Hebron University Research Journal-A (Natural Sciences) - (مجلة جامعة الخليل للبحوث- أ (العلوم الطبيعيه)

Volume 7 | Issue 1 Article 2

2017

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Hebron University Research Journal(A)
Vol.(7), pp.(15-31), 2017

H.U.R.J. is available online at
http://www.hebron.edu/journal

Assessment of Indoor Radon-222 Concentration Levels In Some Dwellings in Tubas City during Summer Of 2015

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Abstract

In this study, the indoor radon concentrations were measured in 87 different rooms in Tubas city located in northern West Bank, Palestine, using CR-39 solid state nuclear track detectors. The measurements were performed during the summer of 2015 for a period of three months using 100 detectors. The detectors were installed in randomly selected apartments, stores, schools, and warehouses in the area under study. The results of indoor radon concentrations and the annual effective dose in rooms were found to vary from 48 to 416 Bqm^{-3} and 1.2 to 10.4 mSv y^{-1}, with average values of 137.0 Bqm^{-3} and 3.43 $mSvy^{-1}$, respectively. The average values of radon concentrations levels in markets and warehouses, houses and apartments, storage rooms and basements, and schools, are: 154.2, 116.5, 168.5, and 112.5 Bqm^{-3}, respectively. The corresponding average annual effective dose values for these places are: 3.86, 2.91, 4.21, and 2.81 m $Svy^{-1,}$ respectively. In general, the results show that radon concentration levels in 81% of the rooms under study are lower than that the indoor action level 150 Bqm^{-3} in the United States. The obtained average annual effective dose value is about 2-3 times higher than the assigned international value (1.3 $mSvy^{-1}$). This might be an indication that the surveyed zones are characterized by high radon exposure doses, and an action should take place.

Key words: Indoor; ^{222}Rn; Radon concentration levels; CR-39 detector; Annual effective dose; dwelling; cancer.

ملخص:

في هذه الدراسة، تم قياس تراكيز غاز الرادون في 87 غرفة مختلفة في مدينة طوباس، شمال الضفة الغربية - فلسطين، وذلك باستخدام كواشف الحالة الصلبة للمسارات النوويةCR-39. أجريت الدراسة خلال فصل الصيف من عام 2015 ولمدة ثلاثة أشهر باستخدام ما مجموعه 100 كاشف. تم توزيع الكواشف في الشقق السكنية والمخازن والمدارس والمستودعات، وقد تم اختيارها عشوائيا في المنطقة محل الدراسة. بينت نتائج الدراسة أن تركيزات غاز الرادون والجرعة السنوية الفعالة الناتجة عن تلك التركيزات في تلك الغرف تتراوح بين48-416 بيكريل/متر^3 و1,20 –10,4ملي سيفرت/ سنة، بمتوسط كلي مقداره 137بيكريل/متر^3 و 3,43 ملي سيفرت/ سنة على التوالي. وأن قيم متوسط تراكيز غاز الرادون في الأسواق والمخازن والمنازل والشقق والمستودعات، والأقبية، والمدارس،هي على التوالي: 154,2، 116,5، 168,5،و 112,5 بيكريل/متر^3. وفي المقابل فان متوسط الجرعة السنوية الفعالة لهذه الأماكن هي: 3,86، 2,91، 4,21، 2,81 ملي سيفرت/ سنة، على التوالي. بشكل عام، فقد بينت النتائج أن مستويات تركيز الرادون في 81٪ من الغرف أقل من مستوى تراكيز الرادون في الأماكن المغلقة 150 بيكريل/متر^3. وأن متوسط قيمة الجرعة الفعالة السنوية التي تم الحصول عليها هي أعلى بحوالي 2-3 مرات من القيمة الدولية المخصصة لذلك. وهذا قد يكون دليلا على أن المناطق التي شملتها الدراسة تتميز بجرعات عالية نتيجة التعرض لغاز الرادون.

