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Radiological hazards due to natural radioactivity and radon concentrations in water samples at Al-Hurrah city, Iraq

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ABSTRACT

Background: This research focuses on study of natural radioactivity (^{226}Ra ^{238}U, ^{232}Th, ^{40}K and ^{222}Rn) in different types of water samples at Al-Hurrah City in Najaf province/Iraq using NaI (Tl) and RAD-7 detector. ***Materials and Methods:*** Samples have been collected from three major sources of water, City Water (Drinking Water), River Water and Underground Water. The daily consumption of these three sources by humans in construction materials determines the standards used to measure the Radiological Contamination in these sources such as Annual Effective Dose, Radium Equivalent, Absorbed Dose rate, External Hazard Indexes, Internal Hazard Indexes and Activity Concentration Index Due to Gamma Ray of long-live Radioisotopes. ***Results:*** The results show that the average of Radioactivity Concentration for Radium-232 were 1.84±0.39Bq/L, 2.31±0.43Bq/Land 7.15±1.88Bq/L, for Thorium-232 were 1.31±0.33Bq/L, 0.98±0.13Bq/Land 2.19±0.44Bq/L, for Potasium-40 were 9.07±1.32Bq/L, 22.29±2.93Bq/Land 40.89±8.93Bq/L and for Radon-222 were 35.5±0.00 mBq/L, 355.50±30.33 mBq/L and 712.00±97.20 mBq/L. Based on Gamma Radionuclides measurement, the mean annual effective doses of city water and river water are lower than the reference level of the effective dose recommended by the ICRP, while the mean annual effective doses of underground water were higher than the reference level of the effective dose recommended by the ICRP. ***Conclusion:*** Finally, the researcher found that all the radiological parameters such as Ra_{eq}, D, H_{ex}, H_{in} and I_{γ} in the water samples were within the range the global limit, thus it's safe to use in construction materials.

Keyword: *Natural radioactivity, radon concentrations, water, annual effective dose and Iraq.*

INTRODUCTION

Water is one of the main important elements for life and environment balance (1, 2), and it's the main reason behind development countries in the world. Water must be free from pollution because it is necessary and precious natural resource for the creature's life. The measurement of natural radioactivity in our physical environment indicates how much pollution caused by radiation exposure. Human daily activities are one of the main reasons of water pollution such as Agriculture Fertilizers (3). These radionuclides are existing in almost every part of the earth's surface. These are present in air, soil and water depending on the geological and geographical features of a region, therefore; radiation measurement and protection require a highly knowledge of their distribution in soils and rocks (4). After the decay of ^{226}Ra, ^{232}Th and ^{40}K, γ-rays will be emitted, thus external exposure to terrestrial radioactivity will react with the emitted γ-rays. The human body will not affected by ^{235}U series despite its presence [5, 6]. By studying internals features of Primary ^{40}K and primary heavy nuclides and their radiant generations, and their existence in food and drinking water will cause heavy radio exposure and. The ingestion of human body to this type of radiation, especially the generation ^{210}Pb [7, 8] will cause a breath congestion and lungs cancer eventually. The effect of radioactive is depending on the physical and chemical composition and how the radionuclide inter the body. These effects may be causing damaging in genetics system, defects of eye, smear of skin, destruction of the circulatory system and lung cancer. Exposure for long period of time by people to certain levels of ^{226}R, ^{232}Th and ^{40}K, can cause also bone cancer and cavity hazard [9]. There are many works concern about study the natural radioactivity in water [3, 4, 9-11]. There was an attempt conducted to evaluate the gamma and alpha content in some samples of water. Al-Hurrah City region of Najaf Governorate were selected to measure the natural radioactivity different types of water for several reasons, its exposure to bombardment and environmental neglect more than the other cities, and the lack of radiation environmental studies around it, in addition to the fact that most of its areas are agricultural and chemical, and pesticides are used frequently compared with other areas in the province. So, the aim of this study is to assess the radioactive contamination such as Radiun-226, Thorium-232, Potasuim-40 and Radon-222 in different types of water, collected in Al-Hurrah City, Najaf/Iraq. Also, in this study we calculated the radiological parameters duo to natural radioactivity and radon concentrations in all samples consume daily by people which make them in danger of this pollution.

Area study

Al-Hurrah city located at (35.4-35.5° latitude, 45.5-45.8° longitude) in the east of Najaf city, it located near Kufa district which is located in (24.28 km) north-east of the Najaf province and in agricultural area raised concerns with the potential exposure of radioactivity because of agricultural products and the radiation exposure of populations.

MATERIALS AND METHODS

Samples collection and preparation

The experiment's samples collected from different locations in Al-Hurrah city in Najaf, 12 samples of city water, 16 samples as river water and 9 samples as underground water as shown in figure 1, then transferred to the laboratory of radiation detection and measurement in the Department of Physics, faculty of Science, university of Kufa. In this work a 1 L polyethylene marinelli beaker and 250 mL are used as a sampling and measuring container using NaI(Tl) detector and RAD-7 detector respectively. Before use, the containers have been washed with dilute hydrochloric acid and rinsed with distilled water.

