 

# Indoor Radon Concentration in Dwellings of Baghdad City and In Dora Refinery Using Rad-7 Detector

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**Abstract**

Indoor radon gas ($^{222}$Rn) has been recognized as one of the health hazards for human. Rn-222 is the most important source of natural radiation and is responsible for approximately half of the received dose from all sources. Most of this dose is from inhalation of the Rn-222 progeny, especially in closed atmospheres. Air radon comes mainly from soil and construction materials. Radon concentration was measured in two room of 9 dwellings from various regions of Baghdad city and in Dora Refinery, electronic detector of radon Rad-7 was used which is an active measurement method. The results show that Radon concentrations of the dwellings were varied from (0) Bq m$^{-3}$ to (82.6) Bq m$^{-3}$ with an average activity value of (22.75) Bq m$^{-3}$. The results show that radon concentration was high in sample B4 and low in samples B2,B5, B6 ,B8, .and for Dora Refinery the high concentration was (71.3 ) Bq m$^{-3}$ in sample D11 and low was (0) Bq m$^{-3}$ in samples D1,D2,D4,D5,D6,D7 and D8 an average activity value 19.2 Bq m$^{-3}$ . the annual effective dose ranged between ( 0-3.3) mSv/y, with a mean value 0.4 mSv/y for Baghdad city and ranged between (0-2.8) mSv/y with a mean value 0.4 mSv/y for Dora Refinery . These results are lower than the value 1 mSv/y recommended by ICRP report.

**Keywords:** Radon, RAD-7, Baghdad city, Dora Refinery, Annual effective dose.

## 1. Introduction

The risks to human health posed by ionizing radiation are well known. Radon gas is by far the most important source of ionizing radiation among those that are of natural origin[1]. Radon radioactive gas is arising from the ($^{238}$U) uranium decay chain, and it is the largest source of radiation exposure to population[2]. High radon exposures have been shown to cause lung cancer[3,4] .Radon is a gaseous element discovered by German physicist Friedrich Ernst Dorn in 1900. Radon is a colorless, odorless, tasteless inert gas. The atomic radius is 1.34 angstroms and it is the heaviest known gas(density= 9.73g/L), (about eight times denser than air)[5]. Radon is a mobile, chemically inert radioactive element, has a high melting point of -71℃ and a boiling point of -62.7℃. Its atomic number of 86 makes it a noble element and therefore both non-reactive chemically and atomically mobile at normal temperatures, so it has greater ability to migrate freely through soil, air, etc.[6 ]The exposure due to inhalation of radon and its daughters present in the environment is highest of the natural radionuclides to which human beings are exposed. It is an established fact that the enhanced levels of indoor radon in dwellings can cause health hazards and may cause serious diseases like lung cancer in human beings [7]. Therefore measurement of $^{222}$Rn concentration in the environment is of special interest to mankind.[8]. There are three natural occurring isotopes of Radon; Radon $^{222}$Rn , a direct product of $^{226}$Ra in the $^{238}$U decay series with physical half-life 3.825 days,
($^{220}$Rn), decay products of $^{232}$Th, Thoron ($^{220}$Rn) , half-life 55.6s is a radioactive noble gas exists in natural radon gas as well, and ($^{219}$Rn), a decay product of $^{235}$U, with half life of 3.6s. Among the three radioactive isotopes $^{222}$Rn is the most significant[9,10]. By diffusion through soil, $^{222}$Rn enters into the atmosphere. The concentration of radon and its decay products show large fluctuations depending upon the building materials, underground soils, ventilation conditions and wind speed etc.[8]. There are two different methods to measure the radon activity concentration. The first measurement technique is by means of integrative, passive radon sampling, and the second method, by means of continuous active radon sampling. The first method is considered passive, and requires no electrical power as in the case of the continuous radon monitor. Continuous active radon detector used in this work[11].

