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# Measurements of Radon- 222 Concentrations in Dwellings of Baghdad Governorate

KEYWORDS: Indoor radon concentration, CR-39 nuclear track detector, Radon-222, indoor air.

| Hazim Louis Mansour | Nada Fathil Tawfiq | Mahmood Salim Karim |
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| Department of Physics, College of Education, Al-Mustansiriyah University, Baghdad-Iraq | Department of Physics, College of Science, Al-Nahrain University, Baghdad-Iraq. | Department of Physics, College of Education, Al-Mustansiriyah University, Baghdad-Iraq |

**ABSTRACT** *In the present work a set of indoor radon measurements was carried out in different dwellings in Baghdad governorate. Radon concentrations were determined by using time-integrated passive radon dosimeters containing (CR-39) solid state nuclear track detectors. Measurements were carried out during the months (July and August, 2013). The results show that, the radon concentrations varied from (27.250±4.1 Bq.m-3) to (79.500±1.5 Bq.m-3) with an average value (51.688±16.7 Bq.m-3) which is less than the lower limit of recommended range (200-300 Bq/m3) (ICRP, 2009). The values of the potential alpha energy concentration were found to vary from (2.946 mWL) to (8.595 mWL) with an average value (5.588±1.5 mWL) which is less than the recommended value (53.33 mWL) given by (UNSCEAR, 1993). The value of exposure to radon progeny vary from (0.354 WLMY-1) to (0.121 WLMY-1) with an average value (0.230±0.1 WLMY-1) recommended range (1-2 WLMY-1) by the (NCRP, 1989). The values of the indoor annual effective dose vary from (0.687 mSv/y) to (2.003 mSv/y) with an average value (1.302±0.4 mSv/y) which is less than the lower limit of the recommended range (3-10 mSv/y) (ICRP, 1993). The values of lung cancer cases per year per million person vary from (12.366) to (36.054) with an average value (23.443±6.1) per million person which is less than the lower limit of the recommended range (170-230) per million person (ICRP, 1993).*

**Introduction**

Radon contributes about one half of the total annual dose from radiations of all kinds [1]. It is a natural inert radioactive tasteless colorless and odorless gas, whose density is about 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 about 3.825 days and half-elimination time from lungs is about 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 $^{214}Bi$ [2].

Most of our time is spent within buildings; therefore, the measurement and limitation of radon concentration of buildings are important [3]. 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 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. 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 (soil of the ground) 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 of 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 [4].

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-particles availability and ease of handling.

The CR-39 plastic detector used in the present study is sensitive to alpha particles of energy up to 40 MeV .It was used as integrating detector of α-particles from $^{222}Rn$ and daughters 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 dwelling [5].

The aims of the present study are to determine indoor radon level in the dwellings of Baghdad governorate and to calculate potential alpha energy concentration (PAEC), exposure to radon progeny ($E_p$) ,annual effective dose (AED), and lung cancer cases per year per million person (CPPP).

**Experimental Procedure**

Baghdad governorate is the capital of Iraq and located on a vast plain bisected by the river Tigris. The Tigris splits Baghdad in half, with the eastern half being called Al-Risafa and the Western half known as Al-Karkh as shown in Figure 1. Table 1 shows the symbol and location name of the different studied sites in Baghdad governorate.

The land on which the city built is almost entirely flat and low-lying, being of alluvial origin due to the periodic large floods which have occurred by the river, with location of latitude (31.30°- 33.10° N), and longitude (44.32°- 44.10° E). It is located about (32 m) above the sea level, with a total area of nearly (4555 km²) [6].

Detectors (CR-39) of thickness (500 μm) and size 1x1 cm²

Volume : 4 | Issue : 2 | Feb 2014 | ISSN - 2249-555X

were exposed to the indoor environment of a dwelling for a known period of time of the order of 60 days (July and August ,2013), in bare mode, 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 of the first floor or ground of the dwelling. 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 so that direct alpha particles from the building materials of the dwelling do not reach the detectors. After two months of exposure the detectors were chemically etched using 6.25 N (NaOH) solution at 60°C for 10 hours. After etching, the detectors were washed for 30 minutes with tap water.. After drying, the tracks were counted using an optical microscope having a magnification of 400X.

