ISSN : 0974 - 7451 Volume 11 Issue 2

Environmental Science
An Indian Journal

Current Research Paper

ESAIJ, 11(2), 2015 [042-050]

Measurement of indoor radon concentration levels inside schools in the north eastern region of hebron province – palestine: case study in summer season

Khalil M.Thabayneh[1]*, Mohammad M.Abu-Samreh[2], Lilia A.Mashal[1]
[1]Faculty of Science and Technology, Hebron University, P.O.Box 40, Hebron, West Bank, (PALESTINE)
[2]Faculty of Arts and Sciences, Arab American University-Jenin (AAUJ),Jenin, West Bank, (PALESTINE)
E-Mail: drkaleelt@yahoo.com

ABSTRACT

In this work, the indoor radon concentration, the annual effective dose rate and the annual equivalent dose to the lung and the populace risk were estimated in 33 elementary and secondary schools in Directorate of Education in the Northern of Hebron province-Palestine. Some rooms from first floor, second floor and third floor were chosen from each school making a total of 513 classrooms and other rooms. The results show that the total average radon concentration levels of Bani Na'im, Sa'ir, Ash Shuyukh, Kuziba and Shuyukh al'Alarrub sites are 71.6, 69.0, 75.4 and 67.5 Bqm^{-3}, respectively, with an average value of 71.1 Bqm^{-3}. These values lead to the average annual effective dose rate 0.45, 0.44, 47 and 0.43 $mSvy^{-1}$, respectively. The annual equivalent doses rates to the lung in the studied area were found to be as follows: 5.73×10^{-8},$5.52 \times 10^{-8,}$ 6.03×10^{-8} and 5.40×10^{-8} $Svyr^{-1}$, respectively. These values are within the ICPR recommended values and the results show no significant radiological risk for the pupils and stuffs in the schools under investigation. Consequently, the health hazards related to radiation are expected to be negligible

KEYWORDS

Indoor radon concentration;
CR-39 detector;
Annual effective dose;
The annual equivalent dose rate to the lung.

INTRODUCTION

Radon is naturally-occurring radioactive noble gas. Of all radon isotopes only two, radon-222 (^{222}Rn) and radon-220 (thoron) (^{220}Rn) occurs in significant amounts indoors. The radioisotope ^{222}Rn is the main source (approximately 55%) of internal radiation exposure to human life[1,2]. Worldwide average annual effective dose from ionizing radiation from natural sources is estimated to be 2.4 mSv, of which about 1.3 mSv is due to radon exposure[2]. It has been recognized that ^{222}Rn is the second most significant risk for lung cancer after tobacco smoking, and case-control studies have shown an associated increase in lung-cancer in the public from radon in their homes[3, 4]. Tremendous measurements of the activity concentrations of radon in different countries along with epidemiological studies regarding the indoor radon and risk of lung cancer have been published in recent years[5].

It has been shown that the risk coefficient for lung cancer is higher for children than that for adults[1, 6]. This fact rose interest in studying the radon levels inside kindergartens and schools[7]. It has been shown that an increase in radon concentration of 100 Bqm^{-3} is associated with approximately a 16% increased chance of developing lung cancer[3]. For calculating the effective dose equivalent rate, the radon concentration measured in these rooms was multiplied with the equilibrium factor (F) of 0.4 to convert it to the equilibrium equivalent concentration of radon[8, 9].

It is of great importance to assess the exposure to ^{222}Rn and its progeny in dwellings, especially houses, offices, and schools, for the purposes of quality control. During the past three decades, many investigators in different countries have studied indoor radon levels in dwellings, buildings and schools. There has been an increase in the number of studies being carried out in normal workplaces such as schools[10-21].

The aim of this work was to determine the radon concentrations in schools in the Directorate of Education in the Northern of Hebron province- Palestine, during the summer months from June to September, using CR-39 track etch detectors.

MATERIALS AND METHODS

In the present work, Solid State Nuclear Track Detector (SSNTD) (CR-39 detectors) were installed, in various rooms in 33 elementary and secondary schools in Directorate of Education in the Northern of Hebron province-Palestine (Figure 1). The study area is located in the southern West Bank and the north eastern of Hebron city and has a population about 80 000.

The typical dosimeter consists of a plastic cup in the form of frustum cone having dimensions of 7.0 cm diameter orifice, 5.0 cm diameter base and 6.5 cm depth. The detector (1.0×1.0 cm in size) is fixed by blue-tag to the bottom of the dosimeter. The top of the cup was covered with a permeable cling film, which is commercially available over the shelf (polyethylene foil of ~1 mm in thickness), to allow only radon gas to pass through the film and to exclude other radon progeny, particulates and alpha-emitters particles from entering the dosimeter[15,22].

