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# Radon gas concentrations and exhalation rates in soil samples of Al-Muthanna governorate, Iraq

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► ***Short report***

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## ABSTRACT

***Background***: Radon gas is one of the sources of radiation in nature. It is a radioactive gas whose danger lies in the fact that it can enter the human body through breathing, causing possible lung cancer. ***Materials and Methods:*** Radon gas was measured by using the Columbia resin-39 (CR-39) alpha track detectors in 42 locations of different nature industrial, residential, and agricultural and investigated the exhalation rates from surface soil. ***Results:*** The results demonstrated that the radon gas concentrations varied from (173.31 to 507.80 Bq ⁄m³) and the average value of the radon exhalation rate in soil was 0.026 Bq ⁄m².h. ***Conclusion:*** The results can be used as baseline data to evaluate any changes in the radioactive background level due to human activities.

## INTRODUCTION

Radiation has a substantial and occasionally vital impact on our daily life. The organisms were subjected to a specific amount of daily natural radiation. Actually, radioactivity exists in our bodies as well as in the air we breathe, soil, and water. Monitoring radioactive material is the first step in protecting the environment. Radon gas, which exists in the atmosphere, is produced by the decay chains of uranium-238 ($^{238}U$) and thorium-232 ($^{232}Th$), respectively. The radon gas's transient decay products are primarily responsible for the risks [1]. Radon gas was the most fluctuating and powerful radiation that increased public exposure Radon -222 ($^{222}Rn$). Due to the radioactivity of radon (an emitter of alpha particles), with a decay constant of (0.1812 days$^{-1}$) and half-life ($T_{1/2}$) of (3.825 days), it has been discovered that the ratio of radon and its daughter's dose per year of lung cancer can be brought on by the intake of high quantities of air, which account for around (55%) of all-natural public exposure [2]. It has been discovered that the risk of lung cancer increases by 16 percent for every 100 Bq/m$^3$ increase in radon concentration as radon exposure increases, which has been shown to have a linear relationship with doses [3]. Radon is a colorless, odorless, and tasteless gas that is heavier than air and tends to dwell close to ground levels [4]. Numerous studies confirm concentrations of soil gas within a few meters of the surface play a significant role in determining prevalence across the entire crust of the planet [5]. Because radon can freely move from the location of its origin via soil pores and wall fissures [6]. Al-Muthanna governorate has been exposed to wars and aerial bombardment from 1991 to 2003 during the Gulf wars. Due to the lack of studies in this area, the current study's objective was to take from various locations (industrial, agricultural, and residential) in the Al-Muthanna city, southern Iraq to measure the radon level and the rate of surface exhalation in soil samples. This study was done by using the cheap and reliable nuclear track detectors Columbia resin (CR-39) to find the alpha particles released by radon gas [7, 8]. It is the first study conducted to measure the content of radon gas levels in soil samples of different sites included various human activities in Al-Muthanna Governorate, southern Iraq.

## MATERIALS AND METHODS

### *Samples collection*

In the present study, 42 soil samples were taken from different locations (industrial, agricultural, and residential) of the Al-Muthanna governorate, as presented in table 1. Al-Muthanna city, located in southern Iraq about 280 km south of Baghdad which covers an area of 51740 km$^2$, which is situated in the Euphrates River between latitudes 31.42° North (N) and longitudes 43.52 ° East (E) as shown in figure 1.

The population of Al-Muthanna city was estimated to be 420,000 people, which is characterized by a diversified economic activity between agriculture and industry [9]. Firstly the soil samples were cleaned by removal the stones, root fragments, and gravel. Then, samples were stored in containers made of plastic with labels until the time of analysis.

