Measurement of Radon Concentration Levels at the Official Institutes of Al-Rifai City, Dhi Qar Governorate, Iraq

Jhan Salman Daaeim and Kawthar Hassan Obayes*

***Abstract*—In this study, the radon concentration was evaluated in an indoor building in Al-Rifai city, Dhi-Qar governorate using a nuclear track detector (CR-39). Also, the radiological hazard risk parameters were calculated. The findings show that radon concentrations varied from 16.05 ± 4.29 Bq/m^3 to 33.85 ± 9.68 Bq/m^3 with an average of 24.96 ± 7.53 Bq/m^3. While, the average values of annual effective dose (AED) and lung cancer cases per million people (CPPP) were 0.63 mSv/y and 11.34×10^{-6}, respectively. It is below the acceptable and recommended limit by the International Committee for Radiation Protection (200-300 Bq/m^3).**

***Index Terms*—Inhalation of radon gas, cancer risks, the official institutes, CR-39 detectors, Dhi Qar.**

I. Introduction

Rn-222 has become a health problem due to indoor air pollution caused by external gamma rays, inhalation of radon and its progeny, and their ingestion into the body through water and food [1]. Natural radiation in the environment is the largest source of radiation exposure, according to the National Council on Radiation Protection (NCRP) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Rn-222 is expected that the internal dose of about 55% radon and its progeny dose for humans and the high levels of radon can be a reason for lung cancer [2]. The radon is present in the atmosphere because the soil and around are significant sources of radon. The radon gas is colorless, odorless, and tasteless, and the gas is produced from the decay of ^{238}U, ^{235}U, and ^{232}Th from rocks, soils, plants, and water all over the world [3]. Radon isotopes existing in nature ^{222}Rn, ^{220}Rn, and ^{219}Rn are the product of a radionuclide series of ^{238}U, ^{232}Th, and ^{235}U respectively. The radon has a half-life of 3.825 days [4]. Indoor radon concentrations in government buildings vary based on location, time, ventilation, elevation above sea level, and older government buildings [5]. Building materials such as concrete, sand, cement, bricks, rocks, and ceramics are the main source of radon, which is usually 4 or 5 times more concentrated than outdoor radon, with contributions from external air, soil, and water [6]. After inhaling radon, its decay products are deposited in the lungs, where alpha radiation produced during successive decays provides a dose, causing changes and damage in the lung [7]. Indoor radon exposure is thought to be responsible for more than 10% of lung cancer cases in the United States [8]. Changes in ventilation rate and temperature differential are the key factors that influence fluctuations in indoor radon levels. The ventilation rate has an impact on the air exchange rate between interiors and outdoors. Temperature changes between indoors and outdoors produce pressure differences, which act as a driving force for radon to enter the residence. The temperature differences are caused by the fact that outdoor temperatures vary considerably throughout the day and night, whilst indoor temperatures do not. The ICRP recommends that radon concentrations in residences be kept to between 200 and 300 Bq/m^3 [9]. Due to the dangers of radon, many studies have been conducted in many countries to determine contamination levels such as India, Italy, and Iraq [10]-[12]. The lack of previous studies covering official departments for sites in Dhi Qar governorate in southern Iraq has been submitted to military operations. In addition, there is a lack of a radiation map for the governorate. The present study aims at determining radon as well as the radiation hazards (AED, CPPP, PAEC, E_P) resulting from exposure to radon measured from various official institutes in AL-Rifai City, Dhi Qar governorate, Iraq.

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II. Material and Method

A. Location of the Studied Area

Al-Rifai city, an Iraqi city and the center of the judiciary administratively attached to the province of Dhi Qar, is one of the large important cities, about 300 km south of the Iraqi capital, Baghdad, and about 80 km north of Nasiriyah, the center of Dhi Qar governorate, as shown in Fig. 1, which has a total area of 1345 km^2, with a population of 74609 people in 2018. The city is located between two latitudes ($31^{\circ}42'09'' - 31^{\circ}44'56''$) degrees north, and between two longitudes ($46^{\circ}08'17'' - 46^{\circ}05'16''$) degrees east. Table I contains the collected data as well as information on locations and codes for 10 different locations in this study.

