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Indoor Radiation Levels Enhanced by Underground Radon Diffusion

A. K. NARULA*, R.S. SAINI†,S. K. GOYAL†, R. P. CHAUHAN††, and S. K. CHAKARVARTI††
**Department of Physics, National Institute of Technology, Kurukshetra-136119*
Emails: anilnarulaktl@gmail.com

The indoor radiation exposure to humans is mainly due to radioactive radon gas and emissions from building construction materials. Its transport mechanism therefore calls for innovative investigations. There are three main factors of radon entrance in to a building environment are: a) Emission of radon from building materials used in construction b) By convection through cracks and openings in the building and c) Diffusion from soil through pore space of construction materials. The transport phenomenon of radon through diffusion is a significant contributor to indoor radon entry. The diffusion of radon in dwellings is a process mainly determined by the radon concentration gradient across the building material structure between the radon source and the surrounding air. Keeping this in mind the radon diffusion studies have been made through soil, brick powder and cement. Simultaneously the indoor radon levels have been measured in dwellings with cemented, bricks and soil flooring.

Key Words: Radon, Diffusion, Soil, Cement, Brick.

INTRODUCTION

There are three main mechanisms of radon entrance into a building[1], emanation from building materials, convection via cracks and openings and diffusion from soil via the pore space of building materials. The emanation from building materials is of less concern when room ventilation is few air exchanges per hour but when it is less the radon concentration may exceed the action level. The radon entry via cracks and openings may be suppressed by sealing the radon entry points. The diffusion from soil via the pore space of building materials is reduced when thickness of the basement slab is about three times the radon diffusion lengths[2].The transport phenomenon of radon through diffusion is a significant contributor to indoor radon entry[3] .

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. Radon

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†Department of Physics, RKSD College, Kaithal (Haryana)-136027
††Department of Physics, National Institute of Technology, Kurukshetra-136119

diffusion through material media obeys the equation:

$$N=N_0 \exp. (-\sqrt{\lambda/D})\, X \qquad (1)$$

where N is the concentration of radon at any time t at a distance X from source, N_0 is the concentration of radon at source and λ is the decay constant of radon.

If N_1 and N_2 are the radon concentrations at distances X_1 and X_2 from source respectively.

then using eq^n (1) the diffusion coefficient D is given by:

$$D = \lambda\, [(X_2 - X_1)/ \ln (N_1/ N_2)]^2 \qquad (2)$$

Eq^n (2) can be used to calculate radon diffusion coefficient through material medium.

The diffusion length can be calculated using the eq^n:

$$L = \sqrt{D/\lambda}, \qquad (3)$$

where D is radon diffusion coefficient and λ is decay constant of radon.

In the present study, radon diffusion coefficients and diffusion lengths through building materials viz.; soil, brick powder and cement have been calculated using eq^n (2) & (3).

EXPERIMENTAL

The apparatus designed for the study of radon diffusion through different material media consists of a hollow plastic cylinder of inner diameter 4.1 cm and length 30 cm deployed vertically. The radon source covered with latex membrane was fixed at the bottom of the cylinder in the cavity. LR-115 type-II plastic track detectors (manufactured by Kodak-Pathe in 2006) were used for radon diffusion study. These detectors are frequently used as α-particles detector to record alpha tracks due to radon. The material medium under study in the pulverized form was filled inside the cylinder. The system was closed and left undisturbed for a period of 30 days for each medium under study. The packing density of each sample was also calculated by taking mass over volume ratio. All samples were subjected to similar process of exposure as described above.

Solid state nuclear track detectors have been used for the measurement of radon concentration in different types of dwellings. In each type of dwelling LR-115 type- II detectors (1 cm x 1 cm size) were exposed for 100 days in bare mode. The types of dwellings chosen for present study were having cement, bricks and soil flooring. The height of detectors was kept about 1.5 m from ground in most of the cases. The sensitive side of the bare detectors was exposed to the environment facing down so that dust may not settle on it.

At the end of the exposure time, the detectors were removed and subjected to a chemical etching process in 2.5N NaOH solution at 60^0C for one and half-hour for both types of study. The detectors were washed and dried. The tracks produced by the alpha particles, were observed and counted under an optical Olympus microscope at 600X. Large number of graticular fields have been scanned to account for statistical errors.The radon concentration for radon diffusion was calculated for each sample in different cases using a calibration factor[4-5] for LR-115. The values of diffusion coefficients for different media were calculated using eq^n (2) and the diffusion lengths using eq^n (3)

For Indoor radon levels the measured track density (Track/cm^2/day) was converted into radon concentration in Bq/m^3 using calibration factors[6-7]. The annual effective dose from radon was calculated according to ICRP Publication[8] as follows:

$D =(C\times K\times H) / (3700\ Bq\ m^{-3} \times 170\ h)$,

Where, D = Annual effective dose (mSv/yr)

C = EEC of Rn (Bq/m^3)

K = ICRP dose conversion factor which is 3.88 mSv WL M^{-1} for general public and 5.0 mSv WLM^{-1} for occupational workers.

H = Annual occupancy at location (7000 hours for residents), i.e. 80% of total time. 170, is taken as exposure time in hours for WLM.

RESULTS AND DISCUSSION

The values of diffusion coefficient and diffusion length calculated for different materials are shown in table-1. The values are found to be minimum for cement, which shows that cement is the least, permeable to radon flow as compared with the other building materials studied. Similar results have been reported[9-11] for cement, soil, sand, etc. The minor differences may be due to the difference in the nature, grain size and porosity of the materials. The radon levels in different types of dwellings and annual effective doses received by residents are shown in tables 2.

The results indicate that the levels are higher in dwellings with soil flooring compared with cement and brick flooring. It may be due to the more underground radon diffusion through soil as compare to cement and brick powder. Based on the experimental investigations, the following conclusions are drawn:

- ➔ For the building materials studied during present investigations, cement is found to be the least permeable to radon flow.
- ➔ The levels are higher in dwellings with soil flooring compared with cement and brick flooring due to the more underground radon diffusion through soil as compare to cement and brick powder.On the basis of these investigations it is suggested that the cemented houses are safer than mud houses from the health hazard point of view from radon and its progeny.

Table-1: Radon Diffusion coefficient and diffusion length for different building materials

Diffusing medium	Sr. No	Packing Density $\times 10^3$ (kg/m^3)	Diffusing Coefficient$\times 10^{-6}$ (m^2/s)	Diffusion Length(m)
Soil	1.	1.43	3.16	1.22
	2.	1.41	3.11	1.21
	3.	1.48	3.73	1.33
AM±SE		1.43±0.01	3.33±0.19	1.25±0.03
Brick Powder	1.	1.32	2.31	1.04
	2.	1.47	2.18	1.01
	3.	1.29	2.33	1.05
AM±SE		1.36±0.05	2.27±0.04	1.03±0.01
Cement	1.	1.40	1.12	0.73
	2.	1.41	1.15	0.75
	3.	1.39	1.09	0.69
AM±SE*		1.4±0.01	1.12±0.01	0.72±0.01

Table-2: Variation in radon levels in dwellings with different types of floorings

Type of Dwelling	No. of Dwellings	EECof Rn (Bq/m3) AM±SE*	Annual effective dose (mSv) AM±SE*
mud flooring	6	144±4	6.0±0.1
brick flooring	8	111±4	5.1±0.2
Cement flooring	8	100 ±3	4.3±0.1

*SE=σ/√N, Where N=No. of observations, σ=Standard deviation.

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