Radon Exhalation Rate and Mean Annual Effective Dose from Radium concentration from Gharraf Canal and Its Some Branches in Thi Qar Governorate (Iraq)

Hayder Abdulwahid Hammood
General Directorate of Education in Thi Qar, Thi Qar, Iraq
h.a.hammood10@gmail.com

Abstract

The radon exhalation rate in term of area was variable (10.4-52.1 $mBq.m^{-2}.h^{-1}$) with the average value (30.1 $mBq.m^{-2}.h^{-1}$) while the radon exhalation rate in term of mass was variable (1.09-5.45 $mBq.kg^{-1}.h^{-1}$) with the average value (3.15 $mBq.kg^{-1}.h^{-1}$) and radium concentration is varied (0.144-0.722 $Bq.kg^{-1}$) with the average value (0.417 $Bq.kg^{-1}$). The annual effective dose of radium for three population groups was carried out, and lifetime risk assessment was about 10^{-4} when used this water as a drinking water. The results compared with safe recommended limit to radium concentration and the annual effective dose of radium in drinking water according to WHO and with other countries.

Keywords: Radon exhalation rate, radium, mean annual effective dose, Gharraf canal.

معدل انبعاث الرادون والجرعة السنوية الفعالة الناتجة من تركيز الراديوم في قناة الغراف وبعض فروعها في محافظة ذي قار (العراق)

الخلاصة

ان معدل انبعاث الرادون لوحدة المساحة يتراوح بين (10.4-52.1 $mBq.m^{-2}.h^{-1}$) وبمعدل (30.1 $mBq.m^{-2}.h^{-1}$) بينما كان معدل انبعاث الرادون لوحدة الكتلة يتراوح بين (1.09-5.45 $mBq.kg^{-1}.h^{-1}$) وبمعدل (3.15 $mBq.kg^{-1}.h^{-1}$) وان تركيز الراديوم يتراوح بين (0.144-0.722 $Bq.kg^{-1}$) وبمعدل (0.417 $Bq.kg^{-1}$). وقد تم حساب الجرعة السنوية الفعالة للراديوم لثلاث مجموعات عمرية من السكان, وان تقدير المخاطر لمدى العمر كان بحدود 10^{-4} عندما تستخدم هذه المياه للشرب. تم مقارنة النتائج مع الحدود الامان الموصى بها لتركيز الراديوم وحدود الجرعة السنوية الفعالة في مياه الشرب طبقا لمنظمة الصحة العالمية و مع الدول الاخرى.

Introduction

Radium is element radioactive, it's the direct parent of radon radioactive gas, radium and radon come from uranium decay series **[Al-Khalifa, 2006, Barooah et al., 2013]**, The earth considers as source to many radioactive elements, where uranium, radium and radon are found in soil, air and water. These radioactive elements can enter the human body by inhalation and ingestion and might cause a health risk. Therefore, the monitoring of these radionuclides was increasing at any level **[Singh et al., 2007]**.

Radium similar calcium when its inters the body is deposited in bone tissue and cause the bone cancer and other problems **[Mahur et al, 2008].** While inhaling of radon released from water which uses in different purpose may cases lung cancer and ingesting of radon in drinking water may have stomach cancer **[Kurnaz and Atıf Çetiner, 2016]**. Where radon soluble in water**,** about 0.5 l of radon may have soluble in 1 l of water at 0°c, therefore, the solubility of radon in water is height specially at reduction the temperature and concentration of other salts **[Voronov, 2004]**. So radium and its daughters in water are causing for a base part of the internal dose absorbed by population from the natural radioactive decay **[Tabar and Yakut, 2014].**

