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Review

Measurement of ^{222}Rn concentration levels in drinking water and the associated health effects in the Southern part of West bank – Palestine

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HIGHLIGHTS

- The radon concentrations are measured for drinking water samples in the southern part of West Bank – Palestine.
- We conclude that there is no significant public health risk from radon ingested and inhalation with drinking water in the study region.
- We recommend that this study can be used as a baseline for information or further research.

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ABSTRACT

Radon concentration and annual effective doses were measured in drinking water in the Southern Part of West Bank – Palestine, by using both passive and active techniques. 184 samples were collected from various sources i.e. tap water, groundwater, rain waters and mineral waters. It is found that the annual effective dose resulting from inhalation and ingestion of radon emanated from all types of drinking water is negligible compared to the total annual effective dose from indoor radon in the region. Results reveal that there is no significant public health risk from radon ingested and inhalation with drinking water in the study region.

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1. Introduction

Radon (^{222}Rn) isotopes, and its decay products ^{218}Po and ^{214}Po, can be quite harmful to human beings. ^{222}Rn is a naturally occurring colorless, odorless, tasteless radioactive gas that is formed in the course of the ^{238}U decay series. Uranium is present in small amounts in most rocks and soil. It slowly decays to other products such as radium (^{226}Ra), which decays to ^{222}Rn. Some of ^{222}Rn moves to the soil surface and enters the air, while part of it remains below the soil surface enters the groundwater. The isotopes in the U-238 decay series that may pose a health risk because of their presence in water are ^{226}Ra and ^{222}Rn (UNSCEAR, 2000; Abdul Kader, 2012; Oyvind et al., 2008).

The solubility of radon in water is low and therefore, it can easily escape from water to air. For this reason, surface waters generally do not contain appreciable amounts of radon. In municipally treated groundwater, radon concentrations are reduced through treatment processes which expose water to air. Groundwater obtained from private wells generally has the highest radon concentrations because this water is less exposed to air before reaching households (Prabjit et al., 2011). Radon is particularly well suited to study groundwater and surface water and their respective interaction, because the activity in groundwater 1–100 $Bq\ell^{-1}$; depending on the lithology of the area, which is much higher than the surface water 1–0.1 $Bq\ell^{-1}$ (Yousuf et al., 2009; Kluge et al., 2007).

^{222}Rn and its progenies ^{218}Po and ^{214}Po emit radiation in the form of alpha particles; once ingested or inhaled, they can cause damage to body tissues and organs. Because alpha particles are heavy and short-ranged, they cannot penetrate physical barriers, including clothing and skin.

Individuals can be exposed to radon in water via inhalation and ingestion, although the primary route of exposure is considered to be inhalation. There is a well-established link between lung cancer and inhalation of radon; ingestion of radon has been weakly linked to stomach cancer (Hopke et al., 2000). Especially, radon has been identified as a public health concern when present in all types of drinking water. High concentration of radon in drinking water causes stomach cancer (Tabassum and Mujtaba, 2012). The cancer risk arising from ingested ^{222}Rn is derived from calculations of the dose absorbed by the tissues. The National Research Council (1999) has estimated that about 30% of the activity concentration of ^{222}Rn in the stomach was integrated in the walls of the stomach (NRC, 1999). Collman et al., (1991) explored the potential link between radon and childhood cancer mortality in North Carolina using county specific levels of radon in groundwater as an indication of exposure. Levels of radon in indoor air are influenced directly by the amount of radon gas which enters a house through tap water. With agitation and heating, some fraction of the original radon in the water used in the home will diffuse into the air. The World Health Organization (WHO) estimated that 10–15% of total radon in indoor air may typically be attributed directly to out gassing from tap water, and that 1–7% of all lung cancer deaths are due to that source: high levels of ^{222}Rn in water (Collman et al., 1991; Cothern et al., 1986).

The aim of this study is to investigate the radon levels of some water sources being used for drinking water in some areas of the Southern part of West Bank – Palestine and to determine the health hazards.