Following this technique, dosimeters were prepared and distributed in five regions (Bani Na'im, Sa'ir, Ash Shuyukh, Kuziba and Shuyukh al'Alarrub) in Hebron province. The detectors were installed in the class rooms, teachers' office, director's office,

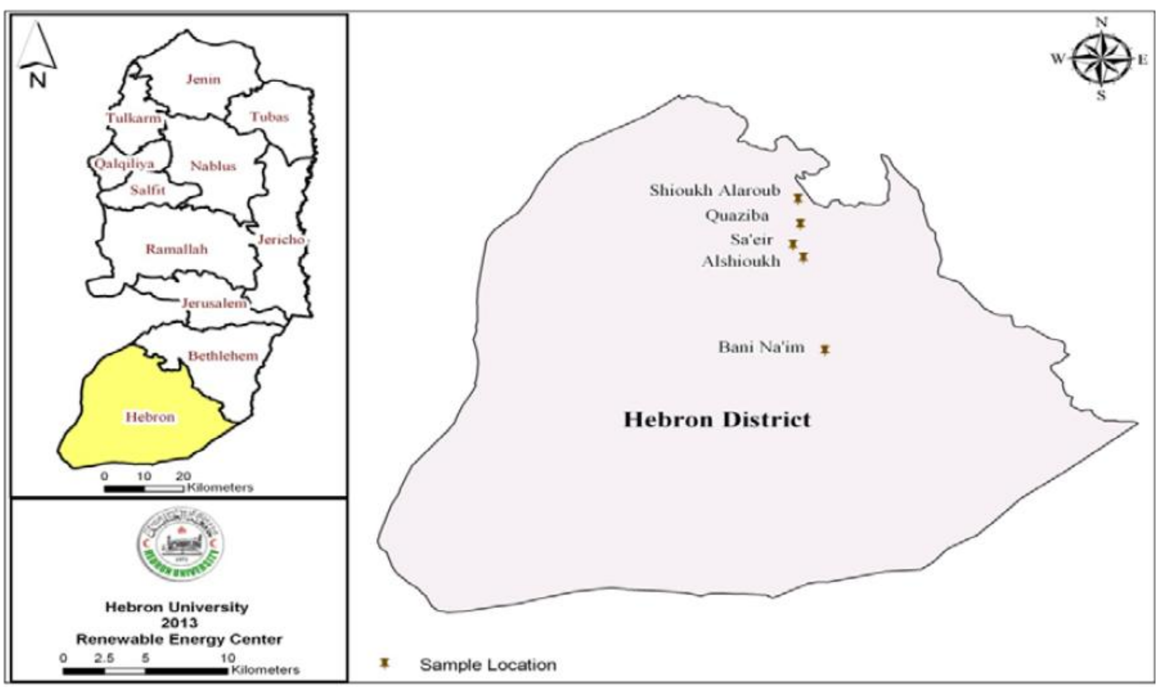

Figure 1 : West Bank geographical map contain the studied region

kitchens, stores, laboratories, libraries, corridors, Bathrooms, canteens etc. In each room two passive detectors were installed ~ 1.25 –1.5 m above the ground. The first detector was placed 0.5 m away and behind the door preventing their exposure to air currents and the second detector was placed against the windows. The schools of district, as almost all Palestinian schools are structures of masonry (concrete and brick) from inside and stones from outside. Most rooms are ventilated only by operable windows (natural ventilation). After three month later (90 days), exposure, the detectors then collected and chemically etched in a 6.25 M, NaOH solution at 72±2 ^{0}C and 8 h etching time in order to reach high resolution latent tracks[9]. After etching process took place, the detectors were washed by distilled water and then dried out. The number of tracks per cm^2 occurred in each detector was counted manually using an optical microscope of 150 times magnification (160×). The tracks were counted trice for each detector and the average was calculated.

THEORETICAL BACKGROUND

The indoor radon concentrations

The track density, ρ, is generally defined as the average number of scratches in section divided by the section area. The obtained track densities were converted into indoor radon concentration levels, $C_{Rn,}$ in Bqm^{-3} by applying the following calibration formula[23]:

$$C_{Rn} = \frac{C_0 \; t_0 \; \rho}{\rho_0 \; t} \quad (1)$$

Where C_o is the radon concentration of the calibration chamber (90 kBqm^{-3}), t_o is the calibration exposure time (48 h), ρ is the measured track number density per cm^2 on the CR-39 detectors inside the used dosimeters, ρ_o is the measured track number density per cm^2 on those of the calibrated dosimeters (3.3 × 10^4 tracks cm^{-2}), and t is the exposure time (2160 h).

