STUDY ON RADON EXPLORATION IN THE BUILDING MATERIALS BY USING LR-115 DETECTOR

Win Ko[1], Toe Toe Lwin[2], Hnin Hnin Than[3]

Abstract

Radon is an alpha emitting radioactive gas. It can exist in ground water, soil, building materials mines, caves and other underground places. In this study, radon concentration in old buildings and new buildings was measured by using LR-115 type II detector in a can mode. The preliminary study, the LR-115 detector was treated with alpha emitter Am-241 for standard. The tracks formed in LR-115 were etched with 2.5 M NaOH at 60 °C for 90 min. The etched tracks in irradiated LR-115 detector were found to be spherical shape by using optical microscope. And then, radon level in old buildings and new buildings was measured by LR-115 detector using the same procedure. The observed shape of track agrees with the preliminary study and it indicates that this is due to interaction between detector and alpha particles via radon present in old and new buildings. The average track density was found to be 133.5484 and 312.3674 track/cm^{2}d in all detectors in Bagaya Monastery and Me Nu Oak Kyaung. According to the observed track density, the average radon activity was found to be 667.7418 and 1561.8369 Bq/m^3 in all detectors in Bagaya Monastery and Me Nu Oak Kyaung. The calculated radon exhalation rate mean values were 1.0755 and 2.5155 mBq/m^{2}h in Bagaya Monastery and Me Nu Oak Kyaung. The average radon concentration was found to be 10.7548 and 25.1553 Bq/m^3 in Bagaya Monsatery and Me Nu Oak Kyaung. The average track density was found to be 39.0459 and 84.8824 track/cm^{2}d in all detectors in new buildings at Sagaing and Monywa. According to the observed track density, the average radon activity was found to be 185.9329 and 404.2021 Bq/m^3 in all detectors in new buildings at Sagaing and Monywa. The calculated radon exhalation rate mean values were 0.3095 and 0.6728 mBq/m^{2}h in new buildings at Sagaing and Monywa. The average radon concentration was found to be 3.0949 and 6.7279 Bq/m^3 in new buildings at Sagaing and Monywa.

Keywords: LR-115, alpha, track density, exhalation rate, radon, Bagaya Monastery, Me Nu Oak Kyaung

Introduction

Radon is a radioactive gas that has no colour, smell or taste. It is produced in the ground from uranium and diffuses into the atmosphere. It can also be found in groundwater supplies and can be released into the indoor air when taps and showers are turned on. For most people, radon is the largest source of radiation exposure throughout their lifetime. Radon is the second most important cause of lung cancer after smoking and the leading cause of cancer among non-smokers. The IAEA has published a safety guide (on Protection of the Public against Exposure Indoors due to Radon and Other Natural Sources of Radiation) to assist national authorities in reducing exposure to radon. This safety guide also includes guidance on how to prepare a radon action plan.

Solid State Nuclear Track Detectors (SSNTDs) in track etch technique has been used in the present study due to their simplicity, low cost, non-destructive, small size, and having integrating capability for large scale studies for the measurement of radon activity, and radon exhalation rates studies in various samples. The SSNTDs can also be used in radiobiological studies as the biological effectiveness of densely ionizing radiation. It is great interest for estimating the radiation risk for the public resulting from exposure to radon and its daughters (Dorschel *et al.*, 2003).

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Applications of SSNTDs related to radon measurements:

1. Radon measurements in tap water, natural water and soil: This kind of measurements is useful in uranium and thorium prospecting. It is also important to identify the radon rich areas. Knowledge of the radon levels in soil is important for classifying different areas for construction purposes and for planning of new buildings.
2. Radon emanation and exhalation from soil and building materials: It is useful to characterize building materials and soils as radon sources.
3. Radon monitoring in mines and other underground places: This is an important issue for radiological protection of miners, as well as in epidemiological studies involving miners.
4. Separation of thoron from radon: This is usually achieved based on the distance, because thoron is relatively very short-lived and cannot diffuse too far from the place of origin.
5. Application in earth sciences and radon measurements in caves.
6. Earthquake predictions: Radon concentrations in underground water and deep wells have been observed to increase significantly before earthquake (**Ng** *et al.*, 2004).
7. Volcanic studies: The radon flux increases before volcanic eruption