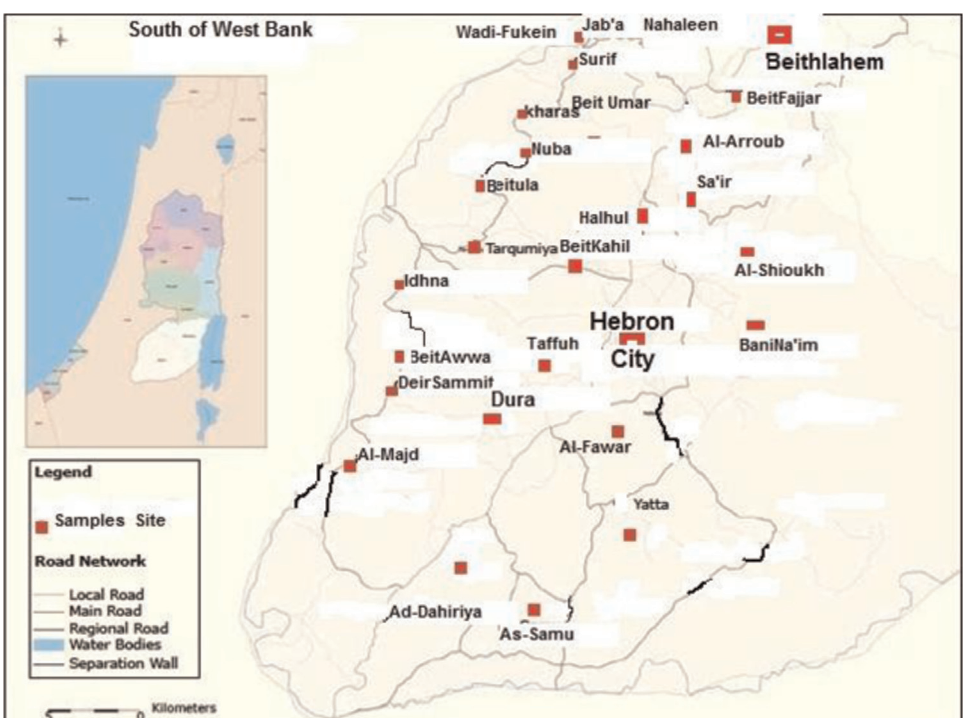

Fig. 1. West Bank geographical map contain the studied region.

2. Materials and methods

2.1. Study area

The study areas are Hebron (Al- Khalil) Governorate and south Bethlehem Governorate (Fig. 1), which is located in the south of the West Bank, extended about 70 km south of Jerusalem. It is the largest area in the West Bank in terms of size and population. Its area is about 1300 km^2, corresponding to about 30% of the total area of the West Bank. The population of study area is around 700,000 according to the estimates of the Palestinian Central Bureau of Statistics (PCBS). The study area lies between 400 m and 1013 m above sea level, thus the difference in altitudes leads to a difference in the wind movement and in the air pressure. The climate is Mediterranean with long hot and dry summers, and short cool and rainy winters. Accordingly, the climate of Palestine is classified as an eastern Mediterranean one.

2.1.1. Water services

The study area suffers from water scarcity, due to lack of rainfall on the territory of the province, and lack of artesian wells. In addition to the Israeli control of water industries/ supplies aggravates the problem. The current sources of water for Hebron and Bethlehem are coming from groundwater wells and water is also purchased from a network of the Palestinian Water Authority (PWA) and Israeli Water Company (MECOROT). According to PWA Hebron is purchasing nearly 59% of the total water supply from Mekorot and producing 41% of the total water supply from the groundwater wells of Bani Naim, Fawwar and As-Samu. The regions also have many water reservoirs with a capacity of many thousands of cubic meters. This is primarily used to provide water to the regions in the summer and is available only once on a weekly basis. The other sources of water in the area under investigations are springs, shallow wells and rain water wells. (ARIJ, 2009; LRC, 2010; OSRO, 2009)