Gharraf canal is drilled from Tigris river by the Sumerian king (Antena) **[Jabir, 2008]**. The length of this canal in the land of Thi Qar governorate about (141 km) which is (61.3%) of the total length of the canal, and also the total lengths of branches is (732.5 km) in Thi Qar governorate **[Ahmed, 2007]**. The population of this governorate about (1979561) according to CSO **[CSO, 2014]**. The water of Gharraf canal and its branches are irrigate 50.77% of the agricultural area in Thi Qar governorate **[Jabir, 2008]**. The water also is supplied to public in most areas of Thi Qar and used as a source of drinking water in some areas, where there are people drinking water from Ghrraf river and branches immediately, some other drinking from supplied water to the public and the third group of people drinking the reverse osmosis (RO) water (RO water reduces the concentration of radiating elements in water **[EPA,**

2015]). Gharraf canal passage through three regions in Thi Qar governorate, Al-Rufai region (including The districts are Al-Fager, Qalat Sukar, Al-Rufai and Al-Naser), Al-Shatrah region (including The districts are Dwaya, Al-Shatrah and Gharraf) and Al-Nassiriah region (including The districts are Al-Nassiriah Said Dkile and Al-Islah). As shown in figure 1.

In this study solid state nuclear track detector SSNTDs LR-115 type II used to evaluate radon exhalation rates in terms of area and mass, and radium concentration in water of Gharraf canal and Its some branches in Thi Qar governorate of Iraq to have a database about the radiating elements concentration. Knowledge mean annual effective dose and assessment risk life from radium concentration when used this water as a drinking water.

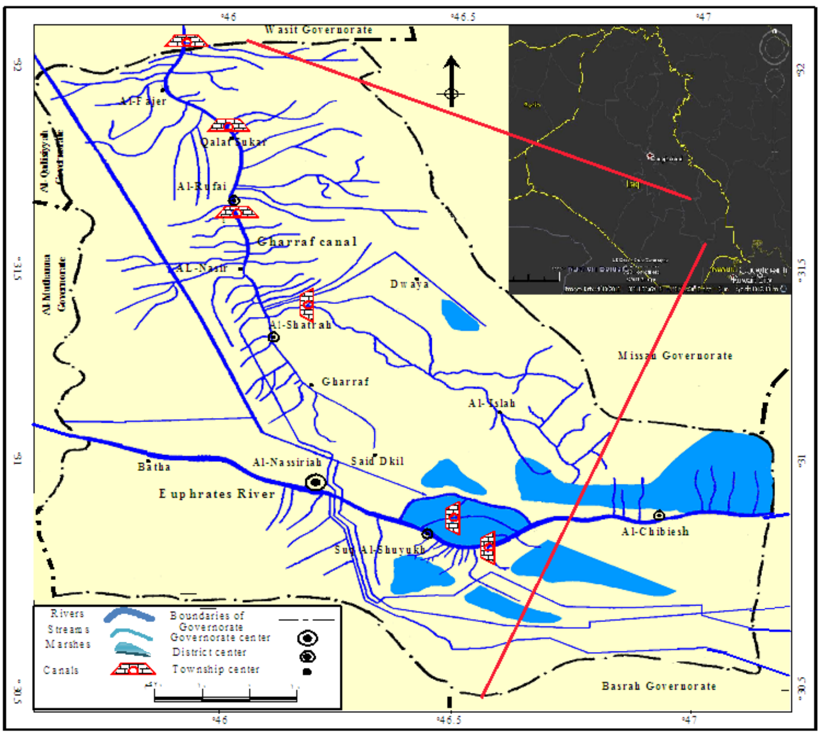

Figure 1. Surface water map in Thi Qar Governorate.

Materials and Method

31 samples of water were collected from Gharraf canal and Its some branches in different places in Thi Qar governorate. Every sample 12 g placed at the bottom of a closed cylindrical plastic container (4 cm diameter) and LR-115 type II detector at the mouth, this arrangement shown in figure 2. After three months the detector extracted and chemically etched using a (NaOH) solution of (2.5 N at 60 ±1 ^{o}C for 2 h). The ordinary microscope uses to count alpha tracks in SSNTDs LR-115 type II detectors.

