Radon concentration measurement in a groundwater in Al-Tuz, Salah Al-Din Governorate using nuclear track detector CN-85

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Abstract. This work aims to determine the radon concentration in different samples of groundwater in Al-Tuz, Salah Alden. The concentrations of radon were studied in 52 samples for different regions using CN-85 nuclear track detector. The results show that the concentration of radon gas in groundwater were ranged between the lowest value (0.727 Bq/L) in the modern morning well sample (w44) and the highest value (4.001 Bq/L) in the west of the district of Tuz well sample (w47) with an average (1.747). The results were found to be below the allowed limit of radon concentrations ²²²Rn (11.1 Bq/L). The mean annual dose of drinking water was ranged between the lowest value (2.619 μ Sv/y) in sample W44 and the highest value (14.45 μ Sv/y) in the sample W47 with an average (6.292 μ Sv/y). All annual doses of drinking water values in this work were lower than the allowed limit (22.024 μ Sv/y).

Keywords: Radon concentration, water, groundwater, mean annual dose, CN-85 detector.

Introduction

Radiation is generally either natural or man-made for different applications, and human exposure to different levels of radiation [1]. The impact of radiation on the environment in recent years, which can affect the genetic structure of humans and animals, causing genetic defects on the next generations, and that is why the radioactive contamination should have an impact on water and soil can be transmitted through the food chain to humans and animals [2]. The food chain is considered to be the most critical route in the rapid transmission of radioactive contaminants, as the contamination of aggregates in the food chain is polluted and the proportion of radioactive materials such as plants and animals and their products increases. The human body can be contaminated with radioactive materials by eating plants or animal meat that feed on plants that contain radioactive material originating from the main soil [3]. The plant absorbs these materials with other natural materials and is classified in construction as well as drinking water. And fluids where water contains a low dose, air breathing, which is the main source of natural radioactive dose that reaches within the human body and the main source of radon in the Earth's atmosphere resulting from the automatic decomposition of uranium [4]. The aim of this study to measure the concentration of radon (Rn-222), in the groundwater samples in Al-Tuz using the nuclear track detector CN-85.

1. Theoretical concepts

The measurement of radon concentration is based on identifying the constant K, which is basically related to the geometry of the chamber used in irradiation process. The constant K can be related to the number of tracks formed in the detector using the following equation [5].

\[ \rho = KCT \]  

(1)
where \( \rho \) is the track density (Tr/cm\(^2\)), \( K \) is the diffusion constant measured by length unit (cm), \( C \) is the concentration of radon in the air space of the irradiation chamber, in (Bq/cm\(^3\)), \( T \) is the irradiation time in (s) and \( D \) is the track density rate (Tr.cm\(^{-2}\).s\(^{-1}\)) which could be given by the following equation [6].

\[
D = \frac{\rho}{T} = KC
\]  

(2)

for the cylindrical chamber of U- shape, \( K \) can be given by [5]

\[
K = \frac{1}{4} r (2 \cos \theta_c - r/R) \quad (3)
\]

where \( r \) is the half of the cylindrical tube of 2.4 cm diameter. \( \theta_c \) critical angle of CN-85 detector for particle occurrence. The critical angle of CN-85 is about 25\(^\circ\). \( R_\alpha \) is the range of alpha particles emitted into the air, which is equal to 4.15 cm[5]. Consequently, replace the values above with the parameters in eqn. (3), the constant propagation (\( K \)) of the cylindrical tube used to be (0.454 cm) was found using the CN-85 reagent. Consider Eqs. (2) and (3), and the intensity of the path the track density rate (Tr.cm\(^{-2}\).s\(^{-1}\)) is:

\[
D_{Rn} = \frac{1}{4} C r (2 \cos \theta_c - r/R_\alpha)
\]  

(4)

By which the concentration of radon in the air space of the cylindrical chamber C (Bq.m\(^{-3}\)) can be estimated. Finally the concentration of radon content within the samples (Cs) can also be calculated using the following equation [6]:

\[
C_s = \lambda_{Rn} C h \frac{t}{L}
\]  

(5)

where \( \lambda_{Rn} \) is radon decay constant \( \frac{\ln 2}{T_{1/2}} = 0.1814 \text{ d}^{-1} \), \( h \) the distance between the sample surface and the exposed surface of the detector = 9.5 cm, \( L \) sample thickness in the irradiation chamber = 1.5 cm and \( t \) the exposure time (60 d).

