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Indoor Radon Concentration Measurements in Tarqumia Girl Schools at Western Hebron Region – Palestine

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Abstract

In this study, radon (^{222}Rn) in indoor air was surveyed in 62 rooms of 4 girl governmental schools in Tarqumia town that lies in the north western part of Hebron city in Palestine, and the annual effective dose equivalent due to the inhalation of radon and its daughters for 2318 pupils and 102 stuff members engage the rooms surveyed were also measured. TASTRAK, a solid state nuclear track detector has been used to measure indoor radon concentrations at these schools. 124 radon detectors were mounted in 4 school buildings. The Radon measurements were performed for 70 days between February 2006 and April 2006. The results showed that the radon concentration and the annual effective dose equivalent in these schools varied from 12.0to 232.5 Bq/m³ with an average 34.1 Bq/m³ and 0.62 to 12.0 mSv/yr with an average 1.76 mSv/yr respectively. The mean values of radon concentration in Tarqumia secondary girl's school, Al-aqsa elementary girl's school, Umsalama elementary girl's school and Tarqumia elementary girl's school were 35.8, 26.7, 25.9 and 47.8 Bq/m³ respectively, and the mean values of the annual effective dose equivalent were 1.85, 1.38, 1.34 and 2.47 mSv/yr respectively. We found from the above results that, most of the values were of nominal state values (that is less than allowed global values) and in few places the concentration were higher than the allowed global values, that would result in annual effective dose higher than annual global level values (1.3 mSv/yr).

poor ventilation and old buildings were, most mobility the main cause of these high concentration. Improving ventilation of these places will increase air exchange rates with the outside, thereby resulting in reduced concentration.

In general, the result shows that protection against radiological hazards would not be necessary for pupils and stuff members engage the room in schools under investigation.

Key words: radon concentration, CR-39 detector, naturally radioactivity, indoor air.

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Introduction

Radon is a naturally occurring radioactive noble (inert) gas released from the normal decay of uranium in soil, rock, and water with the longest half-Life (3.825 d). The decay of each atom of radon to the more stable lead atom ^{210}pb result in the emission of three alpha particles and two beta particles [1,2] . The radon gas seeps up through the ground and diffuses into the air. It decays quickly, giving off tiny radioactive particles. About one – half of the effective dose from natural sources is estimated to be delivered by inhalation of the short – lived radon decay products. Owing to this fact, radon is the most "popular "subject of studies on environmental radioactivity. Large –scale radon surveys have been performed in many countries [3].

Indoor radon and daughter products contribute the largest fraction to the doses received from natural background radiation [4]. UNSCEAR [5] gives a world average value of 2.4 mSv for the annual effective dose equivalent from natural background radiation of which 1.4 mSv comes from radon, thoron and their daughter products. The measurement of short – lived ^{222}Rn decay products concentration in air has become a routine procedure for controlling the radiation exposure by inhalation. In general, the concentration of ^{222}Rn and its decay products in indoor air is by an average (2-10) times higher than in free atmosphere [6]. This is due to low rates of air exchange and the dynamic collection into closed space with additional contributions from ^{222}Rn sources such as building materials [6]. Human exposure due to inhalation of indoor radon and its decay products has recently received the attention of worldwide scientific community such as (ICRP 1994) [7]. When inhaled, these radioactive particles can damage epithelial tissue of the lungs. Long – term exposure to radon can lead to lung cancer, the only cancer proven to be associated with inhaling radon [8, 9]. Radon is also suspected to be a major factor increasing skin cancer, where alpha particles are suspected to induce damage to epithelial cells due to deposition of radon in the skin [10].

Radon concentration in buildings vary, because of the type and age of buildings and soil radon concentrations under and around buildings [4]. In addition, the concentration depends on other variables such as geological composition and soil properties in the building location, building materials, climate and ventilation [11].

