Health risk assessment of radon gas in water samples of Al-Kifl District and Al-Mahawil Center in Babylon Governorate

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Abstract. This study is concerned with developing radon gas concentrations in tap water samples. Radon gas was detected in selected drinking water samples from residential houses. A total of 20 samples were collected. Ten samples were taken from Al-Kafl, and ten were taken from Al-Mahawel. The radon concentration, the annual effective dose, and the cancer risk were calculated. The radon concentrations ranged from (0.157 Bq. L^{-1}) to (0.320 Bq. L^{-1}) at a rate of (0.179 Bq. L^{-1}) and these values are less than the permissible limit (0.5 Bq. L^{-1}) recommended by the World Health Organization (WHO) and EPA. As for the annual effective dose, it ranged from (0.401 μSv. y^{-1}) to (0.817 μSv. y^{-1}) at a rate of (0.457 μSv. y^{-1}). It is also less than the permissible limit (100 μSv.y^{-1}) or (0.1 mSv.y^{-1}). As for the risk of cancer, it ranged from $(0.0154 * 10^{-4})$ to for$(0.0314 * 10^{-4})$ at a rate, which is less than the permissible limit (10^{-4}). On this basis, there are no danger signs for individuals to consume or drink this water.

1 Introduction

Environmental and drinking water pollution caused by radon gas is one of the most important ecological and health issues. This is due to its serious effects on human health. Radon gas is a naturally occurring radioactive gas resulting from the radioactive decay of uranium and thorium elements found in rocks and soil. This colorless, odorless gas can dissolve in groundwater and surface water. Which makes it a major source of risk when using this water for drinking or cooking. Even when inhaled or consumed through water, it accumulates in body tissues and increases the risk of cancer, especially lung cancer. In Iraq, studies have shown increasing interest in measuring radon concentrations in different water sources. Mu'ayyad Tahir Ahmed and others conducted a study to measure radon concentrations in 29 drinking water samples in Kirkuk City, and the result was (0.97 Bq/L^{-1}) [1]. Also, a study was conducted by Dr. Murtada Shaker Aswad, Mustafa Sami Al-Moussawi, and others to measure radon concentrations in 10 samples of drinking water in the Al-Qadisiyah district, and the results were (0.24 Bq. L^{-1}) [2]. Also, a study was conducted by Asaad Hamid Ismail and Saleh Omar Hadi to measure radon concentrations in Erbil Governorate (Iraqi Kurdistan). The results of 42 drinking water samples from 21 main areas were (4.693±2.213 Bq. L^{-1}) [3]. A study conducted by Kamal Al-Bakr Al-Barouni, Abdul Hamid Abdullah Al-