The average radon concentration ($C_{Rn}$) was measured by passive methods, calculated as [7,8]:

$C_{Rn}$ (Bq. m$^{-3}$) = $\rho$ / k.t ……………… (1)

Where (ρ) is the track density (track /mm$^2$), (k) is the calibration factor which was found experimentally to be equal to (0.161 track.mm$^{-2}$/ Bq.d.m$^{-3}$), and (t) is the exposure time which is equal to (60) days

The Potential Alpha Energy Concentration (PAEC) in terms of (WL) units was obtained using the relation [9-11] :

PAEC (WL) = F × $C_{Rn}$ / 3700 ………………… (2)

Where (F) is the equilibrium factor between radon and its progeny and it is equal to (0.4) as suggested by (UNSCEAR, 2000) [12].

Exposure to radon progeny ($E_p$) is then related to the average radon concentration $C_{Rn}$ by following expression [13]:

$E_P$ (WLM Y$^{-1}$) = 8760 × n × F × $C_{Rn}$ / 170 × 3700

where $C_{Rn}$ is in Bq.m$^{-3}$ , n is the fraction of time spent indoors which is equal to (0.8) ,8760 is the number of hours per year ,170 is the number of hours per working month and F is the equilibrium factor for radon is equal to 0.4 .

The annual effective dose (AED) in terms of (mSv/y) units was obtained using the relation [14-16] :

AED (m Sv/y) = $C_{Rn}$ × F × H × T × D …………… (3)

Where F is the equilibrium factor and it is equal to (0.4) , (H) is the occupancy factor which is equal to (0.8), (T) is the time in hours in a year, (T=8760 h/y), and (D) is the dose conversion factor which is equal to [9×10$^{-6}$ (m Sv) / (Bq.h.m$^{-3}$)] .

The lung cancer cases per year per million person (CPPP), was obtained using the relation [9,17,18]: (CPPP) = AED × (18×10$^{-6}$ mSv$^{-1}$.y).

**Results and Discussion**
In the present work indoor radon concentrations, were measured in different compartments for 20 different dwellings in Baghdad governorate. Table 2 summarize the results obtained in the present work for radon gas concentrations in indoor dwellings in different sites in Baghdad governorate, it can be noticed that, the highest average radon concentration in indoor dwellings was found in $B_{16}$ (AL-Zafraniya) region which was (79.500±1.5 Bq/m$^3$), while the lowest average radon concentration was found in $B_{20}$ (AL-Karada) region which was (27.250±4.1 Bq/m$^3$), see Figure (2), with an average value of (51.688±16.7 Bq/m$^3$), which is less than even the lower limit of the recommended range (200- 300 Bq/m$^3$) (ICRP, 2009) [19].

The highest value of the potential alpha energy concentration (PAEC) was found in $B_{16}$ region which was (8.595 mWL), while the lowest value of the potential alpha energy concentration was found in $B_{20}$ region which was (2.946 mWL) with an average value (5.588±1.53 mWL). All results of the potential alpha energy concentration (PAEC) in indoors dwellings in Baghdad governorate were lower than the recommended value of (53.33 mWL) reported by the (UNSCEAR, 1993) [20].

The highest value of exposure to radon progeny ($E_p$) was found in $B_{16}$ region which was equal to (0.354 WLMY$^{-1}$), while the the lowest value of ($E_p$) was found in $B_{20}$ region which was equal to (0.121 WLMY$^{-1}$), with an the average value of (0.230±0.1 WLMY$^{-1}$). All results of ($E_p$) in indoors dwellings in Baghdad governorate were lower than the even the lower limit of the recommended range (1-2 WLMY$^{-1}$) (NCRP, 1989) [9].

Also from Table (2), it can be noticed that , the annual effective dose (AED) received by the residents of the study area varies from (0.687 mSv /y) ($B_{20}$ region ) to ( 2.003 mSv/y) ($B_{16}$ region ) with an average value of ( 1.302±0.4 mSv/y). In all the dwellings surveyed in the present work, the indoor annual effective dose is less than even the lower limit of the recommended range (3-10 mSv/y) (ICRP, 1993) [21].