**Table 1.** Information the areas of collected samples.

| Name of area | Sample code | Latitude & longitude | Nature of region |
|---|---|---|---|
| Al-Naft district | S1 | 31.3134 N, 45.2523 E | Agricultural |
| Al-Bastian Al-Sharqi | S2 | 31.3192 N, 45.3054 E | Agricultural |
| Nissan | S3 | 31.3063 N, 45.3099 E | Agricultural |
| Al-Zarijih | S4 | 31.3292 N, 45.3575 E | Agricultural |
| Bustan Al-Sharif | S5 | 31.3356 N, 45.2998 E | Agricultural |
| Tamim district | S6 | 31.3328 N, 45.2954 E | Agricultural |
| Al-Jarbuiyeh | S7 | 31.3429 N, 45.2558 E | Agricultural |
| Al-Azal district | S8 | 31.2811 N, 45.2819 E | Agricultural |
| Sikka district | S9 | 31.3412 N, 45.2728 E | Agricultural |
| Bustan Al-Ghani | S10 | 31.1918 N, 45.5610 E | Agricultural |
| Imam Mahdi shrine | S11 | 31.3156 N, 45.2161 E | Agricultural |
| Al-Sharqi | S12 | 31.3082 N, 45.2941 E | Agricultural |
| Bustan Muhammad Ali | S13 | 31.3221 N, 45.2728 E | Agricultural |
| (Al-Khudar) Al-Tawba | S14 | 31.2835 N, 45.2992 E | Agricultural |
| Shahada district | S15 | 31.3090 N, 45.2983 E | Residential |
| Al-Haidari  district | S16 | 31.3017 N, 45.2765 E | Residential |
| Al-Sadr district | S17 | 31.3031 N, 45.2652 E | Residential |
| Al-Hussein district | S18 | 31.3149 N, 45.2677 E | Residential |
| Al-Bani district | S19 | 31.3106 N, 45.2719 E | Residential |
| Al-Dubaat district | S20 | 31.3176 N, 45.2729 E | Residential |
| Al-Muealimin district | S21 | 31.3158 N, 45.2794 E | Residential |
| Al-Zuhur district | S22 | 31.2813 N, 45.2853 E | Residential |
| Al-Resala district | S23 | 31.3292 N, 45.3575 E | Residential |
| Al-Jisr street | S24 | 31.3146 N, 45.2919 E | Residential |
| (Al-Khudar) Al-Easkari district | S25 | 31.1996 N, 45.5378 E | Residential |
| (Al-Khudar) Al-Asri district | S26 | 31.1963 N, 45.5370 E | Residential |
| (Al-Khudar) Al-Ansar district | S27 | 31.2032 N, 45.5485 E | Residential |
| (Al-Khudar) Al-Rabdah district | S28 | 31.1997 N, 45.5510 E | Residential |
| Industrial district | S29 | 31.2900 N, 45.2923 E | Industrial – Car repair garage |
| The Shark | S30 | 31.3037 N, 45.3025 E | Industrial – Power station |
| Al-Risala district | S31 | 31.3123 N, 45.2573 E | Industrial – Power station |
| Al-Easkari district | S32 | 31.3032 N, 45.2644 E | Industrial – Petrol station |
| Al-Hukm district | S33 | 31.2916 N, 45.2801 E | Industrial – Electric power plant |
| Al-Naft district | S34 | 31.2542 N, 45.2601 E | Industrial – Samawa refinery |
| Eastern | S35 | 31.3048 N, 45.2978 E | Industrial – Power station |
| Al-Zuhur district | S36 | 31.2867 N, 45.2841 E | Industrial – Gas stations |
| Al-Rumaitha | S37 | 31.5293 N, 45.1948 E | Industrial – Power stations |
| Al-Rumaitha Teacher's district | S38 | 31.534 N, 45.1628 E | Industrial – Electric station |
| (Al-Rumaitha) Al-Muealimin | S39 | 31.5473 N, 45.1748 E | Industrial – Gas factory |
| Al-Khudar 1 | S40 | 31.2065 N, 45.4729 E | Industrial – Gas factory |
| Al-Khudar 2 | S41 | 31.2486 N, 45.3791 E | Industrial – Bricks factory |
| Al-Warka | S42 | 31.4395 N, 45.2864 E | Industrial – Bricks factory |

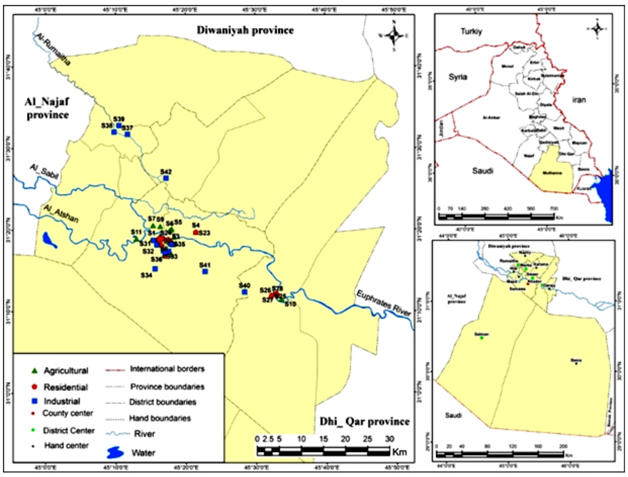


**Figure 1.** Map of Al-Muthanaa governorate showing the location of samples.

***Experimental method***

Utilizing CR-39 detectors of solid nuclear tracks (Pershore Moulding Ltd., UK) CR-39, were used to investigated the radon concentrations and rates of surface radon exhalation in soil samples. In an electric oven, soil samples were heated for two hours at 100 (°C). After that soil samples were ground into a fine powder. The plastic can technique with the dimensions of inner diameter and height is 5 cm and 10 cm, respectively, was used to achieve the purpose of the analysis. The CR-39 tracks with area of $1.5\times1.5 cm^2$ were used to record alpha particles emitted from radon gas in studied soil samplers. The detectors were secured to the interior cover of plastic cans to stop radon leakage, and the plastic can's lid was snugly fastened for 30 days as shown in figure 2. As previously described in other studies, the CR-39 detectors were etched in (NaOH) solutions normality (N=6.25) at 60°C for five hours. The detectors were scanned by an optical microscope (Meiji, China) to view the tracks of alpha. Equation (1) was used to calculate, the density of alpha tracks at 400x magnification (11, 12).

