Determination of Radon Concentration and the Annual Effective Dose in Karbala University Campus, Karbala, Iraq

Abbas, J. Al-saadi

Basic Medical Sciences, College of Dentistry, Karbala University, Karbala, Iraq.

Abstract

Determination of radon gas concentrations in multistory buildings and outdoor in the Karbala University campus (Karbala-Iraq) were carried out by using Solid-state nuclear track detector (CR-39).The detectors were distributed over 20places(14 indoor and others outdoor). The area of the study includes College of Medicine, College of Dentistry, College of Pharmacy, College of Sciences, student's residence and the Central Library. The dosimetric measurements were made over a period of 3 months.(from 15 September to 14 December 2012). After exposure, the detectors were etched in a (NaOH) solution of normality (6.25 N) at temperature of 70 ^{o}C for 3 hours. The tracks were counted by the microscope track-counting system. The indoor radon gas concentrations were found to vary from 41.881 ± 2.463Bq/m^3 to 95.642 ± 5.730 Bq/m^3 with an average value and standard deviation of 70.358 Bq/m^{3}and14.367Bq/m^3 respectively. The outdoor air radon concentrations are ranged from 25.134 ± 1.783Bq/m^3 to 28.594 ± 2.854Bq/m^3 with an average value of 26.974 Bq/m^{3}and standard deviation 1.155 Bq/m^3. In the survey of radon concentration in multistory buildings was observed that the upper floor have lower radon concentration than the ground floor. It has found that, in general, the radon level in lower floors is higher than that in upper ones in all buildings. The annual effective dose to the population from the inhalation of radon was also estimated and this varied from 1.056 ± 0.062mSv/ y to 2.412 ± 0.144mSv/ y, with an average of1.774 mSv/y and standard deviation is 0.362mSv/ y. The ratio between indoor and outdoor radon concentration (mean value) in this study was about 3.The radon concentrations were found to be lower than the higher level recommended by ICRP (200 Bq/m^3) and thus are within safe limits.

Key Words: Natural radioactivity, Radon, indoor air, Radon outdoor air, Annual effective dose,CR-39track detector, environment, Karbala University.

ملخص

تم قياس تركيز غاز الرادون في داخل البنايات المتعددة الطوابق وكذلك في الهواء الطلق داخل الحرم الجامعي لجامعة كربلاء باستعمال كاشف الأثر النووي CR-39.وُزّعتْ الكواشف في 20 مكانٍ داخل الجامعة.تَضمّنتْ منطقةُ الدراسةِ كليَّة الطبِّ، كليَّة طبِ الأسنان، كليَّة الصيدليةِ، كليَّة العِلومِ، سكن الطلابَ والمكتبة المركزية. عرضت الكواشف لثلاثة شهورِ (مِنْ 15 سبتمبر/أيلولِ إلى 14 ديسمبر/كانون الأولِ 2012)، بعد ذلك تمت معالجة الكواشف كيميائيا وقد استخدم لهذا الغرض محلول هيدروكسيد الصوديوم بتركيز 6.25 عند درجة حرارة 70 درجة مئوية لمدة ثلاث ساعات متواصلة ومن ثم حساب عدد الآثار لوحدة المساحة باستخدام المجهر الضوئي. وقد أظهرت النتائج أن تركيز غاز الرادون في داخل بنايات الحرم الجامعي تتراوح بين 95.642±5.730 Bq/m^3- 41.881±2.463Bq/m^3 بمعدل 70.358 Bq/m^3 وبانحراف معياري 14.367 Bq/m^3 في حين كان معدل تركيز غاز الرادون في الهواء الطلق خارج البنايات 26.974 Bq/m^{3}بانحراف معياري1.155 Bq/m^3 وهو اقل من تركيز الرادون في الهواء داخل بنايات . عُموماً أن مستوى تركيز غاز الرادون في الطوابق الأرضية أعلى مِنْ ذلك في الطوابق العلوية في كُلّ البناياتِ. كذلك تم إيجاد الجرعة الفعالة السنوية من استنشاق غاز الرادون في كل موقع فكانت تتراوح بين 0.062mSv/ ±1.056- y2.412± 0.144mSv/ y بمعدل 1.774mSv/y بانحراف معياري 0.362mSv/ y فكانت الجرعة الفعالة السنوية من استنشاق غاز الرادون في الهواء داخل البنايات أعلى من ذلك في خارج البنايات بمقدار ثلاثة أضعاف تقريبا. ان تركيز الرادون في الهواء داخل بنايات الحرم الجامعي كان تحت مستوى الذي أوصت به اللجنة الدولية للحمايةِ الإشعاعيةِ (200 Bq/m^3) وبالتالي ضمن الحدود الآمنة.

