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Investigations of Radon Exhalation Rates, Natural Environmental Radioactivity and Radiation Exposure from Indian Commercial Granites

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Abstract **- Radioactivity, natural and man made, is omnipresent in the earth's crust in different amounts. Building materials may be the possible serious source of radiation exposure in particular if they contain large amount of naturally occurring radionuclides or man made radionuclides. Several varieties of granites are produced and used as building material in India. Commercial type of granites with specific names corresponds to geographical and geological origins and mineral compositions. The natural radioactivity present in rocks having high radiation levels are associated with granites. Studies of radon exhalation from building material, is important for the estimation of public exposure as people spend most of their time (~ 80%) indoors. In the present study, measurement of radon exhalation rates for granite samples used as construction material mainly as flooring material and as ornamental stones were carried out through sealed can technique using LR-115 type II detectors. Natural radioactivity in granite samples has been measured by low level gamma ray spectrometer using HPGe detector. Higher and wide variation in radon exhalation rates are found in the samples. Radon activity is found to vary from 380.00 to 4258.57 Bq m^{-3} with an average value of 1316.23 Bq m^{-3} , whereas radon exhalation rate varies from 227.44 to 2548.81m Bq m^{-2} h^{-1} with an average value of 854.71 m Bq m^{-2} h^{-1}. The variation can be correlated with the color of the granites. Effective dose equivalent, estimated from exhalation rate varies from 26.82 to 300.56 µSv y^{-1} with an average value of 100.79 µSv y^{-1} . From the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in the granite samples, Radium equivalent activity (Ra_{eq}) due to the presence of radio nuclides varies from 34.64 to 1144.84 Bq kg^{-1} with an average value of 278.91 Bq kg^{-1}. Total absorbed gamma dose rates varies from 6 to 535.61 $nGyh^{-1}$ with an average value of 132.33 nGy h^{-1}. Indoor and outdoor annual effective dose rate from these granite samples vary from 0.08 to 2.63 mSv y^{-1} and 0.02 to 0.66 mSv y^{-1} , respectively. External hazard index, H_{ex} for the granite samples studied in this work ranges from 0.09 to 3.16 with a mean value of 0.77. The internal exposure to ^{222}Rn and its radioactive progeny is controlled by the internal hazard index H_{in}. Computed values of H_{in} vary from 0.15 to 4.76 with an average value of 0. 99. since most of the values of H_{ex} are less than unity except four granite samples showing higher values than unity. The use of these granite as construction material can be done without posing significant radiological threat. But care should be taken in the use of any granite slab.**

Keywords: Radon exhalation rate, Effective dose, Gamma ray spectroscopy, Radium equivalent activity, LR-115 type II dector

1. INTRODUCTION

Existence of three primordial radio nuclides (^{40}K, ^{238}U and ^{232}Th) in building materials cause internal and external exposures to residents. External exposure is caused by gamma radiation emitted from ^{40}K and daughter products of ^{238}U and ^{232}Th [1]. It is well known that as a result of inhalation of ^{222}Rn, a daughter product of decay chain of ^{238}U and its daughter products, equivalent dose to entire lung is higher than the equivalent dose in other tissues [2]. Knowledge of natural radiation emitted from the building materials are of particular interest as radiation from building materials are main contributors to radiation exposure to the human beings. Building materials may be the possible serious source of radiation exposure in particular if they contain large amount of naturally occurring radionuclides or man made radionuclides [3,4]. In addition to soil and water building construction materials can be the significant contributor [5,6]of indoor radon in the dwellings. Radon emanation from building materials has been the subject of many studies [7-9]. Studies of radon exhalation from building material, is important for the estimation of public exposure as people spend most of their time (~ 80%) in indoors [10]. Furthermore, it is useful in setting the standards and national guidelines with regard to the international recommendations and in assessing the associated radiation hazard. During the past few year, lot of attention has been devoted to the control of natural radiation in building materials in European, Asian and some African countries

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[11-21]. Construction materials are sources of airborne radioactivity and external radiation from the decay series of uranium in buildings. Radon exhalation (^{222}Rn) from these materials are of interest since the short-lived decay products of radon are the greatest contributors to the lung dose of inhaled radionuclides. Recently India is becoming a relative large market for local and foreign granite usage. Granites are widely used for tiling of houses and flooring materials. Even old houses are renovated by replacing the conventional tiles with granites.

