Practical Study to Assess Radioactive Radon Gas in Groundwater Samples of Dhi-Qar Governorate

Awsam Abdulsattar Marzaali 1*, Mohammed A. Al-Shareefi 2 , and Ali Abid Abojassim 3

1,2 Department of Physics, College of Science, University of Babylon, Babylon, Iraq
3 Department of Physics, Faculty of Science, University of Kufa, Al-Najaf, Iraq

* Corresponding authors: stud.awsam.ali@uobabylon.edu.iq

Abstract

This research focuses on measuring the concentrations of radioactive radon gas (222Rn) in groundwater samples that collected from different places in Dhi-Qar Governorate, using RAD-7 (RAD-7 H2O) detector. Also, annual effective dose (AED) and lifetime cancer risk due to ingestion of 222Rn in samples of present study as drinking water were evaluated. The results show that, 222Rn concentration in Bq/L were ranged from 0.032±0.022 to 0.780±0.110, with an average 0.205±0.04. Also, the range of AED were changed from 0.08 µSv/y to 1.99 µSv/y, with an average 0.52±0.10 µSv/y. While lifetime cancer risk (×10⁻⁴) were ranged from 0.003 to 0.077, with an average 0.020±0.004. Accordingly, 222Rn concentrations in samples of present study (as groundwater) was within the permissible limit according to the Environmental Protection Agency (EPA), as the maximum concentration of radon in the water reached (11.1) Bq/L, but 222Rn concentrations for some samples were higher than the permissible limit for drinking water that equal (0.4 Bq/L) according to WHO2008. Also, The values of AED and lifetime cancer risk in all samples were found lower than the safety limit for the healthy drinking water. So, it may be concluded that groundwater in the Dhi-Qar governorate- Iraq have not environmental impacts For Radioactive Radon Gas on the health of human.

Keyword: radioactive radon, environmental impacts, groundwater, RAD-7 and Dhi-Qar Governorate.

1. Introduction

The radioactive pollution occupies large and dangerous among the other types of pollution. This is due to the proliferation of nuclear industry and expanding the use of nuclear energy and increasing amounts of radioactive waste from the industry and the use of nuclear energy in power generation and uses of radioisotopes in medicine, agriculture, industry and research in various kinds of science [1]. The sources of radiation may be naturally occurring originated from the earth, interstellar space, human body itself or from man-made sources as medical, industrial applications [2]. Radon is occurring naturally, odorless, colorless, radioactive, tasteless, and a noble gas. In fact, it is the heaviest noble gas in nature. It is occurs naturally as a product of the Uranium decay. Radon contributes by over 50% of the total natural radiation that human received [3]. Based on this, radon consists of a significant health hazard which leads to radon monitoring in different environments around the world. The concentration of 222Rn in ground water depends on the concentration of its parent 226Ra in underlying rock. The short-life of 222Rn (3.82 d) together with the slow rate of migration of ground water allows the 222Rn in solution to be in approximate secular equilibrium with the 226Ra in the local rock [4]. Radon concentration in water has been known to be high in most granite and in high-grade metamorphic rocks, whereas less metamorphosed rocks have somewhat less 226Ra [5]. Radon is one of the sources of radioactivity that is dangerous to human health due to its wide spread in the soil, air and groundwater, and thus the water supply networks in these areas are
not free of this gas, to determine the extent and increase of the dangerous concentrations of this gas in the water. Used leading to this successful communication to increase awareness and knowledge that can protect better public health. There are many previous studies on the subject of measuring radon gas concentration in water [6-10]. The aim of the research is to measure the concentrations of radioactive radon gas in groundwater samples of Dhi-Qar Governorate, Iraq using RAD-7 detector and to calculate the annual effective dose with lifetime cancer risk due to radon concentrations and low concentrations that found in samples of the study area. The maps of $^{222}$Rn concentrations, AED, and lifetime cancer risk were in the study area using GIS technique.

