Acta Ciencia Indica, Vol. XLIII P, No. 1, 25 (2017)

STUDY OF RADON GAS DIFFUSION AND ITS PERMEABILITY THROUGH SOME BUILDING CONSTRUCTION MATERIALS BY USING SSNTD TECHNIQUE

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RECEIVED : 20 February, 2017

Study of radon diffusion and radon permeability through some building construction materials has been carried out by using solid state nuclear track detectors (LR-115, type II plastic track detectors). Uranium ore has been used as a radon source. In the present work radon diffusion coefficient and corresponding diffusion length through some building materials like sand stone, gypsum, fly ash, soil, cement, granite, sand and lime stone have been calculated. The comparative radon permeability through these materials has also been studied. The average radon diffusion coefficient and corresponding diffusion length was found maximum (4.23×10^{-6} m^2/s and 1.42 m**)** for sand and minimum (0.05 m^2/s and 0.14 m) for granite. The building construction materials like soil, fly ash and cement are found to be least permeable to radon flow. Similarly the building materials sand stone, gypsum and sand are found to be permeable to radon flow while the building materials lime stone and granite are found to be radon-tight.

KEYWORDS : Radon, Diffusion coefficient, Diffusion length, Building materials, Radon Permeability.

INTRODUCTION

Radon is a radioactive gas that is produced by the decay of uranium. As radon is a radioactive gas, therefore it can diffuse through porous building materials used in the construction work. It has been well established that many building materials used in construction work contains radioactive elements and their decay products. Thus building materials contribute significantly in increasing the natural radiation in the ambient air and poses a health hazard. Radon is also known carcinogen and is estimated to cause up to 10% of all lung cancers in European countries (Darby *et. al*., 2005). Radon is naturally occurring and emanates from soil and rock. It percolates up through the through soil and buildings and if it is not evacuated there can be much higher exposure levels indoors than outdoors (Nazaroff, 1992). As radon is a gas, it is able to diffuse through the soil and other materials around the foundation of a home. Homes tend to operate under a negative pressure, meaning that the air pressure inside the home is lower than the air pressure outside (Gadgil, 1992). This negative pressure comes about from: (a) the stack effect by which the upward flow of warm air inside the home creates a positive pressure area at the top of the home and a negative pressure area at the bottom. (b) Vacuum effect caused by air vented to the outside by exhaust fans, clothes dryers, etc. (c) A downwind draft effect, which is caused by wind blowing past a home. This negative pressure difference tends to be strongest in basements and during the heating season. It acts as a vacuum that pulls radon-rich air into the lower areas of the home through any dirt floor areas or unsealed sumps or cracks, fissures or pores in the building materials. Although numerous factor can influence the radon entry diffusion/convection mechanism (*e.g.* atmospheric pressure, indoor-outdoor-temperature differentials, humidity, rainfall) in homes having natural ventilation, the predominant factors influencing radon entry are the indoor-outdoor differential pressure and in some cases the wind velocity (Riley *et. al.*,1996, Renken *et. al.*,1995). The random movement of the radon gas atoms mixed in the air results in a net migration of the radon gas toward the direction of its decreasing concentration in the air is called molecular or atom diffusion. The transport phenomenon of radon through diffusion is significant contributor to indoor radon entry. The radon diffusion coefficient of a material quantifies the ability of radon gas to move through it when a concentration gradient is the driving force. This parameter is proportional to the porosity and permeability of the medium. High radon concentrations indoors usually caused by intensive radon transport from the underlying soil. The reduction of radon penetration in a dwelling during the construction of underground part of building is achieved by using film-type building insulation materials (or simply materials), if the foundation slab does not provide sufficient radon protection or if such slab is absent and it is necessary to look for building and insulating materials with low radon permeability. The ability to prevent radon transfer through the building materials like soil, brick powder, cement, concrete, mortar, plaster, gypsum, etc. is determined by its thickness and radon diffusion coefficient. The diffusion of radon through the material media is given by the equation:

$$C = C_0 \exp. \{- \sqrt{(\lambda/D)}\, X\}$$

where C is the radon concentration at any time ‘t’ at a distance X from the source, C_0 is the radon concentration at source and λ is the radon decay constant. If C_1 and C_2 are the radon concentrations at distances X_1 and X_2 from the source, then diffusion coefficient ‘D’ is given by

$$D = \lambda\, [(X_2 - X_1) / \ln (C_1/C_2)]^2$$

The radon diffusion length ‘L’ (or Relaxation Length) can be calculated from the diffusion ‘D’ as