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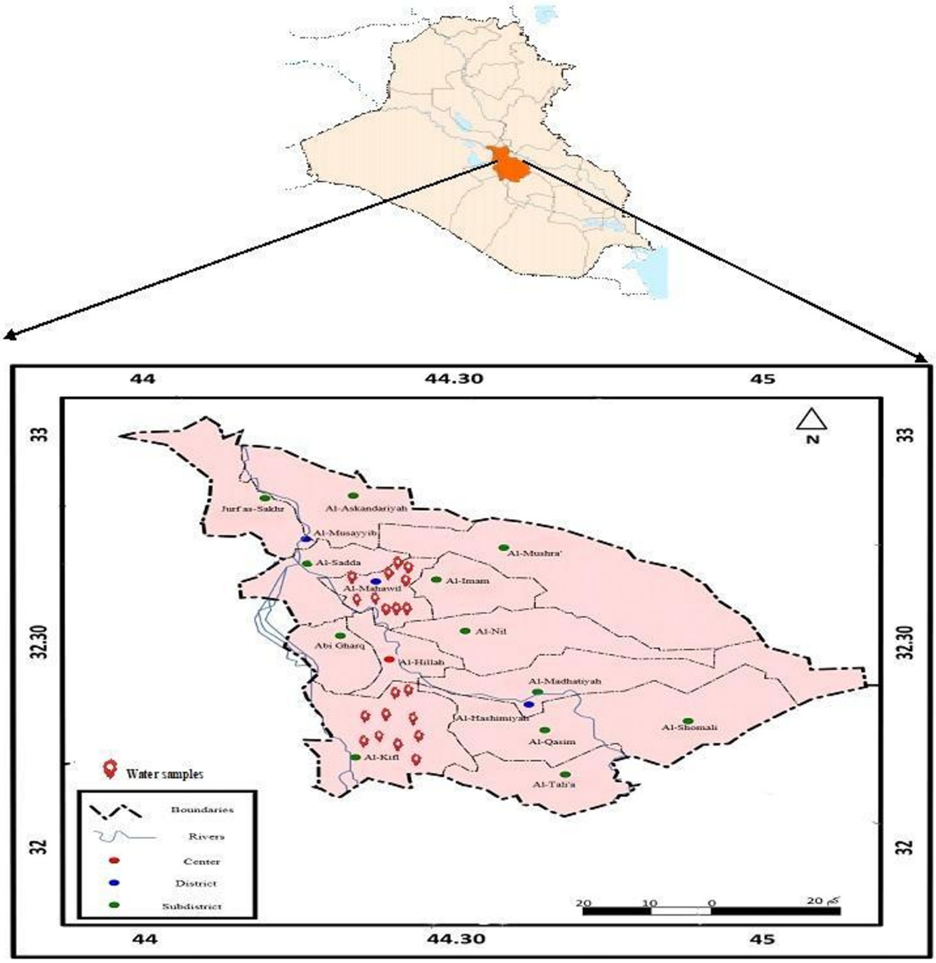
Hadiyati, and others to evaluate the concentration of radon gas in tap water in the city of Haditha, west of Anbar Governorate, with 22 water samples and the concentration results ranged (0.0091-0.031 Bq. L^{-1}) [4]. A study was conducted by Karar Mohammed Taleb, Rasha Asaad Ahmed, and Raghad Saadoun Mohammed to evaluate the concentrations of radon gas in river water and sediment samples in the Diwaniyah and Samawah governorates in southern Iraq. The results in the sediments and rivers were respectively (334.6 $Bq.m^{-3}$) and (477.52 $Bq.m^{-3}$) [5]. Studies related to monitoring radon gas concentrations in water sources in Iraq provide clear ideas, information, and concepts regarding an important environmental and health issue. In addition to the studies mentioned above, many studies show variations in radon concentrations, especially in different water sources, such as tap water and rivers. This indicates the impact of geological factors and human activities on pollution levels. These studies have many clear positives, including increasing awareness about the danger of radon gas and adherence to international standards and guidelines represented by the US Environmental Protection Agency, the World Health Organization, the International Atomic Energy Agency IAEA, the International Commission on Atomic Radiation Protection ICRP, the European Union, and others for protection, as well as geographical analysis, and knowing the places with high and low concentrations. Therefore, such studies must continue, as there is a lack of coverage of the governorates of Iraq, which lack updated studies.

2 Methods

2.1 Study area

Al-Kifl and Al-Mahawil districts are located within Babil Governorate. Al-Kifl district is located south of Babil Governorate in Iraq. The district was named after the Prophet Dhu al-Kifl; peace be upon him. The district is on latitude (320 13) north and longitude (440 22) east. The district is considered part of the alluvial plain and is 20 to 25 meters above ground level. The Euphrates River is also located near the Al-Kifl district and is an important water source. The district is 115 km south of Baghdad Governorate. As for Al-Mahawil, it is situated in the middle of Babil Governorate, north of Hillah District, on latitude (320 37) north and longitude (440 18) east. It is approximately 35 meters above sea level and part of the alluvial plain. Al-Mahawil is 80 km south of Baghdad Governorate. The two sites were identified using the GBS system on the mobile device. Table (1) and Figure (1) show a geographical map of the study area and the sample locations.



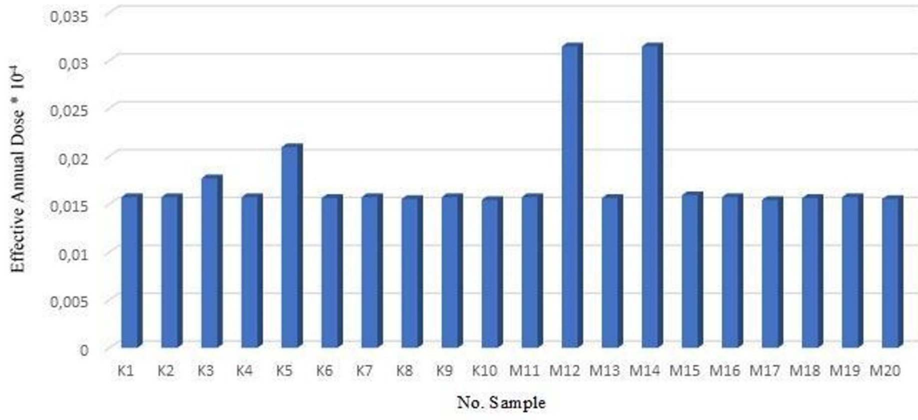


Fig. 1. Map of the study area of Al-Kifl Subdistrict and Al-Mahawil District.