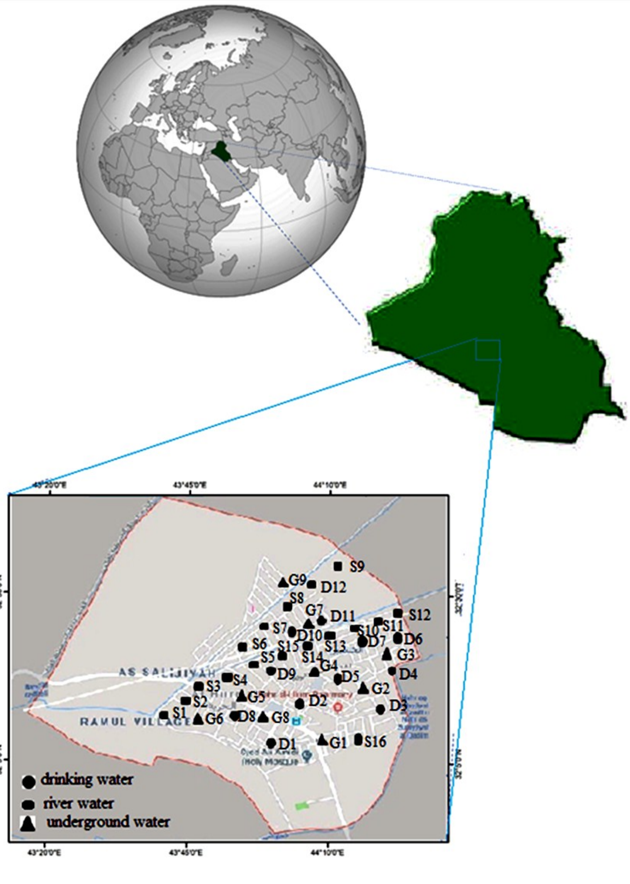

Figure 1. Map An Najaf and localized area of Al-Hurrah city.

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Experimental method

There are two nuclear technique used in this study gamma-ray spectroscopy and RAD-7 (DURRIDGE Company, Inc. USA) detector in same samples at different types of water in area of study, as following:

Gamma ray spectroscopy

Gamma- ray spectroscopy contain of a fasting discover NaI(Tl) type of (3"× ("3crystal dimension, provide by (Alpha Spectra, Inc.-12I12/3, USA), two with a multi-channel analyzer (MCA) (ORTEC-Digi Base) with level of 4096 channel connected with ADC (Analog to Digital Convertor) section through interaction. The spectroscopic measurements and interpretation had been acting via the (MAESTRO-32) software into the PC of testing the quality in the real photo peak discovers legally with gamma-ray power was calibrated using four sources; ^{22}Na, ^{60}Co, ^{54}Mn and ^{137}Cs. The limited work of ^{226}Ra is taken from the 1765 keV gamma of ^{214}Bi (15.96% possibility). Whereas ^{40}K activity is determined by using the 1460 keV gamma ray line (11% possibility).

RAD-7 continuous radon monitor

For these measurements, the RAD-7 had been equipped with the accessory kit for sampling measurements in water, RADH$_2$0 [11], and this is enabling it for measuring Radon-in-water, over a wide activity concentration range, from 3.7 mBq/L (Detection Limit) up to much greater values than 3 kBq/L [12,13], with an accurate reading is achieved in 30 minutes acquisition data runs.

Calculations

Activity concentration and annual effective dose

The radionuclide concentration C and the resulting annual effective dose AED in each water sample were evaluated using equations 1 and 2 respectively, as the following [14]:

$$C = \frac{N(E_\gamma)}{\varepsilon(E_\gamma).I_\gamma .V .t_c} \tag{1}$$

where; $N(E_y)$ is the net peak area of the radionuclide of interest, $\varepsilon(Ey)$ is the efficiency of the detector for the energy E_y, $I_y$is the intensity per decay for the energy E_y, V is the volume of the water sample and $t_c$is the total counting time in second. The annual effective dose (AED) can be calculation according to Equation [15]:

$$AED = \Sigma_i I_i \,.\, 365 \,.\, D_i \tag{2}$$

where $I_i$is the daily intakes of radionuclide I (Bq/d) and the ingestion dose coefficient D_i for ^{226}Ra, ^{232}Th and ^{40}K is reported by the International Commission on Radiological Protection (ICRP,994). 2.8 x 10^{-7}, 6.9 x 10^{-7} and 6.2 x 10^{-9}Sv/Bq respectively [16].

Radiological parameters

The radiological parameters such as Ra_{eq}, D, H_{ex}, H_{in} and I_γ due to long love of gamma-emitting radionuclide in the sample of tap water, surface water and ground water only are calculated, because these samples are commonly used in buildings. In addition to, annual effective dose due to radon-222 were calculated in all samples of water in this study, when used as drinking water.

a. ***Radium equivalent activity (Ra_{eq})***

In order to represent or evaluate the radiological hazards associated with three different radiations belong to ^{226}Ra, ^{232}Th and ^{40}K, a single quantity. A common operator called radium equivalent activity, (Ra_{eq}), is calculated using equation 3, as following [17].

