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Measurement of ^{222}Rn Concentrations in the Air of Qaysery Naqeeb Bazaar Located in Sulaimani Governorate of Kurdistan Region-Iraq

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Abstract

In this study the level of ^{222}Rn concentration at 35 positions in air of the big ancient famous bazaar (Qaysery Naqeeb) which contains 110 shops and located in the center of Sulaimani city have been assessed. During the winter and summer seasons of 2014, ^{222}Rn concentrations have been measured by using (CR-39) solid state nuclear detector. In winter, the maximum and minimum values of ^{222}Rn concentration were (206.901±10.958) Bq/m³ and (44.978±5.109) Bq/m³ respectively, with an average value of (132.849± 8.780)Bq/m³; while in summer the maximum and minimum values of ^{222}Rn concentrations were (255.476± 25.809) Bq/m³ and (99.852± 6.306) Bq/m³ ,respectively, with an average value of (158.215± 12.578)Bq/m³, this difference reveals the role of higher temperature and humidity rates in the variation of radon concentrations were high radon concentrations corresponds to high temperature and low humidity rates. In several positions the obtained values were nearly within the acceptable range of radon level recommended by the International Commission on Radiological Protection and the limit recommended by World Health Organization (WHO), but in the most other positions these limits were exceeded due to the structures of material building and lack of ventilation. The effect of temperature on radon concentration was also observed.

Introduction

Radon has three radioactive gas isotopes ^{219}Rn, ^{220}Rn and ^{222}Rn with half-lives of (3.96sec, 55.6sec and 3.8d) respectively, they are produced from the decay of the natural radioactive (Actinium, Thorium and Uranium) series. ^{222}Rn can be considered to be one of the most dangerous radioactive nuclide in the environment and as a noble gas can be spread out through the atmosphere while ^{219}Rn and ^{220}Rn are not important as ^{222}Rn due to their short half-lives [1,2]. The ^{222}Rn is a terrestrial source of radiation produced by the decay of radium (^{226}Ra) in the uranium series, therefore, it can be present whenever uranium is found and especially in the Earth's crust [2]. The indoor radon concentration depend mainly on the radon exhalation from surrounding materials like soil and building material (brick, rock, cement, gypsum, sand, etc.) which can be considered as a main natural sources of indoor radon [1,3]. ^{222}Rn and its airborne daughters can cause an effect on human health (lung and larynx cancers) especially when uranium or radium content in the soil is high or they are concentrated in an enclosed area in particular in dwelling and in a big markets or bazaar [4]. Several techniques have been used to measure radon concentration and one of these techniques is Solid State Nuclear Track Detector (SSNTD) through using LR-115 and CR-39. The SSNTD technique is a popular and well-established method of measurement in a large number of fields of radioactivity or nuclear interactions.

This work involves the estimation of radon gas concentrations in the most popular space within the center of Sulaimani city which have environmental and health concerns.

Experimental Method and Calculation:

In this study, the indoor radon concentration in a big bazaar (Qaysery Naqeeb) as shown in Fig.(1) which situated in the center of Sulaimani city of Kurdistan Region-Iraq has been measured. The bazaar of Qaysery Naqeeb was built during 1900 in a low level closed area having 5 gates and contains more than 110 shops. As an old trade area, various materials used in shops building such as clay bricks, gypsum, cement and iron structure, and the walls of these shops are often covered by gypsum and wood.

