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# Study the Concentrations of Radon indoor at Different Times of the Day and Seasons of the Year in Al-Najaf City/Iraq

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**ABSTRACT**

In this work, concentrations of radon indoor were measured at 10 locations in Al-Kufa and Al- Najaf cities, using RAD-7 radon monitoring system of Durridge company USA. Some factors affecting on the radon factor have been studied such as times of day (morning, afternoon and evening) and seasons of year (winter, spring, summer and autumn). This study show that the radon concentration indoor increases at mornings, evenings, decreases at afternoon, also increases in winter and autumn, decreases in spring and summer.



## Introduction

Radon is a natural radioactive gas and is considered as chemically inert. It comes from the natural decay of uranium 238 series, with atomic number 86 and mass number 222. It was discovered by the German physicist Friedrich Ernst Dorn in 1900,who called it niton. It has been called radon since 1923. Radon is a colorless, odorless, tasteless gas with a density of 9.72 grams per liter, it is about seven times as dense as air.

Radon condenses to a clear colorless liquid at its boiling point and then freezes to form a yellow, then orange red color solid. It is also moderately soluble in water and, therefore, can be absorbed by water flowing through rock and sand containing radon. Its solubility depends on the water temperature, the colder the temperature of water the greater the radon's solubility [1,2].

Thorium and uranium are both sources of radon and they are common, naturally-occurring elements that are found in low concentrations in rock and soil. Radon is produced from the radioactive decay of the element radium, which is itself a decay product of either uranium or thorium[2]. All the gaseous radon members of the three primordial series, headed by $^{235}$U, $^{232}$Th and $^{238}$U are radioactive alpha-particle emitters. The half – lives of $^{219}$Rn (Actinon, 3.96 s) and $^{220}$Rn (Thoron, 55.6 s) are short, and they have a low abundance relative to $^{222}$Rn (Radon, 3.82 d). Because of these properties and dosimeter considerations; the alpha dose delivered to the trachea bronchial tree from $^{220}$Rn is one third that from $^{222}$Rn per unit exposure of radon $^{222}$Rn; that is generally of primary interest. Special situations, either occupational or environmental, could pose unusual circumstances where measurement of actinon ($^{219}$Rn) or thoron ($^{220}$Rn) would be the primary concern but so far these situations have been rare [3,4].

Radon gas enters houses from the ground through cracks in concrete floors and walls, through gaps between floor and slab, around drains and pipes, and small pores of hollow-block walls. Consequently, radon levels are usually higher in basements, cellars and ground floors. Depending on a number of factors, the concentration of radon indoors varies with the time of the year, from day to day, and from hour to hour. Because of this time-variation, reliable measurements of mean concentrations in air should be made for at least three months [5,6].

There are some scientists to measure concentration of radon indoor at different part of day and season of year. G. V. Ashok and et al. in (2011)[7] studied the radon concentration measurements carried out in dwellings with natural ventilation for 1 y in Bangalore are reported. Measurements, covering three sessions of the day (morning, afternoon, night) were performed two times in a month for 1 y at a fixed place of each dwelling at a height of 1 m above the ground surface in selected dwellings. The low-level radon detection system (LLRDS), an active method, was used for the estimation of radon concentration. A.Leghrouz and et al. in(2012) [8] studied the seasonal variations of indoor radon levels in dwellings located in the Ramallah province and East Jerusalem suburbs, Palestine. The measurements were performed during the summer and winter of the year 2006/2007 using CR-39 solid-state-nuclear-track detectors. Al Zabadi and et al. (2012) [9] used SSNTDs detector for measuring the concentration of radon indoor in Punjab, India .The seasonal variations and the contribution of building materials and ventilation conditions to the indoor radon in dwellings are also studied. The aim of the present study was measured concentration of radon indoor in some of locations in Al-Najaf a Al-Kufa cities at different times of day and seasonal of year using RAD-7 detector.

### Area of Study

Najaf is located on the edge of western plateau of Iraq, at southwest of Baghdad the capital city of Iraq, at 160 km far from the capital. It is 70 meters above sea level and is situated on longitude of 19 degree and 44 minutes, latitude of 31 degree and 59 minutes [10]. It is boarded from north and northwest by Karbalaa city (which is 80 km far from it), and from the south and west by low sea of Najaf, and Abi Sukhair (which is 18 km far from the city) and from the east by Kufa city (which is 10 km far from the city)[11].

In the present study (15) regions were chosen as fair distribution in Al-Kufa and Al-Najaf cities. The regions were determined using(GIS)as shown in Fig.( 1), which was obtained the map sites of the two cities, drawn by using (GPS) technical.

