International Journal of Physics, 2015, Vol. 3, No. 6, 233-238
Available online at http://pubs.sciepub.com/ijp/3/6/2
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DOI:10.12691/ijp-3-6-2

Measurement of Radon Gas Concentrations in Tap Water for Baghdad Governorate by 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 for selected regions (some of them were measured for the first time as far as authors know) in Baghdad governorate by using alpha-emitters registrations which are emitted from radon gas in (CR-39) nuclear track detector. The results of measurements have shown that the highest average radon gas concentration in tap water samples was found in B_{16} (AL-Zafraniya) region, which was equal to (0.190±0.01 Bq/L), while the lowest average radon gas concentration was found in B_{20} (AL-Karada) region, which was equal to (0.073±0.01 Bq/L), with an average value of (0.135±0.03 Bq/L). The highest value of annual effective dose in tap water samples was found in B_{16} region, which was equal to (0.694 μSv/y), while the lowest value of annual effective dose was found in B_{20} region, which was equal t (0.267 μSv/y), with an average value of (0.493±0.12 μSv/y). The present results have shown that radon gas concentrations in tap water samples were less than the recommended value (11.1 Bq/L) given by (USEPA,2012). There for tap water in all the studied sites in Baghdad Governorate is safe as for as radon concentration is concerned.

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

Cite This Article: Nada Fadhil Tawfiq, Hazim Louis Mansour, and Mahmood Salim Karim, “Measurement of Radon Gas Concentrations in Tap Water for Baghdad Governorate by Using Nuclear Track Detector (CR-39).” *International Journal of Physics*, vol. 3, no. 6 (2015): 233-238. doi: 10.12691/ijp-3-6-2.

1. Introduction

Radon (^{222}Rn) is a natural inert radioactive tasteless, colorless and odorless gas, whose density is about 7.5 times higher than that of air [1]. It dissolves in water and can readily diffuse with gases and water vapor, thus building up significant concentrations [2]. The earth’s crust contains trace amounts of ^{238}U and ^{232}Th which decay to ^{222}Rn (radon) and ^{220}Rn (thoron gas) respectively. ^{222}Rn and two of its daughters, ^{218}Po and ^{214}Po, are alpha emitters, while ^{214}Pb and ^{214}Bi are beta/gamma emitters [3]. Inhalation of radon and thoron alpha daughters poses a radiation health hazard to the lungs knowing that the physical half life of radon is 3.825 days and half-elimination time from lungs 30 min [1]. However, thoron is often ignored in these studies because of its short half-life ($t_{1/2}$ = 55.6 seconds) and the fact that it is generally lower in concentration than ^{222}Rn in geological material [4]. Health implication of radon in drinking water (the source of drinking water might be tap water, spring water, river water, Artesian well water…etc) is considered an important factor for limiting radon levels in drinking water, which refers to the ingestion of dissolved radon and will result in a radiation dose to the lining of the stomach. Moreover, inhalation of radon gas that has been released from tap water which will contribute to the radon content of indoor air and, if inhaled, will result in a radiation dose to the lung. Long-term exposure to high concentrations of radon in indoor air increases the risk of lung cancer [5].

In the present work, the passive technique using the solid state nuclear track detectors (SSNTDs) has been utilized to measure the radon concentration for tap water samples for selected regions sites in Baghdad governorate. CR-39 detector was used during the currently conducted study because of its simplicity and long-term integrated read out, high sensitivity to alpha-particle radiation ruggedness, availability and ease of handling. The principle of this technique is based on the production of track in the detector due to alpha particles emitted from radon and its progeny. After exposure, the tracks are made visible by chemical etching and counted manually under the optical microscope. The measured track density is then converted into radon concentration [6].

2. Experimental Procedure

2.1. The Detector

CR-39 plastic detector of thickness of 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 its 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 a moderate magnification [7].