Introduction

Radon is an outsider element in nature because it is the only element that is a gas in a long chain of radioactive decays. All natural radioactive series contain a radioactive radon isotope. This element, with atomic number 86, is colorless, tasteless and, as noble gas, chemically inert. It can also be soluble in some liquids, such as water or natural gas that can transport it over long distances through the soil . Radon is produced from the decay of radium isotopes contained in rocks and minerals; the more interesting ones are: ^{222}Rn present in the (Uranium series),^{220}Rn (Thorium series) and^{219}Rn (Actinium series), starting from ^{238}U, ^{232}Th and ^{235}Urespectively. The radon isotopes occurrence in the environment depends on the local abundance of their respective parent's nuclides, on the physical characteristic of the source medium and on their decay mean life. ^{219}Rn, because of its short half-life (3.96 s) it has a very limited possibility to migrate into free air. Moreover, the low abundance of ^{235}U parent nuclide by weight in natural uranium (0.711 %), implies that corresponding radon isotope is also extremely rare in the atmosphere. the half life of ^{220}Rn (Thoron) is shorter than one minute, so most of its nuclei decay before reaching the air. Instead, the ^{222}Rn isotope is the most common in the environment (and the most studied) , because its half life of 3.82 days makes its diffusion more feasible from its origin point toward external air where, in some cases, it can reach a very high concentrations (thousands Bq/m^3). For this reason, since now, when we will speak about radon, we will refer to ^{222}Rn isotope [1,2].

Radon and its short-lived decay products in dwellings represent the main source of public exposure to natural radiation, contributing nearly 50% of the global effective dose to the population [3]. Soil is considered to be the main source of indoor radon concentration, although building materials that made from stone, sand, cement and or byproducts may contain uranium and radium which is generate radon. Many of these materials such as brick, wallboard or concrete are sufficient porous to allow radon to escape in to the air. Radon gas can get trapped in poorly ventilated dwellings and its concentration can build up to high levels. Inhalation of alpha particles from ^{222}Rn and associated ionizing decay products are known to cause morbidity in humans. Recent researches on natural radiation exposure have recognized ^{222}Rn and its progeny inside houses as a worldwide problem and a significant risk factor for lung cancer. It has been estimated that an increase in radon concentration of 100 Bq/m^{3}is associated with approximately a 16% increased chance of developing lung cancer[4,5,6]. Therefore measurement of indoor radon and its progeny in human dwelling is very important from the health physics point of view. According to Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR) [1] and International Commission on Radiological Protection (ICRP) reports [7], annual effective dose E (mSv/y) to the public from radon and its progeny is estimated using the following equation:

$$E = C \times F \times H \times T \times D \qquad (1)$$

where C is the ^{222}Rn concentration (Bq/m^3), F is an equilibrium factor, H is the occupancy factor (0.8), T is hours in a year (8760 h/y) and D is the dose conversion factor 9.0×10^{-6} mSv/(Bq h/ m^3), the equilibrium factor for radon daughters in indoor air in the range 0.3-0.6, which is assumed to be 0.40 for the mid-point of the range of reported values. The mean equilibrium factor in outdoor air is 0.7.In (ICRP, 1993) [6] report it has recommended that the action levels of radon in dwellings should be set within a range of 3–10 mSv /y.

