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ESTIMATED THE CONCENTRATION OF RADON IN DRINKING WATER IN SELECTED SAMPLES FROM THE UNIVERSITY OF BABYLON / IRAQ

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ABSTRACT

Radon is a radioactive noble gas of a natural origin. It is worthy to carry out the distribution of radon (^{222}Rn) activity concentration and their annual effective dose exposure in drinking water samples from University of Babylon (100 Km) south of capital Baghdad. Water samples were collected before and after winter season and analysed using RAD7 connected to a RAD-H_2O accessory. The measured radon concentration ranges from (0.072 $Bq.L^{-1}$) in W7 (Physical Education) to (0.325 $Bq.L^{-1}$) in W2 (Basic Education College) with an mean value of (0.183 $Bq.L^{-1}$). The measured values of radon concentration are well in the range within the EPA's Maximum Contaminant Level of (11.1$Bq.L^{-1}$). The total annual effective dose resulting from radon in drinking water were (1.74 $\mu Sv.y^{-1}$) significantly lower than the (United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR recommended limit for members of the public of (1 $mSv.y^{-1}$). It 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.

The measured values for sample water from the study area suggested that the area is safe and there is no significant threat to the population as per as radon concentration is concerned.

Key words: Radon concentrations, Water, Annual effective dose, Babylon, RAD7, UNSCEAR.

INTRODUCTION

Radon is a chemical element with symbol Rn and atomic number 86. It is a radioactive, colorless, odorless, tasteless noble gas, occurring naturally as an indirect decay product of uranium or thorium. Its most stable isotope, ^{222}Rn, has a half-life of 3.8 days[1]. Radon is one of the densest substances that remains a gas under normal conditions. It is also

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the only gas under normal conditions that only has radioactive isotopes, and is considered a health hazard due to its radioactivity. Intense radioactivity has also hindered chemical studies of radon and only a few compounds are known[2].

Radon is formed as one intermediate step in the normal radioactive decay chains, through which thorium and uranium slowly decay into lead. Thorium and uranium are the two most common radioactive elements on earth; they have been around since the earth was formed. Their naturally occurring isotopes have very long half-lives, on the order of billions of years. Thorium and uranium, their decay product radium, and its decay product radon, will therefore continue to occur for tens of millions of years at almost the same concentrations as they do now.[1] As radon itself decays, it produces new radioactive elements called radon daughters. Unlike the gaseous radon itself, radon daughters are solids and stick to surfaces, such as dust particles in the air. If such contaminated dust is inhaled, these particles can stick to the airways of the lung and increase the risk of developing lung cancer.[3]

Epidemiological studies have shown a clear link between breathing high concentrations of radon and incidence of lung cancer.[2] Thus, radon is considered a significant contaminant that affects indoor air quality worldwide. According to the United States Environmental Protection Agency, radon is the second most frequent cause of lung cancer, after cigarette smoking, causing 21,000 lung cancer deaths per year in the United States. About 2,900 of these deaths occur among people who have never smoked. While radon is the second most frequent cause of lung cancer, it is the number one cause among non-smokers, according to EPA estimates.[3]

Radon concentration varies widely from place to place, Radon mostly appears with the decay chain of the radium and uranium series (^{222}Rn), and marginally with the thorium series (^{220}Rn). The element emanates naturally from the ground, and some building materials, all over the world, wherever traces of uranium or thorium can be found, and particularly in regions with soils containing granite or shale, which have a higher concentration of uranium. However, not all granitic regions are prone to high emissions of radon. Being a rare gas, it usually migrates freely through faults and fragmented soils, and may accumulate in caves or water. Owing to its very short half-life (four days for ^{222}Rn), radon concentration decreases very quickly when the distance from the production area increases. Radon concentration varies greatly with season and atmospheric conditions[4].

The effects of radon if ingested are similarly unknown, although studies have found that its biological half-life ranges from 30-70 minutes, with 90 percent removal at 100 minutes. In 1999 National Research Council investigated the issue of radon in drinking water. The risks associated with ingestion was considered almost negligible.[2] Water from underground sources may contain significant amounts of radon depending on the surrounding rock and soil conditions, whereas surface sources generally do not.[4], As well as being ingested through drinking water, radon is also released from water when temperature is increased, pressure is decreased and when water is aerated.

Location of the study area

The university of Babylon, is one of the major Iraqi universities. Located in the province of Babylon, (100 Km) south of the capital Baghdad, on the banks of the Euphrates River. It consists of 20 colleges within three compounds, located seven kilometers south of the city of Hillah, in Babylon Province at Latitude (32.392754) north, longitude (44.398928) east, as shown in Fig. 1. The campus was originally the Administrative Institute of Babylon. Later some of the buildings were adopted for use by the medical college of the University of Kufa, before being established as a university in its own right in 1991[5].