TABLE I: Names and Locations with Coordinates of the Study Areas in Al-Rifai City

Sample code	Locations	L. No.	Coordinates	
			Latitude (N)	Longitude (E)
S1	Real estate note Circuit – Al-Saray neighborhood	1 2	31°43′21.97" 31°43′22.30"	46°06′16.48 46°06′17.04"
S2	Water circle - Al-Saray neighborhood	1 2	31°43′18.01" 31°43′17.90"	46°06′16.12" 46°06′16.50"
S3	Civil defense center – Al-Sharq neighborhood	1 2	31°42′47.75" 31°42′48.54"	46°06′23.76" 46°06′23.12"
S4	Model health center - Amir neighborhood	1 2	31°43′05.09" 31°43′05.01"	46°06′05.55" 46°06′05.79"
S5	Statistics and planning Circuit – Al-muealimin	1 2	31°43′19.52" 31°43′18.82"	46°06′27.50" 46°06′30.11"

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	neighborhood			
S6	Civil Status and Passports circle – Al-Eumaal neighborhood	1 2	31°43′23.13" 31°43′22.72"	46°06′45.81" 46°06′45.78"
S7	College of Science, Sumar University – Al-Eumaal neighborhood	1 2	31°43′24.57" 31°43′24.69"	46°06′19.78" 46°06′19.97"
S8	Sewer circuit - Al-Sharq neighborhood	1 2	31°43′02.64" 31°43′02.18"	46°06′52.60" 46°06′52.47"
S9	Electricity Circuit - Hassan neighborhood	1 2	31°42′56.56" 31°42′52.90"	46°07′01.15" 46°07′01.32"
S10	Water project - Amir neighborhood	1 2	31°43′01.09" 31°43′02.57"	46°05′57.64" 46°06′02.29"

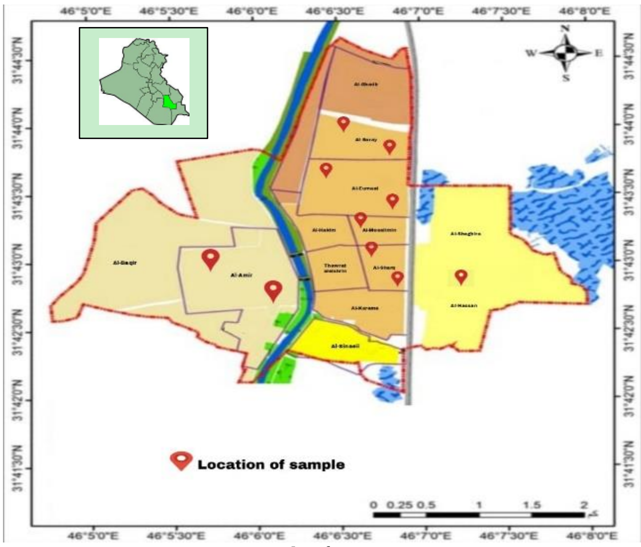

Fig. 1. Al Rifai city area.

III. Collected Samples

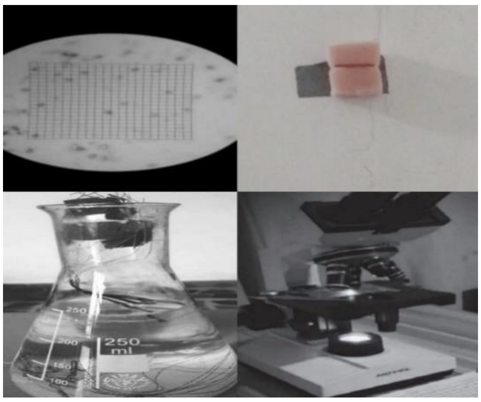
Fig. 2. The track on the detector and optical microscope.

For the purpose of the study, 10 official departments' sites were selected from the city of Al-Rifai in Dhi Qar governorate. The (CR-39) nuclear track detector, which has a thickness of roughly 500 µm (Tasl Company, UK), was principally used in this work. Sharp blades were used to gently cut a large sheet of (CR-39) into little pieces of (2×2) cm^2 area. It was placed inside a sponge and hung on the walls at a distance of (150 cm) from the ground. Where (20) detectors were distributed in official institutes, in every building placed two detectors. The reagents were chemically scraped after 30 days of exposure using a standard (NaOH) solution (6.25 mole/ L) prepared by dissolving (62.5 g) sodium hydroxide granules in (0.25L) distilled water, the skimming solution was heated in a water bath to (60°C), and the reagent (CR-39) was suspended for 5 hours within the skimming solution. The samples were examined under a (400X) magnification optical microscope, and the alpha tracks were read as depicted in Fig. 2.

IV. Calculation

The average number of N_{avg} traces generated was estimated using an optical microscope after the nuclear trace detectors (CR-39) were prepared for measurement. The density of the tracks (ρ) in unit (track mm^{-2}) for each detector was estimated by the following equation [13].

$$\rho = \frac{N_{avg}}{A} \qquad (1)$$

where: N_{avg} = the average number of tracks on the (CR -39) detector surface.

A = area of view field visible under the microscope (20×20) grids area = 0.0676 mm^2.

The radon concentration(C_{Rn}) was calculated using this equation [14].

$$C_{Rn} = \frac{\rho}{K \times T} \qquad (2)$$

where: T = Exposure time (30 day), K = The calibration factor of CR-39 equal (0.169 Track m^{-3}/Bq day mm^{-2}) [15].

