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Radon Concentrations and Ingestion of Effective Dose in Some Iraqi Brands of Drinking Water

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Abstract: *The research aims to determine the quantities of radon (^{222}Rn) commonly of ten brands of drinking water in different governorates of Iraq such as Babylon, Najaf, Zakho, Baghdad, Kirkuk, Wasit, Anbar, Karbala, and Basra. ^{222}Rn concentrations were measured using a RAD-7 detector that was made in the USA. Also, for adults age of ingestion of the effective dose and the cancer risk factor were calculated. The range values of ^{222}Rn concentrations were 0.011 Bq/L - 0.222 Bq/L. While the range values of ingestion of the effective dose and the cancer risk factor in all samples were 0.028 µSv/y - 0.567 µSv/y and 0.108 $\times 10^{-6}$ - 2.183$\times 10^{-6}$, respectively. The results of the ^{222}Rn concentration and ingestion of annual effective dose in all drinking water were below the global average limit. Therefore, all of the Iraqi brands of drinking water do not pose any danger to humans.*

Keyword*: ^{222}Rn in water, effective dose, RAD-7, cancer risk, and Iraq.*

I. Introduction

Environmental pollution constitutes a significant challenge confronting humanity and other living forms upon our planet today. It is characterised as the pollution of the Earth's physical and biological components to a degree that disrupts regular environmental processes. Pollutants may be naturally occurring compounds or energy, although they are deemed pollutants when present in excess of natural amounts. The use of natural resources at a rate beyond nature's ability to replenish itself leads to the contamination of air, water, and soil. [1]. Radon is a natural gas produced by the decay of radioactive elements, such as uranium, in soil, rock, and water. Radon in water comes primarily from underground sources [2], such as private wells that pump water from aquifers. Well water is often contaminated by the decay of uranium, and radon gas is formed, dissolves in groundwater, and accumulates in aquifers [3]. When water is pumped from wells, radon can be released into the air when used in household activities such as bathing, washing dishes, and cooking. Radon contamination of drinking water is a health concern, as it can lead to lung cancer when radon gas is released from water into indoor air. Radon can contaminate drinking water from private wells, especially in areas with high levels of uranium in the soil and rock [4]. Monitoring radon in drinking water is essential for several reasons, including that exposure to radon gas can increase the risk of lung cancer. Radon exposure can also lead to other health effects, such as an increased risk of respiratory illnesses. Therefore, ongoing monitoring of radon in water is essential [3]. Regular monitoring can help detect radon levels in drinking water early. Monitoring can also help identify sources of contamination and take action to address them. Monitoring can also help protect public health by reducing exposure to radon gas. Radon in bottled water may be a concern, but it's not a major one, as the gas dissipates quickly when exposed to air. Water is treated during the bottling process and exposed to air, allowing radon gas to escape [5]. This reduces the likelihood of radon being present in significant quantities in bottled water. However, despite the low levels of radon in bottled water, it can pose a cumulative risk. Studies

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indicate that even low levels can pose a long-term risk [6]. Many local and international researchers have studied the measurement of radon concentrations in drinking water samples (bottled) because of its importance to human health [7-10]. The work aims to measure the ^{222}Rn concentrations in some brands of drinking water (bottled) samples from different Iraqi governorates using the RAD-7 detector. As well as the study of ingestion effective dose and cancer risk factors based on radon gas concentration for all brands under study.

II. Experimental Part

1.1. Detector of Solid Status RAD-7

RAD7 detector (DURRIDGE company, made in the USA) is a versatile detector that is useful for detecting radon gas in air, soil, and water. It has several special features, such as the range detector (4 - 750,000 Bq / m3), has an internal air pump, is light-weight (5 kg), and nominal sensitivity. The RAD7 is a solid-state silicon semiconductor detector containing a 0.7-liter hemispherical cell. The detector operates at voltages ranging from 2000 to 2500 volts. This detector converts the alpha energy produced by the decay of ^{214}Po or ^{218}Po directly into an electrical signal. This device can therefore identify the isotope by distinguishing the electronic energy of the alpha particles. Therefore, we can distinguish radon isotopes ^{218}Po by alpha radiation (6 MeV) or radon isotope ^{214}Po (7.97 MeV) [11]. The RAD7 is a solid-state silicon semiconductor detector containing a 0.7-liter hemispherical cell. The detector operates at voltages ranging from 00 to 2500 volts. This detector converts the alpha energy generated by the decay of ^{214}Po or ^{218}Po directly into an electrical signal. This device can therefore identify the isotope by distinguishing the electron energy of the alpha particles. Therefore, we can distinguish radon isotopes ^{218}Po by alpha radiation (6 MeV) or radon isotope ^{214}Po (7.97 MeV) [12]. Figure 1 shows the internal structure and external appearance of the semiconductor detector.