Tracks Density (ρ) = Average number of total tracks / Area of field view (1)

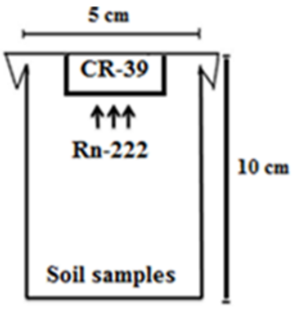


**Figure 2.** Cup technique to determine radon gas in soil samples.

***Calculations***

By comparing the density of the tracks recorded by CR-39 detectors of the unknown samples and the standard samples the amount of radon present in soil samples was determined, by using the relationship (2) (13):

$$CRn\ (Bq/m^3) = \rho_n\ (CRs\ /\ \rho_s) = \rho_n\ /\ slope \qquad (2)$$

Where, $\rho_n$ and $\rho_s$ is the track density in (Track/$mm^2$) of unknown and standard samples. CRn and CRs is radon concentration of unknown and reference sample radon.

In order to investigate the flux of radon gas leaks from the surface soil by using radon exhalation rate parameter (RER) in unit ($Bq.m^{-2}.h^{-1}$) according to the relation (3) (13).

$$RER = CV\lambda\ /\ A\ [T + \lambda^{-1}\ (e^{-\lambda T}-1)] \qquad (3)$$

Where T is exposure duration, (T) = 30 days, A is the sample's surface area ($m^2$), V is the amount of air in a cup (in $m^3$), C is the radon exposure ($Bq.h.m^{-3}$), λ is decay constant of $^{222}Rn = 0.00755 h^{-1}$.

***Statistical analysis***

The analytic results of the soil samples were statistically analyzed using Statistical Package of the Social Sciences (SPSS) and the probability level (P) of the radon gas was estimated by using independent sample *t-Test*.

## RESULTS

Results of radon gas and exhalation rates in samples of soil taken from the Al -Muthanna governorate are displayed in table 2. According to this table, the maximum value of $^{222}Rn$ gas in surface soil is 507.80 Bq/$m^3$ in Al-Warka location, due to the industrial activity of this location which included bricks factory where soil considered the main source of natural radiation. As for the minimum value of $^{222}Rn$ is 175.31 Bq/$m^3$ in sample S19 which belonged to Al-Bani district, because it is a sparsely populated area and free from pollution sources. The average value of radon concentrations in soil samples of Al-Muthanna city is 307.07 Bq/$m^3$ where this value is within the recommended level of radon gas in soil sample 600 Bq/ $m^3$ (13).

Based on these data of the radon gas the highest value of radon exhalation rate (RER) due to radon gas in soil is 0.044Bq /$m^2$.h while lowest value of (RER) is 0.015 Bq /$m^2$ and average value of (RER) is 0.026 Bq /$m^2$.h, which confirms the relation with the radon levels in soil samples.

Table 3 shows the relationship between radon concentration values in soil samples depending on the nature of the area which it was studied, the highest value of radon concentration was in the industrial area, where the average value of radon levels is 416.25 Bq/$m^3$, The lowest value for radon levels is 204.88 Bq/$m^3$ in residential area because it is low in pollution. As for the agricultural areas, it reached to 300.10 Bq/$m^3$. From the above results the industrial region recorded high levels of radon gas.



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**Table 2.** Radon content (Bq/m3) and exhalation rate (Bq/m².h) in soil samples of Al-Muthanna, city.