2.2. Description of Study Area

Baghdad governorate is the capital of Iraq and it is located on a vast plain bisected by the river Tigris. The Tigris splits Baghdad approximately in half, with the eastern half being called Al-Risafa and the Western half known as Al-Karkh as shown in Figure 1. Table 1 shows symbol and location name for the different studied regions (sites) in Baghdad governorate.

Table 1. symbol and location name for samples sites in Baghdad governorate

Symbol	Location name	Symbol	Location name
B_1	AL-Shaab	B_{11}	AL-Mansour
B_2	Haiy Ur	B_{12}	AL-Yarmouk
B_3	Sader City	B_{13}	AL-Ghazaliya
B_4	AL-Habibiya	B_{14}	AL-Mahmudiyah
B_5	Zayona	B_{15}	AL-Kadhimiyah
B_6	Baghdad AL-Jadeeda	B_{16}	AL-Zafraniya
B_7	AL-Madain	B_{17}	AL-Ameen
B_8	AL-Taji	B_{18}	AL-Hurriya
B_9	AL-Dora	B_{19}	AL-Jihad
B_{10}	AL-Aamiriya	B_{20}	AL-Karada

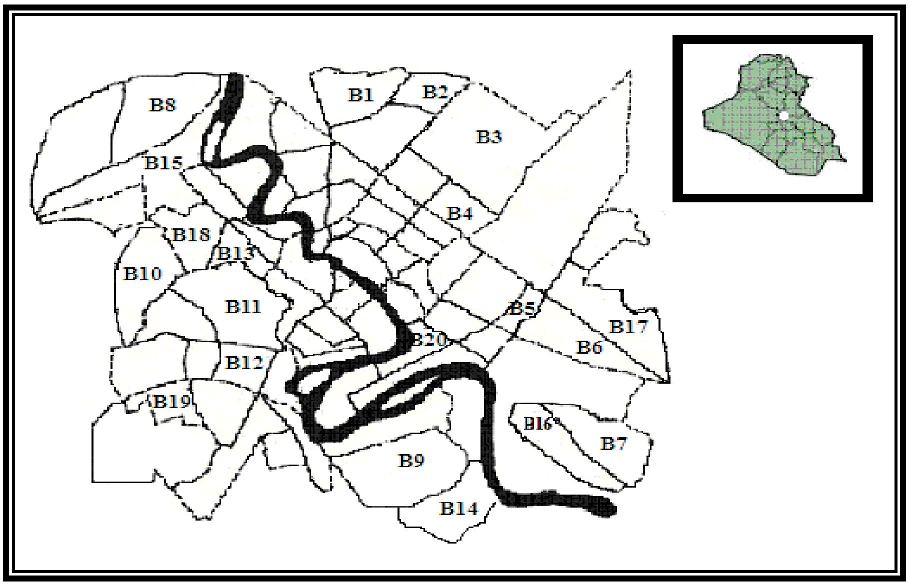

Figure 1. sketch map showing locations for the studied sites in Baghdad governorate

The land on which the city was built is almost entirely flat and low-lying, being of alluvial origin due to the periodic large floods which have been occurred by the river, with location of latitude (31.30º-33.10º N), and longitude (44.32º-44.10º E). It is located about (32 m) above the sea level, with a total area of about (4555 km^2) [8].

2.3. The Exposure

(1/4 litter) in volume of tap water samples were collected from different regions in Baghdad 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-cup (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 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 detectors were ready for track counting. The tracks were then counted using an optical microscope having a magnification of 400x.

