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Survey of radium-226 content and radon-222 exhalation rate in sediments from Gharaf River in Thi Qar, Iraq

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Abstract:
Since radionuclides in sediment transference contribute to total collective dose, and because it is little published data about radionuclides in Gharaf river sediments in Thi Qar province, Iraq. So, it is studied effective radium content (ERC), area exhalation-rate (AER) of radon and mass exhalation-rate (MER) of radon in sediments of Gharaf river and its creeks (GRC) in Thi Qar, this paper might be helpful for monitoring any possible pollution, obtain a data-base for future studies, and to supplement the radiation map of Iraq. Results are displayed and compared with the recommended-limit by OECD, UNSCEAR and previous studies.

Keywords: *Radium content, radon exhalation-rate, sediments, Gharaf river, LR-115 type II.*

Introduction:

Radon is a radioactive gas appeared naturally by the radioactive decay of radium, they occur in the uranium (^{238}U) decay series. Radium founded in all types of rocks and soil, but its concentration changes to the specific site and geological-material [1]. Radiologically, radium is most important from its parents, because radium and its decay daughters are caused 98.5% of radiological effects of ^{238}U decay series [2]. So, it's one of the most health risk elements of internal radiation exposure, inasmuch as it may cause some risky disorders like bone cancer [3][4] while radon, in worldwide, is the second reason of lung-cancer, after smoking [5][6].

The aquatic environment performs a main role in the move of contaminants from a geographic area to other through water and sediment. Therefore, the riverine environment is suitable to study the radioactive elements concentration when compared to other aquatic environments [7][8]. Because many radioactive elements in sediment transference are considerate and its contribute to total collective doses [9]. The radioactive elements in the sediments heaped up from the soil erosion, rocks weathering, and the bottom of river itself. It's important to refer that the sediment of rivers may be used as a building-material[7][8]. In this paper (LR-115 type II) detectors have been used to evaluate ERC, AER of radon and MER of radon in the sediment samples of GRC in Thi Qar province, Iraq, to obtain a data-base for future studies, and assessment the possible risk when using these sediments as a building-material.

Study area

Gharaf river which called locally (Shatt Al-Gharaf) is incised by the ancient Sumerian king (Antena). Gharaf river length within Thi Qar is (141 km), and its creeks total lengths about (732.5 km) in this province. They pass throughAl-Rufai region (include Al-Fajr, Qalat-Sukkar, Al-Rufai and Al-Naser districts), Al-Shatrah region (include Al-Shatrah, Dwaya and Gharaf districts) and Al-Nassiriah region (include Al-Nassiriah, Said-Dkile and Al-Islah districts) in Thi Qar. Water from GRC supply most of the homes in Thi Qar province which is used for various purposes. GRC are also irrigate (about 50.77%) of the agricultural-area in this province[10]. The path of GRC in Thi Qar province are shown in Fig. 1. latitude and longitude of Thi Qar province are30.33° - 32.20° N and 45.37° - 47.12°E respectively [11].

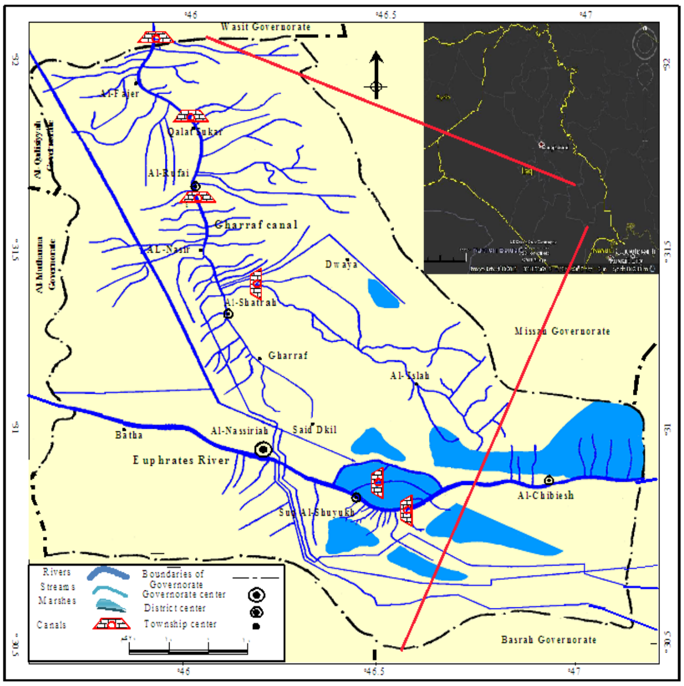

Fig. 1 Water resources in Thi Qar province.