Granite stones emit more radon (Rn) compared to other types of construction materials because of the existence of relatively high uranium content [22] . Granite samples are reported [23,24] main source of Rn emanations. Chen et al [25] observed that slate tiles and granite slabs had relatively higher Rn exhalation rates than other decorative materials. Al-jarallah et al [26] observed that exhalation rate of granite samples was higher than marble and ceramic. Ur-Rehman et al [27] and Sakoda et al [28] reported Rn exhalation from granite samples. Granites are most abundant igneous rocks and due to their properties such as color variety heat and scoratch resistance have multiples uses such as work-surface, flooring and internal cladding [29]. In terms of natural radioactivity granites exhibit enhanced concentration of uranium (U) and thorium (Th) as compared to the very low abundance of these elements observed in the mantle and the crust of the Earth [30,31]. In the present study, radon exhalation rates have been measured in granites samples. The analysis of radioactivity in granite samples used as ornamental purpose and flooring materials in building construction has been measured by low level gamma ray spectrometer. In addition , absorbed radiation doses and radiation risk have also been estimated. The study is important from environmental radiological point of view.

2.EXPERIMENT

2.1 Radon exhalation rate

Radon exhalation rate is of prime importance for the estimation of radiation risk from various materials. In such measurements, it is expected that the exhalation rate depends upon the material and its amount as well as on the geometry and dimension of the can. Collected granite samples were dried and sieved through a 100- mesh sieve. They were placed in the cans (7.5cm height and 7.0 cm diameter) similar to those used in previous calibration experiment [32]. In each can a LR-115 type II plastic detector (2cm × 2cm) was fixed at the top inside of the can, such that the sensitive surface of the detector faces the material and is freely exposed to the emergent radon. Radon decays in the volume of the can record the alpha particles resulting from the Po ^{218} and Po ^{214} deposited on the inner wall of the can. Radon and its daughters will reach an equilibrium in concentration after one week or more. Hence the equilibrium activity of the emergent radon can be obtained from the geometry of the can and the time of exposure. The detectors were exposed to radon for 100 days. After the exposure the detectors were etched in 2.5 N NaOH at 60^{0}C in a constant temperature water bath for revelation of tracks. The resulting alpha tracks on the exposed face of the track detector were counted using an optical microscope at a magnification of 400X. The radon exposure inside the can was obtained from the track density of the detector by using calibration factor of 0.56 tracks cm^{-2} d^{-1} obtained from an earlier calibration experiment [33]. The exhalation rate is found from the expression [34,35]:

$$Ex = \frac{CV\lambda}{A[T + \frac{1}{\lambda}(e^{\lambda t} - 1)]}$$

Where,

Ex	= Radon Exhalation rate (Bq m^{-2} h^{-1})
C	=Integrated radon exposure as measured by LR-115 type II solid state nuclear track detector (Bq m^{-3} h^{-1}).
V	= Volume of can (m^3)
λ	= Decay constant for radon (h^{-1})
T	= Exposure time (h)
A	= Area covered by the can (m^2)