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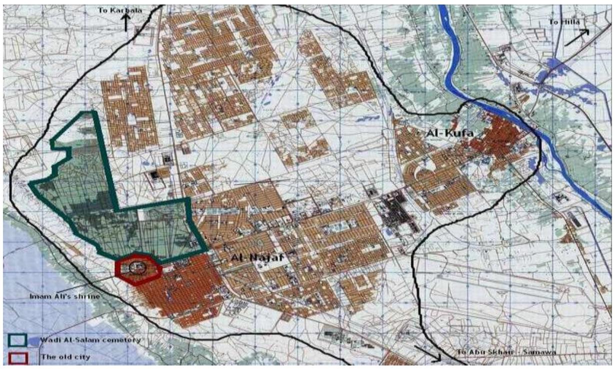


**Fig1. Map of Al-Kufa and Al-Najaf cities**

**Experimental Details**

Sniff mode and circle time was set to be 1 hour in accordance with running time of each path of the valve. In order to investigate radon and thoron released from the sample to air, the sample was enclosed into a column and airborne radon/thoron was measured with a continuous monitor of electrostatic type (RAD-7, Durridge company, USA). The experimental setup shown in Fig. (2) shows the schematic diagram RAD-7-Air in building. The air flow rate was 0.7 L min-1. Room air was drawn from the inlet and radon generated in the air flow system was measured with the RAD-7. The measurement interval was 1 h. The sample weight was different from sample to sample.

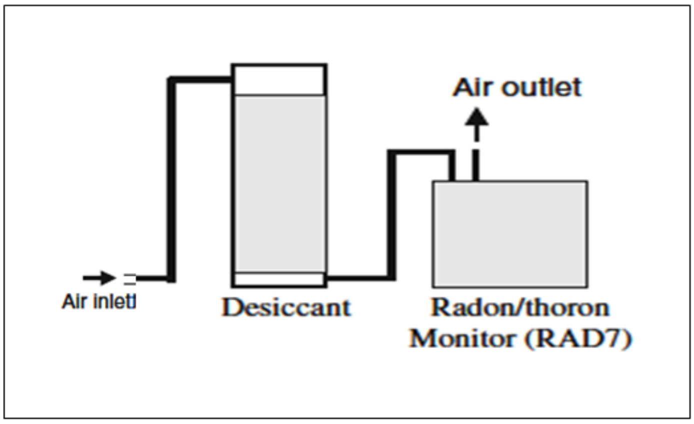


**Fig 2. Setup for measuring radon generated from the source**

**Result and Discussion**

The radon of concentration for 25 samples of air collected at different times of the day (mornings, afternoons and evenings), at different seasons (winter, spring, summer and autumn) at indoors of old buildings was measured by RAD-7 detector.

Tables (2) represents the results of the radon concentration of 15 indoors locations of old buildings for Al-Kufa and Al-Najaf cities in the mornings, afternoons and evenings. Table (3) represents the results of the radon concentration in 10 indoors locations of old buildings in Al-Kufa and Al-Najaf cities at indoor different seasons.

The value of radon concentrations indoor in Table (2) and Fig.(3) increases at morning, at evening and decreases in the afternoons. This variation is due to the increase of temperature in the afternoon which cause radon to escape. From Table (3) and Fig. (4) at the different of year seasons (winter, spring, summer and autumn) it was found the mean values of radon concentrations in the buildings were highest in winter and autumn and lowest in summer and spring.

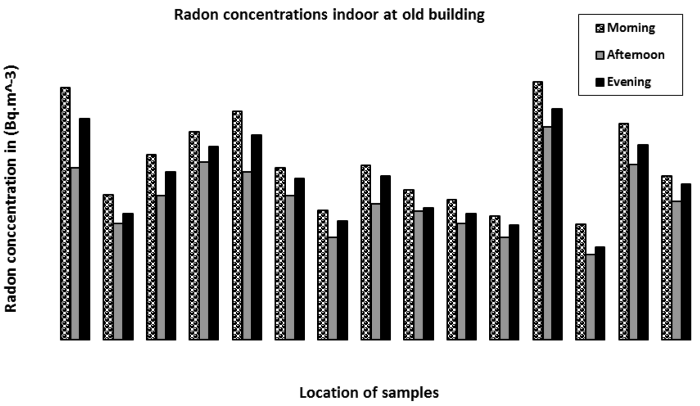


**Fig 3. Radon concentrations indoors of old buildings at (morning, afternoon and evening)**

The seasonal variation of radon levels could be attributed to the meteorological conditions, since in winter, these dwellings were poorly ventilated to save energy but they have good ventilation in the summer time. This result is in agreement with the results of Sivakumar [12].