Introduction:

Radon is the only naturally occurring radioactive gas that results from Uranium decay series. It is an inert, colorless, odorless, tasteless, and insensible gas. Therefore, it can't be detected unless special type of detectors is used. Radon, as a natural noble gas, has three main natural isotopes, namely, radon-222 (^{222}Rn), a decay product of ^{238}U, radon-220 (^{220}Rn known as thoron), produced during the decay series of thorium-232 (^{232}Th), and radon-219 (^{219}Rn), a decay product from the chain originating with ^{235}U (Budnitz, 1974). In particular, ^{222}Rn is the most important one of all radon radioisotopes in this study since it plays a major concern in radiation pollution and human being health hazard (UNSCEAR, 1993). It is well known that ^{222}Rn enters dwellings generally through cracks and joints in the floor, from underground water, and from building materials (cement, rocks, granite) (Khan, 2000). ^{222}Rn can build up, depending on the geological formation beneath the dwellings and the construction materials, to a high level in closed places (badly ventilated dwellings) (ICRP, 1993; Kullab, 2005). Radon level can vary even in the same dwelling, and, in general, it is higher in basements and poor ventilated places as well as unpainted places (Virk, 1999). Besides, Radon concentration fluctuates daily depending on weather condition and the life style of occupants. Exposure to Radon and its progeny constitutes a health hazard due to the interaction of the alpha particles emitted by inhaled radon and its progeny that attached to aerosols with the lining cells of the lung (Sevc et al., 1976; NRC, 1999; UNSCEAR, 2000, 2008; ICRP, 1993, 1994). Therefore, it is of great importance to assess the exposure to ^{222}Rn and its progeny in houses and areas of high ^{222}Rn levels for the purpose of quality control, radioactivity monitoring for building materials and doses received by inhabitants due radon exposures. Accordingly, tremendous investigations were conducted worldwide during the past four decades in order to monitor radon level before an action should take place, and many of these surveys have been compiled in the literature (UNSCEAR, 1993, 2000, 2008; ICRP, 1993, 1994; Al-Zubaidy and Mohammad, 2012).

World organizations such as International Commission on Radiological Protection (ICRP), World Health Organization (WHO),Health Canada, and Environmental Protection Agency (EPA) have recommended different guidelines listed in Table 1 for exposure to radon based on the best available scientific evidence of health risk(ICRP, 1993, 1994, 2009; Health Canada, 2006, 2009; EPA, 2009; WHO 2009).The recommended indoor action level for the population is ranged between 200 and 600 Bqm^{-3} (ICRP 1994). According to the ICRP published reports, each 1Bqm^{-3} of radon level means about 0.025 $mSvy^{-1}$(ICRP, 1987, 2009). So, to estimate the probability of getting lung cancer from radon concentration, Cross found that such possibility is equal to 1.65×10^{-2} for radon concentration of37 Bqm^{-3}(Cross, 1992).

Table 1. Radon concentration levels guidelines for dwellings

Organization	**Radon concentration levels (Bqm^{-3})**	**Annual effective dose ($mSvy^{-1}$)**	**References**
Health Canada	200	5.18	Health Canada 2006, 2009
World Health Organization	100-300	2.59-7.78	WHO 2009
International Commission on Radiological Protection	300	7.78	ICRP 1993, 1994, 2009
Environmental Protection Agency	150	3.89	EPA 2009
European Union	200	5.18	
United Nations Scientific Committee on the Effects of Atomic Radiation	200	5.18	UNSCEAR 2000

In Palestine, indoor radon survey projects were initiated by Fakhri Hassan at Hebron university (Hassan, 1996), Dwikat at An-Najah National University (Dwikat, 2001), a research group at Al-Quds University (Leghrouz et al., 2007, 2011; Shawawra 2011), a research group at Hebron University (Dabayneh, 2006; Dabayneh and Awawdeh, 2007; Thabayneh, 2008; Thabayneh et al., 2012; Jazzar and Thabayneh, 2014; Thabayneh et al., 2015; Thabayneh, 2015; Thabayneh and Arar, 2015; Thabayneh, 2016; Thabayneh et al., 2016), and An-Najah University (Saffarini et.al., 2012). Up to now, 3,685 dwellings located in 53 locations were surveyed. Thus, detailed radon data for many locations in the Palestinian territories are not available yet. The aim of this work is to measure radon concentration levels in Tubas city to provide data for drawing a national radon map in Palestine.