Experimental

The sediment samples were dried, crushed and milled into powder (14 g). Then it's placed at the bottom of sealed can, as shown in Fig. 2. LR-115 type II detector was fixed in the cover of the can from the internal. The detector was recorded the tracks of alpha particles emitted by radon. After (3) months the detector removed and chemically-etched for (2 h) using NaOH solution of (2.5 N) at (60±1 °C). Count alpha tracks in detectors were using an optical microscope.

ERC was calculated using equation [10][12]:

$$ERC = \frac{\rho h A_s}{K T_e M_s} \qquad (1)$$

AER of radon from the sediments was calculated by [16][17]:

$$AER = \frac{(IRC)V\ \lambda_{Rn}}{A_s\,[t + (1/\lambda_{Rn})(e^{-\lambda_{Rn} t} - 1)]} \qquad (2)$$

MER of radon from the sediments was obtained by [14][18]:

$$MER = \frac{(IRC)V\ \lambda_{Rn}}{M_s\,[t + (1/\lambda_{Rn})(e^{-\lambda_{Rn} t} - 1)]} \qquad (3)$$

Where:

ρ (tracks/cm^2) is the track density of alfa particles.

h (m) is the distance from the detector to the sample surface.

A_s (m^2) is the sediment surface-area.

K (0.032 tracks cm^{-2}day^{-1} per Bq m^{-3})is the calibration factor [10][13][14] which depends on radius and length of a sealed can[15].

T_e (d) is the effective time of exposure.

M_s (kg) is the sediment sample mass.

IRC (Bq h/ m^3) is the integrated radon exposure.

V (m^3) is the volume-air inside can.

λ_{Rn} (1/h) is the radon decay-constant.

t (h) is the time since sealing.

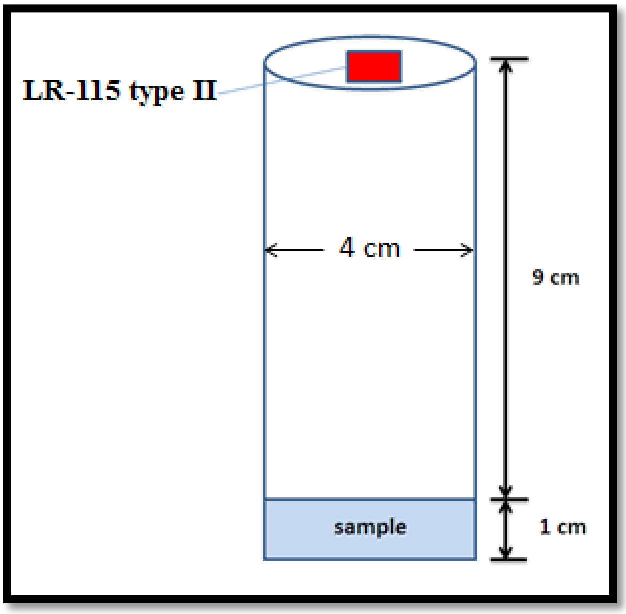

Fig. 2 Arrangement of the detector and sediment sample in a sealed can.

Results and discussion

ERC, AER and MER have been measured from sediment samples that collected from districts in Thi Qar province that GRC pass through them. Results obtained are shown in Table 1. The values of ERC were changed from (0.38±0.05Bq/kg) to (3.63±0.19 Bq/kg), with a mean value of (1.76±0.11 Bq/kg). These values to ERC are less than limit safe value of (370 Bq/kg) as recommended by OECD[19]. The

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AER of radon of sediment samples has been found to vary from (31.66±4.37 mBq/m^2 h) to (306.00±16.18 mBq/m^2 h) with the average value (148.75±9.66 mBq/m^2 h), while the MER of radon was varied from (2.84±0.39 mBq/kgh) to (27.44±1.45 mBq/kgh), with the average value (13.34±0.87 mBq/kgh). The variation of ERC, AER and MER from station to station may come from the sediment formation in the river drainage (because the bottom of river can appear large difference in chemical and mineralogical characteristics, and rare earth elements [20][21]).

AER of radon can be invested to estimate the radiation risks due to radon and its daughters by calculating the contribution of indoor-radon concentration (IRC) when used these sediments as a building-material by [22][23][24]:

$$IRC = \frac{AER \times S}{\lambda_V \times V_R} \qquad (4)$$

To evaluate the annual effective dose (AED) of radon exposure by the following relation [25][22]:

$$AED = IRC \times F_E \times T_{AW} \times F_{DC} \qquad (5)$$

Table 1 ERC, AER and MER in sediments of GRC in Thi Qar.