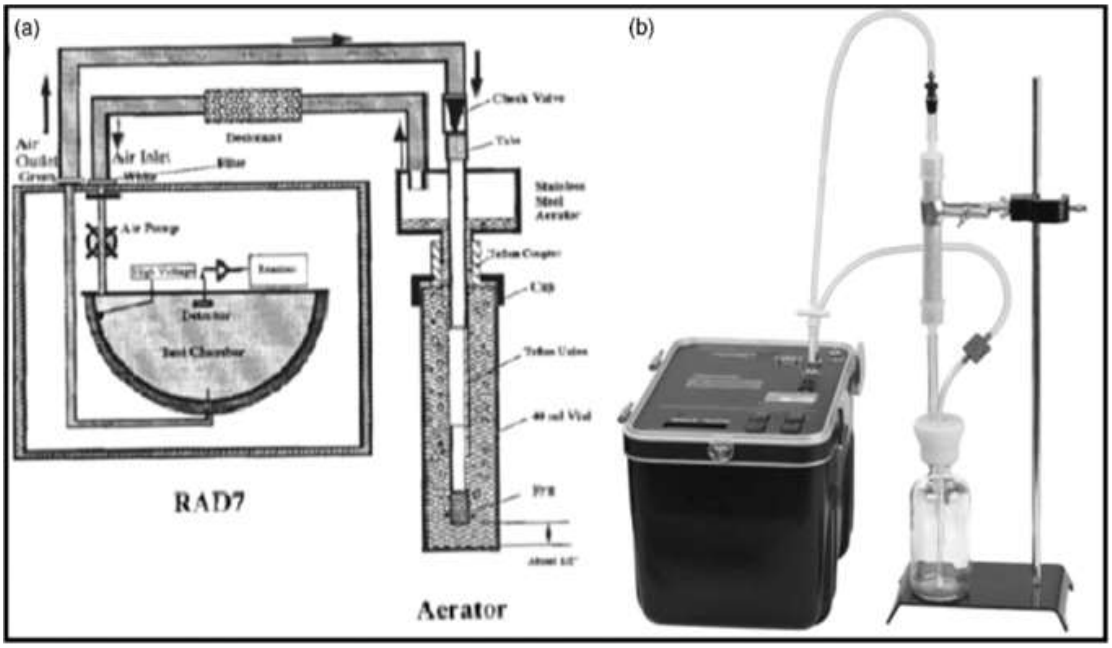

Figure 1. RAD-7 detector structure: a) internal structure and b) external structure.

1.2. Measurement of Radon

The working principle of RAD H_2O for measuring radon in water is to continuously pump radon into the air through a desiccant. In this case, the water sample collected in a 250 ml bottle creates a closed air-water loop that helps remove radon from the water. The readings are acquired within one hour of sample collection, and disinfecting must be performed, namely ensuring that the humidity level is below 6%, after which testing commences by configuring the machine to Grab mode. We installed a pump on the grab to address radon in the water. The radon removal rate from water within the air loop of a 250 ml sample is 94%, indicating a good efficacy. Figure 2 presents a schematic representation of the RADH2O supplement.[12].

Figure 2. RADH$_2$O detector.