The Study Area:

Tubas governorate is surrounded by a hillside mountainous area as shown in Figure 1(TGSS, 2006). It is located at the confluence of latitude 31.45º north, and longitude 35.12º east.

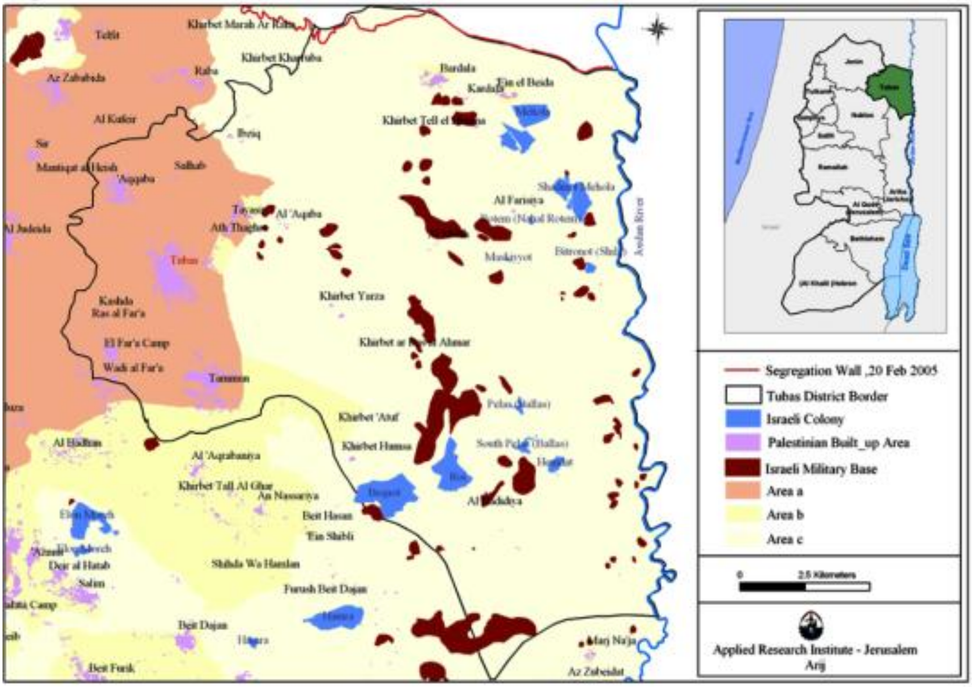

Figure 1.Tubas Governorate borders and localities
(http://vprofile.arij.org/tubas/static/factsheet/newsletter1.pdf)

The rock formation in the surveyed region is dominated by dolomite and dolomite limestone (Issaq, 1995); such formation is characterized by low level of radionuclides. Modern buildings in this region are built of rocks obtained from different quarries locations in the West Bank. Moreover, other building materials such as concrete, stones, ceramic tiles, and granite are used. Usually, the floors separations are constructed from fortified concrete of 0.25 m in thickness. The schools' buildings follow the same construction trends as housing. The old houses are built similarly but with a layer of clay and lime sandwiching the outside and the inside stones

It is worth mentioning that most dwellings are not air conditioned: Even though with the presence of air conditioning, it is not turned on frequently, and the inhabitants tend to open the windows more frequently. Thus, the buildings can be treated as an open system environment all the year around.