Annual Effective Dose for radon in the water samples(AED\(_W\)) [7]

\[
AED_W \left( \frac{Sv}{y} \right) = C_s C_{Rw} D_{Cw}
\]  

(6)

where \( C_s \) (Bq/L) is the radon concentration in a groundwater, \( D_{Rw} \) the annual consumption rate of water is equal(720L/y)[7], and \( D_{Cw} \) the conversion factor is equal to(5x10\(^{-6}\)Sv/Bq).

### 2. Method and materials

Detector CN-85 of thickness 200\( \mu \)m and dimension 1\( \times \)1 cm\(^2\) is exposed to groundwater samples for 60 days. The nuclear track detector CN-85, considering long term measurement technique, has been used to investigate the tracks of alpha particles emitted by radon gas released from the sample.

#### 2.1 Samples collection

A total of 52 samples of groundwater were collected for different areas in Al-TuzKhurmatu, Salah –Al-Din Governorate (geographic coordinates between 34º53N 44º38E) and presented in table 1 and showed in Fig.1. Each sample size was 1L and then (5 g) of each sample was put in a detection process. Place granular samples in U-shaped cylindrical irradiation chambers with an opening diameter of 2.38 cm. The rooms were tightly closed and left for 22 days to obtain an earthly balance of up to 98% between
radon and radium decomposed from the contents of the sample. After 22 days, in order to prevent the decomposing radon from the room area, the room covers were quickly replaced. The CN-85 reagents were sealed under tightly closed covers, while the distance between the detectors was maintained at about 9.5 cm to prevent access to the detector. Therefore, the irradiation process was continued for 60 days, and then detectors pieces were raised from the irradiation chambers and chemically etched to reveal the alpha tracks released by radon content within the samples. Then the set of detectors were etched by aqueous NaOH solution of(2.5 N) at 60±1C. The number and density of the tracks were accounted using an optical microscope. The radiation background is measured for the same duration time that of (60 days) using same irradiation chamber with no sample.

Table 1. The most important information about the wells and their locations between 34^º53N and 44^º38E geographic coordinates.

| No. | Well location                        | Depth of well (m) | History of drilling well | Uses                                |
|-----|--------------------------------------|-------------------|--------------------------|-------------------------------------|
| 1   | Near the southern control of Tuz     | 105               | 2004                     | The gravel and sand factory         |
| 2   | Near the village of Yekja            | 110               | 2014                     | Animal Husbandry                     |
| 3   | East of Yenjka village               | 120               | 2008                     | The gravel and sand factory         |
| 4   | Between the village of Jaragli and the village of Yenjka | 120 | 2006 | The gravel and sand factory |
| 5   | Between the district of Tuz and the village of Gardagli | 100 | 2015 | Animal husbandry and agriculture |
| 6   | North of Gardagli village            | 100               | 1990                     | Agriculture                          |
| 7   | South of Gardagli village            | 72                | 2009                     | Agriculture                          |
| 8   | Downtown Gardagli Village Village    | 70                | 2009                     | Drink                               |
| 9   | West of Gardagli village             | 70                | 2008                     | Animal husbandry and agriculture     |
| 10  | North of Bustamli village            | 100               | 2010                     | Agriculture                          |
| 11  | West of Qarnaz village               | 40                | 2013                     | Agriculture                          |
| 12  | South of Karnaz village              | 100               | 1970                     | Drink                               |
| 13  | North of the village of Albu Hassan  | 91                | 2011                     | Agriculture                          |
| 14  | Between Amri and Qarnaz villages     | 87                | 2011                     | Animal husbandry and agriculture     |
| 15  | The middle of an old man's hand      | 80                | 2011                     | Agriculture                          |
| 16  | Near the village of Shukr             | 145               | 2002                     | Agriculture                          |
| 17  | Near the village of Wadi             | 88                | 1988                     | Agriculture                          |
| 18  | Near the hand of my husband          | 120               | 2007                     | Animal Husbandry                     |
| 19  | Al - Tayyar District                 | 85                | 2009                     | Agriculture                          |
| 20  | Inside Brougli Village               | 155               | 1973                     | Drink                               |
| 21  | North of Braugli village             | 155               | 1999                     | Animal husbandry and agriculture     |
| 22  | Imam Ahmed Tuz neighborhood          | 65                | 2009                     | Firefighting                         |
| 23  | Imam Ahmed neighborhood              | 90                | 2012                     | Cultivation and drinking             |
| 24  | The Shrine of the Imam Ahmed A.      | 95                | 2000                     | Wash                                |
| 25  | West of Tuz                         |                   |                          | Block Factory                        |
| 26  | Cox Village                         | 71                | 2004                     | Drink                               |
| 27  | North of Cox                        | 90                | 2012                     | Drink                               |
| 28  | Khadasarhi Village                  | 55                | 2016                     | Agriculture                          |
| 29  | North Solomon Peck                  | 83                | 2013                     | Block Factory                        |
| 30  | Near Solomon Beck                   | 112               | 2009                     | Block Factory                        |
| 31  | Central Solomon Beck                | 105               | 2013                     | Block Factory                        |
| 32  | West Solomon Bek                    | 100               | 2015                     | Agriculture                          |
| 33  | North of the district of Tuz        | 144               | 2012                     | Agriculture                          |
| 34  | East of the district of Tuz         | 138               | 2013                     | Animal husbandry and agriculture     |
| 35  | West of the district of Tuz         | 125               | 2010                     | Drink                               |
| 36  | West of the district of Tuz         | 120               | 2010                     | Drink                               |
3. Results and discussion