2.2 Radiometric analysis

Gamma ray spectrometric measurements were carried out at Inter-University Accelerator Centre, New Delhi, India using a coaxial n-type HPGe detector (EG&G, ORTEC, Oak Ridge, USA) for estimation of the natural radionuclides, Uranium (^{238}U), thorium (^{232}Th) and potassium (^{40}K). The samples were crushed into fine powder by using Mortar and Pestle. Fine quality of the sample is obtained by using scientific sieve of 150 micron-mesh size. Before measurements samples were oven dried at 110°C for 24h and the samples were then packed and sealed in an impermeable airtight PVC container to prevent the escape of radiogenic gases radon (^{222}Rn) and thoron (^{220}Rn). About 300g sample of each material was used for measurements. Before measurements, the containers were kept sealed about 4 weeks in order to reach equilibrium of the ^{238}U and ^{232}Th and their respective progenies. After attainment of secular equilibrium between ^{238}U and ^{232} Th and their decay products, the samples were subjected to high resolution gamma spectroscopic analysis. HPGe detector (EG&G, ORTEC, Oak Ridge, USA) having a resolution of 2.0 keV at 1332 keV and a relative efficiency of 20% was placed in 4″ shield of lead bricks on all sides to reduce the background radiation from building materials and cosmic rays [36]. The detector was coupled to a PC based 4K multi channel analyzer and an ADC for data acquisition.

The calibration of the low background counting system was done with a secondary standard which was calibrated with the primary standard (RGU-1) obtained from the International Atomic Energy Agency (IAEA). The efficiency for the system was determined using secondary standard source of uranium ore in the same geometry as available for the sample counting. For activity measurements the samples were counted for a period of 72000 seconds. The activity concentration of ^{40}K (C_K) was measured directly by its own gamma ray of 1461 keV. As ^{238}U and ^{232}Th are not directly gamma emitters, their activity concentrations (C_U and C_{Th}) were measured

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through gamma rays of their decay products. Decay products taken for ^{238}U were ^{214}Pb: 295 and 352 keV and ^{214}Bi: 609, 1120 and 1764 keV whereas for ^{232}Th were ^{228}Ac : 338, 463, 911 and 968 keV, ^{212}Bi : 727 keV, ^{212}Pb : 238 keV and ^{234}Pa : 1001 keV gamma ray by assuming the decay series to be in equilibrium [37]. Weighted averages of several decay products were used to estimate the activity concentrations of ^{238}U and ^{232}Th. The gamma ray spectrum was analyzed using the locally developed software "CANDLE" (Collection and Analysis of Nuclear Data using Linux Net work)".

The net count rate under the most prominent photo peaks of radium and thorium daughter peaks are calculated from respective count rate after subtracting the background counts of the spectrum obtained for the same counting time. Then the activity of the radionuclide is calculated from the background subtracted area of prominent gamma ray energies. The concentration of uranium, thorium and potassium is calculated using the following equation:

$$Activity\ (Bq\ kg^{-1}) = \frac{(S \pm \sigma) \times 100 \times 1000 \times 100}{E \times W \times A} \qquad (1)$$

Where S is the net counts/sec (cps) under the photo peak of interest, σ the standard deviation of S, E the counting efficiency (%), A the gamma abundance or branching intensity (%) of the radionuclide and W is the mass of the sample (Kg).

The concentrations of Uranium, Thorium and Potassium are calculated using the following equation:

$$Activity(Bq) = CPS \times 100 \times 100/B.I \times Eff \pm CPS_{error} \times 100 \times 100/B.I \times Eff \qquad (2)$$

Where,
CPS -Net count rate per second
B.I. -Branching intensity, and
E -Efficiency of the detector

3. RESULTS AND DISCUSSION:

Table 1 presents the results of measured data for radon exhalation from different granite samples.

Table 1
Radon activity, radon exhalation rate and effective dose equivalent in different types/colours of granite samples

S.No.	Types /Colours of granite	Radon Activity (Bq m^{-3})	Radon exhalation rate (mBq m^{-2} h^{-1})	Effective dose equivalent (μSv y^{-1})
1	Green, Black and White	522.86	312.93	36.90
2	Manjholi	624.29	373.65	44.06
3	Katni gray and Pink	442.86	265.06	31.26
4	Oman	511.43	306.09	36.09
5	Yellow	841.43	503.61	59.39
6	Katni cream	4258.57	2548.81	300.56
7	Pink granite	481.43	288.14	33.98
8	Sunvar	494.29	295.84	34.89
9	Black	541.43	324.05	38.21
10	Black, Pick and white	3008.57	1800.67	212.34
11	Black and white	3098.57	1854.54	218.69
12	Black and green	468.57	280.45	33.07
13	Orange, Black and white	3070.00	837.44	98.75
14	Gray, Orange and Brown	2837.14	1698.07	200.24
15	Black, Brown, White-I and Gray	2832.86	1695.51	199.94
16	Brown, Gray, Black and white-II	2247.14	1344.95	158.59
17	Ruby red	3334.29	1995.62	235.33
18	Wonder Marble	712.86	426.66	50.31
19	White-II	515.71	308.66	36.39
20	Black-I	380.00	227.44	26.82
21	Black-II	435.71	260.78	30.75
Min		380.00	227.44	26.82
Max		4258.57	2548.81	300.56
Average value		1507.62	854.71	100.79
S.D.		1316.23	758.09	89.39
R.S.D%		67.31	88.69	88.69

