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Radon Concentrations in Tap and Ground Water in Kirkuk Governorate Using Active Detecting Method RAD7

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Abstract Radon gas represents, one of the significant natural sources of public radioactive exposure. Monitoring it's concentrations in air, water and soil is of great importance. In the present work, radon concentrations and Annual Effective Dose in tap and ground water have been investigated at Kirkuk governorate. Fifteen tap water samples along with (fifteen) ground water samples have been taken from (fifteen) different areas at Kirkuk governorate. The electronic radon detector RAD7, has been used thought the research. For tap water, the highest, lowest and average concentration was (2.740 $Bq.l^{-1}$), (0.0359 $Bq.l^{-1}$) and (0.33104 $Bq.l^{-1}$) respectively. The annual effective dose to an individual consumer was (1.501 $mSv.y^{-1}$). For ground water, the highest, lowest and average concentration was (5.630 $Bq.l^{-1}$), (0.108 $Bq.l^{-1}$) and (2.316 $Bq.l^{-1}$) respectively. The annual effective dose for individual consumer was (10.136 $mSv.y^{-1}$). This result is expected since, underground is directly in contact with the soil and rock layer which are the source of radon parents. After storing the samples for one month radon concentration are measured again. The average concentration is lowered to 9.84% of the original one before storage.

Keywords: *water pollution, radioactive pollution, radon concentration, RAD7*

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1. Introduction

One of The largest natural source of radiation exposure to human being is radon gas that exist within air, water and soil [1]. Radon is a chemically inert radioactive gas of atomic number of 86. [2]. There are three naturally occurring isotopes of radon gas. The first one is (^{222}Rn) and called Radon (Radium emanation) which is produced from the decay of ^{238}U series which represents about 99.3% of the natural uranium within the earth's crust. Radon's half-life is about (3.825 days) with decay constant of about (0.1812 day^{-1}) [3]. The second isotope (^{220}Rn) is called Thoron (Thorium emanation) which is naturally produced during the decay of ^{232}Th series. The third isotope (^{219} Rn) is called Actinon (Actinium emanation) which is produced through decay of ^{235}U series [4]. The produced radon gas may diffuse through the soil and rocks and dissolve in ground water [5]. Radon can enter buildings from fractures, cracks and by water systems. Water in rivers and open reservoirs usually contains very little radon concentrations. That's why buildings use tap water usually do not have a radon risk.

The risk is much more when ground water is used as the main water supply for buildings and have closed systems that pumps water directly to consumers with no enough time for radon to escape or decay [6].

The present work aims to investigate radon gas concentrations as one the most important natural radiation sources in the environment. This subject has been chosen because of the importance and frequent use of water in almost every activity of our life. Furthermore no previous studies of radon concentrations has been made on Kirkuk.

Radon is the second leading cause of lung cancer in the U.S, smoking being the first. The nature of building materials, soil, and water used for drinking and other domestic applications can make variable contributions to the radon level in indoor environment [7].

2. Experimental Part

At the current study, fifteen of well water samples and fifteen tap water samples have been collected from different districts of Kirkuk governorate. All water samples were collected in special glass bottles 250 ml capacity designed for radon in-water activity measurement ensuring minimum radon loss by degassing and without any air contact as shown in reference [8]. The samples was analyzed directly with time difference between taking the sample and analyzing it no more than 24 hours.

The water samples should be: a) representative for the water being tested, and b) no contact with air [9].

The RAD7 detector is a semiconductor type that converts radiation energy directly to electrical signal. The

RAD7's internal sample cell is a 0.7 liter hemisphere, coated from inside with an electrical conductor. A solid-state, Ion-implanted, planar, Silicon alpha detector is at the center of the hemisphere as shown in (Figure 1) [9]. The detector should be purged first. Purging is the process whereby the moisture and the old radon in the chamber of the detector are removed. This is done by a pump in the detector, which pumps fresh air into the chamber through a drying unit. The drying unit is 6 cm in diameter and 28 cm in length [10]. The drying unit consists of granules and the purpose of the granules is to absorb moisture, since the detection efficiency of the RAD7 decreases as humidity increases due to the neutralization of polonium ions by water molecules [11].

