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Estimating radon gas levels and radioactive hazard in the water of Al-Abayji area - Baghdad – Iraq

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Abstract :

Radioactive radon is considered one of the most dangerous types of noble gases and is the main cause of lung cancer. Water is an important source of its emissions, so determining its levels and the dose resulting from inhalation or ingestion is important for people's general health. The levels of radium and radon gas concentrations were measured in samples of surface water and groundwater and drainage water collected from various locations in the Al-Abayji area, Baghdad, Iraq, using alpha particle tracking technology. The average results of radium concentrations in surface water, groundwater, and drainage water are 0.223 Bq/L, 0.130 Bq/L, and 0.302 Bq/L respectively. Levels of radon gas concentrations in drainage water are higher than in surface water and groundwater. Levels of radioactive radon gas concentrations were less than the safe limits of 11 Bq/L. Also, the average effective annual dose for ingestion and inhalation of water was less than 100 μSvy−1 that the EU Council and WHO recommend.

Key words: CR-39- Radon- Abayji area- radioactive hazard in the water.

تقدير مستويات غاز الرادون والمخاطر الإشعاعية في مياه منطقة العبايجي - بغداد - العراق

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مستخلص:

يعتبر غاز الرادون المشع من أخطر أنواع الغازات النبيلة والمسبب الرئيسي لسرطان الرئة. ويعتبر الماء مصدراً مهماً لانبعاثه ، لذلك فان تحديد مستوياته والجرعة الناتجة عن استنشاقه أو ابتلاعه أمر مهما لصحة المجتمع. تم قياس مستويات تراكيز الراديوم وغاز الرادون في عينات من المياه السطحية والجوفية ومياه البزل التي تم جمعها من مواقع مختلفة في منطقة العبايجي، بغداد، العراق، باستخدام تقنية تتبع جسيمات ألفا. متوسط نتائج تراكيز الراديوم في المياه السطحية، والمياه الجوفية، ومياه البزل هي 0.223 بيكريل/ لتر، 0.130 بيكريل/ لتر، و0.302 بيكريل/ لتر على التوالي. كانت مستويات تركيزات غاز الرادون في مياه البزل أعلى من تراكيزه في المياه السطحية والمياه الجوفية. وكانت مستويات تراكيز غاز الرادون المشع أقل من الحدود المسموح بها 11 بيكريل/ لتر. كما أن متوسط الجرعة السنوية الفعالة عند الابتلاع او استنشاق الماء كانت أقل من 100 μSvy^{-1} الذي أوصى به مجلس الاتحاد الأوروبي ومنظمة الصحة العالمية.

Introduction

Radon gas is one of the sources of natural nuclear radiation. It is generated mainly from the natural degradation of (^{238}U), (^{232}Th), and (^{235}U) chains. Radon is the only mineral that exists in a gaseous state [1]. Radon has three radioactive isotopes: (^{222}Rn), (^{220}Rn), and (^{219}Rn). The isotope ^{222}Rn is an important isotope in geological and environmental studies because of its relatively long half-life of 3.82 days. The role of the other two isotopes ^{220}Rn and ^{219}Rn can be neglected due to their short half-lives (5.66 and 3.92) seconds, respectively [2].

Exposure to ^{222}Rn gas is a serious health problem, and the relationship between exposure to alpha particle emitters and the incidence of lung cancer has been proven [3]. UNSCEAR estimates that radon, along with the daughter radionuclides resulting from its decay, contributes about three-quarters of the annual effective dose equivalents received by humans [4].

Water is a source of radon emissions. The dissolution of radon in water increases with decreasing temperature. When groundwater passes through soil rocks, it absorbs a significant percentage of radon. When the water is heated, a significant percentage is released into the medium. The amount of ^{222}Rn gas in water depends on the geological characteristics of the rocks and the type of water used [2].

SSNTD technology for detecting traces of alpha particles is considered one of the simplest methods used to measure the level of ^{222}Rn gas concentration in water. It is characterized by its high sensitivity to radiation and resistance to external damage, and it preserves traces for the longest possible period [5].