The radon exhalation rate in term of area E_A and mass E_M from water determined according to the following equations **[Sonkawade et al., 2008]**:

$$E_A = CV\lambda / A[t + 1/\lambda(e^{-\lambda t} - 1)] \qquad (1)$$

$$E_M = CV\lambda / M[t + 1/\lambda(e^{-\lambda t} - 1)] \qquad (2)$$

Where C is the integrated radon exposure of the water sample (Bq.m^{-3}.h), V is the volume of air in the cylindrical plastic container (m^{3}), λ is the decay constant of radon (h^{-1}) which emanates from water samples, A is the surface area of the water sample (m^{2}), M is the mass of the water sample (kg) and t is the time of exposure (h).

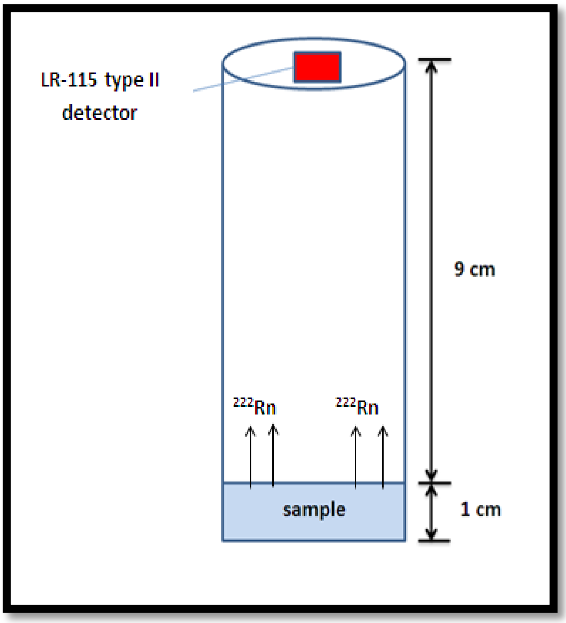

Figure 2. Arrangement of (SSNTDs LR-115 type II) films and a water sample in a closed cylindrical plastic container.

Radium concentration C_{Ra} in water samples calculated using the equation (3) **[Prasad et al., 2008]**:

$$C_{Ra} = \frac{\rho h A}{K T_e M} \qquad (3)$$

Where ρ is the track density due to radon (tracks.cm^{-2}), h is the distance between the detector and the top of the sample (m) and T_e is the effective time of exposure (d).

The calibration factor K given by the following equation **[Somogyi et al., 1984]**:

$$K = \frac{1}{4} a \cos\theta_c \left(2 - \frac{a_1}{a} - \frac{a}{a_\circ}\right) \qquad \text{If } (a_1 \le a \le a_\circ) \qquad (4)$$

Where (a) is the radius of the cylindrical plastic container. θ_c is the critical angle (40°). $a_\circ = R_\circ \cos\theta_c$, $a_1 = R_1 \cos\theta_c$, $R_\circ = R - R_{min}$, $R_1 = R - R_{max}$.

R is the alpha range of radon in air (3.90 cm), (R_{max}= 3.44 cm, R_{min} = 0.80 cm) **[Misdaq et al., 1997]**. The calibration factor is (0.032 $tracks.cm^{-2}.day^{-1}$ per $Bq.m^{-3}$) which compared with **[Klein et al., 1995, fahad, 2001]**.

Results and Discussion

Table 1 showed radon exhalation rate in terms of area and mass in water samples were collected from Gharraf canal and Its some branches in different places from Al-Rufai, Al-Shatrah and Al-Nassiriah regions in Thi Qar governorate.

While the annual effective dose of radium in drinking water D was calculated according to equation (5):

$$D = C_{Ra} U_a D_f \qquad (5)$$

Where U_a is the annual intake of water were 150, 350 and 500 kg. a^{-1} for infants, children and adults respectively **[ICRP, 1994]**, these division considered according to **[UNSCEAR, 2000]**. D_f is the dose conversion factor of the specific radionuclide are given for three population groups by **[ICRP, 1996]**. Radium concentration and the annual effective dose of radium in this water for infants, children and adults are obtained in table 2.