Diagrammatic illustrations of the radon monitor, RAD7 with RAD H_2O accessory for measuring radon in water samples has been shown in the A choice of selection among two different protocols (Wat 40 and Wat 250) is available in the setup of RAD7 for a user enabling him to calculate radon concentration in vials of two different (40 or 250 ml) supplied with the equipment.

In our case we used vials of 250 ml capacity. Water 250 protocol, which automatically configures RAD7 to perform a test according to the selected parameters has been chosen. The pump run for five minutes, aerating the sample and delivering the radon to the RAD7 in this case. The system will wait a further five minutes then start counting. After five minutes, it will print out a short-form report. The same thing will happen again five minutes later, and for two more five-minute periods after that. At the end of the run (30 minutes after the start), the RAD7 prints out a summary, showing the average radon reading from the four cycles counted, a bar chart of the four readings, and a cumulative spectrum. The radon concentration of the water sample will be calculated automatically by the RAD7 after that. All data, except the spectrum, will be also stored in the memory and will be printed [11].

The samples have been stored at the same conditions one month in June 2016, and radon concentrations have been re-measured again in order to notice the effect of storage on them.

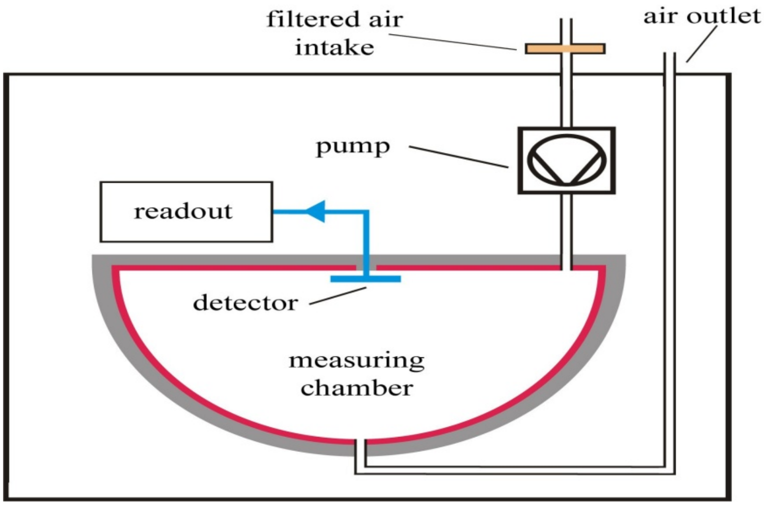

Figure 1. Measurement chamber of the RAD7

Figure 2. Measurement apparatus RAD

2.1. Annual Effective Dose

The annual effective dose of an individual consumer due to intake of radon from tap water and ground water is evaluated using the relationship [12]

$$AED_W = C_w C_{RW} D_{CW} \quad (1)$$

Where AED_w is the annual effective dose (mSv.y^{-1}) due to ingestion of radionuclide from the consumption of water. C_w represents the concentration of radon in the ingested tap or ground water (Bq.l^{-1}). C_{Rw} is annual intake of drinking water (1095 l.y^{-1}) and D_{cw} is the ingested dose conversion factor for ^{222}Rn (4 Sv.Bq^{-1}) [12,13].

3. Results and Discussion

The results of radon concentrations in tap water samples collected from Kirkuk districts are reported in Table 1. The (Mean) represents the value of average concentration, (High) is the highest value and (Low) is the lowest value. The annual effective dose for each sample also has been calculated. We notice a lot of variations for samples of water of different locations as shown in Figure 3. The minimum concentration of ^{222}Rn was noticed at samples from Al-Mas, Al-Nasr (0.0359) Bq.l^{-1}, and the maximum concentration of ^{222}Rn was noticed for samples of Raheemawa (2.740) Bq.l^{-1} with an average concentration equal to (0.33) Bq.l^{-1}. The average annual effective dose was (1.501) mSv.y^{-1}. This is mainly due to the short half-life of ^{222}Rn gas (3.8 day). We believe that the difference between lengths of network pipelines from the source of water supply to the buildings is the main source of this variations.