Indoor air is a dominate exposure for humans, where more than half of the body’s intake during a lifetime is air inhaled in the home [12]. Presence of Radon and its daughters in buildings are due to different sources. Radon escaping from soil into houses is one of the major sources of contamination. Radon can flow from underground to the surface through cracks in walls, floors, joints or pipe holes and lines and finally enters buildings. Building materials are also considered as another major source of radon gas. Radon in water is yet another important source where radon – rich water used inside the houses will increase human exposure to radon gas [13]. All building materials that originate from minerals may contain amounts of radionuclides such as uranium and thorium which are created from their radioactive decay chains. Of these, the most significant is radium (^{226}Ra). Presence of (^{226}Ra) in building materials may affects school pupils, either by inhalation of radon daughters (that decay from radium) that released from the building materials or from floor to building materials as a consequence of the radioactive decay of the natural radionuclides [14]. The rocks used in building materials, either as stony materials or in a loose form to prepare cements are enriched in radon isotopes [15]. In order to estimate the effective dose equivalent due to radon and its progeny for pupils, ^{222}Rn activity concentrations were measured in public schools in the area under investigation. Measurements were performed by using the CR-39 solid state nuclear track detector placed in different rooms of schools under investigation.

The present study has been conducted in four girl governmental schools in Tarqumia town that lies in the north western part of Hebron city in Palestine. Tarqumia population is 15,000 and lies at 450 m height above the sea level. The total number of girls in these four schools is 2318 pupils, aged from 6 to 18 years plus 102 stuff members. The schools are: Tarqumia secondary girl's school, Alaqsa elementary girl's school, Umsalama elementary girl's school, and Tarqumia elementary girl's school. Fig (1) shows Tarqumia location relative to Hebron region.

The aim of this work is to carry out a survey of radon levels (to measure the radon concentration) in Tarqumia girl's schools and to estimate the annual effective dose equivalent due to inhalation of radon and its daughters by young students in the spring season (2006).

