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Determination of Indoor Radon Concentration in Thi Qar Province Houses by using CR-39 SSNTD

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Abstract

The possible detrimental health effects of the inhaled radon and its decay products are in the limelight of interest of professionals as well as of the public. In the present work the passive integrated dosimeter technique with solid state nuclear track detectors (SSNTDs) super grade CR-39, was used to measure the concentration of the radioactive radon gas (Rn-222) indoor for 12 different locations in Thi Qar province. 176 detectors (1.0 cm x 1.0 cm x 0.5 cm) were prepared and were distributed in the chosen locations , after 90 days (November, December 2012 and January 2013) the detectors were collected and treated chemically using etching conditions which controlled by four principals variables (etching solutions ,temperature , morality and etching time). The tracks per unit area in each detector were determined by using MICROS Crocus II MCX100LCD optical microscope. Results obtained showed that radon average concentration indoors was varies from 25.66 Bq/m^3 in Bateha to 113.63 Bq/m^3 in Fuhood, and the annual effective dose according to these concentrations are 0.890 mSv/y and 3.941mSv/y respectively. Results indicate that the houses surveyed had indoor radon levels within permissible level when ICRP1993 recommended limit of 600 Bqm^{-3} was used. Few houses had higher radon levels if NRPB (Health Protection agency) UK and US (environmental protection agency) EPA limits of 200 and 148 Bq m^{-3} were used. The overall average for the concentrations of radon in indoor air in the province of Thi Qar in this study is 66.989 Bq/m^3 with a standard deviation of 48.554 this concentration is less or asymptotic concentration of radon in most of the neighboring countries of Iraq.

Keywords: Radon, radon concentration, CR-39 detector, SSNTD detectors

تحديد تراكيز غاز الرادون في الهواء داخل منازل ١٢ مدينة في محافظة ذي قار باستخدام كاشف الاثر النووي CR–39

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الملخص

الاثار الصحية الضارة المحتملة لاستنشاق غاز الرادون ونواتج اضمحلاله تلقى الكثير من الاهتمام من قبل الباحثين وكذلك من الجمهور. في البحث الحالي تم قياس تراكيز الرادون في هواء منازل 12 مدينة من مدن محافظة ذي قار باستخدام كاشف الاثر النووي CR–39 .وزع 176 كاشف على منازل اختيرت بشكل عشوائي في كل المدن تحت الدراسة وتركت لمدة 90 يوما (تشرين الثاني و كانون الاول 2012 و كانون الثاني 2013). بعد انقضاء هذه

الفترة الزمنية جمع 117 منها حيث تمت معالجتها كيميائيا باستخدام محلول هيدروكسيد الصوديوم NaOH بتركيز 6.25N عند درجة حرارة $70\ C^o$ لمدة 7 ساعات .نظفت الكواشف بشكل جيد بالماء الاعتيادي و الماء المقطر ثم جففت وصنفت .استخدم مجهر ضوئي كمبيوتري لحساب عدد الاثار لوحدة المساحة لكل كاشف على حدة ($track/cm^2$) ومن ثم تم حساب تراكيز الرادون في كل منزل لكل مدينة باستخدام معامل المعايرة المحسوب عمليا في هذا البحث [$Bq/m^3 day/tracks/m^2$] 0.00296 . النتائج التي تم الحصول عليها تشير الى ان معدل تركيز غاز الرادون متباين بشكل واضح من 25.66 Bq/m^3 في مدينة البطحة كاقل تركيز بين المدن الى 113.63 Bq/m^3 في مدينة الفهود كاعلى تركيز بين المدن .ينتج عن هذا التركيز جرعة سنوية فعالة مقدارها 0.890 mSv/y في مدينة البطحة و 3.94 mSv/y في مدينة الفهود.تشير النتائج التي تم الحصول عليها الى ان مستويات تركيز غاز الرادون في منازل جميع المدن تحت الدراسة هي ضمن الحدود المسموحه بالمقارنة مع توصيات ICRP1993 والبالغة $600Bq/m^3$ ولكن عند اعتماد توصيات الوكالة الامريكية لحماية البيئة EPA والمحددة بالقيمة 148 Bq/m^3 والوكالة البريطانية للحماية الصحية NRPB والمحددة بالقيمة 200 Bq/m^3 فان هناك بعض المنازل تتجاوزفيها مستويات تراكيز غاز الرادون توصيات الوكالتين. المعدل العام لتراكيز غاز الرادون في المحافظة هو 66.989 Bq/m^3 بانحراف معياري قدره 48.554 وهو ضمن الحدود المسموحة .