Table 1. Show radon exhalation rate in terms of area and mass from Gharraf canal and Its some branches of Thi Qar governorate.

No.	*The region*	*The district*	*Name of The canal or the branch*	E_A ($mBq.m^{-2}.h^{-1}$)	E_M ($mBq.kg^{-1}.h^{-1}$)
1	Al-Rufai	Al-Fager	Gharraf(1)	31.3	3.27
2			Almkhishi	52.1	5.45
3			Alashtiraki	52.1	5.45
4		Qalat Sukar	Husseiniya	20.8	2.18
5			Almcefna	46.9	4.91
6			Alhabibia	10.4	1.09
7		Al-Rufai	Alsablah alkabir	20.6	2.16
8			Zaidiya	30.9	3.23
9			Alchroah	51.5	5.39
10		Al-Naser	Al Hatam	41.7	4.36

11			Alnaumiyah	10.4	1.09
12			Gharraf(2)	10.4	1.09
13	Al-Shatrah	Al-Shatrah	Gharraf(3)	31.6	3.31
14			Alimhadiyh	31.6	3.31
15			Alkhoania	38.7	4.05
16			Khirbit	31.6	3.31
17		Dwaya	Al Fahal	31.6	3.31
18			Majidiyah	21.1	2.21
19			Alchabshiy	42.2	4.41
20			Maa Dwaya	21.1	2.21
21		Gharraf	Shatt Al-Shatra	10.6	1.10
22			Alrezaqaih	10.6	1.10
23			Abu Shabibah	21.1	2.21
24			Bahisah	10.6	1.10
25	Al-Nassiriah	Al-Nassiriah	Khumessat	23.2	2.43
26			Al Boudjemaa	21.1	2.21
27		Said Dkile	Al Brahim	31.6	3.31
28			Al Toman	50.1	5.24
29		Al-Islah	Gddeer	38.7	4.05
30			Snan	47.5	4.97
31			Al Hsen	38.7	4.05

Table 2. Show radium concentration and the annual effective dose of radium for three population groups in drinking water from Gharraf canal and Its some branches of Thi Qar governorate.

No.	*The region*	*The district*	*Name of The canal or the branch*	C_{Ra} $(Bq.kg^{-1})$	*The annual effective dose D(mSv.a^{-1})*		
					For infants	*For children*	*For adults*
1	Al-Rufai	Al-Fager	Gharraf(1)	0.433	0.0624	0.1212	0.0606
2			Almkhishi	0.722	0.1040	0.2022	0.1011
3			Alashtiraki	0.722	0.1040	0.2022	0.1011
4		Qalat Sukar	Husseiniya	0.289	0.0416	0.0809	0.0405
5			Almcefna	0.650	0.0936	0.1820	0.0910
6			Alhabibia	0.144	0.0207	0.0403	0.0202
7		Al-Rufai	Alsablah alkabir	0.285	0.0410	0.0798	0.0399
8			Zaidiya	0.428	0.0616	0.1198	0.0599
9			Alchroah	0.714	0.1028	0.1999	0.1000
10		Al-Naser	Al Hatam	0.577	0.0831	0.1616	0.0808
11			Alnaumiyah	0.144	0.0207	0.0403	0.0202
12			Gharraf(2)	0.144	0.0207	0.0403	0.0202
13		Al-Shatrah	Gharraf(3)	0.438	0.0631	0.1226	0.0613
14			Alimhadiyh	0.438	0.0631	0.1226	0.0613
15			Alkhoania	0.536	0.0772	0.1501	0.0750
16			Khirbit	0.438	0.0631	0.1226	0.0613
17		Dwaya	Al Fahal	0.438	0.0631	0.1226	0.0613