Study site

Al-Abayji area is located within the alluvial plain area in the northern part of the Baghdad region - Iraq. Between two circles of longitude (44°23’49”-˚44°11’52”) east and two circles of latitude (33°46’37” -33°40’12”) north. It is considered one of the most important agricultural areas. To irrigate crops, it relies on surface water, groundwater, and drainage. Therefore, the importance of the research lies in evaluating the quality of the water used to irrigate crops and the water used for human purposes. Fig. (1) shows the study area.

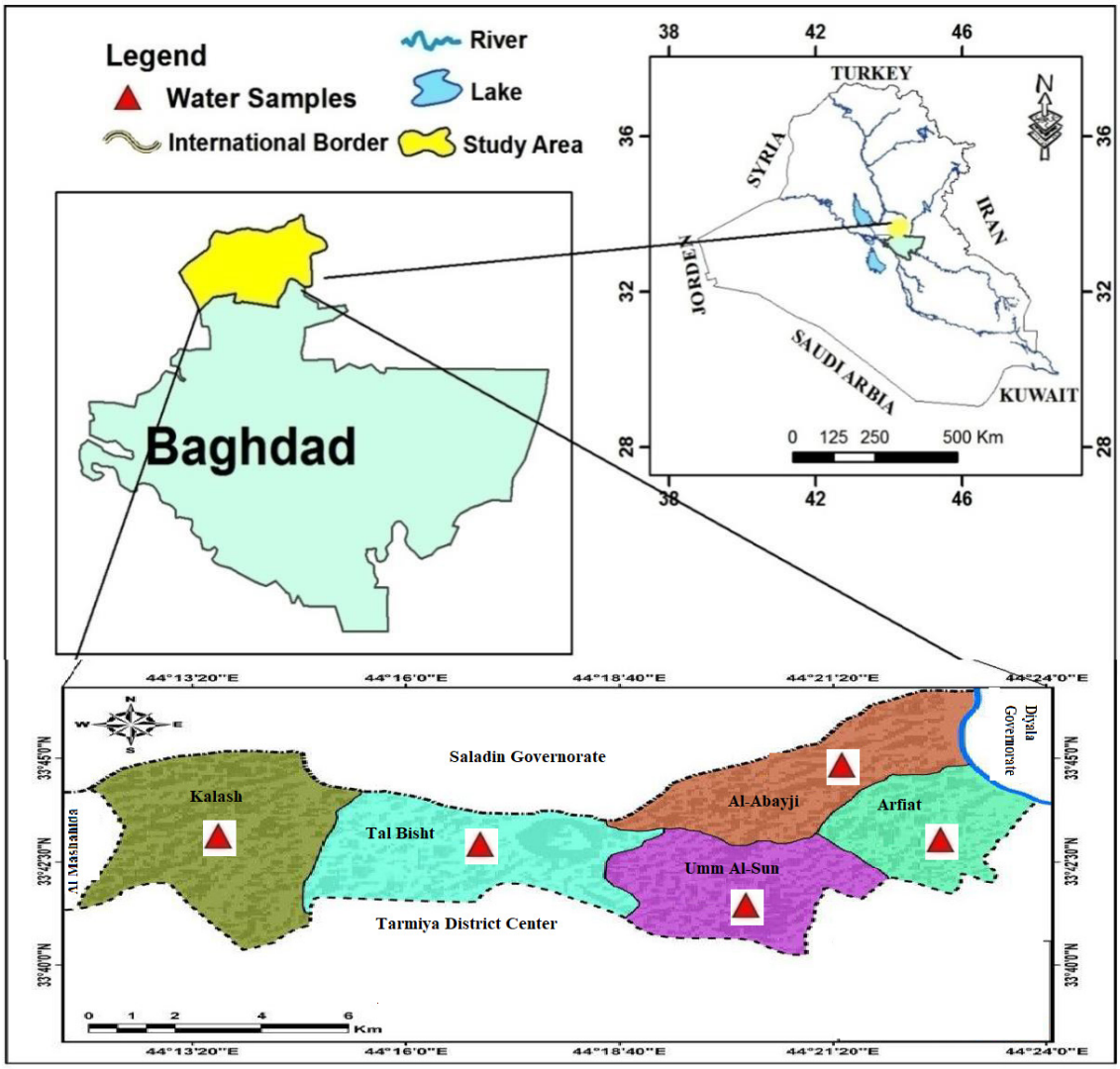

Fig. 1 Water sampling sites from Al-Abayji area - Baghdad - Iraq

Materials and Methods

5 samples of surface water, 5 samples of groundwater, and 3 samples of drainage water were collected within the districts of the Al-Abayji region - Baghdad - Iraq. Table 1 shows the codes and locations for taking water. Half a liter of each sample is taken and placed in plastic containers. A CR-39 detector with dimensions of (1x2) cm^2 was placed on the surface of the container and at a distance of 9 cm above each water sample. The containers were sealed to prevent radon leakage from the water samples. The reagents are left for a full month.

Table 1: Codes and locations for taking water from the Al-Abayji area - Baghdad - Iraq.

Code of model	Water type	Location for taking water samples
Sw1	Surface water	Al-Abayji District
Sw2	Surface water	Tal Bisht District
Sw3	Surface water	Arfiat District
Sw4	Surface water	Umm Al-Sun District
Gw1	Groundwater	Al-Abayji District
Gw2	Groundwater	Tal Bisht District
Gw3	Groundwater	Arfiat District
Gw4	Groundwater	Umm Al-Sun District
Gw5	Groundwater	Kalash District
Dw1	Drainage	Al-Abayji District
Dw2	Drainage	Tal Bisht District
Dw3	Drainage	Umm Al-Sun District
Dw4	Drainage	Kalash District

After the exposure process is carried out, trace detectors are taken to conduct a chemical scraping process using (NaOH) and its standard (6.25N), which is obtained by dissolving (250g) of (NaOH) in one liter of distilled water. The temperature was kept constant (± 1C°) during the skimming process. Low temperatures lead to condensation, which affects the solution. Also, temperatures must be prevented from rising to high values because they cause damage to the detector [6].