Pristine LR-115 (cellulose nitrate, type II, strippable, procured from DOSIRAD, France) is alpha sensitive plastic track detector. It is a 12µm thick film of red dyed cellulose nitrate emulsion coated on inert polyester base of 100µm thickness as shown in Figure 1. It has maximum sensitivity for alpha particles, fission fragments and ionizing particles with high enough linear energy transfer (LET). It is widely used for detection and measurement of weak concentrations of ionizing particles, high-resolution neutron radiographic uses, alpha radiography, cosmic ray investigations etc. The passage of ionizing radiation through insulating solids creates narrow trails of intense damage on atomic scale. These trails are called 'Tracks' which can be made visible under an ordinary optical microscope on being treated with a suitable chemical etchant that preferentially attacks the damaged material and removes the surrounding but undamaged portion at a slow speed (Siems, 2001).

The tracks recorded by these films are not directly visible and must therefore be intensified by treatment in an alkaline solution. The etched tracks get enlarged and represent the sites of original damaged regions. The track etching mechanism of LR-115 has been studied at different temperatures ranging from 30°C to 60°C for different etching times. The recommended etch conditions given by the manufacturer are 10% NaOH, at 60 °C, 65 to 95min (without agitation) (Singh *et al*., 1989).

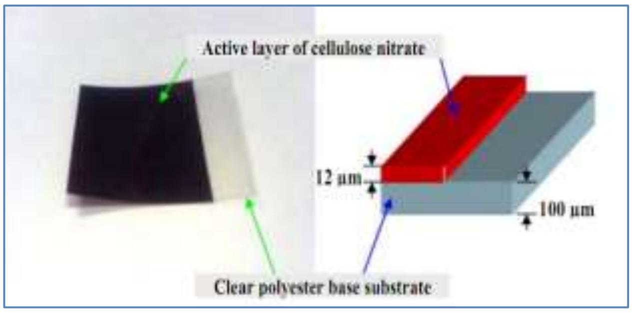


Figure 1 Photo of LR-115 detector

Figure 2 Interaction of LR-115 detectors with standard Am-241 source

Materials and Methods

This section mainly consists of two parts. The first part is concerned with the interaction of LR-115 detector with standard alpha radiations. The second part is concerned with investigation of radon level from old buildings and new buildings by applying LR-115.

Treatment of LR-115 Detector with Standard Am-241

LR-115 detectors were cut into small pieces of 1 cm × 1 cm. The samples were irradiated with alpha from Am-241 source with 12 µCi at 0.5 cm distance from source target for 15 min at Nuclear Physics Laboratory, University of Yangon (Figure 2). The LR-115 was removed from the alpha source and etched chemically in 2.5M NaOH solution at 60 °C for 90 min in an oven. The etched tracks on the detectors were scanned, using an optical microscope at 400x magnification.

Treatment of LR-115 Detector with Alpha Particles from Radon in Old Buildings

The measurement of radon concentration in the Bagaya Monastery built in 1782 and the Me Nu Oak Kyaung built in 1822, Innwa district of Mandalay Region was done by using LR-115 type II detector (Figure 3 and 4). Each five detectors (1m×1cm) were placed under the bridge ladder of the Bagaya Monastery and basement of the Me Nu Oak Kyaung by using "Can" mode for recording the alpha particles emitted by radon-222 gas present in ambient air and also its short-lived daughters typically ^{218}Po and ^{214}Po which generally attached themselves to the aerosols. After the exposure period of three months (90 days), the detectors were etched for 90 min in 2.5M NaOH solution maintained at 60 °C in an oven. At the end of etching, the detectors were removed, washed with distilled water. After drying the detectors are ready to count under an optical microscope for track density measurements. The measured track density was converted in to Bq/m^3 by using a calibration factor (0.2 tracks/cm^{2}d = Bq/m^3) determined by the National Institute of Radiological Science (NIRS), Vietnam (Nguyen Thi Thu Ha *et al*., 2016).

