Indoor Radon Concentration Measurements At Hebron University Campus :A Case Study

قياس تركيز الرادون داخل مباني جامعة الخليل

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ABSTRACT

TASTRAK, a solid state nuclear track detector has been used to measure indoor radon concentrations at Hebron University. Fifty- four radon pot detectors were mounted in the four university buildings. It was found that the radon concentrations vary considerably from about 1 Bq/m^3 to 250 Bq/m^3. The average radon concentrations vary from 20.5 Bq/m^3 in the Main Building to 41.3 Bq/m^3 in the Agriculture Building. The average radon concentration in the four buildings is found to be 29.8 Bq/m^3. This leads to an average effective dose equivalent of 1.49 mSv/y. This dose is slightly higher than the global value of 1.3 mSv/y. Elevated radon concentrations have been found in few rooms. However, these concentrations are well below the action level of 150 Bq/m^3.

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ملخـــص

تم قياس تركيزغاز الرادون ٢٢٢ في الهواء داخل مباني جامعة الخليل باستخدام كاشف الحالة الصلبة للمسارات النووية المعروف باسم TASTRAK .استخدم في هذه الدراسة ثمانون كاشفا ،وقد تركت هذه الكواشف داخل مباني الجامعة لمدة زمنية تتراوح بين اربعين و اربعة و خمسين يوما . ثـــم عولجت الكواشف كيميائيا بمحلول هيدروكسيد الصوديوم بتركيز (6.25N) وفي درجة حراره C(98±2) لمدة ساعة. و استخدم مجهر ضوئي لمسح سطح الكاشف و حساب متوسط عدد المسارات في وحدة المساحة ومن ثم تركيز غاز الرادون في الهواء.

وجد من هذه الدراسة ان تركيز غاز الرادون داخل مباني الجامعة تغير بصورة كبـــيرة من($1 Bq/m^3$) الى ($250 Bq/m^3$).وتغير متوسط التركيز من ($20.5 Bq/m^3$) في المبنى الرئيس الى ($41.3 Bq/m^3$) في مبنى كلية الزراعة . وقد وجد ان متوسط تركيز غاز الرادون في مباني الجامعة يساوي ($29.8 Bq/m^3$) . وينتج عن هذا التركيز جرعه فعاله مكافئه مقدارها (1.49 mSv/y). وهذه الجرعة اكبر قليلا من المتوسط العالمي للجرعة الفعالة و التي تساوي (1.3 mSv/y).وقد امكن الكشف عن مستويات عالية لغاز الرادون في بعض الغرف ولكن هذه المستويات اقل من التركيز الاعلى المسموح به في الولايات المتحدة الامريكية و الذي يساوي ($150 Bq/m^3$) . ان سوء التهوية هو السبب الرئيس في ارتفاع تركيز غاز الرادون في مثل هذه الغرف.

Introduction

Man is continuously exposed to ionizing radiation. The larger part of radiation doses received by the general public (about 82%) comes from natural sources(Gonzalez,1993;Gonzalez and Anderer,1989). Radon-222 is the most important (as far as public health is concerned) of all sources of natural radiation. The United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR) now estimates that, together with its daughters (specially polonium-218 and polonium-214), radon-222 contributes to about three-quarters of the terrestrial sources and about (53%) of all human exposure to natural sources(Ahmed,1994;Gonzalez and Anderer,1989). We will therefore be, mainly interested here in indoor measurements of radon concentrations in Hebron University buildings.

2. The Origin of the Radon Problem

Radon has three main isotopes: radon-222, a decay product of ^{238}U, radon-220(known as thoron), produced during the decay series of ^{232}Th , and radon-219 , from the chain originating with ^{235}U . Because of its very short half-life (4 seconds) and limited abundance (^{235}U to ^{238}U ratio is uniform at about 0.72 %), radon-219 is usually ignored in natural radiation exposure studies(Budnitz,1974).