1.Introduction

Radon is a chemically inert, radioactive, colorless and odorless gas that emanates from soil and rocks. Three radon isotopes ^{222}Rn, ^{220}Rn, and ^{219}Rn are known, which are called radon, thoron and actinon, respectively. Radon is a descendant from the ^{238}U decay chain, while thoron is a descendant from the ^{232}Th decay chain and actinon is a descendant from the ^{235}U decay chain. As thoron and actinon have very short half-lives of 55.6 s and 3.96 s, respectively, comparing to the radon that has half-life of 3.82 days, they are very rare gases in the atmosphere. Radon has four short-lived progeny ^{218}Po, ^{214}Pb, ^{214}Bi, and ^{214}Po. All methods of radon monitoring are based on the detection of either α-particles or γ-rays emitted during the decays both of ^{222}Rn and its progeny[1]. Radon becomes a concern, however, when it seeps through openings such as cracks, loose fitting pipes, sump pits, dirt floors, slab joints or block walls and accumulates in the home. Air pressure inside the home is usually lower than pressure in the soil around the house's foundation. Because of this difference the house acts like a vacuum, drawing radon in through foundation cracks and other openings. Radon has been identified as a risk factor in developing lung cancer because it decays into radioactive particles that can get trapped in the lungs. These particles release bursts of energy that damages lung tissue. It is estimated that radon may be associated with about 21,100 lung cancer deaths per year in the United States, second only to smoking [2]. The chances of getting lung cancer from radon depend on how much radon is in the home, the amount of time spent in the home and whether a person smokes. Smoking, combined with radon, adds to the health risk. Because radon levels are influenced by a variety of factors soil type and moisture, how "tight" the home is, type of heating and ventilation system, movement of air and groundwater, air pressure, and lifestyle behavior of the occupants – the only way to know if a home has elevated levels of radon is to test it [3]. Radon measurements show how much radon was present in the home during the test period. This level varies depending on detector location and the time of year it was used. As mentioned earlier, radon levels are generally highest when the house is closed and in the basement or near possible radon entry routes. Radon gas is measured in units of picocuries per liter (pCi/L) or Bq/m3, a standard measure of radioactivity. The EPA set 4 pCi /L or 148 Bq/m3 as a recommended action level. If a short-term measurement is over 148 Bq/m3, the recommended action is to perform a follow-up test to better characterize the radon levels [4]. If a long-term test measures over 148 Bq/m3, action should be taken to reduce radon exposure. The level of radon in a home may vary considerably from neighbor to neighbor. So the only way to know is to test. [5].

1.1 Annual effective doses

Determination of the Annual Effective Dose In order to estimate the annual effective doses indoors, taking into account the conversion coefficient from absorbed dose in air to effective dose and the indoor occupancy factor. In the (UNSCEAR (B), 2000) Report [6], a value of 9.0 x 10-6 mSvh-1 per Bq/ m3 was used for the conversion factor, 0.4 for the equilibrium factor of Rn-222 indoors and 0.8 for the indoor occupancy factor. Calculating the annual effective dose to the population, the equation below is used (ICRP65, 1993) [7]. At a certain radon concentration CRn in Bq/m3 the annual radon (absorbed) dose, DRn is usually expressed in the unit of mSv from the following relation:

$$D_{Rn}\,(mSv/y) = C_{Rn}.\,D.H.F.T \quad \ldots\ldots\ldots \quad (1)$$

Where CRn is the measured Rn-222 concentration (in Bqm-3), F is the Rn-222 equilibrium factor indoors (0.4), T is the indoor occupancy time [0.4 x staying time in home per day) x365 = ( ) h y-1], and D is the dose conversion factor (9.0x 1 0-6 mSv h-1 per Bq m-3). Now to calculate the annual effective dose, one has to apply a tissue and radiation weighting factors according to ICRP65, 1993. The equivalent dose is the radiation-weighted absorbed dose. The radiation weighting (WR) factor for alpha particles is 20 as recommended by ICRP 1993, 1994. With the effective dose, a tissue weighting (WT) factor is applied. According to ICRP, the tissue weighting factor for lung is 0.12. The annual effective dose (Eaed) is then calculated according to the following equation (UNSCEAR (B), 2000) [6]:

