# Radon Concentration in Al-Gazalia City, Baghdad, Iraq

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**Abstract**

Inhalation of indoor radon has been recognized as one of the health hazards. In the present work a set of indoor radon measurements was carried out, in different Iraqi houses in Al-Gazalia city/ Baghdad, built of the same type of building materials. Radon concentration determined by using time–integrated passive radon dosimeters containing CR-39 solid state nuclear track detector. Measurements were carried out from September to November 2011. The results show that, the radon concentrations varied from (38.7 to 200) Bq $m^{-3}$. The mean values of radon concentrations in second floor hall and first floor of living rooms, kitchens and bathrooms, were: (46.56±9.13), (68.32±8.55), (128.03±21.65) and (168.92±33.52) Bq.$m^{-3}$ respectively. This data shows that, bathrooms and kitchens have significantly higher radon concentrations and the second floor is lower radon concentration in all dwellings.

Keywords: Indoor radon concentration, CR-39 nuclear track detector, track density, radon calibration factor.

## Introduction

Radon contributes one half of the total annual dose from radiations of all kinds [1, 2]. It is a natural inert radioactive tasteless and odorless gas, whose density is 7.5 times higher than that of air, dissolves in water and can readily diffuse with gases and water vapor, thus building up significant concentrations. The physical half-life of radon is 3.825 days and half-elimination time from lungs 30 min. Radon $^{222}$Rn, which is the daughter of uranium $^{238}$U, represents the most important radon isotope. Decay of the radon nucleus $^{222}$Rn yields short-living daughters: polonium $^{218}$Po, lead $^{214}$Pb, $^{214}$ Po and bismuth $^{214}$Bi [3].

If radon makes its way into a (badly ventilated) home, it can build up to high concentrations and may become a health hazard. Although our skin is thick enough to protect us from the alpha-particles emitted by the three polonium isotopes from the decay series of $^{222}$Rn, it are especially these isotopes that are most harmful when they disintegrate inside our lungs. After smoking, which is responsible for 87% of the lung cancer cases, radon is estimated to be the second leading cause (12%) of lung cancer in the USA today [4]. In order to offer an indication of the risks of radiation, the International Commission of Radiological Protection (ICRP) has given norms indicating the maximum dose of radiation that should be acceptable for human health [5].

However, background levels of radon in outdoor air are generally quite low, about 0.003 pCi/l of air. In indoor locations, such as homes, schools, or office buildings, levels of radon and daughters are generally higher than outdoor levels; are generally about 1.5 pCi/l of air [6].

Most of our time is spent within buildings; therefore, the measurement and limitation of radon concentration of buildings are important [7]. The main natural sources of indoor radon are soil, building materials (sand, rocks, cement, etc.), natural energy sources used for cooking like (gas, coal, etc.) which contain traces of $^{238}$U. The topography, house construction type, soil characteristics, ventilation rate, wind direction, atmospheric pressure and even the life style of people.

The dwellers may inhale air polluted with radon and its short-lived progeny, which can enter the lungs during inhalation and then undergo radioactive decay thereby, causing physical damage leading to chemical damage and ultimately biological damage. The continuous damage produced by alpha particles emitted from radon in lungs may cause cancer. The knowledge of radon levels in building is important in assessing population exposure. Radon in indoor spaces may originate from exhalation from rocks and soils around the building or from construction materials used in walls, floors, and ceilings. Indoor radon concentrations are almost always higher than outdoor concentrations. Once inside a building, the radon cannot easily escape. The sealing of buildings to conserve energy reduces the intake of outside air and worsens the situation. Radon levels are generally highest in cellars and basements because these areas are nearest to the source and are usually poorly ventilated. Radon can seep out of the ground and build up in confined spaces, particularly underground, e.g. in basements of buildings, caves, mines etc, and ground floor buildings. High concentrations can also be found in buildings because they are usually at slightly lower pressure than the surrounding atmosphere and so tend to suck in radon (from the soil) through cracks or gaps in the floor[8].

Radon concentration hypothesis is the fundamental basis for the prediction of risk from radiation exposure, and forms the basis for radiation protection practices, when track etched detector were used a significant risk cancer was found for radon concentration at and above the action level for mitigation of houses currently used in many European countries (200-400) Bq/m$^3$ [9].