Figure 3 Detection of alpha particles from radon in Bagaya Monastery (1782)

Figure 4 Detection of alpha particles from radon in Me Nu Oak Kyaung (1822)

Treatment of LR-115 Detector with Alpha Particles from Radon in New Buildings

The measurement of radon concentration in two new buildings at Sagaing and Monywa, (built in 2017) was studied by using LR-115 type II detectors (Figure 5). Each five detectors (1m×1cm) were placed at the bathroom having only one small ventilation in the new building at Monywa and first floor in another new building at Sagaing by using 'Can' mode for recording the alpha particles emitted by radon-222 gas present in ambient air and also its short lived daughters typically ^{218}Po and ^{214}Po which generally attach themselves to the aerosols. After the exposure period of three months (90 days), the detectors were etched for 90 min in 2.5 M NaOH solution maintained at 60 °C in an oven. At the end of etching, the detectors are removed, washed in distilled water. After drying the detectors are ready to count under an optical microscope for track density measurements (Figures 6 and 7). The measured track density was converted in to Bq/m^3 by using a calibration factor (0.2 $tracks/cm^2d = Bq/m^3$) determined by the National Institute of Radiological Science (NIRS), Vietnam (Nguyen Thi Thu Ha *et al*., 2016).

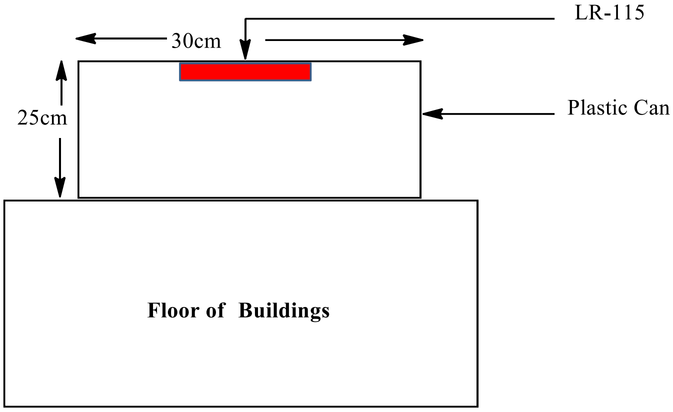


Figure 5 Flow diagram for placing 'Can' mode detector

Figure 6 Chemical etching of the detectors in an oven

Figure7 Microscope with digital camera (OLYMPUS BX-51)

Radon Exhalation Rate (E_x)

The radon exposure inside the can was obtained from the track density of the detector by using calibration factor of 0.21 $tracks/cm^2d$ obtained from an earlier calibration experiment.

The exhalation rate is found from the expression (Eappen and Mayya, 2004).

$$E_x = \frac{CV\lambda}{A[t + \frac{1}{\lambda}(e^{-\lambda t} - 1)]}$$

Where,

E_x = radon exhalation rate (Bq/m^2h)

C = radon activity as measured by LR-115 (Bq/m^3)

t = exposure time (h)

V = volume of Can (m^3)

A = area or sample surface (m^2)

λ = decay constant for radon ($7.56 \times 10^{-3}\ h^{-1}$) (Sharma *et. al.,* 2014)

Radon Concentration (C_{Rn})

The risk of lung cancer from domestic exposure of ^{222}Rn and its daughters can be estimated directly from the inhalation exposure (radon) effective dose. The contribution of radon concentration from the samples can be calculated from the expression.

$$C_{Rn} = \frac{E_x \times A}{V \times \lambda_v}$$

Where,

C_{Rn} = radon concentration (Bq/m^3)

E_x = radon exhalation rate (Bq/m^2h)

A = radon exhalation area (m^2)

V = volume (m^3)

λ_v = air exchange rate (h^{-1}) = 0.5 h^{-1} (Saad *et al*., 2010)

Results and Discussion

Observation of Alpha Particles Emitting from Am-241 Source

The characterization of nuclear tracks by alpha irradiation was found to be the formation of spots and the whole tracks on LR-115. It can be clearly seen in Figure 8. These formations of tracks agreed well with the literature (Dolleiser and Hashemi-Nezhad, 2002).

Figure 8 Photomicrographs for the revelation of the alpha particle tracks in LR-115 detector for Am-241 source

Observation of Radon via Alpha Particles Emitting from Old Buildings

For this purpose, five pieces of LR-115 type II detectors (1cm×1cm) were used for detection of radon in the Bagaya Monastery which was built in 1782 and the Me Nu Oak Kyaung which was built in 1822 at Innwa (Figure 9 and 10).

