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# A Study on Radon ($^{222}Rn$) Exhalation Rate in the Rocks Used as Building Materials in Tiruchirappalli District, TN, India

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## *Abstract*

*Tiruchirappalli district is naturally endowed with rich building material resources, like stone, granite, sand, brick, cement etc. which are also used in the neighbouring districts. Hence, measurement of radon level in these building materials is important, because radon, a radioactive gas, is one of the major causative factors for human lung cancer and it is important to assess its impact on human health. The present study was undertaken to measure the activity concentrations of radon in 14 sedimentary rock (sand stone) quarries and 9 igneous rock (granite) quarries spread over Tiruchirappalli district. The Sealed Can Technique using Solid State Nuclear Track Detector (SSNTD) was employed for the measurement of radon emanation. The activity concentrations of radon in sedimentary rocks analyzed ranged from 13.2±0.7 Bq $m^{-3}$ to 218.0± 10.6 Bq $m^{-3}$ with the geometric mean activity level of 46.3 Bq $m^{-3}$. However, radon concentrations in igneous rocks are distinctly higher than those of sedimentary rocks and ranged from 95.6 ± 8.0 Bq $m^{-3}$ to 1140±95.0 Bq $m^{-3}$ with the geometric mean activity concentration of 392.6±2.1 Bq $m^{-3}$. The geometric mean radium concentration ($C_{Ra}$) recorded in both sedimentary (3.4±2.3 Bq $kg^{-1}$) and igneous rocks (50.2±2.1 Bq $kg^{-1}$) were well within the limit prescribed for dwellings (370 Bq $kg^{-1}$). The mass and surface exhalation rates were also calculated in all the rock samples. The study concludes that the sedimentary rocks and the igneous rocks analyzed were radiologically safe (less than the permissible limit of 600 Bq $m^{-3}$) when used as building materials except the granite rocks from Narthamalai (682±57.3 Bq $m^{-3}$) and Vilathupatti (1140.0 ±121 Bq $m^{-3}$).*

**Keywords:** *sedimentary and igneous rocks; Radon exhalation rate; Solid State Nuclear Track Detector; Tiruchirappalli.*

## 1. INTRODUCTION

Human beings are continuously exposed in their homes and places of work to ionizing radiation and external gamma radiations (Damla *et al.* 2011). The building materials derived from rocks and soil contain the natural radionuclides such as Uranium ($^{238}U$) and Thorium ($^{232}Th$) and their daughter products and singly occurring Potassium ($^{40}K$). The internal radiation exposure, affecting the respiratory tract, is due to radon and radon decay products which emanate from building materials EC 1999. Knowledge of radioactivity present in building materials enables one to assess any possible radiological risk to human health Kumar *et al*. 2003. Radon ($^{222}Rn$) is an alpha emitter that decays with a half-life of 3.82 days into a series of radon progeny. About 70% of the radon in the living rooms originates from the applied building materials and also due to poor ventilation (Stoop *et al.* 1998; Sonkawade *et al.* 2005). Hence construction materials can be significant sources of indoor radon in addition to soil and water. Approximately 18,000 lung-cancer deaths are attributable to radon annually in the United States (US) NAS 1988. In order to assess the possible radiological hazards to human health, it is important to study the radioactivity level emitted by the building materials. The International Commission on Radiological Protection (ICRP) 1993 recommended radon concentration value ranges of 200-600 Bq $m^{-3}$ for dwellings and this concentrations do not pose a significant risk for workers. The US Environmental Protection Agency (EPA) suggests remediation for radon concentration exceeding 2 pCi/L and strongly recommends remediation for

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concentrations exceeding 4 pCi/L EPA 2002. The main objective of the present study is to identify and determine radon concentration in different rocks (Sedimentary and Igneous rocks) which contribute a substantial quantity of building materials. This study would also be useful for establishing a baseline data on radon measurement in rocks from various quarries located in Tiruchirappalli district.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