$$E_{aed}\,(mSv\,y^{-1}) = D_{Rn}.W_R.W_T \quad \ldots\ldots\ldots \quad (2)$$

Where, DRn = Annual Absorbed dose, WR = Radiation Weighting Factor for Alpha Particles, 20, WT= Tissue Weighting Factor for the Lung 0.12 .It is, however, apparent that the time spent by individuals in the home varies widely. The occupancy factor of 0.8 (ICRP65,1993, 1994) [7] over estimates the excess lung cancer risk in the temperate regions but may be valid for the inhabitants of the Immoderate regions, where people spend most of their time in indoors.

2.Materials and Methods

2.1 The study area (houses selection)

In the present study, houses surveyed in the 12 city in Thi Qar province (Al Fajir (Faj), Al Qulah (Qul), Al Rifa'ay (Rif), Al Nasir (Nsr),Al Shatrah (Sha), Al Gharaf (Gha),Al Nasiriyah (Nas), (Suq)Al shiukh, Al Bateha (Bat), Al Fuhood (Fuh),Al Aslah (Asl) and Al Gibiesh (Gib)) were built from baked bricks and cement. Each room contained one or two windows. These included both single and double storey houses. Each house contained at least two rooms. Dosimeters were installed in a bedroom of each of the selected house. In the case of double storey houses, dosimeters were installed in bedroom located at the ground floor. All the houses surveyed were detached and semidetached houses. Dosimeters were installed at head height in bedroom of each house at the ground floor. These dosimeters were exposed to radon for three months (November, December 2012 and January 2013). Fig.(1) show us the map of study area.

2.2 Calibration of CR-39 detectors

Four detectors were exposed to a known activity of 226Ra (Radium is used to produce radon a single gram of radium-226 will produce 0.000l milliliters of radon a day [8]. Then Radium is solid radon source) for a determined period of time. Then these detectors were treated by chemical etching. The average numbers of tracks/cm2 were calculated. These detectors were inserted in the same volume (chamber) of the investigated sample, so they considered as a calibration standard or calibration constant (factor) K were determined by dividing the track density by the total exposure of radon source as in the following equation [9].

$$K = \left(\frac{C_R T_R}{\rho_R}\right) \text{ ---------------------------------- } (3)$$

Where C_R , Concentration of activity of 226Ra (solid radon source) Bq/m3 ; ρ_R, Track density (number of tracks/m2) in detectors exposed to 226Ra; T_R , Exposure time (in days) of detectors exposed to 226Ra, then the radon concentration becomes as follows :

$$C_{Rn}\left(\frac{Bq}{m^3}\right) = K_{1,2,3,4}\left(\frac{\rho_{Rn}}{T_{Rn}}\right) \text{ ------------------- } (4)$$

Where $K_{1,2,3,4} = \frac{K_1+K_2+K_3+K_4}{4}$, $\rho_{Rn} = \frac{N(\text{tracks})}{S(m^2)t(\text{sec.})}$

(The track density (ρ_{Rn}) is the number of tracks recorded on the SSNTD (CR-39 detector) divided by the surface area (S) and by the irradiation time (t)). The calibration factor (K) is determined, where four CR-39 detectors are exposed to 226Ra (Radium Source) of activity concentration 1000 Bq/m3 (from factory) for 90 days. The calibration process for detectors used in this research was carried out at the nuclear laboratory at physics department in The College of science in Thi Qar University. The average calibration factor K is 0.00296 [Bq/m3day/tracks/m2], with standard deviation 9.97%. Substituting calibration constant (Factor) in eq. (4) we get:

$$C_{Rn}\left(\frac{Bq}{m^3}\right) = 0.00296\left(\frac{\rho_{Rn}}{T_{Rn}}\right) \text{ ------------------ } (5)$$