The results of ground water samples are shown in the Table 2. The results are noticeably higher than of tap water as expected. The results are plotted in Figure 4 to show the relative differences of radon concentrations for different areas. The minimum concentration was found at Al-Mas samples (0.108) Bq.l^{-1} while the maximum concentration was at the samples taken from Al-Qadsia (5.630) Bq.l^{-1} with an average (2.316±1.52) Bq.l^{-1}. The average annual effective dose was found to be 10.136±3.183 mSv.y^{-1}. The reason is due to the differences in the geological nature of each region and soil type.

Table 1. Radon gas concentration C_{Rn} (Bq.l^{-1}) and Annual Effective Dose (AED), for tap water samples

Regions Studied	C_{Rn} (Bq.l^{-1})		Mean of C_{Rn} (Bq.l^{-1})	(AED) (mSv/y)
	High	Low		
Al-Nasr	0.144	0.00	0.0359	0.157242
Al-Qadsia	0.144	0.00	0.0716	0.313608
Al-Shorja	0.144	0.00	0.0716	0.313608
Raheemawa	3.320	2.170	2.740	12.0012
Arafa	0.718	0.287	0.503	2.20314
Al-Mas	0.144	0.00	0.0359	0.157242
Al-Mohaphda	0.144	0.00	0.108	0.47304
Moustashfa Al-Atfal	0.287	0.00	0.143	0.62634
Alwhada	0.144	0.00	0.0718	0.314484
Wahid Hizran	0.287	0.00	0.143	0.62634
Tiseen	0.718	0.287	0.431	1.88778
Tareq Baghdad	0.144	0.00	0.108	0.47304
Domez	0.574	0.289	0.396	1.73448
Asra Miphkouden	0.431	0.00	0.215	0.9417
Al-Felik	0.144	0.00	0.0716	0.313608
	Average		**0.33104±0.575**	**1.501±1.22**

Table 2. Radon gas concentration C_{Rn} (Bq.l^{-1}) and annual effective dose (AED), for ground water samples

Regions Studied	C_{Rn} (Bq.l^{-1})		Mean of C_{Rn} (Bq.l^{-1})	(AED) (mSv/y)
	High	Low		
Al-Nasr	3.160	1.730	2.740	12.0012
Al-Khadsia	6.640	4.310	5.630	24.6594
Al-Shorja	2.600	1.580	2.050	8.979
Raheemawa	4.620	2.600	3.430	15.0234
Arafa	1.010	0.431	0.682	2.98716
Al-Mas	0.287	0.00	0.108	0.47304
Al-Mohaphda	4.190	3.160	3.710	16.2498
Moustashfa Al-Atfal	0.574	0.00	0.287	1.25706
Alwhada	3.470	1.730	2.450	10.731
Wahid Hizran	1.880	1.140	1.440	6.3072
Tiseen	3.470	1.580	2.310	10.1178
Tareq Baghdad	6.100	4.650	5.330	23.3454
Domez	4.190	1.590	2.850	12.483
Asra Miphkouden	0.286	0.00	0.143	0.62634
Hay Al-Tubat	2.310	1	1.580	6.9204
	Average		**2.316±1.521**	**10.136±3.183**