Tiruchirappalli district is located in central part of Tamil Nadu and it lies between 10º and 11º - 30' Northern Latitude and between 77º - 45' and 78º - 50' Eastern Longitude. It is the fourth largest district in Tamil Nadu and spread in an area of 4,509 $km^2$. According to the 2011 census, Tiruchirappalli had a population of 27,22,290 with the population density of 604 persons per $km^2$. Tiruchirappalli district is

samples were air-dried for several days to remove moisture and unwanted foreign particles. The samples obtained were oven dried at 110 ºC until they reached a constant weight. **2.3 Analysis** For radon measurement 'Can Technique' was used Eappen and Mayya 2004. 100 g of powdered rock sample was placed in plastic cylindrical can of 13 cm height and 9.4 cm diameter. The Kodak LR 115 film also known as Solid State Nuclear Track Detector (SSNTD) was fixed on the inner side of the lid with adhesive tape. The can is tightly closed and hermetically sealed such that the sensitive side of the detector always faced the specimen and it is exposed freely to the emerging radon in the remaining volume of the can (Fig.2). The can was left for 90 days exposure. At the end of the exposure time, the LR 115 film (SSNTDs) was removed and subjected to a chemical etching

by using spark counter (Model: PSC-SC1). The radon activity or integrated radon exposure inside the can was obtained by using the sensitivity factor 0.021 tracks $cm^{-2}$ $d^{-1}$ Eappen and Mayya 2004. The effective radium content of the sample was calculated using the formula (Singh *et al*. 2010).

$$C_{Ra}\ (\mathrm{Bq\ kg^{-1}}) = \frac{\rho\, h\, A}{K.\, T_e.\, M} \qquad (1)$$

where M is the mass of the sample, A is the area of cross-section of the cylinder in $m^2$, h is the distance between the detector and the top of the samples in meters. The effective exposure time was calculated using the following equation: $T_e = T - 1/\lambda\ (T - e^{-\lambda T})$ (2)

naturally endowed with rich building material resources such sand, stones, granites, cements and bricks which are avidly utilized by several adjacent districts also and the granites and cement are exported to other countries as well. In general, rocks are classified into three types namely Igneous, Metamorphic and Sedimentary based on their formation in the earth curst. However, igneous and sedimentary rocks are commonly found in Tiruchirappalli district.

### 2.2 Sample Collections

The rock samples were collected from 23 quarries spread over Tiruchirappalli district (Fig 1). The coordinates of each sampling site was recorded using hand held GARMIN GPS (Global Positioning System, Model: eTrex 10). About 2 kg of the rock sample was collected from each quarry. The solid matrix of the samples were powdered and sieved through 500 µm mesh. The

Where λ is the decay constant for radon The mass and surface exhalation rate ($E_M$ and $E_A$) of radon is obtained from the following expressions (Mahur *et al*. 2000)

$$E_M\ (\mathrm{mBq\ kg^{-1}\ h^{-1}}) = \frac{C.V.\ \lambda / M}{T + 1/\lambda\ (e^{-\lambda T} - 1)} \qquad (3)$$

$$E_A\ (\mathrm{mBq\ m^{-2}\ h^{-1}}) = \frac{C.V.\ \lambda / A}{T + 1/\lambda\ (e^{-\lambda T} - 1)} \qquad (4)$$

where C-is the integrated radon exposure (Bq $m^{-3}$ $h^{-1}$); V is the volume of air in can ($m^3$); T is the time of exposure (hours); λ is the decay constant for radon ($h^{-1}$); A is area covered by the can or surface area of the sample ($m^2$); M is the mass of the sample (kg).

