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Radon concentrations in dwellings of Baghdad city- Iraq

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Abstract

In this study, radon concentrations were measured in dwellings at specified locations in Baghdad city using ionization chamber radon monitor (ALPHA GUARD PQ2000 PRO). The measurements were carried out at different locations of these dwellings (living rooms, bed rooms, bath rooms, and kitchens). The results of the survey showed that the overall minimum, maximum average and mean average radon concentrations in dwellings were **5.77±0.73** Bq/m^3, **23.27±13.57** Bq/m^3, and **10.67±4.14** Bq/m^3 respectively. The lowest average radon was found in (Ameryia) city, while the highest average radon concentration was found in (Kadmiya) city. Also, the results showed that the highest average radon concentration was found in the kitchens, while the lowest average radon concentration was found in the living rooms. The maximum annual effective dose in dwelling in Baghdad city in current study is 0.59 mSv.

Keywords: Radon, Baghdad, dwellings, effective dose.

تراكيز الرادون في المنازل في مدينة بغداد– العراق

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الخلاصة

تم في هذه الدراسة قياس تراكيز غاز الرادون في المنازل لمناطق منتخبة من مدينة بغداد باستعمال جهاز (ALPHA GUARD PQ2000 PRO). اجريت القياسات في اماكن مختلفة داخل المنازل (غرف الجلوس، غرف النوم، الحمامات، المطابخ). بينت نتائج القياسات ان اقل معدل تركيز للرادون كان(**0.7±5.77**) بكريل/م^3 في منازل العامرية، واعلى معدل تركيز كان (**13.57±23.27**) بكريل/م^3 في منازل الكاظمية بينما كان متوسط معدل تركيز الرادون في المنازل عموما لمدينة بغداد (**4.14±10.67**) بكريل/م^3. كذلك بينت النتائج ان اعلى معدل تركيز للرادون كان في المطابخ بينما كان اقل معدل تركيز في غرف الجلوس. كما بينت الدراسة ان الجرعة المؤثرة السنوية القصوى في المنازل في مدينة بغداد نتيجة استنشاق الرادون هي 0.59 ملي سيفرت.

Introduction

The radiation to which the human population is exposed comes from very diverse sources; some of these sources are natural features of the environment. Others are the result of human activities [1]. The radiation from natural sources includes cosmic radiation, external radiation from radionuclides in the earth's crust and internal radiation from radionuclides inhaled or ingested and retained in the body [2]. The magnitude of these natural exposures depends on geographical location and on some human activities. The worldwide average annual effective dose from natural sources is estimated to be 2.4 mSv, of which about 1.1 mSv is due to the basic background radiation and 1.3 mSv is due to exposure

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to radon [1]. Radon is radioactive noble inert gas and very mobile gaseous daughter of ^{238}U which is found in all rocks and soil [3].

The origin of radon and thoron in the Earth's crust stems directly from the uranium and thorium and their decay products distributed in minute amounts in the ground within a few meters of the Earth's surface. Once formed in or on the rocks and soil particles the radon atoms must reach the air in the soil capillaries before they can be transported to the atmosphere through diffusion or pressure – induced flow [4]. Building materials produce some radon, certain materials act as significant sources of indoor radon [5]. Such materials have a combination of elevated levels of ^{226}Ra (the radioactive parent of radon) and a porosity that allows the radon gas to escape [6]. When radon gas is inhaled, densely ionizing alpha particles emitted by deposited short- lived decay products of radon (^{218}Po, ^{214}Po) that can interact with biological tissue in the lungs leading to DNA damage [7]. The National Research Council has estimated that some 15,000 to 22,000 lung cancer deaths each year are caused by breathing radon gas [8].

The soil is the main contributor to the indoor radon and thoron levels. The contribution of soil-gas radon depends on the soil porosity, grain size and the rock type of the distinct geological unit near the dwellings. Indoor radon, in many countries have been investigated. for instance, researchers have concluded that the activity concentration of radon, thoron and their progeny are largely influenced by factors such as topography, type of house construction, building materials, temperature, pressure, humidity, ventilation, wind speed, and even the life style of the people living in the house [9-15]. The major source of radon in the house is the soil beneath the house but the household water, building materials and cooking gas also influence the indoor radon concentration [16]. The concentration recommended by ICRP that annual average radon gas concentration of 300 Bq/m^3 [17].

