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Measurement of Radon Gas Concentration in Tap Water Samples in Wassit Governorate by Using Nuclear Track Detector (CR-39)

Laith Ahmed Najam[1,*], Mahmood Salim Karim[2], Taghreed Khalid Hameed[2]

[1]Department of Physics, College of Science, University of Mosul, Mosul, Iraq
[2]Department of Physics, College of Education, Al-Mustansiriyah University, Baghdad, Iraq
*Corresponding author: prof.lai2014@gmail.com

Abstract In the present work, we have measured the radon gas concentration in environmental water sample of selected regions in Wassit governorate by using alpha-emitters registrations which are emitted from radon gas in (CR-39) nuclear track detector. The results of measurements indicate that the highest average radon gas concentrations in tap water samples were found in Nuamaniya region, which was equal to (0.820±0.04 Bq/L), while the lowest average radon gas concentration was found in Jassan region, which was equal to (0.325±0.02 Bq/L), with an average value of (0.563±0.12Bq/L). The highest value of annual effective dose (AED) in tap water samples was found in Nuamaniya region, which was equal to (0.08 μSv/y), while the lowest value of annual effective dose (AED) was found in Jassan region, which was equal to (0.03μSv /y), with an average value of (0.05±0.01 μSv/y), the tap water in Wassit governorate is safe as far as radon concentration is concerned.

Keywords: *water sample, tap water, radon concentration, CR-39 detector*

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1. Introduction

Radon (^{222}Rn) is a radioactive gas with a half- life of about (3.825 day) and decay constant of about (0.1812 day^{-1}). It is produced by the decay of naturally occurring radionuclide (radium) (^{226}Ra), which is in turn a decay product in the (^{238}U) series [1].

Thoron gas (^{220}Rn), which is a decay product in the (^{232}Th) series. The half- life is about (55.6 s) which is much shorter than that of radon. Because of such a short half-life of ^{220}Rn, its emanation from building materials such as (soil, brick, gravel,sand, etc…) as well as, its infiltration from the ground. Among the other radon isotopes, is the actinon (^{219}Rn) which is part of the (^{235}U) series, which does not contribute significantly to human radiation exposures due to both low natural abundance of the (^{235}U) precursor and of its very short half-life of about (3.96 s). [2].

Radon gas can enter the dwellings through water systems. In big cities, in many areas, ground water is used as the main water supply for homes and communities. Small public water works and private domestic wells often have closed systems and short transit times that do not remove radon from the water or permit it to decay. This radon escapes from the water to the indoor air as people take showers, wash clothes or dishes, or otherwise use of water [3].

2. Experimental Setup

A- Description of Study Area

Wassit city is located in eastern Iraq, on the border with Iran. Wassit shares internal boundaries with the city of Diyala, Babil, Baghdad, Thi-Qar, Qadissiya and Missan as shown in Figure 1. Wassit is intersected by the Tigris River, along which a ribbon of irrigated farmland runs, giving way to a dry desert landscape to the northeast. Wassit has a dry, desert climate, with temperatures easily exceeding 40°C in summer. Rainfall is scarce and concentrated in the winter months [4].

B- The Detector

The CR-39 plastic detector used in the present study 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 an 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].

C- The Exposure

The samples of water were collected (1/4 litter) volume of samples of tap water were also collected from the same sites in Wassit governorate. The tap water obtained from the water networks in sites houses and the detector area (1×1 cm^2) as shown in Figure 2.

Figure 1. Map showing locations of the studied sites in Wassit city

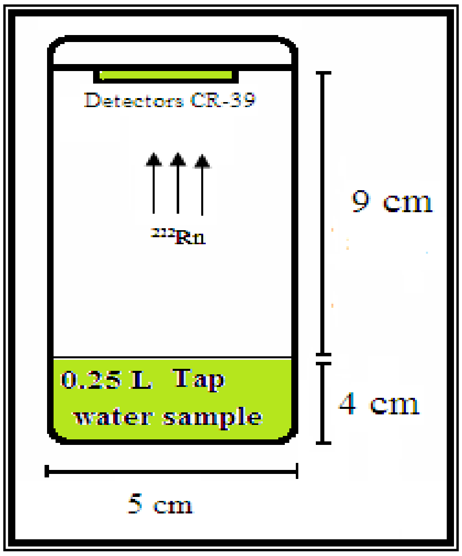

Figure 2. Sealed-cup technique in water sample

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

3. Radon Concentration Measurement

The radon gas concentration in the tap water samples was obtained by using the relation [6]:

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

The standard water sample which was as shown in fig. (3), using the relation [7]:

$$C_X = \rho_X (C_S / \rho_S) \quad (2)$$

Where:
C_X : alpha particles concentration in the unknown sample.
C_S : alpha particles concentration in the standard sample.
ρ_X : track density of the unknown sample (track/mm^2).
ρ_S : track density of the standard sample (track/mm^2).