Annual effective dose rate

In order to obtain the annual effective dose rate due to the indoor radon and its progeny received by the pupils and stuffs, one has to take into account the conversion coefficient from the absorbed dose and the indoor occupancy factor. According to the UNSCEAR 2000 report[2], the committee proposed 9.0 x 10^{-6} mSvh^{-1} per Bqm^{-3} to be used as a conversion factor, 0.4 for the equilibrium factor of ^{222}Rn indoors and 0.8 for the indoor occupancy factor. Calculating the annual effective dose to the population, the equation below is used[1]. The annual absorbed dose, D_{Rn}, in the unit of mSvyr^{-1}, can be calculated from the following relation[24]:

$$D_{Rn} = C_{Rn} \times D \times H \times F \times T \quad (2)$$

Where C_{Rn} is the measured ^{222}Rn concentration (in Bqm^{-3}), F is the equilibrium factor (0.4), H is the occupancy factor (~5 hours per day at school for pupils and stuffs =0.2)[1], T is hours in a year (24 h ×365 = 8760 h y^{-1}), and D is the dose conversion factor (9.0 x 10^{-6} mSvh^{-1} per Bqm^{-3}), which is the effective dose received by adults per unit activity of ^{222}Rn per unit of air volume.

The annual equivalent dose to the lungs

The annual effective dose to the lung, H_E, is calculated using an equation of the form[25]:

$$H_E = D_{Rn} \times W_R \times W_T \quad (3)$$

Where, D_{Rn} is the absorbed dose, W_R is the radiation weighting factor for Alpha particles (=20), W_T is the tissue weighting factor for the lung (=0.12).

In case the radon content of the lung air taken into account, equation (3) is reduced to[2]:

$$H_{lung}(Sv) = 8 \times 10^{-10} C_{Rn} \; (Bq/m^3) \quad (4)$$

RESULTS AND DISCUSSION

The main zones, and the statistical information on detectors and schools in Directorate of Education in the Northern of Hebron province-Palestine, during the summer season, are exhibited in TABLE 1.

Clearly, the radon level concentration data were assessed from 927 dosimeters collected after 90 days as 108 detectors were lost. Statistical methods were employed to analyze the collected data. The range of radon concentrations and the frequency distributions of indoor ^{222}Rn in 33 schools (513 rooms) are

TABLE 1 : Some information to the dosimeters distributed and the schools under investigation

Zone	No. of Schools	No. of rooms	No. of Dosimeters distributed	No. of Dosimeters lost	No. of Dosimeters collected
Bani Na'im	12	191	380	33	347
Sa'ir	12	201	400	36	364
Ash Shuyukh	7	94	200	28	172
Kuziba	1	16	35	7	28
Shuyukh al'Alarrub	1	11	20	4	16
Total	33	513	1035	108	927

TABLE 2 : Range and frequency of radon concentrations of selected schools in the 5 districts investigated in the area under investigation

Zone	Frequency range (Bqm^{-3})				N	%
	0 - 50	51-100	101-200	>200		
Bani Na'im	35	138	18	--	191	37.3%
Sa'ir	48	135	17	1	201	39.2%
Ash Shuyukh	23	54	17	--	94	18.3%
Kuziba	6	10	--	--	16	3.1%
Shuyukh al'Alarrub	2	8	1	--	11	2.1%
Total	114	345	53	1	513	100%
%	22.2%	67.3%	10.3%	0.2%	100%	-

listed in TABLE 2.

As it can be seen from the TABLE 2, about 22.2% of indoor ^{222}Rn levels are found to vary between 0 and 50 Bqm^{-3}. Radon concentrations between 51 and 100 Bqm^{-3} were observed in 67.3% of the studied class rooms. About 10.3% are found to vary between 101 and 200 Bqm^{-3}. Nearly 0.2% of rooms show radon concentrations above 200 Bqm^{-3}, with a maximum value of 327.0 Bqm^{-3}. The frequencies of radon concentration in the surveyed rooms are plotted in Figure 2. The obtained frequency distribution looks lognormal-like distribution, in agreement with most national radon surveys[9, 12, 21, 22, 26].

The minimum, the maximum, and the average concentrations of ^{222}Rn in the investigated rooms in 33 schools in 5 different zones, were listed in TABLE 3.