2.2. Water sampling

In this study, 184 various drinking water samples were collected from 36 regions of the area under investigation (Fig. 1). The main water sources are tap water (97 samples), groundwater (12 samples), rain waters (60 samples) and mineral potable waters (15 samples). For the measurement of radon concentration, a sample of 1000 ml water is collected from the different sources in the region. Sampling of tap water has been using the standard procedure proposed by the USA Environmental Protection Agency, EPA (2006). In this procedure, a bottle was connected via a short plastic hose to the water tap. After the water flowed for several minutes, the flow rate was slowed down and the water was allowed to be collected in the funnel. The other samples were collected in well washed bottles which were sealed immediately so that radon may not get out of it. All bottles were marked and date and time of sample collection were written upon them. The groundwater samples were taken after five minutes from operating the wells, and we put the samples in plastic containers. Information data for each well such as well name, well number, site, data of collection sample and exposure period is registered in a form fixed on container. The radon sampling is complicated by the fact that the gas easily escapes from water and therefore has to be done without any aeration which might lead to out gassing (Binesh et al., 2010). The samples were brought to radiation pollution laboratory of the Faculty of Science and Technology, Hebron University Hebron, Palestine.

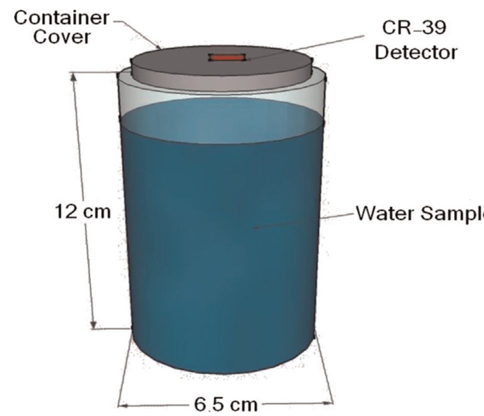

Fig. 2. Schematic diagram for measuring radon concentration in the water samples.

2.3. Experimental technique

2.3.1. Passive method

In this method, radon the calibrated dosimeter techniques were used and long period radon measurements, the measurements were made with the solid state nuclear track detector (SSNTD) technique (Abd-Elmoniem, 2014). The cup technique was employed in this work; each cup container was 12 cm height and 6.5 cm in diameter and contains (1×1) cm square of CR-39 nuclear track detector fixed with double sided adhesive tape to the upper of the cup with its sensitive side downward (Fig. 2). The CR-39 detectors were capable of detecting alpha particles of all energies emitted from radon and its daughters. Some of alpha particles reach the detector and leave tracks, and the number of tracks is proportional to the average radon concentration. The exposed detectors were collected after 75 days of exposure and then chemical etching simultaneously at a constant time 4 h and NaOH for 6.25 N at temperature 70 °C. At the end of the etching process the detectors were washed thoroughly with distilled water and then left to dry. An optical microscope with magnification of 160 was used to count the number of tracks in each detector (Jazzar and Thabayneh, 2014).

2.3.2. Active method

In this method, the spectrometer RAD 7, with special accessories for radon measurement in water ($RADH_2O$) was used for measurements of radon concentration in some drinking water samples in order to make a comparison between the results of the two methods (Durridge Co., USA) (Abd-Elmoniem, 2014). The spectrometer continually measures the radon concentration, showing both methods on a spectrum printout, and also functions as a sniffer with audible count signal to locate radon entry points. The detector was used for measuring radon in water by connecting it with a bubbling kit which enables to grabbing radon from a water sample into the air in a closed loop. A sample of water was taken in a radon-tight reagent bottle of 250 ml capacity. This bottle was connected in a close circuit with a zinc Sulfide coated detection chamber which acts as Scintillator to detect alpha activity and a glass bulb containing calcium chloride to absorb the moisture. Air was then circulated in a closed circuit for a period of 6–12 min until the radon was uniformly mixed with the air and the resulting alpha activity was recorded and it directly gives the radon concentration (Durridge Company, 2012).

3. Theoretical calculations

3.1. The activity concentration of radon

The concentration of ^{222}Rn in the water samples will be calculated in (Bqm^{-3}) unit from the following relation (El-Ghossain and Abu Shammala, 2012):

$$C_{Rn}\,(Bq/m^3) = \frac{c_0 t_0}{\rho_0}\left(\frac{\rho}{t}\right) = k\left(\frac{\rho}{t}\right) \tag{1}$$

where C_{Rn}: activity concentration of ^{222}Rn in a water sample; C_0,: activity concentration of ^{226}Ra (solid radon source) equal 800 Bqm^{-3}; ρ_0: track density (number of tracks/cm^2) in detectors exposed to ^{226}Ra; t_0: exposure time (in days) of detectors exposed to ^{226}Ra, equal 70 days; ρ: track density (number of tracks/cm^2) in detectors exposed to water samples and t: exposure time (in days) of detectors exposed to water samples, equal 75 (El-Ghossain and Abusaleh, 2007).