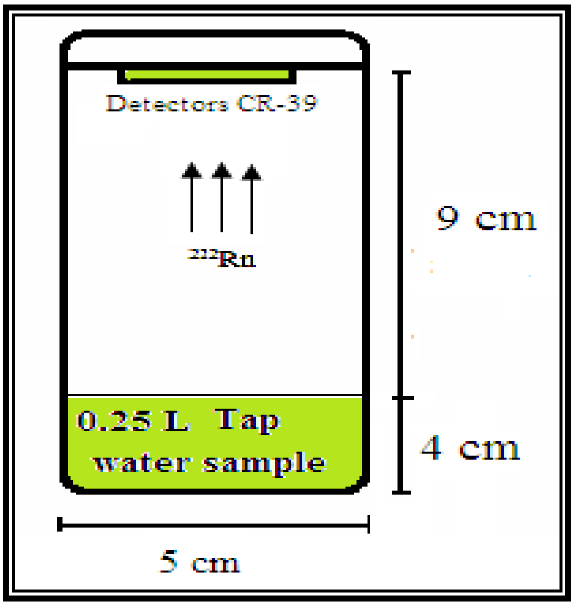

Figure 2. sealed-cup technique used for water samples

2.4. Radon Concentration Measurement

The density of the tracks (ρ) in the samples was obtained according to the following relation [9]:

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

The radon gas concentration 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, using the relation [10]:

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

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).

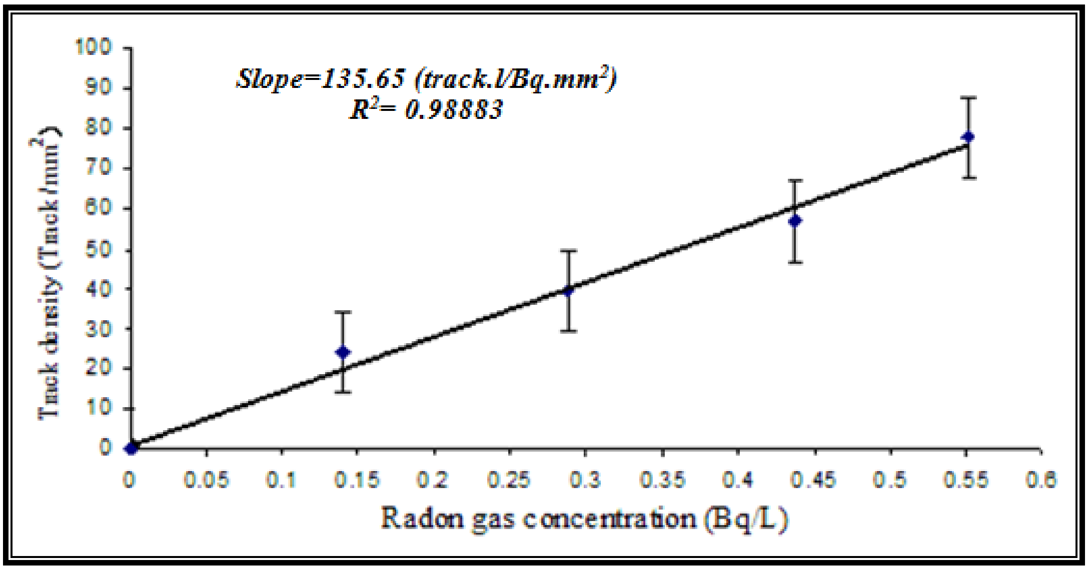

Figure 3. relation between radon gas concentration and track density in standard water samples

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 [11]:

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

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).

2.5.1. Determination of 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.m^{-2}.h^{-1}) can be obtained by the relation [12]:

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

where:
C: is the integrated radon exposure (Bq.m^{-3}.h).
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).

2.5.2. Determination of Dissolved Radon Concentration

The dissolved radon concentration in tap water in terms of (Bq/L) units was obtained using the relation [13].

$$C_d(\text{Bq}/\text{L}) = C_{Rn} \lambda \text{ h T} / \text{L} \quad (5)$$

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 Baghdad governorate obtained by using relation (2). It can be noticed that, the highest average radon concentration in tap water samples was found in B_{16} (AL-Zafraniya) region which was equal to (0.190±0.01 Bq/L), while the lowest average radon concentration was found in B_{20} (AL-Karada) region which was equal to (0.073±0.01 Bq/L), with an average value of (0.135±0.03 Bq/L) see Figure 4.