18	Al-Shatrah		Majidiyah	0.292	0.0420	0.0818	0.0409
19			Alchabshiy	0.584	0.0841	0.1635	0.0818
20			Maa Dwaya	0.292	0.0420	0.0818	0.0409
21		Gharraf	Shatt Al-Shatra	0.146	0.0210	0.0409	0.0204
22			Alrezaqaih	0.146	0.0210	0.0409	0.0204
23			Abu Shabibah	0.292	0.0420	0.0818	0.0409
24			Bahisah	0.146	0.0210	0.0409	0.0204
25	Al-Nassiriah	Al-Nassiriah	Khumessat	0.321	0.0462	0.0899	0.0449
26			Al Boudjemaa	0.292	0.0420	0.0818	0.0409
27		Said Dkile	Al Brahim	0.438	0.0631	0.1226	0.0613
28			Al Toman	0.694	0.0999	0.1943	0.0972
29		Al-Islah	Gddeer	0.536	0.0772	0.1501	0.0750
30			Snan	0.657	0.0946	0.1840	0.0920
31			Al Hsen	0.536	0.0772	0.1501	0.0750

Maximum, minimum and average of radon exhalation rate in terms of area and mass, radium concentration and the annual effective dose of radium in drinking water for three population groups in every region and in total were shown in table 3.

In total, the radon exhalation rate in term of area was variable (10.4-52.1 $mBq.m^{-2}.h^{-1}$) with the average value (30.1 $mBq.m^{-2}.h^{-1}$) while the radon exhalation rate in term of mass was variable (1.09-5.45 $mBq.kg^{-1}.h^{-1}$) with the average value (3.15 $mBq.kg^{-1}.h^{-1}$) and radium concentration is varied (0.144-0.722 $Bq.kg^{-1}$) with the average value (0.417 $Bq.kg^{-1}$), all data were included the safe limit recommended of radium concentration in drinking water 1 $Bq.l^{-1}$ (1 $Bq.kg^{-1}$) according to WHO **[WHO, 2004].** But they were bigger than the maximum allowed value of (0.185 $Bq.kg^{-1}$) EPA **[EPA, 1976]** exception samples (6), (11) and (12) in Al-Rufai region, samples (21), (22) and (24) in Al-Shatrah region.

Table 3. Show maximum, minimum and average of radon exhalation rate in terms of area and mass, radium concentration and the annual effective dose of radium for three population groups in drinking water in every region and in total

The region		E_A $(mBq.m^{-2}.h^{-1})$	E_M $(mBq.kg^{-1}.h^{-1})$	C_{Ra} $(Bq.kg^{-1})$	*The annual effective dose D(mSv.a⁻¹)*		
					For infants	*For children*	*For adults*
Al-Rufai	Maximum	52.1	5.45	0.722	0.1040	0.2022	0.1011
	Minimum	10.4	1.09	0.144	0.0207	0.0403	0.0202
	Average	31.6	3.31	0.438	0.0630	0.1225	0.0613

Al-Shatrah	Maximum	42.2	4.41	0.584	0.0841	0.1635	0.0818
	Minimum	10.6	1.10	0.146	0.0210	0.0409	0.0204
	Average	25.2	2.64	0.349	0.0502	0.0977	0.0488
Al-Nassiriah	Maximum	50.1	5.24	0.694	0.0999	0.1943	0.0972
	Minimum	21.1	2.21	0.292	0.0420	0.0818	0.0409
	Average	35.8	3.75	0.496	0.0715	0.1390	0.0695
Total	Maximum	52.1	5.45	0.722	0.1040	0.2022	0.1011
	Minimum	10.4	1.09	0.144	0.0207	0.0403	0.0202
	Average	30.1	3.15	0.417	0.0600	0.1166	0.0583

