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Study the concentration of radon gas in groundwater in the selected samples of the province of Babel/ Iraq

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ABSTRACT

In this study measuring concentrations of radon in water for Hilla province of Babel (100 Km) south of capital Baghdad. Was chosen as the groundwater study by 22 samples from 22 regions by using the electronic radon detector RAD7, and the average concentration of radon was (2.49 ± 0.54) $Bq.L^{-1}$, where the highest value (7.92 ± 0.52) $Bq.L^{-1}$ and the lowest value (0.54 ± 0.49) $Bq.L^{-1}$ and effective dose for human exposure to radon was (0.14) $mSv.y^{-1}$. Has been chosen this subject of the current study of the importance of water in human life and living, and the lack of previous studies in the study area.

KEYWORDS

Radon concentrations;
Groundwater;
Annual effective dose;
RAD7;
Babel.

INTRODUCTION

Radon is a natural radioactive gas discovered in the 1900s by Dorn, is a naturally occurring, colorless, odorless gas that is soluble in water, Radon occurs as three natural isotopes derived from three different radioactive decay chains, commencing with ^{238}U, ^{232}Th and ^{235}U[1]. ^{222}Rn is that most commonly discussed in this research. Radon-220 (t1/2 = 56 sec.) known as thoron in non-porous material is comparable to the activity of ^{222}Rn, the much shorter half-life time of thoron causes its concentration in air to be relatively low and therefore usually of second interest. The third isotopes is Radon-219 (t1/2 = 3.92 sec) called actinon in reference to its presence in actinium (^{235}U) decay chain[2]. Radon is an unstable radionuclide that disintegrates through short lived decay products before eventually reaching the end product of stable lead. The short lived decay products of Radon are responsible for most of the hazard by inhalation. Radon is readily released from surface water; consequently, groundwater has potentially much higher concentrations of Radon than surface water[3]. Radon moves from its source in rocks and soils through voids and fractures. It can enter buildings as a gas through foundation cracks or dissolve in the ground water and be carried to water-supply wells. While Radon easily dissolves into water, it also easily escapes from water when exposed to the atmosphere, especially if it is stirred or agitated. Consequently, Radon concentrations are very low in rivers and lakes, but could still be high in water pumped from th ground[4].

Drinking water comes from ground water, which was supplied through public drinking water systems. But many families rely on private, household wells and use groundwater as their source of fresh water[5]. Groundwater may contain some natural impurities or contaminants, even with no human activity or pollution.

Natural contaminants can come from many conditions in the watershed or in the ground. Water moving through underground rocks and soils may pick up magnesium, calcium and chlorides[6]. Some ground water naturally contains dissolved elements such as arsenic, boron, selenium, or radon, a gas formed by the natural breakdown of radioactive uranium in soil[7]. Whether these natural contaminants are health problems depends on the amount of the substance present. Radon itself is radioactive because it also decays, losing an alpha particle and forming the element polonium. Some people who are exposed to Radon in drinking water may have increased risk of getting cancer over the course of their lifetime, especially lung cancer[8]. Radon accumulates in groundwater due to two different sources, firstly the radioactive decay of dissolved radium (Radon immediate parent in the uranium decay chain), and secondly the direct release of Radon from the mineral matrix from minerals (in surrounding rocks) containing members of the uranium decay chain[9].

Many factors that affect the formation and movement of Radon in the ground; the uranium content, grain size, and permeability of the host rock and the nature and extent of fracturing in the host rock and these important factors affecting the amount of Radon in groundwater[10]. Radon concentrations in ground water vary from time to time (before and after winter) because of dilution by recharge or changes in contributing areas of the aquifer because of pumping[8].

All the previous studies were concerned on the groundwater quality in province of Babel include chemical, physical and microbiological analysis, but not includenatural radiation analysis. No real researches have been done in this field. So there is a need to investigate the natural radiation (radon) in groundwater in province of Babel.

LOCATION OF THE STUDY AREA

Study area is located in the province of Babel (100 Km) south of the capital Baghdad, where the city of Hilla, which has an area of (49.816) km^2 on both sides of the River Hilla (a branch of the Euphrates River), at Latitude(29′ 32°) north, longitude (26′ 44°) east,as shown in Figure (1)[11] as shown in Figure (1).