In the last 20 years, more attention has been paid to the measurement of radon exhalation from building materials in many countries worldwide, including Great Britain (Abu-Jarad et al.[8]), Finland (Mustonen [9]), Saudi Arabia (Al-Jarallah[10]), Taiwan (Ching-Jiang et al.[11]), Jordan (Abou-Murad et al.[12]) and Turkey (Turhan [13]).Several countries have initiated large scale measurements of prevailing indoor ^{222}Rn levels in houses and the reported levels range from a low of 9 Bq/m^3 to a high value of the order of 200 Bq/m^3 [14].

Study Area

Due to the unusual circumstances of Iraq during the last decade, a limited number of studies exist concerning this important field of investigation. In particular for the Karbala University campus there is no data about the environment regarding the levels of radiation. Present study has been proposed to cover and establish a base line data for the regional radioactivity. There are two places for Karbala University the first (old) campus included medical group (College of Medicine College of Dentistry and College of Pharmacy),while the second place (new campus) included College of Sciences, student's residence and the Central Library.

The location of the studied area has been determined using the Global Positioning System (GPS): for old campus (medical group): Latitude: 32^o 36' 34.11" N. Longitude: 44^o 0' 4.20" E. The location of new campus (Freiha): Latitude 32^o 36' 10.10" N. Longitude: 44^o5' 18.81"E. These locations are shown in figures 1 and 2 respectively. Most of the buildings in the Karbala University campus are constructed of cement bricks and concrete where as in the floors are made of local sandstone, and rocks with a cement paste. Most of the offices had paint as the covering material for the walls and ceilings and carpets for the floors. More the classrooms are of size approximately $4\times6\times3m^3$ with two windows and door. Most of the student's residence rooms are of size $3\times4\times3m^3$ with one window and door.

Figure 1.Showing the area of old Karbala University campus.

Figure 2.Showing the area of new Karbala University campus (Freiha).

Experimental Method

Indoor radon activity concentrations were measured by using nuclear track detectors (NTDs), which is commercially marketed as CR-39, The detector was manufactured by Pershore Molding Ltd.,U.K. 300µm thick in the form of large sheets which were cut into 1.5 cm×1.5 cm which is fixed by double side solo tape on the bottom of the plastic cup. In the cover there is a hole covered with 5mm thick soft sponge as shown in figure (3). The structure of these dosimeters had been described in previous works [12,15,16] .The design of the chamber ensures that all aerosols and radon decay products are deposited on the soft sponge from the outside and that only radon gas, among other gas constituents, diffuses through it to the chamber. During the decay process of radon in the chamber to its progeny, three alpha particles are emitted. Some of these alpha particles will hit the CR-39 detector if it falls within their ranges. In this way, the detector will accumulate over time a number of tracks proportional to the concentration of radon gas in the room. The dosimeters were fixed indoor air in ground, first and second floors. Other samples were fixed for outdoor air outside the buildings. The dosimeter at each site was installed vertically at approximately 2 meters from the floor (breathing zone). After the exposure period of three months (from the 15 September to 14 December 2012) in order to obtain useful statistics, the detectors were removed from cans and etched chemically for three hours in a (NaOH) solution of normality (6.25 N) in constant temperature bath at70^{o}C. After etching, the detector was washed in distilled water for 10 minutes, and then air-dried. The tracks were counted manually under an optical microscope (Optika) consisting of Aiptek HD 1080P camera. The signal from camera was sent to the computer where the picture was digitalized and analyzed (Figure 4).The surface track density was calculated in terms of tracks per cm^2, accordingly. The background track density was determined by processing a virgin detector under the same etching conditions. The background was subtracted from the measured track density. In order to measure radon concentration levels in samples (C_{Rn}) , the surface density of tracks on the employed detectors (ρ) measured in (track/cm^2) and used the following equation [15,17,18] :

$$C_{Rn} = \frac{\rho}{Kt} \quad (2)$$

Where t is the exposure time (day) and K is the calibration factor to convert track density to the radon concentration [(track/cm^2) per (Bq. day / m^3)].

