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Determination of Natural Radioactivity Concentrations in Natural Water Resources of Hebron Province, Palestine

K. M. Thabayneh[1,*], M. M. Abu-Samreh[2], L. Mashal[1], K. M. Awawdeh[3]

[1]*Hebron University, Faculty of Science and Technology.*
[2]*Al-Quds University, Faculty of Science and Technology.*
[3]*Ministry of Education and Higher Education, South Hebron Education.*

ABSTRACT:

In this study, the radioactivity concentrations and the associated annual effective dose rates of natural radionuclides in 60 water samples collected randomly from natural water resources scattered most over parts of Hebron province, West Bank, Palestine have been measured using the well-known high resolution gamma ray spectroscopy.The obtained activity concentrations results were found to range from 1.62 to 9.11 Bq ℓ^{-1}, 0.45 to 4.40 Bq ℓ^{-1}, 0.44 to 2.06 Bq ℓ^{-1}, and 1.57 to 15.60 Bq ℓ^{-1} for ^{226}Ra, ^{232}Th, ^{234}Th, and ^{40}K, respectively. The estimated mean effective doses for the ingestion of these waters by adults were as follows: 0.56 mSv y^{-1} for ^{226}Ra, 0.065 mSv y^{-1} for ^{232}Th, 0.042 mSv y^{-1} for ^{234}Th, and 0.04 mSv y^{-1} for ^{40}K. The obtained activity concentration and annual effective doses data generally exceeded the detection limit and the assigned international values in some sampling sites reported in other countries. A reasonable correlation was found between ^{226}Raand ^{232}Th activity concentrations, and water characteristics (pH, and conductivity).

Key words: Natural radioactivity; Water natural springs; Water wells; Activity concentrations; Annual Effective doses.

* **Corresponding author:** drkaleelt@yahoo.com

الملخص:

لقد تم في هذه الدراسة قياس تراكيز النشاط الإشعاعي الطبيعي، ومعدل الجرعة السنوية الفعالة للنويدات ذات النشاط الإشعاعي الطبيعي في 60 عينة مختلفة من المياه جمعت بشكل عشوائي من الموارد المائية الطبيعية المنتشرة في معظم أجزاء محافظة الخليل في الضفة الغربية – فلسطين، لقياس تراكيز النويدات ذات النشاط الإشعاعي الطبيعي باستخدام مطيافية أشعة جاما ذات قدرة فصل عالية. لقد وجد أن متوسط التراكيز للنويدات ^{40}K، ^{234}Th، ^{226}Ra، ^{232}Th تتراوح ما بين 1.62 – 9.11 بيكريل / كغم ، 0.45 – 4.40 بيكريل / كغم، 0.44 – 2.06 بيكريل / كغم و 1.57 – 15.6 بيكريل / كغم، على التتابع. لقد وجد أن المتوسط السنوي لمعدل الجرعة الفعالة للسكان الذين يشربون هذه المياه هو: 0.56 ملي سيفرت / سنة لـ ^{226}Ra، 0.065 ملي سيفرت / سنة لـ ^{232}Th و 0.04 ملي سيفرت / سنة لـ ^{40}K. النتائج التي حصلنا عليها من التراكيز والجرعات السنوية الناتجة عنها تجاوزت بشكل عام الحد المسموح به عالميا وقياسات أخرى في العديد من الدول. بشكل عام وجد علاقة بين النشاط الإشعاعي وخصائص عينات الماء وخصوصا درجة الحموضة والموصلية لعينات الدراسة.

INTRODUCTION:

Radiations in the environment generally originate from either natural or man-made radioactive resources. The largest portion of human exposure to radiation comes from a direct exposure to natural sources of external radiations such as cosmic and terrestrial radiation, which contributes to more than 70% of the population dose (El Arabi et. al, 2006, UNSCEAR, 2000), and from inhalation or ingestion of natural radioactive materials contained in water or food (El Arabi et.al, 2006). The contribution of radiation in water to the total exposure is very small and it is attributed to the naturally occurring radionuclides in the uranium-238 (^{238}U) and thorium-232 (^{232}Th) decay series (WHO, 1993).