Table 1. Current research's sample number, code, and geographical location.

NO.	Sample code	Location	
		Latitude	Longitude
1	K1	32.13302	44.22151
2	K2	32.13141	44.21560
3	K3	32.12347	44.22054
4	K4	32.13311	44.21191
5	K5	32.13272	44.22418
6	K6	32.13118	44.22047
7	K7	32.13136	44.23019
8	K8	32.12580	44.22178
9	K9	32.13395	44.22078
10	K10	32.14142	44.23458
11	M11	32.64879	44.40972
12	M12	32.64973	44.42003
13	M13	32.65219	44.42191
14	M14	32.64885	44.41238
15	M15	32.65373	44.42128
16	M16	32.39103	44.40865
17	M17	32.39153	44.42506
18	M18	32.39045	44.40458
19	M19	32.41254	44.41785
20	M20	32.38363	44.42514

2.2 Radon gas measurement

We could use an alpha particle detector to measure radon gas concentrations in water samples. It takes about 60 minutes to get the result of one sample. It is necessary to remove the humidity before starting the measurement process for each sample so that the moisture does not exceed 6%. We start the measurement procedures to evaluate the radon concentration in the water samples using the GRAB system by stirring the radon gas dissolved in the water sample using the pump (see Figure 2). In each session, the pump operates for 5 minutes in a stagnation state to reach equilibrium. After that, the radon is taken and given to the RAD-7 device. This process is repeated four times, each taking 5 minutes, so the total time is 30 minutes (measuring the radon concentration, temperature, humidity, and natural deviation). It includes the operating code, the cumulative sectarian distribution, the outcome of the cycles, and a schematic diagram of the four circles [6]. In the 250 ml water sample, 95% is the percentage of radon removal from the water sample, which is a very high percentage.

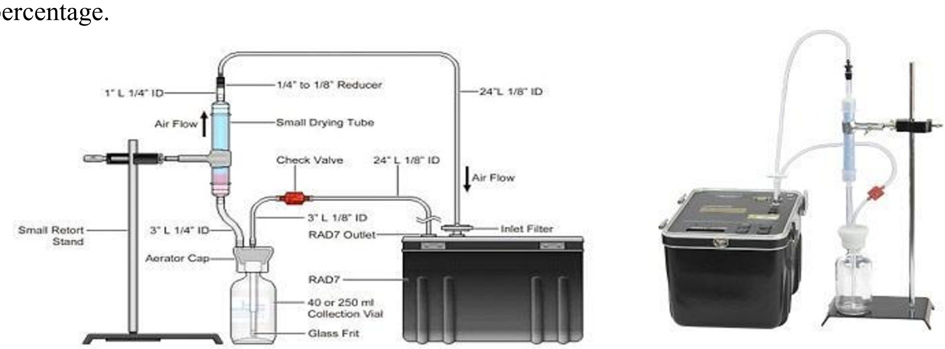


Fig. 2. (a) RAD-7 working diagram. (b) RAD-7 device shape**.**

2.3 Theoretical calculations

The annual effective dose AED was calculated based on the intake of radon gas concentrations from tap water when drinking that water for adults, as it was calculated using equation (1).

$$Effective\ Annual\ Dose\left(\frac{\mu S}{Y}\right) = C\left(\frac{Bq}{L}\right) * WC\left(\frac{L}{Y}\right) * DCF\left(\frac{\mu SV}{Bq}\right) \quad (1)$$

Where C is the concentration of radon gas measured in units (Bq. l-1), WC is the annual amount of water consumed per person, it was also (2 L.d-1), and for a year, it will be equal to (730L/y) [7]. DCF is the conversion index in units ($\frac{\mu SV}{Bq}$) and is equal to ($0.0035\mu Sv/y$) [8]. As for the lifetime cancer risk LTC due to the intake of radon gas in drinking water for adults as well, it was determined using equation (2) [9].

$$L.T.C = AED\left(\frac{\mu Sv}{y}\right) * DL(Y) * RF\left(\frac{1}{Sv}\right) \quad (2)$$

Where DL is the age of the individual (70 years), RF is the risk factor (0.055 Sv^{-1}) by (ICRP) [20].

