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Measurement of Radon Gas Concentrations in Tap Water Samples for Thi-Qar Governorate Using Nuclear Track Detector (CR-39)

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Abstract

In the present work, we have measured the radon gas concentrations in tap water samples are taken directly from drinking tap water in sites houses being carried in Thi-Qar governorate by using nuclear track detector (CR-39). The results of measurements have shown that the highest average radon concentration in water samples is found in AL-Refai region which is equal to (0.223 ± 0.03 Bq/L), while the lowest average radon gas concentration is found in AL-Fajr region which is equal to (0.108 ± 0.01 Bq/L), with an average value of (0.175 ± 0.03 Bq/L). The highest value of annual effective dose (AED) in tap water samples is found in AL-Refai region, which is equal to (0.814 μSv/y), while the lowest value of (AED) is found in AL-Fajr region which is equal to (0.394 μSv/y), with an average value of (0.640 ± 0.1 μSv/y). The present results have shown that radon gas concentrations in tap water samples are less than the recommended international value (11.1 Bq/L). There for tap water in all the studied sites in Thi-Qar governorate is safe as for as radon concentration being concerned.

Keywords

Radon, Solid State Nuclear Track Detectors, CR-39, Radon in Water

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1. Introduction

Radon (^{222}Rn) is a radioactive gas with a half- life (3.825 d). It is produced by the decay of naturally occurring radionuclide (^{226}Ra), which is in turn a decay product in the uranium (^{238}U) series. Thoron gas (^{220}Rn), which is a radon isotope, is a decay product in the thorium (^{232}Th) series. The half-life of thoron (56.6 s) which is much shorter than that of radon. Because of such a short half-life of thoron, its emanation from building materials, as well as, its infiltration from the ground and further migration is restricted to a few centimeters only. When radon is inhaled into the lungs, it decays by means of alpha-emission which causes ionization damage when it strikes the lung tissue. Over time, this damage causes lung cancer [1].

Since radon is a gas, it may escape into the air from the material in which it is formed, and since uranium and radium occur widely in water, rocks and soil, radon gas is ubiquitous-outdoors as well as indoors, the air that we inhale contains radon. The radon gas has been recognized as a radiation hazard causing excess lung cancer among underground miners [2].

Some radon stays in the water tap containing radon which presents a risk of developing internal organ cancers, primarily stomach cancer. However, this risk is smaller than the risk of developing lung cancer from radon released to air from tap water. When water leaves a faucet, dissolved gases are released. This process is increased by mechanical sprays during a shower or by the heating and agitation that occur during laundering, washing, and cooking [3].

The aim of the present work is to determine the radon gas concentration in tap water samples for selected regions sites in Thi-Qar governorate by using alpha-emitters registrations which are emitted from radon gas in (CR-39) nuclear track detector.

2. Experimental Procedure

2.1. Description of Study Area

Thi-Qar governorate situated in the south east of Iraq, and it is lies in the heart of Iraqi's marshland areas. It is bordered by Wassit governorate to the north, Al-Qadissiya governorate to the northwest, Al-Muthanna governorate to the west, Basrah governorate to the south, and Missan governorate to the northeast as shown in **Figure 1**. **Table 1** shows symbol and location name for the different studied sites in Thi-Qar governorate. Its largest city is Al-Nasiriyah, with location of latitude (30.33˚ - 32˚N), and longitude (45.37˚ - 47.12˚E). It is located about (4 - 9 m) above the sea level, with a total area of approximately (12,900 km^2) [4].

2.2. The Detector

CR-39 plastic detector of the chess about (500 μm) and area of about (1 × 1 cm^2) was used in the present study which is sensitive to alpha particles of energy up to 40 MeV. It was used as integrating detector of α-particles from ^{222}Rn and daughters nuclei.

When a α-particle penetrates the detector, the particle causes damage along its path, the damage is then made visible by chemical etching. The etching produces a hole in the detector along the path of the particle. The hole can be easily observed in a light transmission microscope with moderate magnification [5].