2. Materials and Method

2.1. Area of Study and Collection samples

Dhi-Qar is one of the Iraqi governorates. It lies on the banks of the Euphrates River, 370-km southeast of Baghdad, capital of Iraq. It is located 31°05'388.8"N latitudes, 46°26'66.7"E 32.05 longitudes. It rises about 9 m above the sea level [11]. Twenty samples of groundwater were collected from different areas of Dhi-Qar Governorate, Iraq to measure the concentration of radon gas. Table (1) show sample code that were subject to the study and their locations according to the GPS system. Figure 1 shows location of groundwater samples in present study area that draw by GIS technique.

| NNo. | Sample code | location latitude | longitude |
|------|-------------|-------------------|-----------|
| 1    | G1          | 31.282627         | 46.204296 |
| 2    | G2          | 31.282472         | 46.203239 |
| 3    | G3          | 31.283112         | 46.202623 |
| 4    | G4          | 31.283650         | 46.200599 |
| 5    | G5          | 31.284638         | 46.200785 |
| 6    | G6          | 31.284831         | 46.199862 |
| 7    | G7          | 31.282002         | 46.159512 |
| 8    | G8          | 31.281928         | 46.159144 |
| 9    | G9          | 31.283792         | 46.156724 |
| 10   | G10         | 31.283882         | 46.155858 |
| 11   | G11         | 31.284235         | 46.156534 |
| 12   | G12         | 31.284764         | 46.156495 |
| 13   | G13         | 31.284760         | 46.157420 |
| 14   | G14         | 31.285286         | 46.157014 |
| 15   | G15         | 31.284659         | 46.158083 |
| 16   | G16         | 31.284585         | 46.157730 |
| 17   | G17         | 31.284383         | 46.157204 |
| 18   | G18         | 31.284437         | 46.156343 |
| 19   | G19         | 31.285414         | 46.157110 |
| 20   | G20         | 31.284893         | 46.157788 |
2.2. Measurement of Radon Gas

Radon measurements in water, the RADH₂O detector is used as an attachment to the RAD7 detector which is intended to measure radon gas in water and for a wide range of concentrations. The readings are obtained within one hour of taking the sample and disinfection must be carried out, i.e. the humidity degree that is less than 6% must be observed, after which we start testing by setting the system on Grab (when measuring the concentration radon in water we put a Pump on the Grab (i.e. extract radon from the sample). The pump is running for a period of five minutes per session in which radon is drawn from the sample and delivered to the measurement room in RAD7 and after it stops and after more than five minutes it reaches equilibrium and then it is repeated for four sessions with five minutes per session and this means the total test duration is 30 minutes and after the end of each run will print out the included summary (mean radon concentration, humidity and temperature, standard deviation) [13]. Also includes other information about the operating number, the 4-circuit diagram and the accumulated spectrum, the number of turns [14]. The rate of radon removal from
water in the air ring in a sample of 250 ml is 94% and it is very high. Figure (1) shows the schematic diagram of the RADH2O supplement [14,15].

![Figure 1: RADH2O detector [14].](image)

### 2.3. Theoretical calculations

AED in unit (Sv/y) based on the ingestion of 222Rn concentrations from groundwater when using as drinking water for adults was determined by equation (1) [16]:

\[
AED \left( \frac{Sv}{y} \right) = C \left( \frac{Bq}{L} \right) \times WC \left( \frac{L}{y} \right) \times DCF \left( \frac{Sv}{Bq} \right) \ldots \ldots (1)
\]

where C is 222Rn concentration in unit (Bq/L), WC is the annual water consumption for a person that equal 2 in unit (L/d) [9] and DCF is conversion factor in unit (µSv/Bq) that equal 0.0035 µSv/Bq [17].

The lifetime cancer risk based on the ingestion of 222Rn concentrations from groundwater when using as drinking water for adults was determined by equation (2) [18]:

Lifetime cancer risk = \( AED \times DL \times RF \) \ldots \ldots (2)

where, DL is the duration of life (70yr) and RF is the risk factor (0.055 Sv\(^{-1}\)) recommended by the ICRP [19].

### 3. Results and Discussion

The results of 222Rn concentration, AED and, lifetime cancer risk was determined for groundwater samples that collected from different areas of Dhi-Qar Governorate, Iraq as shown in Table (2). Through the results of examining the samples in groundwater shown in Table (1), 222Rn concentration were ranged from 0.032±0.022 Bq/L that recorded in the sample (G9) to 0.780±0.110 Bq/L that recorded in the sample (G17), with an average 0.205±0.04 Bq/L. Through the results in Table (2), it was found that the radon gas concentrations in groundwater of present study were within the permissible limit set by the US Environmental Protection Agency (EPA) because the limit The highest permissible concentration of radon in water (11.1) Bq/L [20]. Also, The results of 222Rn concentration (Figure 2) in groundwater samples when using as drinking water were lower than the permissible concentration limit reported by WHO 1993 (0.4Bq/L) [21], except samples G17 and G19.