Each LR-115 type II detector was fixed at the top of inside each 'can'. And then, each 'can' was placed under the bridge ladder of the Bagaya Monastery and the basement of the Me Nu Oak Kyaung according to facing the detector and α-emitted via from radon in building materials. After the exposure period of three months, they were etched in 10% NaOH at 60 °C for 90 min. The resultant photomicrographs are shown in Figures 9 and 10 respectively. The radon activity, radon exhalation rate and radon concentration are computed as shown in Section. These values are presented in Tables 1 and 2.

From Table 1, the track densities in all detectors were found to be ranged between 124.4942 and 141.4707 track/cm^2 placed under the bridge ladder of the Bagaya Monastery. The average value of track density in ambient air was found to be 133.5484 track/cm^2. According to the observed track density in all five detectors, the radon activity was found to be between 622.4712 and 707.3536 Bq/m^3. The average value was 667.7419 Bq/m^3. The calculated radon exhalation rate values in five detectors were between 1.0026 and 1.1393 mBq/m^{2}h and the average value was 1.0755 mBq/m^{2}h. Therefore, the radon concentration placed under the bridge ladder of this old monastery was found to be 10.7548 Bq/m^3.

From the Table 2, the track density in all detectors was found to be between 305.5768 and 328.2121 track/cm^2 at the basement of Me Nu Oak Kyaung. The average value was found to be 312.3674 track/cm^2. According to the observed track density in all five detectors, the radon activity was found to be between 1527.8839 and 1641.0605 Bq/m^3. The average value was 1561.8369 Bq/m^3. The calculated radon exhalation rate values were between 2.4608 and 2.6431 mBq/m^{2}h and the mean value was 2.5155 mBq/m^{2}h. Therefore, the radon concentration at basement of this old building was found to be 25.1553 Bq/m^3.

It was observed that the radon concentration (25.1553 Bq/m^3) at the basement of Me Nu Oak Kyaung was higher than that (10.7548 Bq/m^3) placed under the bridge ladder of the Bagaya Monastery at Innwa. This may be due to the brick temple of the Me Nu Oak Kyaung. According to the literature, the principle routes of entry of radon into buildings pass through cracks in walls and foundations and gaps where service enter the building (for example, around waste/plumbing and electrical dusts). Other sources of radon in homes are: the building materials, including concrete, bricks, natural building stones, natural gypsum, and materials using industrial by-products such as phosphogypsum, blast furnace slag, and coal fly ash (Kovács *et al*, 2017) and domestic and drinking water supply to the home. Therefore, radon could be more produced in the concrete and bricks at the Me Nu Oak Kyaung than wooden built in Bagaya Monastery.

Outdoor, radon is rarely a problem as it quickly dilutes to very low concentrations. Indoors, radon can build up to very high level. Therefore, decreases in radon concentrations are observed when windows and doors are opened, showing the importance of ventilation (Khan *et al*., 2012).

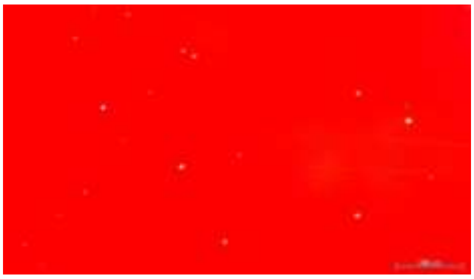
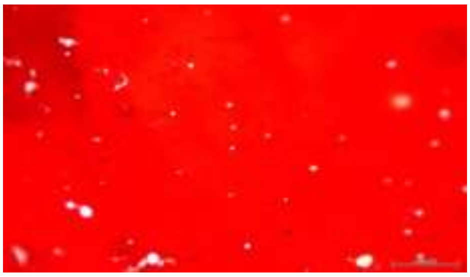


Figure 9 Photomicrographs for the revelation of the alpha particle tracks in LR-115 detector placed at the Bagaya Monastery



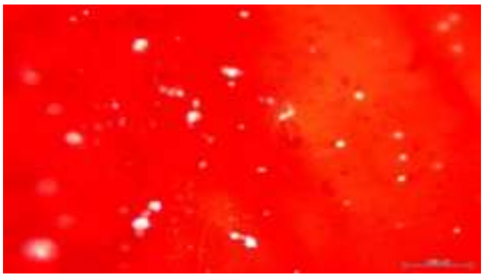


Figure 10 Photomicrographs for the revelation of the alpha particle tracks in LR-115 detector placed at the Me Nu Oak Kyaung