The highest value of annual effective dose (AED) in tap water samples (obtained by using relation (3) was found in (B16 region) which was equal to (0.694 µSv/y) while the lowest value of annual effective dose was found in (B_{20} region) which was equal to (0.267 µSv /y), with an average value of (0.493±0.12 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 Baghdad governorate

Sample location	C_{Rn} (Bq.L^{-1})				Mean of C_{Rn} (Bq.L^{-1})	(AED) (µSv/y)	(RER) (µBq/m^{2}h)	C_d (Bq.L^{-1})
	1	2	3	4				
B_1	0.18	0.17	0.17	0.15	0.168±0.01	0.613	139.764	2.055
B_2	0.11	0.15	0.12	0.09	0.118±0.02	0.431	98.168	1.443
B_3	0.20	0.18	0.18	0.17	0.183±0.01	0.668	152.243	2.238
B_4	0.09	0.08	0.10	0.10	0.093±0.01	0.334	77.369	1.138
B_5	0.13	0.11	0.09	0.08	0.103±0.02	0.376	85.689	1.260
B_6	0.12	0.14	0.10	0.08	0.110±0.02	0.402	91.512	1.345
B_7	0.16	0.14	0.11	0.12	0.133±0.02	0.486	110.646	1.627
B_8	0.12	0.10	0.09	0.09	0.100± 0.01	0.365	83.193	1.223
B_9	0.20	0.18	0.16	0.15	0.173±0.02	0.632	143.924	2.116
B_{10}	0.11	0.10	0.08	0.09	0.095±0.01	0.347	79.033	1.162
B_{11}	0.19	0.17	0.12	0.14	0.155±0.03	0.566	128.949	1.896
B_{12}	0.23	0.19	0.19	0.13	0.185±0.04	0.675	153.907	2.263
B_{13}	0.11	0.09	0.08	0.04	0.080±0.02	0.292	66.554	0.979
B_{14}	0.23	0.18	0.19	0.13	0.183±0.04	0.668	152.243	2.238
B_{15}	0.17	0.17	0.14	0.09	0.143±0.03	0.522	118.966	1.749
B_{16}	0.21	0.19	0.19	0.17	0.190±0.01	0.694	158.066	2.324
B_{17}	0.15	0.13	0.08	0.04	0.100±0.04	0.365	83.193	1.223
B_{18}	0.18	0.18	0.11	0.08	0.138±0.05	0.504	114.806	1.688
B_{19}	0.22	0.20	0.19	0.11	0.180±0.04	0.657	149.747	2.202
B_{20}	0.09	0.08	0.06	0.06	0.073±0.01	0.267	60.731	0.893
Average					**0.135±0.03**	**0.493±0.12**	**112.435 ±28.82**	**1.653±0.42**