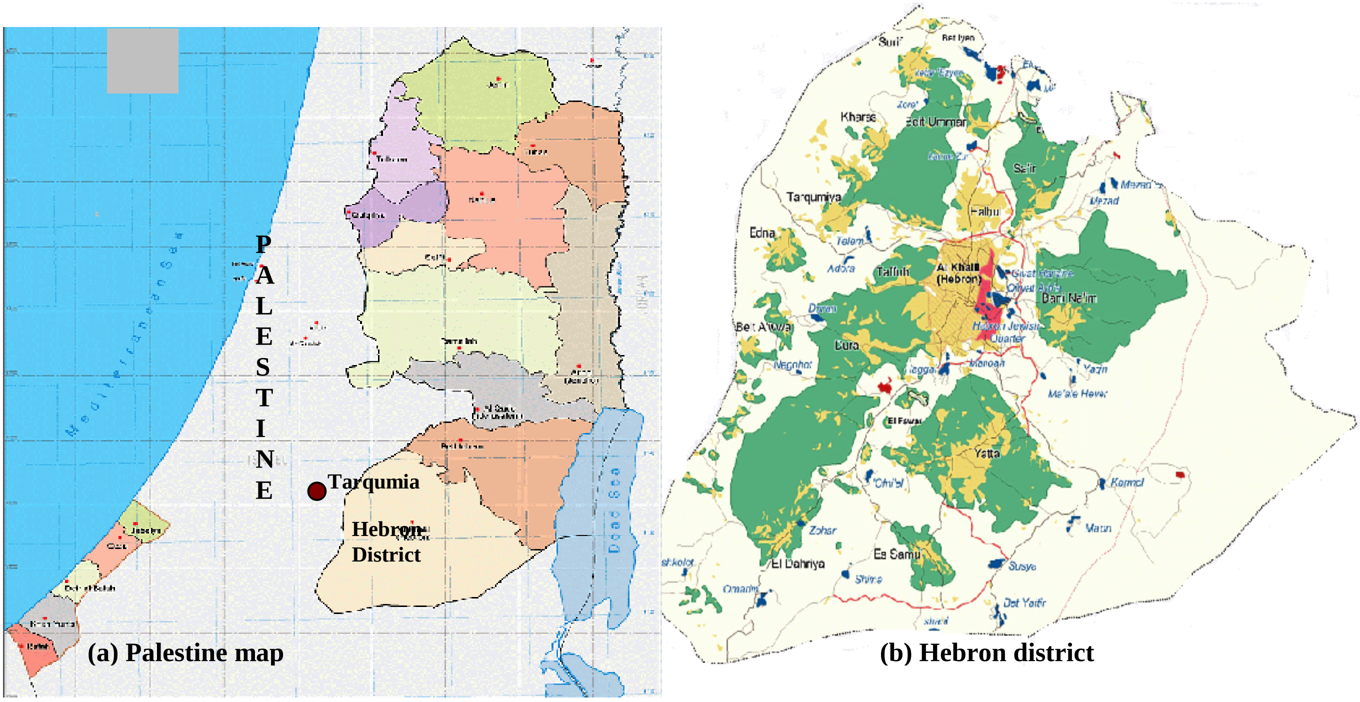

Fig. (1): Tarqumia location relative to

Materials and method

An average radon concentration were determined using CR-39 alpha track detectors (TASTRAK)[16]. These detectors are made up of allyldiglycol carbonate plastic. The detector films have a square shape of size 10 mm × 10 mm and a thickness of 1mm and were attached to the bottom of plastic cups (cylinders with a height of 5cm and a diameter of 5cm in the bottom and 7cm of the top) in a vertical position, the mouths of these were covered with lids to prevent dust particles from entering the cups (see fig.2). Thus radon gas could only pass into the cups by diffusion. One hundred and twenty four detectors were installed in all classes of all four schools in the region under investigation , giving a total of 62 rooms (44 classes, 10 stuff rooms , 4kitchens, 2 store rooms and 2 lab) . Two detectors were suspended in each class at a height of 1.5 m above the ground (the first detector is placed 0.5m away and behind the door preventing their exposure to air currents , and the second detector placed in front of the window) at different measuring points in school classes. After 70 days monitoring period from 4^{th} February 2006 to 15^{th} April 2006, the detectors were collected and the undamaged ones (108 detectors from 62 rooms) were analyzed.

The detectors were covered by aluminum foils so that the detectors could not be influenced by radon and progeny during transport to the radiation laboratory. In the following day, the detectors were chemically processed to the alpha tracks into a visible etch pits. In this process, the detectors where etched in 6.25N *NaOH* solution at 70^{o}C for 4.5 hr (13, 17). During etching the solution was stirred constantly. Detectors were then thoroughly rinsed with tap water and dried.

The tracks were counted manually under an optical microscope with a magnification of x150 to find the track density. Seven detectors were used for determination of background track density. This track density was subtracted from all the measurements before the determination of radon concentration.

The CR-39 radon detector was calibrated in a standard source facility at the National Radiological Protection Board (NRPB), Uk (18). Thirty fields of view were selected at random for each detector. The size of each field of view at x150 magnification where obtained. The counts obtained for all fields of view were averaged and converted in to a count per cm^2. The track density can be converted to radon concentration (in Bq/m^3) using the calibration factor obtained.

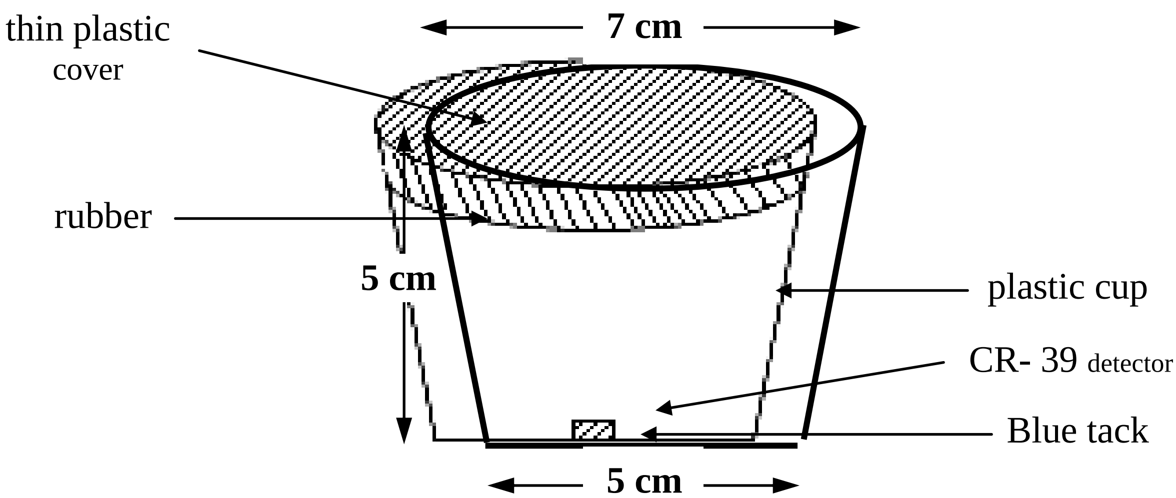

Fig. (2) Schematic diagram showing the CR-39 arrangement in the cup.