EXPERIMENTAL TECHNIQUE:

In this survey, CR-39 solid-state nuclear track detectors (SSNTDs) were used to determine indoor radon levels. The general methodology for preparing the dosimeter was explained in details by many authors (Al-Bataina et al. 1997; Leghrouz et al. 2007, 2011; Dabayneh 2006, 2007; Thabayneh 2012, 2015).

A total of 100 dosimeters were distributed in 87 rooms which include apartments, storage rooms, schools, basements, and warehouses for a period of three months starting from June 2015 to mid-September 2015. The dosimeters were distributed and installed at 0.5 to 1.5 m height depending on the availability of a holder for a period of three months. By September 20, a total of 87 dosimeters were collected, and the rest were lost. The collected dosimeters were distributed among dwellings as in Table 2.

Table 2. The collected distributed dosimeters from various dwellings

Dwelling	Total Number of dosimeters	Floor	Type of dwelling	
			Old	New
Markets and Warehouses	26	1		26
Houses and apartments	39	0		1
		1		27
		2	3	7
		3		1
Storages and Basements	10	0		6
		1		4
Schools	12	0		4
		1		5
		2		3

The detectors were then chemically etched in 6.25 N-solution of NaOH at temperature of 70±2 ^{0}C for eight hours (Kullab et al., 1997; Abu-Samreh et.al., 2016). An optical microscope, 150 times of magnification, was used to count the number of tracks per cm^2 occurring in each detector. The track densities (tracks/cm^2) were measured and converted to radon concentration in Bqm^{-3} using the calibration equation adopted by Yarmouk university radon research group (Al-Bataina, 1997). The annual effective dose received has been calculated according to the equation agreed upon by the International Commission on Radiological Protection (Risica, 1998; UNSCEAR, 2000).

RESULTS AND DISCUSSION:

The obtained data for the radon concentration levels along the annual effective dose were analyzed according to the statistical methods. The minimum (Min), maximum (Max) radon concentrations measured in air, average (Ave), and the average effective dose equivalent of the results obtained for the inspected 87 rooms were summarized in Table 3.

Table 3. Number of collected detectors (N), the radon concentration and the average effective dose equivalent of dwellings selected from the monitored zones.

Dwelling	No.	Radon concentration (Bqm^{-3})			Average annual effective dose ($mSvy^{-1}$)		
		Min	Max	Ave	Min	Max	Ave
Markets and Warehouses	26	48	216	154.2	1.20	5.40	3.86
Houses and apartments	39	54	186	116.5	1.35	4.65	2.91
Storages and Basements	10	82	416	168.5	2.05	10.40	4.21
Schools	12	62	246	112.5	1.55	6.15	2.81
Total	**87**	**48**	**416**	**137.0**	**1.20**	**10.40**	**3.43**

The indoor radon concentration levels in the surveyed 26 markets and warehouses were found to vary from 48 $Bq\text{-}m^{-3}$ to 216 $Bq\text{-}m^{-3}$. There are four readings above the Environmental Protection Agency's (EPA, 2009) recommended safety limit of 150 $Bq\text{-}m^{-3}$ which might need some attention to reduce the levels to the recommended one. These readings belonged to closed storage rooms in the ground floor. The other readings are within the acceptable level, and no action is required.

The indoor radon levels for the surveyed 39 houses and apartments were found to vary from 54 – 186 Bqm^{-3} with a mean value of 116.5 Bqm^{-3}. The lowest concentration value of 54 Bqm^{-3} was found in a living room whereas the highest concentration of 186 Bqm^{-3} was found in a basement.

There are two measurements above the recommended safety limit. These values were reported in closed rooms in basements. In general, the radon levels in living rooms are within the acceptable level. The low values in houses might be due to the good ventilation because the majority of houses were open most of the day. As expected, the obtained results have shown that the average value of the radon concentration is slightly higher in the old houses than the new ones. This is because ventilation rates in old houses range from poor to moderate, and the presence of cracks in floors and walls allow Radon gas to emanate easily from soil and building materials into indoors.