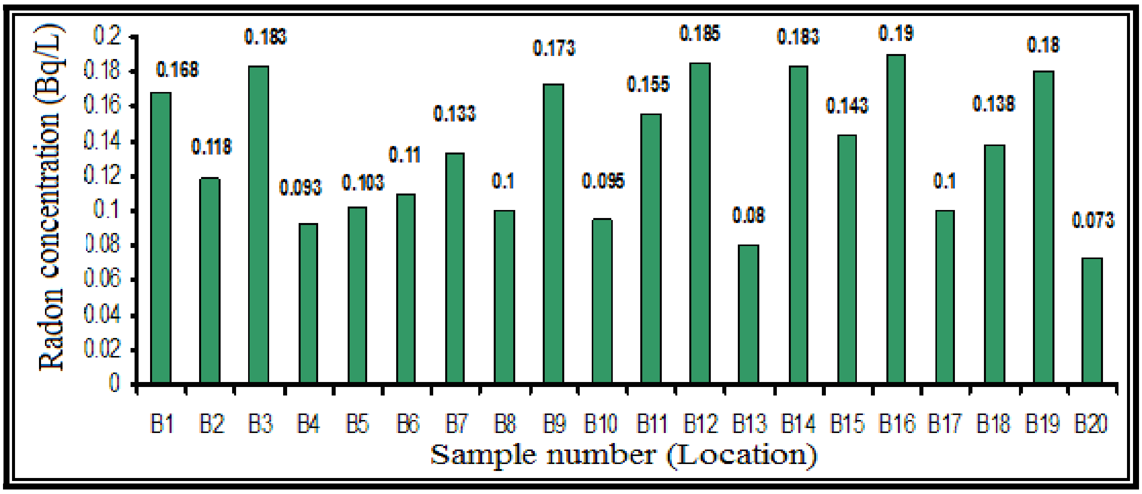

Figure 4. A histogram illustrating the change in radon gas concentration (C_{Rn}) in tap water samples for all regions studied in Baghdad governorate

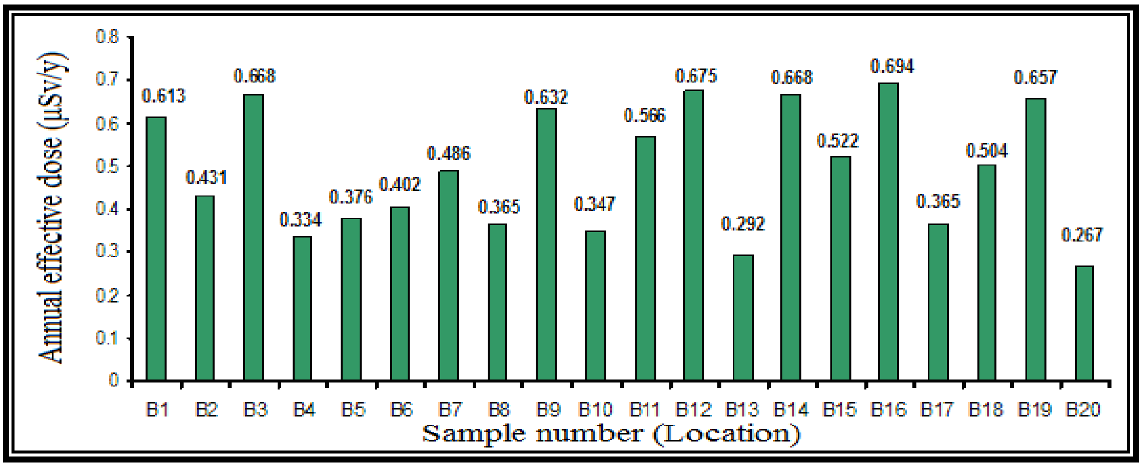

Figure 5. A histogram illustrating the change in annual effective dose (AED) in tap water samples for all regions studied in Baghdad governorate

The highest value of radon exhalation rate (RER) in tap water samples (obtained by using relation (4) was found in (B_{16} region) which was equal to (158.066 μBq/m^{2}h), while the lowest value of radon exhalation rate in tap water samples was found in (B_{20} region) which was equal to (60.731 μBq/m^{2}h), with an average value of (112.435 ±28.82 μBq/m^{2}h), see Figure 6.