3 Results and discussion

According to the World Health Organization, the results showed that all radon gas concentrations in water samples taken from Al-Kifl and Al-Mahaweel Center are less than the permissible limits for radon gas concentration in drinking water samples (0.5 Bq/L). The measurements varied from (0.157 Bq/L) in the (K10, M17) to (0.320 Bq/L) in the (M12) and at a rate of (0.179 Bq/L). As for the annual effective dose AED, its results varied as the lowest value was ($0.4011\mu Sv/y$) in the (K10) and the highest value was ($0.8176\mu Sv/y$) in the (M12, M14)and at a rate of ($0.4576\mu Sv/y$), which is a value less than the permissible limit ($100\mu Sv/y$) or ($0.1\ mSv/y$) according to the World Health Organization 2011. As for the lifetime risk of cancer, it ranged for ($0.0154 * 10^{-4}$) in the sample (K10, M17) to for($0.0314 * 10^{-4}$ in the two samples (M12, M14), which is much less than the permissible limit (10^{-4}). We notice that most concentrations are close in quantity, which can be attributed to the similarity of environmental conditions—most houses from which the water samples were taken share a unified water distribution network. The reason for the low radon concentration in most of the samples may be due to the exposure of the water tanks in the houses to ventilation as a result of uncovering them, which leads to the evaporation of radon gas, unlike the values of radon gas concentrations in groundwater, which are high, even higher than the concentrations of surface water, because this water is confined between rocks, so radon gas does not leak from it [10-15]. All of these measurements for radon concentrations, annual effective dose, and lifetime cancer risk are shown in Table (2).

Table 2. Radon concentrations, annual effective dose, and lifetime cancer risk.

No.	STUDY AREA	Sample code	Rn concentrations (Bq/L)	S. D	$AED(\mu Sv/y)$	$LTC * 10^{-4}$
1	Kifl	K1	0.16	0.012649111	0.4088	0.0157388
2	Kifl	K2	0.16	0.012649111	0.4088	0.0157388
3	Kifl	K3	0.18	0.013416408	0.4599	0.01770615
4	Kifl	K4	0.16	0.012649111	0.4088	0.0157388
5	Kifl	K5	0.213	0.01459452	0.544215	0.020952278
6	Kifl	K6	0.159	0.01260952	0.406245	0.015640433
7	Kifl	K7	0.16	0.012649111	0.4088	0.0157388
8	Kifl	K8	0.158	0.012569805	0.40369	0.015542065
9	Kifl	K9	0.16	0.012649111	0.4088	0.0157388
10	Kifl	K10	0.157	0.012529964	0.401135	0.015443698
11	Mahawil	M11	0.16	0.012649111	0.4088	0.0157388
12	Mahawil	M12	0.32	0.017888544	0.8176	0.0314776
13	Mahawil	M13	0.159	0.01260952	0.406245	0.015640433
14	Mahawil	M14	0.32	0.017888544	0.8176	0.0314776
15	Mahawil	M15	0.162	0.012727922	0.41391	0.015935535
16	Mahawil	M16	0.16	0.012649111	0.4088	0.0157388
17	Mahawil	M17	0.157	0.012529964	0.401135	0.015443698
18	Mahawil	M18	0.159	0.01260952	0.406245	0.015640433
19	Mahawil	M19	0.16	0.012649111	0.4088	0.0157388
20	Mahawil	M20	0.158	0.012569805	0.40369	0.015542065
Minimum		---------	0.157	0.012529964	0.401135	0.017618
Maximum		---------	0.320	0.017888544	0.8176	0.031478
average		---------	0.1791	0.013286846	0.457601	0.017618
Permissible limit		---------	0.5	---------	100	10

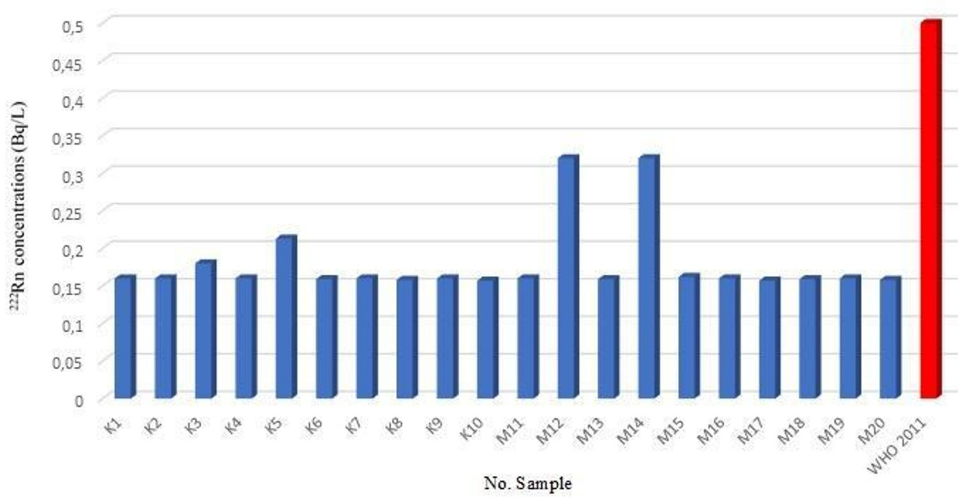


Fig. 3. Comparing ^{222}Rn concentrations in water samples with permissible value for drinking water (Al-Kifl Subdistrict and Al-Mahawil Center).