III. Health risk factor

There are two health risk factors in the present work calculated, which it is the ingestion of effective dose ($AED_{ingestion}$) and cancer risk. The calculations of these factors are dependent on several parameters such as C_{RnW} (^{222}Rn concentrations), C_W (consumption of water), $DCF_{ingestion}$ (conversion factor), DL (life age), and RF (conversion cancer factor), , as follows [13-15]:

$$AED_{\text{ingestion}} = C_{Rnw} \times C_W \times DCF(\text{ingestion}) \tag{1}$$

$$CR = AED_{\text{ingestion}} \times DL \times RF \tag{2}$$

IV. Results and Discussion

^{222}Rn concentrations in drinking water in different governorates of Iraq, such as Babylon, Najaf, Zakho, Baghdad, Kirkuk, Wasit, Anbar, Karbala, and Basra, for ten brands were measured using a RAD-7 detector. Two health risk factors associated with radon in water were also calculated. Table 1 shows the results of the ^{222}Rn concentration, $AED_{ingestion}$, and CR in all samples of the present work. From Table 1, the data ^{222}Rn ranged from 0.011 Bq/L in Sawa Iraq - Babylon to 0.222 Bq/L in Alwaha Iraq - Karbala. While the results of $AED_{ingestion}$, and CR were ranged from 0.028 µSv/y to 0.567 µSv/y and from 0.108 ×10^{-6} to 2.183×10^{-6}, respectively.

Table 1. Results of ^{222}Rn concentrations, $AED_{ingestion}$, and CR in water in the present study.

No.	Brands name and original	^{222}Rn concentration (Bq/L)	Effective dose (µSv/y)	CR×10^{-6}
1	Sawa Iraq - Babylon	0.011	0.028	0.108
2	Al-Tur, Iraq - Najaf	0.029	0.075	0.288
3	Brtha Iraq - Najaf	0.026	0.067	0.258
4	Life Iraq - Zakho	0.177	0.453	1.744
5	Gardens Iraq - Baghdad	0.036	0.091	0.349
6	Mina Iraq - Kirkuk	0.012	0.031	0.118
7	Lara Iraq - Wasit	0.221	0.564	2.170

8	Saha Iraq - Anbar	0.130	0.332	1.277
9	Alwaha Iraq - Karbala	0.222	0.567	2.183
10	Dinar Iraq - Basra	0.198	0.507	1.952

When comparing the results of our current study with the globally permissible limit for radon concentrations in drinking water, which is 0.5 Bq/L established by the WHO [16], it was found that our results were within the globally permissible and acceptable limit, as shown in Figure 3.

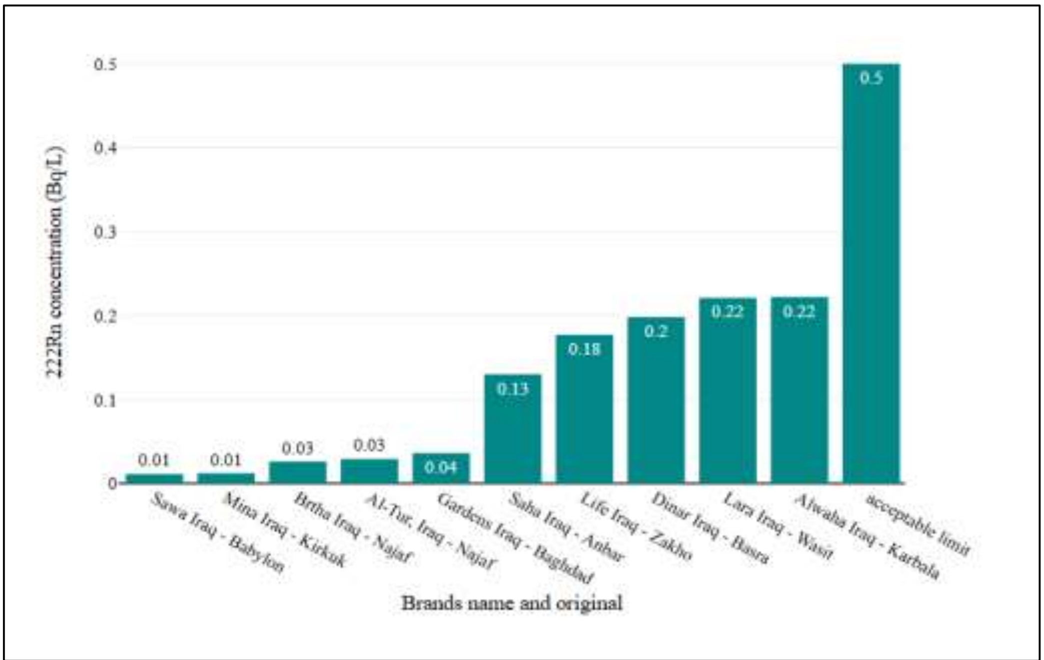

Figure 3. Comparison of the results of radon-222 in the current study with the acceptable limit.