Table 1 Measurement of Track Density, Radon Activity, Radon Exhalation Rate and Radon Concentration at the Bagaya Monastery (1782)

Detectors	Track Density (tracks/cm^{2}d)	Radon Activity (Bq/m^3)	Radon Exhalation Rate (mBq/m^{2}h)	Radon Concentration (Bq/m^3)
1	124.4942	622.4712	1.0481	10.4814
2	130.1531	650.7654	1.1393	11.3928
3	135.8119	679.0595	1.0937	10.9371
4	135.8119	679.0595	1.0026	10.0257
5	141.4707	707.3536	1.0937	10.9371
Mean Value	133.5484	667.7418	1.0755	10.7548

Table 2 Measurement of Track Density, Radon Activity, Radon Exhalation Rate and Radon Concentration at the Me Nu Oak Kyaung (1822)

Detectors	Track Density (tracks/cm^{2}d)	Radon Activity (Bq/m^3)	Radon Exhalation Rate (mBq/m^{2}h)	Radon Concentration (Bq/m^3)
1	305.5768	1527.8839	2.4608	24.6085
2	305.5768	1527.8839	2.4608	24.6085
3	311.2356	1556.1780	2.5064	25.0642
4	311.2356	1556.1780	2.5064	25.0642
5	328.2121	1641.0605	2.6431	26.4313
Mean Value	312.3674	1561.8369	2.5155	25.1553

Observation of Radon via Alpha Particles Emitting from New Building

For this purpose, five LR-115 type II detectors (1cm×1cm) were used for detection of radon in the bathroom of new bridge building which was built in Monywa, 2017 and in the first floor of new bridge building which was built in Sagaing in 2017.

Each LR-115 type II detector was fixed at the top of inside the each ‘can’. And then, each five can are placed at the bathroom of new bridge building in Monywa and at the first floor of new bridge building in Sagaing according to facing the detector and α-emitted via from radon in building materials. After the exposure period of two months, each LR-115 detectors were etched in 2.5 M NaOH at 60°C for 90 min. The resultant photomicrographs are shown in Figures 11 and 12, respectively. The radon activity, radon exhalation rate and radon concentration are computed as shown above in Section. These values are presented in Tables 3 and 4.

From the Table 3, the track density was found to be between 50.9295 and 101.8590 track /cm^2 in all detectors at the bathroom of new bridge building in Monywa. The average value was found to be 84.8824 track/cm^2. According to the observed track density, the radon activity was found to be between 242.5213 and 485.0425 Bq/m^3. The average was 404.2021 Bq/m^3. The calculated radon exhalation rate values were between 0.4037 and 0.8074 mBq/m^{2}h and the mean value was 0.6728 mBq/m^{2}h. Therefore, the radon concentration in the bathroom of new building was found to be 6.7279 Bq/m^3.

From the Table 4, the track density is found to be between 33.9530 and 42.4412 track/cm^2 in all detectors at the first floor of new bridge building in Sagaing. The average value is found to be 39.0459 track/cm^2. According to the observed track density, the radon activity was found to be between 161.6808 and 202.101 Bq/m^3. The average was 185.9329 Bq/m^3. The calculated radon exhalation rate values were between 0.2691 and 0.3364 mBq/m^{2}h and the mean value was 0.3095mBq/m^{2}h. Therefore, the radon concentration in the first floor of new bridge building was found to be 3.0949 Bq/m^3.

It was observed that the radon concentration (6.72792 Bq/m^3) in the bathroom of new bridge building at the Monywa was higher than that of (3.0949 Bq/m^3) first floor of new bridge building at the Sagaing. This is due to the lesser ventilation which one of the factors on radon accumulation. Therefore, radon could be more produced in ground floor than in the upper floor.

According to the literature, radon is a known cause of lung cancer when it is inhaled. Living for one year in a house with radon concentration of 300 Bq/m^3 results in effective dose of the order of 10 mSv which is equivalent to: four head CT scan, 25 years of exposure to average external background radiation, or smoking 1 cigarette per day. The lung cancer increases by approximately 16% for every 100 Bq/m^3 of radon exposure in the home (Krewski *et al,* 2005). Fortunately, the observed radon concentrations in these new buildings are very low for risk of lung cancer.