It was found that half of the readings of the measurements in storage rooms and basements were below the recommended level and the second half was above the recommended level. The high reported data were found in closed storage rooms under renovation. The radon levels in basements, stairways and storage rooms are all within the acceptable level except for five readings reported in poorly ventilated places kept closed for most of the time, and they are unpainted.

The Radon levels in the classrooms of the two schools are not included in this study because, from our previous work, the students tend to damage the dosimeters. Levels were found to vary from 62 to 246 Bqm^{-3} with an average value of 112.5 Bqm^{-3}.

The effective dose equivalent:

According to the UNSCEAR report, the annual effective dose equivalent D_{Rn} in ($mSvy^{-1}$) to the public due to ^{222}Rn and its progeny is estimated using the following equation (UNSCEAR, 2000; Zakariya *et al.*, 2013):

$$D_{Rn}(mSvy^{-1}) = C_{Rn} \times \mathrm{F_R} \times \mathrm{H} \times \mathrm{T} \times \mathrm{D} \quad (1)$$

Where C_{Rn} is the radon concentration (Bqm^{-3}), F_R is equilibrium factor of ^{222}Rn indoors (0.4), H is the occupancy factor (0.8), T is hours in a year (8760 hy^{-1}) and D is the dose conversion factor (9.0×10^{-6} mSv per $Bqm^{-3}h$), which is the effective dose received by adults per unit ^{222}Rn activity per unit of air volume (UNSCEAR, 2000).

The annual effective dose equivalent due to radon exposure is also provided in Table 3. The data show that the value of the annual effective dose equivalent to the corresponding measured radon concentration were found to vary from: 1.2 -5.4 $mSvy^{-1}$, 1.35-4.65 $mSvy^{-1}$, 2.05-10.4 $mSvy^{-1}$, and 1.55-6.15 $mSvy^{-1}$, in markets and warehouses, houses and apartments, storage rooms and basements, and schools, respectively.

The average values of radon concentrations levels in markets and warehouses, houses and apartments, storages and basements, and schools, are: 154.2, 116.5, 168.5 and 112.5 Bqm^{-3} respectively. The subtotal average of radon concentration levels is 137.0 Bqm^{-3}. The corresponding average annual effective dose values for markets and warehouses, houses and apartments, storages and basements, and schools are 3.86, 2.91, 4.21and 2.81$mSvy^{-1}$, respectively, with a total average values of 3.43$mSvy^{-1}$. The total dose average values are about 2-3 times higher than the accepted international UNSCEAR value of 1.3 $mSvy^{-1}$ (UNSCEAR, 1993). The results show that, 19% of measurements are higher than the assigned international radon level of 150 Bqm^{-3}, and the annual effective dose equivalent average is 2-3 times higher than the normal background effective dose equivalent value assigned by EPA (EPA, 2009).

It is worth mentioning here that the highest levels are found in places of poor ventilations. Accordingly, the calculated average excluding the basement, storage rooms, and stairway, is 117.6 Bqm^{-3}, which is 9.14% less than that of all over average of 137.0. The possibility of the increase of lung cancer cases among the average persons in the studied area is 1.94%.

Although this study had been performed during summer where the average radon concentration is supposed to be lower than that during winter, high radon concentration values have been detected in some places. Higher ^{222}Rn concentration values were reported in houses with poor ventilation. This confirms the importance of ventilation in order to avoid the accumulation of radon to high levels. Furthermore, higher concentration values were also recorded in some houses having unfinished walls and floors. This stresses the importance of completing room paints and decorations since this plays a major role in decreasing radon concentration. Finally, the effects of building materials on the indoor radon concentration values are expected to be rather significant.

The radon concentration in the present study as well as in other studies for many different sites in West bank - Palestine was compared in Table 4. It is obvious that the radon concentration is greater than many reported data for other sites.

Table 4. Comparison levels of radon concentrations for many different sites in West bank – Palestine.