$$Ra_{eq}\ (Bq / Kg) = A_{Ra} + 1.43\ A_{Th} + 0.077\ A_K \tag{3}$$

Where; A_{Ra}, A_{Th} and A_K are the specific activities of Uranium, Thorium and potassium respectively. While defining Ra_e activity, it is assumed that 10 Bq/kg of ^{226}Ra, 7 Bq/kg of ^{232}Th and 130 Bq/kg of ^{40}K produced equal gamma ray dose. The maximum value of Ra_{eq} must be less than the acceptable safe limit of 370 Bq/kg [18].

b. Absorbed dose rate

The absorbed dose rate is arising from the gamma radiations in air at "one meter" above surface of the earth. For the regular distribution of the naturally occurring radionuclides (^{226}Ra,

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^{232}Th and ^{40}K), it is used to describe the terrestrial radiation. It's usually expressed in nGy/h or pGy/h. We assumed that the contributions from other naturally occurring radionuclides are insignificant. Therefore, absorbed dose rate can be calculated by equation 4, as following [17]:

$$D(nGy/h)=0.462A_{Ra}+0.604A_{Th}+0.0417A_K \quad (4)$$

Where A_{Ra}, A_{Th}, and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq /kg respectively.

c. *External hazard radiation index (H_{ex})*

The existence of natural radionuclides causes the emission of gamma-ray in the environment. The external hazard index (H_{ex}) is used in order to estimate the biological hazard of the natural gamma radiation and it is given by equation 5, as following [17]:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (5)$$

Where A_U, A_{Th}, and A_K are the specific activities (Bq /kg) of ^{226}Ra, ^{232}Th *and* ^{40}K, respectively. The value of this index must be less than unity in order to keep the radiation hazard insignificant. The maximum value of H_{ex} equal to unity corresponds to the Higher limit of radium Equivalent activity (370 Bq/k) [18].

d. *Internal Radiation Hazard Index (H_{in})*

The internal hazard index is a criterion for index radiation hazard. In addition to gamma rays, ^{222}Rn plays an important role for internal exposure in a room. Effectively, the radio toxicity of ^{226}Ra is increased by a factor of two to allow for the contribution from ^{222}Rn and its short lived progeny. The internal exposure due to radon and its daughter products is quantified by the internal hazard index H_{in}, which has been calculated by equation 6, as shown below [18]:

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (6)$$

The internal hazard index is defined so as to reduce the acceptable maximum concentration of ^{226}Ra to half the value appropriate to external exposures [18].

The values of the index must be less than the unity in order to keep the radiation hazard to be insignificant unity corresponding to the upper limit of radiation equivalent activity (370 Bq/Kg) [19,20].

e. *Representative level index (I_γ)*

Level of gamma radiation hazard associated with natural gamma is estimated by the representative level index I_γ , which it is calculated using equation 7, as following [19]:

$$I_{\gamma} = \frac{A_{Ra}}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \quad (7)$$

The representative level index (I_γ) must be lower than unity for saving the radiation hazard insignificant [20].

RESULTS

Table 1 shows the values of activity concentrations for ^{226}Ra, ^{232}Th and ^{40}K as well as the value of total annual effective dose in drinking water samples at Al-Hurrah City using gamma-ray spectroscopy, while table 2 obtains the values of radiological parameters such as Ra_{eq}, D, H_{ex}, H_{in} and I_γ when it is used buildings due to long-live of gamma ray in drinking water. Figure 2, shows the average value of radon concentrations in drinking water samples at Al-Hurrah City using RAD-7 detector when it is used as drinking water. From table 1, the values of activity concentration in drinking water samples for ^{226}Ra have been found to lie in the range of BLD "Below Limit Detection" to 2.92±0.48Bq/L with an mean of 1.84±0.39Bq/L, the values of activity concentration for ^{232}Th vary from BLD to 2.51±0.23Bq/L with an mean value of 1.31±0.33Bq/L and the values of activity concentration for ^{40}K have been found to lie in the range of 3.90±0.51 Bq/L to 18.66±1.82Bq/L with an mean value of 9.07±1.32Bq/L. Also, from *Table I*, it is found that the total annual effective dose due to activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in drinking water samples were ranged from 0.01mSv/y to 0.81mSv/y with an average 0.30±0.08mSv/y. While the radium

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equivalent calculated according to equation (3) which values vary from 0.42Bq/L to 6.00with mean value of2.86±0.58Bq/Las mentioned in *Table II*. The absorbed dose rate of the samples have been calculated according to equation (4), it is found that ranges from 0.23nGy/h to 2.70nGy/h with an average value of 1.34±0.26nGy/has mentioned in table 2. The calculated values of hazard index (external and internal) for the water samples have been obtained according to equation (5) and equation (6) respectively. The results of H_{ex} ranged from 0.001to 0.016with a mean value of 0.007±0.001and from 0.001to 0.020with a mean value of 0.010±0.002for H_{in} as mentioned in table 2. The values of I_γ which calculated by using equation (7) are in range from 0.001to 0.021with a mean value 0.010±0.002as mentioned in table 2. The measurement of radon concentration in drinking water samples at Al-Hurrah City using RAD-7 detector, where the results are summarized in the figure 2, in which the all values that it has of radon concentration found the same where the amount of (35.5mBq/L).