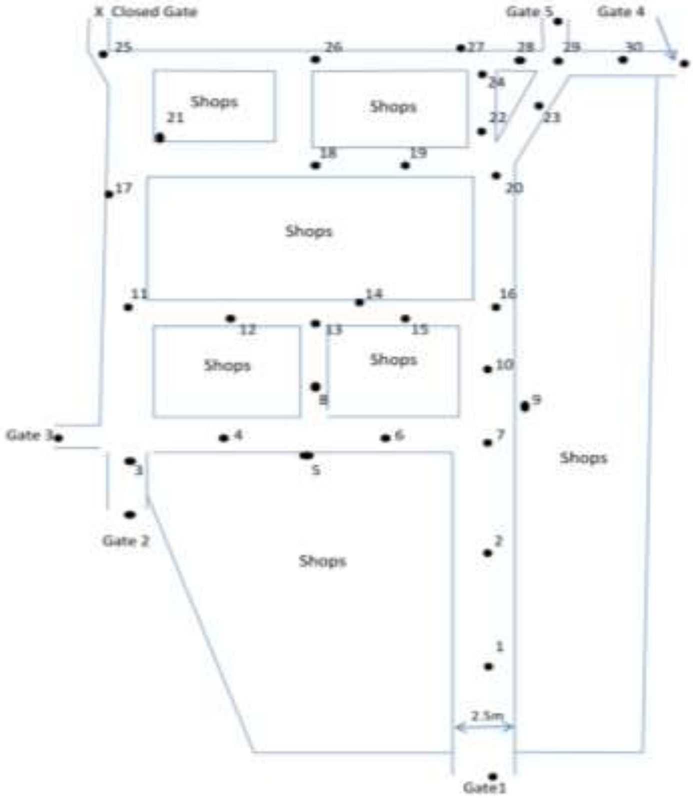

Fig.(1): Graphical shape of Qaysery Naqeeb Bazaar.

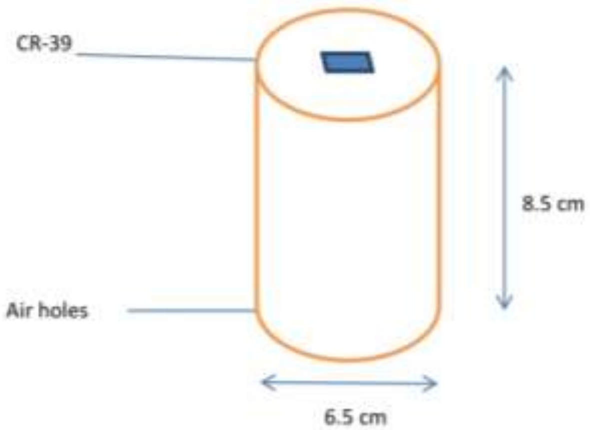

Fig.2a Fig.2b

Fig. 2(a): The designed dosimeter. Fig. 2(b): The used dosimeter.

The design of the used passive radon dosimeter is shown in Fig. 2(a) and Fig. 2(b). It is a closed chamber, into which radon diffuses, composed of steel, 6.5cm in diameter and 8.5cm in height.
Within the bazaar space the dosimeters have been suspended through a wire on the walls of shops and others suspended at the center of bazaar in different positions, Fig. 2(b). After 60 days of exposure the suspended dosimeters were collected.
The CR-39 solid state nuclear track detector (SSNTD) is the most sensitive and widely used in the passive method of radon measurement technique. So in this study it has been used to record the tracks of α–particles produced from ^{222}Rn in the air samples within the dosimeter. Sufficient pieces of the detector sheets having dimension of (1×1.5) cm^2 were fixed at the upper part of the dosimeter chamber to record the α–particles.
The efficiency Calibration for the used CR-39 detector was done by using the ^{241}Am standard source (known activity) by taking the track data for 1, 2, 3, 4, 5 and 6 second α–particle exposures and then calibrating the detector for recognizing the tracks which produces from other unknown α–particle activities. For plastic detectors, the most frequently used etchant is the aqueous solution of NaOH with concentration molarities of 6.25 M and the temperatures usually employed are in the range of (40-70) C°[5].
In this work, the method of chemical etching has been adopted. This type of etching is usually carried out in thermo statistically controlled baths kept at constant temperature of 70 ± 0.5 C°.
The solution concentration of 6.25 M (C_{sol}) has been obtained using the following expression:

$$C_{sol} = \frac{W_{NaOH} \text{ x } 1000}{W_{at} \text{ x } V_f} \qquad \text{----------} \ (1)$$

Where : W_{NaoH} = weight of NaOH (62.5 g)

W_{at} = atomic weight of NaOH (40)

V_f = Volume of filtered water (250 ml)

Process was done continuously for 6 hours at a temperature of 70 C^o. After etching, the detectors were washed using distilled water and then dried by a hot air–dryer to remove water from their surfaces [6].