Site	Radon concentration (Bqm^{-3})		Reference
	Range	Average	
Hebron University	1.0 - 250	29.8	(Hassan, 1996)
Nablus City	--------	98.8	(Daragmeh, 2001)
Hospitals - Nablus	--------	39.0	(Dwikat, 2001)
Tarqumia schools	12.0 – 232.5	34.1	(Dabayneh, 2006)
Dura city	51.5 – 92.7	69.4	(Dabayneh and Awawdeh, 2007)
Beit Fajjar	18.6 – 215.6	78.6	(Thabayneh et al., 2012)
Ramallah	Summer season: 43.0 – 192 Winter season: 38.0 - 375	----	(Leghrouz et al., 2012)
East Jerusalem	Summer season: 30.0 – 655 Winter season: 35.0 - 984	----	(Leghrouz et al., 2012)
Elementary Schools - Tulkarem	3.5 – 210.5	40.4	(Mallah, 2013)
Illar	4.9 - 116	38.3	(Jazzar and Thabayneh, 2014)
Schools -North eastern Hebron	12.1 - 327	71.1	(Thabayneh et al., 2015)
Beit Ummar	Old building: 67.0 – 357 New building: 48 - 380	154 147	(Thabayneh and Arar, 2015)
Hospitals -southern part of west bank	33.0 - 298	144.7	(Thabayneh et al., 2016)
Arab American University - Jenin	26.0 - 258	76.6	(Abu-Samreh002 et al., 2016)
Tubas city	**48.0 - 416**	**137.0**	**Present study**

CONCLUSIONS:

In general, the results show that radon concentration levels in 81% of the investigated dwellings are lower than the indoor radon action level of 150 Bqm^{-3} in the United States. The dose average values were about 2-3 times as high as the accepted international UNSCEAR 1993 value of 1.3 $mSvy^{-1}$. This might be an indication that the surveyed zones are characterized by high radon exposure doses, and an action should be taken. The majority of the elevated values were found in uninhabited and unpainted places usually in the ground level which are characterized by bad ventilation. The increase in the probability of radon related cancer cases in the surveyed region is found to be about 1.94%.

In conclusion, we believe that poor ventilation, construction materials, and stone quarries are the main reasons of the highly reported radon concentration values. Improving ventilation of these places will increase air exchange rates with outside, thereby resulting in reducing radon concentration. While designing new houses, it is important to pay attention to the flooring and make sure that they cracks-free. This reduces the building up of radon inside houses. As for decision-makers, our recommendation is that protective countermeasures should be taken especially for dwellings having higher radon levels than the international assigned values.

ACKNOWLEDGEMENT:

The authors would like to thank Yusuf Abu–Al Shawarib, Chemistry Lab. technician for performing the etching processes. Besides, the authors would like to thank Mr. Sakhir Abu-Zahra, Faculty of Applied Sciences, for facilitating the use of the microscope. Thank you very much for each of Dr. Isar Yaser and Dr. Imad Abu Hassan, for check the language of the article.

References

Abu-Samreh, M., Hussain, A., Daraghmeh, M., Abu- Lebdah, A. (2016). Radon concentration measurements in some buildings of AAUJ. *J Arab Amer Univ* 2(1), 21- 36.

Al-Bataina, B., Ismail, A., Kullab, M., Abumurad, K., Mustafa, H. (1997). Radon measurements in different types of natural waters in Jordan. *Radiat. Meas*. 28(1–6), 591–594.

Al-Zubaidy, N., and Mohammad, A. (2012). Health effects on public of Malka region due to radon gas, using (CR-39) detector. *Adv. Theor. Appl. Mech.* 5(2), 61 – 67.

Budnitz, R. (1974). Radon-222 and its daughters, *Health Phys***.** 26, 145-163.

Cross, F., (1992). Indoor radon and lung cancer: reality or myth. In: Proceeding of the Twenty ninth Hanford on Health and Environment. Battle, *Columbus*, 27-29.

