Diffusion Length of Radon in Building Materials

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Abstract

The present work aims to find out the diffusion coefficients and diffusion lengths in some brick samples. The diffusion coefficients and diffusion lengths have been calculated using solid state nuclear track detectors (LR-115). The diffusion lengths varied from 55.4×10^{-3}m to 924.8×10^{-3} m. The calculated values of radon concentration of brick samples varied from 30 ± 18.1467 Bqm^{-3} to167 ± 37.0239 Bqm^{-3}. The diffusion coefficients varied from 0.0065×10^{-6} m^2s^{-1} to 1.79×10^{-6} m^2s^{-1}. The annual effective doses varied from 0.52 ± 0.3121$mSvyr^{-1}$ to 2.87 ± 0.6368$mSvyr^{-1}$. The value of annual effective dose was recommended by International Commission on Radiological Protection Publication (ICRP) is 5 $mSvyr^{-1}$. This study reveals that there is no serious radiation health hazard to the public using the brick samples.

Key words: solid state nuclear track detectors(SSNTD), diffusion lengths

Introduction

The diffusion of radon in dwelling is a process determined by the radon concentration gradient across the building material structure between the radon source and the surrounding air and can be significant contributor to indoor radon inflow. Radon can originate from the deeply buried deposit beneath homes and can migrate to the surface of earth. Radon emanates to the surfaces mainly by diffusion processes from the point of origin following decay of Ra in underground soil and building materials used, in the construction of floors, walls and ceilings.

Radon

Radon is an invisible, odorless, tasteless, radioactive gas. It is formed by the disintegration of radium, which is a decay product of uranium. Some amount of radon and radon daughters are present everywhere in the soil, water and air. Particularly high radon levels occur in regions where the soil or rock is rich in uranium. Radon daughters are inhaled with air and deposit in the lungs. The lung absorbs alpha particles emitted by the radon daughters. The resulting radiation close increases the risk of lung cancer.

Radon is drawn into a building

Buildings are typically at a lower pressure than the surrounding air and soil. The radon and other soil gases are drawn into the building. There are several reasons for this occurs. One cause reason is that there are exhaust fans, removing air from a building. When air is exhausted, outside air enters the building to replace it. Much of the replaced air comes in from the underlying soil.

Action and reference level

WHO presented in 2009 a recommended reference level (the national reference level), 100 Bq /m^3, for radon in dwellings. The recommendation also says that where this is not possible, 300 Bq /m^3 should be selected as the highest level. A national reference level should not be a limit, but it should represent the maximum acceptable annual average radon concentration in a dwelling.

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Uses of Radon

Radon has little particle use. Some medical treatments have employed radon in small sealed glass tubes, called seeds, these are specially manufactured to contain the exact amount of radioactivity needed for the application. Radon spas are used extensively in Russia and Central Europe to treat a number of conditions. Radon has been used to monitor atmospheric mixing investigate monsoon circulation patterns, predict volcanic eruptions and earthquakes and map geological faults and in geochemical exploration.

Reducing of Radon in the Building

The four principle ways of reducing the amount of radon accumulating in a house are:

1. Sub-slab depressurization (soil suction) by increasing under-floor ventilation;
2. Improving the ventilation of the house and avoiding the transport of radon from the basement into living rooms.
3. Installing a radon sump system in the basement;
4. Installing a positive pressurization or positive supply ventilation system.

Solid State Nuclear Track Detectors

Solid state nuclear track detectors (SSNTDs) are the materials that are damage in such a way by incident energetic particles that the particle tracks can be developed by subsequent etching and observed microscopically. SSNDTs are widely used as control tools as they are relatively cheap and give long measuring time averaged values. These detectors are often used in radon monitoring in the air, soil gas, etc.. but rarely used to measure radon content in soil.