## 2. Materials and Methods

Radon concentration was measured in two room 9 dwellings in Baghdad city and in Dora Refinery during 2014, The RAD-7 continual radon measuring instrument from Durridge Company, USA, was used for active measurements. RAD-7 is equipped with the semiconductor α-detector and works on the principle of the converting energy of α-particles directly into electrical signals (figure 1). This enables determination of isotopes that are the products of radiation ($^{218}$Po, $^{214}$Po), so that radon can be distinguished from its daughters and noise signal. The measuring range is between 4 and 750000 Bq m$^{-3}$[12]. The internal acquisition provides storage for up to 1000 radon concentration measurements. After passing through a dry stick to lower the relative humidity to below 10% the sampled air enters an interaction chamber; the air-flow is 1 l/min. The RAD-7 pumps the air for 5

 

minutes into the cell of the detector, and then waits for 5 minutes and only then counts for 5 minutes. $^{218}$Po has a half-life of 3.05 min and it takes about 3-5 half-lives for the $^{218}$Po activity to reach secular equilibrium, hence, in about 9-15 minutes. The decays of the $^{218}$Po would then be counted after 10 min. (5 min. of pumping plus 5 min. of waiting), in which time 95% of equilibrium would have been reached. Finally, each set of readings includes four 5- min cycles that at last takes 30 min. so, during the measurement process we must close all doors and windows tightly, and the lack of air-conditioning system or vent. (Figure 1) show the scheme of Rad-7[13].
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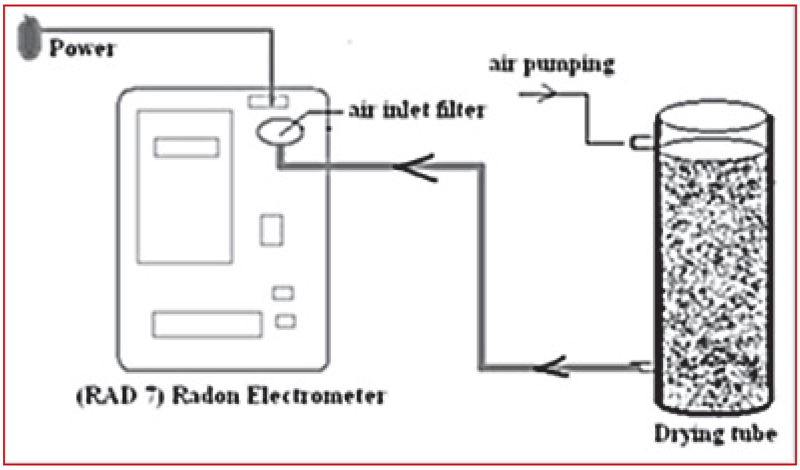



Figure1 The scheme of Radon Electrometer (Rad-7).

**3. Results and Discussion**

Indoor radon levels can be determined by different parameters, such as atmospheric conditions, seasonal situations (ventilation and soil emission), local geology, building features (type of building material, ceiling height, and house orientation), and the habits of the occupants. Generally, the large variations in indoor radon activity among the different dwellings in these localities can be explained by the different ventilation rates, nature of the soil underneath, and particularly, geological considerations. Table (1and 2 ) represent the Indoor radon activity concentrations were measured in the kitchen and living room of 9 dwellings in Baghdad city and in Dora Refinery respectively , Indoor radon release is affected by moisture content, temperature, and other factors, therefore these factors are also observed and listed in Table 1. The radon concentration was found to be high in sample B4 and low in samples B2, B5, B6, B8, D1, D2, D4, D5, D6, D7, D8 which is seen some figures of recorded by radon monitor . The radon levels varied from (0) Bq m$^{-3}$ to (82.6) Bq m$^{-3}$ with an average activity value of (22.75) Bq m$^{-3}$ in Baghdad city. And for Dora Refinery the high concentration was (71.3) Bq m$^{-3}$ in sample D11 and low was (0) Bq m$^{-3}$ in samples D1, D2, D4, D5, D6, D7 and D8 an average activity value 19.2 Bq m$^{-3}$. The variation in the indoor radon concentration due to many reasons such as the different ventilation rate and nature of the building materials, etc. It is widely agreed that the principal source of $^{222}$Rn in houses is the soil gas in the surroundings, but it could be reduced by a high ventilation rate .It is clear that the detected concentration values of $^{222}$Rn in Baghdad city and in Dora Refinery are lower than those values reported in otherworld wide locations.