3.2. The annual effective dose

The annual effective dose due to the inhalation of radon, H_{inh}, resulting from the radon concentration in drinking water, was calculated according to the following expression (Sujo et al., 2004):

$$H_{inh}\,(nSv/yr) = C_{Rn} \times R \times F \times T \times 9nSv\,(\mathrm{Bqhm}^{-3})^{-1} \tag{2}$$

where C_{Rn} is the average indoor air radon concentration, in Bqm^{-3}, R is the air–water concentration ratio ($=10^{-4}$), F is the equilibrium factor between indoor radon and its progeny ($=0.4$), T is the exposure time to this concentration, in hours (assumed to be equal to 7000 h per year) and $9nSv\,(Bqhm^{-3})^{-1}$ is the dose conversion factor (UNSCEAR (B), 2000).

The annual effective dose due to the ingestion of radon from water, H_{ing}, was calculated according to equation (Tabassum and Mujtaba, 2012):

$$H_{ing}\,(mSv/yr) = C_{Rn} \times D_{ing} \times L \tag{3}$$

where H_{ing}: committed effective dose, $mSvy^{-1}$; C_{Rn}: radon concentration in water, $Bq\ell^{-1}$; D_{ing}: conversion factor, equal to $1\times10^{-8}\,SvBq^{-1}$; and L is annual water consumption by an adult in liters. We have used daily water consumption by an adult as 2 l (730 l per year) (UNSCEAR, 1993). The United Nations Scientific Committee on the Effects of Atomic Radiation estimated that the committed effective dose from the ingestion of radon in water is $10^{-8}\,SvBq^{-1}$for an adult, $2\times10^{-8}\,SvBq^{-1}$for a child and $7\times10^{-8}\,SvBq^{-1}$for an infant (UNSCEAR, 1993). According to UNSCEAR, doses to children and infants for similar consumption rates could be a factor of 2 and 7 higher, respectively (UNSCEAR, 2000).

4. Results and discussions

Long term measurement using the SSNTDs was done for all samples in different locations in the area under investigation, and short term measurements using the RAD7 accessories for some drinking water samples for comparison between passive and active techniques are used.

4.1. The activity concentration of radon

4.1.1. Results from CR-39 detector

The results presented and discussed in this study includes 97 tap water samples, 60 rain water samples, 12 groundwater samples and 15 minerals (potable) water samples were collected from

Table 1
Results of ^{222}Rn concentrationsand the average annual effective dose due to the ingestion (H_{ing}) and inhalation (H_{inh}) of radon in tap water sampled from dwellings.

Zone	No. of samples	^{222}Ra (Bq/ℓ)			Av. H_{ing} (μSv/yr)			Av. H_{inh} (μSv/yr)
		Min.	Max.	Av.	Adult	Child	Infant	
Hebron	8	0.22	0.91	0.49	3.6	7.2	25.0	1.23
Halhul	3	0.51	1.74	1.02	7.5	14.9	52.1	2.56
Beit Umar	3	0.31	0.96	0.67	4.9	9.8	34.2	1.67
Surif	6	0.15	1.16	0.65	4.8	9.5	33.2	1.63
Nuba	5	0.21	1.11	0.63	4.6	9.2	32.2	1.57
Kharas	4	0.29	0.51	0.41	3.0	6.0	21.0	1.02
Beit Ula	2	0.23	0.41	0.32	2.3	4.7	16.4	0.80
Tarqumia	6	0.35	1.74	0.66	4.8	9.6	33.7	1.64
Idhna	4	0.32	0.54	0.39	2.9	5.7	19.9	0.98
Yatta	5	0.30	0.81	0.52	3.8	7.6	26.6	1.29
BeitAwwa	2	0.20	0.30	0.25	1.8	3.7	12.8	0.63
Dura	9	0.24	0.90	0.51	3.7	7.5	26.1	1.27
Al-Majd	2	0.12	0.28	0.20	1.5	2.9	10.2	0.50
Ad-Dahiriya	3	0.29	0.45	0.39	2.9	5.7	19.9	0.98
As-Samu	7	0.20	1.41	0.77	5.6	11.2	39.4	1.92
Bani Na'im	3	0.39	0.71	0.52	3.8	7.6	26.6	1.31
Sa'ir	5	0.30	0.62	0.46	3.4	6.7	23.5	1.16
Al-Shioukh	2	1.00	1.10	1.06	7.8	15.5	54.2	2.66
Taffuh	3	0.57	0.93	0.77	5.6	11.2	39.3	1.93
Deir Sammit	2	0.31	0.43	0.37	2.7	5.4	18.9	0.92
Beit Kahil	2	0.63	0.91	0.77	5.6	11.2	39.4	1.93
Al- Fawwar	2	1.08	1.38	1.23	9.0	18.0	62.9	3.08
Al- Arroub	2	0.68	0.83	0.75	5.5	11.0	38.3	1.88
Nahaleen	2	0.69	0.73	0.71	5.2	10.4	36.3	1.77
Beit Fajjar	2	0.62	0.74	0.68	5..0	9.9	34.8	1.70
Wadi- Fukein	1	–	–	0.43	3.1	6.3	22.0	1.08
Jab'a	2	0.43	0.58	0.51	3.7	7.5	26.1	1.27
Total	**97**	**Total**	**Average:**	**0.60**	**4.4**	**8.7**	**30.6**	**1.50**