It is apparent from Table 1, that radon activity varies from 380.00 Bq m^{-3} to 4258,57 Bq m^{-3} with an average value of 1507.62 Bq m^{-3}, exhalation rate varies from 227.44 mBq m^{-2} h^{-1} to 2548.81 mBq m^{-2} h^{-1} with an average value of 854.71 mBq m^{-2} h^{-1} .Thus there is a wide variation in radon exhalation rates in granite samples and it is observed that granites have higher radon concentration and may be the main source of radon emanation as compared to other building materials such as cement, sand , bajari and concrete etc. The frequency distribution of radon exhalation rate from granite samples is shown in Fig 1.

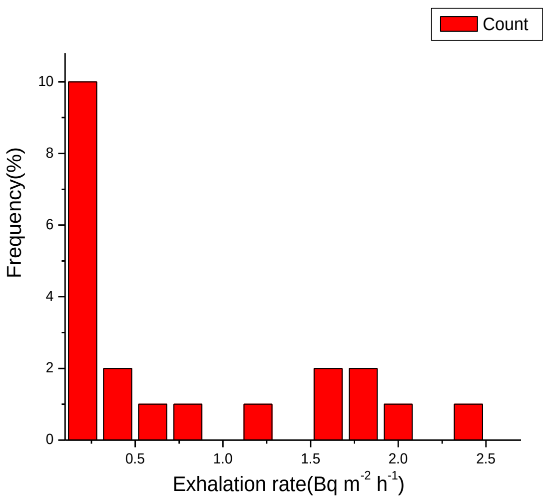

Fig 1 Frequency distribution of radon exhalation rates from granite samples

It is apparent from Fig.1, that the distribution seems to be log-normal. Granites can be a significant source of radon in houses, when used in tiling large enclosed areas, besides being source of external gamma radiation from uranium decay series.

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Gamma ray spectrum of one typical granite sample is shown is Fig 2

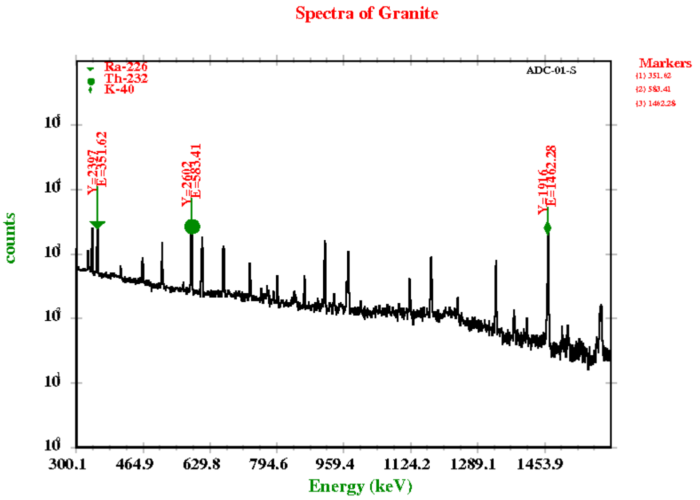

Fig 2 Spectrum of a granite sample

Measured ^{238}U, ^{232}Th, and ^{40}K activity concentrations in the granite samples and computed Radium equivalent activity, absorbed gamma dose rate, annual effective doses, external hazard index and internal hazard index in granite samples are presented in Tables 2 and 3.