Table 1. Symbol and location name for samples sites in Thi-Qar governorate.

Symbol	Location name	Symbol	Location name
T1	AL-Refai	T11	AL-Nasiriyah (Sayed Dakhil)
T2	Qulat-Sikar	T12	AL-Nasiriyah (Askan district)
T3	AL-Shatra	T13	AL-Nasiriyah (AL-Askary district)
T4	AL-Fajr	T14	AL-Nasiriyah (Baghdad street)
T5	Suq-AL-Shuyukh	T15	AL-Hammar
T6	AL-Fuhud	T16	AL-Tar
T7	AL-Nasir	T17	AL-Islah
T8	AL-Dwaya	T18	Garmat Beni Saeed
T9	AL-Garraf	T19	AL-Aekeckh
T10	AL-Nasiriyah (Ur district)	T20	AL-Fadlia

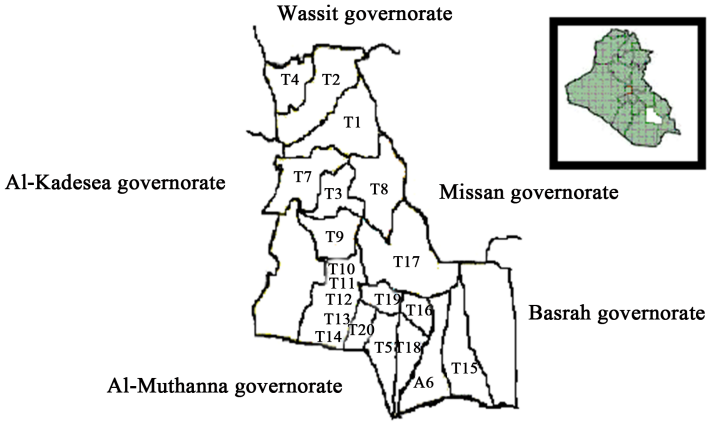

Figure 1. Sketch map showing locations for the studied sites in Thi-Qar governorate.

2.3. The Exposure

About (1/10 litter) in volume of tap water samples were collected from different regions in Thi-Qar governorate. The drinking water samples were obtained from the water networks in dwellings, (four samples were taken from each of the twenty studies regions).

The radon gas concentrations in tap water samples were obtained using the sealed can technique as shown in **Figure 2**.

After one month of exposure the detectors were etched chemically in NaOH solution for 6.25 N at temperature 60˚C for 6 hours. After the etching, the detectors were washed for 30 minutes with running cold water, then with distilled water and finally with a 50% water/alcohol solution. After a few minutes of drying in the air, the detector were ready for track counting. The tracks were counted using an optical microscope having a magnification of 400×.

2.4. Radon Concentration Measurement

The density of the tracks (ρ) in of the samples were obtained according to the following relation [6]:

$$\text{Tracks density}(\rho) = \frac{\text{Average number of total pits (track)}}{\text{Area of field view}} \quad (1)$$

The radon gas concentrations in water samples were obtained by the comparison between track densities registered on the detectors of the samples and that of the standard water samples, which are shown in **Figure 3**, using the relation [7]:

$$C_x = \rho_x \cdot (C_s / \rho_s) \quad (2)$$

where:

C_X: is the radon gas concentration in the unknown sample;

C_S: is the radon gas concentration in the standard sample;

ρ_X: is the track density of the unknown sample (track/mm^2);

ρ_S: is the track density of the standard sample (track/mm^2).

Figure 3 shows the relation between radon gas concentration and track density in standard water samples.

2.5. The Annual Effective Dose in Water

The annual effective dose (AED) of an individual consumer due to intake of radon from tap water in terms of (μSv/y) units was obtained using the relation [8]:

$$\text{AED}(\mu Sv/y) = C_{Rn} C_{Rw} D_{cw} \quad (3)$$

where C_{Rn} is the concentration of radon in the ingested tap water in (Bq/L) units, C_{Rw} is consumption rate of water and it is equal to 730 L/y and D_{cw} is the dose conversion factor and it is equal to (5×10^{-9} Sv/Bq) [9].