The data presented in TABLE 3 show that the average indoor radon concentrations obtained varied from 8.7 to 140.6 Bqm^{-3} in Bani Na'im region, from 12.1 to 327.0 Bqm^{-3} in Sa'ir region, from 29.5 to 172.9 Bqm^{-3} in Ash Shuyukh region, and from 33.2 to 123.0 Bqm^{-3} Kuziba and Shuyukh al'Alarrub, with an overall average values of 71.6, 69.0, 75.4 and

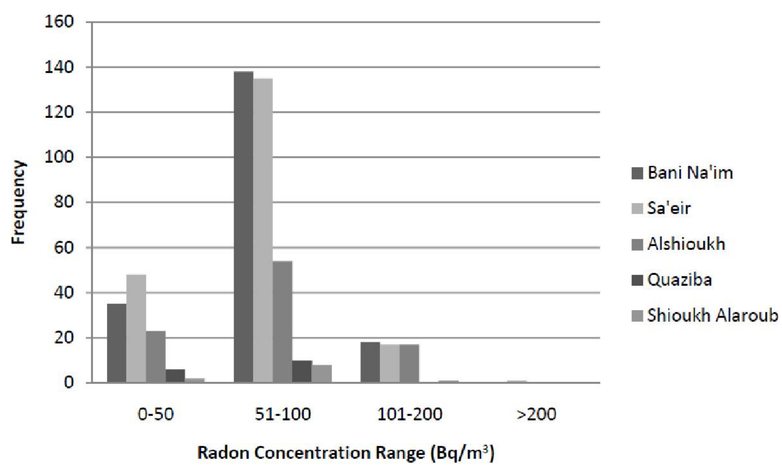

Figure 2 : Frequency distributions of radon concentrations in 33 schools located in the north-east part of Hebron province

TABLE 3 : Statistical parameters of the concentrations of ^{222}Rn, C_{Rn}, in different rooms of schools

Zone	Bani Na'im		Sa'ir		Ash Shuyukh		Kuziba and Shuyukh al'Alarrub	
Rooms Types	No. of Rooms	C_{Rn} (Bqm^{-3}) Min Max v.	No. of Rooms	C_{Rn} (Bqm^{-3}) Min Max v.	No. of Rooms	C_{Rn} (Bqm^{-3}) Min Max Av.	No. of Rooms	C_{Rn} (Bqm^{-3}) Min Max Av.
Class- Room	106	12.3 131.5 70.5	125	12.1 327.0 66.1	58	29.5 172.9 79.3	13	33.2 123.0 74.9
Administration	14	8.7 107.2 71.1	11	42.9 124.2 75.3	3	39.9 46.9 42.8	3	39.8 61.5 51.1
Secretary	7	54.5 137.7 91.1	5	68.7 91.8 77.6	3	38.1 47.7 43.1	2	54.9 59.7 57.3
Teachers	8	40.4 137.7 76.8	11	42.8 123.6 72.1	5	34.1 99.6 60.6	3	37.4 83.8 63.3
Bath-Rooms	12	43.4 94.3 64.3	13	33.5 106.3 82.3	5	50.8 147.1 88.0	2	48.9 69.4 59.2
Kitchens	10	49.2 100.2 68.4	14	41.6 130.6 85.7	5	49.8 149.1 97.6	2	60.9 98.3 79.6
Stores	4	32.8 80.9 60.3	5	34.6 102.3 70.3	3	36.4 71.6 49.1	-	-
Libraries	5	52.1 87.3 63.7	5	59.5 100.5 66.4	3	44.5 73.4 51.4	2	59.1 63.9 61.5
Scientific labs and computer	13	46.3 140.6 77.5	5	34.1 87.2 58.3	6	43.3 149.0 86.5	-	-
Corridors	12	48.6 106.1 77.3	7	43.9 78.6 51.2	3	40.4 85.0 59.1	-	-
	191	Total Av. 71.6	201	Total Av. 69.0	94	Total Av. 75.4	27	Total Av. 67.5

67.5 Bqm^{-3}, respectively. The total average of the indoor radon concentration in all rooms is 71.1 Bqm^{-3}. Generally speaking, most of the obtained indoor concentration data were found to be less than ICRP action level of 200 Bqm^{-3} [1], except one reading (327 Bqm^{-3}), in a classroom part of the first floor of a schools in Sa'ir district. 17 results were found to be less than a 150 Bqm^{-3}, the reference level set by the USEPA [27] for the USA, and to vary between 100 and 150 Bqm^{-3}. Generally speaking, almost 99% are below the reference level of 100 Bqm^{-3} assigned by WHO [28] for the remedial action to be taken, and higher than the world average radon concentration of 40 Bqm^{-3}[2].