| Sample code | Radon content ± St. Dev. | RER |
|---|---|---|
| S1 | 250.88 ± 62.01 | 0.021 |
| S2 | 344.58 ± 67.85 | 0.030 |
| S3 | 365.74 ± 47.69 | 0.032 |
| S4 | 386.90 ± 61.65 | 0.033 |
| S5 | 253.90 ± 59.23 | 0.022 |
| S6 | 253.90 ± 57.66 | 0.029 |
| S7 | 335.51 ± 61.12 | 0.023 |
| S8 | 262.97 ± 50.66 | 0.021 |
| S9 | 290.17 ± 62.24 | 0.021 |
| S10 | 244.83 ± 62.60 | 0.028 |
| S11 | 326.44 ± 60.15 | 0.023 |
| S12 | 262.97 ± 61.65 | 0.028 |
| S13 | 317.37 ± 67.92 | 0.027 |
| S14 | 305.28 ± 64.04 | 0.026 |
| S15 | 190.42 ± 60.52 | 0.016 |
| S16 | 220.65 ± 60.52 | 0.019 |
| S17 | 199.49 ± 60.75 | 0.017 |
| S18 | 211.58 ± 55.73 | 0.018 |
| S19 | 175.31 ± 50.21 | 0.015 |
| S20 | 208.56 ± 61.12 | 0.018 |
| S21 | 220.65 ± 68.99 | 0.019 |
| S22 | 189.21 ± 54.15 | 0.016 |
| S23 | 205.54 ± 63.11 | 0.017 |
| S24 | 214.60 ± 58.06 | 0.018 |
| S25 | 190.42 ± 54.15 | 0.016 |
| S26 | 217.63 ± 46.43 | 0.019 |
| S27 | 199.49 ± 65.11 | 0.017 |
| S28 | 223.67 ± 57.66 | 0.019 |
| S29 | 420.14 ± 57.66 | 0.036 |
| S30 | 444.33 ± 56.46 | 0.038 |
| S31 | 371.78 ± 54.15 | 0.027 |
| S32 | 471.53 ± 71.78 | 0.036 |
| S33 | 432.42 ± 68.99 | 0.037 |
| S34 | 456.42 ± 59.61 | 0.039 |
| S35 | 405.03 ± 74.28 | 0.035 |
| S36 | 450.37 ± 54.82 | 0.039 |
| S37 | 498.73 ± 70.56 | 0.043 |
| S38 | 471.53 ± 71.78 | 0.041 |
| S39 | 462.46 ± 54.15 | 0.040 |
| S40 | 438.28 ± 70.56 | 0.038 |
| S41 | 468.51 ± 66.56 | 0.040 |
| S42 | 507.80 ± 60.15c | 0.044 |
| **average** | 307.07 ± 60.82 | 0.026 |

**Table 3.** Radon concentrations in soil samples as a function of area classification.

| Area classification | No. of samples | Mean ± St. Dev. |
|---|---|---|
| Industrial | 14 | 416.25 ± 64.48 |
| Agricultural | 14 | 300.10 ± 60.46 |
| Residential | 14 | 204.88 ± 54.25 |

## DISCUSSION

From the results obtained in tables 2 and 3, the level of radon gas concentration in soil samples of Al-Muthanna governorate ranged between 507.80 Bq/m$^3$ to 175.31 Bq/m$^3$ with average value equals to 307.07 Bq/m$^3$. The industrial areas in the city of Al-Muthanna have the highest level of radon gas and exhalation rate because they contain many activities such as refineries, fuel stations, cement and brick factories, gas and power stations. As for the lowest value of radon gas and exhalation rate, it was found in residential areas because it is free from human activities so that it is low in pollution. Also the soil samples of agricultural areas recorded high levels of radon gas this finding may be attributed to the use of phosphate fertilizers to increase the yield of agricultural lands. Therefore, the degree of pollution in relation to radon concentration and exhalation rate of the studied areas is the following arrangement industrial> agricultural > residential. The mean value of radon gas levels in studied soil samples is less than the safety global level of radon in soil 600 Bg/m$^3$ as mentioned elsewhere [13]. That means the analyzed soil samples dose not polluted with radon gas.

Table 4 illustrates the comparison between the results of the present investigation and other studies. From this table the figures of the current study are higher than Brazil, Malaysia, Saudi Arabia and lower than those of Pakistan, India, and Iraq (Baghdad).

**Table 4.** Comparison of the radon concentrations (Bg/m3) with other studies.

| Location | Mean | Ranges | References |
|---|---|---|---|
| Brazil | 69 | 4 – 404 | (14) |
| Malaysia | 198.44 | 67.21–295.06 | (15) |
| Saudi Arabia | 75.41 | ……. | (16) |
| Pakistan | 376 | ……. | (17) |
| India | 330.5 | 117.5 – 583.4 | (18) |
| Iraq (Baghdad) | 994.4 | ……. | (9) |
| Iraq (Al- Diwaniyah) | 350.64 | 163.58 – 689.89 | (20) |
| Iraq (Al-Muthanna) | 307.13 | 175.31– 507.80 | Present study |

## CONCLUSION

Radon gas levels and exhalation rates were determined in selected surface soil samples collected from Al-Muthanna governorate, Iraq. In light of these findings, it can be roughly said that the area are safe in terms of its impact on health. Confirmed radon concentration standards refer, showed that they are generally within the safe limits of 600 Bq/m$^3$.

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***Ethical consideration***: Surface soil samples were collected from different locations of Al-Muthanna governorate, southern Iraq. The results of the radon gas levels were within the safety levels, so these areas are considered safe and free of risks for the population.

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***Author contribution*: Both authors contributed equally at all stages of the research and preparation of manuscript.**

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