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INVESTIGATING RADON TRANSPORT THROUGH DIFFERENT SAUDI BUILDING MATERIALS

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ABSTRACT

Radon has been recognized by various international health organizations as a major lung carcinogen. The onset of cellular carcinogenesis involves DNA damage to bronchi epithelial cells by particles emitted by radon progeny. Radon diffusion is an important release mechanism for radon that is produced inside a building material. The physical parameter that characterizes this process is the radon diffusion coefficient D ($m^{-2}\,s^{-1}$). The diffusion constant and diffusion length has been measured as 2.15 x 10^{-6} $m^{-2}\,s^{-1}$, 1.01 m for soil, 1.65 x 10^{-6} $m^{-2}\,s^{-1}$, 0.89 m for sand and 0.21 x 10^{-6} $m^{-2}\,s^{-1}$, 0.31 m for Saudi crushed aggregate respectively. The values were found to be the lowest that shows that Saudi crushed aggregates are least permeable to radon flow as compared with the other building materials studied so far. The results obtained in this study are comparable worldwide.

Keywords: Radon, transport, Saudi building, materials.

INTRODUCTION

^{222}Rn, a progeny of ^{238}U, is a colourless, odourless, noble, radioactive gas. Its half-life is 3.82 days and it decays with the emission of 5.48 MeV α-particles. Being a noble gas and with long- half life it can move large distances through porous building materials. It's long half-life makes it a useful tool for the study of earthquake prediction, uranium exploration and environmental pollution (Fleischer, 1980; Igarshi, 1990; King, 1978; Singh, 1992). It has been estimated that radon, largely in homes, constitutes more than 50% of the dose equivalent received by the general population from all sources of radiation, both naturally occurring and man-made (BEIR V, 1990). Its mitigation and remediation strategies, therefore, call for efficient and effective innovative means. It is well known that exposure of a population to high concentrations of radon and its daughters for a long period leads to respiratory functional changes and lung cancer (BEIR VI, 1999). A number of biological and epidemiological studies have shown that approximately 12% of lung cancers reported worldwide can be linked to radon gas exposure from the environment (EPA, 2003). Health effects of ^{222}Rn and its decay products have been a cause of concern since these isotopes may reach quite high levels in buildings which either lack adequate ventilation or have strong sources of radon. This has led to numerous studies on the sources and the methods of ^{222}Rn transport (Kerry, 1982; Keller and Folkerts, 1984; Nazaroff and Nero, 1988).

Solid state nuclear track detection (SSNTD) is a widely used technique for detection of nuclear radiation (Durrani and Bull, 1987). This method owes its popularity to its simplicity, cost effectiveness and capacity to store permanent records. Although minerals and glasses have been tested as SSNTDs, the higher sensitivity of the plastic materials to many charged particles, and the ease of track development and evaluation have made plastic materials more popular as SSNTDs. Since the introduction of plastics as SSNTDs in 1965 (Collver *et al*., 1965), a number of plastic materials, such as cellulosics, polycarbonates, acrylates and polyvinyls, have been extensively studied as track detectors. The introduction of polyallyldiglycol carbonate (PADC) polycarbonate (Cartwright *et al*., 1978) replaced many plastics due to its very high sensitivity to many charged particles, and superior optical properties. In the present study radon diffusion through soil, sand and crushed aggregate has been carried out using Polyallydigycol (CR-39) solid state nuclear track detectors.

Radon monitoring has become a global phenomenon due to its hazardous effects on population (Durrani and Elic, 1997). Radon appears mainly by diffusion processes from the point of origin following α-decay of ^{226}Ra in underground soil and building materials used in the construction of floors, walls, and ceilings. Radon can originate from a deeply buried deposit beneath homes and can then migrate to the surface. There are two major transport mechanisms that determine the amount of radon gas that enters a residential building: (1) advection caused by the pressure differential across the foundation structure between the soil gas and the building air; and (2) diffusion caused by the radon concentration gradient across the foundation structure between the soil and indoor air. Both these transport mechanisms are connected to the properties of intermediate media which separates the two regions. The transport phenomenon of radon through diffusion is a significant contributor to indoor radon entry

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(Renken and Rosenberg, 1995). Radon diffusion and transport through different media is a complex process and is affected by several factors (Tanner, 1980; Singh *et al*., 1999). It is well known that for material medium the porosity, permeability and diffusion coefficient are the parameters, which can quantify their capability to hinder the flow of radon soil gas. The radon diffusion coefficient of a material quantifies the ability of radon gas to move through it when concentration gradient is the driving force. Radon diffusion through material media obeys the equation:

$$N = N_o \exp\left(-\sqrt{\frac{\lambda}{D}}\right)X \quad (1)$$

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

If C_1 and C_2 are the radon concentrations at distances X_1 and X_2 from source respectively, then using Eq. (1) the diffusion coefficient D is given by

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

Eq. (2) can be used to calculate the radon diffusion coefficient through a material. The diffusion length can be calculated using the equation:

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

where D is the radon diffusion coefficient and λ is the decay constant of radon. In the present study, radon diffusion coefficients and diffusion lengths through soil, sand and crushed aggregates have been calculated using Eqs. (2) and (3).

MATERIALS AND METHODS

The apparatus designed for the study of radon diffusion through different Saudi material media is shown in figure 1. It consists of a hollow plastic cylinder with a diameter of 9 cm and a length of 120 cm, opened at the bottom and closed at the top was deployed vertically. The radon source (uranium rock) was fixed to the inside bottom of the cylindrical tube. The material medium under study was filled inside the cylinder. Facing the radon source, 6 calibrated dosimeters were employed at a height of 20, 40, 60, 80, 100 and 120 cm to record radon tracks from the source through different Saudi building materials. Each dosimeter contained a piece of CR-39 plastic 500 μm thick (1.5x1.5 cm^2) of Page Moulding Ltd., U.K was fixed at the bottom of a plastic, using double sided Cellotape.