According to the data in TABLE 3, the difference between the minimum and maximum of indoor concentrations levels in the surveyed schools of five districts are relatively high. This large variation is mainly due to the difference in the ventilation methods used, the difference in the schools heights and the difference in the number of floors. Small values of concentration levels are generally reported in schools newly built under the supervision of Western countries (USA, Germany) and Japan as donation for Palestinian pupil. Such schools highly the health requirements such air-conditioning, pigments contain materials free of ^{222}Rn sources, and widely spaced windows that guaranteed well ventilation.

TABLE 4, shows the average concentrations of ^{222}Rn, and other radiological effects, in the schools in five sites in different floors of the regions under investigation. Figure 3, shows the comparison of radon average concentrations in different floors in the studied regions.

The concentration levels data exhibited in TABLE 4 are shown graphically in Figure 3, as well as other radiological effects decreases with the floor-level. The first floor is generally characterized by a high radon concentration level with respect to the other floor levels. This may be due to several reasons, among: Firstly, upper floors have better ventilation than the lower ones. Secondly, the chances for radon to reach upper floors are very small compared to its chances to reach lower ones. Finally, the radon exhalations rates from the ground are de-

TABLE 4 : The concentrations levels of ^{222}Rn, C_{Rn}; the annual absorbed dose, D_{Rn}; the annual effective dose, H_E; and the radon content of the lung air, H_{lung} belong to different floors in the surveyed schools

Zone	Floor No.	C_{Rn} (Bqm^{-3}) Min Max Av.	D_{Rn} ($mSvyr^{-1}$) Min Max Av.	H_E ($mSvyr^{-1}$) Min Max Av.	H_{lung}($\times 10^{-8}$) ($Svyr^{-1}$) Min Max Av.
Bani Na'im	1	36.9 140.6 90.6	0.23 0.89 0.57	0.55 2.14 1.37	2.95 11.24 7.25
	2	12.3 137.7 63.2	0.08 0.87 0.40	0.19 2.10 0.96	0.98 11.02 5.06
	3	37.5 100.2 61.5	0.24 0.63 0.39	0.58 1.51 0.94	3.00 8.02 4.92
Sa'ir	1	12.2 327.0 88.0	0.08 2.10 0.55	0.19 5.04 1.32	0.98 26.20 7.04
	2	12.1 125.4 68.3	0.08 0.79 0.43	0.19 1.90 1.03	0.97 10.03 5.46
	3	34.1 89.5 50.7	0.21 0.56 0.32	0.50 1.34 0.77	2.73 7.16 4.06
Ash Shuyukh	1	35.2 172.8 96.4	0.22 1.10 0.61	0.53 2.64 1.46	2.82 13.82 7.71
	2	29.5 112.6 54.4	0.19 0.71 0.34	0.46 1.70 0.82	2.36 9.00 4.35
Kuziba	1	37.4 68.8 42.7	0.24 0.43 0.27	0.58 1.03 0.65	3.00 5.50 3.42
	2	49.6 71.8 63.0	0.31 0.45 0.40	0.74 1.08 0.96	3.97 5.74 5.04
	3	33.2 82.0 59.9	0.21 0.52 0.38	0.50 1.25 0.91	2.66 6.56 4.79
Shuyukh al'Alarrub	1	41.0 123.0 68.2	0.26 0.77 0.43	0.62 1.85 1.03	3.28 9.84 5.46

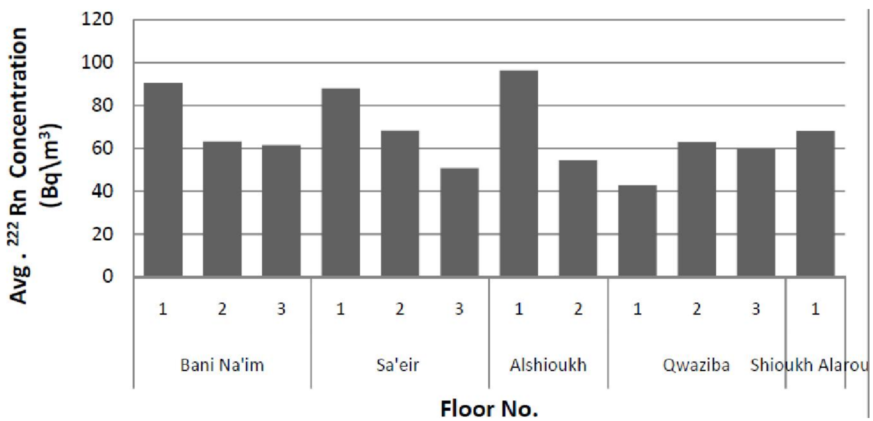

Figure 3 : Histogramshowing the average radon concentration levels in different floors of the studied regions

creasing fast as going to higher floors. However, there is a large variation in the radon concentrations within the same floor, especially the ground and the first floor.