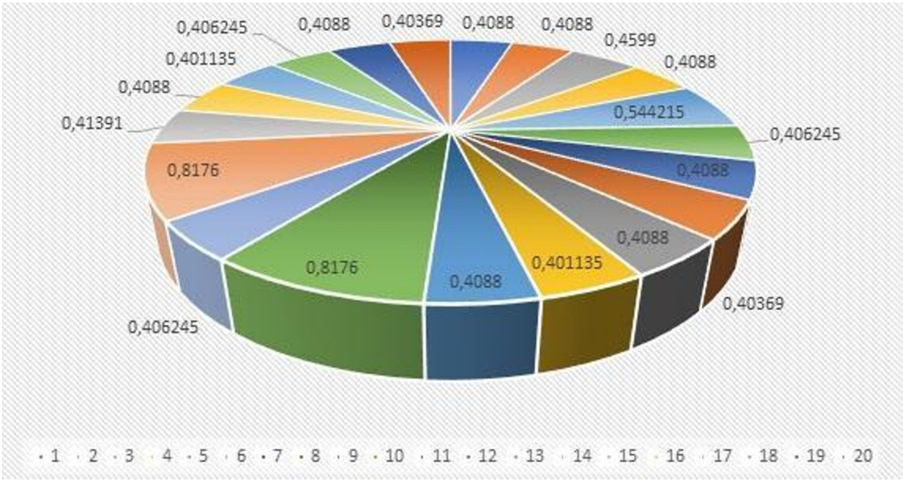


Fig. 4. Percentage of AED in samples under study (Al-Kifl Subdistrict and Al-Mahawil Center).

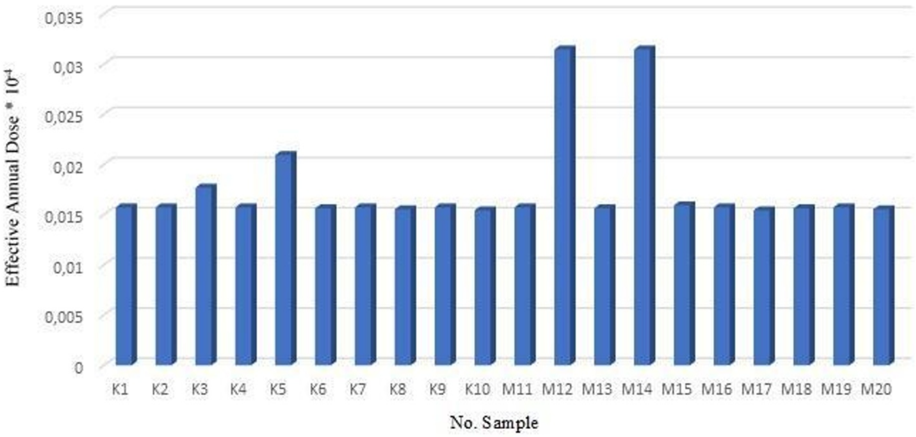


Fig. 5. Comparing cancer risk factors associated with 222Rn concentrations in water samples against the permissible limits for drinking water (Al-Kifl Subdistrict and Al-Mahawil Center).

Table 3. Radon concentrations in drinking water from Al-Kifl Subdistrict and Al-Mahawil Center.

Country	Radon concentration (Bq/L)
Turkey	2.7-34.11
India	1.69-3.97
Palestine/ Nablus	0.9-1.3
Romania	0.5- 12.9
Syria	2.8-9.0
Saudi Arabia	0.76-9.15
Iraq (Baghdad)	0.03-0.15
Iraq (Erbel city, Kurdistan region)	2.01- 4.69
Iraq-Kirkuk	0.07- 5.02
Iraq (Anbar)	2.16-11.88
Iraq (Hilla)	0.03-0.11
Current Study	0.1791

4 Conclusions

In this research, we have reached a certain result, which shows that all water samples taken from residential homes carry radon concentrations lower than the permissible global limits. Also, the cancer risk values in all samples were lower than the permissible limit, and the effective annual dose was lower than the allowable limits, according to the World Health Organization 2011. On this basis, radon gas in drinking water in the Al-Kifl district and Al-Mahawil center does not have any dangerous effects on the health of individuals when using that water.

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