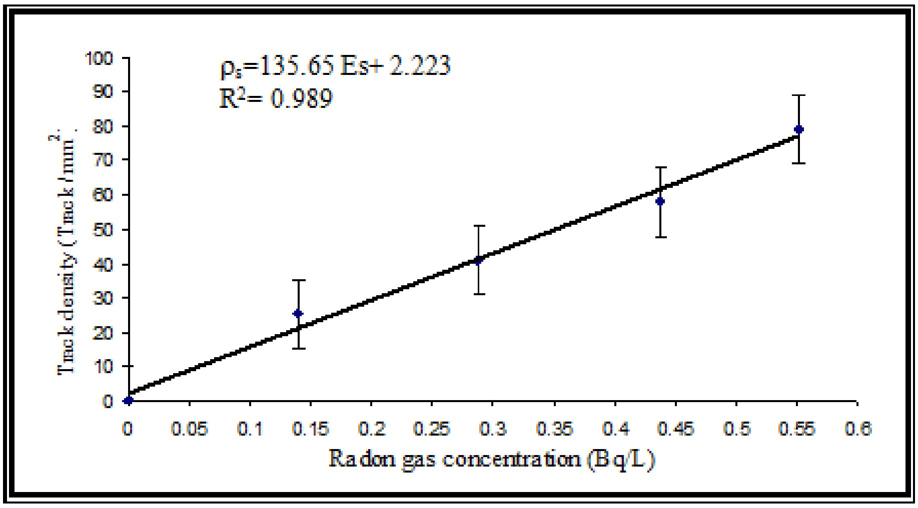

Figure 3. the relation between (C_{Rn}) and track density in water standard samples

3.1. The Annual Effective dose in Water

The annual effective dose of an individual consumer due to intake of radon from tap water is evaluated using the relationship [8]

$$AED_w = C_w C_{Rw} D_{cw} \quad (3)$$

Where AED_w is the annual effective dose (Sv/y) due to ingestion of radionuclide from the consumption of water.
C_w is the concentration of radon in the ingested tap water (Bq/L).
C_{Rw} is the annual intake of tap water (L/y)
D_{cw} is the ingested dose conversion factor for radon (Sv/Bq). As an example:

$$C_w = 19.5\ Bq/L, C_{Rw} = 730L/y, D_{cw} = 5\times10^{-9} Sv/Bq.$$

3.2. Radon Exhalation Rate (RER)

The radon exhalation rate (RER) in units $Bq.m^{-2}.h^{-1}$ can be calculated by [9]:

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

Where:
C: is the integrated Radon exposure($Bq.m^{-3}$).
V: is the volume of air in the cup (m^3)
λ :is the decay constant for ^{222}Rn (h^{-1}) = 0.1812 day^{-1} =0.00755 h^{-1}
A: is the surface area of the sample (m^2)
T: is the exposure time (h) = 30 day =720 h

3.3. Calculation of Dissolved Radon Concentration

The dissolved radon concentration tap water in terms of (Bq/L) units was obtained using the relation [10].

$$C_d(Bq/L) = C_w \lambda hT/L \quad (5)$$

Where:
C_w = the integrated radon exposure ($Bq.L^{-1}$)
λ = Decay constant for ^{222}Rn (h^{-1}) = 0.1812 day^{-1} = 0.00755 h^{-1}
h = the distance from the surface of water to detector (m) = 0.09 m
T = the exposure time (h) =30 day = 720 h
L = the depth of the sample (m) = 0.04m.

4. Results and Discussion

This study was to measure the radon concentration (C_{Rn}) in water sampling, the water samples were taken directly from tap water (tap water) in sites houses was carried 10 samples in Wassit governorate by using the sealed-cup technique.

Table 1 present C_{Rn} the water samples from different regions in Wassit governorate. It can be noticed that, the highest average C_{Rn} in tap water samples was found in Nuamaniya region which was equal to (0.820±0.04 Bq/L), while the lowest average C_{Rn} was found in Jassan region which was equal to (0.325±0.02 Bq/L), as shown in Figure 4, with an average value of (0.563±0.12 Bq/L). The highest value of (AED) in tap water samples was found in Nuamaniya which was equal to (0.08 μSv/y), while the lowest value of (AED) was found in Jassan region which was equal to (0.03 μSv/y), with an average value of (0.05±0.01 μSv/y), the highest value of (RER) in tap water samples was found in Nuamaniya region which was equal to (0.95 $\mu Bq/m^2h$), while the lowest (RER) in tap water samples was found in Jassan which was equal to (0.38 $\mu Bq/m^2h$), with an average value of (0.65 ±0.14 $\mu Bq/m^2h$), the highest value of (C_d) in tap water was found in Nuamaniya region which was equal to (10.03 Bq/L), while the lowest (C_d) in tap water samples was found in Jassan which was equal to (3.98 Bq/L), with an average value of (6.89±1.4 Bq/L). The present results in Wassit governorate show that the radon gas concentration in tap water samples is below the allowed limit from (EPA, 2000) which was equal to (11 Bq/L) [11], while the (AED) in all samples study is below the normal limits of world which was equal to (1 mSv/y) [12], therefore the tap water in Wassit governorate is safe as far as radon concentration is concerned.