Dabayneh, K. M. (2006). Indoor radon concentration measurements in Tarqumia girl schools at western Hebron region –Palestine. *Isotope and Radiation Research J*. 38(4), 1067-1077.

Dabayneh, K. M. and Awawdeh, K. (2007). Measurements of ^{222}Rn concentration levels and calculates exhalation rates in some dwellings of Dura city – Palestine. *Al-Azhar J. of Science* 18(2), 17-28.

Daragmeh A. (2001). Measurement of radon -222 in dwellings in old Nablus City. M.Sc. thesis, An-Najah National University, Nablus-Palestine.

Dwikat, N. (2001). Indoor radon concentration measurements in four hospitals and two health centers in Nablus city, M.Sc. thesis, An-Najah National University, Nablus- Palestine.

EPA (2010), U.S. Environmental Protection Agency. A Citizen's Guide to Radon: The Guide to Protecting Yourself and Your Family from Radon, 2009. Available at: http://www.epa.gov/radon/pubs/index.html

Hassan, F. (1996). Indoor radon concentration measurements at Hebron University campus a case study. **An-Najah J. Res**. 4(10), 92-107.

Health Canada. Report of the Radon Working Group on a New Radon Guideline for Canada, 2006.

Health Canada (2009). It's your health, 2009. Available at: http://www.hc-sc.gc.ca/hl-vs/iyh-vsv/environ/radon-eng.php.

ICRP (1987), International Commission on Radiological Protection. Lung cancer risk from indoor exposure due to radon daughters. Oxford: Pergamon Press; ICRP Publication 50; Annals of the ICRP 17(1); 1987.

ICRP (1993), International Commission on Radiological Protection. Protection against radon-222 at home and at work. Oxford: Pergamon Press; ICRP Publication 65; Annals of the ICRP 23(2); 1993.

ICRP (1994), International Commission on Radiological Protection. Protection against radon-222 at home and work. England, Elsevier Science, Ltd.; ICRP Publication 65; 1994.

ICRP (2009), International Commission on Radiological Protection. International Commission on Radiological Protection Statement on Radon; 2009. ICRP Ref 00/902/09. Available at: http://www.icrp.org/docs/ICRP_Statement_on_Radon.

Issac, J. (1995).Environmental profile for the West Bank; Bethlehem, Hebron, and Jerusalem Districts. Applied Research Institute-Jerusalem (ARIJ) Vol. 1, 2, and 6 respectively, 1995.

Jazzar, M. M. and Thabayneh, K. M. (2014). Exposure of dwelling populations to alpha particles and its health impact in Illar region, Tulkarem – Palestine. *International J. of Environmental Engineering and Natural Resources* 1(3), 171-178.

Khan, A. (2000). A study of indoor radon levels in Indian dwellings, influencing factors and lung cancer risks. *Radiat Meas* 32, 87–92.

Kullab, M., Al-Bataina, B., Ismail, A., Abumurad, K., Gaith, A. (1997). Study of radon-222 concentration levels inside kinder gardens in Amman. *Radiation Measurements*, 28(1-6), 699-702.

Kullab, M. (2005). Assessment of radon-222 concentrations in buildings, building materials, water and soil in Jordan. *Applied Radiat Isotopes* 62, 765–773.

Leghrouz, A., Abu-Samreh, M., Awawdeh, K., Abu-Taha, M., Saleh, A., Kitaneh, R., Darwish, S. (2007). Indoor ^{222}Rn concentration measurements in some buildings of Hebron province during the winter season of the year 2000. *Radiat Protect Dosim* 123,226 – 233.

Leghrouz, A., Abu-Samreh, M., Shehadeh, A. (2012).Seasonal variations of indoor radon-222 levels in dwellings in Ramallah province and east Jerusalem suburbs, Palestine. *Radiat Protect Dosim* 148(2), 268–273.

Mallah, K. (2013). Indoor Exposure Assessment and Health Hazard of radon in the elementary schools of Tulkarem province, Palestine. M.Sc. thesis, An-Najah National University, Nablus- Palestine.