The lifetime risk due to 222Rn in water samples intake (see Table 2 and Figure 4) was ranged from 0.003×10\(^{-4}\) to 0.077×10\(^{-4}\), with an average (0.020±0.004)×10\(^{-4}\), which it less than the admissible limit of 10\(^{-4}\) [23]. The source of groundwater in these areas is either from rain water that penetrates into the ground through its rock layers, or geological water originating...
from rocks between fresh water or seas that store water between its rocks. The results shown in Table (2) indicated that there are variations in radon concentrations in all samples which it can be attributed to the difference in the geological nature of each area as well as to the movement of water and its speed [24]. On the other hand, radon gas concentration varies due to factors such as temperature, air pressure, humidity and changes in the Earth's layers. Figure (5), (6) and (7) showed the geographical distribution of $^{222}$Rn concentrations, AED, and lifetime cancer risk in groundwater samples at Dhi-Qar Governorate, Iraq that draw by GIS technique. Finally, Can be found that through the results that the groundwater in present study area has not exceeded the allowable limit and has not affected on health human and environmental according to levels of radioactive radon gas.

| No. | Sample code | $^{222}$Rn concentrations (Bq/L) | AED (µSv/y) | Lifetime cancer risk×10$^{-4}$ |
|-----|-------------|---------------------------------|-------------|-------------------------------|
| 1   | G1          | 0.160±0.050                     | 0.41        | 0.016                         |
| 2   | G2          | 0.192±0.055                     | 0.49        | 0.019                         |
| 3   | G3          | 0.222±0.059                     | 0.57        | 0.022                         |
| 4   | G4          | 0.188±0.054                     | 0.48        | 0.018                         |
| 5   | G5          | 0.159±0.050                     | 0.41        | 0.016                         |
| 6   | G6          | 0.118±0.043                     | 0.30        | 0.012                         |
| 7   | G7          | 0.042±0.026                     | 0.11        | 0.004                         |
| 8   | G8          | 0.199±0.056                     | 0.51        | 0.020                         |
| 9   | G9          | 0.032±0.022                     | 0.08        | 0.003                         |
| 10  | G10         | 0.170±0.052                     | 0.43        | 0.017                         |
| 11  | G11         | 0.096±0.039                     | 0.25        | 0.009                         |
| 12  | G12         | 0.112±0.042                     | 0.29        | 0.011                         |
| 13  | G13         | 0.264±0.064                     | 0.67        | 0.026                         |
| 14  | G14         | 0.182±0.053                     | 0.47        | 0.018                         |
| 15  | G15         | 0.170±0.052                     | 0.43        | 0.017                         |
| 16  | G16         | 0.197±0.055                     | 0.50        | 0.019                         |
| 17  | G17         | 0.780±0.110                     | 1.99        | 0.077                         |
| 18  | G18         | 0.053±0.029                     | 0.14        | 0.005                         |
| 19  | G19         | 0.669±0.102                     | 1.71        | 0.066                         |
| 20  | G20         | 0.092±0.038                     | 0.24        | 0.009                         |
| Minimum                                  | 0.032±0.022                     | 0.08        | 0.003                         |
| Maximum                                   | 0.780±0.110                     | 1.99        | 0.077                         |
| Average±S.E                               | **0.205±0.04**                  | **0.52±0.10** | **0.020±0.004**               |
Figure (2): Comparing $^{222}$Rn concentrations in water samples with permissible value for drinking water.

Figure (3): Percentage of AED in samples under study.
Figure (4): Results of lifetime cancer risk in samples under study.

Figure (5): Map of $^{222}\text{Rn}$ concentrations in groundwater samples at Dhi-Qar Governorate.
Figure (6): Map of AED due to $^{222}$Rn concentrations in groundwater samples at Dhi-Qar Governorate.

Figure (7): Map of lifetime cancer risk due to $^{222}$Rn concentrations in groundwater samples at Dhi-Qar Governorate.
4. Conclusions

It can conclude that the RAD7 Solid State Detector (Silicon Detector) technology is a good and modern technology when compared to other technologies, as this technology is easily equipped with energy and high speed to detect alpha particle radiation. Through the results obtained in the current study, it is found that the radioactive radon gas concentration in groundwater samples reached the lowest level compared to the permissible limit in the Environmental Protection Agency The United States (EPA) and WHO 1993. Also, AED was less than the permissible limit according to the WHO 2011 which is 0.1 mSv/y. As well as All values of lifetime cancer risk was less than the permissible limit. So, radioactive radon gas in groundwater samples at Dhi-Qar Governorate, Iraq were no danger when using it by human in drinking and other uses.

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