Sample number	Region	District	Station name	ERC Bq/kg	AER mBq/m^2 h	MER mBq/kgh
1	Al-Rufai	Al-Fajr	Gharaf(1)	1.50±0.08	126.62±7.13	11.36±0.64
2			Almkhishi	1.38±0.10	116.07±8.43	10.41±0.76
3			Alashtiraki	2.50±0.13	211.04±11.04	18.93±0.99
4		Qalat-Sukkar	Husseiniya	3.63±0.19	306.00±16.18	27.44±1.45
5			Almcefna	2.13±0.13	179.38±11.19	16.09±1.00
6			Alhabibia	2.38±0.14	200.48±11.61	17.98±1.04
7		Al-Rufai	Alsablah alkabir	1.88±0.14	158.28±11.97	14.20±1.07
8			Zaidiya	1.13±0.09	94.97±7.77	8.52±0.70
9			Alchroah	1.38±0.12	116.07±10.14	10.41±0.91
10		Al-Naser	Al Hatam	1.88±0.11	158.28±8.92	14.20±0.80
11			Alnaumiyah	2.88±0.11	242.69±9.66	21.77±0.87
12			Gharaf(2)	2.25±0.14	189.93±11.42	17.03±1.02
		Average		2.08±0.12	174.98±10.45	15.69±0.94
13		Al-	Gharaf(3)	2.13±0.1	179.38±11.	16.09±1.0

		Shatrah		3	19	0
14	Al-Shatrah		Alimhadiyh	1.50±0.08	126.62±7.13	11.36±0.64
15			Alkhoania	1.88±0.13	158.28±10.55	14.20±0.95
16			Khirbit	1.50±0.12	126.62±9.93	11.36±0.89
17		Dwaya	Al-Fahal	2.00±0.11	168.84±9.33	15.15±0.84
18			Majidiyah	2.00±0.09	168.84±7.43	15.15±0.67
19			Alchabshiy	1.13±0.11	94.97±9.61	8.52±0.86
20			Maa Dwaya	2.88±0.15	242.69±12.53	21.77±1.12
21		Gharaf	Shatt al-Shatra	2.75±0.22	232.15±18.65	20.83±1.67
22			Alrezaqaih	0.75±0.08	63.31±6.67	5.68±0.60
23			Abu Shabibah	2.63±0.17	221.59±14.27	19.88±1.28
24			Bahisah	0.38±0.05	31.66±4.37	2.84±0.39
		Average		1.79±0.12	151.25±10.14	13.57±0.91
25	Al-Nassiriah	Al-Nassiriah	Khumessat	1.75±0.11	147.72±9.33	13.25±0.84
26			AlBoudjemaa	1.50±0.11	126.62±9.10	11.36±0.82
27		Said-Dkile	Al-Brahim	1.13±0.09	94.97±7.77	8.52±0.70
28			AlToman	1.13±0.08	94.97±6.67	8.52±0.60
29		Al-Islah	Gddeer	0.75±0.08	63.31±6.67	5.68±0.60
30			Snan	1.25±0.09	105.52±7.64	9.47±0.69
31			Al-Hsen	0.75±0.06	63.31±5.35	5.68±0.48
		Average		1.18±0.09	99.49±7.50	8.93±0.68
	Total	Average		1.76±0.11	148.75±9.66	13.34±0.87

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Where:
S (m^2) is the room area.
V_R (m^3) is the room volume.
λ_V (0.5/h) is the air exchange-rate.
F_E (0.4) is the equilibrium factor.
T_{AW} (7000 h/y) is the annual work time.
F_{DC} (16.75 nSv m^3/Bq h) is the dose conversion-factor for radon decay products [25][26].

To get the maximum IRC from building-materials by assuming (S/V_R = 2.0 m^{-1}). Average values of IRC and AED in these samples in every region and in total with maximum and minimum values were shown in Table 2. Where IRC of sediment samples has been found to vary from (0.01±0.002 Bq/m^3) to (0.12±0.006 Bq/m^3) with the average value (0.06±0.004 Bq/m^3). While the values of AED of indoor-radon exposure were changed from (0.59±0.08 µSv/year) to (5.67±0.3 µSv/year) with a mean value of (2.77±0.18 µSv/year). The values of AED are less than the average worldwide (0.48 mSv/year - where 0.41 mSv/year from it come from indoors and 0.07 mSv/year from outdoors) and typical range (0.3-0.6 mSv/year) of exposure to total external terrestrial radiation, and below the values of (1.26 mSv/year - where 1.15 mSv/year from it come from radon) and (0.2-10 mSv/year) the average worldwide and typical range of total inhalation exposure respectively [27].