3. Measurements and calculation

The CR-39 (Columbia Resin-39) is the trade name of the thermo set plastic which is a polymeric form of poly-allyl diglycol carbonate (PADC) Tastrak. It's simple formula is a ($C_{12}H_{18}O_7$)n with a density of 1.31 g cm-3. These detectors are manufactured by TASL (Track Analysis Systems Ltd, Bristol, UK). They are square in shape, 1.0 × 1.0 cm in size and 0.5 cm thickness used in present work, to measure the concentration of the radioactive radon gas Rn-222 indoor for 12 deferent cities in Thi Qar province. 176 detectors were prepared and were distributed in the chosen locations. Each detector consist of assembly system include CR-39 detector enclosed in small plastic chamber (10 cm height, 9 cm diameter) and an arm to install the detector assembly on the wall, Fig.(2a). After 90 days the CR-39 detectors were collected from various cities of Thi Qar province. The CR-39 detectors were visualized in a solution of 6.25N NaOH for 7hr at 70 Co, washed in clean water for 10 minutes and then with distilled water. After a few minutes of drying in air, the detectors were ready for track counting. The tracks on the CR-39 were counted per unit area in each detector using computerized optical microscope type MICROS Crocus II MCX100LCD made by MICROS Produktions, Vienna, AUSTRIA. The average calibration factor K for CR-39 detectors is 0.00296 [Bq/m3day/tracks/m2], with standard deviation 9.97% determined in the present work.

4. Results and Discussion

The measurements of 222Rn concentration were performed for a period of 3 months from November 2012 to January 2013. The dosimeter at each house was installed using holder arm at bedroom with approximately 1.8 meters from the floor (breathing zone) and 0.3 meter from the wall as shown in Fig (2b). After the 3-month period of exposure, 117 detectors from 176 were retrieved; other detectors are missing or damaged As a result of messes of some occupants in these detectors, because of lack of awareness of the health hazard posed by indoor radon, table (1). The present survey was limited to 176 houses chosen randomly from many houses in these cities because of the limited number of detectors that we had and also due to the difficulty in placing the detectors in various houses. The track densities found on the analyzed NTDs were converted into radon concentrations (Bq/m3) using eq.(5) for the utilized radon dosimeter. The results for 117 houses were obtained, table (2). The variation of radon concentration in the 117 houses surveyed are shown in Fig.(2). This variation in concentration between cities because of radon concentrations in dwellings depend on meteorological and geological conditions, lifestyle, construction materials, and ventilation. The arithmetic mean, standard deviation, and range of indoor 222Rn concentration in Thi Qar province houses were 66.898, 48.55, and 16.3–280.1 Bq/m3, respectively.. All of the houses surveyed had indoor radon levels within permissible level when ICRP1993 recommended limit of 600 Bqm-3 was used. Few houses had higher radon levels if NRPB (Health Protection agency) UK and US. (environmental protection agency) EPA limits of 200 and 148 Bq m-3 were used. In The present survey the annual effective dose Eaed (mSvyr-1) to the occupants is estimated corresponding to average radon concentration in each city using eq.(2) shown in table (3) and Fig.(3).

5. Conclusion

From our findings we can conclude that the most of indoor levels, as expected, were well below the US EPA limit of 148 Bq/m3, just 4 houses (3.4%) of 117 monitored shown concentration levels above limit, but the average indoor radon concentration in all cities are below the US EPA recommendation limit. The majority of our estimates for indoor radon are within the normal risk level. However, Al Fajir, Al Qulah, Al Nasir, Al-Gharaf, Al Nasiriyah, Suq Al Shiukh, Al Bateha and Al Aslah fell within normal risk while Al Fuhood, Al Gibiesh, Al Rifa’ay and Al Shatrah can be classified as higher than normal risk corresponding to average radon concentration in each city. Furthermore smoking increased the risk of death from radon-induced cancer. Our data suggest that increased attention needs to be paid to exposure to radon and the associated health risks in order to preserve public health and reduce the incidence of cancer.

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Table (1): Number of detectors distributed, collected and missing or Damaged in different cities of Thi Qar province.