One of the sources that forms large risk on the human being life and it is so important to determine it is the radon gas inhalation from different types of materials into the human body. Table 2 shows the intensity of the tracks (ρ) using Equation 2 in ground water samples and the radon concentration in both the space air of irradiation chamber using Equation (3) and within the groundwater samples used Equation (4). It is shown that the radon concentration values ranged between the lowest value (0.72 Bq/L) in the sample (W44) and the highest value (4.00 Bq/L) in the sample (W47) with the average (1.74784), its less than the value of the global limit of radon concentrations Rn-222 (11.1 Bq/L)[8]. The mean annual dose of drinking water(AEDw) were calculated using equation (6). Fig.3 shows the lowest AEDw value (2.62 μSv/y) in sample (W44) and the highest value (14.41 μSv/y) in the sample (W47) with the average (6.29 μSv/y), results of AEDw were lower than the allowed value 1 mSv/year[9]. The spatial variations in radon concentration in wells water could be a function of the geological structure of

![Figure 1: The locations of studied samples](image_url)
the area, depth of the water in the well and also differences in the climate, geo-
hydrological processes that occur in the area and the age of well.

Table 2: The intensity of the effects and concentration of the radon in the sample and the concentration of radon in the aerobic space as well as the annual effective dose of radon

| Sample ID | Intensity of effects (track/mm²) | Radon concentration in the sample (Bq/L) | Concentration of radon in aerobic space (Bq/L) | AEDw (µ Sv/y) |
|-----------|---------------------------------|----------------------------------------|-----------------------------------------------|--------------|
| 1         | 10964.29                        | 2.94                                   | 0.26                                          | 10.58        |
| 2         | 4642.86                         | 1.24                                   | 0.11                                          | 4.48         |
| 3         | 4428.57                         | 1.19                                   | 0.10                                          | 4.27         |
| 4         | 3285.71                         | 0.88                                   | 0.08                                          | 3.17         |
| 5         | 6142.86                         | 1.65                                   | 0.14                                          | 5.93         |
| 6         | 6000.00                         | 1.61                                   | 0.14                                          | 5.79         |
| 7         | 5607.14                         | 1.50                                   | 0.13                                          | 5.41         |
| 8         | 8892.86                         | 2.38                                   | 0.21                                          | 8.58         |
| 9         | 3142.86                         | 0.84                                   | 0.07                                          | 3.03         |
| 10        | 5500.00                         | 1.47                                   | 0.13                                          | 5.31         |
| 11        | 3785.71                         | 1.01                                   | 0.09                                          | 3.61         |
| 12        | 6071.43                         | 1.63                                   | 0.14                                          | 5.86         |
| 13        | 4464.29                         | 1.20                                   | 0.11                                          | 4.31         |
| 14        | 3535.71                         | 0.95                                   | 0.08                                          | 3.41         |
| 15        | 3107.14                         | 0.83                                   | 0.07                                          | 3.00         |
| 16        | 4821.43                         | 1.29                                   | 0.11                                          | 4.65         |
| 17        | 9892.86                         | 2.65                                   | 0.23                                          | 9.55         |
| 18        | 6035.71                         | 1.62                                   | 0.14                                          | 5.82         |
| 19        | 5892.86                         | 1.58                                   | 0.14                                          | 5.69         |
| 20        | 7678.57                         | 2.06                                   | 0.18                                          | 7.41         |
| 21        | 6642.86                         | 1.78                                   | 0.16                                          | 6.41         |
| 22        | 6607.14                         | 1.77                                   | 0.16                                          | 6.38         |