The suggested radiation dosage was kept below 0.1 mSv/y through the consumption of radionuclides in drinking water [16]. The ingestion of radon-222 concentrations in water yielded findings below the permissible threshold of 0.1 mSv/year.as shown in Figure 4.

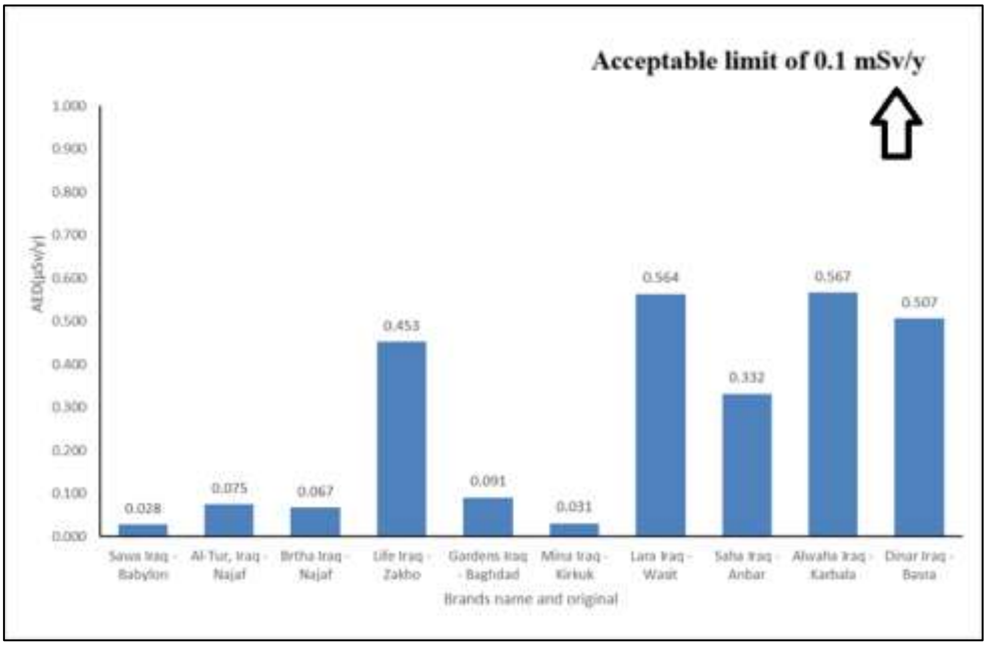

Figure 4. Comparison of the results of $AED_{ingestion}$ in the current study with the acceptable limit.

Upon comparing the results of our current investigation with the internationally accepted threshold for cancer risk associated with radon levels in drinking water, set at 10^{-4} [17], it was determined that our results fell within the allowed and acceptable range., as shown in Figure 4.

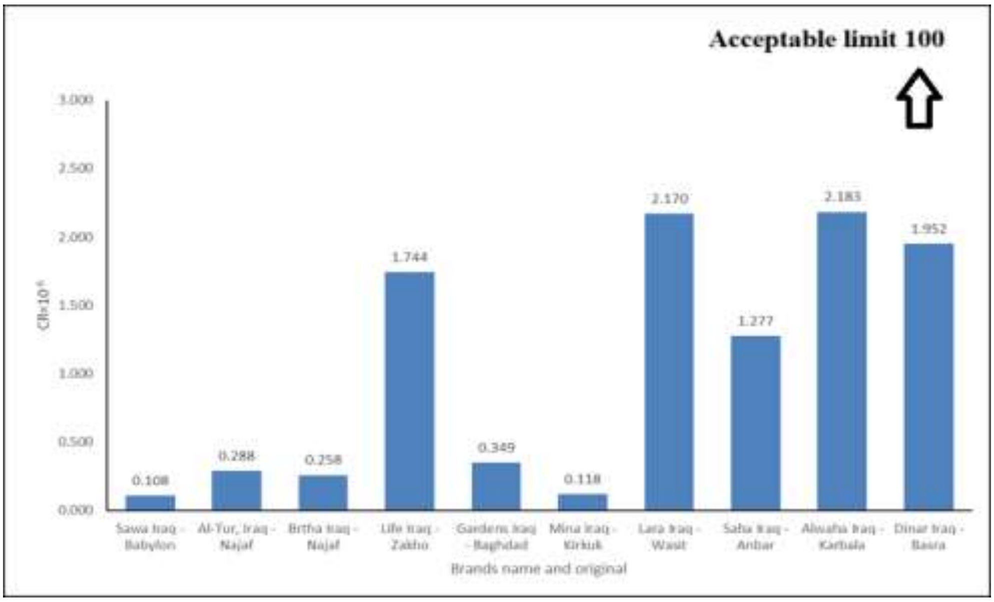

Figure 5. Comparison of the results of CR in the current study with the acceptable limit.

