Analysis of Radon Concentrations in Drinking Water in Erbil Governorate (Iraqi Kurdistan) and its Health Effects

Asaad Hamid Ismail[1] & Salih Omer Haji[2]

(1)Physics Department/Science Education College/Salahaddin University,Erbil,Iraq.
(2) Physics Department/Science College/Salahaddin University, Erbil,Iraq.

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Abstract

This paper presents the results of radon level in drinking water in Erbil governorate and its districts. The measurements were carried out on 42 samples (tap water) of 21 major areas, and alpha track detectors (type CR-39) were used for the estimations. The average values for radon concentration of tap water were variable from the district to another, and it was found to be (4.693±2.213 Bq/l) with a maximum of 9.61Bq/L in Hugran region and minimum of 2.01 Bq/L in Haji-Omaran city. In addition, the average annual effective doses, and equilibrium factor between radon and its daughter were measured in each area and it was found to be (11.546±8.566 µSv/Yr) and (0.204±0.06) respectively. On the other hand, this paper presents an evaluation of the inhalation and ingestion doses from exposure to radon and also the contribution of radon concentration in drinking water to indoor radon concentration was estimated. When the results were compared with the internationally recommended reference levels (U.S Environmental Protection Agency limit 11.1 Bq/l), there were no indications of existence of radon problems in the water sources in this survey. therefore the drinking water in Erbil governorate is safe as far as radon concentration is concerned.

Introduction

Radon (^{222}Rn) is a natural inert radioactive tasteless and odorless gas, whose density is 7.5 times higher than that of air [1]. It dissolves in water and can readily diffuse with gases and water vapor, thus building up significant concentrations [2]. The earth's crust contains trace amounts of ^{238}U and ^{232}Th which decay to ^{222}Rn (radon) and ^{220}Rn (thoron gas) respectively. ^{222}Rn and two of its daughters, ^{218}Po (Radium A) and ^{214}Po (Radium C), are alpha emitters, while ^{214}Pb (Radium B) and ^{214}Bi (Radium C) are beta/gamma emitters [3].

Inhalation of radon and thoron alpha daughters poses a radiation health hazard to the lungs and the physical half-life of radon is 3.825 days and half-elimination time from lungs 30 min [1]. However, thoron is often ignored in these studies because of its short half-life ($t_{1/2}$ = 55.3 seconds) and the fact that it is generally lower in concentration than ^{222}Rn in geological material [4]. ^{222}Rn measurements in drinking water are discussing in this paper.

The ^{222}Rn concentration in water is due to the decay of ^{226}Ra associated with the rock and soil. Apparently, the radon gas percolates through the soil and rock, and dissolves in the water {The radon solubility in water is 510 cm^3/ kg at 0 C^o and decreases at higher temperatures [5]}.Therefore, the concentration of radon in water is higher than one would expect if the activity were due only to supporting dissolved ^{226}Ra in the water.

As radon is a gas it is easily lost from water when it is agitated for example when river or lake water flows over rocks or is moved by wind. In this way surface water (lake , river water, spring wells), which currently accounts for approximately 70% of drinking water supplies in Erbil Governorate and its districts.

Health an implication of radon in drinking water (The source of drinking water such as spring water, river water, Artesian wells water… etc considering an important factor for limiting radon levels in drinking water) refers to ingestion of dissolved radon will result in a radiation dose to the lining of the stomach. Moreover, inhalation of radon gas that has been released from tap water will contribute to the radon content of indoor air and, if inhaled, will result in a radiation dose to the lung. Long-term exposure to high concentrations of radon in indoor air increases the risk of lung cancer [6].

To monitor radon, both active and passive techniques have been developed, and active methods are usually used for short-term measurements of radon. Passive methods are more suitable for the assessment of radon exposure over long time scales and can be used for large-scale surveys at moderate cost. Solid-state nuclear track detectors (SSNTDs) have low costs and are more convenient detectors for long-term measurements of radon and its progeny in the environment [7], this means that this type of detector is considered as a good detector for this project.