The calibration factor (K)value was determined by the calibration process which used standard radon source (Radium ^{226}Ra)and used the following equation [17,19] :

$$K = \frac{\rho_0}{C_0 t_0} \quad (3)$$

Where,C_0 is the standard radon concentration (Bq/m^3) , ρ_0 is the number of track density (track/cm^2), and t_0 is the exposure time (day) for the calibration process. The calibration experiment performed at nuclear laboratory, department of physics, collage of sciences, Karbala University. Three detectors were exposed to the standard radon concentration; the average value of calibration factor and its standard deviation was 0.204±0.012 track/cm^{2}per (day .Bq/m^3).The estimated calibration factor of radon measurements is in good agreement with those reported by other investigators [15, 20, 21].

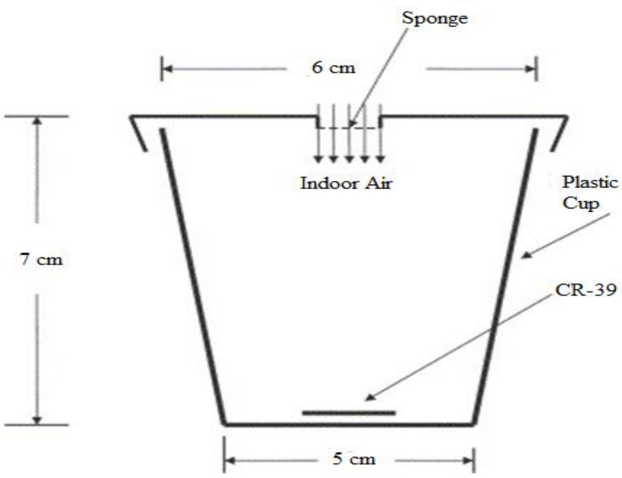

Figure 3. The Structure of the dosimeter showing the geometry of the radon dosimeter.

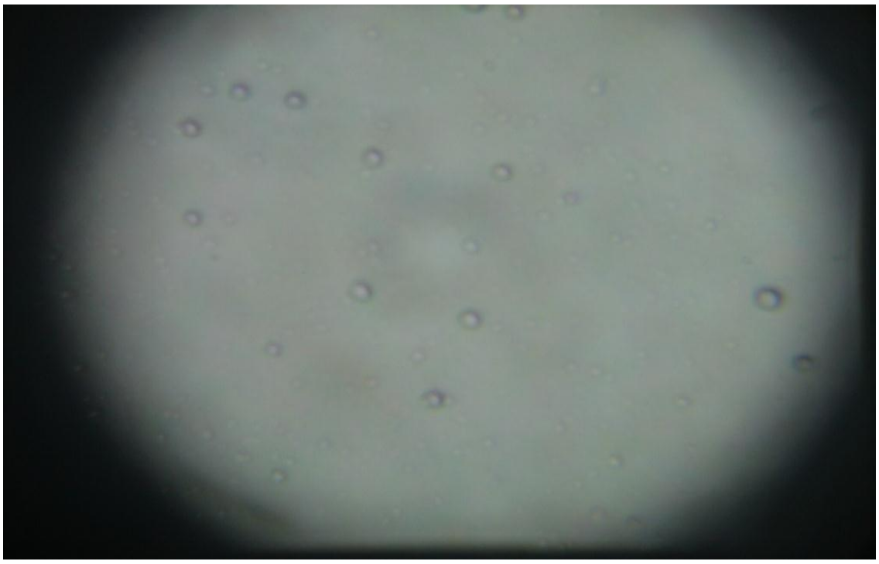

Figure 4. Tracks of alpha particles emitted by radon in a CR-39 detector, which wasexposed for three months in the first floor of central Library. One viewing fieldfrom the microscope has the area of about 0.5 mm^2.