Uranium isotopes (^{238}U, ^{235}U and ^{234}U) have non-negligible radio toxicity (WHO, 1993), but ^{238}U is the predominant contributor to natural radioactivity. In addition, several radionuclides in the radioactive decay chain starting from ^{238}U are highly radiotoxic. The most radiotoxic among them is radium-226 (^{226}Ra), which is a known carcinogen and exists in several isotopic forms (Ahmed, 2004; Dabayneh et. al, 2008). ^{226}Ra enters groundwater by dissolution of aquifer solids or by direct alpha decay recoil across the liquid–solid boundary during its formation (De Oliveira, 2001).

Naturally occurring radionuclides in water can enter the human body mainly by inhalation of radon and thoron gases and their decay products and or by ingestion of primordial radionuclides (^{40}K, ^{238}U and ^{232}Th) and their progeny present with water and food. It was found that even a small activity in a radioactive substance which can be ingested or inhaled into the body may produce a damaging biological effect and can create a serious health risk (Isam, 2002)

The presence of natural radionuclides in water is determined by their concentrations in the bedrock containing these water reservoirs (Walencik et. al,

2010). As the doses from these pathways are strongly related to the amount of radionuclides present, the accurate evaluation of the amounts of radionuclides in the collected water samples is an important step for the radiological protection of the population. Furthermore, the determination of naturally occurring radionuclides in groundwater is very essential in environmental and public health studies (Isam, 2002).

The World Health Organization (WHO) has assigned activity concentrations guidelines for drinking water quality that can be used as a reference to scale the radionuclides activity concentration measurements worldwide and leaves the door open for countries to establish their own national standards. The current guideline for the annual dietary intake of ^{238}U is ~5 $Bq\ell^{-1}$ in areas of normal natural activity, but it can be considerably higher if drinking water is rich in uranium isotopes (UNSCEAR, 2000). In 2003 WHO proposed a provisional guideline of 15 $\mu Bq\ell^{-1}$ for ^{238}U, which is based on its chemical toxicity risk (Isam, 2002;Walencik et. al, 2010; WHO, 2004).^{226}Ra activity concentration as recommended by WHO is $1Bq\ell^{-1}$(WHO, 1993). The radium content of surface water is usually very low and normally ranges from 0.01 to 0.1 $Bq\ell^{-1}$ (Iyengar, 1990). In groundwater, ^{226}Ra concentrations can reach values up to $38Bq\ell^{-1}$(Gascoyne, 1989). The assigned reference for the annual effective dose is 0.1 $mSv\ y^{-1}$ for water workers, which practically includes isotopes of ^{238}U and ^{226}Ra (UNSCEAR, 2000).

The measurement of radioactivity in drinking water, allows the determination of population exposure to radiation by the habitual consumption of water. During the past three decades, tremendous investigations are conducted worldwide to assess the ^{238}U and ^{232}Th contents in drinking waters in different countries using various analytical methods (Herranz et. al, 1997; ICRP, 1996). To the best of our knowledge, there are not any such investigations in Palestine, but there is only one investigation concerning the environmental management of rainwater harvesting in the southern part of Palestine (Al-Salaymeh, 2011). Moreover, this study aimed to explore several concerning the water resources in Hebron province, including: Firstly, to issues understand the occurrence and distribution of natural radionuclides in water resources in the area under investigation. Secondly, to obtain a comprehensive data of the activity concentrations of natural radionuclides in water resources and of the radiation doses from drinking water for people living in the neighborhood who are using these water supplies. Thirdly, to investigate any possible relationships between radionuclides concentration in water and characteristic factors (pH and conductivity). Finally, to compare the values obtained for the activity concentrations and the effective doses with the reported international values.

EXPERIMENTAL METHODOLOGY

1.STUDY AREA

Hebron province, represents the southern part of West Bank of Palestine, it is about 35 kilometers south of Jerusalem (Figure 1). Hebron province has a Mediterranean climate, characterized by a mild summer and short, cool, rainy winters. There is an increase in drinking water demand in Hebron province due to the increasing population growth; more than 650,000 inhabitants are living in an area of less than 600 square kilometers. The water resources are limited to rainfall; with about 500 mm of annual rainfall according to the Palestinian Metrological Department, which is not sufficient to fulfill the population needs and the underground reservoirs. Presently, a large number of populations living in Hebron province fulfill their drinking water needs almost exclusively with waters obtained from underground resources such as surface springs and water wells.