Table 1: Indoor radon concentration in kitchen room and living room in Baghdad city.

| Sample No. | Location | Type of room | radon concentration Bq/m$^3$ | Temperature(℃) | Moisture RH |
|---|---|---|---|---|---|
| B1 | Sadder City /R* | Living room | 17.7 | 26.4 | 8% |
| B2 | Ghadeer/R | Living room | 0.00 | 27.1 | 8% |
| B3 | Zayouna/R | kitchen | 5.90 | 28.0 | 7% |
| B4 | New Baghdad/R | Living room | 82.6 | 28.6 | 9% |
| B5 | Amen district/R | Living room | 0.00 | 27.4 | 8% |
| B6 | Mansour/K* | Living room | 0.00 | 37.1 | 9% |
| B7 | | kitchen | 12.0 | 36.5 | 8% |
| B8 | Haifa Street/K | Living room | 0.00 | 38.6 | 7% |
| B9 | | kitchen | 5.90 | 36.2 | 7% |
| B10 | Amil district/K | Living room | 11.8 | 35.3 | 9% |
| B11 | | kitchen | 5.99 | 33.2 | 8% |
| B12 | HorreyaK | Living room | 0.00 | 39.5 | 7% |
| B13 | | kitchen | 5.99 | 36.2 | 9% |

*R; mean Rusafa site and K; karkh site.

Table 2: Indoor radon concentration in Dora Refinery.

| Sample No. | Type of room | Radon concentration Bq/m$^3$ |
|---|---|---|
| D1 | Department of Research and Quality Control / Laboratory Gas | 0 |
| D2 | Department of Research and Quality Control / Laboratory fat / break room associate | 0 |
| D3 | Department of Research and Quality Control Laboratory fat / Room upgraders | 35.7 |
| D4 | Department of Research and Quality Control / Laboratory control | 0 |
| D5 | The board of the fat / fat head room 1 | 0 |
| D6 | The board of the fat / control vac1 | 0 |
| D7 | Board power / control generators | 0 |
| D8 | The board of Energy / Energy Engineers Room 1 | 0 |
| D9 | Department of medicine / darkroom | 35.7 |
| D10 | Procurement Section / basement | 35.7 |
| D11 | Department of medicine / x-ray room | 71.3 |
| D12 | Department of Human Resources / basement | 35.7 |
| D13 | Department of Environment / Division of reducing air pollution and radiation | 35.7 |

**Radon exposure and radiation hazards**

When exposure to radon (and radon progeny) is to be compared to the exposure from other radiation sources, it is necessary to estimate the effective dose per unit radon gas exposure. In the past this has predominantly been done by using the dosimetric evaluation of the absorbed dose to basal cells of the bronchial epithelium and applying the ICRP convention for calculating effective dose (effective dose equivalent). The indoor radon concentration is expressed in terms of equilibrium-equivalent radon concentration (EECRn) by using the following relation: EECRn = F × ARn …..(1)

Where F is the equilibrium factor (F=0.45) and $AR_n$ is the measured indoor radon activity. The equivalent dose received by bronchial pulmonary regions of human lungs has been calculated using a conversion factor 1.0 x$10^{-5}$ mSv per Bq.h/m$^3$. Taking the solubility factor for soft tissues to be 0.4 and assuming that the short-lived decay products decay in the same tissue as radon gas, the following relationship for soft tissues other than the lungs was derived from [15].

$$D_{\text{soft tissues}}(\text{nGyh}^{-1}) = 0.005\, X_{\text{Rn,air}}\ (\text{Bq m}^{-3}) \quad \dots (2)$$

In the case of the lungs, assuming the air volume in the lungs to be 3.2x$10^{-3}$ m$^3$ for the 'Reference Man', the dose rate due to alpha-radiation was determined as.