$$L = \sqrt{(D/\lambda)}$$

Where λ is the radon decay constant and is equal to $2.1 \times 10^{-6}\ S^{-1}$. The characteristics distance travelled by the radon atoms during one half-life is known as diffusion length. The diffusion length is also known as relaxation length. The radon diffusion length may also define as the distance through which the radon concentration decreases to 37% of its initials value. The radon diffusion coefficient and diffusion length is independent of the thickness of the materials and depends upon the porosity and density of materials for powder samples (Keller 1992). The flux through a sample decreases with the thickness. In order to understand the radon permeability through the building construction materials, they are divided into three categories; radon-tight, less permeable and permeable. Accordingly, a material is said to be radon-tight, if the radon diffusion length is less than 0.5 m. In this case only 3-5% of the initial radon only passes the sample and radon flux is reduced nearly by 20 times. If the radon diffusion length lies between 0.5 m and 1.0 m, then the material is said to be radon less permeable and the materials having radon diffusion length more than 1.0 m, is said to be radon permeable (Narula *et. al.*, 2009, 2010, 2013., Keller *et. al.* 1999, 2001). The main objective of this work is to calculate the radon diffusion coefficient and diffusion length and also study the radon permeability through some building construction materials (Folkerts *et. al.,* 1984).

EXPERIMENTAL TECHNIQUE

The experimental setup for the study of radon diffusion and radon permeability through some building construction materials is shown in the figure1. It consists of a hollow plastic cylinder of inner diameter 20 cm and length 100 cm was deployed vertically. Uranium ore has been used as a radon source. The radon source was fixed to the inside at the bottom of the cylinder in the cavity and it was covered with latex membrane. Sixteen open-ended cylindrical diffusion tubes of diameter 2.0 cm and lengths 20 cm and 30 cm were installed in hallow plastic cylinder fixed with radon source. For the study of radon diffusion coefficient, diffusion length and radon permeability through different building materials, LR-115 type-II plastic track detectors (size 1.5 cm × 1.5 cm) was fixed at the top end of each diffusion tubes to record alpha tracks due to radon diffusion at different heights from the source. The detector film was fixed in such a way that the sensitive side of the film always faces the source of radon. Building materials under study in fine powder for (pulverized form) was filled in each cylindrical diffusion tubes. The whole system was closed and left without any disturbance for a period of 30 days.

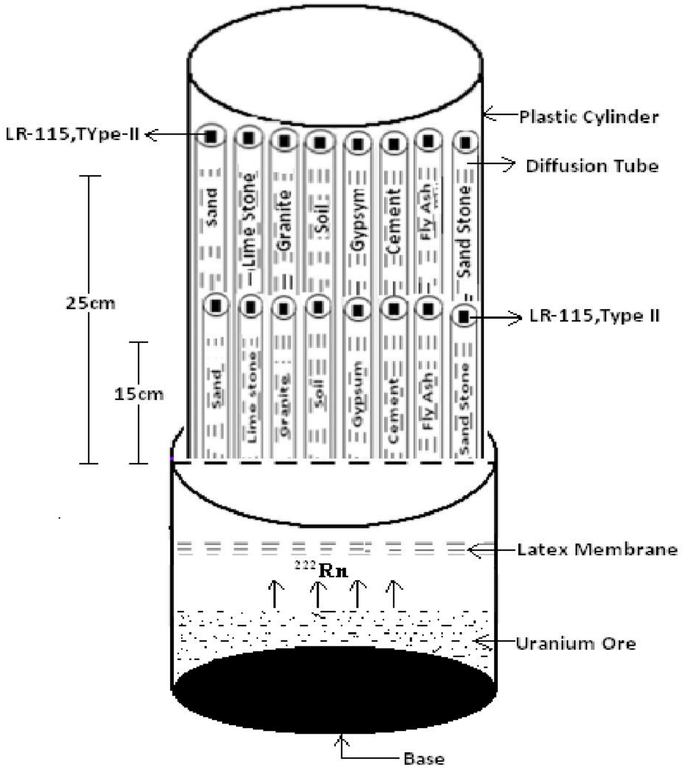

Fig. 1. Experimental technique for measuring radon diffusion coefficient and diffusion length.