The annual effective dose of radium in drinking water for three population groups carried out, for infants were between (0.0207-0.1040 mSv.a^{-1}) with the average value (0.0600 mSv.a^{-1}), while being between (0.0403-0.2022 mSv.a^{-1}) with the average value (0.1166 mSv.a^{-1}) for children, and for adults were between (0.0202-0.1011 mSv.a^{-1}) with the average value (0.0583 mSv.a^{-1}). Some values of the annual effective dose of radium in drinking water exceed recommended limits suggested by WHO of (0.1 mSv.a^{-1}) **[WHO, 2004]**, apparently, in samples (2), (3) and (9) in Al-Rufai region for three population groups. And a less proportion of samples (1), (5), (8) and (10) in Al-Rufai region, samples (13), (14), (15), (16), (17) and (19) in Al-Shatrah region and samples (27), (28), (29), (30) and (31) in Al-Nassiriah region for children only, these results obtained in table 2. Point out, the average value of the annual effective dose of radium in drinking water for children in Al-Rufai region (0.1225 mSv.a^{-1}), Al-Nassiriah region (0.1390 mSv.a^{-1}) and total (0.1166 mSv.a^{-1}) have also exceeded the value of (0.1 mSv.a^{-1}), these details in table 3. All the results of the annual effective dose of radium in drinking water were below the Jordanian level of (0.5 mSv.a^{-1}) **[Al-Amir et al., 2012]**.

To evaluate lifetime risk assessment, 7.3 x 10^{-2} Sv^{-1} is the normal probability coefficient was recommended by ICRP **[ICRP, 1991]**, 1kg per day a consumption rate was assumed and the dose coefficient is 280 nSv.Bq^{-1} , to the age of 70 years, lifetime risk assessment obtained in table 4.

Table 4. Estimated lifetime risk of radium in drinking water of the Gharraf canal in Thi Qar governorate.

The region	*C_{Ra} (Bq.kg^{-1})*	*Lifetime risk*
Al-Rufai	0.438	2.3 x 10^{-4}
Al-Shatrah	0.349	1.8 x 10^{-4}
Al-Nassiriah	0.496	2.6 x 10^{-4}

Total	0.417	2.2 x 10^{-4}

Maximum of the lifetime risk of radium was (2.6 x 10^{-4}) in Al-Nassiriah region, while minimum of the lifetime risk of radium was (1.8 x 10^{-4}) in Al-Shatrah region, and the average of the lifetime risk of radium risk of (2.2 x 10^{-4}).

Also the results of radium concentration compared with other countries in table 5. Observably, the range radium concentration of Gharraf canal (0.144-0.722 $Bq.kg^{-1}$) was greater than the results of United State, China, Poland and Romania, while being less than the high range of Finland, Germany, Italy, Switzerland and Spin.

The radon exhalation rate of water in this study was less than radon exhalation rate in term area and mass of water in India were (245.21-690.24 $mBq.m^{-2}.h^{-1}$) and (8.95-25.08 $mBq.kg^{-1}.h^{-1}$) respectively **[Chauhan et al., 2001].**

Table 5. Radium concentration in drinking water in some countries [UNSCEAR, 2000].

The country	*C_{Ra} $Bq.kg^{-1}$*
United State	0.0004-0.0018
China	0.0002-0.12
Finland	0.010-49
France	0.007-0.7
Germany	0.001-1.8
Italy	0.0002-1.2
Poland	0.0017-0.0045
Romania	0.0007-0.021
Switzerland	0-1.5
Spin	<0.02-4
UK	0-0.18

The diagram between radon exhalation rate in term of area and radium concentration, and also between radon exhalation rate in term of mass and radium concentration were linear one (R^2 =1), where R^2 is the squire of the correlation coefficient, these diagrams showed in figures 3 and 4 respectively.