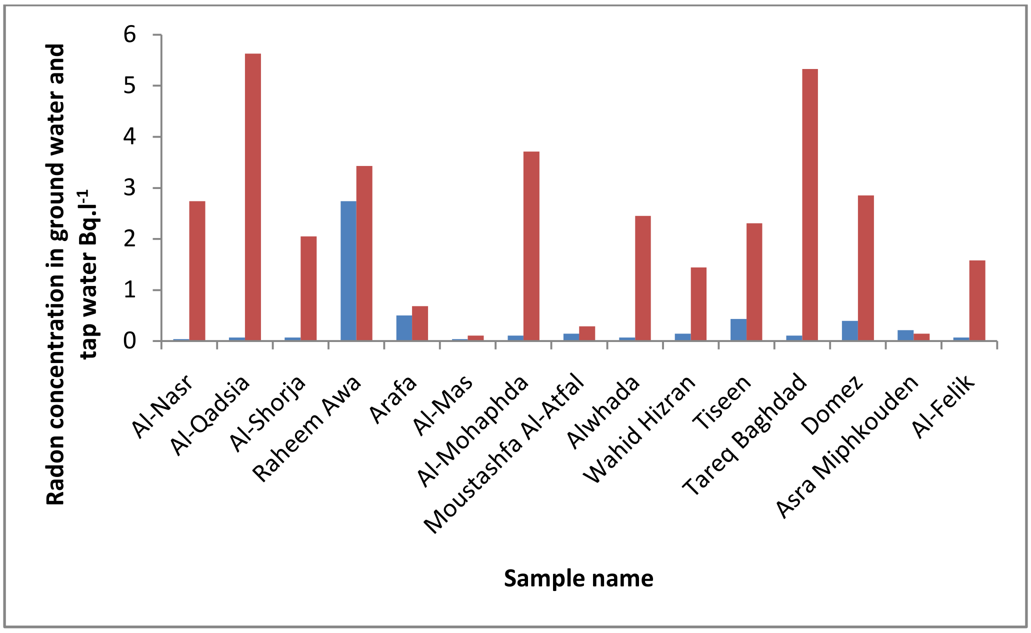

Figure 3. Bar diagram showing variation in radon concentration of the ground water and tap water samples

Table 3. Radon concentration in groundwater as reported by previous studies

Water type	Country	Average radon concentration Bq.l^{-1}	Reference
Ground water	Iraq, Nenava	1.133	[14]
Tap water	Iraq, Al-shomaly	0.29	[15]
Tap water	Turkey	0.091	[16]
Tap water	Kuwait	0.74	[17]
Ground water	Syria	13	[18]
Tap water	Iran	0.21-3.89	[19]
Ground water	Jordon	3.9	[20]
Ground water	Khartoum	59.2	[21]
Ground water	Algeria	7	[22]
Ground	Italy	1.80-52.70	[23]
Drinking	Poland	0.42-10.52	[24]
Groundwater	China	110-36.00	[25]
Groundwater	India	11.7-381.2	[26]

Table 4. Regions studied, radon gas concentration C_{Rn} (Bq.l^{-1}), annual effective dose (AED), for tap water and ground water samples in Kirkuk governorate before and after the storage

Regions Studied	C_{Rn} (Bq.l^{-1}) before the storage		Mean of C_{Rn} (Bq.l^{-1})	C_{Rn} (Bq.l^{-1}) after the storage		Mean of C_{Rn} (Bq.l^{-1})
	High	**Low**		**High**	**Low**	
Al- Mohaphda	0.144	0.00	0.108	0.144	0.00	0.0359
Alwhada	0.144	0.00	0.0718	0.00	0.00	0.00
Arafa	1.010	0.431	0.682	0.144	0.00	0.108
Al-Whada	3.470	1.730	2.450	0.144	0.00	0.0718
Raheemawa	4.620	2.600	3.430	0.287	0.00	0.144
Al-Qadsia	6.640	4.310	5.630	0.144	0.00	0.0716
Asra-Miphkouden	0.286	0.00	0.143	0.143	0.00	0.0357
Tiseen	3.470	1.580	2.310	0.144	0.00	0.108
Tareq Baghdad	6.100	4.650	5.330	0.287	0.00	0.143
	Average		**2.239±1.496**	**Average**		**0.0797±0.282**