Table 2
Results of ^{222}Rn concentrations and the average annual effective dose due to the ingestion (H_{ing}) and inhalation (H_{inh}) of radon in rain water sampled from water containers.

Zone	No. of samples	^{222}Ra (Bq/ℓ)			Av. H_{ing} (μSv/yr)			Av. H_{inh} (μSv/yr)
		Min	Max	Av.	Adult	Child	Infant	
Hebron	2	0.83	0.92	0.88	6.4	12.8	45.0	2.19
Halhul	2	0.58	1.25	0.92	6.7	13.4	47.0	2.28
Beit Umar	3	0.53	0.98	0.75	5.5	11.0	38.3	1.87
Surif	2	1.02	1.10	1.06	7.7	15.5	54.2	2.65
Nuba	3	0.41	1.00	0.75	5.5	11.0	38.3	1.88
Kharas	1	–	–	0.18	1.3	2.6	9.2	0.45
Beit Ula	2	0.20	0.46	0.33	2.4	4.8	16.9	0.83
Tarqumia	3	0.27	0.82	0.54	3.9	7.9	27.6	1.36
Idhna	2	0.55	0.64	0.59	4.3	8.6	30.1	1.49
Yatta	4	0.29	0.57	0.47	3.4	6.9	24.0	1.17
Beit Awwa	3	0.25	1.67	0.95	6.9	13.9	48.5	2.38
Dura	8	0.18	0.72	0.40	2.9	5.8	20.4	0.99
Al-Majd	1	–	–	0.82	6.0	12.0	41.9	2.06
Ad-Dahiriya	5	0.51	0.91	0.71	5.2	10.4	36.3	1.77
As-Samu	3	0.28	0.55	0.40	2.9	5.8	20.4	1.01
Bani Na'im	2	0.22	0.31	0.26	1.9	3.8	13.3	0.66
Sa'ir	3	0.26	0.77	0.59	4.3	8.6	30.1	1.47
Al- Shioukh	2	1.10	1.13	1.11	8.1	16.2	56.7	2.78
Taffuh	2	0.34	0.55	0.44	3.2	6.4	22.5	1.11
Deir Sammit	1	–	–	0.89	6.5	13.0	45.5	2.21
Beit Kahil	1	–	–	0.91	6.6	13.3	46.5	2.29
Al- Fawwar	1	–	–	1.12	8.2	16.4	57.2	2.80
Nahaleen	1	–	–	1.51	11	22.0	77.2	3.78
Beit Fajjar	1	–	–	1.16	8.5	16.9	59.3	2.89
Wadi- Fukein	1	–	–	0.99	7.2	14.5	50.6	2.47
Jab'a	1	–	–	0.92	6.7	13.4	47.0	2.30
Total	**60**	**Total**	**Average:**	**0.76**	5. 5	11.0	38.6	1.89

Table 3
Results of ^{222}Rn concentrations and the average annual effective dose due to the ingestion (H_{ing}) and inhalation (H_{inh}) of radon in ground water sampled from wells.