$$D_{lung}\,(nGh^{-1}) = 0.04X_{Rn,air}\,(Bq\,m^{-3})$$ ….(3)

Taking a quality factor of 20 for alpha-radiation and applying a weighting factor of 0.12 for the lungs and Taking a quality factor of 20 for alpha-radiation and applying a weighting factor of 0.12 for the lungs and of 0.88 for other tissues, the effective dose equivalent rate was calculated as

$$H_{eff}(nSvh^{-1}) = 0.18\,X_{Rn,air}\,(Bq\,m^{-3})$$ …. (4)

Table 3 and Table 4 shows Variation of dose relationship from radon measurements from indoor air in Baghdad city and in Dora Refinery respectively. the annual effective dose ranged between ( 0-3.3) mSv/y, with a mean value 0.4 mSv/y for house in Baghdad city and ranged between (0-2.8) mSv/y a mean value 0.75 mSv/y for for Dora Refinery [15] .

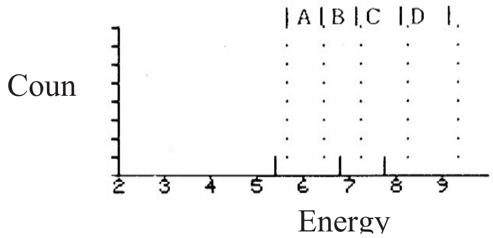
Table 3: EEC and Ann. eff. Dose of indoor radon-222 and Variation of dose relationship from indoor radon measurements from air in Baghdad city.

| Sample No. | Radon concentration $Bq/m^3$ | EEC Bq $h/m^3$ | Annual effective Dose mSv/y | D soft tissues $nGyh^{-1}$ | D Lung nGy $h^{-1}$ | H eff nSv $h^{-1}$ |
|---|---|---|---|---|---|---|
| B1 | 17.7 | 8 | 0.7 | 0.09 | 0.7 | 3.2 |
| B2 | 0.00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| B3 | 5.90 | 2.7 | 0.2 | 0.03 | 0.24 | 1.1 |
| B4 | 82.6 | 37.2 | 3.3 | 0.4 | 3.3 | 14.9 |
| B5 | 0.00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| B6 | 0.00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| B7 | 12.0 | 5.4 | 0.5 | 0.06 | 0.48 | 2.2 |
| B8 | 0.00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| B9 | 5.90 | 2.7 | 0.2 | 0.03 | 0.24 | 1.1 |
| B10 | 11.8 | 5.3 | 0.5 | 0.06 | 0.47 | 2.1 |
| B11 | 5.99 | 2.7 | 0.2 | 0.03 | 0.24 | 1.1 |
| B12 | 0.00 | 0 | 0 | 0 | 0 | 0 |
| B13 | 5.99 | 2.7 | 0.2 | 0.03 | 0.24 | 1.1 |

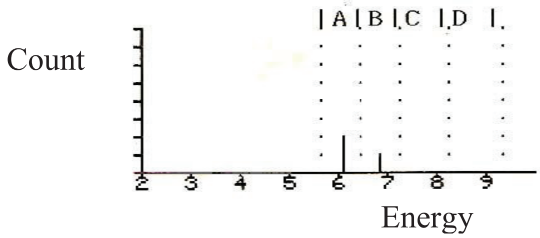
Table 4: EEC and Ann. eff. Dose of indoor radon-222 and Variation of dose relationship from indoor radon measurements from air in Dora Refinery.