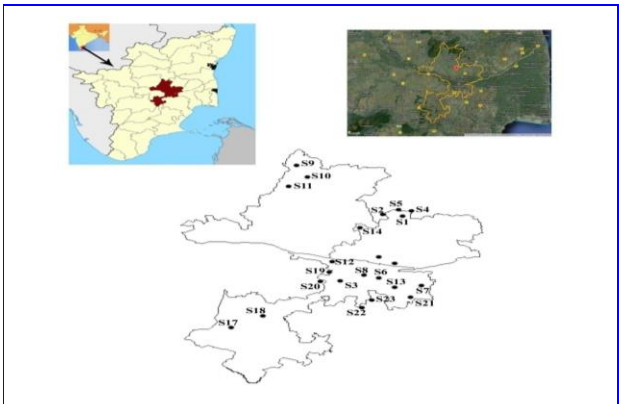

**Fig. 1: map showing sampling stations**

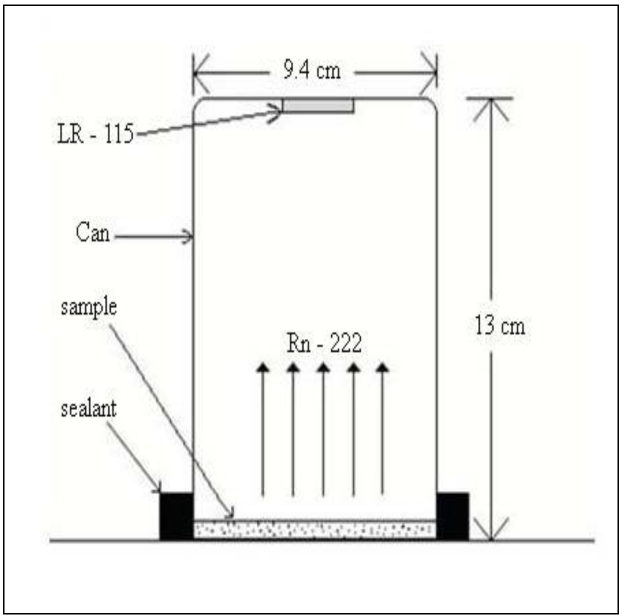


**Fig. 2: Radon measurement by can technique**

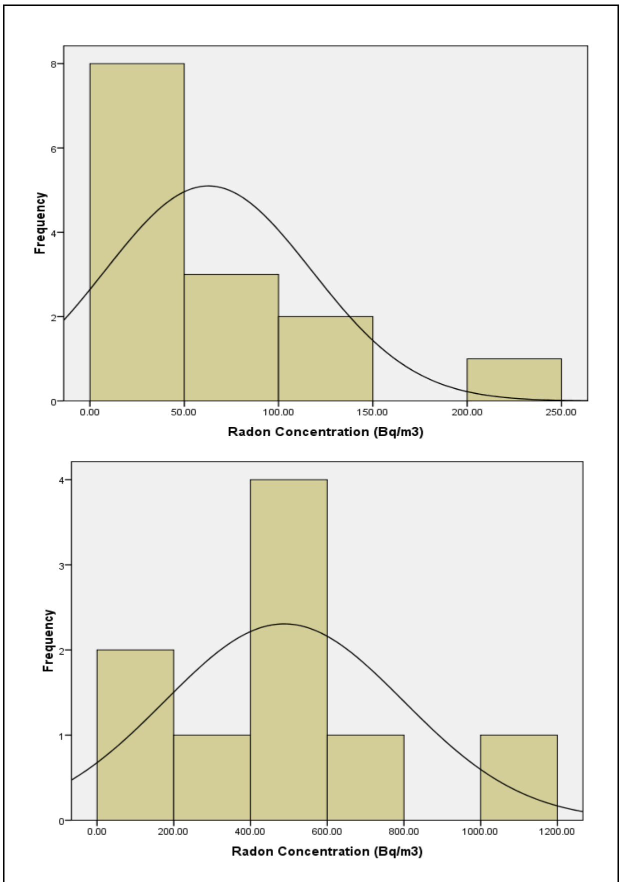


**Fig. 3 and 4: Shows the Frequency Distribution of Radon Activities detected for both Igneous and Sedimentary Rocks in the Study Area.**

## 3. RESULTS AND DISCUSSION

The data on radon concentrations and exhalation rate in the rock samples collected from 23 quarries spread over Tiruchirappalli district were presented in Table 1. Out of the 23 quarries sampled 14 are sedimentary rocks (stone) and 9 igneous rocks (granite). It is evident from that in sedimentary rocks, the radon activity concentrations varied from 13.2±0.7 Bq $m^{-3}$ (Kelavadi) to 218±10.6 Bq $m^{-3}$ (Thiruvellarai) with geometric mean value of 46.3 Bq $m^{-3}$. On the other hand, in igneous rocks the activity concentrations of radon ranged from 95.6±8.0 Bq $m^{-3}$ (K.K.Nagar) to 1140±121 Bq $m^{-3}$ (Vilathupatti) with geometric mean value of 392.6 Bq $m^{-3}$. The radium activity ($C_{Ra}$) in sedimentary rocks varied from 0.98±0.09 Bq $kg^{-1}$ (Kelavadi) to16.2±1.8 Bq $kg^{-1}$ (Vilathupatti). In contrast the radium concentration of igneous rocks ranged from 7± 0.6 Bq $kg^{-1}$ (K.K.Nagar) to 85.6±7.9 Bq $kg^{-1}$ (Vilathupatti). The mass exhalation rate in sedimentary rocks fluctuated from 1.8± 0.1 mBq $kg^{-1}$ $h^{-1}$ (Kelavadi) to 29.2 ±2.6 mBq $kg^{-1}$ $h^{-1}$ (Vilathupatti) with geometric mean value of 6.2 mBq $kg^{-1}$ $h^{-1}$. On the contrary, in igneous rocks the mass exhalation rate varied from 13.1±1.3 mBq $kg^{-1}$ $h^{-1}$ (K.K.Nagar) to 156.2±11.4 mBq $kg^{-1}$ $h^{-1}$ (Vilathupatti). The radon exhalation rate in terms of surface area of sedimentary rocks ranged from 13±0.3 mBq $m^{-2}$ $h^{-1}$ (Kelavadi) to 94 ±8.2 mBq $m^{-2}$ $h^{-1}$ (K.K.Nagar) with geometric mean value of 46.2 mBq $m^{-2}$ $h^{-1}$. On contrary, surface exhalation rate in igneous rocks varied from 215.4 ±12.3 mBq $m^{-2}$ $h^{-1}$ (Thiruvellarai) to 1127 ±186.2 mBq $m^{-2}$ $h^{-1}$ (Vilathupatti) ) with geometric mean value of 387.8 mBq $m^{-2}$ $h^{-1}$. The value of radium concentration and radon exhalation rate are also found to be higher in igneous rocks when compared to sedimentary rocks. Fig: 3 and 4 shows the frequency distribution of the radon activities detected for both igneous and sedimentary rocks in the study area. It can be observed that the skewness and kurtosis co-efficient of all radionuclides in the rock samples are not closer to the null value indicating the non-existence of a normal distribution. The variation of radon concentration at different sampling sites is due to the variation of concentrations of $^{238}$U and $^{232}$Th in the geological formation (El-Arabi *et al*. 2007). The radionuclides linked minerals such as Zircon, Iron Oxides and fluorite play an important role in controlling the distribution of uranium and thorium. Zircon usually contains uranium and thorium concentrations which ranged from 0.01 % to 0.19 % and 1 % to 2 % respectively Cuney *et al*. 1987. Uranium in iron oxides is first trapped by adsorption (Speer *et al*. 1981).