EXPERIMENTAL PART

In this study, groundwater samples were collected from twenty two wells and radon concentrations were

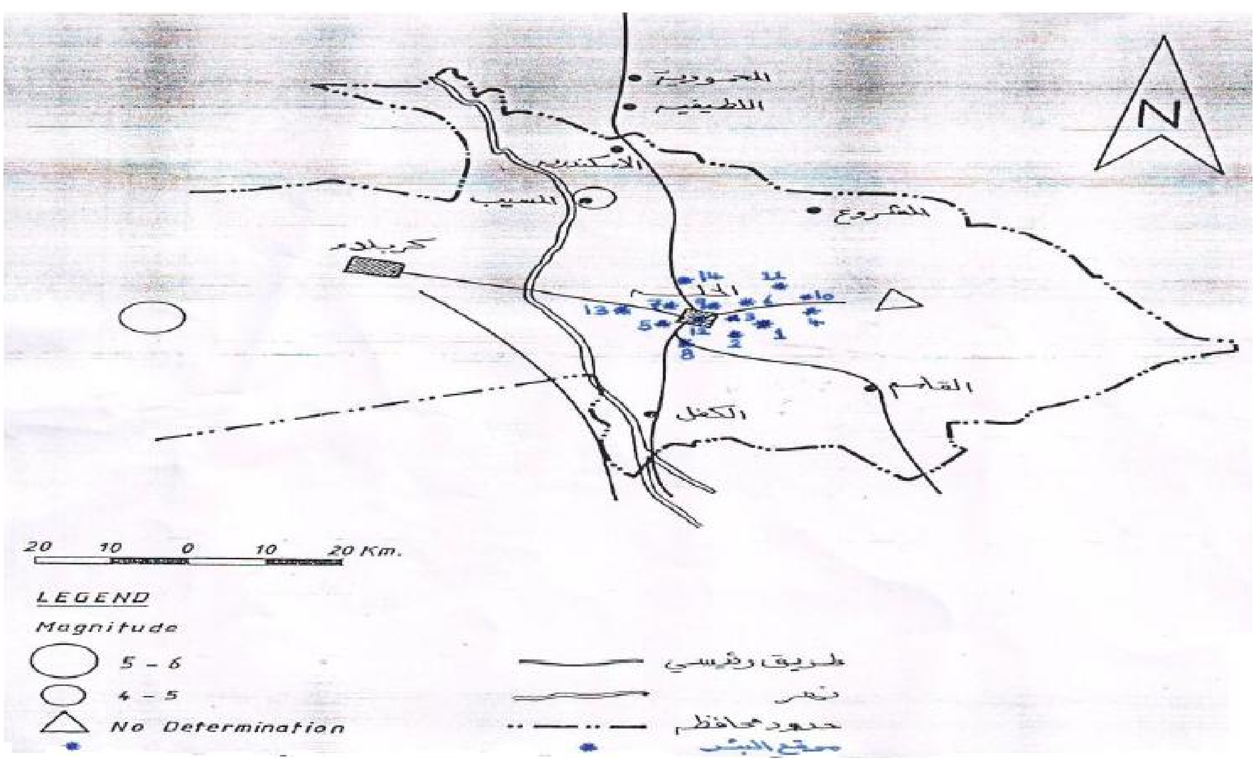

Figure 1 : Map showing sampling locations [11]

measured as part of a water-quality. The samples were collected from different location covering most of the region that represent province of Babel five wells from the district Al-Kufl, seven wells from the district Al-Shomaly and eight wells from different regions from Hilla,were taken and all these wells were used for domestic water. Each sample was duplicated to determine radon concentration using RAD7 detector as show Figure (2).

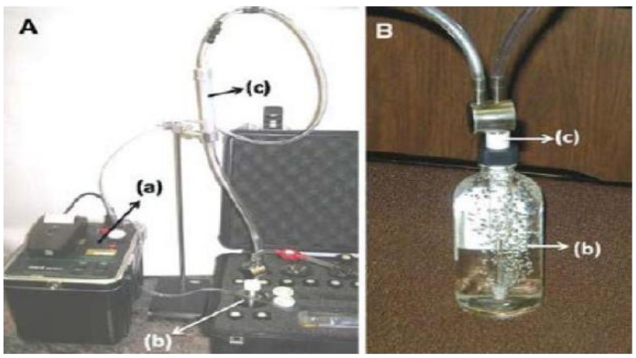

Figure 2 : Schematic presentations of radon-in-air monitor RAD-7. Adapted from reference with permission[12]

To ensure the quality control and reliability of the sampling and measurement methods, each sample was analyzed in 4 cycles where we calculated the mean of these 4 readings and finally we calculated the mean.

The RAD-H_2O method employs a closed loop aeration scheme whereby the air volume and water volume are constant and independent of the flow rate. The air re-circulates through the water and continuously extracts the radon until a state of equilibrium develops. The RAD-H_2O system reaches this state of equilibrium within about 5 min, after which no more radon can be extracted from the water. The operation of this device is based on the following principle; (1) radon is expelled from a water sample by using a bubbling kit, (2) expelled radon enters a hemisphere chamber by air circulation, (3) polonium decayed from radon is collected onto a silicon solid-state detector by an electric field and (4) radon concentration is estimated from the count rate of polonium[13].