2.SAMPLING AND SAMPLE PREPARATION

In order to measure the natural activity concentrations in drinking water that represent most of water resources, 60 samples were collected from 11 different sites, cities, and suburbs in the province. Figure 1, shows the geographical map of the West Bank, including Hebron province. The locations of the sites from where water samples were collected are shown in Figure 1.

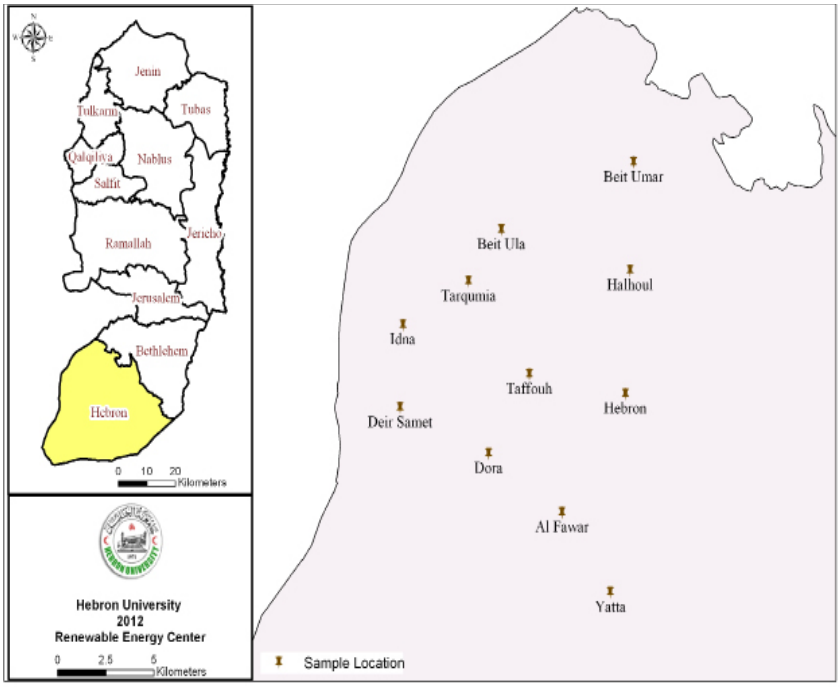
All the samples were collected in polypropylene bottles having a capacity of 5 ℓ. Before making use of the bottles, they were washed with dilute hydrochloric acid and rinsed with distilled water. Each bottle was filled up to its rim and a tight cap was pressed on so that the bottle becomes air free. The sampling methods and sample preparation are described exclusively in the literature (WHO, 1993).

In order to maintain the homogeneity of the sample and to avoid radionuclides adsorption on walls of the container, all samples were acidified with (0.1 N) HNO3 for 48 hr (ICRP, 1996).Then in de-ionized water for a few minutes, and finally rinsed three times with double-distilled de-ionized water. Then, water was poured into in standard 1000 ml plastic Marinelli beakers and stored for over 30 day to establish secular equilibrium between ^{226}Ra and ^{232}Th with their progeny and to allow ^{226}Ra–^{222}Rn equilibrium before radiometric analysis.

3.MEASUREMENTS OF PHYSICAL PARAMETERS

During sample collection, all physical parameters such as density, temperature, pH, and electrical conductivity (EC) were measured using potentiometric techniques, A HI 9829 Multimeter manufactured, by Hanna Instruments, Portugal (P) Ltd was employed.(http://www.hannainst.com/usa/prods2.cfm?ProdCode=HI%209829&id=005002). The meter was calibrated with buffer solutions and the instrument was immersed in a well-mixed sample and readings were noted down (Ramteke and Moghe, 1988). The

Figure 1. The West Bank geographical map (left) and map of Hebron province showing the location of the villages and cities under investigations (right).



test was performed on soil solution supernatant made of 5 g soil samples in 25 ml distilled water, after being filtered by blue ripping watt man filter. Soil texture was done by determining the percentage of sand, silt and clay in the soil samples. The findings were plugged into a texture analysis triangle to determine soil classification according to (Kettler et al., 2001).