We see from the last two tables, the radon concentration was found to be higher in old schools, poor ventilation and lower floors than that in the newly constructed schools, having good ventilation and in higher floors. The ground floor of such schools is directly constructed on top of soil with a coating of concrete, which allows more radon to diffuse inside the rooms because of the higher porosity of materials used.

The observed variations of radon concentrations among various regions can be attributed to many factors as the geological structure of the site, the various types of building materials used for the construction of the schools, the number of floor, painted and ventilation rates, the aging effect on the building as well as the number of pupils in the rooms. Other variations of the radon concentrations may be attributed to human activities, such as opening windows and doors. Human activities are definitively different for schools from that of homes. Schools in Palestine are mainly operate from 5 to 6hours, and closed for the rest of the day. In addition, with the exception of weekends, there are also long periods in the year when schools are closed especially during summer holidays. When schools are closed, an increase of radon concentration is expected due to poor ventilation. Accordingly, indoor radon concentrations in schools are expected to be higher than in houses.

The obtained data were compared to that obtained in other investigations performed in the surrounding regions, and the two results are comparable or slightly higher.

The results of the total average values of concentrations of ^{222}Rn, and the rest of radiological effects such as the annual absorbed dose, D_{Rn} ; the

TABLE 5 : The total average values of concentrations of ^{222}Rn, C_{Rn}; the annual absorbed dose, D_{Rn}; the annual effective dose, H_E; and the radon content of the lung air, H_{lung}; in different locations in the north-east part of Hebron province-Palestine

Region	C_{Rn} (Bqm^{-3})	D_{Rn} (mSvyr^{-1})	H_E (mSvyr^{-1})	H_{lung}($\times10^{-8}$)(Svyr^{-1})
Bani Na'im	71.6	0.45	1.08	5.73
Sa'ir	69.0	0.44	1.04	5.52
Ash Shuyukh	75.4	0.47	1.14	6.03
Kuziba and Shuyukh al'Alarrub	67.5	0.43	1.02	5.40
Average	71.1	0.45	1.07	5.70

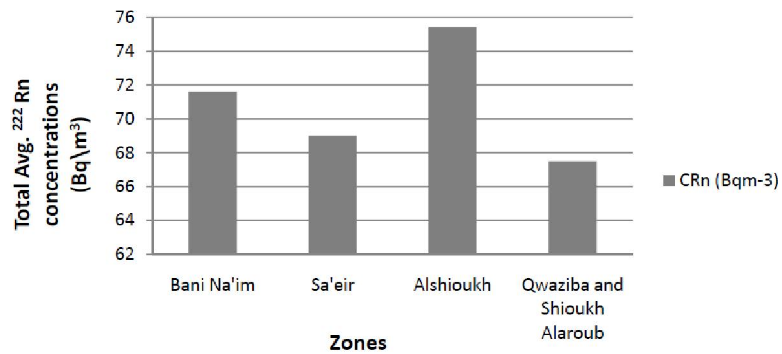

Figure 4 : The total average radon concentrations level in the different schools the studied regions

annual effective dose, H_E; and the radon content of the lung air, H_{lung}; in the surveyed districts were summarized in TABLE 5.

A histogram represents the average radon concentrations levels measured in different zones in the studied regions is shown in Figure 4.

The overall average values of D_{Rn}, H_E, and H_{lung} are respectively, 0.45 mSvyr^{-1}, 1.08 mSvyr^{-1} and 5.73 $\times10^{-8}$Svyr^{-1}in Bani Na'im region; 0.44mSvyr^{-1}, 1.04 mSvyr^{-1} and 5.52 $\times10^{-8}$Svyr^{-1}in Sa'ir region; 0.48mSvyr^{-1}, 1.14 mSvyr^{-1} and 6.03 $\times10^{-8}$Svyr^{-1}, in Ash Shuyukh region; and 0.43mSvyr^{-1}, 1.02mSvyr^{-1} and 5.40 $\times10^{-8}$Svyr^{-1}, in Kuziba and Shuyukh al'Alarrub region. The values of D_{Rn} are within or less than the ICPR recommended values (0.5 mSvy^{-1})[1], and dose interval of 0.3–0.6 mSv assigned by UNSCEAR 2000[2],for ''worldwide typical range of annual effective dose'' values for terrestrial gamma-rays. The results of other radiological effects show no significant radiological risk for the pupils and stuffs in the schools under investigation[29].

