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Measurement of Radon Gas Concentrations and Hazard Effects in Underground Water Samples in Karbala Governorate of Iraq

Abstract- One of the most characterizations of social health is the existence availability of sources irrigation water. Since the main source of water, contamination is radon gas. Six regions in Karbala province in Iraq were chosen to evaluate Radon level in underground water-samples by using (SSNTD-CR-39) Detector. The current measurements showed that highest level was in Al-Horr region to be $4.152 \pm 2.2 \text{ Bq/L}$, where lowest concentration was in Hay-Rumdan $2.165 \pm 1.6 \text{ Bq/L}$. The maximum Annual-Effective Dose (AED) was found in Al-Horr to be $14.34 \pm 3.5 \mu\text{Sv/y}$, whereas the minimal value indicated at Hay-Rumdan $8.66 \pm 3.1 \mu\text{Sv/y}$. In general, it has been found that Radon-level concentration, in the studied groundwater-samples, was less than allowed permissible value 11.1 Bq/L and annual effective-doses were below the recommended international value 1 mSv/y . Therefore, groundwater in all underground water studied in Karbala province is safe where the focus of radon obsession is not a public concern.

Keywords- Radon, underground-water, Annual Effective Dose, CR-39.

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1. Introduction

The ^{210}Rn decay to ^{225}Rn among seventeen radioactive radon isotopes has different half-lives of 14.6h to 2.4h respectively. The longer half-life 3.8235day is for ^{222}Rn [1]. Since the underground-water passes through different formation of rocks and soil, dissolves minerals, many compounds, and radioactive materials. Therefore, underground water may have more radioactive isotopes than the surface water [2]. Radon concentrations are formed from gamma emitting following the decay of the radon progeny ^{214}Pb and ^{214}Bi , after reaching the secular equilibrium with ^{222}Rn [3, 4]. The ingestion of radon gives an additional exposure dose to the human body which possesses a risk factor [5]. Hence, the content of radon in underground water-samples must be determined by different reliable methods. Several procedures can be found in the literatures to assess radon measurements in groundwater using different techniques such as solid-state detector or gamma spectrometry [6, 7, 8]. The aim of this study is to investigate radon level measurements in underground water –samples, via CR-39 detectors, from selected regions in Karbala city.

2.1. Study-Area

Figure 1 explains the sites of selected underground water-samples areas [9].

2.2. The Detector-used

SSNTD-CR-39 with chemical composition $\text{C}_{12}\text{H}_{18}\text{O}_7$, thickness $500 \mu\text{m}$, density 1.360 gm/cm^3 and area 1 cm^2 was used. The etching makes holes which can be simply recognized in microscope [10].

2.3. Sampling and Exposure-Time

Samples were collected from 6 groundwater wells. This supplied the irrigation area around, see Table 1. These samples were collected and analyzed for physical and chemical properties according to the standard methods. Sealed plastic-can technique was used as shown in Figure 2. The water samples were exposed for three months, first month was for pre-equilibrium.

2. Materials and Methods

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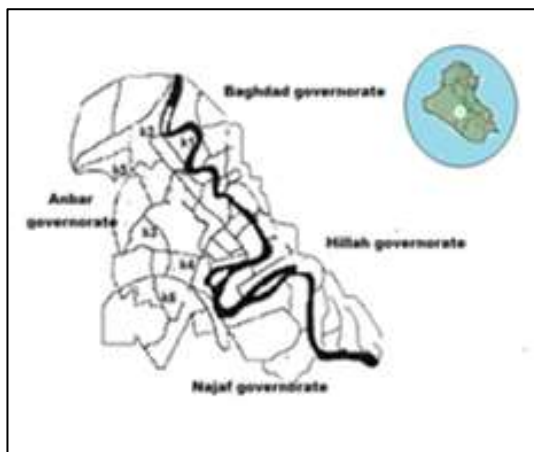


Figure 1: Underground water-samples locations throughout Karbala-City

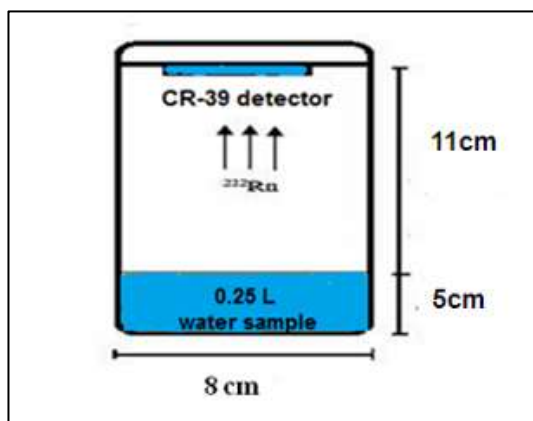


Figure 2: Sealed plastic -can technique used for ground water samples.