4.MEASUREMENTS OF ACTIVITY CONCENTRATION

In this study, and after the isolation period, the activity concentrations of ^{226}Ra, ^{232}Th, ^{234}Th and ^{40}K radionuclides in the collected various water resources (surface water wells and surface springs) were measured using a high resolution gamma spectroscopy system having a high purity germanium (HPGe) detector with 15% relative efficiency, 1.85 keV (FWHM) gamma energy resolution at 1332.5 keV of ^{60}Co and MCA with 8000 channel. In order to reduce the gamma-rays (γ-rays) background, the detector was shielded by a cylindrical lead shield with a fixed bottom and movable cover composed of three inner concentric shells of lead, cadmium and copper (Dabayneh, 2007).

The spectrometer calibration was conducted using standard sources (solids) packed in a Marenilli beaker having the same geometry similar to that used for

water samples preparation. The standard sources are: ^{139}Ce (166 keV), ^{203}Hg (279 keV), ^{113}Sn (392 keV), ^{85}Sr (514 keV), ^{137}Cs (662 keV), ^{88}Y (898 and 1836 keV) and ^{60}Co (1173 and 1332 keV) in the energy range (166–1850) keV. The calibration efficiency curve beyond 1850 keV was constructed using different energy peaks of 226R in order to cover the range from 60 up to 2500 keV(Dabayneh et al, 2008; Helmer, 1982).

An empty bottle with the same geometry was also used for subtracting the background. The measuring time of both activity and background measurements was 7.0×10^4 seconds. The background spectra were used to correct the net γ-rays peak areas. Absolute efficiency calibration curves were calculated in order to test isotopes by using the last standard sources and chemically pure KCl dissolved in distilled water at different concentrations (Dabayneh et. al, 2006). The standard activity was provided by the instrument catalogue. The radionuclides activity concentrations measurements were performed using γ-energies listed in Table 1 (Sesana et. al, 2006; Huy and Luyen, 2005).

Table 1. γ-energies lines of radionuclides used for radioactivity measurements

Series or Element	Element	γ – Energy lines (kev)
^{238}U- Series	^{226}Ra	186.2
	^{214}Bi	295.2 351.9
	^{214}Bi	609.3 1120.3 1764.8
^{232}Th- Series	^{212}Pb	238.6
	^{228}Ac	338.5 911.1 968.9
	^{208}Tl	583.1
Potassium	^{40}K	1461.8

5.EVALUATION OF EFFECTIVE DOSES

The effective doses due to intake of ^{226}Ra, ^{232}Th, ^{234}Th and 40K natural radionuclides from drinking water were calculated using the following empirical formula (Alam, 1999):

$$D_{eff} = C_R I_F E_D \quad (1)$$

where D_{eff} is the individual annual effective dose due to ingestion of radionuclides (Sv y^{-1}), CR is the activity concentration of radionuclides in the ingested drinking water (Bq ℓ^{-1}), I_F represents the annual intake of drinking water (ℓy^{-1}) and E_D is the ingested dose conversion factor for radionuclide (Sv Bq^{-1}). The data of E_D were taken from the annals of the ICRP publication 72 (ICRP, 1996). The activity concentrations of radionuclides in the investigated samples were calculated using the following empirical formulae (Dabayneh and Jazzar, 2012)

$$C_R = \frac{C_a}{I \times \varepsilon_{eff} \times M_s} \quad (2)$$

where C_a is the net gamma counting rate (counts per second), ε_{ff} the detector efficiency of the specific γ-ray, I is the intensity of the γ-line in a radionuclide and M_s is the mass of the sample measured in kilograms.