Figure 1. Modified Ondo Google Satellite Map Showing Zones of Sample Collection. Map data ©2017 Google (14)

Sample Code	Specific activity (Bq/L)						Total Annual effective Dose (mSv/y)
	^{226}Ra		^{232}Th		^{40}K		
	S.A	S.D	S.A	S.D	S.A	S.D	
D1	0.23	0.13	<BLD	-------	7.36	0.80	0.04
D2	<BLD	------	<BLD	-------	10.02	0.94	0.02
D3	1.10	0.29	<BLD	-------	3.01	0.51	0.11
D4	2.92	0.48	0.44	0.11	6.65	0.76	0.42
D5	2.69	0.46	0.53	0.10	3.90	0.58	0.41
D6	<BLD	------	<BLD	-------	10.90	0.98	0.02
D7	<BLD	------	<BLD	-------	5.58	0.70	0.01
D8	2.22	0.59	<BLD	-------	18.66	1.82	0.26
D9	2.00	0.48	1.67	0.14	7.71	0.82	0.64
D10	2.05	0.40	1.36	0.13	10.02	0.94	0.57
D11	<BLD	------	1.38	0.15	14.1	1.39	0.37
D12	1.57	0.47	2.51	0.23	10.93	1.32	0.81
Minimum	<BLD		<BLD		3.90±0.51		0.01
Maximum	2.92±0.48		2.51±0.23		18.66±1.82		0.81
Average±S.D	1.84±0.39		1.31±0.33		9.07±1.32		0.30±0.08

Surface water samples

The results of the specific activity and total annual effective dose of the surface water for the surveyed areas have been presented in *table 9*. The results of the radiation risk parameters for surface water samples which include Ra_{eq}, AD, H_{ex}, H_{in} and have been presented in *table 0*. Results of radon concentrations have been presented in figure 3. The results of specific activity for Radium-226 from surface water in Al -Hruaa city ranged from <BLD to 5.34±0.87Bq/L with an average of 2.31±0.43Bq/L, while the results of specific activity for Thouruim-232 and Potasum-40 in same of surface water in study area ranged from <BLD to 1.94±0.25Bq/L with an average of 0.98±0.13Bq/L and from 4.07±0.60 Bq/L to 38.57±1.84Bq/L with an average of 22.29±2.93Bq/L respectively. The total annual effective dose of radiation due to ingested surface water ranged from 0.25 to 0.90 mSv/yr with an average of 0.50±0.05 mSv/y. The average value of Ra_{eq}, AD, H_{ex}, $H_{in.}$ and I_γ were 5.21±0.49Bq/L, 2.50±0.23 nGy/h, 0.014±0.001, 0.020±0.002 and 0.019±0.001 respectively. While radon concentration in surface water samples were ranged from BLD to 355.5 Bq/m^3 with an average of 138.54 mBq/L, as shown in figure 3.

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Table 3. Activity concentrations for ^{226}Ra, ^{232}Th and ^{40}K of surface water.

Sample code	Specific activity (Bq/kg)						Total Annual effective Dose (mSv/y)
	^{226}Ra		^{232}Th		^{40}K		
	S.A	S.D	S.A	S.D	S.A	S.D	
S1	1.26	0.31	0.87	0.13	19.42	1.31	0.39
S2	0.15	0.11	1.16	0.16	33.96	1.73	0.38
S3	<BLD	……	0.76	0.13	29.79	1.62	0.26
S4	0.47	0.19	0.58	0.11	26.69	1.53	0.25
S5	2.92	0.48	1.03	0.15	4.07	0.60	0.56
S6	5.34	0.87	1.26	0.22	9.87	1.26	0.88
S7	2.77	0.46	0.08	0.04	14.98	1.15	0.33
S8	0.55	0.20	1.25	0.16	33.96	1.73	0.44
S9	2.37	0.43	<BLD	……	8.78	0.88	0.26
S10	4.11	0.57	1.41	0.17	38.57	1.84	0.86
S11	1.26	0.31	0.91	0.14	19.15	1.30	0.40
S12	1.10	0.29	0.94	0.14	34.32	1.74	0.42
S13	1.97	0.39	1.20	0.16	14.36	1.12	0.53
S14	1.68	0.45	1.94	0.25	8.37	1.06	0.67
S15	3.87	0.55	0.08	0.04	35.47	1.77	0.49
S16	4.96	0.78	1.37	0.21	24.90	1.86	0.90
Minimum	<BLD		<BLD		4.07±0.60		0.25
Maximum	5.34±0.87		1.94±0.25		38.57±1.84		0.90
Average±S.D	2.31±0.43		0.98±0.13		22.29±2.93		0.50±0.05

Table 4. Radiological Parameters due to ^{226}Ra, ^{232}Th and ^{40}K in surface water

Sample code	Ra_{eq}(Bq/L)	AD (nGy/h)	$H_{ex.}$	$H_{in.}$	I_{γ}
S1	3.99	1.92	0.010	0.014	0.015
S2	4.42	2.19	0.012	0.012	0.017
S3	3.38	1.71	0.009	0.009	0.013
S4	3.35	1.68	0.009	0.010	0.013
S5	4.70	2.14	0.012	0.020	0.016
S6	7.90	3.64	0.021	0.035	0.027
S7	4.03	1.95	0.010	0.018	0.014
S8	4.95	2.43	0.013	0.014	0.019
S9	3.04	1.46	0.008	0.014	0.010
S10	9.09	4.37	0.024	0.035	0.033
S11	4.03	1.93	0.011	0.014	0.015
S12	5.08	2.51	0.013	0.016	0.019
S13	4.79	2.23	0.012	0.018	0.017
S14	5.09	2.29	0.014	0.018	0.018
S15	6.71	3.32	0.018	0.028	0.025
S16	8.83	4.16	0.023	0.037	0.031
Minimum	3.04	1.46	0.008	0.009	0.010
Maximum	9.09	4.37	0.024	0.037	0.033
Average±S.D	5.21±0.49	2.50±0.23	0.014±0.001	0.020±0.002	0.019±0.001