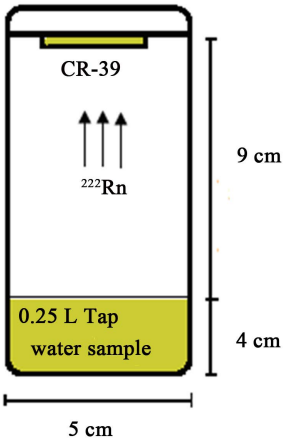

Figure 2. Sealed-cup (can) technique use for water samples.

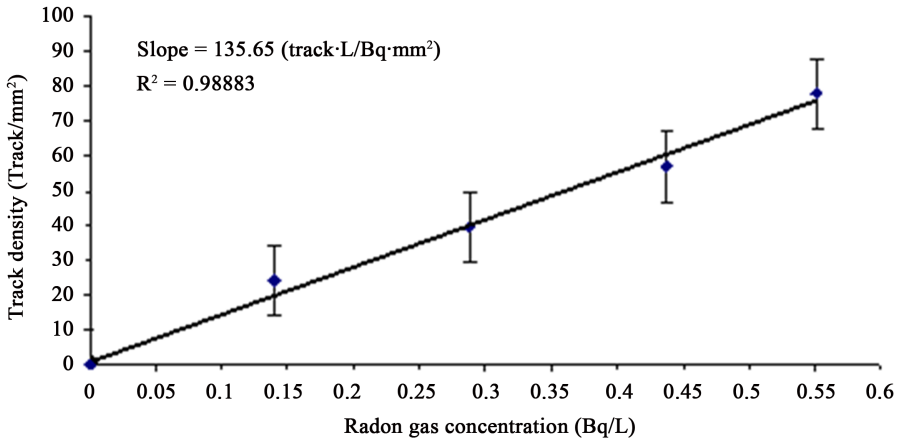

Figure 3. Shows the relation between radon gas concentration and track density in standard water samples.

2.6. Determination Radon Exhalation Rate in Water Samples

The radon exhalation rate (RER) or (E_A) of any sample is defined as the flux of radon released from the surface of material. The radon exhalation rate in terms of area (surface exhalation rate) in units of $Bq \cdot m^{-2} \cdot h$ can be obtained by the relation [10]:

$$\mathrm{RER} = \frac{CV\lambda}{A\left[T + \lambda^{-1}\left(e^{-\lambda T} - 1\right)\right]} \tag{4}$$

where:

C: is the integrated radon exposure ($Bq \cdot m^{-3} \cdot h^{-1}$);
V: is the volume of air in the cup (m^3);
λ: is the decay constant for ^{222}Rn (h^{-1});
A: is the surface area of the sample (m^2);
T: is the exposure time (h).

2.7. Determination of Dissolved Radon Concentration

The dissolved radon concentration in tap water in terms of (Bq/L) units was obtained using the relation [11].

$$C_d\left(Bq/L\right) = C_{Rn}\lambda hT/L \tag{5}$$

where:

C_{Rn}: is the concentration of radon in the ingested tap water in (Bq/L) units;

λ: is the decay constant for ^{222}Rn (h^{-1});

h: is the distance from the surface of water to the detector (m);

T: is the exposure time (h);

L: is the depth of the sample (m).

3. Results and Discussion

Table 2 presents the radon gas concentrations in tap water samples for selected regions in Thi-Qar governorate (obtained by using relation (2)). It can be noticed that, the highest average radon concentrations in tap water samples was found T_1 (AL-Refai) region which was equal to (0.223 ± 0.03 Bq/L), while the lowest average radon concentration was found in T_4 (AL-Fajr) region which was equal to (0.108 ± 0.01 Bq/L), with an average value of (0.175 ± 0.03 Bq/L), see **Figure 4**.