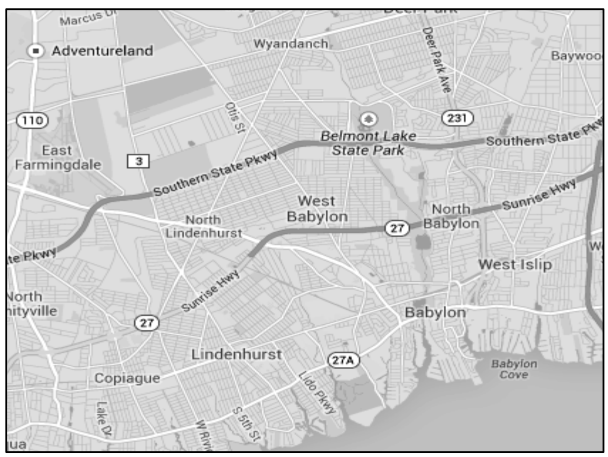

Fig. 1: Map of University of Babylon[5]

EXPERIMENTAL

In this study, were collected 13 samples from residential tap water (selected randomly) in the 13 different regions (colleges) of University of Babylon using the RAD H_2O technique, this device offers an accurate measurement, faster reading, it is portable and eliminates the need for noxious chemicals. The schematic diagram of this device is presented in Fig. 2 below. Using RAD H_2O technique employs closed loop concept, consisting of three components; (a) the RAD7 or radon monitor, on the left, (b) the water vial with aerator, in the case near the front, and (c) the tube of desiccant, supported by the retort stand above as marked in the Fig. 6.

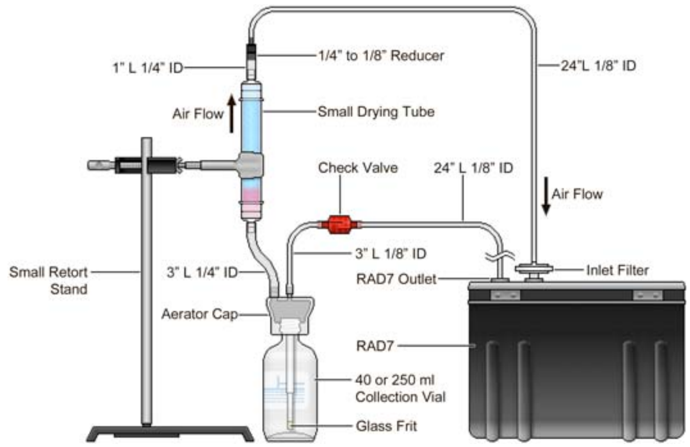

Fig. 2: Schematic presentations of radon-in-air monitor RAD-7. Adapted from reference with permission[7]

The RAD-H_20 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_20 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[7].

On the RAD7, one among the two available protocols (i.e., Wat-40 and Wat-250) will be selected depending on the size of vial (40 or 250 mL) that is being used for water sampling (here we used Wat-250 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 Wat-250, the extraction efficiency was usually very high, typically 95% for a 250 mL sample vial[6].

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 RAD-7 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 (RAD-7) 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 of ^{222}Rn concentration in air[6,7].

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[6,8]. 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[7].

The annual effective dose to an individual consumer due to intake of radon from drinking water is evaluated using the Eq. (1)[9], as shown in the Table 1.

$$E = K*C*KM*t \qquad \ldots(1)$$

where E is the committed effective dose from ingestion (Sv), K is the ingesting dose conversion factor of ^{222}Rn (10^{-8} $Sv.Bq^{-1}$)[9], C is the concentration of ^{222}Rn (BqL^{-1}), KM is the water consumption (2 $L.day^{-1}$), t is the duration of consumption (365 days)[10]. The radon concentration of drinking waters decreases during storage, processing, etc., so by the evaluation of dose, the consumption test is that of water taken directly from the tap[9].

RESULTS AND DISCUSSION

Table 1 shows the results obtained in this study where the : (Mean) represents the value of average concentration, (SD) represents the value of the standard deviation, (High) highest value, (Low) is lower value of the average radon concentration and are all measured in ($Bq.L^{-1}$), (W) refers to Water.

Table 1: Radioactive Radon gas concentrations in samples from water university of Babylon

Sample point	Mean ($Bq.L^{-1}$)	High ($Bq.L^{-1}$)	Low ($Bq.L^{-1}$)	Effective dose ($mSv.y^{-1}$)
W1	0.29 ± 0.23	0.579	0	0.015
W2	0.325 ± 0.13	0.435	0.145	0.017
W3	0.108 ± 0.13	0.288	0	0.005
W4	0.254 ± 0.24	0.579	0	0.013
W5	0.217 ± 0.08	0.29	0.145	0.011
W6	0.144 ± 0.16	0.29	0	0.007
W7	0.072 ± 0.08	0.145	0	0.003
W8	0.144 ± 0.11	0.29	0	0.007
W9	0.108 ± 0.07	0.145	0	0.005
W10	0.108 ± 0.13	0.29	0	0.005
W11	0.217 ± 0.18	0.435	0	0.011
W12	0.108 ± 0.07	0.145	0	0.005
W13	0.289 ± 0.2	0.576	0.145	0.015

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 for the 13 samples' means. Table 1) show there is difference in measurement results for water according to locations samples as shown in Fig. 3 where the radon concentrations ranged from (0.325 to 0.072) $Bq.L^{-1}$ with a mean of 0.18 $Bq.L^{-1}$. The main Study finding points that all the readings for wells and springs were lower than the maximum contaminated level (MCL) of 11.1 $Bq.L^{-1}$.[3,11] These generally low concentration levels of radon in water tap could be explained from the geological context of the surrounding rocks. Indeed and environmental conditions[12].