The background radiation studies for Erbil governorate [3], and the different sources of drinking water {according to the reports of KRG Ministry and the studies of FAO organization, Erbil governorate and its districts consist; (3461) of spring wells, (3463) of surface wells, (1077) of Artesian wells and (259) of pile wells. It has about (3461) of spring wells, (3463) of surface wells, (1077) of Artesian wells and (259) of pile wells} it made to choosing this governorate for studying radon concentration in drinking water and its risks in this governorate. The water samples were taken directly from tap water (drinking water) and it was collected in a large grid (100Km×150Km) with a distance of a bout (10Km to 50Km) between them (see Table 1& figure 1).

Experimental Methods

Radon Chamber

The sensitivity of a radon chamber is dependent on the material and volume of the detector chamber:

Detection Material

CR-39 is the most popular member of the solid state nuclear track detectors (SSNTDs) family; it was selected because of its good sensitivity, stability against various environmental factors, and high degree of optical clarity. Pershore moulding, Ltd., in UK supplied large sheets of CR-39. Sheets of 600 μm thickness were used for robustness and to avoid the possibility of tracks on the back surface being detected by the image analyzer. And the sheets were cut into square shapes sized 1.5 cm 1.5 cm.

Detector Chamber

The detector chamber is a cylindrical cup of 7 cm in radius and 9 cm in height. Cups covered by a piece of sponge as a filter to discriminate short-lived thoron by delaying the entry of gases into the chamber. The CR-39 on the bottom of the detector chamber is fixed by holder to reduce any error that might be caused by its movement. Radon enters the holder with a half time for entry about 1 minute, which is short compared with the radon half-life of 3.82 days. This means that the radon concentration inside the detector chamber quickly approaches that outside. It can be shown that the long-term average radon concentration inside the detector chamber is the same as that outside, despite any variations in the outside concentration. Nevertheless the radon concentration may be overestimated because the short halftime for entry will allow some thoron to enter the detector [4]. Moreover, radon cup developed in this study is shown in Figure 2.

Track Etching System

For any track, etching system should be taking account, the optimum etching conditions, such as; type of solution (NaOH or KOH), normality solution, temperature of solution, and time of etching. In the preview works [3] , we was calibrated this detector and the optimum etching condition for CR-39 was 6 N NaOH solutions at 70 ºC over a 4.5 hour period; therefore one considered that is an optimum etching condition for this study.

Track Counting System

Etched tracks are observing by using an optical microscope (Olumps) fitted with an objective lens of 150 times magnification. At this magnification, one counting field covers an area of 0.99 mm^2. Unexposed detectors used for the assessment of background track density, and 50 different fields were scanning.

Regions surveyed

The main sources of drinking water in Erbil governorate are variable from region to another because the geological formations are variable. The black spots in Erbil's governorate location in figure 1 represent the area under study.The regions which were surveyed for ^{222}Rn in drinking water were dependent on the background studies of those regions, especially when we studied the radon activity concentration in the soils of those regions in 2004 [3].

The most precipitations in Iraqi Kurdistan region are in the form of snow, which on the highest ground can fall for six months of the year. In an otherwise water-starved region, Iraqi-Kurdistan is blessed with abundant precipitation, making it one of the few watersheds of the Middle East. Rivers like the Tigris, Euphrates, and Khabur …etc and their major tributaries spring from the mountains of Kurdistan and those tributaries become major source for drinking water.

The measurements were carried out on 42 samples of 21 major areas and the samples in all regions are taken directly from the tap water and in each region were taken two samples for calculating the average value and the standard deviation. Region names, source of drinking water, radon activity concentration in region soil and the geographical distance between the regions are listing in table (1).