Calculation of the basic radiation Quantities

*1- **Radon Concentration** : (19)*

The concentration of radon (in Bq/m^3) was calculated using the following equation.

$$C_{Rn} = \frac{N - N_B}{KATM} \rightarrow \textbf{(1)}$$

Where C_{Rn} is the radon concentration; N is the number of tracks, N_B is background tracks, A is the area of view, K=0.18α-tracks cm^{-2} d^{-1} per Bq m^{-3} is a calibration factor of radon and M is the number of fields studied in the detector surface.

2- **Radon Dose Equivalent** : [20,21]

The effective dose equivalent (D), due to the inhalation of radon and its daughters in schools can be expressed by the following equation:

$$D = \frac{C_{Rn} \times F \times DCF \times t}{(3700 Bq/m^3) \times (170 hr)} \rightarrow (2)$$

Where the mean time t is about 1750 hr (occupancy factor 0.2) per year (~5 hr per day) at schools for pupils and stuffs; C_{Rn} is the radon concentration (in Bq / m^3); F is equilibrium factor taken as 0.4 according to International Commission on Radiological Protection (ICRP)65[21]., DCF=3.88 mSv/WLM is the ICRP[21] conversion factor, where WLM is working-level-month-old unit for exposure attained by 170 hr breathing in air in which radon of concentration of 3700 Bq/m³.

For the young population, the conversion factors are multiplied by a factor of 12 to evaluate the annual effective dose equivalent.

Results and discussions

The average indoor radon concentration and the annual effective dose equivalent received by persons in the four school buildings were summarized in Table (1). Fig. (3) shows a comparison of the average indoor radon concentration and average annual dose of each school. The details of the measurements are shown in Tables 3 to 6.

The radon concentration recorded in different schools vary from a minimum value of 12.0 Bq/m³ in the first floor in Alaqsa elementary school to a maximum value of 232.5 Bq/m³ in ground floor in Tarqumia elementary girl's school. The mean concentration in the four schools is 34.1 Bq/m³. The annual effective dose equivalent received by pupils and stuff members in the four schools vary from 0.62 mSv/yr in first floor in Alaqsa elementary girls school to 12.0 mSv/yr in ground floor in Tarqumia elementary girls school. The average annual effective dose equivalent for the four schools is 1.76 mSv/yr. The average dose in the schools is slightly higher than the average global dose of 1.3 mSv/yr, while the internal and external exposure to all natural radiation source amounts to 2.4 mSv/yr[3].

It is clear that 82 readings of the radon concentration are less than 40 Bq/m³, these readings are in the nominal state readings whereas 25 readings ranging between (40 – 100) Bq/m³ which are unacceptable state readings, and only 1 of the radon concentration found is more than 200 Bq/m³ which means that is a high risk state.

Table (1): Summary of radon concentration and the annual effective dose equivalent in Tarqumia girl schools buildings

School Name	Floor	No. of detector	Radon Concentration (Bq/m³) Minimum	Maximum	Average	Annual effective dose equivalent (mSv/yr)
Tarqumia secondary girl's school	Ground First	18 14	18.4 12.2	73.4 61.2	41.3 35.8 28.0	2.14 1.85 1.45
Alaqsa elementary girl's school	Ground First	9 16	18.4 **12.0**	73.4 30.6	36.7 26.7 19.2	1.90 1.38 0.99
Umsalama elementary girl's school	Ground First Second	7 15 9	18.4 12.2 12.2	79.5 36.7 30.6	40.4 23.7 25.9 19.1	2.09 1.23 1.34 0.99
Tarqumia elementary girl's school	Ground	20	12.2	**232.5**	47.8	2.47 2.47
Total		108	Total average		34.1	1.76