Table 2
Activity concentration of ^{238}U, ^{232}Th, and ^{40}k, in granite Samples

Sample Code	**^{238}U (Bqkg^{-1})**	**^{232}Th (Bq kg^{-1})**	**40k (Bq kg^{-1})**
G1	12.01±.61	8.93±.37	140.90±2.12
G2	267.76±3.83	446.15±5.53	3415.56±26.59
G3	44.92±1.35	5.67±.27	59.94±.96
G4	35.80±1.47	5.88±.18	138.26±2.09
G5	33.58±1.28	23.04 ± .81	396.95 ± 5.29
G6	32.02±1.37	14.04±.58	152.99±2.29
G7	137.23±2.44	103.87±2.25	1553.04±15.44
G8	21.34 ± .89	14.16 ± .55	236.22 ± 3.38
G9	26.88±1.17	10.73 ± .47	226.17 ± 3.22
G10	91.30± 1.85	133.93 ± 2.66	1350.02 ± 13.96
G11	24.59 ± .98	26.74 ±.91	739.67 ± 8.82
G12	234.19± 3.46	325.52 ± 4.59	2812.62 ± 23.39
Min	12.01±.61	5.67±0.18	59.94±.96
Max	267.76± 3.83	446.15 ± 5.53	3415.56 ± 26.59
Average Value	80.14 ± 1.73	93.22 ± 1.59	935.19 ± 8.96
S.D	87.40±1.01	145.03±1.80	1135.94±8.87

It is apparent from Table 2 that the activity concentrations were found to vary from 12.0 ± 0.61 to 267.76 ± 3.83 Bq kg^{-1} with an average value of for ^{238}U , from 5.67 ± 0.27 to 446.15 ± 5.53 Bq kg^{-1} with an average value of 93.22 ± 1.59 for ^{232}Th and 59.94 ± .96 to 3415.56 ± 26.59 Bq kg^{-1} with an average value of 935.19 ± 8.96 for ^{40}K. The plots between ^{238}U and ^{232}Th activity concentration and ^{232}Th and ^{40}K activity concentrations are shown in Figs.3 and 4, respectively. The correlation between ^{238}U and ^{232}Th activity concentration and ^{232}Th and ^{40}K activity concentration in the granite samples is shown in Fig 3 and Fig 4.

Correlation Coefficient (R) = .97236

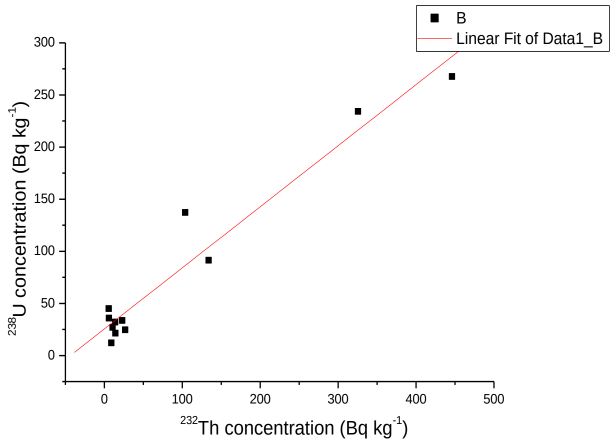

Fig 3 Variation of ^{238}U activity concentration versus ^{232}Th activity in granite samples

Correlation Coefficient (R) = **.97929**

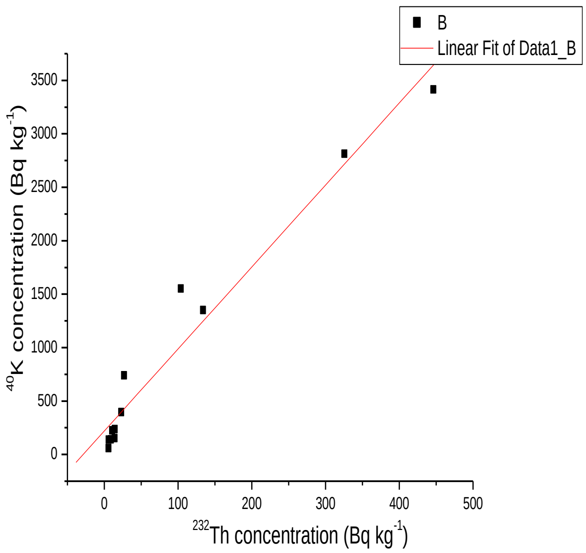

Fig 4 Variation of ^{40}K activity concentration versus ^{232} Th activity in granite samples