Procedures And Measurements

Scanning (track counting)

The dosimeters (See Figure 2) which were containing nuclear track detector type CR-39 were organised for 42 samples. Water samples were taken in clean plastic bottles directly from tap water , and in order to prevent radon leakage , the bottles were closed tightly at the sit and carried gently to minimize degassing (Temperature of water samples were between 21-24C^o) . After an exposure time (91 days), the dosimeters were collected and chemically etched (6N NaOH at 70 C^o over a 4.5 hour period).To account the number of tracks per cm^2 occurred in each detector an optical microscope with a magnification of 400X was used.3.2 Calculations and Evaluation

Radon concentration which is emitting from drinking water calculate from the following relation

$$C_{wRn^{222}} = \frac{D_o}{K} \text{.................................}(1)$$

Where, K is the detector sensitivity (K=0.22 track.cm^{-2}.d^{-1} per Bq.m^{-3}) [8] and D_o is the track density (track/cm^2.day) of the closed–can technique.

For estimation the effective dose from ^{222}Rn progeny in the samples, it is necessary to know the equilibrium factor between radon and its daughter which can be obtained by relation [9]

$$F = a \exp \frac{bD_o}{D} \text{............................}(2)$$

where D and D_o represents the track densities (track/cm^2. day) of the open (D: without filter) and closed (D_o: with a filter) –can technique respectively. The constant, a= 14.958 and b=-7.436 [8].

The relationship between radon drinking water and indoor radon concentration is an important problem of environmental radiology. During domestic water use, radon from water could release into the indoor air and could affect indoor radon concentration, as described by Nazaroff and others [10] as:

$$C_{aRn^{222}} = C_{wRn^{222}} \times W \times \frac{e}{(V \times \lambda c)} \text{.........................}(3)$$

where $C_{aRn^{222}}$ is the contribution of radon concentration in drinking water to indoor radon concentration (in Bq/m^3) , $C_{wR_{222}}$ is radon concentration of drinking water (in k Bq m)3), W is the consumption of water (in m^3 /h per person), V is the bulk of indoor room (in m^3 per person), e is the coefficient of radon transfers from domestic water to indoor air (zero dimension), and λc is the exchange rate of air (unit is h^{-1}). If it was supposed

$$f = W \times \frac{e}{(V \times \lambda c)} \quad (4)$$

Equation (3) can be replaced as

$$C_{a\,Rn^{222}} = C_{w\,Rn^{222}} \times f \quad (5)$$

where f is the conversion coefficient of radon in water, or named as the contribution coefficient of water radon to indoor radon. According to references [11,12], the coefficient of radon transfers from domestic water to indoor air e is commonly 0.5, λc is 0.7 h^{-1}, W is 0.01 m^3 /h per person, V is 20 m^3 per person, the calculating result of the conversion coefficient of radon in water f is 3.57×10^{-4}, which means 1 kBq/m^3 (1 Bq/l) of ^{222}Rn in drinking water can produce an accessorial indoor radon concentration of 0.357 Bq $/m^3$(3.57×10^{-4} Bq/l). The effective dose rate indoors in units of μSv/ y, H_E, was calculated by the following formula [9, 13]:

$$H_E = C_{a\,Rn^{222}}(d_o + d_e F) \quad (6)$$

Where $C_{a\,Rn^{222}}$ (Bq/m^3) is the contribution value of drinking water to indoor radon concentration, (d_o) and (d_e) are the recommended values for the effective dose conversion factors for radon and its progeny as (d_o) =0.33μSv·y^{-1}per $Bq.m^{-3}$ and (d_e) =80 μSv·y^{-1}per $Bq.m^{-3}$.

Results And Discussion

The recorded values of radon concentration (Bq/l) in drinking water are given in table (2). The average radon concentration in drinking water in Erbil governorate and its districts was 4.693±2.213 Bq/l. This value is smaller than the international recommended limit of 11Bq/l as proposed by the Environmental Potential Agency, USA [14]. On the other hand, radon concentration was varying from region to another, depended on the variation of the structure of the source of drinking water and it has a maximum of 9.61Bq/L in Hugran village and minimum of 2.01 Bq/L in Haji-Omaran city, and this shown in fig.3.