The highest value of annual effective dose (AED) (obtained by using relation (3)) in tap water samples was found in (T_1 region) which was equal to (0.814 μSv/y), while the lowest value of annual effective dose was found in (T_4 region) which was equal to (0.394 μSv/y), with an average value of (0.640 ± 0.1 μSv/y), see **Figure 5**.

Table 2. Sample location, radon gas concentration (C_{Rn}), mean of (C_{Rn}), annual effective dose (AED), radon exhalation rate (RER) and dissolved radon concentration in tap water (C_d), for tap water samples in Thi-Qar governorate.

Sample location	Track density (Track·mm^{-2})	C_{Rn} (Bq·L^{-1})	(AED) (μSv/y)	(RER) (mBq/m^{2}h)	C_d (Bq·L^{-1})
T_1	30.25	0.223 ± 0.03	0.814	0.185	2.728
T_2	28.48	0.210 ± 0.02	0.767	0.174	2.569
T_3	25.50	0.188 ± 0.01	0.686	0.156	2.299
T_4	14.65	0.108 ± 0.01	0.394	0.089	1.321
T_5	28.48	0.210 ± 0.02	0.767	0.174	2.569
T_6	24.14	0.178 ± 0.02	0.650	0.148	2.177
T_7	19.39	0.143 ± 0.02	0.522	0.118	1.749
T_8	28.48	0.210 ± 0.03	0.767	0.174	2.569
T_9	23.73	0.175 ± 0.01	0.639	0.145	2.140
T_{10}	16.27	0.120 ± 0.01	0.438	0.099	1.468
T_{11}	18.71	0.138 ± 0.02	0.504	0.114	1.688
T_{12}	26.45	0.195 ± 0.01	0.712	0.162	2.385
T_{13}	27.80	0.205 ± 0.01	0.748	0.170	2.507
T_{14}	20.34	0.150 ± 0.02	0.548	0.124	1.835
T_{15}	29.84	0.220 ± 0.01	0.803	0.183	2.691
T_{16}	23.06	0.170 ± 0.01	0.621	0.141	2.079
T_{17}	28.48	0.210 ± 0.02	0.767	0.174	2.569
T_{18}	22.11	0.163 ± 0.02	0.595	0.135	1.993
T_{19}	17.63	0.130 ± 0.01	0.475	0.108	1.590
T_{20}	21.70	0.160 ± 0.02	0.584	0.133	1.957
Average	23.77 ± 3.82	0.175 ± 0.03	0.640 ± 0.1	0.145 ± 0.02	2.144 ± 0.36

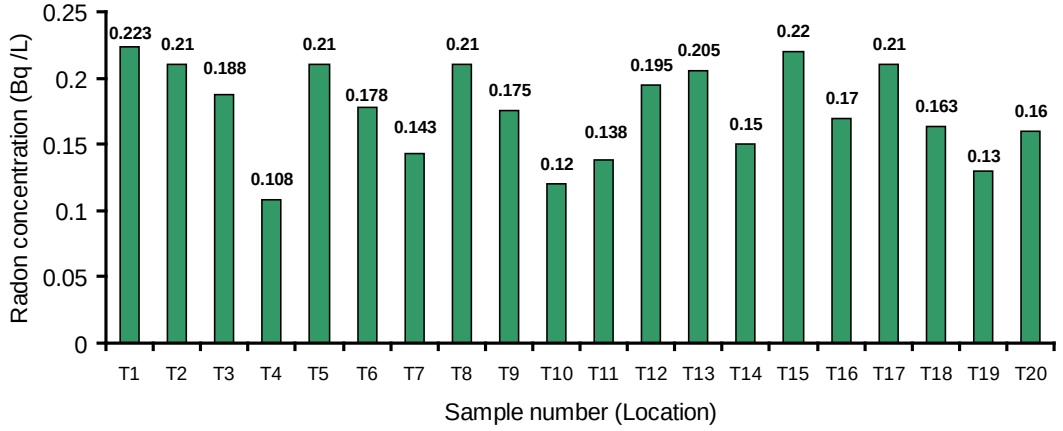

Figure 4. A histogram illustrating the change in radon gas concentration (C_{Rn}) in tap water samples for all regions studied in Thi-Qar governorate.