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A positive correlation exists between ^{238}U and ^{232}Th activity concentration and a Positive correlation between ^{232}Th and ^{40}K activity concentration in the granite samples studied here.

3.1 Radium equivalent activity (Ra_{eq})

Exposure to radiation is defined in terms of radium equivalent activity (Ra_{eq}) in Bq kg^{-1} to compare the specific activity of materials containing different amounts of ^{238}U (^{226}Ra), ^{232}Th and ^{40}K. It is calculated by the following expression [38,39] :

$$Ra_{eq} = C_U + 1.43\, C_{Th} + 0.07 C_K \qquad \text{………… (3)}$$

Where C_U, C_{Th} and C_K are the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in Bq kg^{-1} respectively. In the above equation for defining Ra_{eq} activity it has been assumed that the same gamma dose rate is produced by 370 Bq kg^{-1} of ^{238}U or 259 Bq kg^{-1} of ^{232}Th or 4810 Bq kg^{-1} of ^{40}K. There will be variations in the radium equivalent activities of different materials and also within the same type of materials. The results may be important from the point of view of selecting suitable materials for use in building construction materials.

3.2 Absorbed gamma dose rate measurement (D)

Outdoor air absorbed dose rate D in nGy h^{-1} due to terrestrial gamma rays at 1m above the ground can be computed from the specific activities, C_U, C_{Th} and C_K of $^{238}U/^{226}Ra$, ^{232}Th and ^{40}K in Bq kg^{-1}, respectively by Monte Carlo method [40] :

$$D\ (nGy\ h^{-1}) = 0.462 C_U + 0.604 C_{Th} + 0.0417 C_K \qquad \text{………..(4)}$$

To estimate the annual effective dose rate, E, the conversion coefficient from absorbed dose in air to effective dose (0.7 Sv Gy^{-1}) and outdoor occupancy factor (0.2) proposed by UNCSEAR (2000) were used. The indoor effective dose rate in units of mSv y^{-1} was calculated by the following relation:

$$E\ (mSv\ y^{-1}) = \text{Dose rate } (nGy\ h^{-1}) \times 8760\ h \times 0.8 \times 0.7\ Sv\ Gy^{-1} \times 10^{-6} \qquad \text{……….. (5)}$$

The outdoor effective dose rate in units of mSv y^{-1} was calculated by the following relation:

$$E\ (mSv\ y^{-1}) = \text{Dose rate } (nGy\ h^{-1}) \times 8760\ h \times 0.2 \times 0.7\ Sv\ Gy^{-1} \times 10^{-6} \qquad \text{………..(6)}$$

3.3 External (H_{ex})and Internal (H_{in}) hazard index

The external hazard index is obtained from Ra_{eq} expression through the supposition that its allowed maximum value (equal to unity) corresponds to the upper limit of Ra_{eq} (370 Bq kg^{-1}). For limiting the radiation dose from building materials in Germany to 1.5 mGy y^{-1} . Krieger (1981) proposed the following relation for H_{ex}:

$$H_{ex} = \frac{C_U}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \le 1 \qquad \text{…… (7)}$$

This criterion considers only the external exposure risk due to γ-rays and corresponds to maximum Ra_{eq} of 370 Bq kg^{-1} for the material. These very conservative assumptions were later corrected and the maximum permission concentrations were increased by a factor of 2 [41] which gives

$$H_{ex} = \frac{C_U}{740 Bqkg^{-1}} + \frac{C_{Th}}{520 Bqkg^{-1}} + \frac{C_K}{9620 Bqkg^{-1}} \le 1 \qquad \text{……… (8)}$$