Table 2 shows the evaluation results of the contribution of radon concentration in drinking water to indoor radon concentration. The increase of indoor concentration induced by drinking water in Erbil governorate is varying from 7.175×10^{-4} Bq/l (0.7175 Bq/m^3) to 34.307×10^{-4} Bq/l (3.4 Bq/m^3). The contribution to the indoor radon concentration is significantly higher in the houses where the drinking water is from artisan well water.

Carrying out linear relationship between radon concentration in drinking water and its contribution to indoor radon concentration are clearing in fig.4 and it was good agreement between theoretical value (3.57×10^{-4}) and experimental results (3.5699×10^{-4}).

The difference in radon concentration in different types of natural water is great. Generally, the radon concentration of spring and surface water is lower and drilled well water is higher. Therefore, the source of drinking water determines the effect level of radon in water to indoor radon concentration.

The analysis results of equilibrium factor between radon and its daughter, annual effective dose for radon concentrations in drinking water, Life time risks for whole body and Annual cancer death risk for whole body are listed in Table 3. The estimate results of average annual effective dose equivalents (Which are resulting from contribution of radon concentration in drinking water to indoor radon concentration) were 11.546-±8.566 μSv/Yr. In addition, this study was estimated by using ICRP Publication 65 methodology [15].

Tables (4) represent the summary of the annual dose equivalent to the bronchial epithelium, stomach and the whole body, which was induced from radon concentration in drinking water. In this table one observe that the annual dose equivalent to the bronchial epithelium which is due to lung cancer (0.5071±0.239) was higher than the levels for stomach (0.1267±0.059) $\times10^{-4}$ and the whole body (0.2535±0.119) $\times10^{-6}$, therefore levels found in this investigation are a good measure of the annual value. It is a good idea to repeat measurements at different times of the year to confirm this.

Conclusions

In this study radon in drinking water was surveyed in 42 samples of 21 major areas in Erbil governorate and its districts , and estimation some important parameters was processed such as; radon concentration, equilibrium factor and annual effective dose which are limiting the risks of annual dose equivalent to the bronchial epithelium ,stomach and the whole body in this governorate.

The radon concentration in this governorate was varying from region to another, and it has lower value 2.01 Bq/L in Haji-Omaran city (Spring well water) and higher value 9.61 Bq/L in Hugran region (Artesian well water) the reason is related to the type of source of drinking water and the geologic structure for that sources (see table1), so surface water is lower and groundwater is higher. Therefore the source of drinking water determines the effect level of radon in water to indoor radon concentration.

When these values are compared with the internationally recommended reference levels (U.S Environmental Protection Agency limit 11 Bq/l), we concluded that there are no indications of existence of radon problems in the water sources in this survey.

From this research, it may be concluded that the radon concentration in drinking water will bring a definite additional radiological risk to the population. The average contribution of radon concentration in water to indoor radon concentration was (16.756±7.903) $\times10^{-4}$ Bq/l.

The estimate results of annual effective dose equivalents of drinking water in Erbil Governorate was (11.546±8.566) μSv/Y and this result was under estimating of ICRP Publication 65 methodology [15].

From table (4) one may be concluded that the drinking water contaminated by radon may increase the chances of developing stomach cancer and the breathing air high in radon concentration is more harmful to the health. Breathing in radon gas over a long period can increase the risk of lung cancer. In this research when we comparing our results within the seven countries ;Denmark, Finland, Germany, Greece, Ireland, Sweden and the Czech Republic, which have a set reference levels for radon in drinking water. {Reference levels are in the range 20 to 1000 Bq/l which is in broad agreement with EU recommendations on the protection of the public against exposure to radon in drinking water supplies [16-18]} one are concluding that the drinking water in Erbil governorate is safe as far as radon concentration is concerned.