To detect traces of alpha particles, an optical microscope (400 x) was used. The average number of traces (Nave) for the sample (x) is divided by the calculated unit area (A) to obtain the density of traces using the eq.1

$$(\rho_x) = \frac{N_{ave}}{A} \quad \text{.....(1)}$$

Where : ρ_x ($Track/mm^2$) density of traces, N_{ave} the rate of total effects within the area (A (mm^2)7]].

The Calculations

the technique of calculating the effects of alpha particles emitted from radon gas was used to calculate the concentrations of ^{222}Rn gas in surface water, groundwater and Drainage water in the Al-Abayji region - Baghdad - Iraq.

Through comparison with standard samples using Eq. 2, the concentrations of radioactive radon gas were calculated [1]

$$C_x = \left(\frac{C_S}{\rho_S}\right) x\rho_x \ \dots\dots\dots (2)$$

Where ρ_x and ρ_C ($Track/mm^2$) density of traces for the unknown and standard samples, respectively: $C_x and\ C_s$ (Bq/L) Radon concentration for the unknown and standard samples, respectively [7].

As for the concentrations of radium (Ra) in the water of the Al-Abayji region - Baghdad, Iraq, they are calculated through the eq.3 [8].

$$C_{Ra}(Bq/Kg) = \frac{\rho hA}{slope\ T_e M} \ \dots\dots\dots (3)$$

Where: h is the distance between the sample and the detector, A is the surface area of the sample, M is the mass of the sample, T_e is the effective time and is calculated from the eq.4

$$T_e = T - \left(1 - e^{-\lambda t}\right) \dots\dots\dots (4)$$

Where: λ is the decay time for radon gas = 0.181 day^{-1} , t is the exposure time.

The annual effective dose from drinking water was calculated through eq.5

$$AED_{ing}\left(mSv/_y\right) = C_{Rn}\, xD_W\, xcf\, x\, T \quad \dots\dots\dots (5)$$

Where: C_{Rn} :is Radon gas concentrations in water (Bq/l), D_W the daily consumption of water (2 L/day), cf Specificity factor (10^{-8} Sv/Bq), $T = 365\ \frac{day}{y}$ [9].