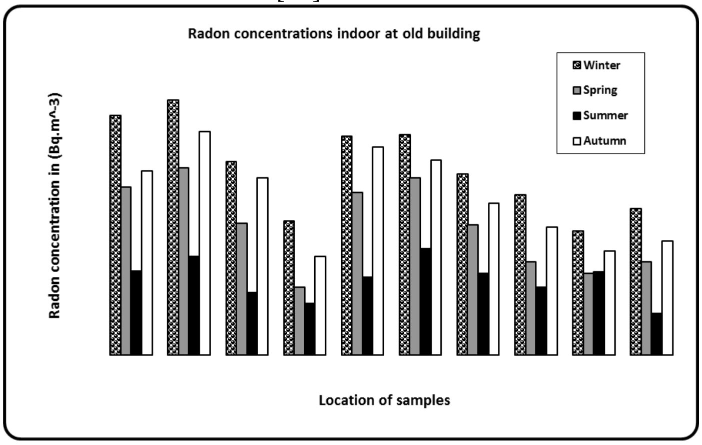


**Fig 4. Radon concentrations indoors of old buildings in (winter, spring, summer and autumn)**

The average $^{222}$Rn concentrations indoors in Al-Kufa and Al-Najaf city are which is much lower than the recommended EPA indoor of (200-400) Bq/m$^3$ [13]. Comparing these results with those of the Arabic countries it was found that the range of average radon concentration in Jordan (west of Iraq) building measured is (9.95 – 68.15) Bq/m$^3$ [14] and in Egypt particularly in some region, the average radon concentration in air of buildings was reported to be about 79.505 Bq/m$^3$ in range from (38.62-120.39)Bq/m$^3$ [15].

The annual effective doses are calculated by Eq.(1). The dose conversion factors values for indoor and outdoor which are used to calculate the annual effective dose for $^{222}$Rn in the present study are 3.6 and 5.4 (nSv/h)/(Bq/m3) respectively [16].

$$D_{Rn} = C_{Rn}\, A\, n\, Df_{Rn} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where: $D_{Rn}$ is the annual effective dose from $^{222}$Rn exposure indoor (mSv/year), $\boldsymbol{C_{Rn}}$ is the concentration of $^{222}$Rn in indoor or outdoor air (Bq/m$^3$), A is the occupancy factor (7000 hours indoor), $n$ is the conversion factor from nano (n) to milli (m) and $Df_{Rn}$ is the dose conversion factor for $^{222}$Rn, calculated from Eq.(2).

$$Df_{Rn} = F\, Dc \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where: $F$ is the equilibrium factor (0.4 for indoor) and $\boldsymbol{Dc}$ is the dose coefficient which is equal (9).

The annual effective dose was calculated using eq.(1) and the highest value in sample (K2) at winter season, are (0.086) mSv.y$^{-1}$,(1.804374)mSv.y$^{-1}$.

**Table 1. show the sites studied in two cities.**

| No. | Location name | Location sample | Coordinates |
|---|---|---|---|
| 1 | Al.Motanaby | K1 | $44^{0}22^{/}$ $53.662^{//}$ E , $32^{0}1^{/}$ $48.533^{//}$ N |
| 2 | Meassan | K17 | $44^{0}22^{/}$ $2.231^{//}$ E , $32^{0}3^{/}$ $15.717^{//}$ N |
| 3 | Al.Rashadiah | K14 | $44^{0}23^{/}$ $17.486^{//}$ E , $32^{0}1^{/}$ $18.365^{//}$ N |
| 4 | Al.Asatethah | K13 | $44^{0}24^{/}$ $12.41^{//}$ E , $32^{0}1^{/}$ $57.693^{//}$ N |
| 5 | Tamoz | K4 | $44^{0}23^{/}$ $19.438^{//}$ E , $32^{0}1^{/}$ $2.182^{//}$ N |
| 6 | Al.Askary | N3 | $44^{0}20^{/}$ $19.734^{//}$ E , $32^{0}33^{/}$ $49.585^{//}$ N |
| 7 | Al.Mohandssen | N10 | $44^{0}18^{/}$ $61.340^{//}$ E , $32^{0}2^{/}$ $10.576^{//}$ N |
| 8 | Al.Hendaa | N2 | $44^{0}20^{/}$ $31.904^{//}$ E , $32^{0}3^{/}$ $12.871^{//}$ N |
| 9 | Al.Makrma | N4 | $44^{0}19^{/}$ $26.353^{//}$ E , $32^{0}4^{/}$ $3.396^{//}$ N |
| 10 | Al.Ameer | N22 | $44^{0}21^{/}$ $52.161^{//}$ E , $32^{0}0^{/}$ $32.683^{//}$ N |
| 11 | Al.Adala | N15 | $44^{0}21^{/}$ $30.821^{//}$ E , $32^{0}1^{/}$ $18.069^{//}$ N |
| 12 | Al.Forat | N16 | $44^{0}21^{/}$ $7.855^{//}$ E , $32^{0}1^{/}$ $13.828^{//}$ N |
| 13 | Adan | N32 | $44^{0}20^{/}$ $59.407^{//}$ E , $31^{0}59^{/}$ $33.891^{//}$ N |
| 14 | Al.Ansar | N37 | $44^{0}22^{/}$ $24.948^{//}$ E , $31^{0}59^{/}$ $36.667^{//}$ N |
| 15 | Al.Saad | N25 | $44^{0}20^{/}$ $28.962^{//}$ E , $32^{0}0^{/}$ $01.317^{//}$ N |