Recommendations

From this research, we concluded that there is no direct relationship between the amount of uranium in the underlying rocks and soil and the concentration of radon in the water supply. Therefore, it is not possible to predict if any areas of Erbil governorate are more at risk than other. For this reason we recommends that all domestic water supplies of groundwater , surface water ,…etc should be tested for radon (samples should be taken directly from the source of drinking water because radon is a gas that is readily lost from water over time or due to agitation of the water).

On the other hand, we recommend that the indoor radon concentration in each major area for this governorate should be estimating to know the contribution ratio of radon concentration in drinking water, soil and rocks to indoor radon concentration. For reducing the radon concentration, we recommend that the water should be boiled before consuming, because the boiling effectively removes almost all of the radon dissolved in the water and this boiling of water should be carried out in a well-ventilated space

Table (1): Background Information of the area understudy (Erbil Governorate): Distance between Erbil city center and the districts, source of drinking water and the estimation of radon density on their soils.

Region No.	Region Name	Distance Km	Source of drinking water	Soil radon concentration (C_{SRn} ^{222}) Bq/l [Ref. 3]
1.	Erbil city	City center	Artesian wells+ River basins	222±37
2.	Kasnazan	10	Artesian wells + River basins	333±74
3.	Ainkawa	8	Artesian wells	814±185
4.	Qushtappa	12	Artesian wells	999±185
5.	Shakholan	14	surface wells	407±37
6.	Makhmur	23	Artesian wells	1036±185
7.	Koisnjaq	59	spring waters+ River basins	592±148
8.	Hujran	111	Artesian wells	2331±296
9.	Pirmam	130	surface wells	592±148
10.	Shaqlawe	140	Spring+ surface wells	2257±296
11.	Heeran	147	surface wells	1073±185
12.	Harir	180	surface wells + Artesian wells	3441±370
13.	Khalifan	194	Spring waters	1147±222
14.	Diyane	200	Spring waters	1295±222
15.	Mergasur	280	Spring waters	1332±222
16.	Sherwan-Mazn	330	Spring waters + surface wells	1628±259
17.	Barzan	367	spring waters +surface wells	1887±259
18.	Barsreen	355	Spring waters	
19.	Joman	390	Spring waters	1147±222
20.	HajOmaran	380	Spring waters	2775±333
21.	Cidakan	390	Spring waters	1406±222

Fig. (1): Sketch map of Iraq

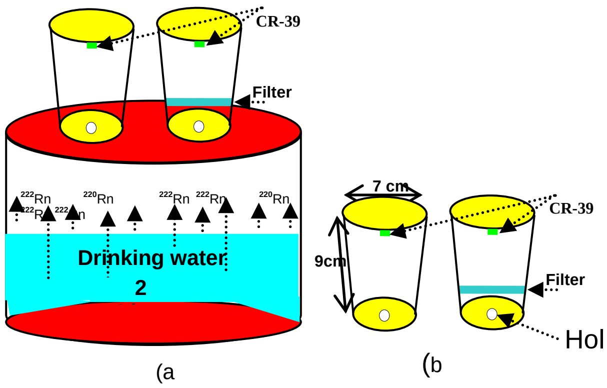

Fig. (2): configuration of the: a) Chamber system for the measuring of radon in drinking water; b) dosimeters

Table (2): Radon concentration in drinking water (C_{wRn}^{222}) and the contribution of to indoor radon concentration (C_{aRn}^{222}) for Erbil Governorate and its districts.