The annual effective dose (AED) in unit mSv/y is calculated from the equation following [2].

$$AED\ (mSvy^{-1}) = C_{Rn} \times F \times O \times T \times DCF \qquad (3)$$

where: F: equilibrium factor equals (0.4), O: occupancy factor equals (0.8), T: indoor occupancy time in a year equals (8760 h y^{-1}) , DCF: dose conversion factor equal (9.0×10^{-6}mSv h^{-1} (Bq m^{-3})) [16].

The lung cancer cases per year per million people (CPPP), were obtained using the following equation [17].

$$(CPPP) = AED \times (18\times10^{-6}\ mSv^{-1}\ y) \qquad (4)$$

To find the Potential alpha energy concentration (PAEC) of the radon daughter was calculated using the relation [2].

$$PAEC(WL) = F \times C_{Rn}/3700 \qquad (5)$$

where F is the equilibrium factor of(0.4) [16].

Exposure to radon progeny (E_p) in term of ($WLM\ Y^{-1}$)units were calculated using the following equation [18]:

$$E_p(WLMY^{-1}) = 8760 \times n \times F \times C_{Rn}/170 \times 3700 \qquad (6)$$

where (C_{Rn}) is the radon concentration in Bq.m^{-3} units, (8760) is the number of hours per year (n) is the fraction of time spent indoors which is equal to (0.8) (F) is the equilibrium factor and it is equal to (0.4) and (170) is the number of hours per working month [16].

V. Results and Discussion

As shown in Table II, the concentrations of radon in 10 of the official institutes of Rifai city/Dhi Qar governorate are 16.05 ± 4.29 Bq/m^3 to 33.84 ± 9.68 Bq/m^3. The height concentration in the College of Science, Sumar University in S_7 is due to the buildings being very old and the ventilation is not good. The radon concentration is low in the official institutes study area by comparisons with the International Commission on Radiological Protection (ICRP) depending on the lower than the action levels of 200 –300 Bq/m^3 as recommended [9], Fig. 4 shows levels concentration of radon official institutes using (CR-39). The minor differences in radon concentration due to the difference in nature, and to the fact that they are buildings with poor ventilation or through cracks in floor and walls [19]. The annual effective dose (AED) was computed (Ep) in addition to lung cancer cases per mill persons on (CPPP), potential Alpha energy concentration (PAEC), and radon progeny exposure in Table II, the mean values of AED, CPPP, PAEC, and E_P were found to be 0.63 mSv/y, 11.34×10^{-6}, 2.69 mWL and 0.11 $WLMY^{-1}$, respectively. When the results of the indices in Table II were compared to the world-level value, it was determined that the yearly effective dose (AED) was within (1.2) mSv/y and recorded by ICRP [20], and the number of lung cancer cases per million people (CPPP) was between 170 and 230 [21]. Furthermore, according to the table of possible alpha energy concentrations, all of the samples were below the UNSCEAR average (53.33 mWL) [22]. Conclusions on radon progeny exposure were drawn from the table (E_p) and were within average limited (1 - 2$WLMY^{-1}$) recorded by NCRP [17], Fig. 3 shows average values for radon concentration(Bq/m3), the annual effective dose (AED), lung cancer cases per mill persons on (CPPP), potential Alpha energy concentration (PAEC), and radon progeny exposure(Ep). The concentration of indoor radon differs significantly between the samples. Furthermore, the official concentration of radon varies throughout time, and is associated with the nature of the construction of buildings and it also depends on the pressure, wind, moisture, temperature, and ventilation. In Table III, the findings were compared to those of other researchers. Radon concentrations are extremely less than for Qadisiyah, Babylon, Basrah, Baghdad, and Erbil in Iraq. As shown in Table III, it is noticed that the variation in the concentration of radon is different from one city to another. The concentrations of radon often fell below the acceptable range. Internal radon concentrations in government buildings do not pose a significant risk to employees.