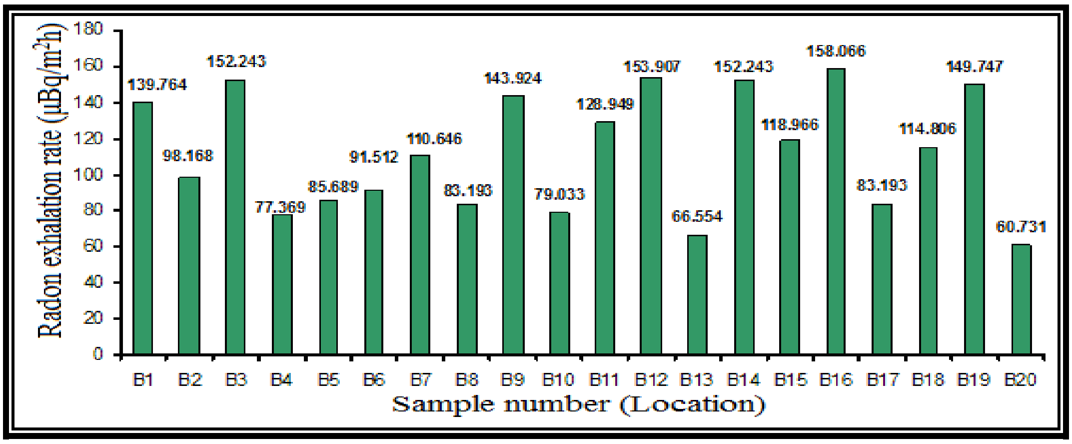

Figure 6. A histogram illustrating the change in radon exhalation rate (RER) in tap water samples for all regions studied in Baghdad governorate

The highest value of dissolved radon concentration in tap water samples (C_d) (obtained by using relation (5) was found in (B_{16} region) which was equal to (2.324 Bq.l^{-1}), while the lowest dissolved radon concentration in tap water samples was found in (B_{20} region) which was equal to (0.893 Bq/L), with an average value of (1.653±0.42 Bq.l^{-1}), see Figure 7.

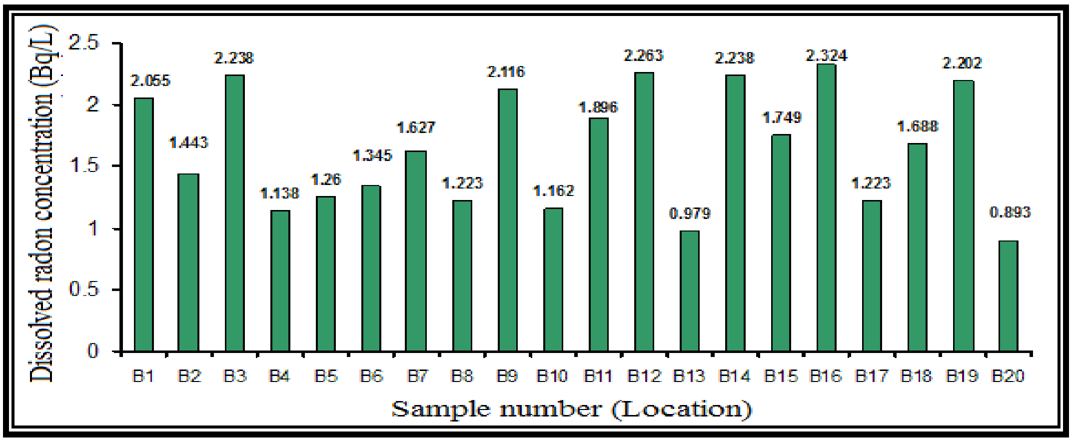

Figure 7. A histogram illustrating the change in dissolved radon concentration (C_d) in tap water samples for all regions studied in Baghdad governorate

The present results for Baghdad governorate have shown that the radon gas concentration 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) [14]. 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) [15]. Therefore the tap water in all the studied regions in Baghdad governorate are safe as far as radon concentration is concerned. 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 as (AL-Karada, Zayona and AL-Aamiriya) regions in Baghdad governorate, were obtained for the first time as far as authors know.

4. Conclusions

The highest average radon gas concentration in tap water samples was found in B_{16} (AL-Zafraniya) region, which was equal to (0.190±0.01 Bq/L), while the lowest average radon gas concentration was found in B_{20} (AL-Karada) region, which was equal to (0.073±0.01 Bq/L), with an average value of (0.135±0.03 Bq/L). The radon gas concentration in tap water samples were found to be less than the recommended value of (11.1 Bq/L) given by (USEPA,2012). Therefore, the tap water in all the studied regions in Baghdad governorate is safe as far as radon concentration is concerned.

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