^{226}\text{Ra}$  for each samples were then obtained by analyzing with GSPEC-SA Multichannel Analyzer for a period of 50,000 seconds. The weights of the samples were measured and the activity concentration of radium ( $C_{\text{Ra}}$ ) was obtained (in  $\text{Bq/kg}$ ) for each samples using the formula:

$$C_{\text{Ra}} = \frac{N}{T} \times \frac{100}{\gamma\%} \times \frac{100}{\eta\%} \times \frac{1}{W_t} \quad (4)$$

Where,  $\frac{N}{T}$  = Background subtracted net photo peak counts in time 'T'.

$\gamma$  = abundance of gamma ray under consideration.

$\eta$  = absolute detection efficiency obtained from the energy efficiency calibration.

$W_t$  = weight of the sample

### C. Emanation Factor

The fraction of radon atoms generated that escape the solid phase in which they are formed and become free to migrate through the bulk medium is defined as the emanation factor of radon. The emanation factor ( $f$ ) can be calculated using the formula [16]:

$$f = \frac{J_m}{C_{\text{Ra}} \lambda} \quad (5)$$

$C_{\text{Ra}}$  - Radium activity concentration ( $\text{Bq/kg}$ )

$\lambda$  - Decay constant of radon (in hr.)

$J_m$  - Mass exhalation rate of radon ( $\text{mBq/kg/hr}$ )

#### IV. RESULTS AND DISCUSSIONS

Table 1 gives the results of measurement of radon mass exhalation rates, radium activity concentration and radon emanation factor in soil samples collected from a total of 27 locations within the specified study area. It was found that the measured radium activity concentration obtained in this report was found to be in the range of 12.90 Bq/kg to 43.39 Bq/kg, having an average value of 26.84 Bq/kg. The radium activity concentration in all the sample were found to be quite comparable with the worldwide average value of 35 Bq/kg, as proposed by UNSCEAR[2]. Also, they were much lower than the critical value of 1000 Bq/kg set by IAEA[17].

The radon mass exhalation was also measured and was found to be in the range of 0.92 mBq/kg/hr to 51.97 mBq/kg/hr, with an average value of 26.57 mBq/kg/hr. These results were quite comparable to the results obtained [18] in other districts of Mizoram. From the measured values of radium activity concentration and radon mass exhalation rates, the radon emanation factor was calculated and was found to be in the range of 0.002 to 0.25, with an average of 0.13. The radon emanation factor usually ranges from about 0.05 to 0.70 in typical rocks and soils [19], and the result obtained in this report were quite comparable to the given range.

Figure 3 shows the correlation between the measured values of radium activity concentration and the radon mass exhalation rate in the collected samples. The correlation coefficient was obtained by plotting the radium activity concentration along X-axis and the radon mass exhalation rate along Y-axis, and the correlation coefficient was found to be  $R^2 = 0.309$ . This result shows that there is a positive correlation between the two parameters, although the correlation is not quite strong. Although the radon mass exhalation rate depends on the radium activity concentration[20], the possible reason for this weak correlation may be because of other factors such as soil moisture content, porosity, grain size distribution etc, which radon mass exhalation is also dependent upon.