RESULTS AND DISCUSSION

The measured eater sampler characteristics such as density, pH and conductivity of the investigated samples are presented in Table 2; while the measured activity concentrations of $^{22}6Ra$, ^{234}Th, ^{232}Th, and ^{40}K radionuclides are exhibited in Table 3. The pH values of the investigated water samples typically ranged from 7.92 to 8.6 with a mean value of 8.16. According to the reported pH values in Table 2, the water was alkaline and thus, unfavorable reactions are unlikely to occur (Zhu et. al, 2004). Table 2, also shows that water samples had low mean values for conductivity (949.5 μScm^{-1}). The obtained results of pH, and conductivity were below the maximum levels established by Palestinian and WHO standards (Al-Salaymeh, 2011), except in three samples namely, Taffouh spring, Wadi Qamra and Al-Symia well water samples. According to Table 3, the activity concentrations of ^{226}Ra, ^{232}Th and ^{234}Th radionuclides were found to vary from 1.62to 9.11Bq ℓ^{-1}, 0.45to 4.40Bq ℓ^{-1} and from 0.44to 2.06Bq ℓ^{-1},respectively. Moreover, the activity concentration of^{40}K was found to be higher than ^{226}Ra, ^{232}Th and ^{234}Th activity concentrations and ranged between 1.57to 15.60Bq ℓ^{-1}. This narrow range for the activity concentrations was probably due to the fact that the investigated sites may have similar aquifer lithologies; and hence, small differences in radionuclide solubility and mobility were detected. The calculated activity concentrations of ^{226}Ra, ^{232}Th, ^{234}Th, and ^{40}K natural radionuclides were found to exceed the limit of detection in some sampling sites reported in other countries(Maragheh et. al, 2002; Desideri et. al, 2007; WHO, 2003), in general. It was also found that, the ^{226}Ra, 232Th, ^{234}Th, and 40K activity concentration of samples taken from water samples of surface springs were lower than the obtained data for

samples taken from wells of higher depths.

Table 2. Sampling location, Name, Type and Sample coding, density, ph, and conductivity of the studied waters samples collected from 11 sites in Hebron province

City or Village	Water Resource		Number of Samples	Sample Number	Code	Density (gm/cm^3)	pH	Conductivity (µs/cm)
	Type	Common Name						
Beit Umar	Spring	Marina	2	1	BUSM1	1.04	8.54	752
Halhoul	Spring	Ain Baggar	2	2	HSAB1	1.21	8.07	828
BeitUla	Well	Khalat El-far	2	3	BUWKF	1.08	8.47	1006
	Well	BaiaretJaber	2	4	BUWBJ	1.07	8.28	1106
	Well	Beir Al-Qaus	2	5	BUBA	1.07	8.67	870
	Well	Beir Abu-Kabsa	2	6	BUBAK	1.04	8.48	639
Hebron West	Spring	Ain El-Shinar	2	7	HWSAS	1.18	8.43	394
Tarqumia	Spring	Ain El-Hajj	2	8	TSAH	1.19	8.71	621
	Well	Beir Al-Taybeh	2	9	TWBT	1.07	8.84	967
	Well	Beir El-Najed	2	10	TWBN	1.04	8.44	434
	Well	Beir Al-Sufla	2	11	TWBS	1.09	8.07	406
Idna	Spring	Twar Musa	2	12	ISTM	1.19	8.57	916
	Well	Al-Bass	2	13	IWAB	1.07	8.49	1504
Taffouh	Spring	Ain Al-Sahleh	2	14	TSAS	1.17	7.99	2400
Dora	Spring	Wadi-Alsweiti	2	15	DSWS	1.06	8.6	537
	Spring	Wadi Abu-Qamrah	2	16	DSWA	1.17	8.35	2230

	Spring	Ain Saeid Talahmeh	2	17	DSAST	1.18	8.24	745
	Spring	Ain Abu Shekha	2	18	DSAAS	1.04	7.94	1069
	Spring	Fredies	2	19	DSF	1.16	8.05	688
	Spring	Jabal Gnaim	2	20	DSJG	1.07	8.03	1295
	Fall Rain	Dora middle	2	21	DSDM	1.15	8.23	162
Deir Samet	Well	Al-Symia	2	22	DSWS	1.18	8.03	2950
	Spring	Ain Al-rayan	2	23	DSSAR	1.06	8.02	922
Al Fawar	Spring	Al Delbeh	2	24	AFSAD	1.09	8.42	770
	Spring	Al Hijri	2	25	AFSAH	1.19	7.99	1011
Yatta	Spring	Al-Karmel	2	26	YSAK	1.20	7.88	1370
	Spring	Ezaiz	2	27	YSE	1.19	7.92	655
	Spring	Jeb Hober	2	28	YSJH	1.16	8.04	566
	Well	Ezaiz	2	29	YWE	1.08	7.96	1371
	Fall Rain	Yatta North	2	30	YWYN	1.16	8.13	362

Table 3. The measured activity concentrations of natural radionuclides ^{234}Th, ^{232}Th, ^{226}Ra and ^{40}K obtained for water samples collected from all over parts of Hebron province – Palestine.