In Iraq, many researchers have studied the concentration of radon in soil, indoor and outdoor, using different techniques. For instance, Ali, et al., studied radon concentration in soil Gas using RAD7 in the environs of Al-Najaf Al-Ashraf city; the results obtained from this study indicate that the region has background radioactivity levels within the natural limits [18]. However, Al-Hamidawi [19] measures the Radon Concentrations for Some Houses in Al-Najaf City which found to be between (11.6-53.6) Bq/m^3. Nada, et al., [20] investigated the concentration of radon in dwelling in Baghdad using CR-39. The results show that the radon concentration ranged from 83.4 Bq/m^3 to 238.8 Bq/m^3 with average 116.78 Bq/m^3 and concluded that indoor radon concentration was in agreement to radon concentration levels (300 Bq/m^3) recommended by the International Commission on Radiological Protection (ICRP). Also, radon exposure and risk of cancer in Al-Najaf City was estimated [21]. The result showed that radon concentrations ranged between 74.2 Bq/m3 to 478.1 Bq/m3. Battawy [22], studied the indoor radon concentration measurement in selected factories in northern and central Iraq and showed that the radon concentration in these factories ranges from (36.36 – 125.10) Bq.m-3 with an average of (59.93Bq.m-3). Najeba and Mohamad [23] assessed the indoor radon concentration in dwellings in Iraqi Kurdistan using CR-39 dosimeters. The results show that the levels of radon in the kitchen of the dwellings ranged between 99.947 Bq m-3 and 360.112 Bq m^{-3}, with an average activity of 187.215 Bq m-3. More studies will be discussed later in the following paragraphs.

In the current study, the concentration of radon will be measured using the radon detector ALPHA GUARD. Effective dose radon exhalation rate, the alpha potential energy, the absorption effective dose exposure will be estimated.

Materials and Methods

The concentrations of radon in dwellings have been measured in 13 sites in Baghdad as shown in Figure-1. Two houses were investigated at every site. The measurements were carried out in different locations in the dwellings (living rooms, bed rooms, bath rooms, and kitchens) within one month (June) in summer of 2015.

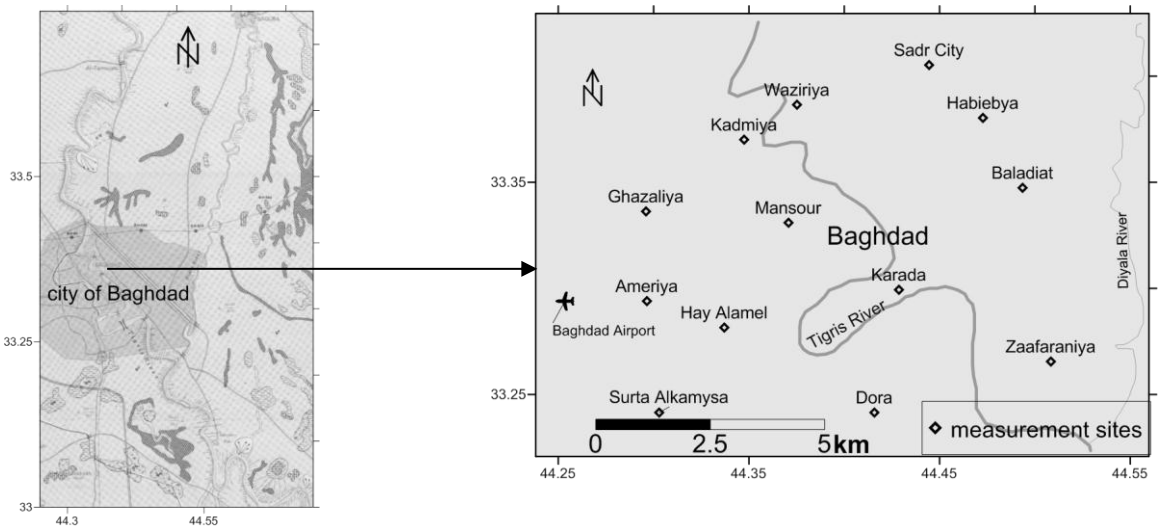

Figure 1- Radon measurement sites in Baghdad city in the current study

Radon concentration has been evaluated using an ionization chamber radon monitor (ALPHA GUARD PQ2000, Genitron Instruments GmbH, Germany) available in Radiation Protection Center (RPC) as shown in Figure-2.