The interaction of radiation with these types of polymers occurs due to degradation or molecular cross linking with each other. These effects cause some changes in the polymer properties. Therefore, when radiation falls on these polymers, it causes to excite and ionize the atoms which subsequently break down the bonds within the CR-39 and produces damage as a trace in the polymer at normal conditions [7]. These traces have capability to interact with alkaline solution like (NaOH) comparing with the undamaged region. Due to this interaction, these regions have more energy than the others, then the chemical solution penetrates easily in the radiated position causing tracks with higher depth and diameter that can be observed using optical microscope with a magnification of (400X) [8].

The tracks from 24 fields on each of the CR-39 detectors are counted and the numbers of α-particle tracks per each field are calculated over the number of fields after subtracting the background. The chamber slide is used to determine the dimension and area of the fields. Fig. (3) present a sample field on one of the prepared slide at which four tracks can be easily seen.

Fig.(3): Microscopic photo of α-Tracks.

To calculate radon concentration using the dosimeter chamber, it's necessary to determine the diffusion constant (K) characteristic for the system (dosimeter) using the relation [9]:

$$\rho = K\ Ca\ T \qquad \text{.................(2)}$$

Where ρ- Track density Track\cm^2

K- Diffusion constant

Ca - Rn concentration in air space inside the steel chamber (Bq\cm^3)

T- Exposure time (60 days)

Then K can be calculated for the specified dimensions of the steel chamber [10]:

$$K = 1/4\ (r)\ [2\cos\theta_t - r\backslash R\alpha\ ] \qquad \text{..................(3)}$$

Where r - chamber radius for the diffusion volume (3.25 cm)

θ_t - Threshold angle for the CR-39 detector (35^o) ,[10]

Rα - Range of α- particle in air from Rn and can be calculated from this relation [11]:

$$R\alpha = (0.005\ E_\alpha + 0.285)\ E_\alpha^{3/2} \qquad \text{.....................(4)}$$

= 4.019cm (for alpha energy of 5.489 MeV)

Substituting these values in Eq. (3), the diffusion constant is found to equal 0.058244 Tr.cm^{-2}.hr^{-1}/ Bq.m^{-3} for the present dosimeter.

Results and Discussions

The measured values of Radon concentration in winter and summer at different positions are shown in Table 1 and plotted in Figs.(4 and 5).

Table 1: Radon concentration values in winter and summer seasons at different positions.

position	Winter		Summer	
	ρ (Tr/cm²)	Ca 1 (Bq/m³)	ρ (Tr/cm²)	Ca 2 (Bq/m³)
1	353.700	101.202 ± 7.663	471.750	134.978± 9.912
2	314.400	89.957± 7.225	544.540	155.805±
3	503.040	143.931± 9.139	555.859	159.044±
4	471.600	134.935± 8.849	598.617	171.278±
5	393.000	112.446± 8.078	560.889	160.483±12.85
6	554.823	158.747± 9.598	565.920	161.922±
7	723.120	206.901 ± 10.958	892.890	255.476±
8	554.823	158.747± 9.598	571.579	163.541±
9	503.040	143.931± 9.139	603.648	172.717±
10	628.800	179.914± 10.218	503.040	143.931±
11	524.000	149.928± 9.328	503.040	143.931±
12	443.859	126.998± 8.585	550.200	157.424±
13	353.700	101.202± 7.663	387.969	111.006± 7.392
14	314.400	89.957± 7.225	477.888	136.734±
15	591.811	169.331± 9.913	565.920	161.922±
16	668.100	191.158± 10.532	691.680	197.905±
17	628.800	179.914± 10.218	628.800	179.914±
18	167.679	47.976± 5.277	503.040	143.931±
19	353.700	101.202± 7.663	704.256	201.503±
20	345.840	98.953± 7.578	704.256	201.503±
21	440.160	125.940± 8.549	499.267	142.851±
22	377.280	107.948± 7.915	471.600	134.935± 9.907
23	503.040	143.931± 9.139	565.920	161.922±
24	353.700	101.202± 7.663	418.780	119.822± 8.290
25	157.200	44.978± 5.109	348.984	99.852± 6.306
26	471.600	134.935± 8.849	553.344	158.324±
27	704.256	201.503± 10.814	660.240	188.909±
28	681.200	194.906± 10.635	503.040	143.931±
29	314.400	89.957± 7.225	440.160	125.939± 8.933
30	471.600	134.935± 8.849	607.420	173.796±
Gate1	377.280	107.948± 7.915	477.888	136.734±
Gate2	440.160	125.940± 8.549	492.120	140.806±
Gate3	599.875	171.638± 9.980	628.800	179.914±
Gate4	534.480	152.927± 9.420	597.360	170.918±
Gate5	432.300	123.691± 8.472	503.040	143.931±
Average		132.849± 8.780		158.215±
Maximum		206.901± 10.958		255.476±
Minimum		44.978± 5.109		99.852± 6.306