Internal exposure to ^{222}Rn and its radioactive progeny is controlled by the internal hazard index (H_{in}) as given below [42].

$$H_{in} = \frac{C_U}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \le 1 \qquad \text{………(9)}$$

3.4 Effective Dose Equivalent (E_P)

The risk of lung cancer from domestic exposure of ^{222}Rn and its daughters can be estimated directly from the indoor inhalation exposure (radon) effective dose. The contribution of indoor radon concentration from the samples can be calculated from the expression [43]:

$$C_{Rn} = \frac{E_X \times S}{V \times \lambda_V}$$

Where C_{Rn}, E_x, S, V, and λ_V are radon concentration (Bq m^{-3}), radon exhalation rate(Bq m^{-2} h^{-1}), radon exhalation area (m^2), room volume (m^3) and air exchange rate (h^{-1}) ,respectively. In these calculation, the maximum radon concentration from the building material was assessed by assuming the room as a cavity with S/V = 2.0 m^{-1} and air exchange rate of 0.5 h^{-1}. The annual exposure to potential alpha energy E_p (effective dose equivalent) is then related to the average radon concentration C_{Rn} by the following expression:

$$E_p\ (WLM\ yr^{-1}) = 8760 \times n \times f \times C_{Rn} / 170 \times 3700$$

Where C_{Rn} is in Bq m^{-3}; n, the fraction of time spent indoors; 8760, the number of hours per year; 170, the number of hours per working month and F is the equilibrium factor for radon. Radon progeny equilibrium factor is the most important quantity when dose calculations are to be made on the basis of the measurement of radon concentration. Equilibrium factor F quantifies the state of equilibrium between radon and its daughters and may have values 0< F < 1. The value of F is taken as 0.4 as suggested by UNSCEAR (1988). Thus the values of n = 0.8 and F = 0.4 were used to calculate E_P. From radon exposure, effective dose equivalents were estimated by using a conversion factor of 6.3 mSv WLM^{-1} [44].

It is apparent from Table 3 that the radium equivalent activity (Ra_{eq}) due to the presence of radio nuclides varies from 34.64 to 1144.84 Bq kg^{-1} with an average value of 278.91 Bq kg^{-1}. Total absorbed gamma dose rates in the surrounding air are found vary from 16.82 to 535.61 nGy h-

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^{1} with an average value of 132.33 nGy h^{-1}. Figure 5 shows a frequency plot of the variation of ^{238}U, ^{232}Th, ^{40}K and absorbed dose rate in these granite samples.

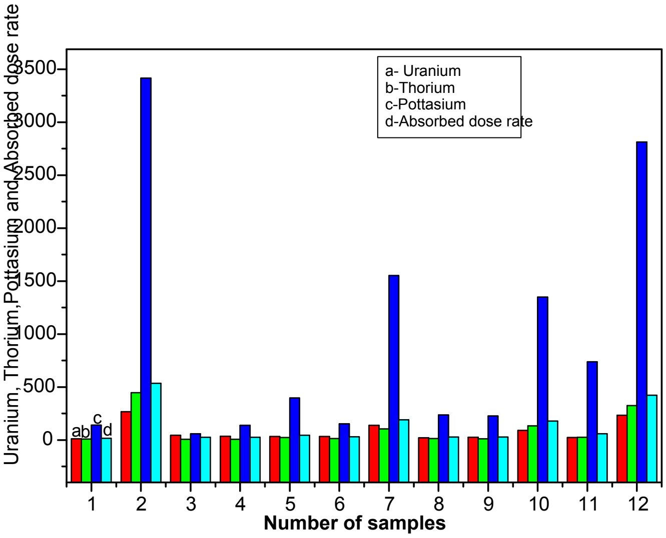

Fig 5 Bar diagram showing activity concentration of ^{238}U, ^{232}Th, and ^{40}K and absorbed gamma dose rate in different samples