Region No.	Region name	Water Radon Concentration (C_{wRn}^{222}) Bq/l	Contribution of radon concentration in drinking water to indoor radon concentration (C_{aRn}^{222}) Bq/l ×10^{-4}
1.	Erbil city	5.11±0.044	18.242±0.157
2.	Kasnazan	5.61±0.08	20.0277±0.285
3.	Ainkawa	6.12±0.2	21.8484±0.714
4.	Qushtappa	7.33±0.11	26.1681±0.392
5.	Shakholan	4.82±0.053	17.207±0.189
6.	Makhmur	8.42±0.2	30.059±0.714
7.	Koisnjaq	3.14±0.09	11.209±0.321
8.	Hujran	9.61±0.25	34.3077±0.892
9.	Pirmam	4.63±0.09	16.529±0.321
10.	Shaqlawe	3.27±0.1	11.673±0.357
11.	Heeran	3.42±0.11	12.209±0.392
12.	Harir	8.83±0.13	31.523±0.464
13.	Khalifan	4±0.081	14.28±0.289
14.	Diyane	4.21±0.11	15.029±0.392
15.	Mergasur	3.56±0.13	12.709±0.464
16.	Sherwan-Mazn	3±0.084	10.71±0.299
17.	Barzan	2.62±0.077	9.353±0.274
18.	Barsreen	3.89±0.1	13.887±0.357
19.	Joman	2.51±0.074	8.96±0.264
20.	HajOmaran	2.01±0.034	7.175±0.121
21.	Cidakan	2.46±0.066	8.782±0.235
	Average	**4.693**	**16.756**
	STDEV	**±2.213**	**±7.9**

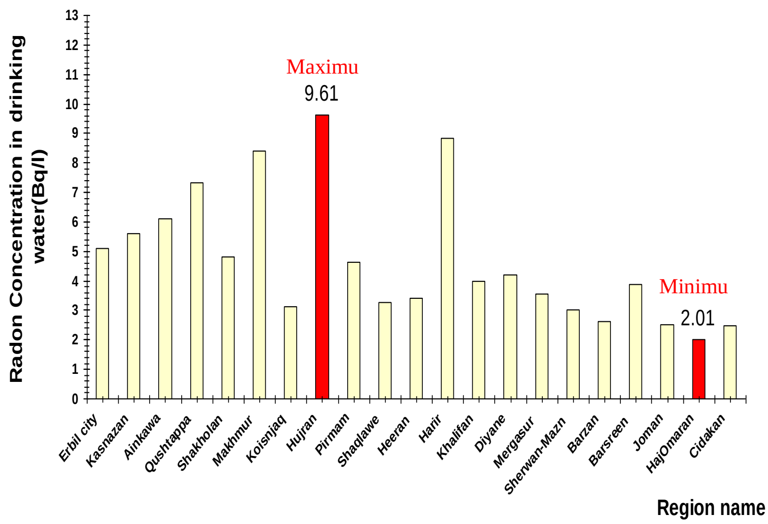

Fig. (3): Results of radon concentration in drinking water in Erbil governorate and its districts.

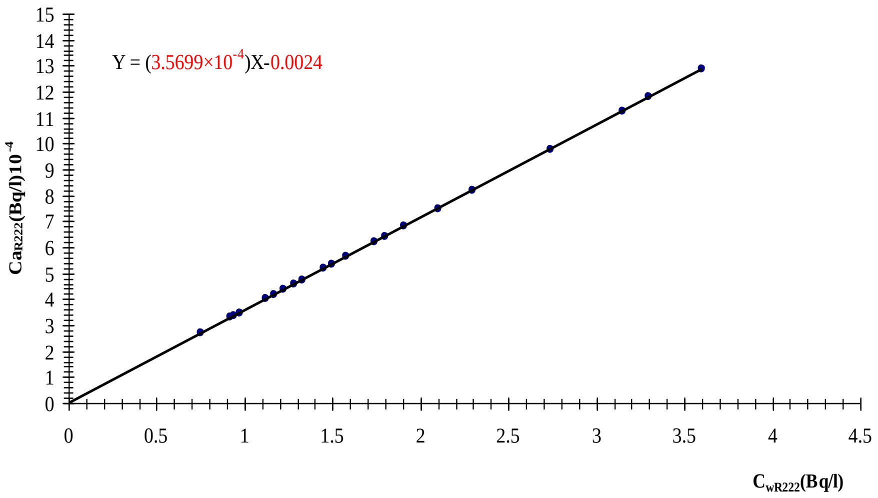

Fig. (4): Achieved linear relationship between radon concentration in drinking water and its Contribution to indoor radon concentration

Table (3): List of the equilibrium factor between radon and its progeny and the annual effective dose in drinking water for Erbil governorate.