On the RAD7, one among the two available protocols (i.e., Wat40 and Wat250) will be selected depending on the size of vial (40 or 250 mL) that is being used for water sampling (here we used Wat250 and sample size of 250 mL). This also decides the extraction efficiency or percentage of radon removed from the water to the air loop. For our used protocol of Wat250, the extraction efficiency was usually very high, typically 95% for a 250 mL sample vial[12].

The 250 mL sample bottle was connected to the RAD-7 and the internal air pump of the radon-monitor was used for re-circulating a closed air-loop through the water sample, purging radon from the water into the air-loop. The air is re-circulated through the water continuously to extract the radon until RAD-H_2O system reaches a state of equilibrium within about 5 min, after which no more radon can be extracted from the water. After reaching equilibrium between water, air, and radon progeny attached to the passivity implanted planar silicon detector, the radon activity concentration measured in the air loop was used for calculating the initial radon-in-water concentration of the respective sample. The RAD7 allows determination of radon-in-air activity concentrations by detecting the alpha decaying radon progeny ^{218}Po and ^{214}Po using passivity implanted planar silicon detector. The radon monitor (RAD7) uses a high electric field above a silicon semi-conductor detected at ground potential to attract the positively charged polonium daughters (^{218}Po and ^{214}Po) which are counted as a measure ^{222}Rn concentration in air[14].

The pump runs for 5 min, aerating the sample and delivering the radon to the RAD7. The system will wait a further 5 min and then it starts counting. During the 5 min of aeration, more than 95% of the available radon is removed from the water and the components automatically perform everything required to determine the radon concentration in the water. After 5 min, it prints out a short-form report[13].

The same thing is repeated again for 5 min later, and for two more 5-min periods after that. Thus, radon gas is collected through the energy specific windows which eliminate interference and maintain very low backgrounds and later counted for the radon concentration. ^{222}Rn activities are then expressed with uncertainty down to under ± 5%. At the end of the run (30 min after the start), the RAD7 prints out a summary, showing the average radon readings from the four cycles, counted a bar chart of the four readings, and a cumulative spectrum[12,15].

The RAD-H_2O system has been calibrated for a sample analysis temperature of 20 C°. In our study, the mean ± standard deviation (M ± SD) temperature value for the wells' samples was 23.6 ± 0.74. Therefore, a very limited or no effect of temperature was seen on the results.

The RAD7 calculates the sample water concentration by multiplying the air loop concentration by a fixed conversion coefficient that depends on the sample size. This conversion coefficient has been derived from the volume of the air loop, the volume of the sample, and the equilibrium radon distribution coefficient at room temperature. For the 250 mL sample volume, the conversion coefficient was around 4[16].

Samples were taken in specific bottles designed for the RAD device and provided by the manufacturer. The collections of the samples and their analysis were done between 27th of January 2014 and 24th of February 2014. Tap water sampling and analysis from different regions of Hilla city were done between 25th of February 2014 and 20th of March 2014.

The annual effective dose to an individual consumer due to intake of radon from drinking water is evaluated using the Eq. (1) [17],as shown in the TABLE (1).

$$\mathbf{D_w = C_w\, C_{Rw}\, D_{cw}} \quad \mathbf{(1)}$$

where D_w is the annual effective dose (Sv y^{-1}), C_w concentration of ^{222}Rn (Bq. L^{-1}) C_{Rw} annual intake of drinking water (1095 L y^{-1}), D_{cw} is the ingested dose conversion factor for ^{222}Rn ($5*10^{-9}$ Sv. Bq^{-1})[18].

RESULTS AND DISCUSSION

TABLE 1 shows the results were obtained in this study where the :

(Mean) represents the value of average concentration, (SD) represents the value of the standard

TABLE 1 : Radioactive radon gas concentrations in samples from the groundwater in different regions

Sample Point	Mean ($Bq.L^{-1}$)	High ($Bq.L^{-1}$)	Low ($Bq.L^{-1}$)	Effective dose($mSv.y^{-1}$)
G1	3.92±1.6	5.59	2.16	0.214
G2	4.01±1.5	6.34	2.9	0.219
G3	1.92±0.18	2.17	1.73	0.105
G4	1.81±0.27	2.17	1.59	0.09
G5	2.46±0.5	3.19	2.03	0.134
G6	1.95±0.45	2.32	1.3	0.106
G7	2.03±0.92	3.33	1.16	0.111
G8	6.17±0.27	6.41	5.91	0.337
G9	1.66±0.3	2.03	1.3	0.09
G10	7.92±0.52	8.55	7.28	0.433
G11	0.68±0.24	1.01	0.43	0.037
G12	0.54±0.49	1.16	0.14	0.029
G13	4.27±0.75	5.36	3.62	0.233
G14	4.67±0.72	5.65	4.06	0.255
G15	1.34±0.77	2.46	0.72	0.073
G16	1.88±0.36	2.31	1.45	0.102
G17	2.64±0.87	3.77	1.87	0.144
G18	0.61±0.24	0.86	0.29	0.033
G19	0.65±0.082	0.72	0.57	0.035
G20	1.59±0.26	1.87	1.3	0.087
G21	1.27±0.43	1.74	0.72	0.069
G22	0.86±0.2	1.01	0.57	0.047