A Technique of Solid State Nuclear Tracks Detection

The technique used in radon diffusion length measurements in brick sample is based on Solid State Nuclear Tracks Detector LR-115 type II cellulose nitrate films. The technique of SSNTDs is based on the damage created in an insulating solid along the path of a heavily ionizing particle such as an alpha particles or a fission fragment. The damage along the path called a track may become visible under an ordinary optical microscope after etching with suitable chemical.

The LR-115 Type II (cellulose nitrate) as SSNTD

The plastic track detector LR-115 type II is a cellulose nitrate red dyed film, manufactured by Kodak Pathe' France. The sensitive surface for alpha particle, red dyed, is of 10 m thickness of cellulose nitrate (CN) layer on a colourless insert backing material and the base is 100   m polyester.

Some Useful features of Tracks Detector

They are inexpensive, convenient to use and quite robust. They can be obtained in any size, from very small to very large detectors can be used to measure particles fluxes in odd locations while large detectors are used to record very rare events in cosmic ray studies. They are insensitive to light. Their development or etching is simple and rapid and does not required dark room facilities.

Nuclear Track Formation

Particle track in a crystal-damage consists of continuous disorder composed of vacant lattice sites and of interstitial ions or atoms. Particle track in a polymer-polymer new chain ends and other chemically reactive sites are formed.

Sample Collection

The brick samples were made from Sein cement, Dragon cement, Sand and Lime from Taunggyi township.

Sample (1) is made from Sein cement: Sand (6:1)

Sample (2) is made from Dragon cement: Sand (6:1).

Sample (3) is made from Lime: Sand (1:1).

Sample (4) is made from Lime: Sand: Sein cement(1:1:6).

The four brick samples are shown in Figure. (1) and (2).

Figure 1. The Four Brick Samples

Experimental Procedure

Technique

For the measurement of radon concentration of the bricks, we used the solid-state nuclear track detector method. The SSNTDs (LR-115) plastic track detectors about (1cm x 1cm) were fixed at three sides with suitable height (0cm, 5cm, 10cm) over a period of 100days.

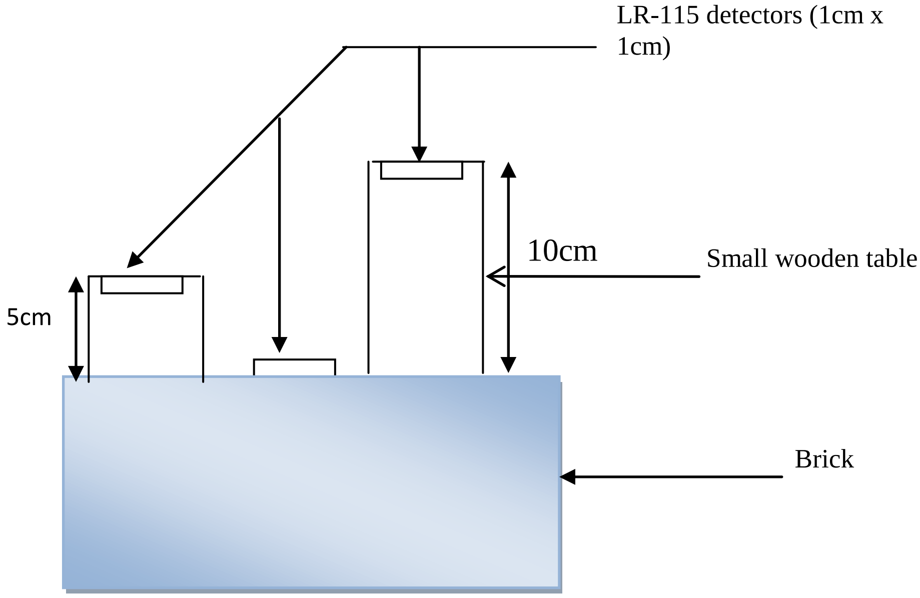

Figure 2. The schematic diagram of the experiment

Etchant Preparation

6 N NaOHsolution was prepared for etching the radon exposed LR-115 detectors.

To obtain 6 N NaOH solution, 48 g of NaOH were put into 200 ml measuring cylinder.

