

Design and Fabrication of New Radon Chamber for Radon Calibration Factor of Measurement

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Abstract- This study consists of two parts: the first part is concerned with designing a new radon chamber that is constructed using a continuous radon monitor together CR-39 Nuclear Track Detectors (NTDs). The aim behind designing such a chamber is to measure radon at different times. The chamber has a cubic shape and it is made of pixy glass with a volume of $0.125m^3$. The solid radium 226 source with an activity $5\mu Ci$ was placed at the bottom of the chamber to generate radon. The result has shown that the track density increased when increasing the exposure time to radon and the latter's homogenous concentration inside the chamber until it reached $38.377 \pm 20 \text{ kBq}m^{-3}$. Second, the calibration factor for radon has been measured using CR-39 NTDs. Besides, PVC was used to calculate the calibration factor k. The values of the calibration factor for radon was 0.024 ± 0.004 ($tr.cm^2$ per $Bq.m^{-3}.d$) under three parameters, temperature, humidity and efficiency; accordingly the values were as such $27 \pm 1^\circ C$, 57 ± 5 RH % ; 80 % respectively .The study further revealed that the best PVC chamber that detects and measures the real value of airborne radon concentration is $237.67cm^3$.

Keywords: Chamber Design; Calibration Factor; CR-39; Radon Monitor; Radon

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1. Introduction

The public exposure to radon and to its radioactive daughters present in the environment largely contributes to the average effective dose received by human beings [1]. The international recommendation of the annual dose of the natural radiation obtained from the public is 1 mSv [2]. Radon is an alpha emitted with energy of 5.49 Mev with a half-life of 3.8 days. As a common alpha particle, it is characterized by being relatively heavy and positively charged. Therefore, all the radiation energy will be absorbed in very small volume of matter immediately. Several techniques have been used to measure radon and its daughters in this area. One of these techniques is the solid state nuclear track detectors SSNTDs. Such a technique has been increasingly used in passive time – integrated modes to measure the radon and thoron present in the environmental medium [3, 4]. In fact, this work includes two main parts: the first part is dedicated to design a cubic-shaped chamber that is made of pixy glass and under three parameters. The latter, embed temperature, humidity and the speed of the flux inside the chamber. It further aims at measuring the concentration of radon by using a continuous radon monitor. The second part is concerned with designing and constructing PVC chambers radon

dosimeter via estimating the optimum volume of the dosimeters. Such a step helps measure the calibration factor of radon. The calibration factor was determined through the following expression [5]:

$$k = \frac{\rho}{tc} \quad (1)$$

where k is the calibration factor ($tr.cm^2$ per $Bq.m^{-3}.d$); c is the standard radon concentration ($Bq.m^{-3}$); ρ is the track density ($tr.cm^2$); and t is the exposure time (d) .

2. Radon chamber design

A new radon chamber was designed and fabricated in the Medical Physics at the School of Physics, Universiti Sains Malaysia. The chamber is cubic in shape and is made in laboratory. Its dimensions are (50 cm \times 50 cm \times 50 cm). Fig. 1 showcases two photos of the chamber and its continuous radon monitor. It further clarifies most of the following described features:

The chamber consists of four openings. The first opening is located at the top and it is of the size (15 cm, 15 cm). This opening is used to put materials

inside the chamber. The second and third openings are opposite to one another. They are fitted with a thick rubber glove to manoeuvre things inside the chamber and to turn on and off the continuous radon monitor and printing the results. The fourth opening is adjusted to join the power supply for the detector. Furthermore, a fan is fitted to provide the internal air circulation needed inside the chamber. The fifth groups of CR-39 are sized $(10 \times 15 \times 0.50)$ mm³, produced by the Track Analysis Systems Ltd., Napier House, Meadow Grove, Bristol, and (BS11 9PJ, UK). All these pieces were placed inside the chamber. PVC chamber was designed

with a different volume for each detector, as shown in Fig. 2. The radium source (Ra^{226} ; $5\mu Ci$) was used to obtain radon gas. In this study, the experimental conditions inside the chamber were properly under a controlled climate. The radon exhalation rate can be calculated by referring to the following climatic conditions each time: the relative humidity, which is 57 ± 5 RH % and temperature, which is $27 \pm 1^\circ C$. The continuous radon monitor was placed in SNC calibration chamber, using a radon chamber of the US Department of Energy, Environmental Measurement Laboratory.