Location* (cities)	No. of detectors distributed	No. of detectors collected*	No. of detectors missing
Faj	20	11	9
Qul	10	7	3
Rif	20	13	7
Nsr	6	4	2
Sha	20	18	2
Gha	10	8	2
Nas	20	14	6
Suq	20	12	8
Bat	10	5	5
Fuh	10	6	4
Asl	10	6	4
Gib	20	13	7
Total detectors	176	117	59

* No. of detectors completely valid for measurements.

Table (2): Indoor radon concentrations and standard deviation in houses of 12 city in Thi Qar province

Location (Cities)	Radon concentration (C_{Rn}) Bq/m³	Average Con.* Bq/m³	Std.dev. SD
Faj	21.5,21.8,23.0,41.9,28.4,25.2,26.3, 36.2,31.6,68.1,88.4	37.49	20.576
Qul	26.8, 38.9, 34.5, 50.0, 19.3, 66.2, 23.8	37.07	15.22
Rif	48.0,39.6,67.3,27.2,69.8,38.5, 124.6,76.7,98.4,187.9,116.3,98.1, 214.5	92. 838	54.77
Nsr	40.6, 33.8, 28.0, 26.2	32.15	5.63
Sha	25.4,36.5,109.2,52.4,112.6,18.3, 102.7,196.2,280.1,133.5,94.2,66.6, 33.8,44.1,178.5,78.2,43.9,31.8	89.84	64.78
Gha	18.2,19.4,28.4,25.2,54.3,30.7,26.8, 20.7	27.96	10.79
Nas	37.1,68.0,81.4,62.3,53.1,71.6,64.4, 76.5,78.2,38.6,46.1,40.8,42.3,50.7	57.93	15.15
Suq	64.5,61.3,76.7,66.1,78.2,92.1,81.0, 77.3,54.4,52.2,45.4,48.7	66.48	14.04
Bat	19.3, 26.7, 31.3, 27.8, 23.2	25.66	4.1
Fuh	68.5,88.6,194.3,153.4,104.7,72.3	113.63	45.71
Asl	43.9,29.4,38.4,66.3,33.8,40.13	41.988	11.80
Gib	65.1,96.4,55.8,80.3,89.4,54.1,76.0, 139.3,128.5,248.8,91.5,107.4	102.71	50.74

Con.*=Concentration

Table (3): Average indoor radon concentration and calculated values of annual effective dose (D_{aed}) for 12 selected City in Thi Qar Province.

Location (cities)	Average Con. (Bq/m³)	Dose Rate (nSv/h)	Annual Effective Dose (D_{aed}) [mSv/y]
Faj	37.49	211.9	1.300
Qul	37.07	209.7	1.285
Rif	92.83	524.6	3.220
Nsr	32.15	181.7	1.115
Sha	89.84	513.7	3.152
Gha	27.96	158.2	0.963
Nas	57.93	327.8	2.009
Suq	66.48	375.9	2.306
Bat	25.66	145.0	0.890
Fuh	113.63	713.4	3.941
Asl	41.98	236.8	1.455
Gib	102.71	580.5	3.562

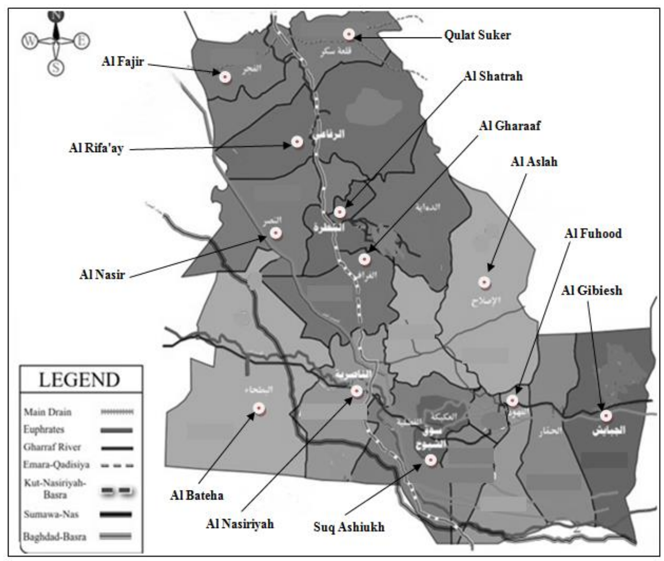

Fig.(1): The location of 12 cities in Thi Qar Province (Study area).