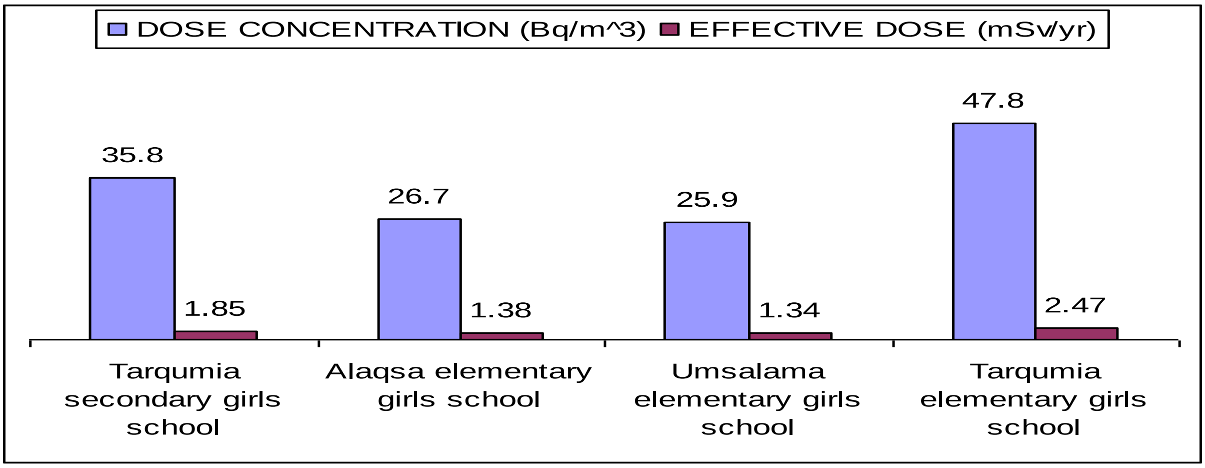

Fig (3): A comparison of the average indoor radon concentration and average annual dose of each school

The radon concentration and the annual effective dose equivalent in the present study as well as in other studies for many different countries were compared in Table (2). Some values obtained in the present study were noticeably low and others were higher than international values. This is due to the fact that radon concentration and effective dose equivalent in the study region were generally around the international levels.

Table (2): Comparison levels of radon concentration and the annual effective dose equivalent for many different countries

Region – Country	Place of study	C_{Rn}(Bq/m³)		Effective dose equivalent (mSv/yr)		Ref.
		Range	Average	Range	Average	
Hebron university – Palestine	University buildings	1-250	29.8	1.1-2.2	1.49	[22]
Different locations – Algiers	Schools	21-31	25.6	0.21-0.31	0.25	[4]
Lanzarote – Canary Islands	Dwellings	-	50	-	0.75	[11]
El-Minia – Egypt	Dwellings	20-300	123	-	-	[6]
Inchas – Egypt	Nuclear research center	-	12	0.016-0.152	0.094	[1]
Different houses – Bangladesh	Dwellings	4-190	-	1.7-4.1	3.1	[23]
Cairo – Egypt	Dwellings	47.9-84.3	-	0.88-1.4	-	[19]
Different cities – Jordan	Dwellings	27-88	-	-	-	[24]
Different schools – Irich	Schools	-	93	-	0.3	[25]
Qatif – Saudi Arabia	Dwellings	124-302	22	-	-	[26]
Chalkidikis – Greek	Dwellings	37-1700	-	-	4.5	[27]
Different schools – Slovenia	Schools	82-168	-	-	-	[28]
Ankara – Turkey	Dwellings	2-408	25	-	-	[29]
Kuwait capital – Kuwait	Schools	16-19	-	0.4-0.48	-	[30]
Tarqumia schools – Palestine	Schools	12.0-232.5	34.1	0.62-12.0	1.76	Present work

Table (3), presents the result of radon concentration measured for Tarqumia secondary girls school. The concentration for all rooms varied from 12.2 Bq/m³ in the first floor to 73.4 Bq/m³ in the ground floor with an overall average of 35.8 Bq/m³. The mean annual dose to an inhalation in school due to radon exposure to the lungs is estimated to be 1.85 mSv/yr. It is clear that 76% of the radon concentration were less than 40 Bq/m³ which classified under the nominal state and 24% of the readings were more than 40 Bq/m³ which classified under the unacceptable state.

The results for radon concentration measured by track detectors for Alaqsa elementary girls school were shown in Table (4). The concentration ranged between 12.0 and 73.4 Bq/m³. The minimum value corresponds in first floor and the maximum value in ground floor. The mean concentration and annual effective dose were 26.7 Bq/m³ and 1.38 mSv/yr respectively. The measurements recorded in this school were lower than the other schools.