Then distilled water was poured on the NaOH in the measuring cylinder and stired with a glass rod, until NaOH were dissolved.

The distilled water was added to get 200 ml solution. After that, the solution was poured into a 250 ml glass beaker.

N = Normality = Molarity

6N = Water 200 ml + NaOH 48g

Figure 3. Etching of Detectors

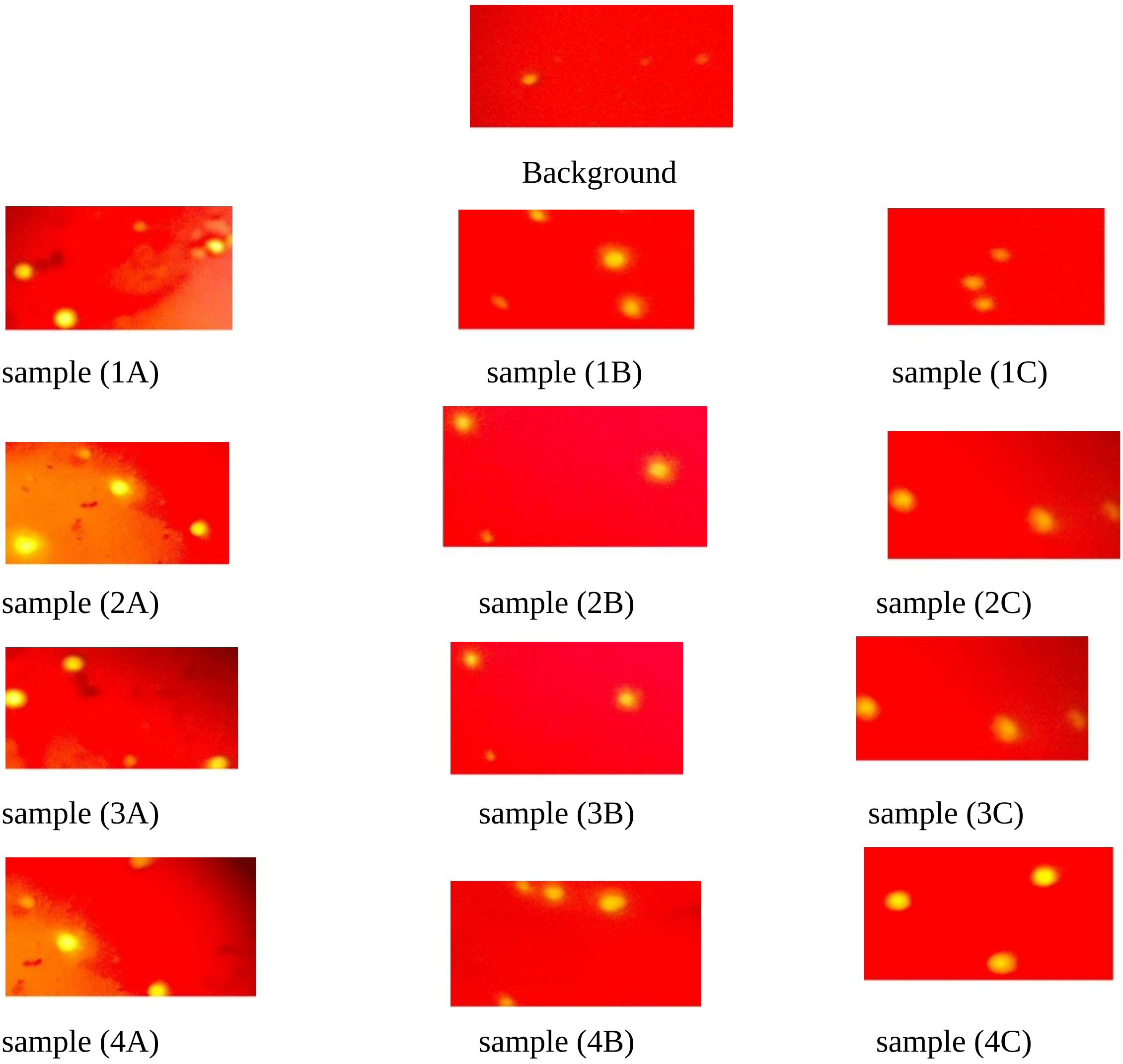

Figure 4. Photomicrographs of LR-115 in Four Kinds of Brick Samples

Optical Microscope

For track visualization and counting in LR-115 were performed by using the optical microscope (400x).The microscope consists of eyepiece 10x magnification and four lenses each with 10, 20, 40 and 100 times magnification.

The ^{222}Rn measurement details using LR-115 detectors

Detector	- LR-115
Measurement Method	- The solid-state nuclear track detector method
Sample	- Four brick samples
Location of detectors	- Detector 1 at 0cm Detector 2 at 5cm Detector 3 at 10cm
Irradiation Time	- 100days

Etchant - 6 N NaOH solution at 60˙C

Etching Time - 90 min

Microscope - Optical Microscope (400x)

Calibration factor used for LR-115 was

0.05016 $trackcm^{-2}day^{-1}$ = $1Bqm^{-3}$ (MandlaMahlobo)

Diffusion Equations

Diffusion coefficient D is,

$$D = \lambda\left[\left(X_2 - X_1\right)/\ln\left(N_1 / N_2\right)\right]^2 (m^2 s^{-1})$$

where, N_1 = Radon concentration at distance X_1 from source (Bqm^{-3})

N_2= Radon concentration at distance X_2 from source (Bqm^{-3})

X_1, X_2 = Distances from source (m)