TABLE II: RADON CONCENTRATIONS AND RADIOLOGICAL INDICATORS OF THE STUDIED SAMPLES

Sample code	C_{Rn} (Bq/m^3)	AED (mSv/y)	CPPP × 10^{-6}	PAEC (mWL)	E_P ($WLMY^{-1}$)
S1	27.43 ±7.99	0.70	12.45	2.96	0.12
	32.97 ±12.91	0.83	14.97	3.56	0.15
S2	27.42 ±12.95	0.69	12.45	2.97	0.12
	23.93 ±3.56	0.60	10.86	2.58	0.11
S3	26.26 ±12.99	0.66	11.92	2.83	0.12
	22.47 ±6.01	0.57	10.20	2.42	0.10
S4	23.63 ±4.08	0.60	10.73	2.55	0.11
	25.68 ±10.38	0.65	11.66	2.77	0.12
S5	21.30 ±4.33	0.54	9.67	2.30	0.09
	23.93 ±4.60	0.60	10.86	2.58	0.12
S6	28.59 ±9.61	0.72	12.98	3.09	0.13
	26.55 ±6.76	0.67	12.06	2.87	0.12
S7	20.72 ±6.63	0.52	9.41	2.23	0.09
	33.85 ±9.68	0.85	15.37	3.65	0.15
S8	24.22 ±9.94	0.61	10.99	2.61	0.11
	29.76 ±11.56	0.75	13.51	3.21	0.13
S9	16.05 ±4.29	0.40	7.29	1.73	0.07
	18.09 ±1.57	0.46	8.21	1.95	0.08
S10	29.47 ±7.00	0.74	13.38	3.18	0.13
	16.92 ±3.75	0.43	7.68	1.82	0.08
max	33.85 ±9.68	0.85	15.37	3.65	0.15
min	16.05 ±4.29	0.40	7.29	1.73	0.07
Ave	24.96 ±7.53	0.63	11.34	2.69	0.11
World	200-300 [21]	1.2 [20]	170-230 [21]	53.33Mwl [20]	1-2 [17]

TABLE III: COMPARISONS THE CONCENTRATION OF INDOOR RADON WITH RESULTS FROM IRAQI CITIES

Country	Radon concentration (Bq/m^3)	References
Qadisiyah	168.3	[15]
Baghdad	91.77±0.12	[23]
Erbil	44 ±12	[24]
Babylon	4.11 ±1.1	[25]
Basrah	13.53-51.17	[26]
Dhi Qar	24.96 ±7.53	Present study

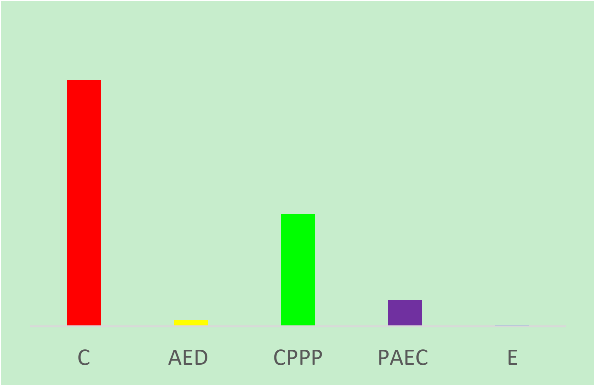

Fig. 3. Average values for radon concentration(Bq/m^3), the annual effective dose (AED), lung cancer cases per mill persons on (CPPP), potential Alpha energy concentration (PAEC), and radon progeny exposure(Ep).

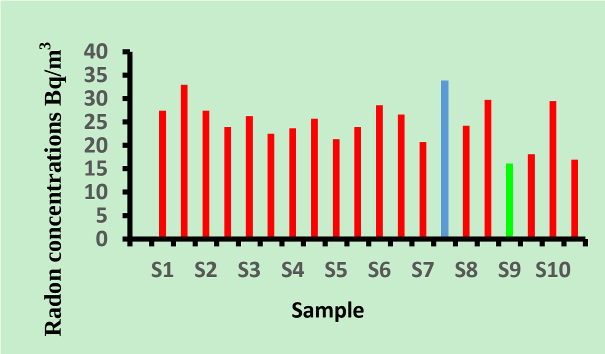

Fig. 4. Levels concentration of radon official institutes using (CR-39).

IV. Conclusion

Through the results obtained for the official departments in the city of Al-Rifai / Dhi Qar governorate, Iraq, using a nuclear track detector (CR-39), it was found that the radon concentration with high values in some official institutes could be owing to ventilation rate, building type, and geological formation. In the Electricity circuit and the College of Science, Sumar University, the radon concentration and risk characteristics had lower and higher values. Different ventilation rates, geological formations, natural building materials, and uranium grades all contribute to this. It is concluded that these results were within the acceptable level or less than the acceptable level recorded by ICRP which is equal to (200-300) Bq/m^3, when compared to various worldwide reports and scientific studies, the majority of our findings were below acceptable levels in Table III. Finally, all the buildings investigated are within the safe limits of radon exposure.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

JS has distributed the nuclear trace detectors (CR-39) in the official departments in Al-Rifai city in Dhi Qar Governorate, Iraq. The measurements were made with the help of KH in the Advanced Nuclear Physics Laboratory in the Physics Department - College of Education - University of Al-Qadisiyah. KH wrote the paper, extracted the results, interpreted them, and cited the sources.

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1- https://iopscience.iop.org/article/10.1088/1742-6596/1003/1/012023
2- https://neptjournal.com/upload-images/(26)D-1267.pdf
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