In the present investigations, the passive technique using the Solid State Nuclear Track Detectors (SSNTDs) has been utilized for the comparative study of the indoor radon level in the dwellings of Al-Gazalia city/ Baghdad. Nuclear track detection technique based on radon measurement with CR-39 detector was used during the currently conducted study because of its simplicity and long-term integrated read out, high sensitivity to alpha-particle radiation ruggedness, availability and ease of handling.

The principle of this technique is based on the production of track in the detector due to alpha particles emitted from radon and its progeny. After exposure the tracks are made visible by chemical etching and counted manually under the optical microscope. The measurement track density is then converted into radon concentration [10].

## Experimental Procedure

### The Detector

The CR-39 plastic detector used in the present study is sensitive to alpha particles of energy up to 40 MeV [11]. It was used as integrating detector of α-particles from $^{222}$Rn and Rn daughter nuclei. When an α-particle penetrates the detector, the particle causes damage along its path.

The damage is then made visible by chemical etching. The etching produces a hole in the detector along the path of the particle. The hole can be easily observed in a light transmission microscope with moderate magnification. The detector film detects α-particles from both $^{222}$Rn and its daughters during the time of exposure in the indoor environment of a house.

### The Dwellings

Measurements were made in 10 detached houses at 10 different locations in Al-Gazalia city/Baghdad. In a detached house, multistory buildings. The houses selected for the present study were of different styles of construction, the dwellings under study were built, in general using different materials, cement, sand, blocks, and bricks, iron structure, marble and concrete as the construction materials. Several of these materials are expected to contribute significantly to sources of indoor radon. Each house having from two to five rooms with size approximately (3 × 4 × 3) m$^3$ with one or two window and a door, and all houses used for this survey were built around (greater than 15 years).

### The Exposure

Detectors of size 1.5x1.5 cm were exposed to the indoor environment of a house for a known period of time of the order of 60 days (September- November 2011), during which time the alphas originating from $^{222}$Rn and its progeny would leave tracks on it. At least four detectors were placed in different rooms i.e., living room, kitchen, and bathroom for the first floor and in the hall of the second floor for each house. The exposure is done by placing the detector film at a height of about 2 m from the ground and at least 1 m away from the ceiling and the walls by means of a thread and paper clip. After two months of exposure the detectors were etched chemically in NaOH solution for 6.25 N at temperature 70°C for 6 hour. After the etching, the detectors were washed for 30 minutes with running cold water, then with distilled water and finally with a 50% water/alcohol solution. After a few minutes of drying in air, the detector were ready for track counting. The tracks were counted using an optical microscope having a magnification of 400X.

## Radon Concentration Measurement

In order to estimate the radon concentration in buildings, experimental method for radon detection and measurement are based on alpha-counting of radon and its daughters. The track density was calculated in terms of number of tracks per $mm^2$, the average number of tracks was determined by processing an unexposed films CR-39 detector under identical etching condition. The signal measured by etched track detectors is integrated track density, ρ(track. $mm^{-2}$) recorded on the detector, (K) the average value of the calibration factor of $^{222}Rn$ in [(Bq. day$m^{-3}$) per (tracks. $mm^{-2}$) ] and (T) exposure time (day) has been applied to determine $^{222}Rn$ concentration ($CRn$) in (Bq/$m^3$) using the following equation [12,13]:

$$C_{Rn} = \mathrm{K}\left(\frac{\rho}{T}\right)$$

The calibration process for the dosimeters were exposed for 60 days of Radium $^{226}Ra$ (Radon source) of activity concentration 0.33 x $10^4$ (Bq) it gives 0.1175[(track.$mm^{-2}$) per (Bq. $m^{-3}$. day)] [14].