**Table 1. Radon activity, Radon exhalation rate and Radium concentration in Sedimentary and Igneous rocks from Tiruchirappalli District.**

| Station code | Rock type/ Sampling station | GPS Coordinates | | Radon activity (Bq $m^{-3}$) | Radon Exhalation rate | | Radium Concentration ($C_{Ra}$) (Bq $kg^{-1}$) |
|---|---|---|---|---|---|---|---|
| | | Lat.(N) | Long.(E) | | Mass Exhalation rate $E_M$ (m Bq $kg^{-1} h^{-1}$) | Surface Exhalation rate $E_A$ (m Bq $m^{-2} h^{-}$) | |
| | **Sedimentary Rock** | | | | | | |
| S1 | Uthangal | 11º05′.461 | 78º49′.649″ | 48±1.6 | 6.8±1.0 | 47.4±7.4 | 3.4±0.2 |
| S2 | Tholuthur | 11.40′.978″ | 79.01′.442″ | 81±3.0 | 11.0±0.4 | 80±3.0 | 6±0.2 |
| S3 | Kallikudi | 10º46′.306″ | 78º37′.475″ | 41±1.6 | 5.4±0.2 | 40.4±1.6 | 3±0.5 |
| S4 | Padalur | 11º05′.521″ | 78º49′.686″ | 37.6±0.6 | 5±1 | 37±0.9 | 2.6±0.5 |
| S5 | Thirlukurichi | 11º05′.421″ | 78º49′.649″ | 54±2.4 | 7.4±1.4 | 53.2±2.4 | 3.8±0.6 |
| S6 | Kuttimalai | 10º45′.595″ | 78º39′.808″ | 112±9.6 | 15.2±1.4 | 110.8±9.4 | 8.2±0.6 |
| S7 | Thiruverumbur | 10º45′.595″ | 78º50′.129″ | 52.6±3.4 | 6±1 | 52±3.4 | 3.8±0.3 |
| S8 | Erattamalai | 10º46′.311″ | 78º39′.808″ | 45.2±8.0 | 6±3.8 | 44.6±7.8 | 3.2±0.6 |
| S9 | Podalathi | 11º14′.881″ | 78º32′.189″ | 16.8±0.8 | 2.2±0.1 | 16.6±1.7 | 1.2±0.1 |
| S10 | Kelavadi | 11º09′.120″ | 78º38′.100″ | 13.2±0.7 | 1.8±0.1 | 13±0.3 | 0.98±0.09 |
| S11 | Kunnupatti | 11º08′.876″ | 78º38′.838″ | 13.4±1.2 | 1.9±0.1 | 13.2±0.3 | 1±0.9 |
| S12 | Iyermalai | 10º52′.180″ | 78º22′.072″ | 33.6±0.9 | 4.6±0.4 | 33.2±0.2 | 2.4±0.12 |
| S13 | Kajamalai | 10º41′.522″ | 78º41′.427″ | 112.4±7.3 | 18.1±1.3 | 130.8±8.4 | 9.8±0.7 |
| S14 | Thiruvellarai | 10º57′.612″ | 78º40′.303″ | 218±10.61 | 29.2±2.6 | 215.4±12 | 16.2±1.8 |
| **Range** | | | | **13.2±0.7-218±10.61** | **1.8±0.1-29.2±2.6** | **13±0.3-215.4±12** | **0.98±0.09-16.2±1.8** |
| **GM×÷GSD** | | | | **46.3×÷2.25** | **6.2×÷2.28** | **46.2×÷2.29** | **3.4×÷2.3** |
| | **Igneous Rock** | | | | | | |
| S15 | Ponmalai | 11.40′.978″ | 78º42′.823″ | 173.2±12 | 23.6±2.4 | 171.2±10.3 | 13.1±2.1 |
| S16 | Rockfort | 10º46′.306″ | 78º41′.889″ | 252.6±9.6 | 34.6±3.2 | 249.6±17.9 | 18.8±2.6 |
| S17 | Enamkulathur | 10º43′.625″ | 78º33′.564″ | 496±28.2 | 67.9±5.7 | 490±29.6 | 37±2.7 |
| S18 | Parappatti | 10º43′.832″ | 78º33′.564″ | 516±29 | 38.7±3.6 | 509.4±28.6 | 70.7±2.1 |
| S19 | Allithurai | 10º44′.527″ | 78º25′.561″ | 487.2±61 | 66.7±4.8 | 481.4±36.1 | 36.4±18 |
| S20 | Thogamalai | 10º43′.776″ | 78º24′.578″ | 547.4±23 | 75±5.1 | 540.8±15.8 | 41±1 |
| S21 | K.K.Nagar | 10º45′.865″ | 78º41′.578″ | 95.6±8 | 13.1±1.3 | 94±8.2 | 7±0.6 |
| S22 | Narthamalai | 10º30′.869″ | 78º46′.286″ | 682±57.3 | 93.4±6.9 | 674.4±29.7 | 51.2±3.8 |
| S23 | Vilathupatti | 11.40′.978″ | 78º42′.823″ | 1140±121 | 156.2±11.4 | 1127±186 | 85.4±7.9 |
| **Range** | | | | **95.6±8-1140±121** | **13.1±1.3-156.2±11.4** | **94±8.2-1127±186** | **7±0.6-85.4±7.9** |
| **GM×÷GSD** | | | | **392.6×÷2.1** | **31.5×÷2.24** | **387.8×÷2.13** | **50.2×÷2.13** |