In regular operation the measuring gas gets in diffusion mode and flow mode. The ALPHA GUARD) has a linear response from 2 to 2,000,000Bq/m3 (0.05 to 50000 pCi/l), operating temperature is (-10° to +50°C) [24]. It is a continuous active radon sampling sensor. It has an ionization chamber and uses an alpha spectroscopy to detect radon. For determinations of the radon concentration in air (diffusion mode), ALPHA GUARD is used only [24]. The radon detector ALPHA GUARD is based on the optimized design of pulse-ionization chamber. In regular operation this detector measures the radioactivity of the air using the diffusion of gas through the large surface of the glass fiber filter installed inside the ionization chamber. This filter permits that only the ^{222}Rn gas can pass through and prevents the products of the radon decay from entering to the ionizing chamber. It also protects the ionizing chamber from contamination by dust particles [24].

The monitor is calibrated in labs of (RPC) with standard sources of known radon activity. One hour for each measurement was applied at each place. Radon concentration is measured in Bq/m^3.

The annual effective dose due to exposure to radon is calculated using the following equation:

$$\mathbf{D\ (nSv) = C_R\ (Bq/m^3)* 0.4*7000*9\ nSv\ (Bq/m^3)^{-1}}$$

Where D is the annual effective dose, C_R is average radon concentration, 0.4 is the average of equilibrium factor [25], 7000 hours is the indoor occupancy and 9 nSv is the dose conversion factor [26].

Figure 2- ALPHA GUARD radon monitor used in current study

Results and Discussion

The results of measurement in the present study are shown in Table -1. According to the results, the average radon concentration in Baghdad city was (10.67±4.14 Bq/m³).The highest radon concentration was (23.27±13.57 Bq/m³) in Kadmiya Figure-2 due to the old construction of the dwellings, and lack of ventilation in this site (field notes), while the lowest was (5.77±0.73 Bq/m³) in Ameryia site because the dwellings are mostly newly constructed, and good ventilated. Moreover it was noticed that rooms of the highest average radon concentration were kitchens because of the continuous use of cooking gas, water, existence of floor drain. However, bathrooms and kitchens have long range of radon concentration Figure-3 and Figure-4. It should be noted that these estimated values based on short term measurements that may not reflect radon levels throughout the year. Indoor concentration depends on the geological aspects and the features of building materials [5].

The concentration of radium-226, the parent of radon, in building materials used in Iraq was found to be ranged between below detection limit (0.5 Bq/kg) to 223.7Bq/kg [5]. This wide range of activity of radium in building materials definitely causes wide range of radon concentration in dwelling. On the other hand, migration of radon, through joints and pores, into indoor air cause increase of radon concentration as well [1], this depends on the type of the upper soil and floor cover materials. Generally, the upper soils of Baghdad city are represented by quaternary deposits of the Mesopotamian basin which mainly consist of sand, silt and clay [27]. So, it seems that the main source of the difference in the radon concentrations in study area is due to the differences of building materials used in construction of the dwellings in addition to the design and ventilation level of those dwellings. The indoor radon concentrations in Baghdad city are much lower than the recommended IAEA action level of 200-600 Bq/m^3 [28]. On the other hand, it is comparable with the average concentration of radon in most countries which was estimated to be 40 Bq/m^3, while the typical European value was reported to be 99 Bq/m^3 [29], although some European countries reported higher concentration by several order [30].