| Sample No. | Radon concentration $Bq/m^3$ | EEC Bq $h/m^3$ | Annual effective Dose mSv/y | D soft tissues $nGyh^{-1}$ | D Lung nGy $h^{-1}$ | H eff nSv $h^{-1}$ |
|---|---|---|---|---|---|---|
| D1 | 0 | 0 | 0 | 0 | 0 | 0 |
| D2 | 0 | 0 | 0 | 0 | 0 | 0 |
| D3 | 35.7 | 16.1 | 1.4 | 0.18 | 1.4 | 6.4 |
| D4 | 0 | 0 | 0 | 0 | 0 | 0 |
| D5 | 0 | 0 | 0 | 0 | 0 | 0 |
| D6 | 0 | 0 | 0 | 0 | 0 | 0 |
| D7 | 0 | 0 | 0 | 0 | 0 | 0 |
| D8 | 0 | 0 | 0 | 0 | 0 | 0 |
| D9 | 35.7 | 16.1 | 1.4 | 0.18 | 35.7 | 6.4 |
| D10 | 35.7 | 16.1 | 1.4 | 0.18 | 35.7 | 6.4 |
| D11 | 71.3 | 32.1 | 2.8 | 0.36 | 2.852 | 12.8 |
| D12 | 35.7 | 16.1 | 1.4 | 0.18 | 35.7 | 6.4 |
| D13 | 35.7 | 16.1 | 1.4 | 0.18 | 35.7 | 6.4 |

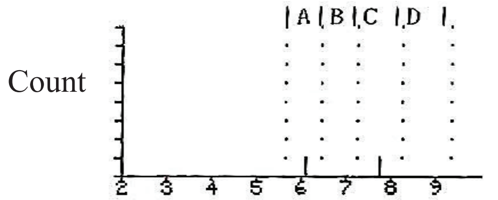
 



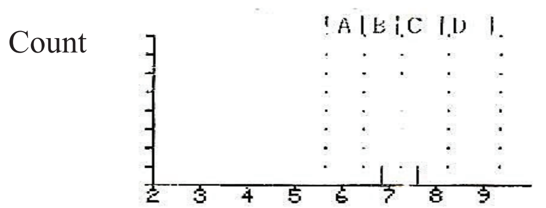

A: For sample B5.



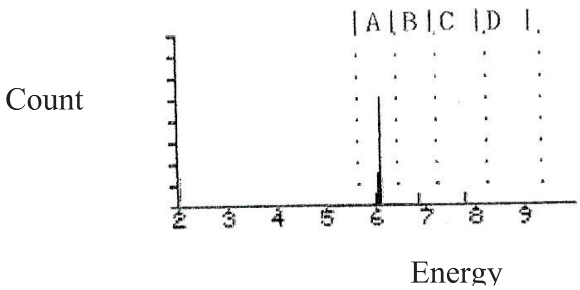

B:For sample B10.




C: For sample B Energy




D: For Sample E Energy




F: For sample B4.

Figure 2: Some of Alpha energy spectrum of sample B5, B10, B8, B11and B4.

## 4. Conclusion

Uranium and thorium are widely distributed in rocks and soils of the earth's crust. Thus, parent materials for radon daughter isotopes are also available worldwide. The most important radon isotope from a health viewpoint is Rn-222. Its decay products, especially $^{218}$Po and $^{214}$Po, can have a pronounced adverse effect on lung tissues, leading to lung cancer in many cases. Radon entry into dwellings usually occurs through cracks, joints, pipe fittings in walls and building material, loose sealants or caulking around windows, and so on. Rn-222 was measured in air inside the houses of Baghdad city and in Dora Refinery, The mean of radon concentrations was (22.75) Bq m$^{-3}$ for house Baghdad city and (19.2 Bq m$^{-3}$) for Dora Refinery. These results are lower than these median values 46 Bq m-3, reported by UNSCEAR 2000 [14].except B4 for house Baghdad city and D11 for Dora Refinery were more than the median value ,that we thought the reason was the type of building material and low ventilation in this place and for radon hazard the mean was value of Annual effective Dose was(0.6 mSv/y) for in house Baghdad city and for Dora Refinery ,which is lower than the value 1 mSv/y recommended by ICRP report [15]. The accumulated Annual effective Dose for some people who work in for Dora Refinery will be more hazard specially who work in D3,D9,D10,D11,D12,D13,those which has low ventilation and basement .so we suggest that more ventilation and using other building as like ceramic that can help us to decrease the radon concentration and its hazard.

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