Fig. 1. The radon chamber and the continuous radon monitor model (1023)

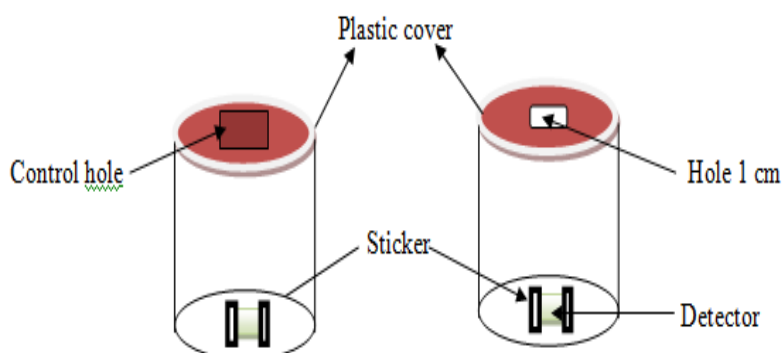


Fig. 2. Homemade radon diffusion chamber

3. Measuring the Concentration of Radon Activity

In order to determine the concentration of the radon activity inside the chamber, a continuous radon monitor was calibrated from the company. Such work has continued for two month and every 91.2 h, one has to register the results for each hour.

Furthermore, the fifth groups of CR-39 were performed inside the PVC at different exposure times and different levels of exposure. This step has been achieved by controlling the hole in the tap of PVC by placing it differently inside the chamber. Such a process helps measure the homogeneity of the radon inside the chamber. Figures 3 and 4 shows the track densities against the exposure time. They further showcase six photos of the track

densities with different times. Figures 3 and 4 also show how the track density increased when increasing the exposure time. The results were then compared with other researches, and were found identical [3]. The average radon concentration was

determined to be $38.377 \pm 20 \text{ kBqm}^{-3}$. All the detectors were treated under etching conditions with water-bath and an optical microscope connected to a computer was used to count and measure the track density.