3. Basic Considerations

3.1. Radon Gas-Concentration

The following Equation was used to calculate the track density [11]:

$$\text{Tracks density } (\rho) = \frac{\text{Averagenumber of totalpits(track)}}{\text{Area of thefield view}} \quad (1)$$

See Figure 3, Radon concentrations can be obtained as [12]:

$$C_x(\text{sample})/\rho_x(\text{sample}) = C_s(\text{standard})/\rho_s(\text{standard}) \quad (2)$$

$$C_x = \rho_x \cdot (C_s / \rho_s) \quad (3)$$

This relation is cleared in Figure 3, as defined in Ref. [9].

3.2. Annual-Effective Dose in Water

For intake consumption of radon, AED can be estimated for popular as [13]:

$$\text{AED } (\mu\text{Sv/y}) = C_{Rn} \cdot C_{Rw} \cdot D_{cw} \quad (4)$$

Where C_{Rn} (Bq/L)=concentration of radon, $C_{Rw}=730\text{L/y}$ and $D_{cw}=5 \times 10^{-9} \text{ Sv/Bq}$ [14].

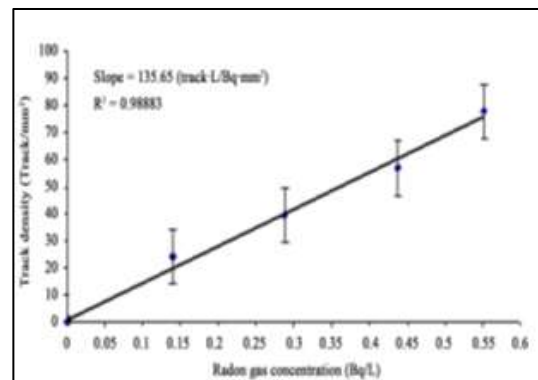


Figure 3: Density of the tracks versus concentrations of radon in standard water samples

3.3. Ra-222 Parameter's in Water Samples

3.3.1. Exhalation-Rate

It defined by [15]:

$$E_A(\text{Bq} / \text{m}^2 \cdot \text{h}) = \frac{CV\lambda}{A[T + 1/\lambda(e^{-\lambda T} - 1)]} \quad (5)$$

Where C is the integrated Radon-exposure ($\text{Bq} \cdot \text{h} \cdot \text{L}^{-1}$). A, V, λ and T are as defined in Ref. [9, 13].

3.3.2. Dissolved Radon-Concentration in Water

It can be calculated according to the following Equation [16]:

$$C_d (\text{Bq/L}) = C_{Rn} \cdot \lambda \cdot D \cdot T / L_s \quad (6)$$

Where C_{Rn} is the radon-concentration in the ingested water (Bq/L), D is the distance between water surface and the detector (m), and L_s is the sample depth (m).

4. Results and Discussion

The concentrations of radon in the underground water-samples are presented in Table 1. Figure 4 illustrates that maximal value was recorded in Horr $4.152 \pm 2.2 \text{ Bq/L}$, while the minimum occurred in Hay Rumdan $2.165 \pm 1.6 \text{ Bq/L}$, with an average $2.848 \pm 1.7 \text{ Bq/L}$. The maximum value of annual effective dose $14.34 \pm 3.5 \mu\text{Sv/y}$ estimated at Al-Horr and the minium occurred in Hay-Rumdan $8.66 \pm 3.1 \mu\text{Sv/y}$, with an average $10.80 \pm 3.1 \mu\text{Sv/y}$, as explained in Figure 5.

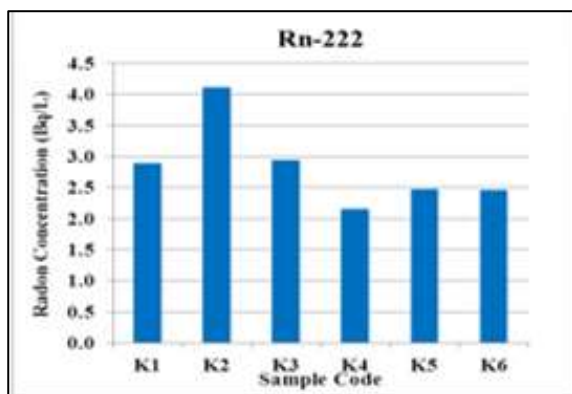


Figure 4: Radon concentration in groundwater samples in Karbala Governorate.