Table 1. Regions studied, radon gas concentration C_{Rn} ($Bq.L^{-1}$), annual effective dose (AED), radon exhalation rate (RER), radon concentration dissolved in water (C_d), for tap water samples in Wassit governorate

Regions Studied	C_{Rn} ($Bq.L^{-1}$)				Mean of C_{Rn} ($Bq.L^{-1}$)	(AED) (μSv/y)	(RER) ($\mu Bq/m^2h$)	Cd ($Bq.L^{-1}$)
	1	2	3	4				
Kut	0.43	0.48	0.39	0.36	0.415±0.04	0.04	0.48	5.08
Al-Hai	0.42	0.44	0.38	0.47	0.427±0.03	0.04	0.49	5.23
Badra	0.65	0.72	0.66	0.69	0.680±0.03	0.07	0.79	8.32
Jassan	0.34	0.33	0.28	0.35	0.325±0.02	0.03	0.38	3.98
Sheek Saad	0.53	0.51	0.55	0.47	0.515±0.03	0.05	0.6	6.30
Zorbatya	0.66	0.57	0.63	0.59	0.612±0.03	0.06	0.71	7.49
Al-Suwira	0.75	0.68	0.77	0.73	0.732±0.03	0.07	0.85	8.96
Al-Azezia	0.47	0.52	0.55	0.57	0.527±0.03	0.05	0.61	6.45
Nuamaniya	0.87	0.77	0.79	0.85	0.820±0.04	0.08	0.95	10.03
Al-Wahda	0.54	0.63	0.58	0.57	0.580±0.03	0.06	0.67	7.09
	Average				**0.563±0.12**	**0.05±0.01**	**0.65 ±0.14**	**6.89±1.4**

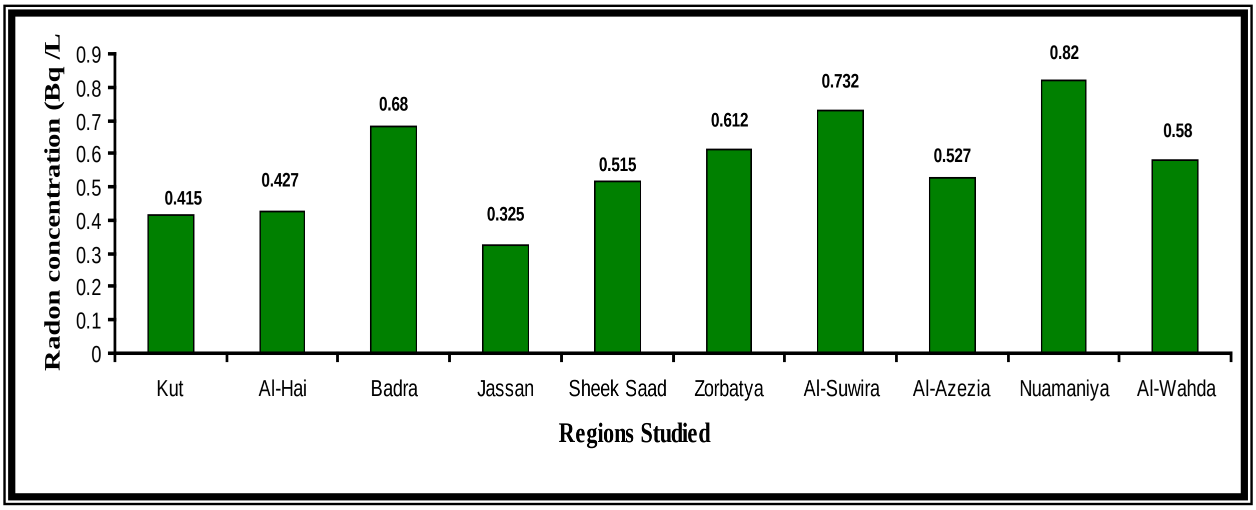

Figure 4. Histogram illustrating the change in (C_{Rn}) in tap water samples in all regions studied in Wassit governorate

5. Conclusions

The tap water samples in all regions in Wassit governorate is lower than the recommended value of (11 Bq/L) reported by the (EPA), so that the tap water was safe for consumption and does not constitute a danger or hazard to the citizens

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