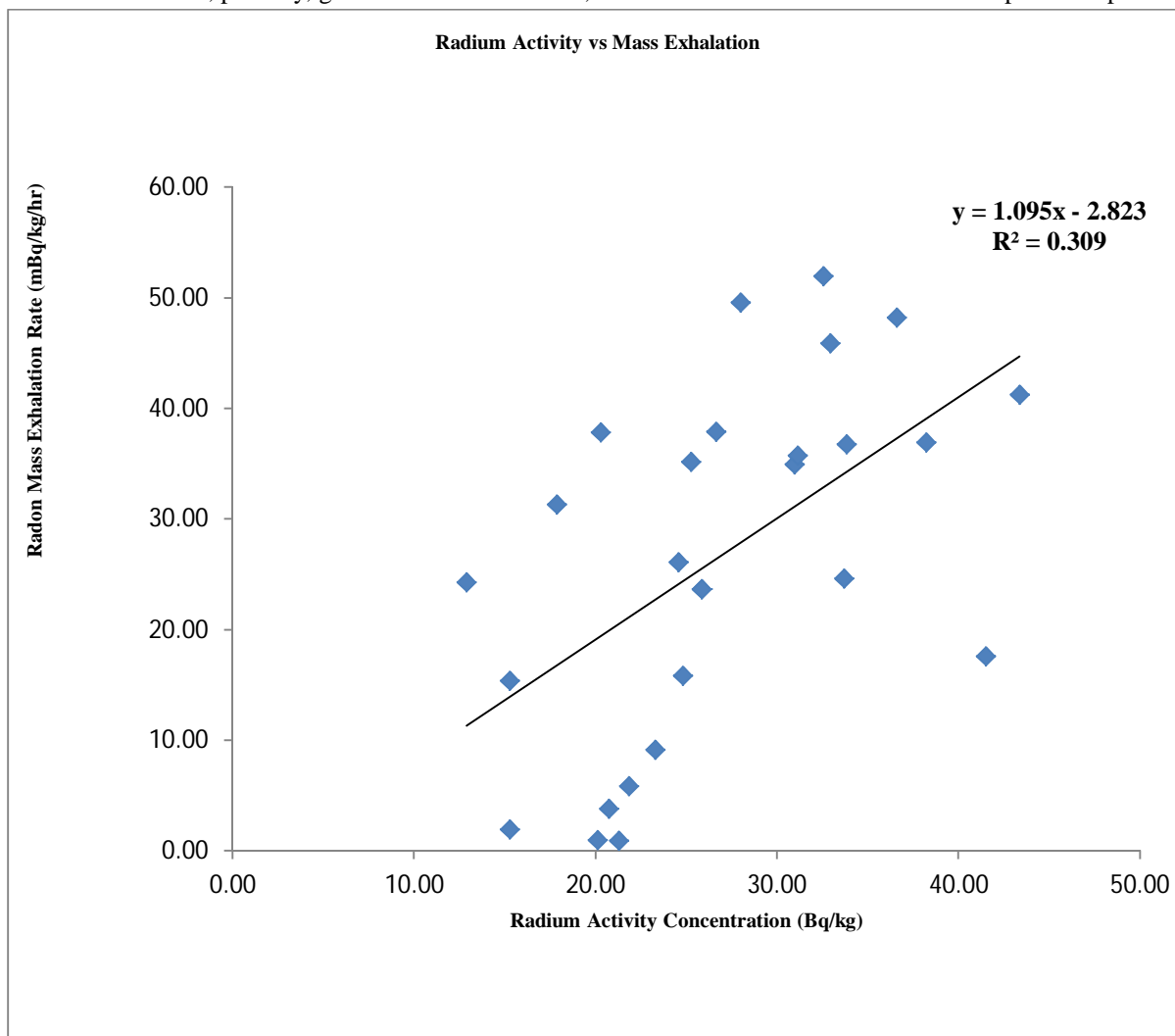


Fig. 3: Correlation between Radium Activity Concentration and Radon Mass Exhalation Rate.

Table 1: Measurement of radon mass exhalation rate, radium activity concentration and emanation factor of radon in soil samples collected

Sl. No.	Location Codes	Radium Activity Concentration ( $C_{Ra}$ ) (Bq/kg)	Radium Activity Concentration ( $C_{Ra}$ ) in (mBq/kg)	Mass Exhalation Rate ( $J_m$ ) (mBq/kg/hr)	Emanation Factor (f)
1	K-1	43.39	43386.40	41.24	0.13
2	K-2	24.58	24578.34	26.09	0.14
3	K-3	20.28	20275.27	37.86	0.25
4	K-4	20.73	20728.21	3.81	0.02
5	K-5	30.97	30965.29	34.94	0.15
6	K-6	28.00	28003.76	49.56	0.24
7	K-7	24.83	24825.05	15.87	0.09
8	K-8	25.83	25829.95	23.67	0.12
9	K-9	25.83	25829.95	23.67	0.12
10	K-10	23.28	23284.73	9.16	0.05
11	K-11	31.13	31132.96	35.76	0.15
12	K-12	25.27	25272.67	35.18	0.19
13	K-13	36.60	36602.60	48.24	0.18
14	K-14	32.92	32920.78	45.91	0.19
15	K-15	12.90	12899.49	24.27	0.25
16	K-16	15.28	15275.39	15.37	0.14
17	K-17	20.10	20101.04	0.99	0.01
18	K-18	15.28	15280.87	1.93	0.02
19	K-19	32.54	32544.82	51.97	0.21
20	K-20	33.83	33833.31	36.78	0.15
21	K-21	38.23	38226.92	36.93	0.13
22	K-22	26.65	26647.15	37.89	0.19
23	K-23	17.87	17870.13	31.32	0.24
24	K-24	33.69	33687.68	24.61	0.10
25	K-25	21.82	21822.64	5.87	0.04
26	K-26	41.49	41491.89	17.63	0.06
27	K-27	21.28	21280.20	0.92	0.01
Average		26.84	26836.94	26.57	0.13
Minimum		12.90	12899.49	0.92	0.02
Maximum		43.39	43386.40	51.97	0.25

### V. CONCLUSIONS

The measured values of radon mass exhalation rate in Kolasib district ranged from 0.92 mBq/kg/hr to 51.97 mBq/kg/hr, with an average value of 26.57 mBq/kg/hr. These values were comparable to the results obtained in other districts of Mizoram. The radium activity concentration was found to ranged between 12.90 Bq/kg to 43.39 Bq/kg, with an average value of 26.84 Bq/kg. These values were found to be much lower than the critical value set by IAEA[17]. Also, correlation between radon mass exhalation rate and radium activity concentration shows that they have a positive correlation.