The radon induced lung cancer risks for dwellings in the selected locations in Baghdad governorate was found to vary from (12.366) ($B_{20}$ region) to (36.054) ($B_{16}$ region) with an average value of (23.443±6.1) per million person. These values are less than the lower limit of the range (170-230) per million person recommended by the (ICRP, 1993) [21].

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 dwellings in Baghdad governorate. Radon levels in room air can be lowered in a number of ways, from sealing cracks in floors and walls to changing the flow of air into the building. Among the principle ways of reducing the amount of radon entering a dwelling are:
1- Improving the ventilation of the dwelling.
2- Sealing floors and walls.
3- Increasing under-floor ventilation.
4- Installing a radon sump system.
5- Installing a whole dwelling positive pressurization or positive supply ventilation system.

However, some of these solutions are not suitable for all types of dwellings, nor are they suitable for all levels of radon. In some cases, more than one solution is needed in resolving the radon problem.

**Conclusions**
The results of the present work provide an additional database on indoor radon level in Baghdad governorate. The indoor radon concentration values measured in Baghdad governorate varies from (27.250±4.1 Bq/m$^3$) to (79.500±1.5 Bq/m$^3$) with an average value of (51.688±16.7 Bq/m$^3$) which is lower than the range (200-300 Bq/m$^3$) recommended by (ICRP, 2009). The present values of indoor annual effective dose varies from (0.687 mSv/y) to (2.003 mSv/y) with an average value of (1.302±0.4 mSv/y) which is on the lower side of the recommended range (3-10 mSv/y) (ICRP, 1993), and hence will pose relatively none serious health risk.

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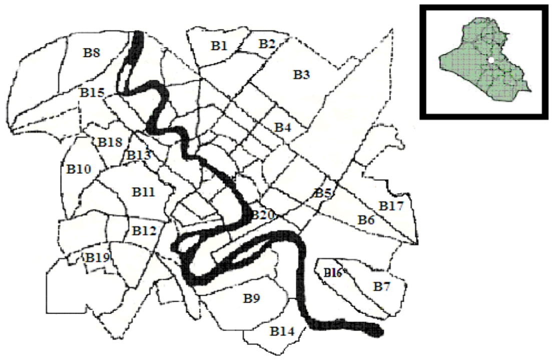


**Figure 1: Sketch map shows locations of study samples in Baghdad governorate.**

**Table 1: Symbol, and location name of the different studied sites in Baghdad governorate**

| Symbol | Location | Symbol | Location |
|---|---|---|---|
| $B_{1}$ | AL-Shaab | $B_{11}$ | AL-Mansour |
| $B_{2}$ | Haiy Ur | $B_{12}$ | AL-Yarmouk |
| $B_{3}$ | Sadr City | $B_{13}$ | AL-Ghazaliya |
| $B_{4}$ | AL-Habibiya | $B_{14}$ | AL-Mahmudiyah |
| $B_{5}$ | Zayona | $B_{15}$ | AL-Kadhimiyah |
| $B_{6}$ | Baghdad AL-Jadeeda | $B_{16}$ | AL-Zafraniya |
| $B_{7}$ | AL-Madain | $B_{17}$ | AL-Ameen |
| $B_{8}$ | AL-Taji | $B_{18}$ | AL-Hurriya |
| $B_{9}$ | AL-Dora | $B_{19}$ | AL-Jihad |
| $B_{10}$ | AL-Aamiriya | $B_{20}$ | AL-Karada |

**Table 2: Radon gas concentration ($C_{Rn}$), potential alpha energy concentration (PAEC), exposure to radon progeny ($E_{P}$) ,annual effective dose (AED), and lung cancer cases per year per million person (CPPP)**