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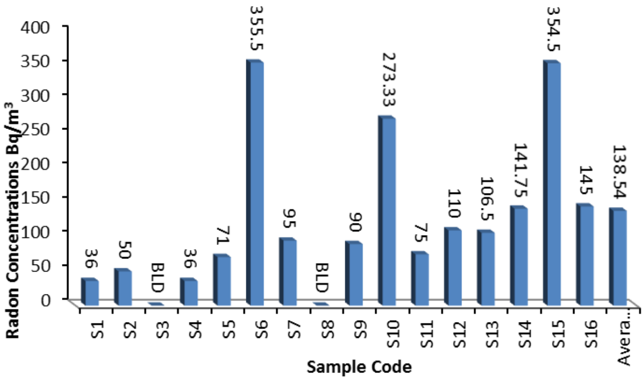

Figure 3. Radon concentrations in surface water samples.

Ground water samples

From table 5, the values of activity concentration in underground water samples for ^{226}Ra have been found to lie in the range of 1.02±0.28Bq/L to 16.60±1.56Bq/L with an mean of 7.15±1.88Bq/L where found maximum value in G7 and minimum value in G6, and the values of activity concentration for ^{232}Th vary from 0.29±0.08Bq/L to 3.67±0.28Bq/L with an mean value of 2.19±0.44Bq/L where the maximum value in G9 and minimum value in G1, and the values of activity concentration for ^{40}K have been found to lie in the range of 7.89±0.83Bq/L to 92.14±2.85Bq/L with an mean value of 40.89±8.93Bq/L where the maximum value in G9 and minimum value in G5 . Also from table V, it is found that the values of annual effective dose were varied from 0.48mSv/y to 4.62mSv/y with a mean value of 2.44±0.51. While the average values of Ra_{eq}, AD, H_{ex}, H_{in} and I_{γ} (see table 6) were 13.44±2.27 Bq/L, 6.34±1.06 nG/h, 0.036±0.006, 0.055±0.01 and0.048±0.007 respectively. Rad-7 system is used for measuring of radon concentration of water samples, where the results are summarized in figure 4. The sample (G5) was representing the highest value of radon concentration where the amount of 712mBq/L, while samples G3 had represented the BLD, and the average value is 367.35 mBq/L.

Figure 5. Activity concentrations for ^{226}Ra, ^{232}Th and ^{40}K in groundwater.

Sample code	Specific activity (Bq/kg)						Total Annual effective Dose (mSv/y)
	^{226}Ra		^{232}Th		^{40}K		
	S.A	S.D	S.A	S.D	S.A	S.D	
G1	4.19	0.57	0.29	0.08	46.82	2.03	1.23
G2	2.32	0.22	2.92	0.48	12.94	1.07	1.34
G3	3.37	0.60	2.86	0.29	56.71	2.63	1.69
G4	7.60	0.77	3.65	0.28	52.50	2.15	2.95
G5	13.93	1.05	2.82	0.25	7.89	0.83	4.23
G6	1.02	0.28	0.64	0.12	31.48	1.67	0.48
G7	16.60	1.56	1.46	0.24	35.70	2.43	4.62
G8	5.78	0.67	1.45	0.18	31.83	1.68	1.89
G9	9.58	0.87	3.67	0.28	92.14	2.85	3.54
Minimum	1.02±0.28		0.29±0.08		7.89±0.83		0.48
Maximum	16.60±1.56		3.67±0.28		92.14±2.85		4.62
Average±S.D	7.15±1.88		2.19±0.44		40.89±8.93		2.44±0.51

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Table 6. Radiological Parameters due to ^{226}Ra, ^{232}Th and ^{40}K in groundwater.

Sample code	Ra_{eq}(Bq/L)	AD (nGy/h)	$H_{ex.}$	$H_{in.}$	I_{γ}
G1	8.20	4.07	0.022	0.033	0.032
G2	7.49	3.37	0.020	0.026	0.026
G3	11.82	5.66	0.031	0.041	0.044
G4	16.86	7.92	0.045	0.066	0.061
G5	18.57	8.47	0.050	0.087	0.063
G6	4.35	2.17	0.011	0.014	0.017
G7	21.43	10.05	0.057	0.102	0.074
G8	10.30	4.88	0.027	0.043	0.037
G9	21.92	10.51	0.059	0.085	0.080
Minimum	4.35	2.17	0.011	0.014	0.017
Maximum	21.92	10.51	0.059	0.102	0.080
Average±S.D	13.44±2.27	6.34±1.06	0.036±0.006	0.055±0.01	0.048±0.007