Indoor and outdoor annual effective dose rate from these granite samples vary from 0.08 to 2.63 mSv y^{-1} and 0.02 to 0.66 mSv y^{-1} , respectively. External hazard index, H_{ex} for the granite samples studied in this work ranges from 0.09 to 3.16 with a mean value of 0.77. The internal exposure to ^{222}Rn and its radioactive progeny is controlled by the internal hazard index H_{in}. Computed values of H_{in} vary from 0.15 to 4.76 with an average value of 0.99. since most of the values of H_{ex} are less than unity except four granite samples G2, G7, G10, G12 showing higher values than unity (shown in Fig 6). The use of these granite as construction material can be done without posing significant radiological threat. But care should be taken in the use of any granite slab.

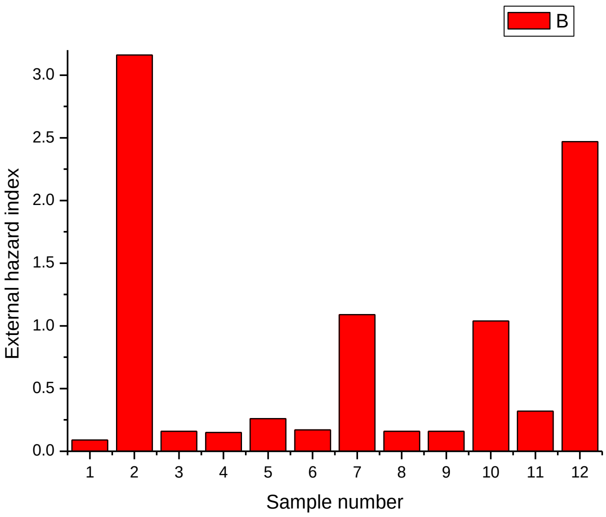

Fig 6 Bar diagram showing the values of external hazard index

4. CONCLUSIONS

There is a wide variation in radon exhalation rates in granite samples and it is observed that granites have higher radon concentration and may be the main source of radon emanation as compared to other building materials such as cement, sand , bajari and concrete etc. Granites can be a significant source of radon in houses, when used in tiling large enclosed areas, besides being source of external gamma radiation from uranium decay series.

Table 3
Radium equivalent activity, absorbed gamma dose rate, annual effective doses, External hazard index and internal hazard index in granite samples.

Samples Code	Radium equivalent activity Ra_{eq} (Bq kg^{-1})	Absorbed gamma dose rate D(nGy h^{-1})	Annual effective Dose (mSv y^{-1})		External Hazard Index (H_{ex})	Internal Hazard Index (H_{in})
			In door	Out door		
G1	34.64	16.82	0.08	0.02	0.09	0.13
G2	1144.84	535.67	2.63	0.66	3.16	3.88
G3	57.22	26.68	0.13	0.03	0.16	0.28
G4	53.89	25.86	0.13	0.03	0.15	0.24
G5	94.31	45.98	0.23	0.06	0.26	0.35
G6	62.81	29.65	0.15	0.04	0.17	0.26
G7	394.48	190.89	0.94	0.23	1.09	1.47
G8	58.12	28.26	0.14	0.03	0.16	0.22
G9	58.06	28.33	0.14	0.03	0.16	0.23
G10	377.32	179.37	0.88	0.22	1.04	1.29
G11	114.61	58.36	0.29	0.07	0.32	0.39
G12	896.57	422.09	2.07	0.52	2.47	3.11
Average Value	278.91	132.33	0.65	0.16	0.77	0.99
S.D	371.62	174.04	0.85	0.21	1.03	1.26
R.S.D %	133.24	131.52	130.77	131.25	133.27	127.27

The radium equivalent activity in granite samples is less than 370 $BqKg^{-1}$, which is acceptable for safe use [45]. Since most of the values of H_{ex} are less than unity except four granite samples G2, G7, G10, G12 showing higher values than unity (shown in Fig 6). Therefore use of these granite as construction material can be done without posing significant radiological threat. But care should be taken in the use of any granite slab.

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