Diffusion length can be calculated using this equation,

$$L = \sqrt{\frac{D}{\lambda}}$$

L = Diffusion length (m)

D = Diffusion coefficient (m^2s^{-1})

= Decay constant of radon

Results and Discussion

Radon is the biggest contributor to natural radiation in the environment and causes lung cancer. The main hazard is from inhalation of the element and its radio decay products which collected on dust in the air. The problem of radon is an important global problem of radiation hygiene concerning the world population.

To estimate the risk from exposure to radon, we have evaluated the annual effective dose, diffusion coefficient and diffusion length for four kinds of bricks. The diffusion coefficients varied from 0.065×10-8 m^2s^{-1} to 1.79×10-6 m^2s^{-1} and the diffusion lengths varied from 0.0554 m to 0.9248 m. The annual effective doses varied from 0.51 ± 0.3121 $mSvyr^{-1}$ to 2.87 ± 0.6368 $mSvyr^{-1}$.The value of annual effective dose was recommended by International Commission on Radiological Protection Publication (ICRP) is 5 $mSvyr^{-1}$.This study reveals that there is no serious radiation health hazard to the public using those four brick samples.

Table 1. The Diffusion Coefficient and Diffusion Length for four brick samples

Sr. No	Sample	Diffusion Coefficient (D) (10-6 m^2s^{-1})	Diffusion Length (L) (m)
1	Sample (1)	0.098	0.2169
2	Sample (2)	0.006	0.0554
3	Sample (3)	1.79	0.9248
4	Sample (4)	0.0065	0.0557