Zone	No. of samples	^{222}Ra (Bq/ℓ)			Av. H_{ing} (μSv/yr)			Av. H_{ing} (μSv/yr)
		Min.	Max.	Av.	Adult	Child	Infant	
Hebron	1	–	–	0.58	4.2	8.5	29.6	1.44
Halhul	1	–	–	0.80	5.8	11.7	40.9	1.99
Beit Umar	1	–	–	0.86	6.3	12.6	43.9	2.15
Beit Ula	1	–	–	0.42	3.1	6.1	21.5	1.05
Dura	1	–	–	0.71	5.2	10.4	36.3	1.77
Bani Na'im	1	–	–	0.61	4.5	8.9	31.2	1.52
Sa'ir	2	0.34	0.75	0.54	3.9	7.9	27.6	1.36
Taffuh	1	–	–	0.49	3.6	7.2	25.0	1.22
Nahaleen	1	–	–	0.50	3.7	7.3	25.6	1.26
Wadi- Fukein	2	0.81	0.98	0.89	6.5	13.0	45.5	2.24
Total	**12**	**Total**	**Average:**	**0.64**	**4.7**	**9.4**	**32.7**	**1.60**

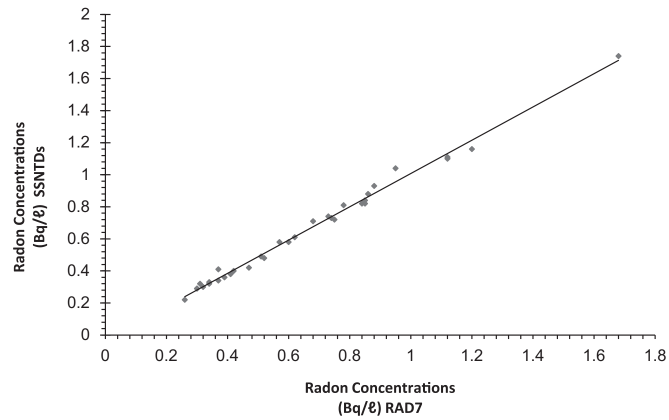

Fig. 3. The linearity between the results of two detectors; active (RAD7) and passive (SSNTDs).

Table 4
Results of ^{222}Rn concentrations and the average annual effective dose due to the ingestion (H_{ing}) and inhalation (H_{inh}) of radon in mineral spring (potable) water.

Sample name	No. of Samples	^{222}Ra (Bq/ℓ)			Av. H_{ing} (μSv/yr)			Av. H_{inh} (μSv/yr)
		Min.	Max.	Av.	Adult	Child	Infant	
Heron Spring 1	3	0.44	0.45	0.44	3.2	6.4	22.5	1.11
Heron Spring 2	1	–	–	0.84	6.1	12.3	42.9	2.10
Ain Gidi 1	2	0.59	0.70	0.65	4.7	9.5	33.2	1.62
Ain Gidi 2	1	–	–	1.14	8.3	16.6	58.3	2.85
Arwa	2	0.42	0.58	0.50	3.7	7.3	25.6	1.25
Veira	2	0.31	0.60	0.46	3.4	6.7	23.5	1.14
Jericho	2	0.45	0.73	0.59	4.3	8.6	30.1	1.47
Aqeunova	1	–	–	0.60	4.4	8.8	30.7	1.50
Vivan	1	–	–	0.73	5.3	10.7	37.3	1.82
Total	15	**Total**	**Average:**	**0.66**	4.8	9.7	33.8	1.65