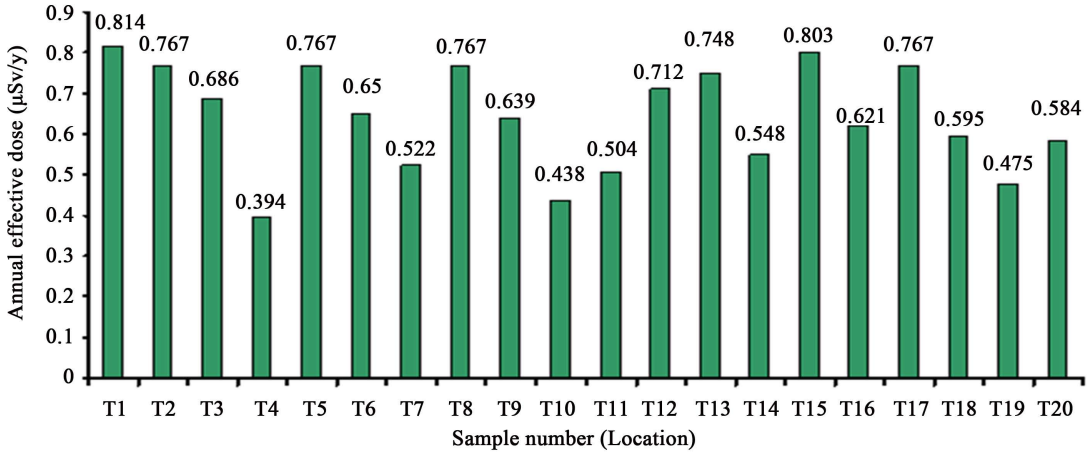

Figure 5. A histogram illustrating the change in annual effective dose (AED) in tap water samples for all regions studied in Thi-Qar governorate.

The highest value of radon exhalation rate (RER) (obtained by using relation (4)) in tap water samples was found in (T_1 region) which was equal to (0.185 mBq/m^{2}h), while the lowest value of radon exhalation rate in tap water samples was found in (T_4 region) which was equal to (0.898 mBq/m^{2}h), with an average value of (0.230 ± 0.14 mBq/m^{2}h), see **Figure 6**.

The highest value of dissolved radon concentration (C_d) (obtained by using relation (5)) in tap water samples was found in (T_1 region) which was equal to (2.728 Bq/L), while the lowest dissolved radon concentration in tap water samples was found in (T_4 region) which was equal to (1.321 Bq/L), with an average value of (2.144 ± 0.36 Bq/L), see **Figure 7**. It is interesting to mention that, some of the present results concerning the radon gas concentrations and dissolved radon gas concentrations for tap water samples, such (AL-Tar, AL-Fajr, AL-Refai) regions in Thi-Qar governorate, were obtained for the first time as for as authors know.

The present results for Thi-Qar governorate have show that the radon gas in all tap water samples were found to be less than the recommended value given by (USEPA, 2012) which was equal to (11.1 Bq/L) [12], Also the annual effective dose in all studied samples were found to be less than the recommended value (1 mSv/y) given by (EPA, 2000) [13]. Therefore, the tap water in all the studied regions in Thi-Qar governorate is safe as far as radon concentration is concerned

4. Conclusion

The higher average radon gas concentration was found in Thi-Qar governorate in (AL-Refai) region which was