| 23        | 5678.57                         | 1.52                                   | 0.13                                          | 5.48         |
| 24        | 4571.43                         | 1.23                                   | 0.11                                          | 4.41         |
| 25        | 3000.00                         | 0.80                                   | 0.07                                          | 2.89         |
| 26        | 7071.43                         | 1.90                                   | 0.17                                          | 6.82         |
| 27        | 4607.14                         | 1.23                                   | 0.11                                          | 4.45         |
| 28        | 5357.14                         | 1.44                                   | 0.13                                          | 5.17         |
| 29        | 9107.14                         | 2.44                                   | 0.21                                          | 8.79         |
| 30        | 5285.71                         | 1.42                                   | 0.12                                          | 5.10         |
| 31        | 5142.86                         | 1.38                                   | 0.12                                          | 4.96         |
| 32        | 6642.86                         | 1.78                                   | 0.16                                          | 6.41         |
| 33        | 4678.57                         | 1.25                                   | 0.11                                          | 4.51         |
| 34        | 3892.86                         | 1.04                                   | 0.09                                          | 3.76         |
| 35        | 8107.14                         | 2.17                                   | 0.19                                          | 7.82         |
| 36        | 3821.43                         | 1.02                                   | 0.09                                          | 3.69         |
| 37        | 12250.00                        | 3.28                                   | 0.29                                          | 11.82        |
| 38        | 10107.14                        | 2.71                                   | 0.24                                          | 9.75         |
| 39        | 5214.29                         | 1.40                                   | 0.12                                          | 5.03         |
| 40        | 4857.14                         | 1.30                                   | 0.11                                          | 4.69         |
| 41        | 7964.29                         | 2.13                                   | 0.19                                          | 7.69         |
| 42        | 6857.14                         | 1.84                                   | 0.16                                          | 6.62         |
| 43        | 6964.29                         | 1.87                                   | 0.16                                          | 6.72         |
| 44        | 2714.29                         | 0.73                                   | 0.06                                          | 2.62         |
| 45        | 11571.43                        | 3.10                                   | 0.27                                          | 11.17        |
| 46        | 7464.29                         | 2.00                                   | 0.18                                          | 7.20         |
| 47        | 14928.57                        | 4.00                                   | 0.35                                          | 14.41        |
| 48        | 13000.00                        | 3.48                                   | 0.31                                          | 12.54        |
| 49        | 9428.57                         | 2.53                                   | 0.22                                          | 9.10         |
| 50        | 7000.00                         | 1.88                                   | 0.17                                          | 6.75         |
| 51        | 6928.57                         | 1.86                                   | 0.16                                          | 6.69         |
| 52        | 7714.29                         | 2.07                                   | 0.18                                          | 7.44         |
| Average Value | 6520.6  | 1.74 | 0.15 | 6.29 |
Figure 2: The concentration of radon in the samples

Figure 3: The annual effective dose.

4. Conclusions

One of the most important conclusions of this work is that the concentrations of radon are increasing in the old wells and with increasing depth. The results of the present study show that the average concentration of radon $^{222}$Rnin the ground waters of the city of Tuz Khurmatu city in Salah Al-Din is lower than the values of the allowed values (11 Bq/L) and the mean annual dose of drinking water lower than the allowed value (1 mSv/year) [9].

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