## VI. ACKNOWLEDGEMENT

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## REFERENCES

- [1] Ya-xin Yang, Xin-min Wu, Zhong-ying Jiang, Wei-xing Wang, Ji-gen Lu, Jun Lin, Lei-Ming Wang, Yuan-fu Hsia, Radioactivity concentration in soil of the Xiazhuang granite area, China Appl. Isot. Radiat. 2005, 63:255-259.
- [2] UNSCEAR (2000). United Nations Scientific Committee on the effects of atomic radiation: Sources and effects of ionizing radiation. United Nations, New York.
- [3] Kumar, Manish, Sarin, Amit, Sahoo, B. K., Sharma, Navjeet, Measurement of radon concentration in the drinking water and assessment of age dependent ingestion dose to local population in Kapurthala district of Punjab, India. J. Env. Bio-Sci., 2017, 31 (2):479-484
- [4] Gusain, G.S., Prasad, Ganesh, Prasad, Yogesh, Ramola, R.C., Comparison of indoor radon level with radon exhalation rate from soil in Garhwal Himalaya. Radiation Measurements, 2009, 44:1032–1035.
- [5] Majumdar, D., Radon in the Environment and Associated Health Problems, Resonance, July 2000, 44-55.
- [6] Ahmad, Nisar, Jaafar, Mohamad Suhaimi, Khan, Sohail Aziz, Correlation of radon exhalation rate with grain size of soil collected from Kedah, Malaysia. Sci. Int. (Lahore), 2014, 26 (2): 691-696.
- [7] Elzain, Abd-Elmoniem A., Determination of Radium concentration and radon exhalation rate in soil samples using CR-39. Adv. Appl. Sci. Res., 2015, 6(2):96-102.
- [8] Abbas J. Al-Saadi, Abdalsattar K. Hashim, and Hayder J. Musa, Determination of Radium and Radon Exhalation Rates in Soil Samples Collected from Kerbala Governorate, International Journal of Physics, 2015, Vol. 3, No. 5: 208- 212. doi: 10.12691 / ijp-3-5-2.
- [9] Hassan, Nabil M., Tokonami, Shinji, Fukushi, Masahiro, A simple technique for studying the dependence of radon and thoron exhalation rate from building materials on absolute humidity. J. Radioanal Nucl. Chem., 2011, 287:185–191, DOI 10.1007/s10967-010-0665-7.
- [10] Mujahid, S. A., Hussain, S., Ramzan, M., Measurement of radon exhalation rate and soil gas radon concentration in areas of southern Punjab, Pakistan. Radiation Protection Dosimetry, 2010, pp. 1–4. doi:10.1093/rpd/ncq119.
- [11] NCDIR-NCRP (ICMR) (2016), Three year report of Population Based Cancer Registries: 2012 – 2014 (Reports of 27 PBCRs in India), Bengaluru, India, 43-45.
- [12] Amanjeet, Kumar, Ajay, Kumar, Suneel, Measurements of mass and surface exhalation rate from soil of eastern Haryana, India. International Journal of Applied Engineering Research, 2018, Volume 13, Number 5: 2181-2186.
- [13] Lekshmi, R., Arunima, S., Jojo, P. J.(2018). Determination of radon exhalation rates and emanation factor of some soil samples collected from southern seashore of Kerala, India. JUSPS-A, 2018. Vol. 30(1): 80-85
- [14] International Standard, ISO 18589-3:2007(E), 7.3.1. Energy calibration.
- [15] Bureau International des Poids et Mesures Table of Radionuclides (2004). Monographie BIPM-5.
- [16] Lekshmi R, Jojo, PJ, A Correlation Study between Radium Content and Radon Exhalation Rates in Soil Samples along the Coastal Regions of Perumathura and Vizhinjam, Trivandrum District, Kerala, IJRASET, 2018, Volume 6 Issue I, January 2018, 728-732, ISSN: 2321-9653
- [17] IAEA Annual Report for 2004, Reference Data Series No. 1, IAEA, Vienna (2004)
- [18] Chhangte, LZ, Rohmingliana, PC, Sahoo, BK, Sapra, BK, Hmingchungnunga, Vanramlawma, Remlalsiama, Pachua, Z, Zoliana, B, Determination of Radon Mass Exhalation Rate in the Region of Highest Lung Cancer Incidence in India, Radiation Environment and Medicine, 2019, Vol.8, No.2: 113–117.
- [19] Nazaroff, W.W., Moed, B.A., Sextro, R.G., Soil as a source of indoor radon: Generation, migration, and entry. In: Nazaroff, W.W.; Nero, A.V. (eds). Radon and its decay products in indoor air. New York: Wiley and Sons, 1988, pp. 57- 112.
- [20] Khan, M., Shakir, Naqvi, A.H., Azam, A., Srivastava, D.S., Radium and radon exhalation studies of soil. Iran. J. Radiat. Res., 2011, 8(4): 207-210



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