Table 1 indicates that fluctuations in radon gas levels in drinking water can be ascribed to various factors, including the water source and the geological characteristics of the extraction locations.
, in addition to environmental factors such as climate and human use (mining and drilling) [18].

Figure 6 represents a box plot of the distribution of radon concentrations for the water samples under study. A box plot is a statistical tool used to represent the distribution of data [19]. From the figure, we can see that the distribution of concentrations was normal, with no outliers.

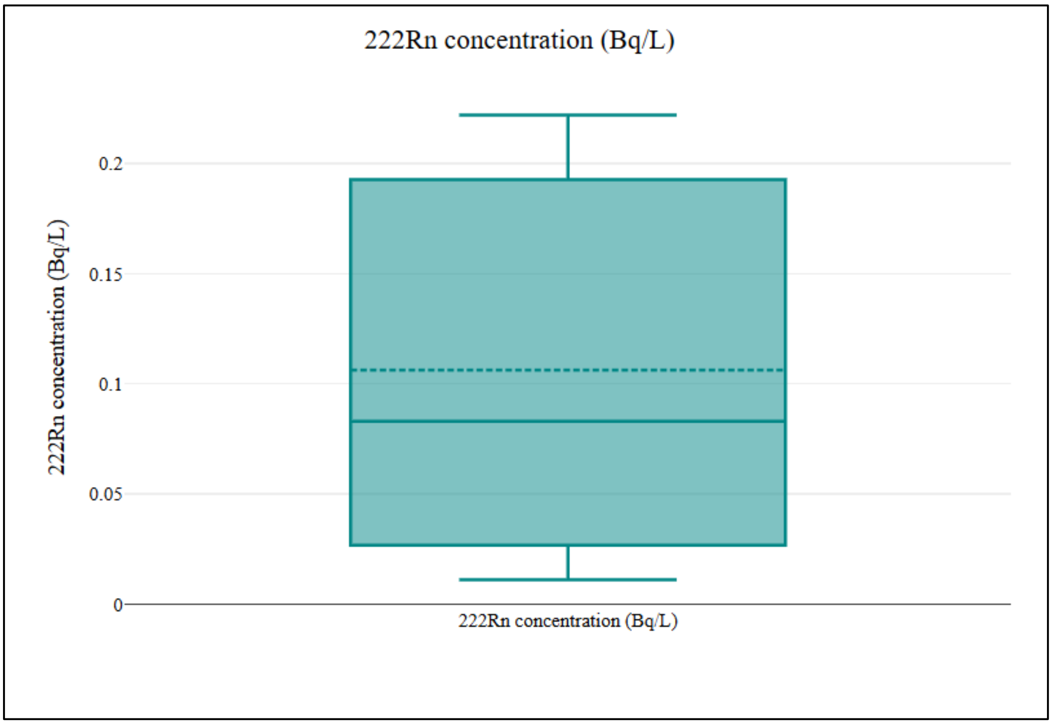

Figure 6. Boxplot of the results of ^{222}Rn concentration in the current study.

^{222}Rn concentrations in drinking water samples were compared with the current study similar investigations in other countries such as Jordan, Kuwait, Syria, Iraq (Nineveh), and Algeria [20]. Since the results of our study were higher than those of our study. Therefore, it is found that the results of radon concentrations in bottled water in the current study were within the safe and acceptable limits and lower than the global acceptable limit and previous studies.

V. Conclusions

^{222}Rn concentration values in all drinking water samples were found to be within desirable limits considered by the WHO. The results of AED ingestion and CR based on radon-222 in the present samples are lower than the worldwide values by the WHO and other reports. Therefore, it is safe to drink in terms of radon-222 concentrations because it has values lower than the permissible limit.

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