Region name	Equilibrium Factor(F)	Effective dose (μSv/Y)	**Life time risks for whole body ×10^-8	*Annual cancer death risk for whole body ×10^-10
Erbil city	0.211±0.09	31.394±4.44	0.138±0.012	0.2761±0.04
Kasnazan	0.19±0.06	11.642±1.67	0.1515±0.018	0.3031±0.061
Ainkawa	0.198±0.04	13.277±2.07	0.1653±0.018	0.3307±0.061
Qushtappa	0.112±0.06	9.087±1.44	0.198±0.02	0.3961±0.081
Shakholan	0.124±0.05	6.586±1.22	0.1302±0.011	0.2604±0.035
Makhmur	0.117±0.04	10.896±2.04	0.2275±0.02	0.455±0.072
Koisnjaq	0.193±0.07	6.585±1.301	0.0848±0.01	0.1696±0.021
Hujran	0.145±0.02	40.929±8.63	0.2596±0.03	0.5193±0.101
Pirmam	0.152±0.05	7.757±1.29	0.1251±0.02	0.2502±0.032
Shaqlawe	0.208±0.08	7.39±1.27	0.0883±0.01	0.1767±0.021
Heeran	0.198±0.03	7.388±1.27	0.0924±0.01	0.1848±0.021
Harir	0.112±0.05	10.944±2.33	0.2385±0.021	0.4771±0.076
Khalifan	0.202±0.05	8.83±2.02	0.108±0.012	0.2161±0.031
Diyane	0.25±0.06	11.466±2.61	0.1137±0.01	0.2275±0.03
Mergasur	0.291±0.08	11.21±2.14	0.0961±0.012	0.1923±0.031
Sherwan-Mazn	0.278±0.07	9.023±2.01	0.081±0.01	0.1621±0.02
Barzan	0.239±0.06	6.741±1.01	0.0707±0.01	0.1415±0.02
Barsreen	0.247±0.09	10.398±2.04	0.1051±0.02	0.2102±0.3
Joman	0.291±0.09	7.897±1.83	0.0678±0.01	0.1356±0.02
HajOmaran	0.285±0.06	6.191±1.0	0.0543±0.009	0.1086±0.01
Cidakan	0.257±0.08	6.851±1.01	0.0664±0.01	0.1329±0.023
Average	**0.204**	**11.546**	**0.1267**	**0.2536**
STDEV	**±0.06**	**±8.566**	**±0.0598**	**±0.1196**

*Assuming 60yr at risk for whole body cancer death, and the value 2×10^{-10} was used for the conversion factor per 1Pci/l (37Bq/l) Rn concentration in drinking water [5].
** the value 1×10^{-8} was used for the conversion factor per 1Pci/l Rn concentration in drinking water[5].

Table (4): Summary of the annual dose equivalent to the bronchial epithelium, stomach and the whole body from radon concentration in drinking water.