**Table 2. Statistical data for radon concentration in sedimentary and igneous rock samples from Tiruchirappalli District**

| Rock Type | Activity concentration of Radon (Bq $m^{-3}$) |
|---|---|
| **sedimentary** | |
| Range | 13.2 – 218 |
| GM | 46.3 |
| GSD | 2.25 |
| Skewness | 1.960 |
| Kurtosis | 4.467 |
| Frequency distribution | log normal |
| **Igneous** | |
| Range | 95.6 - 1140 |
| GM | 392.6 |
| GSD | 2.13 |
| Skewness | .961 |
| Kurtosis | 1.667 |
| Frequency Distribution | log normal |

The high uranium content in the mineralized granite and pegmatite are attributed to the ability of iron oxide in them on adsorbing uranium. It is observed that high percentage of $U_3O_8$ and $ThO_2$ in granite were responsible for higher activity concentration of radon. Zircon typically contains 2-2000 g $t^{-1}$ of $^{232}$Th and 5-4000 g $t^{-1}$ of $^{238}$U Deer *et al.* 1997. Overall the values of radium concentration in rock samples in present investigation are much lower than the permissible value of 370 Bq $kg^{-1}$ OCED 1979.. The average radon concentration in both Sedimentary and Igneous rocks analyzed were below the permissible level recommended by the ICRP 1993.

## 4. CONCLUSION

A preliminary data base on the radon concentrations in Sedimentary and Igneous rock of Tiruchirappalli district is generated. The distribution of radon concentration in this study region is not uniform. The high radon activity levels are found in granite type of

rocks (igneous). All other radiological parameters like, mass exhalation rate and surface exhalation rate are derived. The study concludes that the sedimentary rocks and the igneous rocks analyzed were radiologically safe when used as building materials except the granite rock from Narthamalai and Vilathupatti which exhalate radon at a higher rate than the recommended limit of 600 Bq $m^{-3}$.

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## CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.



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