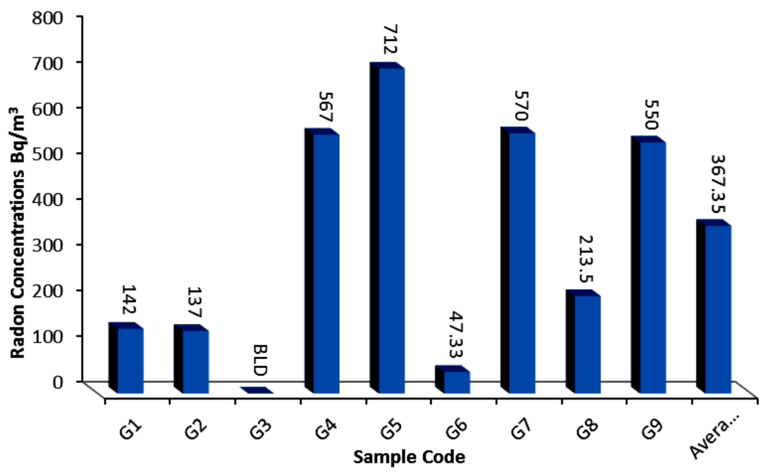

Figure 4. Radon concentrations in groundwater samples.

Figure 5 shows the specific activity of radiun-226, thorium-232 and potassium-40 in drinking, surface and ground water. It is appear that power focus of potassium is higher than thorium and the focus of uranium is lower than thorium in all elements.

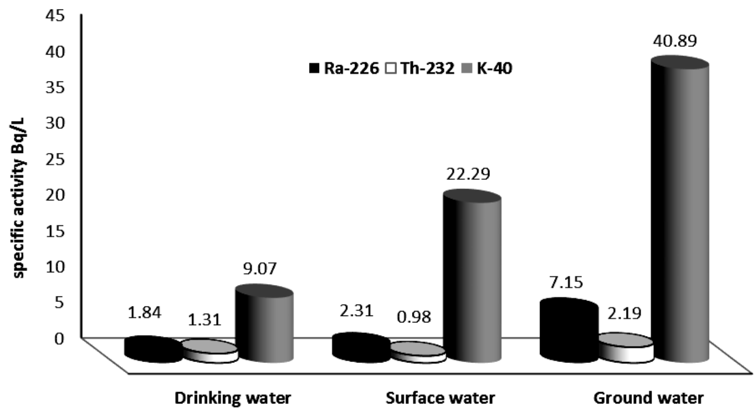

Figure 5. Summary of specific activity of uranium, thorium and potassium in water samples.

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Figure 6 shows that compare between the average radon concentrations in drinking, surface and ground samples under study using RAD-7 and average of specific activity of radium-226 using NaI(Tl) detector. Most of the samples have successfully completed measurements of specific activity of ^{226}Ra and ^{222}Rn respectively. It's possible to be observed from the data which are plotted in figure 6 a good linear correlation (0.76, 0.82 and 0.88) between specific Activity of ^{226}Ra and ^{222}Rn in drinking, surface and ground water samples respectively.

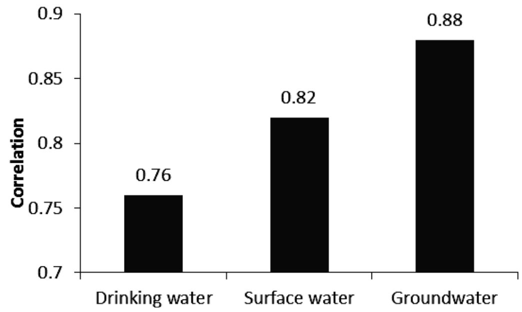

Figure 6. Correlation between Radiunm-226 and Radon-222 in samples during study period.

DISCUSSION

The specific activity of ^{40}K was observed to be comparatively higher than that of both ^{226}Ra and ^{232}Th in all of the water sampling locations studied as tables 1, 3 and table 5. Reference values for ^{226}Ra, ^{232}Th and ^{40}K activity concentrations in water (drinking water, surface water and ground water) are higher than value of world limit according to UNSCEAR 2000 "United Nations Scientific Committee on the Effects of Atomic Radiation" (5). In our investigation, in the majority of cases the concentration of ^{226}Ra exceeded that of ^{232}Th. The reason is that the geological and solubility properties of ^{226}Ra and ^{232}Th are different. Their occurrences in water are determined by several factors such as the geology and their geochemistry (21). From table 1 noted that some samples have the value of BLD of ^{226}Ra and ^{232}Th. This is because the origin of the raw water of the two stations, the basic Hurrah station and the Zaidi station, is the same, being supplied by intake from the River Euphrates. This study shows that the total annual effective dose in drinking water sample give much higher internal exposures than the UNSCEAR (20) reported world average value of 0.12 mSv/y and the WHO "World Health Organization" (22) limit of 0.1 mSv/y and lower than the ICRP "International Commission on Radiological Protection" (23) preference limit of 1.0 mSv/y, While surface water and ground water samples are given much higher internal exposures than the UNSCEAR, WHO and ICRP respectively. The highest value of Ra_{eq} due to radionuclides in all samples under study were less than the 370 Bq/L recommended maximum levels of radium equivalents (18), Thus, the water are suitable for use as drinking and building materials. The maximum value of absorbed dose rate is found is lower than the worldwide average 58 nGy/h (20). The values of H_{ex}, H_{in} and I_γ of all samples studied in this work are far less than unity. The results of the average radon concentration in water samples turn out to be lower than the accepted limit as reported in WHO (22): 0.4Bq/L and the reference limit prescribed by European Union Commission: 100Bq/L (24). The abundance of ^{40}K power notice in all elements may be or perhaps due to above works going on the area that include the use of potassium fertilizers which may have been moved to the groundwater, given that ^{40}K is a highly soluble element (25). The concentration of ^{226}Ra and ^{222}Rn in the ground water are greater than surface and drinking water. This might be an indication that the investigated ground water resources in this part of the world are not suitable for humanitarian use. Accordingly, the investigated waters resources were not suitable as drinking water supplies for life-long human consumption and a reduction in either consumption or an immediate treatment of radionuclide concentration is required.