## Results and Discussion

Table (1) and (2) summarizes the results of track density and the radon concentration, indoor radon concentration levels, measured in different compartments [2nd floor hall, 1st floor (living room, kitchen, and bathroom)] for ten different houses in Al-Gazalia city. Where the observation have been taken from September, 2011 to November, 2011. The data show that the indoor concentration obtained in the present investigations, varies from (38.7 to 200) Bq $m^{-3}$,as shown in Fig. (1) and (2), with overall average value (102.96 ± 55.86) Bq $m^{-3}$ which is lower than the recommended ICRP action level of 200 Bq $m^{-3}$[10]. From Fig.(2), The lowest value concentration was found in the second floor hall, 46.56±9.13 Bq $m^{-3}$, also if we compared it with the living room of the first floor as shown in Fig.(2), which is probably due to high ventilation, there are decrements in radon concentration between successive floors. This trend indicates that the principle source of indoor radon is likely to be soil gas entering the building at ground level. The importance of pressure-driven flow of air through soil and into buildings has been well established by U.S. investigators [15].

Whereas the highest concentration was found in the bathroom, 168.92±33.52 Bq. $m^{-3}$, that are probably due to water works and the building materials, which are usually considered as important income paths of radon in building and they can consequently increases the radon component. The mean value of the radon concentration in second floor hall and first floor of (living rooms, kitchens, and bathrooms) were: (46.56±9.13), (68.32±8.55), (128.03±21.65) and (168.92±33.52) Bq $m^{-3}$ respectively as shown in Fig.(1, 2). The results indicate that radon concentrations in some compartments like kitchens and bathrooms, in all apartments we investigated, were significantly higher than the radon concentrations measured in living rooms and second floor, whereas no significant difference was observed between kitchens versus bathrooms. Although kitchens and bathrooms are constructed mainly from the same skeletal building materials (concrete and cement blocks), the finishing materials used in such compartments, largely differ from that used in other locations within the same apartment. Ceramic, in particular is used extensively to replace the traditional painting materials, commonly used in living room and second floor hall [16], previous reports have indicated that ceramic is a potential source of radon, from where radon is mainly emerging from the decay of thorium and uranium in these materials [17]. Another factor explaining the high levels of radon and exhalation rates in these compartments, are the poor ventilation status due to the relatively narrow openings. Using natural gas in houses [18], and supplying kitchens and bathrooms with water originated from underground sources are considered as a potential source for indoor radon [19], the radon concentration is distinctly greater at ground level. We can show the comparison of radon concentration in each compartment for ten dwellings as Fig.(3). Our study showed that a secondary source of indoor radon is associated with the natural radioactivity of bricks, concrete, cement and gravel used in construction of houses in Baghdad.

***Table (1)***
***The track density ρ (tracks.mm$^{-2}$) for 10 dwellings.***

| House no. | Track density ρ (tracks.mm$^{-2}$) | | | |
|---|---|---|---|---|
| | 2$^{nd}$ floor hall | 1$^{st}$ floor Living room | 1$^{st}$ floor Kitchen | 1$^{st}$ floor Bathroom |
| 1 | 282±120 | 469.5±178.6 | 939.8±280 | 1400.9±260 |
| 2 | 328±230 | 532.9±170.7 | 1099.8±327 | 1410±382.9 |
| 3 | 296.1±250 | 432.9±107 | 775.5±261 | 1321.2±427 |
| 4 | 272.8±117 | 458.3±224.3 | 686.7±332.8 | 721.2±408 |
| 5 | 347±143 | 618.5±321 | 937.7±262.9 | 1378.3±387 |
| 6 | 284.1±171 | 422.3±125.7 | 1060.3±275.7 | 1232.9±328.6 |
| 7 | 274.9±148.6 | 430±311 | 860.1±311 | 1132.9±251 |
| 8 | 321.5±158.6 | 447±161 | 671.4±294 | 846±285.7 |
| 9 | 407.5±178.6 | 509±250 | 937.7±357 | 1161.4±297 |
| 10 | 468.1±158.6 | 496.3±117 | 1057.5±156.9 | 1304.3±115.7 |
| Mean | 328.27±64.36 | 481.67±60.35 | 902.65±152.62 | 1190.91±236.32 |