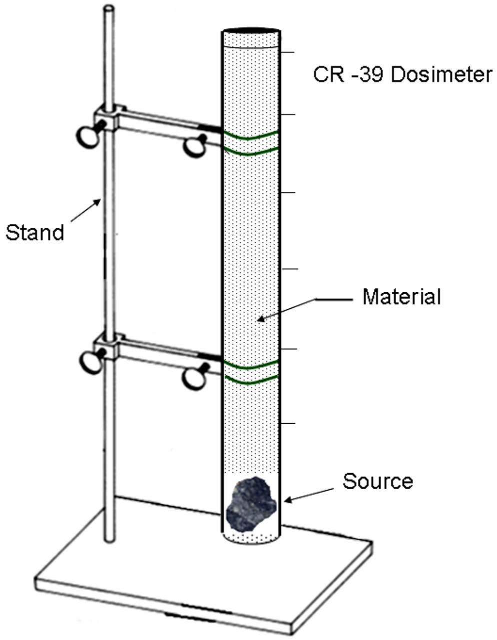

Fig.1. Experimental set up for radon transport studies through different materials.

A circular hole 0.75 cm in radius was made at the centre of the lid. The lid was then sealed from inside with a piece of sponge measuring 2 x 2 cm and 0.5 cm thick (Fig. 2). The system was closed and was left undisturbed for a period of 30 days for each medium under study. At the end of the exposure time, the detectors were removed and subjected to a chemical etching process in 6M NaOH solution at 70° C for 180 minutes and were thoroughly washed and dried. The alpha tracks were counted using a Carl Zeiss binocular optical microscope at the magnification of 400x. A Large number of graticular fields of the detectors was scanned to reduce statistical errors. The calibration factor adopted for this research was obtained after preparing identical dosimeters and sending to the National Radiological Protection Board (NRPB) in the UK for calibration. All necessary measures were taken for the calibration of the dosimeters.

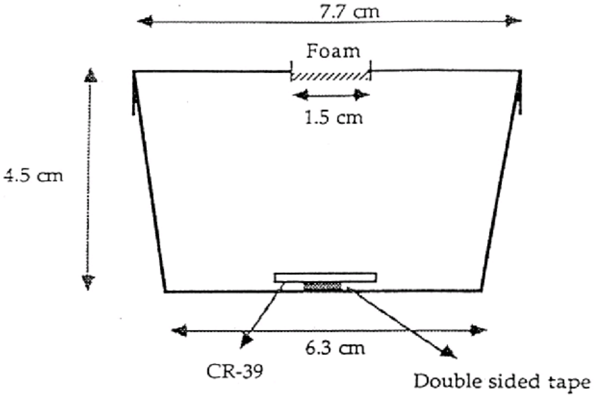

Fig. 2. Schematic diagram of radon dosimeter.

The calibration factor used was 0.0052 tracks m^{-2} per $Bq.m^{-3}h$. The radon concentration was calculated at each height in different cases using this calibration factor. It is worth mentioning that a background measurement was also carried out using the same procedure (without source) and the net concentration was computed by subtracting the background from the original track density for each material under study. In the present study the values of diffusion coefficients and diffusion lengths for different Saudi building materials have been calculated using Eqs. (2) and (3) respectively.

RESULTS AND DISCUSSION

The variation of radon concentration due to radon as a function of the thickness of different diffusing materials is shown in figure 3. The values of diffusion constant and diffusion length found to vary as 2.15 x 10^{-6} m^{-2} s^{-1}, 1.01 m for soil, 1.65 x 10^{-6} m^{-2} s^{-1}, 0.89 m for sand and 0.21 x 10^{-6} m^{-2} s^{-1}, 0.31 m for crushed aggregate used as Saudi building materials respectively. The values are found to be the lowest for crushed aggregates, which shows that crushed aggregate is least permeable to radon flow as compared with the other building materials studied.

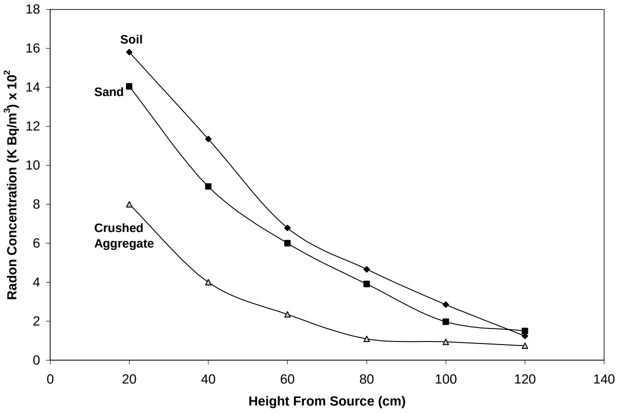

Fig. 3. The variation of radon concentration as a function of height from the source.

The values obtained in soil fall in the range reported by Kraner *et al.* (1964) and Holkko and Liukkonen (1992). In the case of dry sand, diffusion constant and diffusion length values are comparable with that reported by Tanner (1964). Minor differences may be due to the difference in the nature, grain size and porosity of the materials. The rate of diffusion of radon is found to depend upon the porosity of the medium. The research work is in the progress. It will be good to find the porosity of these materials. The study also confirms an exponential decrease in radon concentration with increasing thicknesses of the material.

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