The international commission on radiation protection (ICRP-65, 1993) has recommended that the action level for radon concentration in ambient air should be in the range 200-600Bq/m^3. The measured radon concentration values are below the recommended action level.

Therefore, decreases in radon concentrations should be opened windows and doors and the room without window set up exhaust fan.

According to the experimental results from old building and new building, revealed that radon concentration in old building is higher than that of new building. This is due to route of entry of radon into buildings is through cracks in walls and foundations and gaps. Therefore, people stay in old building should put wallpaper on the wall to prevent the radon which causes lungs cancer.

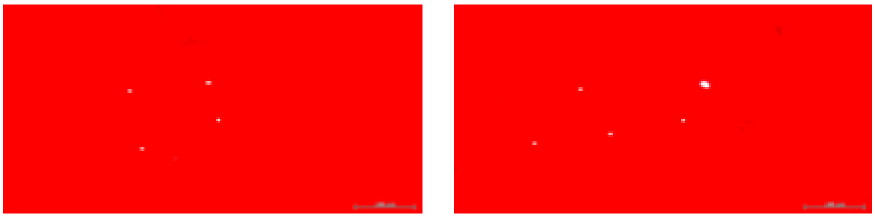


Figure 11 Photomicrographs for the revelation of the alpha particle tracks in LR-115 detector placed at Sagaing, 2017

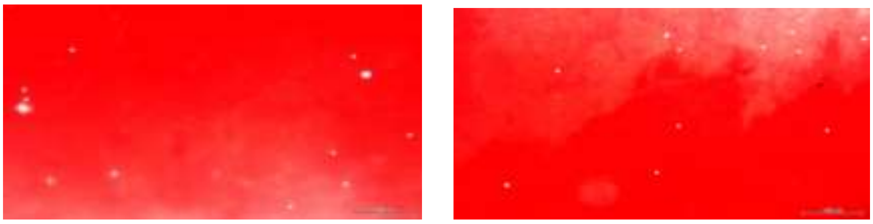


Figure 12 Photomicrographs for the revelation of the alpha particle tracks in LR-115 detector placed at Monywa, 2017

Table 3 Measurement of Track Density, Radon Activity, Radon Exhalation Rate and Radon Concentration at Monywa (2017)

Detector	Track Density (tracks/cm^{2}d)	Radon Activity (Bq/m^3)	Radon Exhalation Rate (mBq/m^{2}h)	Radon Concentration (Bq/m^3)
1	50.9295	242.5213	0.4037	4.0368
2	84.8824	404.2021	0.6728	6.7279
3	93.3707	444.6223	0.7401	7.4007
4	93.3707	444.6223	0.7401	7.4007
5	101.8589	485.0425	0.8074	8.0735
Mean Value	84.8824	404.2021	0.6728	6.7279

Table 4 Measurement of Track Density, Radon Activity, Radon Exhalation Rate and Radon Concentration at Sagaing (2017)

Detector	Track Density (tracks/cm^{2}d)	Radon Activity (Bq/m^3)	Radon Exhalation Rate (mBq/m^{2}h)	Radon Concentration (Bq/m^3)
1	33.9530	161.6808	0.2691	2.6912
2	33.9530	161.6808	0.2691	2.6912
3	42.4412	202.1010	0.3364	3.3640
4	42.4412	202.1010	0.3364	3.3640
5	42.4412	202.1010	0.3364	3.3640
Mean Value	39.0459	185.9329	0.3095	3.0949

Conclusion

In this study, it can be concluded that the concentration of radon was detected in all samples (Bagaya Monastery, Me Nu Oak Kyaung, the floor of a new building in Sagaing, and a bathroom of the new building in Monywa) as alpha emitted radioactive substance. According to the results, the radon concentration in the old building is higher than that of the new building. Therefore, people who stay in the old building should be noticed the health risk from radon.

Radon is a known cause of lung cancer when it is inhaled (Krewski *et al*., 2005). Therefore, decreases in radon concentrations are observed, when windows and doors are opened showing the importance of ventilation.

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