For the sake of comparison, the radon concentration levels were compared with that of other schools in different countries. This is shown in TABLE 6.

The obtained radon concentration levels in the regions under consideration are slightly higher in comparison to the majority results of some other national and international areas as it can be seen in TABLE 6. This may be due to the structure of the soil and rocks, which consist mainly of limestone. In addition, it may be due to the geological and topographical nature of Hebron district, having many stones quarry using for manufacturing building stones and marbles, and the excavation activity of the earth crust because of building and road construction purposes. Moreover, there is another intervening factor to influence the survey results and rise up thread on concentration. This factor is the fact that the always in the schools of Palestine be less than other schools in the world (4 – 5 hours); this implies that their rooms are kept closed during the time when the students are outside the schools (schools that it remains closed for many hours per day and many days per year due to holidays, as previously. This might be an important factor in raising the radon concentration levels due to lack of ventilation. Finally, the results obtained were less than the ICRP standard level, the standard reference level set by the USEPA for the USA, and WHO assigned level in general[27, 28].

TABLE 6 : Radon concentrations levels in schools of north-east Hebron Province, Palestine, and schools in different countries

Country	C_{Rn} (Bqm^{-3}) Min Max Av.	Reference
Algiers	21.0 31.0 25.6	(Amrani, 2000)
Serbia and Montenegro	21.0 35.0 ----	(Bandanna et al., 2006)
Kuwait - 1st Floor - 2nd Floor	---- ---- 16 ---- ---- 19	(Maged, 2006)
Slovenia	89 6615 ----	(Janja and Ivan,2006)
Egypt	25 78 ----	(Abdel-Ghany, 2008)
Greece	45 958231	(Clouvas et al., 2009)
Pakistan - Kashmir schools - Punjab schools	22 22878 18 168 52	(Rafique et al., 2010) (Rahman et al., 2010)
Tunisia	6 169 27	(Labidi et al., 2010)
Portugal	---- ---- 400	(Antão, 2014)
ICRP action level	---- ----200	(ICRP, 1993)
UNSCEAR	---- ---- 40	(UNSCEAR, 2000)
WHO	---- ---- 100	(WHO, 2009)
Palestine - Tarqumia Schools - Bethlehem Schools - North eastern of Hebron Schools	12 23334 31 400 125 ---- ---- 71	(Dabayneh, 2006) (Leghrouz et al.,2013) Present Study

CONCLUSIONS

According to obtained results for radon concentration and other radiological effects inside schools in Directorate of Education in the Northern of Hebron province-Palestine, discussed in this article, the following conclusion can be made:

The observed level of the indoor radon concentrations in 99.98% of the investigated rooms are lower than the recommended ICRP action level of 200 Bqm^{-3} and the average value is higher than the assigned world average radon concentration of 40 Bqm^{-3} for radon radiation background value reported by UNSCEAR, 2000.

The average annual effective dose received by the resident within or less than the recommended value reported in ICRP, 1993 report, which is 0.5 $mSvy^{-1}$ and the dose interval of 0.3–0.6 mSv reported by UNSCEAR 2000.

The values of the annual equivalent dose rate to the lung in the studied districts are less than the ICPR report recommended values and the results show no radiological significant risk for the pupils and stuffs in the schools under investigation.

The results had shown that the values on the ground floors are higher than those in the upper floors and the old buildings values were higher than the newly constructed buildings.

Detectors behind the door have higher concentrations as compared to the ones against the windows. This was due to their exposure to air current.

Even though the study was conducted during the summer season, where the average radon level is expected to be lower than that during winter season, high radon concentration levels were reported in a few rooms. We believe that poor ventilation, construction materials, old buildings and radon exhalation from the ground stand for the main reasons for the high concentrations. Improving ventilation of these rooms resulting in increasing air exchange rates with the outside, thereby results in lowering the radon concentrations. The easier thing to do is to carry out indoor survey in all the schools of the region and advise residents with the rooms of high radon concentrations to increase ventilation of their schools. Advice should be given to the constructors of new schools and selection of the construction site accurately. Measurement obtained stresses the need for a more extended survey on radon risk all over the country. The measurements taken in this study represent a baseline database of activity levels that can serve as a reference point for future studies to indicate impacts from future events.

ACKNOWLEDGMENT

The authors thank applying to workers in the Directorate of Education, north of Hebron, as well as school administrators and teachers who helped with pleasure during the period of distribution and collection of dosimeters. Many thanks will go to the Deanship of Scientific Research at the Hebron University for its continued support for this research.

REFERENCES

[1] [ICRP] International Commission on Radiological Protection, Protection against Radon-222 at home and at work, ICRP Publication 65, Annals of the ICRP.23, Pergamon Press, Oxford, **(1993)**.