The annual effective dose for water inhalation was calculated through eq. 6

$$AED_{inh}\left(mSv/_y\right) = C_{Rn}\, xRxD\, xF\, x\, T \quad \dots\dots\dots (6)$$

Where: C_{Rn} :is Radon gas concentrations in water (Bq/l),R : this means that radon concentrations of 10 Bq/L in water are equivalent to 1 Bqm^{-3} in air, D : the dose conversion factor ($9\ \frac{nSv/h}{Bq/m^3}$),*F*thefactorofequilibriumbetween ^{222}Rn gas and its progeny indoors (0.4), $T: is\ indoot\ time = 7000\ \frac{h}{y}$ [9]

The total annual effective dose was calculated through eq. 7 [9].

$$AED_{total}\left(mSv/y\right) = AED_{ing} + AED_{ing} \ldots\ldots\ldots\ldots (7)$$

Results and Discussion

Alpha particle tracking technology was used to calculate the levels of Radium and ^{222}Rn gas concentrations in the water of the Al-Abayji area - Baghdad - Iraq. The results of the levels of Radium and ^{222}Rn gas concentrations in surface water are listed in Table 2. It is noted from the table that the highest concentration of Radium and ^{222}Rn gas levels was in Tal Bisht District, and the lowest concentration of Radium and ^{222}Rn gas levels was in Arfiat District. The average concentration for Radium is 0.223 Bq/L and for ^{222}Rn gas is 3.673 Bq/L. The results of the levels of Radium and ^{222}Rn gas concentrations in groundwater were listed in Table 3. It is noted from the table that the highest concentration of Radium and ^{222}Rn gas levels was in the Al-Abayji District, and the lowest concentration of Radium and ^{222}Rn gas was in the Umm Al-Sun District. The average concentration of Radium is 0.130 Bq/L and that of ^{222}Rn gas is 2.138 Bq/L.

The results of the levels of Radium and ^{222}Rn gas concentrations in drainage were also listed in Table 4. It is noted from the table that the highest concentration of Radium and ^{222}Rn gas levels was in the Umm Al-Sun District, and the lowest concentration of radium and radon was in the Kalash District. The average Radium concentration is 0.302 Bq/L and the average ^{222}Rn gas concentration is 4.988 Bq/L.

Table 2: Concentration levels of Radium and radioactive radon gas in surface water taken from the Al-Abayji area - Baghdad - Iraq.

Code of model	density of traces (Track/mm2)	concentrations of radon gas (Bq/L).	Radium concentration (Bq/L)
Sw1	4149.828	3.42	0.207
Sw2	5108.414	4.21	0.255
Sw3	3810.076	3.14	0.190
Sw4	4756.528	3.92	0.238
Average	**4456.2112**	**3.673**	**0.223**

Table 3: Concentration levels of radium and radon gas in groundwater taken from the Al-Abayji area - Baghdad - Iraq.

Code of model	density of traces (Track/mm2)	concentrations of radon gas (Bq/L).	Radium concentration (Bq/L)
Gw1	3300.448	2.72	0.165
Gw2	2256.924	1.86	0.113
Gw3	2451.068	2.02	0.122
Gw4	1917.172	1.58	0.096
Gw5	3045.634	2.51	0.152
Average	**2594.249**	**2.138**	**0.130**

Table 4: Concentration levels of radium and radioactive radon gas in drainage taken from the Al-Abayji area - Baghdad - Iraq.