City or Village	Sample number	Code	Activity concentration (Bq/ℓ)			
			^{234}Th	^{232}Th	^{226}Ra	^{40}K
Beit Umar	1	BUSM1	0.44	1.33	8.28	1.91
Halhoul	2	HSAB1	0.50	0.45	1.62	----
BeitUla	3	BUWKF	0.59	1.00	6.94	3.44
	4	BUWBJ	0.78	4.40	7.74	7.11
	5	BUBA	0.91	1.87	6.46	6.46
	6	BUBAK	---	1.47	9.11	9.70
Hebron West	7	HWSAS	0.86	0.98	4.39	4.01
Tarqumia	8	TSAH	0.95	1.51	3.86	4.71
	9	TWBT	0.94	0.79	3.72	4.19

	10	TWBN	2.06	1.30	9.06	8.46
	11	TWBS	0.91	1.58	4.30	2.56
Idna	12	ISTM	0.93	1.10	7.22	8.63
	13	IWAB	1.00	1.07	4.64	9.16
Taffouh	14	TSAS	1.10	0.77	2.88	10.90
Dora	15	DSWS	0.80	0.94	2.37	4.84
	16	DSWA	1.04	0.83	4.84	11.38
	17	DSAST	0.87	0.80	3.11	6.90
	18	DSAAS	0.94	0.64	2.77	7.24
	19	DSF	1.00	1.70	6.37	4.15
	20	DSJG	0.87	1.30	1.95	8.36
	21	DSDM	--	0.66	2.33	2.46
Deir Samet	22	DSWS	0.85	1.18	6.88	15.60
	23	DSSAR	1.10	1.20	6.97	15.53
Al Fawar	24	AFSAD	0.95	0.95	7.95	7.75
	25	AFSAH	1.10	0.90	5.40	1.60
Yatta	26	YSAK	0.86	0.46	5.80	1.57
	27	YSE	0.74	0.69	6.28	2.46
	28	YSJH	0.70	0.50	2.44	---
	29	YWE	1.03	2.16	7.00	7.24
	30	YWYN	----	0.94	3.60	2.40

The ^{226}Ra activity concentrations were found to be higher than the activity concentrations of both ^{232}Th and ^{234}Th in all surveyed sites. This probably reflects the abundance of uranium-bearing minerals associated with granite rocks commonly found in the investigated sectors. Furthermore, the high activity concentrations of ^{226}Ra reflect the fact that radium is more soluble in groundwater than thorium and uranium precursors, and its solubility is enhanced by the common-ion effect (when dissolved solids are high). Similar findings have been reported by other investigators (Maragheh et. al, 2002; Desideri et. al,2007; WHO, 2003).

The annual equivalent effective doses of ^{226}Ra, ^{232}Th, and ^{40}K were assessed in the tissues and organs of the human body according to equation (1), using the consumption rate and the conversion factors values reported by ICRP and WHO (ICRP, 1996; WHO, 2003). The calculated mean effective doses for the ingestion of these waters by adults were as follows: 0.56 mSv y^{-1} for ^{226}Ra, 0.065 mSv y^{-1} for ^{232}Th, 0.042 mSv y^{-1} for ^{234}Th and 0.04 mSv y^{-1} for ^{40}K. Obviously, the measured ^{226}Ra effective dose was higher than the recommended effective dose reference level of 0.1 mSv y^{-1} as recommended by WHO and IAEA research groups for one year's consumption of drinking water (WHO, 2003; IAEA, 2002). The

reported activity concentration and the annual effective doses of ^{226}Ra in some countries as well as the present Hebron measurements are exhibited in Table 4 (Ben Fredj et. al, 2005; Jasminka et. al, 2007; Higgy, 2000; Lopez et. al, 2004; Vesterback, 2007; Ismail et. al, 2009; Bomben et. al, 1996; Shahbaziand Saeb, 2008). As shown in Table 4, the reported values of 226Ra in the present work for both activity concentration and annual effective dose of ^{226}Ra were higher than reported data by other countries. This might be an indication that the investigated 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.