The specific activity of ^{226}Ra, ^{232}Th and ^{40}K as well as ^{222}Rn concentrations in water samples from the studied areas was compared with those from similar investigations in other countries and summary results were given in tables 7 and 8 respectively.

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Table 7. The value of ^{238}U, ^{232}Th and ^{40}K and ^{222}Rn in the water for other countries compared to the present research.

No.	Country	Type water	Specific activity in Bq/l			References
			^{226}Ra	^{232}Th	^{40}K	
1	China	ground water	Up to 4	0.3	-----	[26]
2	Nigeria		4.04	0.77	4.81	[27]
3	Egypt		2.1	1.1	-----	[28]
4	Pakistan	drinking water	0.113	0.052	0.1409	[29]
5	Nigeria		0.57 - 26.86	0.20 -60.06	0.35 - 29.01	[30]
6	Saudi Arabia		11	9	63	[31]
7	Present Study	ground water	7.15	2.19	40.89	-----
		drinking water	1.84	1.31	9.07	-----

Table 8. The values of ^{222}Rn concentrations various types of water worldwide.

No.	Country	^{222}Rn Bq/l	References
1	Brazil	0.95-36.00	[32]
2	China	110-36.00	[33]
3	India	11.7–381.2	[34]
4	Saudi Arabia	0.76- 4.69	[35]
6	Present Study	0.0355 (drinking water)	-----
		0.355 (surface water)	-----
		0.712 (ground water)	-----

CONCLUSION

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K contributed the largest activity concentration and ^{222}Rn contributed least activity in all water sample. The use of drinking and surface water samples that have been investigated in this study show much lower internal exposures than ICRP reference limits of 1.0 mSv/y and higher than the UNSCEAR reported world average value of 0.12 mSv/y and the WHO reference limits of 0.1 mSv/y, while the use ground water much higher than internal exposures than UNSCEAR, ICRP WHO. The radioactive concentration of ^{222}Rn of drinking, surface and ground water are lesser than the accepted limit as reported in WHO (0.4Bq/L) and the reference limit prescribed by European Union Commission (100Bq/L). Also, it can be concluded according to some radiological parameters such as Ra_{eq}, D, H_{ex}, H_{in} and I_{γ} were lower than the permissible limit that recommended by UNSCEAR and ICRP, so it may be used in building without and radiation hazard.

***Conflicts of interest**: Declared none.*

REFERENCES

1. International Atomic Energy Agency (2004) Extent of environmental contamination by naturally occurring radioactive material (NORM) and technological options for mitigation. *International Atomic Energy Agency.*
2. Abojassim, AA, Najam, LA, Naji D, Hussain TA (2017) The effective radium content and radon exhalation rate in hair dyes samples. *Int J Radiat Res, **15(2):** 207-211.*
3. Pujol L, and Sanchez-Cabeza JA (2000) Natural and artificial radioactivity in surface waters of the Ebro river basin (Northeast Spain). *Journal of Environmental Radioactivity, **51(2):** 181-210.*
4. Abojassim AA, Bakir HAA, Zbalh MA, Al-Ruwaishidi BA (2017) Using SSNTD technique to assess radon flux density in liquid cleaning materials samples available in Iraqi pharmacies and markets. *Research Journal of Pharmacy and Technology, **10(8):**1-5.*
5. United Nations. Scientific Committee on the Effects of Atomic Radiation. (2000) Sources and effects of ionizing radiation: sources (Vol. 1). United Nations Publications.
6. Choppin G, Liljenzin JO, Rydberg J (2002) Radiochemistry and nuclear chemistry. Butterworth-Heinemann. *Elsevier, USA.*
7. Abojassim A A, Al-kufi FA, Hameed DN, Gaghan OA, Hameed EN (2017) 222Rn and 238U concentrations in some samples of hair dyes in local Iraqi pharmacies. *Research Journal of Pharmacy and Technology, **10(6):** 1592.*
8. Abbasi A and Bashiry V (2016) Measurement of radium-226 concentration and dose calculation of drinking water