Thirty one nuclear track detector were placed in Umsalama elementary girls school. The minimum and maximum concentrations recorded throughout the study were 12.2 and 79.5 Bq/m³ respectively are shown in Table 5. The minimum value corresponds to a room in the second floor, and the maximum value were recorded at a room in ground floor. The mean concentration and annual effective dose were 25.9 Bq/m³ and 1.34 mSv/yr respectively. These readings were generally around the global levels.

Table (3): Radon concentration and annual effective dose equivalent in Tarqumia secondary girls school

Floor	Room number	Type of room	No. of detectors	Place of detectors				Average radon concentration (Bq/m³)	Average annual effective dose (mSv/yr)
				Behind the door		Front of the window			
				Radon concentration (Bq/m³)	Annual effective dose (mSv/yr)	Radon concentration (Bq/m³)	Annual effective dose (mSv/yr)		
Ground floor	1	Stuff-A	2	30.6	1.58	18.4	0.95	24.5	1.27
	2	Stuff-B	2	61.2	3.17	24.5	1.27	42.9	2.22
	3	Stuff-C	2	87.3	3.49	24.5	1.27	45.9	2.38
	4	Class	2	48.9	2.53	24.5	1.27	36.7	1.90
	5	Class	2	67.3	3.49	61.2	3.17	64.3	3.33
	6	Class	2	73.4	3.80	42.8	2.22	58.1	3.01
	7	Class	2	73.4	3.80	48.9	2.53	61.2	3.17
	8	Class	2	42.8	2.22	30.6	1.58	36.7	1.90
	9	Kitchen	1	--	-	24.5	1.27	24.5	1.27
	10	Store	1	--	-	18.4	0.95	18.4	0.95
First floor	11	Class	2	24.5	1.27	12.2	0.63	18.4	0.95
	12	Class	2	36.7	1.90	12.2	0.63	24.5	1.27
	13	Class	2	24.5	1.27	12.2	0.63	18.4	0.95
	14	Class	2	61.2	3.17	30.6	1.58	45.9	2.38
	15	Class	2	12.2	0.63	12.2	0.63	12.2	0.63
	16	Class	2	30.6	1.58	12.2	0.63	21.4	1.11
	17	Lab	2	61.2	3.17	48.9	2.53	55.1	2.85

Table (4): Radon concentration and the annual effective dose equivalent in Alaqsa elementary girls school

Floor	Room number	Type of room	No. of detectors	Place of detectors				Average radon concentration (Bq/m³)	Average annual effective dose (mSv/yr)
				Behind the door		Front of the window			
				Radon concentration (Bq/m³)	Annual effective dose (mSv/yr)	Radon concentration (Bq/m³)	Annual effective dose (mSv/yr)		
Ground	1	Stuff-A	2	36.7	1.90	24.5	1.27	30.6	1.59
	2	Stuff-B	2	42.8	2.22	24.5	1.27	33.7	1.75
	3	Stuff-C	1	73.4	3.8	-	-	73.4	3.8
	4	Class	2	36.7	1.90	30.6	1.58	33.6	1.74
	5	Kitchen	1	-	-	18.4	0.95	18.4	0.95
	6	Store	1	30.6	1.58	-	-	30.6	1.58
First	7	Class	2	24.5	1.27	18.4	0.95	21.5	1.11
	8	Class	2	30.6	1.58	12.0	0.62	21.3	1.10
	9	Class	2	24.5	1.27	18.4	0.95	21.5	1.11
	10	Class	2	24.5	1.27	18.4	0.95	21.5	1.11
	11	Class	2	18.4	0.95	12.2	0.63	15.3	0.79
	12	Class	2	18.4	0.95	12.2	0.63	15.3	0.79
	13	Class	2	30.6	1.58	18.4	0.95	24.5	1.27
	14	Class	2	12.2	0.63	12.2	0.63	12.2	0.63

Table (5): Radon concentration and the annual effective dose equivalent in Umsalama elementary girls school