**Table 2. ($^{222}Rn$) concentrations in (15) locations in Al-Kufa city and Al-Najaf city indoors of old buildings at (morning, afternoon and evening).**

| No. | Location sample | Radon concentration at morning ($Bq.m^{-3}$) | | | AED (mSv/y) | Radon concentration at afternoon ($Bq.m^{-3}$) | | | AED (mSv/y) | Radon concentration at evening ($Bq.m^{-3}$) | | | AED (mSv/y) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min. | Max. | Mean | | Min. | Max. | Mean | | Min. | Max. | Mean | |
| 1 | K1 | 59 | 70.2 | 63.925±5.343 | 1.6132113 | 43 | 44 | 43.5±0.577 | 1.097766 | 52 | 60 | 56±3.4034 | 1.413216 |
| 2 | K17 | 35 | 38 | 36.75±1.258 | 0.927423 | 28 | 31 | 29.5±1.291 | 0.744462 | 30 | 34 | 32±2.3094 | 0.807552 |
| 3 | K14 | 44 | 49 | 47±2.160 | 1.186092 | 35 | 38 | 36.5±1.5 | 0.921114 | 40 | 45 | 42.5±2.8868 | 1.07253 |
| 4 | K13 | 51 | 54 | 52.75±1.5 | 1.331199 | 44 | 46 | 45±0.957 | 1.13562 | 48 | 50 | 49±1.1547 | 1.236564 |
| 5 | K4 | 55 | 60 | 58±2.160 | 1.463688 | 41 | 44 | 42.5±1.291 | 1.07253 | 48 | 56 | 52±3.8622 | 1.312272 |
| 6 | N3 | 42 | 45 | 43.5±1.290 | 1.097766 | 35 | 38 | 36.5±1.258 | 0.921114 | 39 | 43 | 41±2.3094 | 1.034676 |
| 7 | N10 | 32 | 34 | 32.75±0.957 | 0.826479 | 23 | 29 | 26±1.291 | 0.769698 | 29 | 31 | 30±1.1547 | 0.75708 |
| 8 | N2 | 42 | 47 | 44.25±2.217 | 1.116693 | 33 | 36 | 34.5±1.291 | 0.870642 | 39 | 44 | 41.5±2.8868 | 1.047294 |
| 9 | N4 | 37 | 39 | 38±1.154 | 0.958968 | 31 | 34 | 32.5±1.258 | 0.82017 | 31 | 36 | 33.5±2.8868 | 0.845406 |
| 10 | N22 | 32 | 39 | 35.5±3.109 | 0.895878 | 28 | 31 | 29.5±1.291 | 0.744462 | 29 | 35 | 32±3.4641 | 0.807552 |
| 11 | N16 | 29 | 33 | 31.25±1.70 | 0.788625 | 25 | 27 | 26±1.258 | 0.656136 | 28 | 30 | 29±1.1547 | 0.731844 |
| 12 | N15 | 64 | 67 | 65.5±1.29 | 1.652958 | 53 | 55 | 54±0.816 | 1.362744 | 57 | 60 | 58.5±1.7321 | 1.476306 |
| 13 | N32 | 23 | 28 | 29.25±0.957 | 0.738153 | 20 | 23 | 21.5±1.5 | 0.542574 | 22 | 25 | 23.5±1.7321 | 0.593046 |
| 14 | N37 | 53 | 58 | 54.75±2.217 | 1.381671 | 43 | 46 | 44.5±1.414 | 1.123002 | 46 | 53 | 49.5±3.9476 | 1.249182 |
| 15 | N25 | 39 | 44 | 41.5±2.081 | 1.047294 | 34 | 36 | 35±0.816 | 0.88326 | 37 | 42 | 39.5±2.8868 | 0.996822 |