taps, containers, wells and shops. The results of radon concentration levels in residential tap water are listed in Table 1. As presented, the average radon concentrations ranged from 0.20 to 1.23 Bqℓ$^{-1}$ with a total average value of 0.6 Bqℓ$^{-1}$. Tap water which is supplied to the public is also obtained from tube well. People store this water in small tanks for daily use and after passing through pipes it is used in drinking, cooking and bathrooms. Low level of radon in piped treated water is due to the fact that most of the dissolved ^{222}Rn in water is vented/ released during treatment and transportation (Tabassum and Mujtaba, 2012). Table 2, represents the radon concentration levels in the rain waters in the 26 sites of the regions. The average concentration range was from 0.18 to 1.51 Bqℓ$^{-1}$ with a total average value of 0.76 Bqℓ$^{-1}$. The recorded values of radon concentration in groundwater samples are given in Table 3. I found that the average radon concentrations in these samples ranged from 0.42 to 0.89 Bqℓ$^{-1}$ with a total average value of 0.64 Bqℓ$^{-1}$. The ^{222}Rn concentrations obtained for the mineral (potable) water samples at the used as drinking water in the area under investigation are presented in Table 4. The average radon concentrations obtained ranges from 0.44 to 1.14 Bqℓ$^{-1}$ with a total average value of 0.66 Bqℓ$^{-1}$. It is observed that the radon total average concentration in rain water samples is the highest and that in tap water, it is the lowest. The rain water in the area under investigation dissolves some uranium oxide in the clay and thus enhances the uranium content in water.

The radon concentration measured in the mineral (potable) water samples used as drinking water in the area under investigation is lower than the maximum allowable concentration in portable water of 18 Bqℓ$^{-1}$,as recommended by the EPA (2011). In the UNSCEAR, Report, it was tentatively estimated that between 1% and 10% of the world's population consumes water containing concentrations in order of 100 Bqℓ$^{-1}$or higher, drawn from relatively deep wells (EPA, 2011; UNSCEAR, 1982). For a reminder, who consumes water from aquifers or surface sources, the weighted world average concentration is probably less than 1 Bqℓ$^{-1}$ (UNSCEAR, 1982). This is below the maximum allowable radon concentration of water as recommended by the EPA and UNSCEAR for the weighted world average concentration of water drawn from relatively deep wells, but higher than the weighted world average concentration of water from aquifers or surface sources (UNSCEAR, 1982; Yeğingil, 1989). It is apparent that radon in water is a significant source of radon in dwellings only when the radon concentration in water is the order of 11 Bqℓ$^{-1}$or more (Yeğingil, 1989), or above 400 Bqℓ$^{-1}$as recommended by UNSCEAR.

The measured values of radon concentration in all water samples were found within the United States Environmental Protection Agency (US-EPA) recommended limits (11 Bqℓ$^{-1}$) (EPA, 2011; NAP, 1999). Because radon is easily released by agitation in water, many uses of water release radon into the indoor air, which contributes to the total indoor airborne radon concentration. Since (10,000 Bqℓ$^{-1}$) in water translates to about (1 Bqℓ$^{-1}$) in air, relatively there is no need to worry about the health risks due to water-borne radon (NAP, 1999).

4.1.2. *Results from RAD7 accessories*

A correlation between results of the active and passive detectors has been made and shown in Fig. 3. The correlation appears no differences between results obtain from long time measurements (75 days) and short time measurements (1 h). It shows a very good correlation.

4.2. *Annual effective doses from ^{222}Rn ingested and inhaled with water*

Radon enters the human body through ingestion and through inhalation as radon is released from water to indoor air. Therefore, radon in water is a source of radiation dose to the stomach and lungs. The annual effective doses for ingestion and inhalation due to radon from water, for adult's, child's and infants were calculated according to parameters introduced by UNSCEAR, report (UNSCEAR, 2000). The annual effective dose due to inhalation and due to ingestion is listed in 1–4, for all types of drinking water. From the present data, the total average effective dose from ^{222}Rn due to intake of all sorts of drinking water is for less than the recommended maximum value of 0.1 mSvy^{-1} (Somlai et al., 2007; WHO, 2004). Therefore, the contribution to the dose can be neglected.

5. Conclusions

The Radon concentrations in drinking water were analyzed for 184 samples in the Southern Part of West Bank – Palestine covered most of the residential area. From the measured radon concentration, annual effective doses received by the inhabitants of the surveyed area have been estimated. The minimum total average value of radon concentration is found in tap water, which is used by the maximum population of the surveyed area, while the maximum total average value is in rain container water. The results of this study will indicate that the radon concentrations and the annual effective doses in all types of drinking water samples of the studied area are mostly low enough and below the proposed concentration limits. Compared with the international references, our findings showed that there was no increase in the exposure of radon in the different drinking water sources in the southern part of West Bank – Palestine.

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