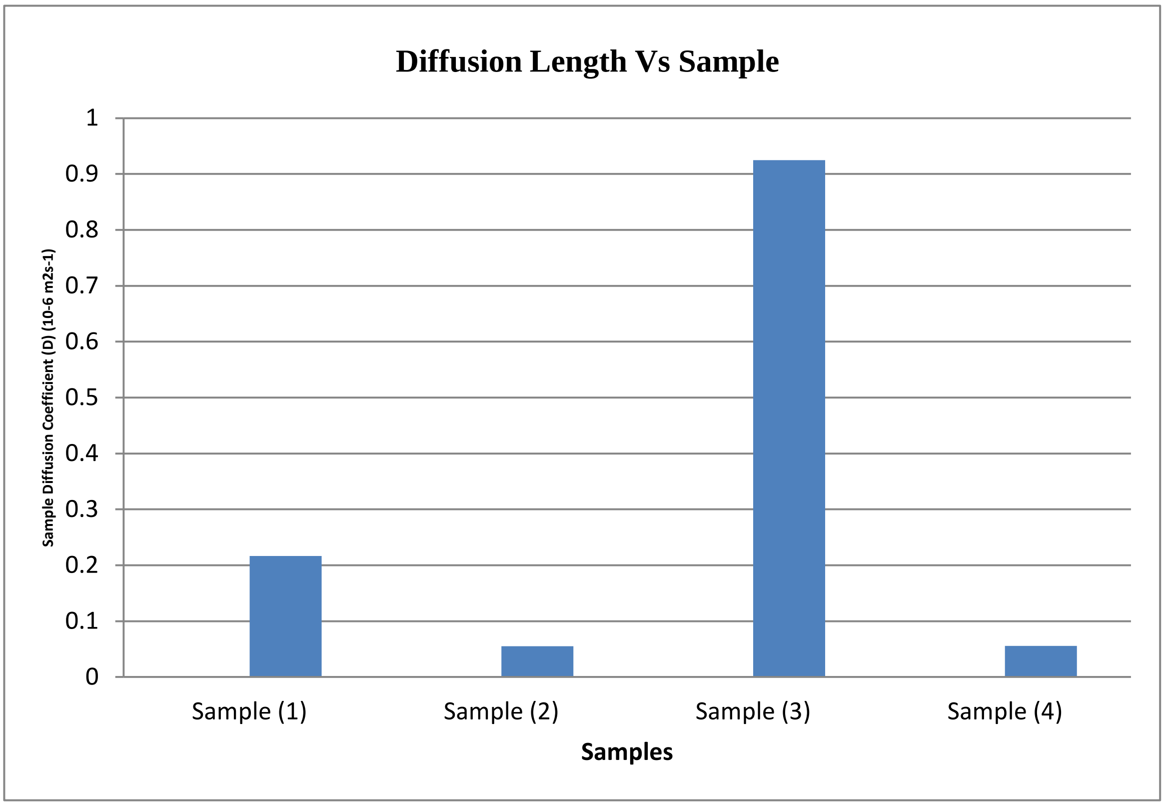

Figure 5. The Comparison Graph of Diffusion Lengths Four Brick Samples Using LR-115

Table 2. The Annual Effective Dose in three distances from source for four brick samples

Sr. No	Sample	Annual Effective Dose ($mSvyr^{-1}$) Distance - 0m	Annual Effective Dose ($mSvyr^{-1}$) Distance - 0.05m	Annual Effective Dose ($mSvyr^{-1}$) Distance - 0.1m
1	Sample (1)	1.84 ± 0.3581	1.18 ± 0.3343	0.93 ± 0.3652
2	Sample (2)	2.07 ± 0.3841	1.27 ± 0.3319	0.51 ± 0.3121
3	Sample (3)	2.87 ± 0.6368	0.99 ± 0.2953	0.93 ± 0.3128
4	Sample (4)	1.91 ± 0.4828	1.31 ± 0.3109	0.53 ± 0.3208

Conclusion

According to the data, there is no sign of danger and no health hazards to the users and the people of that community. The Sample (3) has the highest annual effective dose, diffusion coefficient and diffusion lengths are compared with other brick samples used by the LR-115 detectors. Although the diffusion lengths varied from 5.54cm to 92.48cm, the annual effective dose of four brick samples are lower than ICRP,2007 limited level $5mSvyr^{-1}$. So, it can be concluded that the tested radon level and the annual effective doses are low in four brick samples. These bricks are handmade bricks. These bricks include cement, limes and sand in different ratios, used in construction of building.

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