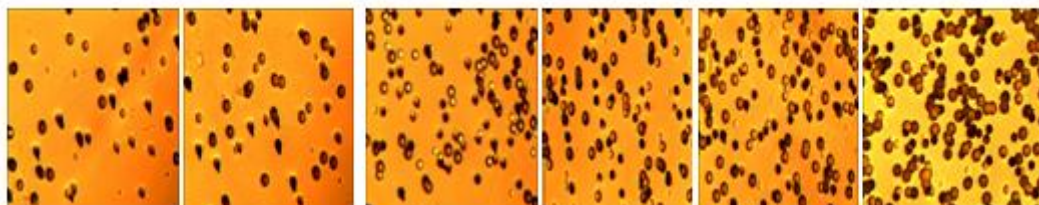


Fig.3. The track densities with different times exposure radon

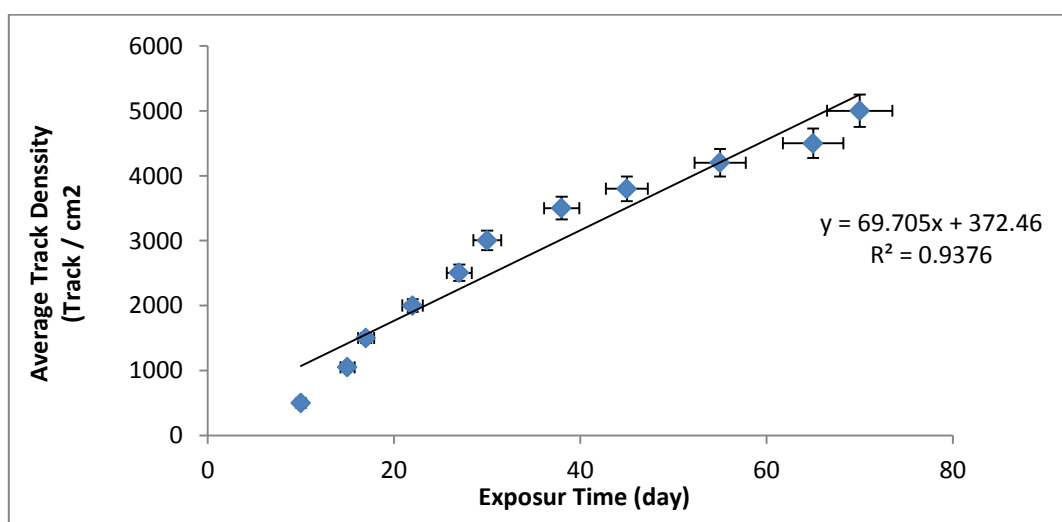


Fig. 4. The track densities against the exposure time

4. Measuring Radon Homogeneity

Homogeneity of radon inside the chamber was tested using the fifth groups CR-39 detectors. These CR-39 groups were arranged inside the chamber differently and in accordance with the position of the fan. The distribution of radon inside the chamber was uniform and its homogeneity might be considered acceptable as the

differences were less than 10%. It should also be noted that the average track densities observed, (around $3500 \pm 10 \% \text{ track/cm}^2$), were not affected by the exposure circumstances. Fig. 5 shows the average track densities in relation to the different locations of the detector.

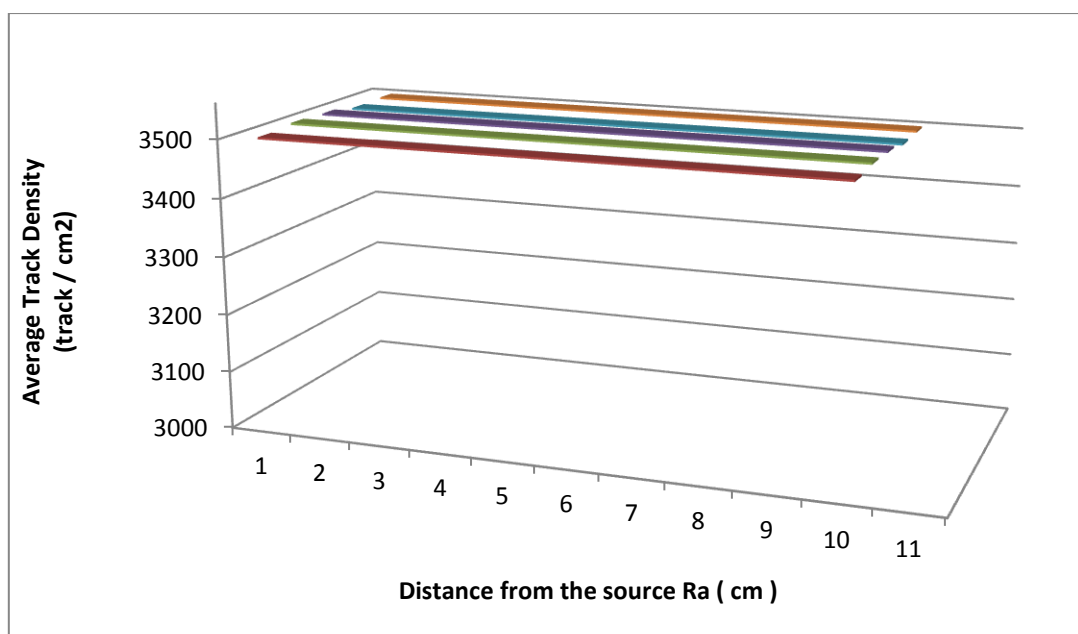


Fig. 5. The track densities with the locations of the detector inside the chamber

4. Measuring the Calibration Factor (k)

The calibration process of the CR-39 was very important in radon detection. The efficiency was measured because the latter was affected by the time of storage. The efficiency the detector was calculated using the radium source. Under these etching conditions, the calculated efficiency (η) was 80% , using the following formula:

$$\eta = 1 - \sin(\Theta_c) \quad (2)$$

where Θ_c is the critical angle; V_B and V_T are the bulk and track etch rates, respectively. The calibration measured under the etching conditions was 6.25 N NaOH – 70 °C [6, 7], using the optimum time of etching, 6 h.