All building material samples were subjected to analysis under similar process of exposure as described above. After the completion of exposure time, (about 30 days), all the detectors were retrieved and subjected to chemical etching process with 2.5N NaOH solutions for a period of 90 min. (Ramola *et al*., 1992, 1996., Jojo, *et. al*., 1994., Ramachandran, 1998) at a bath temperature of about 60°C. After that the detectors were washed and dried. When alpha particles strikes on LR-115 film it creates narrow trails called Tracks. The Tracks produced by the alpha particles were counted by using spark counter. The concentration of radon was calculated for each building materials samples in different cases. The packing density of each building material samples were also calculated by taking mass over volume ratio. (*i.e.* Density = Mass/Volume).

RESULT AND DISCUSSION

The measured values of radon diffusion coefficient, diffusion length and their comparative permeability through some building constructional materials are given in the table 1.The average values of radon diffusion coefficient and corresponding diffusion length for sand stone was found 2.51×10^{-6} m^2/s and 1.09 m. For gypsum, the average values of radon diffusion coefficient and corresponding diffusion length was found 2.59×10^{-6} m^2/s and 1.10 m. For lime stone, the average values of radon diffusion coefficient and corresponding diffusion length was found 0.42×10^{-6} m^2/s and 0.45 m. For granite, the average values of radon diffusion coefficient and corresponding diffusion length was found 0.05×10^{-6} m^2/s and 0.14m. For soil, the average values of radon diffusion coefficient and corresponding diffusion length was found 1.62×10^{-6} m^2/s and 0.88m. For fly ash, the average values of radon diffusion coefficient and corresponding diffusion length was found 2.05×10^{-6} m^2/s and 0.99 m. For cement, the average values of radon diffusion coefficient and corresponding diffusion length was found 1.20×10^{-6} m^2/s and 0.75 m. For sand, the average values of radon diffusion coefficient and corresponding diffusion length was found 4.23×10^{-6} m^2/s and 1.42 m. The building construction materials like soil, fly ash and cement are found to be least permeable to radon flow. Similarly the building materials sand stone, gypsum and sand are found to be permeable to radon flow while the building materials lime stone and granite are found to be radon-tight. The radon diffusion coefficient and corresponding diffusion length was found maximum for sand and minimum for granite. From the observation it was also found that the radon diffusion coefficient and corresponding diffusion length is different for different building construction material. This difference may be due to the difference in nature, grain size and porosity of the materials. The variation of radon diffusion coefficient and corresponding diffusion length for different building materials are shown in figure 2 and 3.

Table : Measured values of radon diffusion coefficient, diffusion length and its comparative permeability

Sr. No.	Building Materials	Packing Density ($\times 10^3$Kg/m^3)	Diffusion Coefficient ($\times 10^{-6}$ m^2/s)	Diffusion Length (m)	Comparative Radon Permeability
1	Sand Stone	2.29	2.51	1.09	Permeable
		2.28	2.52	1.09	
		2.30	2.50	1.09	
		Avg. = 2.29	Avg.= 2.51	Avg.=1.09	
2	Gypsum	2.20	2.59	1.10	Permeable
		2.19	2.62	1.11	
		2.21	2.58	1.10	
		Avg.= 2.20	Avg.= 2.59	Avg.=1.10	

3	Lime Stone	1.47 1.52 1.48	0.45 0.39 0.41	0.46 0.44 0.45	Tight
		Avg.= 1.49	Avg.= 0.42	Avg.=0.45	
4	Granite	2.50 2.68 2.58	0.07 0.04 0.05	0.17 0.10 0.14	Tight
		Avg.= 2.58	Avg.= 0.05	Avg.=0.14	
5	Soil	1.39 1.34 1.37	1.62 1.66 1.59	0.88 0.90 0.87	Least Permeable
		Avg.= 1.36	Avg.= 1.62	Avg.=0.88	
6	Fly Ash	1.25 1.20 1.19	2.04 2.05 2.07	0.98 0.99 0.99	Least Permeable
		Avg.= 1.21	Avg.= 2.05	Avg.=0.99	
7	Cement	1.45 1.39 1.40	1.16 1.25 1.19	0.74 0.77 0.75	Least permeable
		Avg.= 1.41	Avg.= 1.20	Avg.=0.75	
8	Sand	1.50 1.55 1.51	4.32 4.16 4.22	1.44 1.40 1.41	Permeable
		Avg.= 1.52	Avg.= 4.23	Avg.=1.42	