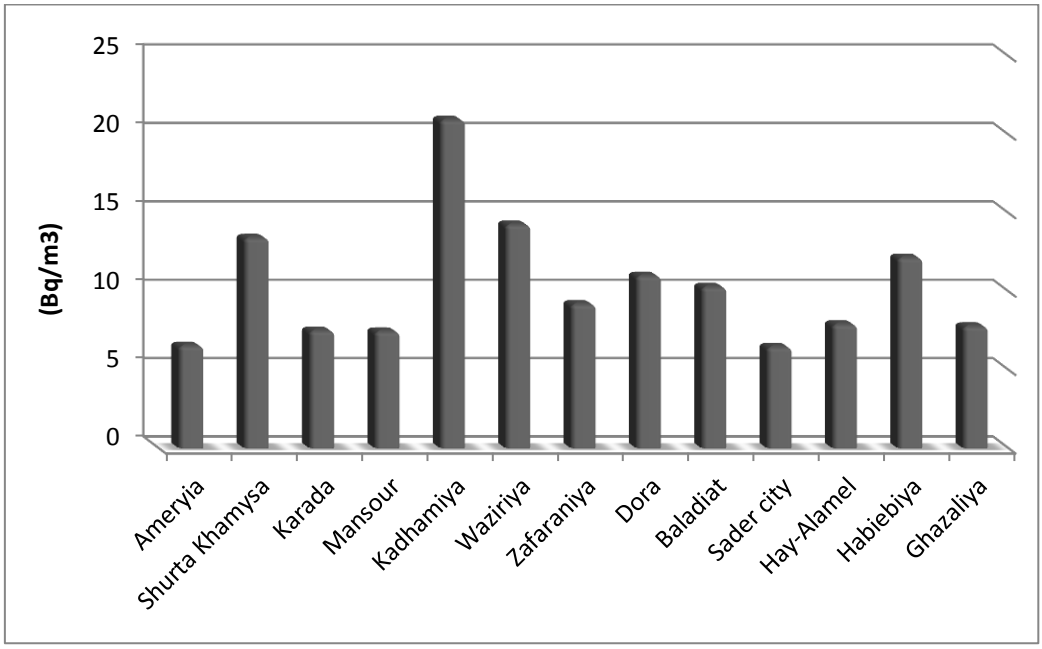

Figure 3- Average Radon concentrations in measurement sites in Baghdad city.

Table 1- Radon concentrations in dwellings of Baghdad city

Location	living room (Bq/m3)	kitchen (Bq/m3)	bathroom (Bq/m3)	bedroom (Bq/m^3)	average (Bq/m3)
Ameryia	5.67	6.55	5.09		5.77±0.73
Baladiat	15.42	*	8.83	8.70	10.98±3.84
Dora	11.70	*	8.29	16.70	12.23±3.19
Ghazaliya	7.13	9.00	7.15	*	7.76±0.97
Habiebiya	*	8.99	12.14	15.29	12.14±3.14
Hay-Alamel	8.60	8.83	7.20	6.91	7.88±0.96
Kadmiya	9.49	24.24	36.08	*	23.27±13.57
Karada	6.57	7.42	6.17	9.77	7.48±1.61
Mansour	8.12	3.93	8.22	9.34	7.40±2.37
Sadr city	7.59	6.51	4.30	7.34	6.43±1.49
Shurta Khamysa	10.48	8.64	17.49	16.98	13.40±4.5
Waziriya	4.97	35.57	10.09	*	16.87±16.49
Zafaraniya	8.21	7.06	6.09	*	7.12±1.05
Average	8.66	11.52	10.55	11.38	10.67±4.14