Code of model	density of traces (Track/mm2)	concentrations of radon gas (Bq/L).	Radium concentration (Bq/L)
Dw1	6358.216	5.24	0.318
Dw2	6042.732	4.98	0.302
Dw3	6455.288	5.32	0.322
Dw4	5351.094	4.41	0.267
Average	**6051.833**	**4.988**	**0.302**

Figure 2 shows a comparison between the concentrations of ^{222}Rn gas and Radium in types of water taken from the Al-Abayji area - Baghdad - Iraq. It is noted from the figure that the highest concentration of ^{222}Rn gas and Radium was in the water taken from Drainage. Drainage contains a lot of salts and minerals dissolved in it. It is also noted that the concentrations of ^{222}Rn gas and Radium in surface water are higher than in groundwater. The reason for this is that the study area is an agricultural area and its cultivation depends on phosphate fertilizers that contain levels of radionuclides. The concentrations of ^{222}Rn gas in the samples from the Al-Abayji region - Baghdad - Iraq, did not exceed the maximum threshold of contamination of 11.11 Bq/L suggested by the USEPA [9].

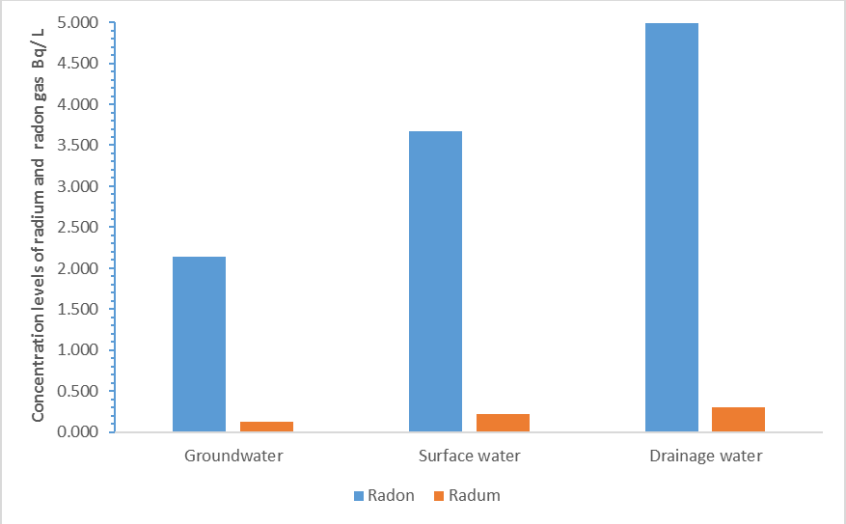

Fig. 2: comparison between the concentrations of ^{222}Rn gas and Radium in types of water taken from the Al-Abayji area - Baghdad - Iraq

The average annual dose of radon gas resulting from drinking and inhaling water is shown in Table 5. It is noted from the table that the effective dose of radon gas resulting from drinking and inhaling water is less than the maximum limit of 100 μSvy^{-1} that the EU council and WHO recommend [10].

Table 5: The annual effective dose resulting from drinking water and inhaling water and the total annual effective dose

Code of model	$AED_{Ingestion}\left(\mu Sv/y\right)$	$AED_{inhalation}\left(\mu Sv/y\right)$	$AED_{total}\left(\mu Sv/y\right)$
Sw1	24.97	8.62	33.58
Sw2	30.73	10.61	41.34
Sw3	22.92	7.91	30.83
Sw4	28.62	9.88	38.49
Average	**26.81**	**9.25**	**36.06**
Gw1	19.86	6.85	26.71
Gw2	13.58	4.69	18.27
Gw3	14.75	5.09	19.84
Gw4	11.53	3.98	15.52
Gw5	18.32	6.33	24.65
Average	**15.61**	**5.39**	**21.00**
Dw1	38.25	13.20	51.46
Dw2	36.35	12.55	48.90
Dw3	38.84	13.41	52.24
Dw4	32.19	11.11	43.31
Average	**36.41**	**12.57**	**48.98**

Conclusion

The levels of concentrations of Radium and radioactive radon gas were measured in the water of the Al-Abayji area, Baghdad, Iraq, using the alpha particle tracer technique. The Al-Abayji area is considered one of the most important agricultural areas in Baghdad. Models of surface water, groundwater, and other models of drainage water were chosen. The results showed that the highest concentrations of radium and radon were in the drainage water samples. Levels of radioactive radon gas concentrations were less than the safe limits of 11 Bq/L. Also, the average effective annual dose for ingestion and inhalation of water was less than 100 μSvy−1 that the EU Council and WHO recommend.

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