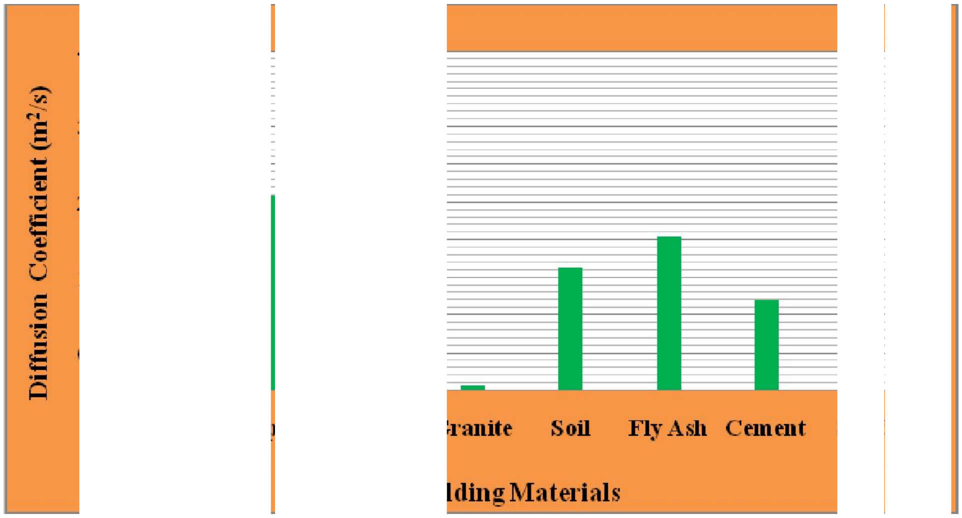

Fig. 2. Variation of radon diffusion coefficient with different building materials

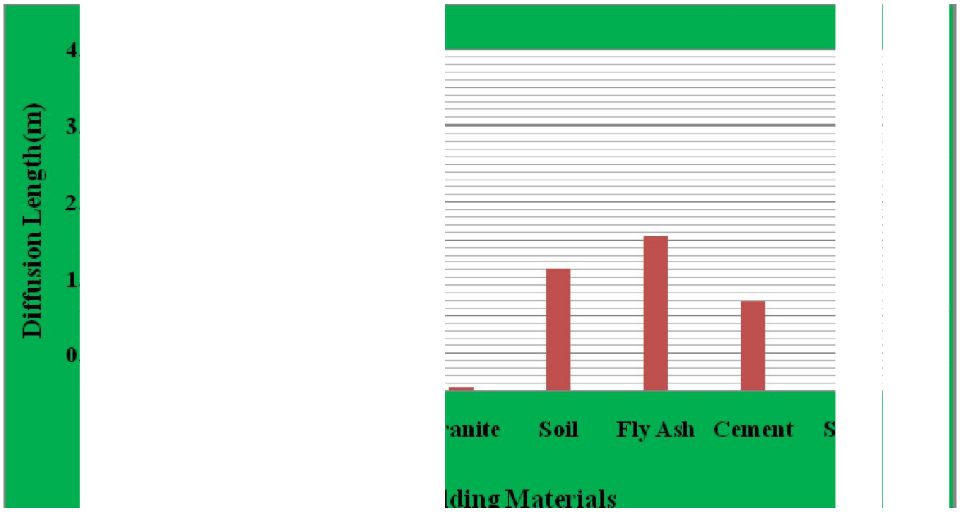

Fig. 3. Variation of radon diffusion length with different building materials

CONCLUSION

The values of radon diffusion coefficient and corresponding diffusion length calculated for different building constructional materials are reported in the table 1. Based on the result it was found that the building materials like soil, fly-ash and cement are least permeable to radon flow. Similarly the building materials like sand stone, gypsum and sand are found to be radon permeable while the building materials like lime stone and granite are found to be radon-tight. Observed result shows that the radon diffusion coefficient and corresponding diffusion length is maximum for sand and minimum for granite. From the result it was also found that the radon diffusion coefficient and corresponding diffusion length is different for different building construction material. This difference may be due to the difference in nature, grain size and porosity of the materials. Results obtained in the present work will play an important role in all comparative studies proposed in forth coming time and provide better insight into the selection of building constructional materials capable of controlling the indoor radon concentration.

ACKNOWLEDGEMENT

The author is thankful to Dr. Mohammad Tariq, Department of Physics M.B.P. Govt. (P.G.) College Ashiana, Lucknow and Dr. R.B.S. Rawat, Department of Physics M.S. (P.G.) College Saharanpur for providing all necessary facility to carry out this work.

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