Where ρ – Track density on the CR-39 detector
Ca1 - Radon concentrations in winter season
Ca2 - Radon concentration in summer season

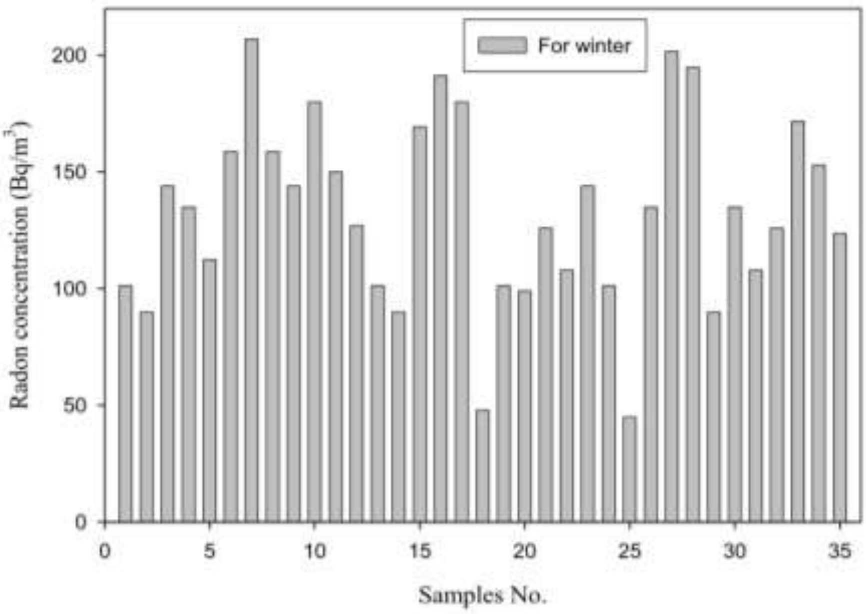

Fig.(4): Radon concentrations with Qaysery Naqeeb Bazaar positions in Winter season.

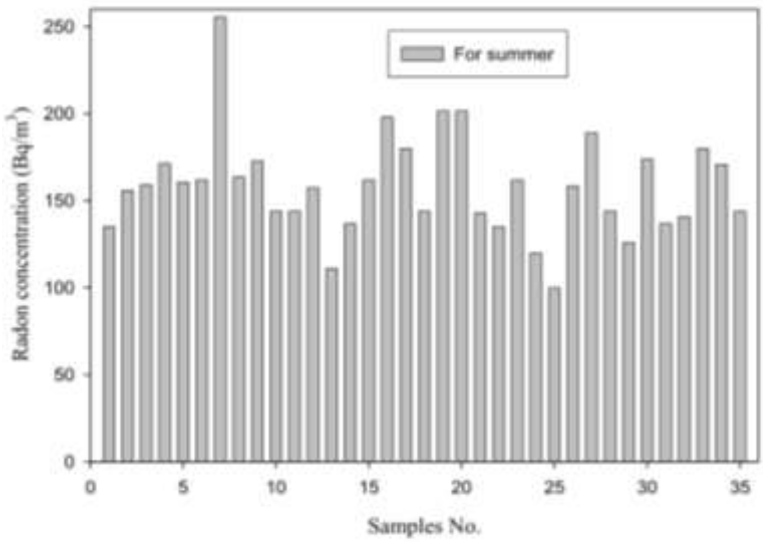

Fig.(5): Radon concentrations with Qaysery Naqeeb Bazaar positions in Summer season.