***Table (2)***
***The mean radon concentration Bq.m$^{-3}$ for 10 dwellings.***

| House no. | Radon Concentration Bq.m$^{-3}$ | | | |
|---|---|---|---|---|
| | 2$^{nd}$ floor hall | 1$^{st}$ floor Living room | 1$^{st}$ floor Kitchen | 1$^{st}$ floor Bathroom |
| 1 | *40* | *66.6* | *133.3* | *198.7* |
| 2 | *46.6* | *75.6* | *156* | *200* |
| 3 | *42* | *61.4* | *110* | *187.4* |
| 4 | *38.7* | *65* | *97.4* | *102.3* |
| 5 | *49.2* | *87.7* | *133* | *195.5* |
| 6 | *40.3* | *59.9* | *150.4* | *174.9* |
| 7 | *39* | *61* | *122* | *160.7* |
| 8 | *45.6* | *63.4* | *95.2* | *120* |
| 9 | *57.8* | *72.2* | *133* | *164.7* |
| 10 | *66.4* | *70.4* | *150* | *185* |
| Mean | *46.56±9.13* | *68.32±8.55* | *128.03±21.65* | *168.92±33.52* |

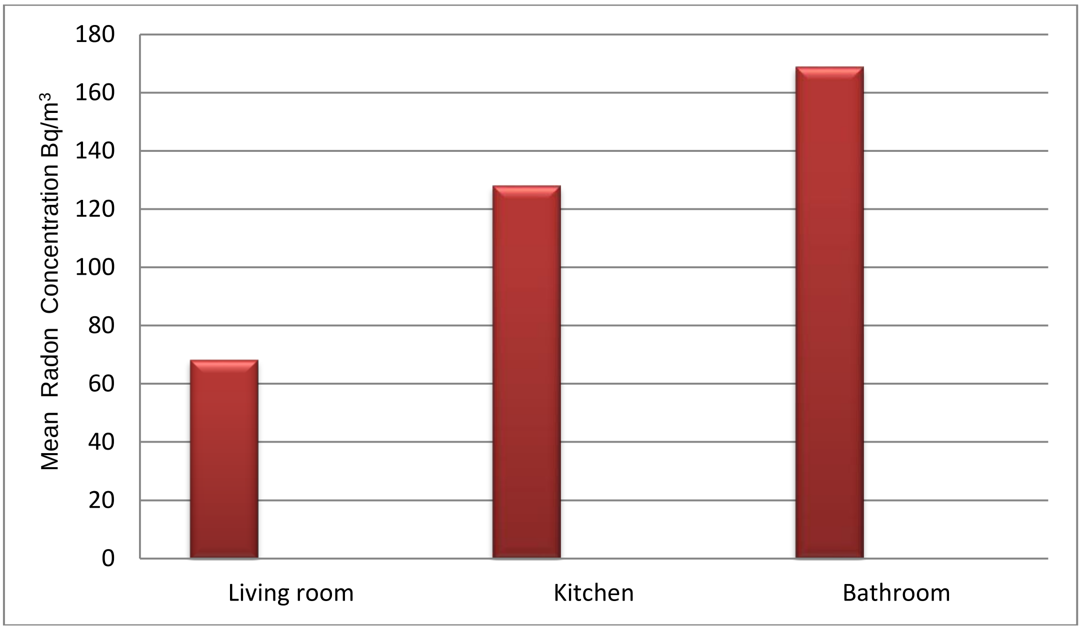



***Fig. (1) Mean Radon Concentration with the different compartments in first floor of dwellings.***

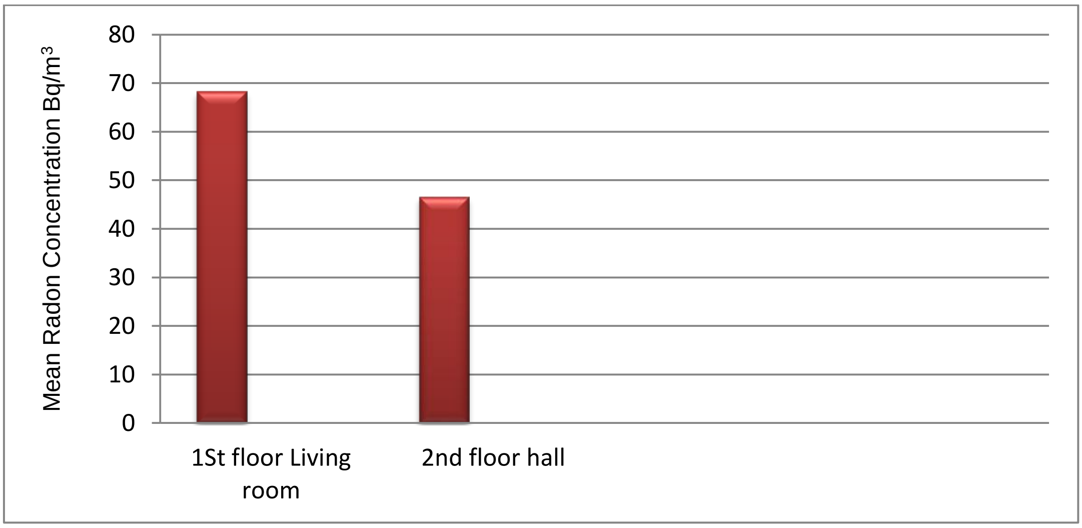
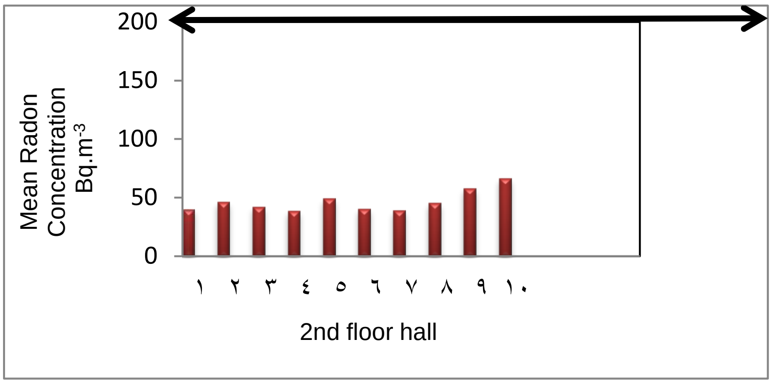
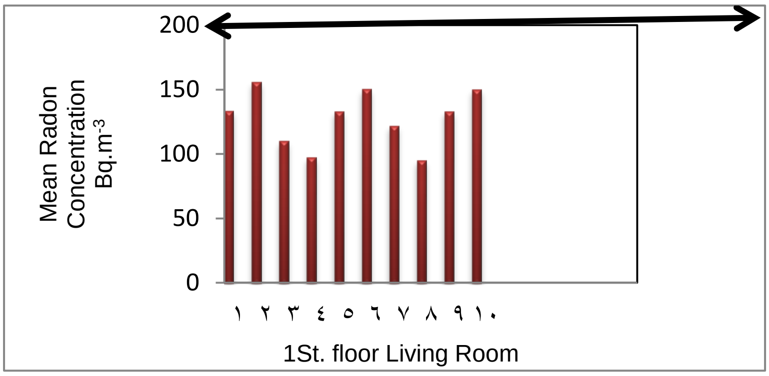
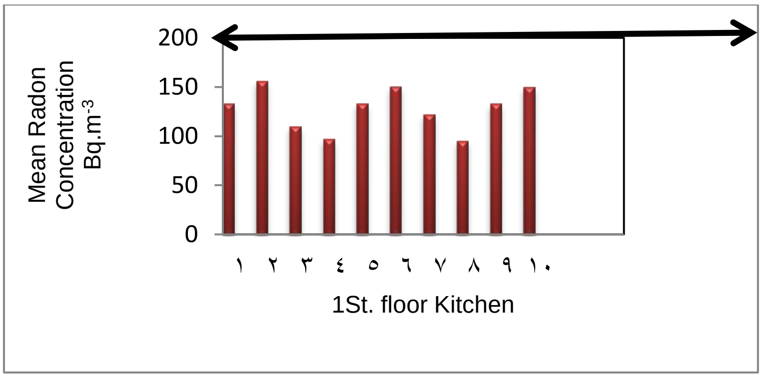