The concentrations of radon before and after one month storage also has been investigated and the results are shown in Table 4. We notice the samples of tap water in (Al-Mohaphda, Alwhada) districts have concentration (0.0718, 0.108 Bq.l^{-1}) respectively before storage. The concentrations of radon is lowered to (0.00-0.0359 Bq.l^{-1}) respectively for the same districts after storage. We also notice that the effect of storage was significant on radon concentrations for samples taken from Al-Qadsia well. The concentration of radon before storage was the highest 5.630 Bq.l^{-1}, while after storage it was lowered to 0.0716 Bq.l^{-1}. The average concentration is lowered to 9.84% of the original one before storage samples. This is due to short half-life of Radon ^{222}Rn (3.8 day) compared to the storage time.

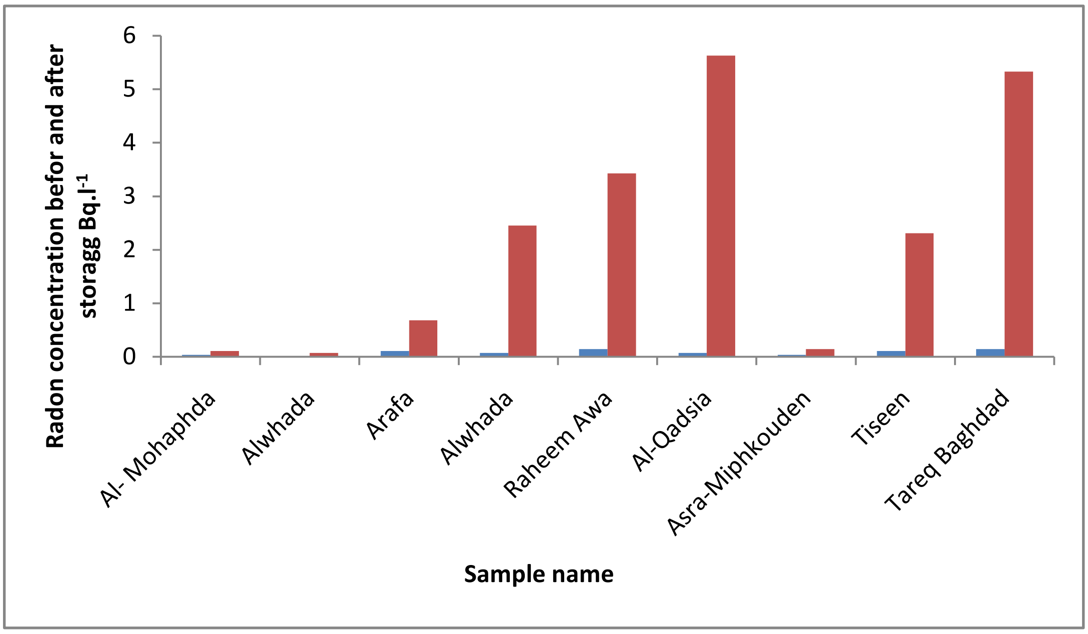

Figure 4. Bar diagram showing the concentration of Radon before and after storage

For comparison between Kirkuk city results and other places we tabulated results of some previous studies in Table 3. We notice that our results are higher than Turkey results which was (0.091 Bq.l^{-1}) and concentrations of Kuwait which was equal to (0.74 Bq.l^{-1}). While our results are very close to that of Al-shomaly which was (0.29 Bq.l^{-1}) this is because of similarity of the geological structure between Al-Shomaly district and Kirkuk governorate.

4. Conclusions

The obtained results show that radon concentration in ground water before treatment was (2.316 Bq.l^{-1}). This is below 11 Bq.l^{-1} the maximum contamination level recommended by the United States Environmental Protection Agency (USEPA). Public water supply networks for treatment and storage caused even more lowering to radon concentration. So we conclude that the consumed water within Kirkuk city is safe from point of view radioactive pollution.

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