**Table 3. ($^{222}$Rn) concentrations in (10) locations in Al-Kufa city and Al-Najaf city indoors of old buildings in (winter, spring, summer and autumn)**

| No. | Location sample | Radon concentration in winter (Bq.m$^{-3}$) | | | AED(mSv/y) | Radon concentration in spring (Bq.m$^{-3}$) | | | AED(mSv/y) | Radon concentration in summer (Bq.m$^{-3}$) | | | AED(mSv/y) | Radon concentration in autumn (Bq.m$^{-3}$) | | | AED(mSv/y) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min. | Max. | Mean | | Min. | Max. | Mean | | Min. | Max. | Mean | | Min. | Max. | Mean | |
| **1** | K1 | 88 | 94 | 91.5±2.645 | 2.309 | **59** | **70.2** | 63.925±5.34 | 1.613 | 29 | 35 | 32±2.582 | 0.80755 | 69 | 72 | 70.25±1.5 | 1.77282 |
| **2** | K2 | 94 | 101 | 97.25±2.986 | 2.454 | **70** | **75** | 73.25±2.217 | 1.848 | 36 | 40 | 37.5±1.914 | 0.94635 | 84 | 86 | 85.25±1.291 | 2.15136 |
| **3** | K8 | 70 | 77 | 73.75±2.986 | 1.861 | **49** | **53** | 50.25±1.892 | 1.268 | 23 | 25 | 23.75±0.957 | 0.59935 | 66 | 69 | 67.5±1.291 | 1.7034 |
| **4** | K15 | 49 | 54 | 51.25±2.217 | 1.293 | **24** | **28** | 25.75±1.707 | 0.649 | 18 | 21 | 19.5±1.291 | 0.49210 | 36 | 39 | 37.5±1.291 | 0.9463 |
| **5** | K16 | 81 | 86 | 83.5±2.0817 | 2.107 | **59** | **67** | 62±3.55902 | 1.564 | 28 | 31 | 29.5±1.291 | 0.74446 | 78 | 81 | 79.5±1.291 | 2.00626 |
| **6** | N1 | 83 | 87 | 84.25±1.893 | 2.126 | **65** | **70** | 67.5±2.380 | 1.703 | 39 | 42 | 40.5±1.291 | 1.02205 | 72 | 76 | 74.25±1.7078 | 1.87377 |
| **7** | N5 | 67 | 71 | 69±1.825 | 1.741 | **48** | **52** | 49.5±1.9148 | 1.249 | 29 | 33 | 31.25±1.707 | 0.78862 | 56 | 60 | 57.75±1.7078 | 1.45737 |
| **8** | N22 | 58 | 64 | 61.25±2.753 | 1.545 | **32** | **39** | 35.5±3.1091 | 0.895 | 25 | 27 | 25.75±0.957 | 0.64982 | 47 | 51 | 48.75±1.7078 | 1.23025 |
| **9** | N16 | 46 | 50 | 47.25±1.893 | 1.192 | **29** | **33** | 31.25±1.707 | 0.788 | 31 | 33 | 31.75±0.957 | 0.80124 | 38 | 42 | 39.5±1.9149 | 0.99682 |
| **10** | N30 | 54 | 58 | 55.75±1.707 | 1.406 | **33** | **37** | 35.5±1.732 | 0.895 | 14 | 18 | 15.75±1.707 | 0.39746 | 42 | 45 | 43.5±1.291 | 1.09776 |

All results of the annual effective dose for indoors building $^{222}$Rn concentration in Al-Kufa city and Al-Najaf city are lower than the indoor normal limits of the world (3-10) mSv.y$^{-1}$ [17].

**Conclusions**

1. All results of radon concentrations were obtained in this study are less than the allowed concentration level.
2. The annual effective dose in buildings air of Al-Kufa and Al-Najaf cites are less than the allowed maximum concentration level in buildings air.
3. Radon concentration indoor are changed with the times of a day (morning, afternoon and evening) where it is increase in morning , evening and decrease in afternoon
4. Radon concentration indoor are changed with the seasons (winter, spring, summer and autumn) where it is increase in winter, spring and decrease in autumn, summer.

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