- Not measured

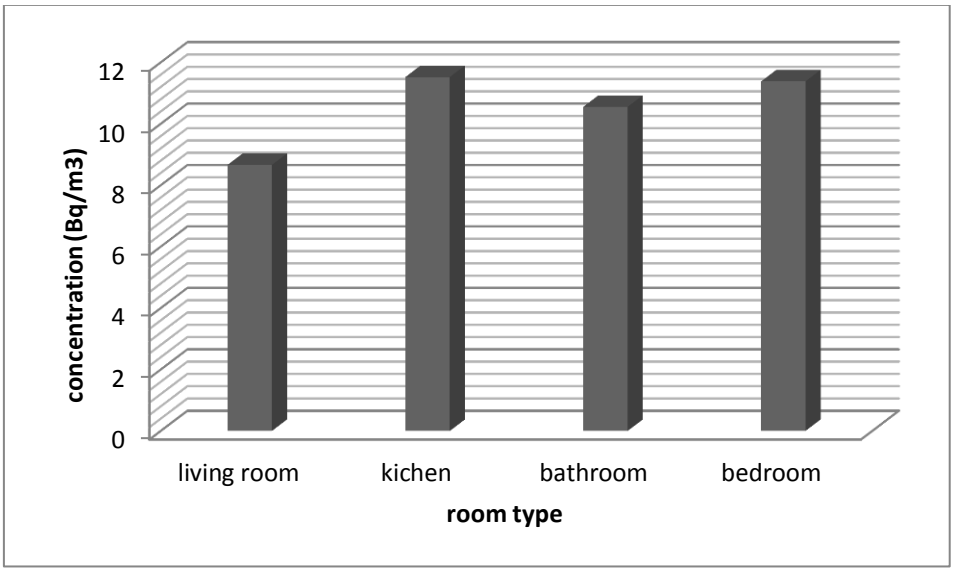

Figure 4- Average radon concentrations vs. room type

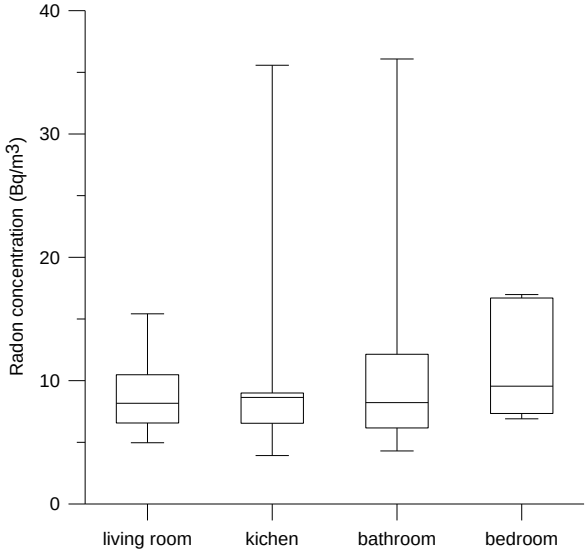

Figure 5- Box-whisker plots of radon concentrations

According to European Commission (EC) recommendation[31] and previously ICRP, [26] the reference level in European countries for remedial action is 400 Bq/m^3, while the WHO [32] recommended that the concentration of radon indoor does not exceed 100 Bq/m^3, or 300 Bq/m^3 in exception cases. The latest recommendation by ICRP [17] to reference level in indoor and all buildings with high occupancy rates by public to be 300 Bq/m^3. Table -2 summarizes the recommended value by various agencies of concern.

Table 2- Reference level of radon as recommended by EC, ICRP and WHO

Reference	Reference level (Bq/m^3)
EC	400
ICRP	400
WHO	100
WHO	300 exception cases
ICRP (Revised)	300

Contour map for Iso- radon distribution was plotted as shown in Figure-5. It seems that city center have lower concentration of radon while it increases toward northern and southern parts of the city.
The current study showed that the average concentration of radon in dwellings in Baghdad is lower than those of other cities in Iraq Table-2.

Table 2- The comparison of Radon concentrations between present study and other studies in Iraq.

Region	Radon concentration *(Bq/m3)*	Reference
Al-Hamdanya Nenava	37.4	33
Baghdad	16.64	34
Basrah	13.532-51.176	35
Al-Gazaliya Baghdad	38.7-200	36
Sahel Nenava	53.5	37
Al-Najaf	11.654 ±4.216 53.610 ±8.777	19
Thi-Qar	25.66-113.63	38
Baghdad	14.7-46.17	39
Baghdad	51.688 ±16.7	40
Baghdad	10.67 ±4.14	present study