Results and Discussion

The result of measurements indoor radon concentrations as well as the annual effective dose at different places in multistory buildings of Karbala University campus in ground and first floor are shown in Table (1).The indoor radon concentrations were found to vary from 41.881± 2.463Bq/m^3 to 95.642± 5.730 Bq/m^3 with an average value and standard deviation of 70.358 Bq/m^3 and 14.367 Bq/m^3 respectively. The variation of radon concentration in the places surveyed is shown in Figure 5. The maximum concentration was noticed in the ground floor of Collage of Pharmacy (95.642± 5.730 Bq/m^3). This can be justified because it is old building and there is a crack in the walls which allow radon to diffuse inside the room from ground floor and wells. The minimum concentration was observed in the second floor of the central library (41.881± 2.463 Bq/m^3). The little difference between the values of radon concentration in the most places of Karbala University campus may be due to both of materials have approximately the same uranium content. Overall, the mean value of radon concentrations in the ground floor was higher than that in the first and second floors. This is because the radon gas that emanated from the soil would had a better opportunity of flowing to the ground floor rather than the first floor through common pathways, such as cracks and pipes entering the work places. The observed radon concentration in this area are found below action value recommended by ICRP (200 Bq/m^3)[(22)]. It is very important to find annual effective dose in the university buildings in order to have an estimate of the radiation risk to the inhabitants. Thus, the estimation of the annual effective dose expected to be received by the students and workers due to radon and its daughters was based on calculations from the radon exhalation rate(equation1). The values of annual effective doses were found to vary from 1.056 ± 0.0622 mSv/ y to 2.412 ± 0.144 mSv/y with a mean of 1.774 mSv/y. On the basis of ICRP, 1993 recommendation it has been observed that all the dwellings monitored for indoor radon concentration show values below the action level (3–10 mSv /y). The outdoor radon concentration and annual effective dose obtained for each location are shown in the Table (2). The outdoor radon concentrations were found to vary from 25.134 ± 1.783 Bq/m^3 to 28.594 ± 2.854 Bq/m^3 respectively. The average outdoor radon concentration was 26.974 Bq/m^3 with standard deviation 1.155 Bq/m^3. It is observed that the radon values outdoor area is found lowered than indoor buildings. The outdoor annual effective dose radon were found to vary from 1.109 ± 0.078 mSv/y to1.262 ± 0.126 mSv /y with an average value and standard deviation of 1.191 mSv /y and 0.051 mSv /y respectively.

Conclusions

Radon concentration levels and the annual effective doses in multistory buildings and outdoor in the Karbala University campus (Karbala-Iraq) were calculated using the can technique. The indoor radon concentration varies from 41.881± 2.463Bq/m^3 to95.642± 5.730 Bq/m3, with an average value of 70.358Bq/m^3. The minimum concentration was observed in the second floor of the central Library while the maximum concentration was noticed in the ground floor of Collage of Pharmacy**.** The little difference between the values of radon concentration in the most places of Karbala University campus may be due to both of materials have approximately the same uranium content. The indoor effective annual dose varies from 1.056 ± 0.062 mSv /y to 2.412± 0.144 mSv /y with an average value 1.774 mSv /y. In the survey of radon concentration in Karbala University campus was observed that the upper floor have lower radon concentration than the ground floor. The outdoor radon concentration varies from 25.134 ± 1.783 Bq/m^3 to 28.594± 2.854 Bq/m^3, with an average value of 26.974 Bq/m^3.Theoutdoor effective annual dose varies from 1.109 ± 0.078 mSv /y to 1.262 ± 0.126 mSv /y with an average value of 1.191 mSv /y. It is observed that the radon values in outdoor area are lowered than indoor buildings, the ratio between indoor and outdoor radon concentration (mean value) was about (3). The results of this study indicated that the radon concentration in buildings of Karbala University campus were low enough, and below the ICRP recommended values of (200 Bq/m^3) and thus are within safe limits.

Table 1. Indoor radon concentrations and annual effective doses distributed among different places in Karbala University campus.

Place	floor	Sample code	Radon concentration (Bq/m^3)	Annual effective dose (mSv/ y)
College of Medicine	Ground	MEDG	86.165±5.134	2.173± 0.129
	First	MED1	67.851± 3.991	1.711± 0.100
College of Dentistry	Ground	DENG	82.244±4.897	2.074± 0.123
	First	DEN1	61.272± 3.694	1.545± 0.093
College of Pharmacy	Ground	PHAG	95.642±5.730	2.412± 0.144
	First	PHA1	73.571±4.327	1.856± 0.109
College of Science	Ground	SCIG	81.481± 4.793	2.055± 0.121
	First	SCI1	64.747± 3.808	1.633± 0.0961
Library	Ground	LIBG	76.006± 4.471	1.917± 0.112
	First	LIB1	58.658± 3.450	1.479± 0.087
	Second	LIB2	41.881± 2.463	1.056± 0.062
Student's residence	Ground	STG	77.124± 4.536	1.945± 0.114
	First	ST1	67.047± 3.943	1.691± 0.099
	Second	ST2	51.328± 3.019	1.294± 0.0761
Mean value for all locations			70.358	1.774
Standard deviation			14.367	0.362

Table 2.Outdoor radon concentrations and annual effective doses distributed among different places in Karbala University campus.