Table 2 IRC and AED in every region and in total with maximum and minimum values.

The region		IRC Bq/m^3	AED µSv/year
Al-Rufai	Average	0.07±0.004	3.24±0.19
Al-Shatrah	Average	0.06±0.004	2.84±0.19
Al-Nassiriah	Average	0.04±0.003	1.87±0.14
Total	Minimum	0.01±0.002	0.59±0.08
	Maximum	0.12±0.006	5.67±0.3
	Average	0.06±0.004	2.77±0.18

When compared these results with other studies, show that ERC in this study is closed from the values (average: 1.498 Bq/kg and range: 0.742 Bq/kg - 2.379 Bq/kg) in Euphrates river sediments (Thi Qar, Iraq)by Hammood (2017). Because both of these studies in the same province (spatially close), where they have alike geological materials. This study values was greater than ERC (average: 0.247 Bq/kg and range: 0.213 Bq/kg - 0.287 Bq/kg) in Al-Husseiniya river sediments (Karbala, Iraq) by Al-Alawy et al. (2018), (average: 133.0 mBq/kg and range: 49.9 mBq/kg - 272.3 mBq/kg) in Cauvery river sediments (South India) by Kaliprasad and Narayana (2018)and (average: 328.36 mBq/kg and range: 73.76 mBq/kg - 599.18 mBq/kg) Hemavathi river sediments (India) by Shivanandappa and Yerol (2018). Other studies, including the world-wide (average: 35 Bq/kg) by UNSCEAR (2000), were greater than this data, as shown in Table 3.

AER of radon in this work is less than AER of radon in other studies. Excepting two studies, the first one (average: 126.17 mBq/m^2 h and range: 62.52 mBq/m^2 h - 200.34 mBq/m^2 h) in Euphrates river sediments (Thi Qar, Iraq) by Hammood (2017) was closed to results of this study, and the second one (average: 35.283 mBq/m^2 h and range: 30.413 mBq/m^2 h - 41.037 mBq/m^2 h) in Al-Husseiniya river sediments (Karbala, Iraq) by Al-Alawy et al. (2018) was less than this data, as presented in Table 3.

MER of radonin this study is near the data of (average: 11.32 mBq/kg h and range:5.61 mBq/kg h- 17.97 mBq/kg h) in Euphrates river sediments (Thi Qar, Iraq) by Hammood (2017) and (average: 7.091 mBq/kg h and range:6.112 mBq/kg h- 8.247 mBq/kg h) in Al-Husseiniya river sediments (Karbala, Iraq) by Al-Alawy et al. (2018). While other studies in Table 3 were greater than MER in this study.

CONCLUSION

31 samples were collected from sediments along GRC in Thi Qar province to obtain results about ERC, AER of radon and MER of radon by using LR-

115 type II, these data showed that ERC and radon exhalation-rate were lower than most other studies and the world average, exception the studies in Iraq which were relatively closed. ERC was below the safe recommended according to OECD. So, the sediments from Gharaf river and its some creeks are considered safe to use as building-materials according to UNSCEAR. But the low level radioactivity in these sediments may pose the accumulated dose can be taken into account because that any exposure may have some risk.

Table 3 Comparison of this study results with sediments of other rivers of the world and worldwide.

Stations	ERC (Bq/kg)	AER(mBq/m^2 h)	MER(mBq/kg h)	Reference
Average (range)				
Worldwide	35			[27]
White oak river, USA		(27 - 60) atoms/m^2 s*		[28]
Nile river, Egypt	(7 - 188)			[20]
Fırtına river, Turkey	(15 - 116)			[29]
Kallada river, India	48.6			[30]
Cauvery river, India	133.0 (49.9 - 272.3) mBq/kg	327.1 (122.8 - 669.61)	(45.5 - 332.9)	[7]
Hemavathi river, India	328.36 (73.76 - 599.18) mBq/kg	(181.36 - 1473.25)	(67.30 - 546.70)	[31]
Euphrates river, Iraq	1.498 (0.742 - 2.379)	126.17 (62.52 - 200.34)	11.32 (5.61 - 17.97)	[13]
Al-Husseiniya river, Iraq	0.247 (0.213 - 0.287)	35.283 (30.413 - 41.037)	7.091 (6.112 - 8.247)	[32]
Gharaf river, Iraq	1.76 (0.38- 3.63)	148.75 (31.66 - 306.00)	13.34 (2.84- 27.44)	This study

*AER of radon of 21.0 mBq/m^2 s = 1 atom/cm^2 s

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