Region name	Annual dose equivalent to bronchial epithelium (mSv)	Annual dose equivalent to stomach (mSv)×10^{-4}	Annual dose equivalent to whole body (mSv)×10^{-6}
Erbil city	0.552±0.102	0.138±0.012	0.2761±0.04
Kasnazan	0.606±0.11	0.1515±0.018	0.3031±0.061
Ainkawa	0.6612±0.101	0.1653±0.018	0.3307±0.061
Qushtappa	0.792±0.12	0.198±0.02	0.3961±0.081
Shakholan	0.5208±0.1	0.1302±0.011	0.2604±0.035
Makhmur	0.910±0.14	0.2275±0.02	0.455±0.072
Koisnjaq	0.3392±0.09	0.0848±0.01	0.1696±0.021
Hujran	1.0384±0.18	0.2596±0.03	0.5193±0.101
Pirmam	0.5004±0.1	0.1251±0.02	0.2502±0.032
Shaqlawe	0.3532±0.09	0.0883±0.01	0.1767±0.021
Heeran	0.3696±0.08	0.0924±0.01	0.1848±0.021
Harir	0.954±0.11	0.2385±0.021	0.4771±0.076
Khalifan	0.432±0.101	0.108±0.012	0.2161±0.031
Diyane	0.4548±0.1	0.1137±0.01	0.2275±0.03
Mergasur	0.3844±0.1	0.0961±0.012	0.1923±0.031
Sherwan-Mazn	0.324±0.08	0.081±0.01	0.1621±0.02
Barzan	0.2828±0.09	0.0707±0.01	0.1415±0.02
Barsreen	0.4204±0.102	0.1051±0.02	0.2102±0.3
Joman	0.2712±0.087	0.0678±0.01	0.1356±0.02
HajOmaran	0.2172±0.08	0.0543±0.009	0.1086±0.01
Cidakan	0.2656±0.09	0.0664±0.01	0.1329±0.023
Average	**0.5071**	**0.1267**	**0.2536**
STDEV	**±0.239**	**±0.0598**	**±0.1196**

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تحليل تركيز غاز الرادون في مياه الصلح للشرب في محافظة أربيل وتأثيراتها الصحية

اسعد حميد اسماعيل[١] و صالح عمرحاجي[٢]

[١]قسم الفيزياء ، كلية تربية العلوم ، جامعة صلاح الدين
[٢]قسم الفيزياء ، كلية العلوم ، جامعة صلاح الدين

الملخص:

تُقدّمُ هذا البحث نتائج مستوى غاز الرادون في الماء الصالح للشرب في محافظةِ أربيل ومناطقها(الاقضية والنواحى) . اخذت المقاييس من ٤٢ عينةِ من ماء الحنفيةِ في ٢١ منطقةِ ، حيث استخدمت كواشف الاثر النووي الصلب من نوع CR-39 للتخمينات .

معدل القيم لتركيز غاز الرادون في مياه الحنفية كَانتْ تتغيّرة مِنْ منطقةِ(اقضية ونواحي) إلى أخرى، وقد وجدت تساوى (Bq/l ٢,٢١٣±٤,٦٩٣)، مَع حَدّ أعلى (Bq/l ٩,٦١) في منطقةِ حجران ، وحَدّ أدنى (Bq/l ٢,٠١) في مدينة حاج عمران. اضافة الى ذالك، متوسطة الجُرَع الفعّالة السنوية وعامل موازنةِ بين الرادون ووليداتها قيس في كل مساحة (منطقة دراسية) ووُجِدَا تساوي (µSv/Yr ٨,٥٦٦±١١,٥٤٦) و(٠,٢٠٤ ±٠,٠٦) على التوالي.

من ناحية الأخرى، هذا البحث تقدم تقييمَ الجُرَعِ المبتلعة والمستنشقة نتيجة التعرض الى غاز الرادون ،وكذلك تخمين مساهمة تركيز الردون في مياه الشرب في زيادة تركيز الرادون داخلى(Indoor radon). وعندما قورنت النَتائِج بمستويات الموصّى بهاِ دولياً (وكالةِ حمايةِ البيئي الامريكى حدد ب 11.1 Bq/l)ليس هناك علامات وجود مشاكل غاز الرادون في مصادر المياه في هذا السرد. لذا المياه الصالح للشرب في محافظةِ أربيل سالمة بقدر ما تعني بتركيز عاز الرادون .