***Fig. (2) The comparison between the mean radon concentration in 1st. and 2nd floor for 10 dwellings.***



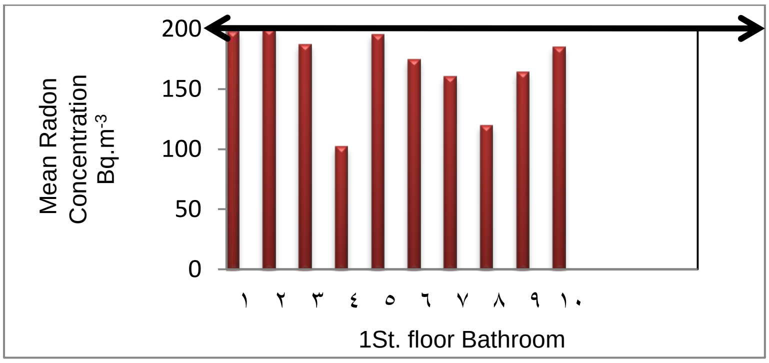




***Fig. (3) Comparison of mean radon concentration in 10 dwellings for each compartment in each dwelling, where [←→] the recommended action level of radon concentration.***

## Comparison

*Table (3)*
*The comparison of mean radon concentrations in indoor air samples with different studies in different locations.*

| *Study number* | *Location* | *Mean radon concentration. Bq $m^{-3}$* | *Reference number* |
|---|---|---|---|
| 1 | Mesan governorate | 35-46 | [20] |
| 2 | Baghdad governorate | 7.11 | [14] |
| 3 | Mousel governorate | 40-75 | [21] |
| 4 | Middle & north governorates | 33-100 | [22] |
| 5 | Al Gazalia city, Baghdad | 38.7-200 | Present Study |

***A comparison of average radon concentrations of studied area with national data is given in table (3). Values from the present survey are higher than those reported in many other studies conducted at national levels and greater than average concentration in some other ones. Higher values for indoor radon concentrations (as compared to other studies at national level) are reported in current study. There may be a number of reasons.***

***(1) houses were bad separated and room's dimensions were considerably different in district Al- Gazalia city as compared to houses in other parts of Iraq.***
***(2) in many of houses ventilation system was remarkably not good enough, and***
***(3) building materials, which are usually considered as important income paths of radon in buildings and its different between cities [21].***

## Conclusions

The indoor radon level have been estimated in 10 dwellings (10 locations) in Al-Gazalia city using integrating etched track detector. The radon concentrations are found to be higher in bathrooms in first floor compared to other compartments of the same dwelling. It is suggested that improvement of ventilation in such compartments is easily possible by simply reducing radon content of their ambient air. Occupants of these dwellings are therefore, relatively safe. Expanded studies are planned to determine the extent and severity of radon problems in other locations of Baghdad.

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**الخلاصة**

يعد غاز الرادون من الأخطار الصحية المنتشرة التي يُستهان بها. ففي كل يوم يتعرّض الكثيرون لمخاطره دون علمهم، وذلك من خلال المباني التي يعملون أو يسكنون فيها، حيث يتسرّب هذا الغاز عبر الشقوق الصغيرة الموجودة في أسس المباني. وان تقييم مستويات الرادون في البيوت والمباني العامة من الخطوات الهامة الأولى التي ينبغي اتخاذها. لذا في هذا البحث تم ايجاد تركيز غاز الرادون في منازل منفصله ومتعددة الاتجاهات في منطقة الغزاليه ببغداد العراق. حيث تم بناء هذه المنازل من نفس مواد البناء تقريبا. تم ايجاد تركيزغاز الرادون باستخدام كواشف الأثر النووي الصلبة CR-39 حيث تم تعريضها لمدة ٦٠ يوما ابتداءا من شهر سبتمبر الى شهرنوفمبر ٢٠١١. من هذه الدراسة وجد ان معدلات تركيز غاز الرادون يتغير من (٣٨.٧-٢٠٠) بيكرل في المتر المكعب. حيث وجد معدل تركيز غاز الرادون لكل من الطابق العلوي و غرفة المعيشه و المطبخ والحمام في الطابق الارضي لكل منزل من المنازل التي تم فحصها، وكانت النتائج كالاتي: (٤٦.٥٦±٩.١٣)، (٦٨.٣٢±٨.٥٥)،(١٢٨.٠٣±٢١.٦٥)،(١٦٨.٩٢±٣٣.٥٢) على التوالي بيكرل للمتر المكعب الواحد. من هذه النتائج استنتج ان اعلى تركيز لغاز الرادون في كل من الحمام والمطبخ للطابق الارضي وان اقل تركيز في الطابق العلوي لكل منزل.