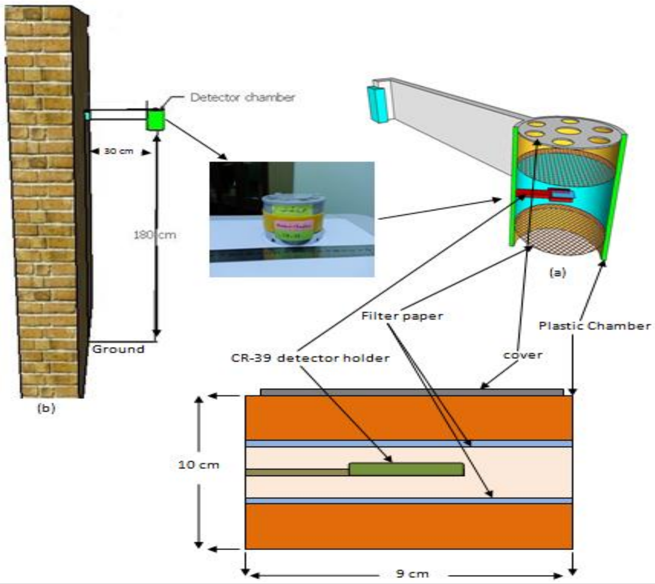

Fig.(2): Measurement technique used in the present work (a) radon chamber structure, (b) detector installation position in the house,

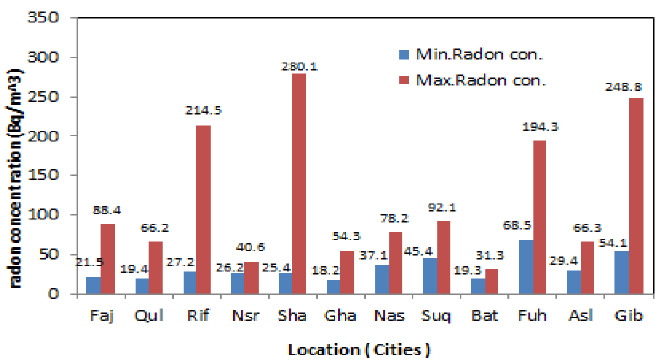

Fig.(3): Maximum and minimum of Indoor radon concentration (Bq/m^3) for 12 selected city in Thi Qar province.

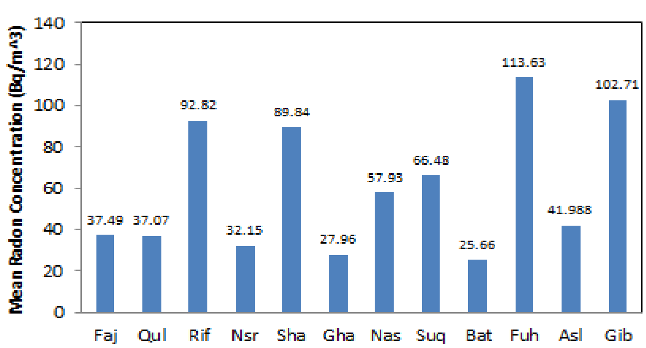

Fig.(4): Mean indoor radon concentration (Bq/m^3) for 12 selected city in Thi Qar province .

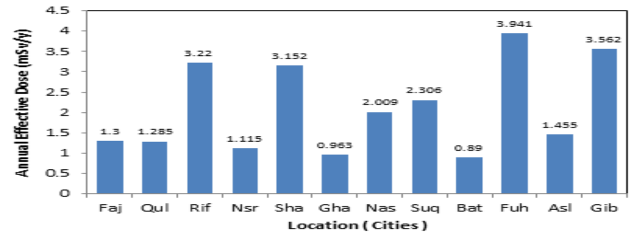

Fig.(5): Annual effective dose (mSv/m^3) corresponding to mean indoor radon concentration in each city.

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