Table 4. International activity concentration and the annual effective doses of ^{226}Ra obtained for drinking water resources in some countries.

Country	^{226}Ra concentration (Bq/ℓ)			Annual effective dose (mSv/y)			Reference
	Min	Max	Avg	Min	Max	Avg	
USA	4.0×10^{-4}	1.8×10^{-3}	-	-	-	-	(Ben Fredj. et.al,2005)
China	2.0×10^{-4}	0.12	-	-	-	-	(Ben Fredj. et.al,2005)
France	7.0×10^{-3}	0.7	-	-	-	-	(Ben Fredj. et.al,2005)
Germany	1.0×10^{-3}	1.8	-	-	-	-	(Ben Fredj. et.al,2005)
Italy	2.0×10^{-4}	1.2	-	-	-	-	(Ben Fredj. et.al,2005)
UK	0	0.18	-	-	-	-	(Ben Fredj. et.al,2005)
Tunisia	0.4	1.77	-	-	-	-	(Ben Fredj. et.al,2005)
Serbia	0.092	0.289	-	-	-	-	(Ben Fredj. et.al,2005)
Egypt	6×10^{-3}	39×10^{-3}	16.7×10^{-3}	0.014	0.083	-	(Higgy, 2000)
Spain	0.12	5.4	-	0.35	0.72	-	(Lopez. et. al, 2004)
Romania	1.0	3.0	-	-	-	-	(Botezatu. et.al, 2001)

Sweden	-	-	0.014	-	-	-	(Botezatu. et.al, 2001)
Portugal	-	-	0.027	-	-	-	(Botezatu. et.al, 2001)
Finland	0.003	0.05	-	0.02	0.41	-	(Vesterbacka, 2007)
Scotland	-	-	-	0.03	0.05	-	(Vesterbacka, 2007)
Austria	-	-	-	0.4	0.7	-	(Vesterbacka, 2007)
Jordan	-	-	5.5	1.7	1.9	-	Ismail. et.al,2009)
Argentina	<0.002	0.04	-	0.004	0.014	-	(Bomben. et.al, 1996)
Slovenia	0.007	0.61	-	-	-	-	(Bomben. et.al, 1996)
Iran	0.008	0.061	0.041	-	-	0.0064	Shahbazi and Saeb, 2008)
Croatia	0.006	0.412	-	-	-	0.0086	Shahbazi and Saeb, 2008)
Pakistan	-	-	0.012	-	-	0.0041	Shahbazi and Saeb, 2008)
Turkey	-	-	0.019	-	-	0.0093	Shahbazi and Saeb, 2008)
WHO	-	-	1.0	-	-	0.1	(WHO, 1993)
Palestine	1.62	9.11	-	-	-	0.56	Present work

CONCLUSION

The obtained activity concentrations results of ^{226}Ra, ^{232}Th, ^{234}Th, and ^{40}K were found to be higher than the assigned limit of detection in some sampling sites reported in other countries. Based on the present measurements, high activity concentrations of the detected radionuclides in the investigated water samples may be attributed to the abundance of uranium-bearing minerals associated with granite rocks commonly found in Hebron district. It was also found that, the ^{226}Ra, ^{232}Th, ^{234}Th, and 40K activity concentration of samples taken from surface springs water were lower than samples taken from wells of higher depths. The estimated values of annual effective dose rates were found to be higher than those reported by WHO and other countries worldwide. The results showed that, samples having high activity concentrations of ^{226}Ra, also have a high conductivity, and the conductivity of rain- fall water samples were lower than that of other samples.

In conclusion, the present study has pointed out that further investigations are needed for better understanding of the presence of high radionuclide concentrations in the surveyed area and to explore the ion types such water resources might have.

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