| Location Sample | $C_{Rn}$ ($Bq/m^3$) | | | | Mean of $C_{Rn}$ ($Bq/m^3$) | PAEC (m WL) | ($E_{P}$) (WLM $Y^{-1}$) | (AED) (mSv /y) | Lung Cancer /$10^6$ person |
|---|---|---|---|---|---|---|---|---|---|
| $B_{1}$ | 36 | 32 | 40 | 33 | 35.250±3.5 | 3.811 | 0.157 | 0.888 | 15.984 |
| $B_{2}$ | 89 | 77 | 69 | 72 | 76.750±8.8 | 8.297 | 0.342 | 1.934 | 34.812 |
| $B_{3}$ | 51 | 45 | 39 | 40 | 43.75±5.5 | 4.730 | 0.195 | 1.103 | 19.854 |
| $B_{4}$ | 36 | 41 | 44 | 31 | 38.000±5.7 | 4.108 | 0.169 | 0.958 | 17.244 |
| $B_{5}$ | 50 | 61 | 47 | 52 | 52.500±6.0 | 5.676 | 0.234 | 1.323 | 23.814 |
| $B_{6}$ | 32 | 40 | 36 | 39 | 36.750±3.5 | 3.973 | 0.164 | 0.926 | 16.668 |
| $B_{7}$ | 81 | 71 | 69 | 77 | 74.500±5.5 | 8.054 | 0.332 | 1.877 | 33.786 |
| $B_{8}$ | 55 | 61 | 49 | 52 | 54.250±5.1 | 5.865 | 0.242 | 1.367 | 24.606 |
| $B_{9}$ | 71 | 66 | 69 | 61 | 66.750±4.3 | 7.216 | 0.298 | 1.682 | 30.276 |
| $B_{10}$ | 40 | 31 | 39 | 36 | 36.500±4.0 | 3.946 | 0.163 | 0.920 | 16.550 |
| $B_{11}$ | 61 | 55 | 62 | 53 | 57.750±4.4 | 6.243 | 0.257 | 1.455 | 26.190 |
| $B_{12}$ | 70 | 66 | 64 | 62 | 65.500±3.4 | 7.081 | 0.292 | 1.650 | 29.700 |
| $B_{13}$ | 34 | 32 | 29 | 30 | 31.250±2.2 | 3.378 | 0.139 | 0.788 | 14.184 |
| $B_{14}$ | 78 | 80 | 69 | 70 | 74.250±5.5 | 8.027 | 0.331 | 1.871 | 33.678 |
| $B_{15}$ | 40 | 44 | 36 | 39 | 39.750±3.3 | 4.297 | 0.177 | 1.001 | 18.018 |
| $B_{16}$ | 80 | 82 | 77 | 79 | 79.500±1.5 | 8.595 | 0.354 | 2.003 | 36.054 |
| $B_{17}$ | 62 | 49 | 54 | 54 | 54.750±5.3 | 5.919 | 0.242 | 1.380 | 24.804 |
| $B_{18}$ | 61 | 48 | 51 | 55 | 53.750±5.6 | 5.811 | 0.240 | 1.355 | 24.390 |
| $B_{19}$ | 41 | 34 | 29 | 36 | 35.000±4.9 | 3.784 | 0.156 | 0.882 | 15.876 |
| $B_{20}$ | 31 | 26 | 22 | 30 | 27.250±4.1 | 2.946 | 0.121 | 0.687 | 12.366 |
| Average | | | | | 51.688±16.7 | 5.588±1.5 | 0.230±0.1 | 1.302±0.4 | 23.443±6.1 |
| Global limit | | | | | (200-300Bq/$m^3$) (ICRP,2009) [19] | (53.33 mWL) (UNSCEAR, 1993) [20] | (1-2WLM $Y^{-1}$) (NCRP,1989) [9] | (3-10 mSv/y) (ICRP,1993) [21] | (170-230 ) (ICRP,1993) [21] |

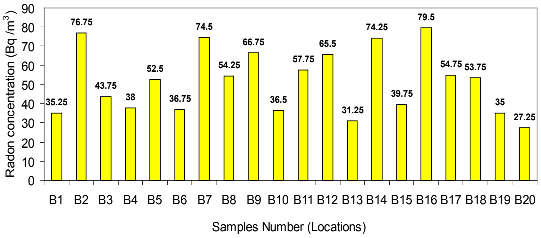


**Figure 2: A histogram illustrating the change in radon gas concentration (Bq/m$^3$) in indoor dwelling samples in all regions studied.**

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