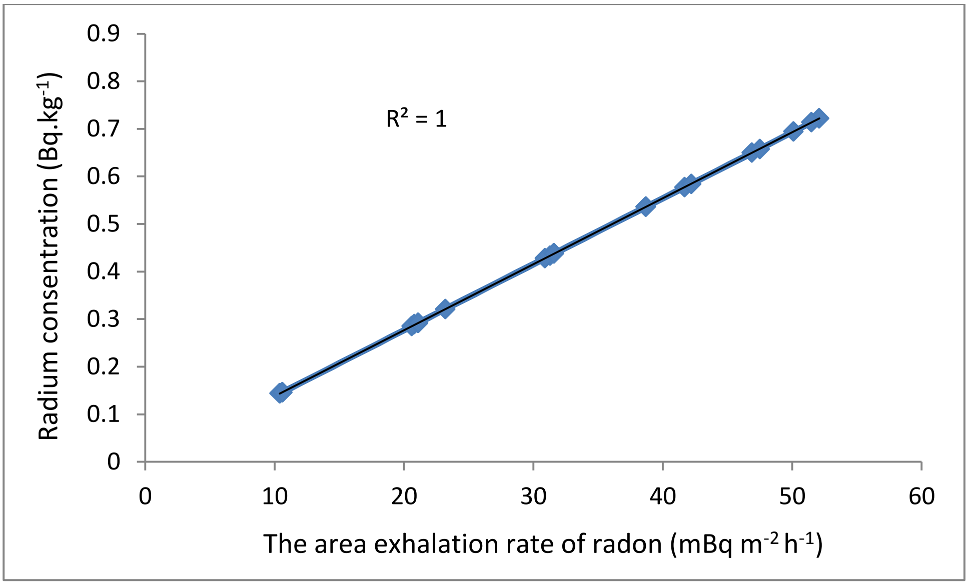

Figure 3. Show the relation between the area exhalation rate of radon and radium concentration.

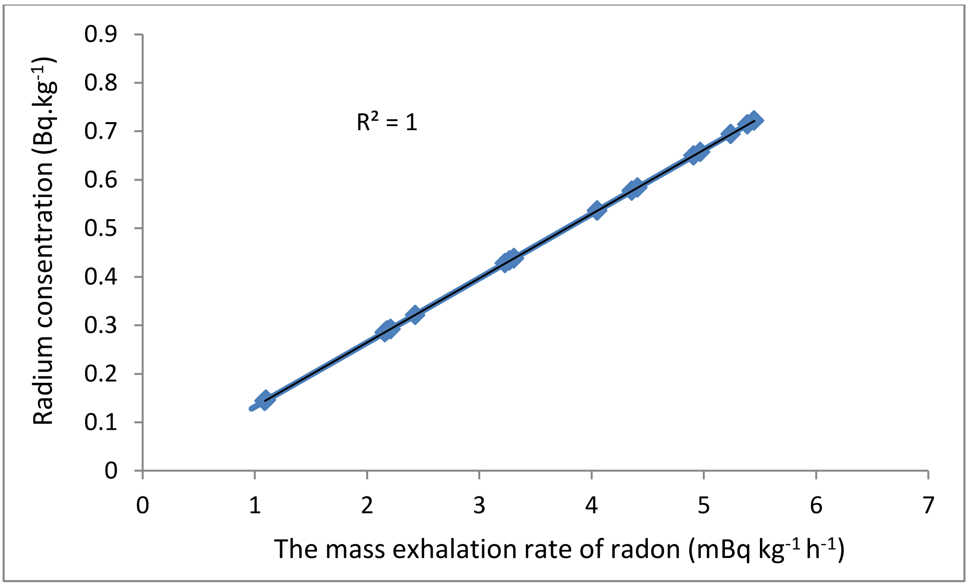

Figure 4. Show the relation between the mass exhalation rate of radon and radium concentration.

Conclusion

1- Radium concentration in water of Gharraf canal and its some branches was included the safe recommended according to WHO. But the most results were bigger than the maximum allowed value according to EPA.
2- The annual effective dose of radium in drinking water is exceeding recommended limits suggested by WHO in three samples in Al-Rufai region for three population groups. Generally, the annual effective dose of radium in drinking water for children was exceeding the recommended limit in many branches and in average in Al-Rufai region, Al-Nassiriah region and total. When used the Jordanian level that the results the annual effective dose of radium in drinking water were below.
3- The lifetime risk assessment was about 10^{-4}.
4- Radium concentration in water of Gharraf canal was about middle when compared to the radium concentration in drinking water in other countries.
5- From figures 3 and 4 the linear relation between (the area exhalation rate of radon and radium concentration) and (the mass exhalation rate of radon and radium concentration). This led, from radium concentration can get a good estimate about radon exhalation rate or versa.

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