Floor	Room number	Type of room	No. of detectors	Place of detectors				Average radon concentration (Bq/m³)	Average annual effective dose (mSv/yr)
				Behind the door		Front of the window			
				Radon concentration (Bq/m³)	Annual effective dose (mSv/yr)	Radon concentration (Bq/m³)	Annual effective dose (mSv/yr)		
Ground	1	Stuff-A	1	-	-	30.6	1.58	30.6	1.58
	2	Stuff-B	1	42.8	2.22	-	-	42.8	2.22
	3	Class	2	42.8	2.22	18.4	0.95	30.6	1.59
	4	Class	2	79.5	4.12	18.4	0.95	49.0	2.54
	5	Kitchen	1	48.9	2.53	-	-	48.9	2.53
First	6	Class	2	24.5	1.27	30.6	1.58	27.6	1.43
	7	Class	2	24.5	1.27	24.5	1.27	24.5	1.27
	8	Class	2	18.4	0.95	12.2	0.63	15.3	0.79
	9	Class	1	-	-	24.5	1.27	24.5	1.27
	10	Class	2	36.7	1.90	24.5	1.27	30.6	1.59
	11	Class	2	30.6	1.58	18.4	0.95	24.5	1.27
	12	Class	2	30.6	1.58	12.2	0.63	21.4	1.11
	13	Class	2	18.4	0.95	24.5	1.27	21.5	1.11
Second	14	Class	1	30.6	1.58	-	-	30.6	1.58
	15	Class	1	-	-	18.4	0.95	18.4	0.95
	16	Class	2	24.5	1.27	12.2	0.63	18.4	0.95
	17	Class	1	-	-	12.2	0.63	12.2	0.63
	18	Class	1	24.5	1.27	-	-	24.5	1.27
	19	Class	1	-	-	12.2	0.63	12.2	0.63
	20	Class	1	-	-	18.4	0.95	18.4	0.95
	21	Class	1	18.4	0.95	-	-	18.4	0.95

Table 6 presents the radon concentration recorded in different classes in Tarqumia elementary girls school, the concentration vary from a minimum value of 12.2 Bq/m³ to a maximum value of 232.5 Bq/m³ with an average value of 47.8 Bq/m³. The effective dose ranges between 0.63 and 12.0 mSv/yr with an average value of 2.47 mSv/yr. Some values obtained in this school were noticeably higher than the global values.

Table (6): Radon concentration and the annual effective dose equivalent in Tarqumia elementary girls school

Floor	Room number	Type of room	No. of detectors	Place of detectors				Average radon concentration (Bq/m³)	Average annual effective dose (mSv/yr)
				Behind the door		Front of the window			
				Radon concentration (Bq/m³)	Annual effective dose (mSv/yr)	Radon concentration (Bq/m³)	Annual effective dose (mSv/yr)		
Ground	1	Stuff-A	2	24.5	1.27	12.2	0.63	18.4	0.95
	2	Stuff-B	2	55.1	2.85	18.4	0.95	36.8	1.90
	3	Lab	2	48.9	2.53	30.6	1.58	39.8	2.10
	4	Kitchen	2	61.2	3.17	36.7	1.90	49.0	2.54
	5	Class	2	232.5	12.0	91.8	4.75	162.2	8.38
	6	Class	2	30.6	1.58	36.7	1.90	33.7	1.74
	7	Class	2	18.4	0.95	12.2	0.63	15.3	0.79
	8	Class	2	73.4	3.80	36.7	1.90	55.1	2.85
	9	Class	2	61.2	3.17	24.5	1.27	42.9	2.22
	10	Class	2	30.6	1.58	18.4	0.95	24.5	1.27

Conclusion

Measurements of radon concentration and annual effective dose equivalent in 62 rooms of 4 schools in Tarqumia town – Palestine showed the following conclusions:

1. Radon concentration varied from 12.0 Bq/m³ measured in the first floor in Alaqsa elementary girls school to 232.5 Bq/m³ measured in ground floor in Tarqumia elementary girls school.
2. The mean radon concentration in four schools is 34.1 Bq/m³ which is lower than the action limit of the ICRP
3. The annual effective dose equivalent received by pupils and stuff members in the four schools vary from 0.62 mSv/yr to 12.0 mSv/yr within average of 1.76 mSv/yr. This value is slightly higher than the average annual effective dose limit for the members of public (1.3 mSv/yr)
4. Most values obtained in the present study were noticeably low, where other values were higher than global values. This is due to the fact that the radon concentration in the study region were generally around the global levels.
5. The study also showed that the values in the ground floors were higher than those in upper floors, also old buildings measuring values were higher than newly constructed buildings (Tarqumia elementary girls school was the oldest building).
6. Behined the door samples were having higher concentrations compared to window front samples. This was due to their exposure to air current.

Finally, it must be noted that, this work is the first work to be conducted in Tarqumia town schools, further work is to be conducted to cover other places in different seasons.

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