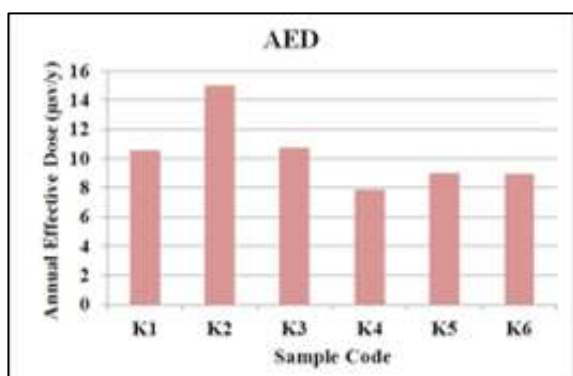


Figure 5: Annual effective dose in groundwater samples in Karbala governorate

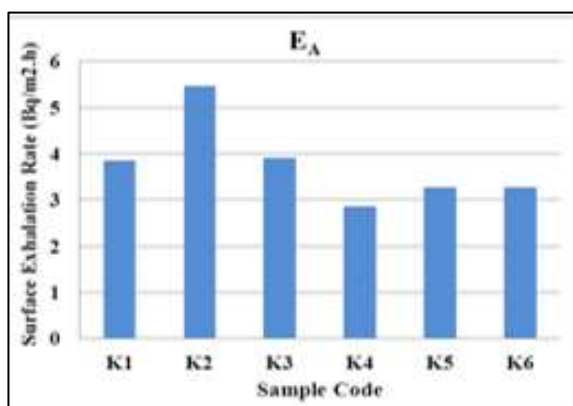


Figure 6: Surface exhalation rate in groundwater Samples in Karbala governorate.

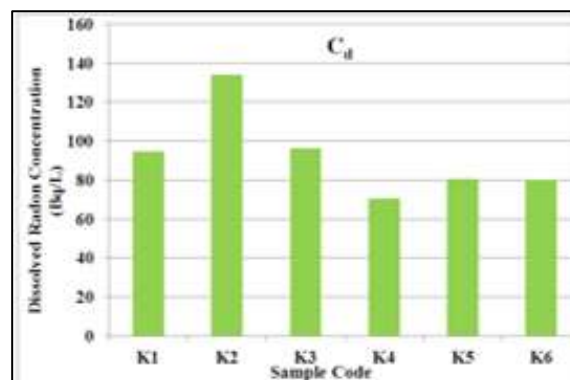


Figure 7: Dissolved radon concentration in groundwater samples in Karbala governorate

The average radon exhalation rate (E_A) was $2.629 \pm 1.6 \text{ Bq/m}^2 \cdot \text{h}$. With a maximum $3.834 \pm 1.8 \text{ Bq/m}^2 \cdot \text{h}$ found in Al-Horr and the minimum recorded in Hay-Rumdan $1.984 \pm 1.3 \text{ Bq/m}^2 \cdot \text{h}$, see Figure 6. Figure 7 illustrates the (C_d). The maximum was in Al-Horr $124.842 \pm 10.1 \text{ Bq/L}$, and the minimum was found in Hay-Rumdan $66.42 \pm 8.4 \text{ Bq/L}$, with an average $87.716 \pm 8.9 \text{ Bq/L}$.

The assess results of all samples shows the concentrations of radon was lower than drinking water limit 300 pCi/L (or 11.1 Bq/L) [17]. Also the AED results were less than 1 mSv/y [18]. Hence, all results were safe and not worrisome because they are less than conventional in international organizations [19, 20].

Table 2 tabulated different concentrations ranges of radon for five regions throughout Iraq territory are comparable with the present result, which is higher than others.

Table 2. Radon-concentrations in groundwater for different regions in Iraq.

Region (year)	Technique used	C_{Rn} (Bq/L)	Ref.
Iraq/Al- Hella (2013)	RAD-7	0.036 -0.941	Al-Mashhadany et al. [21]
Iraq/Karbala	CR-39	Shut- al-Hella's water	Abdalsattar [22]
Al-Hindiyah City (2014)		0.549 ± 0.041 Drill well water	
		0.410 ± 0.054 Ground water	
Iraq/Najaf (2014)	RAD-7	$0.569 - 5.010$ Groundwater	Alasedi [23]
Iraq/Najaf/ Al-Haidariya Nahia (2015)	RAD-7	0.487 ± 0.121 Groundwater	Abojassim et al. [24]
Iraq/Babyl-Al-Qasim City (2015)	RAD-7	$0.793 - 8.005$ Groundwater	Hasan et al. [25]
Present work (2016)	CR-39	2.848 ± 1.7	Present-work

5. Conclusions

Six groundwater samples collected from all territory of Karbala City were examined for determination Radon level-concentrations. The results indicate that Radon-concentrations in groundwater are below the contamination level 11.1Bq/L as announced by 'USEPA'. The total concentrations in samples recorded 2.165 ± 1.6 Bq/L as minimum level and 4.152 ± 2.2 Bq/L as maximum. In addition, the annual effective dose results were less than 1mSv/y recorded by 'WHO' and 'UNSCEAR'. For this reason, groundwater in Karbala'-City is safe and not bothersome as the results of the concentration of radon are concerned.

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