deviation, (High) highest value, (Low) is lower value of the average radon concentration and are all measured in(Bq.L^{-1}), (G) refer to Groundwater.

Groundwater often moves through rock containing natural uranium that releases radon to the water. That is why, water from wells normally has much higher concentrations of radon than surface water such as rivers, lakes, and streams. Results from this study indicate that the activity concentrations of ^{222}Rn in the range of (0.54 - 7.92) Bq.L^{-1}, with an overall average of (2.49) Bq.L^{-1} and corresponding annual effective dose in the range of (0.029–0.433) mSv.y^{-1} with an average of (0.14 mSv.y^{-1}, and its indicate that the difference between the minimum and maximum radon concentrations in the governorate is high may be due to the difference in the soil type, rock type and the depth of these wells. this clear in wells No. (G8, G10, G13, G14,G17). Some locations in province of Babel that have low level radon are considered to be rural and farms territories. This is probably due to the little content of clay rocks which contain the main source of radon in surveyed area. Groundwater often moves through rock containing natural uranium that releases radon to the water. That is why, water from wells normally has much higher concentrations of radon than surface water such as rivers, lakes, and streams[18,19]. The U.S. National Academy of Sciences reports that the average concentration of radon in public water supplies derived from surface waters is usually less than 0.4 Bq.L^{-1}, and it is about 20 Bq.L^{-1} in ground water[20].

These values are within the levels allowed recommended by the EPA[20]. The study covered only a limited area of the country (Province of Babel), which should also include epidemiological survey of incidences of radiation related health effects[18], is recommended.

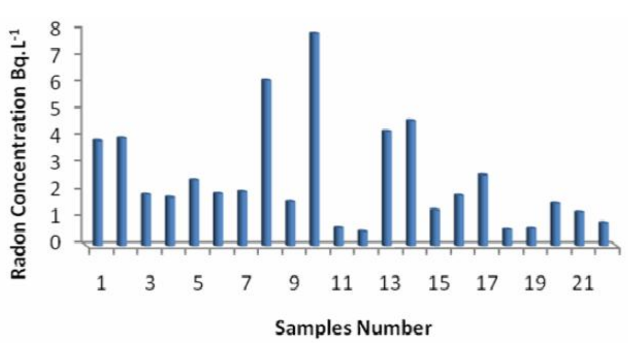

Figure 3 : Radon concentration for each water sample in province of Babel

TABLE 2 : Shows the average of radon concentration in the water for some countries compared to the present research

country	Radon concentration average
Iraq- Nenava	1.133 Bq.L^{-1}[21]
present study	2.49. Bq.L^{-1} Iraq-Babel
Turkey	0.091 Bq.L^{-1}[22]
Kuwait	0.74 Bq.L^{-1}[23]
Syria	13 Bq.L^{-1}[24]
Iran	(0.21-3.89) Bq.L^{-1}[25]
Jordon	3.9 Bq.L^{-1}[26]
Khartoum	59.2 Bq.L^{-1}[27]
Algeria	7 Bq.L^{-1}[28]
Finland	130Bq.L^{-1}[29]
Italy	52.7 Bq.L^{-1}[30]
United Kingdom	2 Bq.L^{-1}[31]

This survey will be important to establish data on other parameters such as well depth, water discharge rate and aquifer thickness. These parameters did not form part of this study due to limited duration of the study. These parameters are however required in the assessment of doses from ^{222}Rn and other radionuclides in water.

By comparing the results of this study with the studies described in the table (2), we find that the average concentration of radon in water lower as compared with these studies.

CONCLUSIONS

In this paper, the results of the ^{222}Rn measurements in 20 groundwater samples collected from al Hilla district are presented. The measurements were performed by RAD7 radon detector manufactured by Durridge Company Inc. The observed values of radon concentration in groundwater of different areas Babel State are within the international recommended limit and hence safe for drinking purposes. The total effective dose in all locations of the studied area is found to be within the safe limit (1 mSv.y^{-1}) recommended by World Health Organization and EU Council. The results show no significant radiological risk due to radon ingestion for the inhabitants of the studied regions.

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