NRC (1999), National Research Council. Committee on Health Risks of Exposure to Radon: BEIR VI. Health effects of exposure to radon. Washington, DC: National Academy Press.

Risica, S. (1998). Legislation on radon concentration at home and at work. *Radiat Prot. Dosim*. 78,15-21.

Saffarini, G., Dwaikat, N., El-Hasan, M., Sato, F., Kato, Y., Iida, T. (2012). The effect of infrared laser on the activation energy of CR-39 polymeric detector. *Nuclear Instruments and Methods in Physics Research* **A**680, 82-85.

Sevc, J., Kunz, E., Placek, V. (1976).Lung cancer in uranium miners and long term exposure to radon daughter products. *Health Phys*. 30, 433.

Shawawra, K. (2011). Indoor radon-222 concentration levels measurements in the offices and school rooms in Bethlehem province, West Bank, Palestine. Al-Quds University, M.Sc. Thesis, unpublished.

Thabayneh, K. M. (2008). Rn-222 concentration level measurements and exhalation rates in different types of building materials used in Palestinian buildings. *Isotope and Radiation Research J*., 40(2), 277- 289.

Thabayneh, K. M., Abu-Samreh, M. M., Elian, M.M. (2012). Assessment of indoor radon levels in dwellings of Beit Fajjar city, Palestine. *Hebron University Research J*.**(A)** 6, 47 – 60.

Thabayneh, K. M., Abu-Samreh, M. M., Mashal, L.A. (2015). Indoor radon concentration levels inside schools in the north eastern region of Hebron province – Palestine: Case study in summer season. *Environmental Science: An Indian Journal ESAIJ* 10(7), 260-268.

Thabayneh, K. M. (2015). Measurement of ^{222}Rn concentration levels in drinking water and the associated health effects in the southern part of West Bank- Palestine. *Applied Radiation and Isotopes J*. 103, 48-53.

Thabayneh, K. M. and Arar, A. (2015). Monitoring of indoor radon and assessment of lung cancer risk to population of Beit Umar city, West Bank – Palestine. *Ulutas Med J*. 1(2), 31-37.

Thabayneh, K. M. (2016). Determination of alpha particles concentration in some soil samples and the extent of their impact on the health. *Sains Malaysiana Journal* 45(5), 699- 707.

Thabayneh, K. M., Mashal, L. A., Adnan, M. A. (2016). Study of radon concentration and the associated health effects in selected hospitals in the southern part of West bank – Palestine. *Asian J. of Science and Technology* 7(2), 2502- 2508.

TGSS (2006), Tubas Governorate Surveillance System. Tubas Governorate profile January, 2006, Available at:
http://vprofile.arij.org/tubas/static/factsheet/newsletter1.pdf

UNSCEAR (1993), United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation. UNSCEAR Report to the General Assembly, with Scientific Annexes. New York: United Nations.

UNSCEAR (2000), United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and Effects of Ionizing Radiation. UNSCEAR Report to the General Assembly, with Scientific Annexes, Vol I: Sources. New York: United Nations.

UNSCEAR (2008), United Nations Scientific Committee on the Effects of Atomic Radiation. Effects of Ionizing Radiation. UNSCEAR Report to the General Assembly, with Scientific Annexes A and B, Volume I: Sources. New York: United Nations.

Virk, H. (1999). Indoor radon levels near the radioactive sites of Himachal Pradesh. *India. Environ Internat* 25, 47–51.

WHO (2009), World Health Organization. WHO handbook on indoor radon a public health perspective. International Radon Project; 2009. Available at: http://whqlibdoc.who.int/publications/_eng.pdf.

Zakariya, A., Mohamad, S., Asaad H. (2013). Measurement of indoor radon concentration levels and its Risks inside hospitals in Iraqi Kurdistan region: Cases study in autumn season. *Online Journal of Physical and Environmental Science Research*, 2(1), 1 – 6.