Place	Sample Code	Radon concentration (Bq/m^3)	Annual effective dose (mSv/ y)
Near College of Medicine	MEDO	27.233 ± 2.429	1.202±0.107
Near College of Dentistry	DENO	26.416± 2.757	1.166±0.121
Near College of Pharmacy	PHAO	28.594± 2.854	1.262±0.126
Near College of Science	SCIO	26.960± 1.912	1.190± 0.084
Near Library	LIBO	25.134± 1.783	1.109±0.078
Near Student's residence	STO	27.505±1.693	1.214±0.074
Mean value for all locations		26.974	1.191
Standard deviation		1.155	0.051

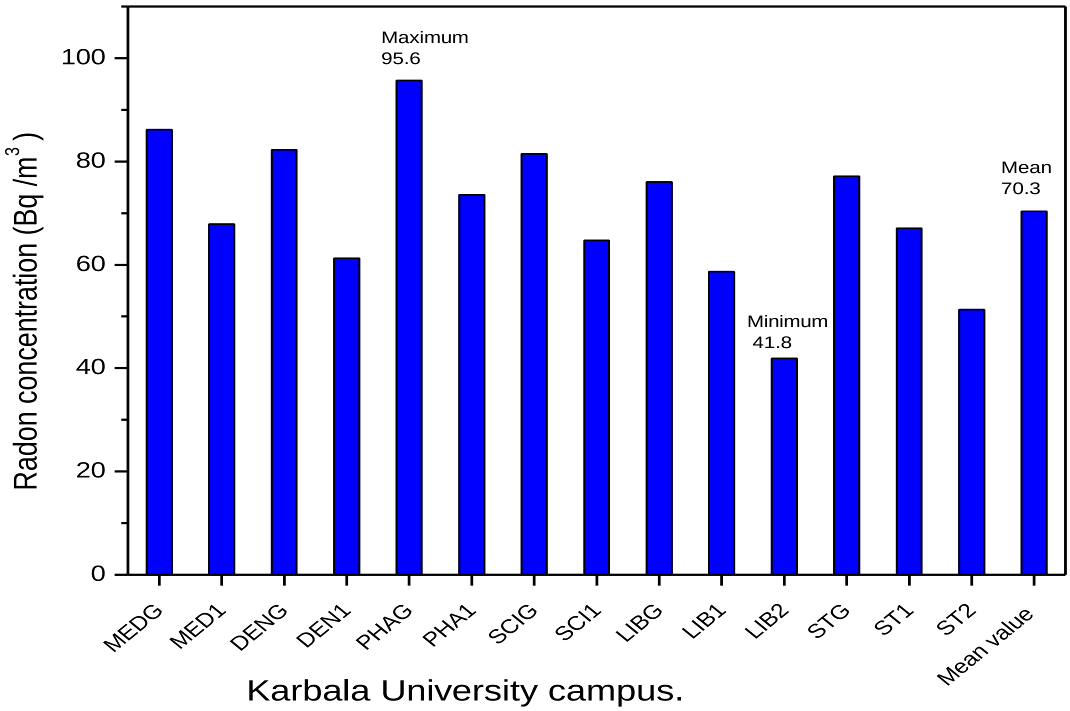

Figure 5.Variation of indoor radon concentration in the Karbala University campus.