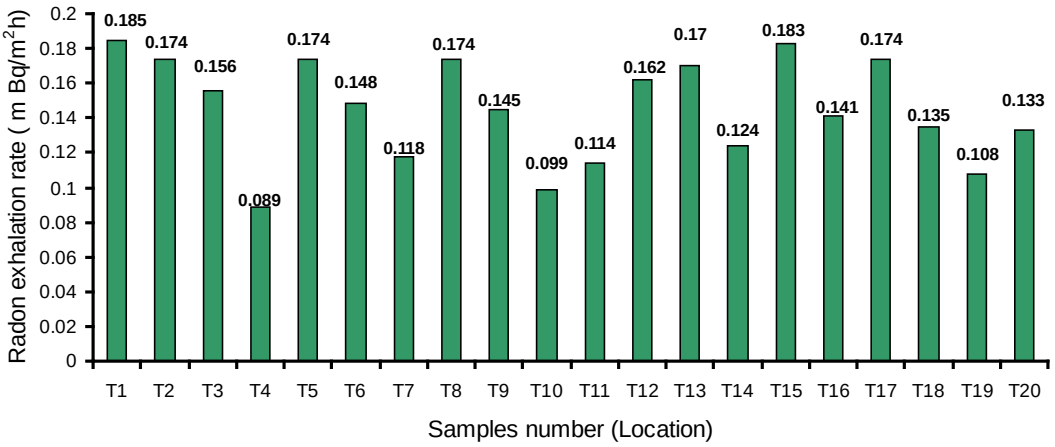

Figure 6. A histogram illustrating the change in radon exhalation rate (RER) in tap water samples for all regions studied in Thi-Qar governorate.

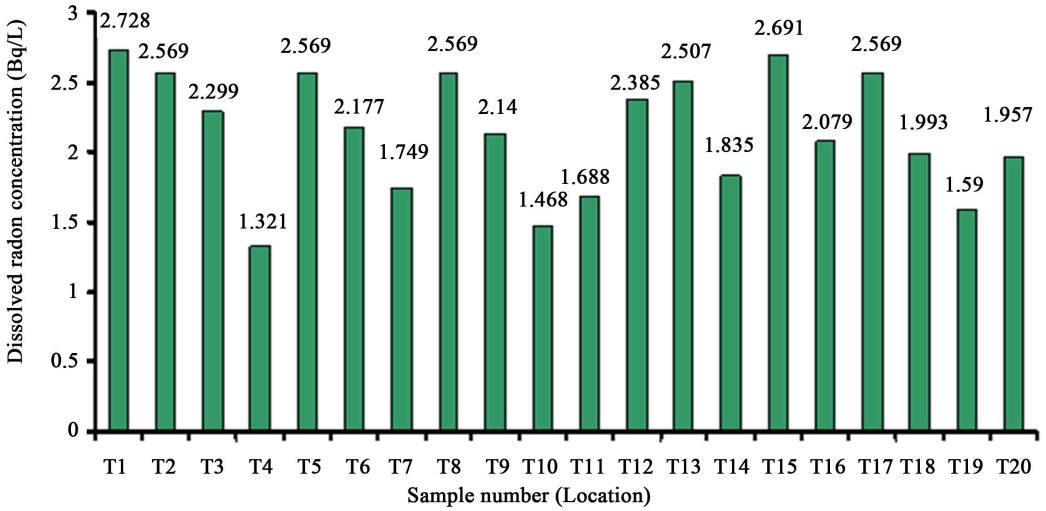

Figure 7. A histogram illustrating the change in dissolved radon concentration (C_d) in tap water samples for all regions studied in Thi-Qar governorate.

(0.223 ± 0.03 Bq/L), while the lowest average radon gas concentration was found in T_4 (AL-Fajr) region which was equal to (0.108 ± 0.01 Bq/L), with an average value of (0.175 ± 0.03 Bq/L), the radon gas concentration in tap water samples was below the allowed limit equal to (11.1 Bq/L).

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