[2] [UNSCEAR] Sources and Effects of Ionizing Radiation-United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR 2000 Report to the General Assembly with Scientific Annexes, United Nations, New York **(2000)**.

[3] S.Darby et al.; Br.Med.J., **330**, 223–227 **(2005)**.

[4] [AGIR] Advisory Group on Ionizing Radiation.Radon and Public Health, Documents of the Health Protection Agency, Report RCE-1, **(2009)**.

[5] R.Field, D.Steck, C.Brus, J.Neuberger, E.Fisher, C.Platz, R.Robinson, R.Woolson, C.Lynch; Am.J.Epidemiol., **151**, 1091-1102 **(2000)**.

[6] F.Najeba, S.Mohamad; Health and the Environ.J., **3(3)**, 23 **(2012)**.

[7] M.Kullab, B.Al-Bataina, A.Ismail, K.Abumurad, A.Ghaith; Radiat.Measur., **28(1-6)**, 699-702 **(1997)**.

[8] A.Ali Hassan, H.Salih Omer, A.Hiwa Hamad; J.of Physical Science and Application, **2(7)**, 240-244 **(2012)**.

[9] K.Dabayneh, K.Awawdeh; Al-Azhar J.of Science, **18(2)**, 17-28 **(2007)**.

[10] D.Amrani; Radia.Prot.Dosim., **87(2)**, 133–135 **(2000)**.

[11] R.Bandanna, A.Dragić, B.Grabež, D.Joković, D.Markushev, B.Panić, V.Udovičić1, I.Aničin; Series: Physics, Chemistry and Techno., **4(1)**, 93 – 100 **(2006)**.

[12] K.Dabayneh; Isotope and Rad.Res., **38(4)**, 1067-1077 **(2006)**.

[13] A.Maged; Health Phys., **90(3)**, 258-262 **(2006)**.

[14] V.Janja, K.Ivan; ActaChim.Slov., **53**, 8–12 **(2006)**.

[15] H.Abdel-Ghany; Iran.J.Radiat.Res., **6(3)**, 113-120 **(2008)**.

[16] A.Clouvas, G.Takoudis, S.Xanthos, C.Potiriadis, M.Kolovou; Radia.Prot.Dosim., **136(2)**, 127–131 **(2009)**.

[17] M.Rafique et al.; Radiat.Prot.Dosim., **142(2-4)**, 339-346 **(2010)**.

[18] S.Rahman, Matiullah; J.Anwar; J.Radiol.Prot., **29(2)**, 273-277 **(2009)**.

[19] S.Labidi, D.Al-Azmi, H.Mahjoubi, B.Ben Salah; Radioprotection, **45(2)**, 209–217 **(2010)**.

[20] R.Obed, H.Lateef, A.Ademola; J.Med.Phys., **35(4)**, 242–246 **(2010)**.

[21] A.Leghrouz, M.Abu-Samreh, A.Shehadeh; Health Phys., **104(2)**, 163-167 **(2013)**.

[22] M.Abu-Samreh, K.Thabayneh, M.Eliayn; Hebron University Research J.(A), **6**, 47–60 **(2012)**.

[23] B.Al- Bataina, A.Ismail, M.Kullab, K.Abumurad, H.Mustafa; Radiat.Meas., **28(1–6)**, 591–594 **(1997)**.

[24] J.Nsiah, O.Fletcher, A.Andam; Research J.of Environ.and Earth Sciences, **3(2)**, 124-130 **(2011)**.

[25] [ICRP] International Commission on Radiological Protection, Recommendations of the ICRP, Publication 60.Annals of the ICRP, 21,Pergamon Press, Oxford, **(1991)**.

[26] A.Leghrouz, M.Abu-Samreh, A.Shehadeh; Radia.Prot.Dosim., ncr013, **148(2)**, 268-273 **(2012)**.

[27] [USEPA] US EPA, Environments Division (6609J).A citizen’s guide to Radon:The guide to protecting yourself and your family from Radon.Washington DC **(2004)**.

[28] [WHO] World Health Organization, WHO Handbook on Indoor Radon.A Public Health Perspective.WHO Press, Switzerland **(2009)**.

[29] M.Rafique, N.Manzoor, S.Rahman, S.Rahman, M.Rajput, Matiullah; Iran.J.Radiat.Res., **10(1)**, 19-29 **(2012)**.

[30] [HU] Hebron University, Renewable Energy Center, HU, (REC) **(2012)**.

[31] A.Antão; Procedia Earth and Planetary Scie., **8**, 7-12 **(2014)**.