In winter (with the average temperature of 19.2C^{o} and average humidity of 26.3 inside the bazaar), the maximum and minimum values of radon concentrations are (206.901± 10.958 and 44.978± 5.109) Bq/m^{3}, respectively, with an average value of (132.849± 8.780) Bq/m^{3}. In summer (with the average temperature of 31.8C^{o} and average humidity of 17.8 inside the bazaar), the maximum and minimum values of radon concentrations were (255.476± 25.809 and 99.852± 6.306) Bq/m^{3}, respectively, with an average value of (158.215± 12.578) Bq/m^{3,}

The observation of these values reveals that:

1. In winter:
   a. at 11 positions (6, 7, 8, 10, 15, 16, 17, 27, 28, Gate3 and Gate4) the radon concentration exceeds the recommended range of (50-150)Bq/m^{3} declared by the International Commission on Radiological Protection (ICRP) [12], while according to the limit of 100 Bq/m^{3} set by the World Health Organization (WHO) [13] all the positions (except 2, 18, 20, 25 and 29) shows higher radon concentration.

b. at the two positions of (18) and (25) lower limits of (47.976± 5.277) Bq/m^3 and (44.978± 5.109)Bq/m^3 than that of ICRP and WHO have been recorded.

2. In summer:
   a. at 20 positions (2, 3, 4, 5, 6, 7, 8, 9, 12, 15, 16, 17, 19, 20, 23, 26, 27, Gate3 and Gate4) the radon concentration exceeds the recommended range of (50-150)Bq/m^3 declared by ICRP, while according to the limit of 100 Bq/m^3 set by the WHO all the positions (except 25) shows higher radon concentration.

Within the bazaar the locations at which radon concentrations were found to be higher than ICRP and WHO limits are those having old building structures (built from regional soil bricks). Related to this is a recent study done on the regional soil of Sulaimani governorate in which an average uranium (the main source of radon gas) content of 4 ppm [14] has been recorded. In addition, these locations inside the bazaar possess a poor ventilation mechanism which causes low gas expelling and hence more indoor radon gas accumulation.

In the table, the effect of temperature and humidity are involved through the two different seasons of winter and summer, where the higher temperature and humidity rate causes more emanation of radon through cracks in ancient shop frames and building materials itself, while the lower temperature reduces these effects, so the present results certifies this fact as indicated previously [15- 17].

In general, the level Qaysery Naqeeb bazaar is lower than local big bazaar by about (1-2 m), a state causing more precipitation and accumulation of heavy gases (including radon) and difficult ventilation of the bazaar space, this effect can also be observed from the background dose rate measurement which was (0.146 - 0.21) μSv/hr inside the Qaysery Naqeeb bazaar to be higher than that of the big bazaar (0.109 - 0.139) μSv/hr. Furthermore, the cancer risk can be estimated by adopting a mean absolute risk factor of 5.38×10^{-4} per WLM (Working Level Month) exposing to1 pCi/L (=37 Bqm^{-3}) of radon gas, the radon daughter exposure rate is 0.144 WLM per year. The average risk of a fatal lung cancer due to lifetime exposure (70 year as an average) at 1pCi/L (=37 Bqm^{-3}) is then [18]:

$(0.144\ WLM/y)\ (70\ y/lifetime)\ (5.38\times10^{-4}\ /WLM) \cong 0.54\%$

Accordingly, the inhabitants of the studied bazaar area are exposed to an average cancer risk of about 1.95% in winter (132.849 Bqm^{-3}) and about 2.32% in summer (158.215 Bqm^{-3}) due to lifetime exposure of 70 year as an average.

Conclusion

The measurement of radon (^{222}Rn) concentrations in the oldest bazaar in Sulaimani governorate (Qaysery Naqeeb) reveals that the radon concentrations were higher in summer season in compare to that of winter due to the effect of temperature and humidity on radon activity. The old buildings made from soil bricks and poor ventilation areas within the bazaar reveal higher radon concentrations. Due to its lower level, the background dose rate measurement was higher inside the bazaar than that outside. Throughout the whole measurements, it appears that the radon concentration values exceed the recommended values and limits sets by ICRP and WHO, for this we recommend an environmental management of this situation by recovering the old shops, filling the wall cracks in buildings and setting a modern ventilation system inside this old bazaar.

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