References

1. UNSCEAR 2000 report sources and effects of ionization radiation**,**United Nations Scientific Committee on the Effects of Atomic Radiation,2000, Report to the General Assembly with scientific annexes Volume1United Nations New York.
2. Durrani, S.A., 1993 “Radon as a Health at Home: What are the Facts”, Nucl. Tracks Radiat. Meas.:22, 303-317.
3. UNSCEAR 1993, Exposure from natural sources of radiation, United Nations Scientific Committee on the Effect of Atomic Radiation , 1993. United Nations, New York.
4. Evans, RD, Harely JH, Jacobi W, Mclean AS, Mills WA and Stewar CG, 1981“ Estimation of risk from environmental exposure to and its daughter products”, Nature: 290, 98-100.
5. Nero AV.,1988“Estimated risk of lung cancer from exposure to radon decay products in US homes ” A Brief Review Atoms Environ :22,2205-2211.
6. ICRP International Commission on Radiological Protection,1993 "Protection Against Rn-222 at Home and at Work", ICRP publication No.65. Pergamon Press, Oxford.
7. ICRP International Commission on Radiological Protection,1987 Pub. No. 50, 17 New York.
8. Abu-Jarad, F., Fremlin, J.H. and Bull, R., 1980 “A Study of Radon Emitted from Construction Materials Using Plastic α-track Detectors” Phys. Med. Biol.:25,483-694.
9. Mustonen, R., 1984 “Natural Radioactivity in and Radon Exhalation from Finnish Building Materials”, Health Phys.: 46,1195-1203.
10. Al-Jarallah, M.I., 2001 “Radon Exhalation Rates from Granite Used in Saudi Arabia”, Journal of Environmental Radioactivity :53, 91-98.
11. Ching-Jiang, C., Pao-Shan, W. and Fieh-Chi, C., 1993 “Radon Exhalation Rate from Various Building Materials”, Health Physics:64, 613-619.
12. Abu-Murad K.M. and Al-Tamimi, M.H., 2005 “Natural radioactivity due to radon in Soum region, Jordan”, Radiation Measurement : 39, 77-80.
13. Turhan, S.,2008 “Assessment of the Natural Radioactivity and Radiological Hazards in Turkish Cement and Its Raw Materials”, Journal of Environmental Radioactivity: 99, 404-41.

14. Subba Ramu MC, Ramachandran TV, Muraleedharan TS and Shaikh AN.,1990 “Indoor levels of radon daughters in some high background areas in India " RadiatProt Dosit:30, 41-44.
15. Farid, S. M., 1992 "Measurement of concentrations of radon and its daughters in dwellings usingCR-39 nuclear track detector", Journals of Islamic Academy of Sciences:, 5:1,4-7.
16. Abu-Jarad, F., Fazal-ur-Rehman, Al-Jarallah, M.I., Al-Shukri, A., 2003“Indoor radon survey in dwellings of nine cities of the eastern and the western provinces of Saudi Arabia”Radiat. Prot. Dosim: 106, 227–232.
17. Mayya Y. S., Eappen K. P., K. and Nambi S. V.,1998 “Methodology for mixed field inhalation dosimetry in monazite areas using a twin-cup dosimeter with three track detector” Rad. Prot. Dosim., 77(3), 177-184.
18. Asaad H. I. and Salih O. H. 2008 “Analysis of Radon Concentrations in Drinking Water in Erbil Governorate (Iraqi Kurdistan) and its Health Effects ”Tikrit Journal of Pure Science Vol. 13 No.(3).
19. Marcia Pires de Campos and Elaine Wirney Martins,2007“ Calibration of the solid state nuclear track detector CR-39 for radon measurements”2007 International Nuclear Atlantic Conference - INAC 2007 Santos, SP, Brazil, September 30 to October 5, 2007– ABEN ISBN: 978-85-99141-02-1
20. Ferdoas S. Al-Saleh,2007 “Measurements of indoor gamma radiation and radon concentrations in dwelling of Riyadh City, Saudi Arabia”, Applied Radiation and Isotopes :65 ,843-848.
21. Younis M., KhrtamAbd-Aladel, Hameed B. and Muhammed A.,2010“Determination of radon-22 concentration in center of Misan City using nuclear track detectors CR-39”,Basrah Journal of Sciences(A) Vol.6 No.36,35-38.
22. ICRP International Commission on Radiological Protection,2000 “ Lung cancer risk from indoor exposure to radon daughters Publication 66.