From the spectra that shown in Fig. 4 and 5 for lower and higher of location sample in study area can be noted the relation between the count rate and the energy which consist of Radon daughters in A(^{218}Po), B(^{214}Po) and Thoron daughters D(^{216}Po), E(^{212}Po).

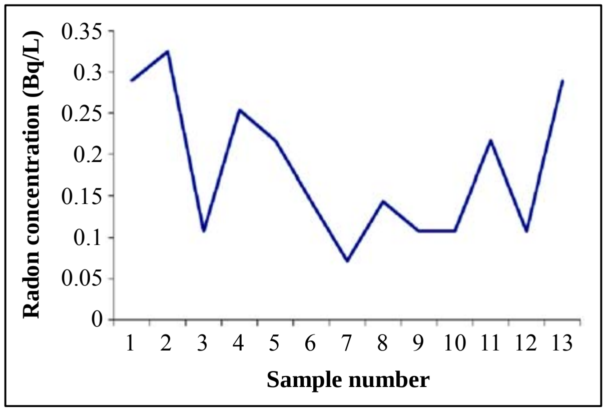

Fig. 3: Diagram showing variation in radon concentration of the water samples

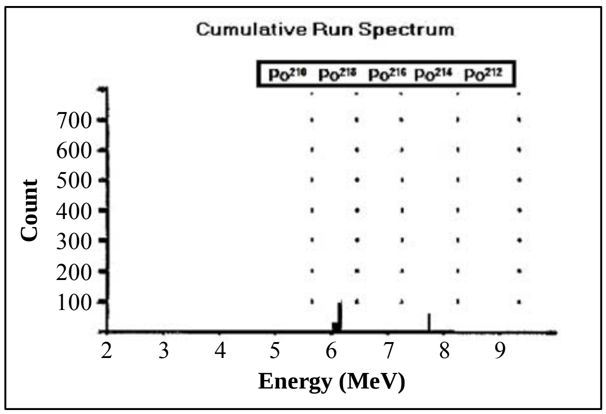

Fig. 4: Alpha energy spectrum of location Sample (W7)

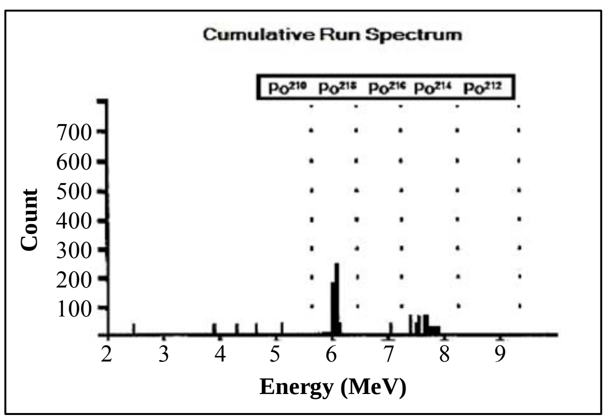

Fig. 5: Alpha energy spectrum of location Sample (W2)

As there is no absolute safe value of radiation from radon on general public. Although there are few studies on radon level in the water in Iraq[13,14] no water radon level reference has been established and therefore, there has been no specific safe limit value for radon until now in Iraq. Even in the neighbor countries, no standard safe level has been developed and they still depend on the U.S. or European standard safe levels. In comparison with radon concentration in some countries the studies described in the Table 2, we find that the average concentration of radon in water lower as compared with these studies:

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

Country	Radon concentration average	[Ref.]
Iraq- Nenava	1.133 $Bq.L^{-1}$	[13]
Iraq -River Hilla	0.181 $Bq.L^{-1}$	[14]
Present study	Iraq-Uni. of Bab. 0.183 $Bq.L^{-1}$	
Iraq- Najaf	Range (0.188 – 0.027) $Bq.L^{-1}$	[15]
Turkey	0.091 $Bq.L^{-1}$	[16]
Kuwait	0.74 $Bq.L^{-1}$	[17]
Syria	13 $Bq.L^{-1}$	[18]
Iran	(0.21-3.89) $Bq.L^{-1}$	[19]
Jordon	3.9 $Bq.L^{-1}$	[20]
Khartoum	59.2 $Bq.L^{-1}$	[21]

CONCLUSION

(i) Compared with the international references, our findings showed that there was no increasing in the exposure of radon in the different drinking water sources in University of Babylon. Several factors might explain the findings: radon decay and radon aeration, mixture of water from different sources before pumping, and the travel distance and time.

(ii) All results for samples were less than the allowed concentration level of 11.1 Bq.L-1 (As defined by the Environmental Protection Agency EPA)[3] and the effective dose (1.74) μSv.y1 was less than the UNSCEAR and WHO recommended limit for members of the public of 1 mSv.y-1.[10,11]

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