To determine the calibration factor, equation 1 was used. The fifth groups of CR-39 were performed with different volumes of PVC. They were then put inside the radon chamber for 91.2 h. It was noted that the calibration factor for radon detection depended on the geometric of its dosimeter. Besides, the emitted alpha particles located at a distance more than 8 cm has revealed that the dosimeters does not affect the detectors at least in this height - 10 cm with different diameters [8]. For this purpose, the fifth groups were listed as follows:

- (1) Group one were exposed with the PVC volume 34.64 cm^3 and with (10 and 2.1 cm) height and diameter, respectively.
- (2) Group two were exposed with the PVC volume 96.25 cm^3 and with (10 and 3.5 cm) height and diameter, respectively.
- (3) Group three were exposed with the PVC volume 159.1 cm^3 and with (10 and 4.5 cm) height and diameter, respectively.
- (4) Group four were exposed with the PVC volume 237.67 cm^3 and with (10 and 5.5 cm) height and diameter, respectively.
- (5) Group five were exposed with the PVC volume 331.96 cm^3 and with (10 and 6.5 cm) height and diameter, respectively.

All detectors were etched and counted using the same condition described earlier. The optimum values for the calibration factor was $(0.024 \pm 0.004) \text{ (tr. cm}^2 \text{ per Bq. m}^{-3} \cdot \text{d)}$ at an optimum volume that equals 237.67 cm^3 , as shown in Fig. 6.

Table 1 depicts the values of calibration factor presented in this paper which agrees with the previous obtained results [9, 10, 11, and 12].

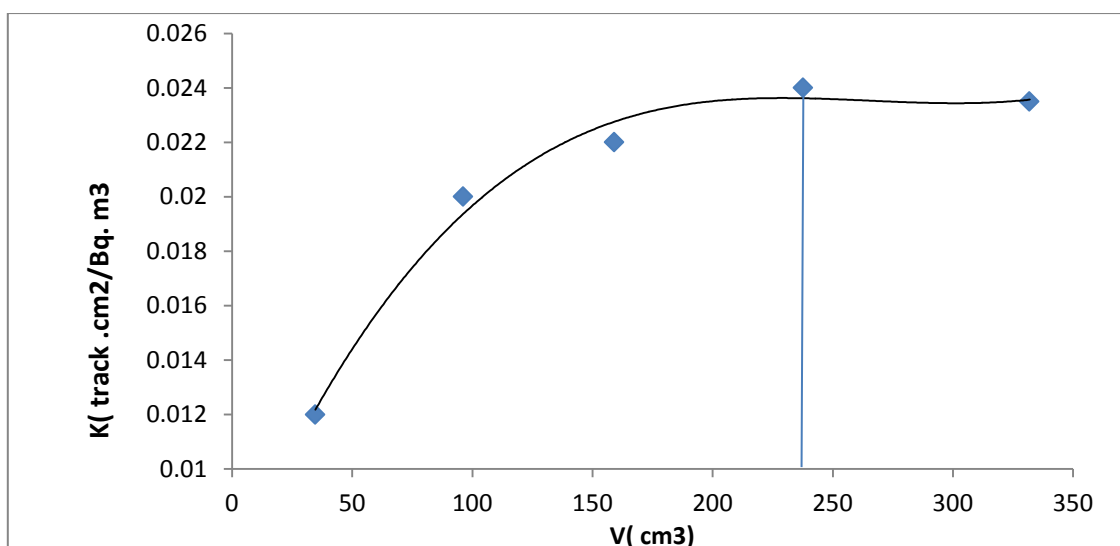


Fig.6. Calibrating as the dosimeter volume.

5. Conclusions

A new chamber fitted with many features was designed and fabricated to enable the calibration of radon measurement. Controlling the temperature, humidity and many other parameters was achieved. The track densities were noted to increase with increase in radon concentration. The concentration of radon measured inside the chamber was $38.377 \pm 20 \text{ kBq m}^{-3}$. The calibration factor was $0.024 \pm 0.004 \text{ (tr.cm}^2\text{per Bq}^{-3}\text{.d)}$ at 80 % efficiency. Besides, the optimum volume in this study was 237.67 cm^3 . This work was in line with the previously conducted studies in the same field of knowledge.

Acknowledgments

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Table: 1Comparison results between present work and other references

Calibration factor	References	Details of exposure
0.0027 ± 0.0004	[9]	-
0.05	[10]	Placed in a cup with polyethylene lid inside FRED
0.028	[11]	Aerosol load provided to simulate dwelling condition
0.02	[12]	Place in a plastic cup with special rubber membrane and exposed in a radon chamber
0.024	Present study	PVC chamber inside the chamber cubic and exposure time of radon

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