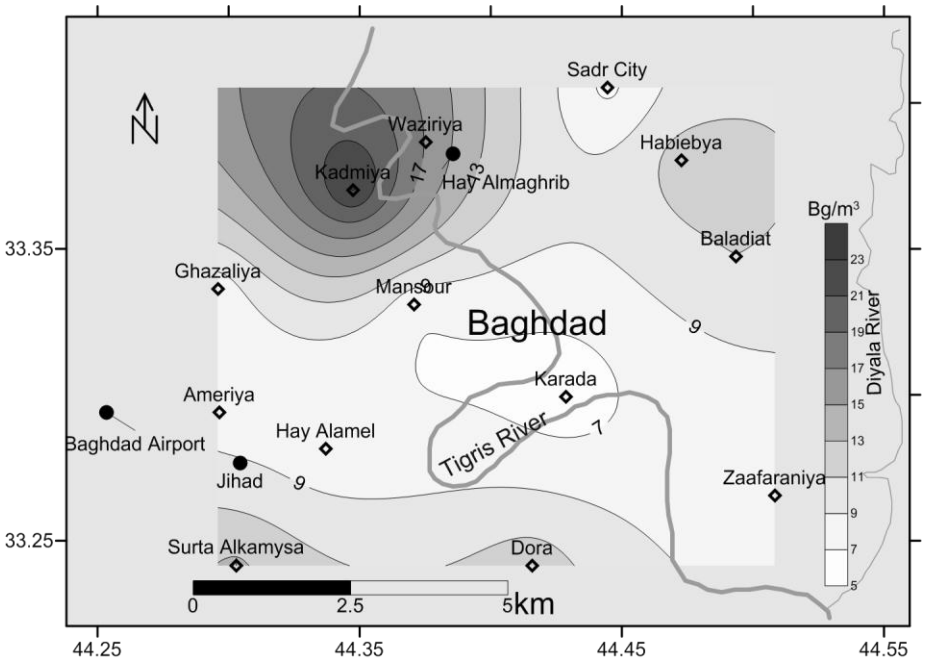

Figure 6- contour map shows the distribution of radon in city of Baghdad. Contour interval is 2 Bq/m^3.

Table-3 shows the annual mean effective dose in dwellings in study area. The maximum annual effective dose in dwelling in Baghdad city in current study is 0.59 mSv. It is about half the world wide average dose (= 1.15 mSv/y) caused by radon and its decay products [41].

Table 3- The annual mean effective dose

site	Average radon concentration (Bq/m^3)	annual mean effective dose (mSv)
Sadr City	6.43	0.16
Habiebya	12.14	0.31
Baladiat	10.98	0.28
Zafaraniya	7.12	0.18
Waziriya	16.87	0.43
Kadhmiya	23.27	0.59
Ghazaliya	7.76	0.20
Mansour	7.4	0.19
Karada	5.77	0.15
Ameriya	7.88	0.20
Hay Alamel	7.48	0.19
Surta Alkamysa	13.4	0.34
Dora	12.23	0.31

Conclusions

The concentrations of radon gas in dwellings were measured using ALPHA GUARD radon monitor, and they were found lower than the recommended IAEA action level. The average radon concentration in dwellings was (**10.67±4.14** Bq/m^3). The kitchens have the highest in radon gas concentration because of the continuous use of water, cooking gas, and the existence of floors drain. The maximum annual effective dose caused by radon in dwelling in Baghdad city is 0.59 mSv. It is about half the world wide average dose (= 1.15 mSv/y) caused by radon and its decay products. All results of indoor radon showed that no action is required to reduce radon levels inside dwellings of Baghdad city.

Also, the results showed that the indoor radon gas concentrations depend mainly on the following things:

- The main origin of ^{222}Rn indoors is the ground underneath a building. Building materials can also be an origin of 222Rn indoors, though usually they are a much less significant origin than the ground. But according to the wide range in concentration of radium in building materials used in Iraq, the difference in radon concentration in Baghdad may be related to the different construction materials.
- The age and the quality of the dwellings construction materials, where old houses with a lot of cracks in walls and floors where the highest in radon gas concentration while newly built ones with cracks – free walls and floors were the lowest in radon gas concentration. Type of ventilation inside dwellings, is an important factor, although it was not verified in the present study.

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