samples in Guilan province of Iran. *Int J Radiat Res,* ***14(4):*** *361-366.*
9. Ahmed NK (2004) Natural radioactivity of ground and drinking water in some areas of upper Egypt. *Turkish Journal of Engineering and Environmental Sciences,* ***28(6):*** *345-354.*
10. Elzain AEA (2014) Measurement of radon-222 concentration levels in water samples in Sudan. *Advances in Applied Science Research,* ***5(2):*** *229-234.*
11. Abojassim AA, Kadhim SH, Mraity A, Abid H, Munim RR (2017) Radon levels in different types of bottled drinking water and carbonated drinks in Iraqi markets. *Water Science and Technology: Water Supply,* ***17(1):*** *206-211.*
12. Al-Hamidawi AAA (2015) Monitoring of 220Rn concentrations in buildings of Kufa technical institute, Iraq. Science and Technology of Nuclear Installations.
13. Durridge RAD (2012) Radon Detector. Owner's Manual (Bedford, MA.), USA.
14. Abojassim AA, AL-GAZALY HH, Obide ES (2016) Natural radioactive contamination in shampoo and dishwashing samples used in Iraq by NaI (Tl) detector. *Asian journal of chemistry,* ***28(10):*** *2173-2176.*
15. Lydie RM and Nemba RM (2009) The annual effective dose due to natural radionuclides in the reservoir and tap water in Yaoundé area, Cameroon. *The South Pacific Journal of Natural and Applied Sciences,* ***27(1):*** *61-65.*
16. Valentin J (2002) Basic anatomical and physiological data for use in radiological protection: reference values: ICRP Publication 89. *Annals of the ICRP,* ***32(3-4):*** *1-277.*
17. Kobeissi MA, El Samad O, Zahraman K, Milky S, Bahsoun F, Abumurad KM (2008) Natural radioactivity measurements in building materials in Southern Lebanon. *Journal of Environmental Radioactivity,* ***99(8):*** *1279-1288.*
18. Beretka J and Matthew PJ (1985). Natural radioactivity of Australian building materials, industrial wastes and by-products. *Health physics,* ***48(1):*** *87-95.*
19. Ravisankar R, Vanasundari K, Chandrasekaran A, Rajalakshmi A, Suganya M, Vijayagopal P, Meenakshisundaram, V (2012) Measurement of natural radioactivity in building materials of Namakkal, Tamil Nadu, India using gamma-ray spectrometry. *Applied Radiation and Isotopes,* ***70(4):*** *699-704.*
20. United Nations Scientific Committee on the effects of atomic radiation (2008). Report of the United Nations Scientific Committee on the Effects of Atomic Radiation: Fifty-sixth Session (10-18 July 2008) (No. 46). *United Nations Publications.*
21. Molinari J and Snodgrass WJ (1990) The chemistry and radiochemistry of radium and the other elements of the uranium and thorium natural decay series. *The environmental behavior of radium,* ***1:*** *11-56.*
22. World Health Organization. (1993). Guidelines for drinking-water quality. (Vol.1), World Health Organization, Geneva.
23. Mountford PJ and Temperton DH (1992) Recommendations of the international commission on radiological protection (ICRP) 1990. Springer, Verlag.
24. Hooghe L (2001) The European Commission and the integration of Europe: images of governance. Cambridge University Press.
25. Agbalagba EO and Onoja RA (2011) Evaluation of natural radioactivity in soil, sediment and water samples of Niger Delta (Biseni) flood plain lakes, Nigeria. *Journal of Environmental Radioactivity,* ***102(7):*** *667-671.*
26. Ziqiang P, Yin Y, Mingqiang G (1988) Natural radiation and radioactivity in China. *Radiation Protection Dosimetry,* ***24 (1-4):*** *29-38.*
27. Nwankwo LI (2012) Study of natural radioactivity of groundwater in Sango-Ilorin, Nigeria. *Journal of Physical Science and Application,* ***2(8):*** *289.*
28. Ahmed NK (2004) Natural radioactivity of ground and drinking water in some areas of Upper Egypt. *Turkish Journal of Engineering and Environmental Sciences,* ***28(6):*** *345-354.*
29. Fatima I, Zaidi JH, Arif M, Tahir SNA (2006) Measurement of natural radioactivity in bottled drinking water in Pakistan and consequent dose estimates. *Radiation Protection Dosimetry,* ***123(2):*** *234-240.*
30. Ajayi OS and Owolabi TP (2007) Determination of natural radioactivity in drinking water in private dug wells in Akure, Southwestern Nigeria. *Radiation Protection Dosimetry,* ***128(4):*** *477-484.*
31. Ibrahim M, Shalabiea O, Diab H (2014) Measurement of some radioactive elements in drinking water in Arar city, Saudi Arabia. *American journal of life sciences,* ***2(1):*** *24-28.*
32. Marques AL, Santos WD, Geraldo LP (2004) Direct measurements of radon activity in water from various natural sources using nuclear track detectors. *Appl Radiat Isot,* ***60:*** *801–804.*
33. El-Taher A and Madkour HA (2014) Environmental studies and radio-ecological impacts of Anthropogenic areas: shallow marine sediments Red Sea, Egypt. *J Isot Environ Health Stud,* ***50:*** *120-133.*
34. Somashekar R, and Ravikumar P (2010) Radon concentration in groundwater of Varahi and Markandeya river basins, Karnataka State, India. *Journal of Radioanalytical and Nuclear Chemistry,* ***285(2):*** *343-351.*
35. El-Taher A (2012) Radon and its decay products in underground water from Qassim and its radiation hazards. *J. Environ Sci Technol,* ***5(6):*** *475-481.*