Radon-222 has a half-life of 3.8 days, while thoron is short-lived with a half-life of only 55 seconds.^{238}U and ^{232}Th occur naturally in soil and rocks (Baxter,1993). In terms of α-activity, ^{238}U and ^{232}Th are approximately of equal abundance(Camplin et al,1988). In contrast to thoron, the relatively long-lived radon is able to penetrate considerable distances through soil and rocks. It can diffuse readily out of surface soil into air or buildings. For this reason radon-222 is considered more important(about 20 times more important) in terms of environmental radiation than thoron. The term radon will thereafter be used to denote radon-222 unless stated otherwise.

Radon, which is a colorless, odorless and tasteless gas can be trapped in poorly ventilated buildings; its concentrations may build up to high levels. Radon indoor concentrations depend mainly on building characteristics(such as: the rate of radon entry, air exchange rate and building materials), geographic area, water, natural gas and meteorological conditions(Mullen and Nevissi,1990). Radon from the ground mixes with outside air and gets very diluted. Normally, indoor radon concentrations are eight to ten times larger than outside.

Radon itself is not a major concern to human health. However, it decays into polonium-218 which, in turn, decays within minutes to lead-214, bismuth-214, and polonium-214. These radon daughters (or radon progeny) are solids and can attach themselves to dust particles and be breathed into the lungs. The decay chain of radon involves the release of five energetic particles: Three α-particles(with energies of 5.49, 6.0 and 7.69 MeV) and two β-particles with endpoints ranging from 0.69 to 3.26 MeV (Prichard and Gesell,1977). The energy deposition in lungs is extremely localized and may increase the risk of lung cancer(Bren[MO]ner,1989;Sevc et al,1967).

3. The Radon Detector

The radon detectors used in these experiments were TASTRAK*plastic. TASTRAK is a polymer derived at Bristol University from polyallyl diglycol carbonate(PADC). The detector was first discovered and developed in Berkeley(Cartwright et al,1987) under its commercial name CR-39. The detector is very sensitive to α-particles; but it is insensitive to electromagnetic radiation and electrons.

When an α-particle passes through the detector it's path is delineated by a tail of damage. Subsequent etching in NaOH results in bulk etching of the surface at a rate characteristic of the polymer, the NaOH concentration and the temperature(Camplin et al,1988). Thus, the latent particle track becomes an etch track. Detectors were etched for (50-60)min. at (98 ±2)C in 6.25N- solution of NaOH.

Detectors of dimensions (10×13)mm were used. A detector was inserted flat in to the bottom of a yoghurt pot held in place by a small piece of blu-tac. The mouth of the pot was completely covered with a single layer of

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* Supplied by Track Analysis Systems Ltd, HH Wills Physics Laboratory , Bristol ,UK.

cling film [1] that was held by an elastic band (see Fig.1). This film was used as a permeable

Membrane to exclude isotopes of radon as well as all radon daughters(Camplin et al.1988). In some places the total α-particle concentrations were measured using an open yoghurt pot detector.

Fig. 1

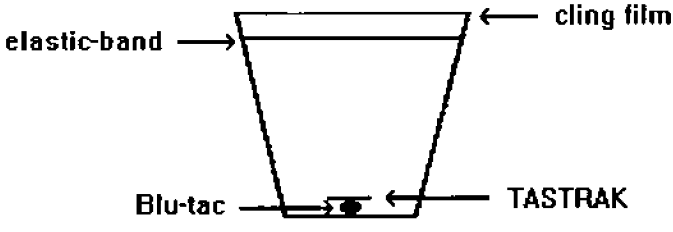

Fig 1: The radon detector.

[1] Cling film, Plastfoil, Cinderella, Israel.

4. Technical Details

Eighty radon detectors were used to measure indoor radon concentration at Hebron University. Fourteen detectors were lost or

Table 1: **Distribution of radon detectors used in this work .**

	No. of detectors	lost or damaged
Main Building:		
Ground Floor	22	2
First Floor	7	0
Second Floor	2	2
Third Floor	2	1
Agriculture Building:		
Ground Floor	5	2
First Floor	6	1
Science Building:		
Ground Floor	8	1
First Floor	6	2
Research Center:		
First Floor	6	2
Second Floor	4	1
TOTAL:	68	14

damaged either through chemical treatment or by direct sunlight. Ten detectors were used with open pot (without cling film) to measure α-particle concentrations in air. These detectors have not yet been analyzed due to calibration problems. Two detectors were used to measure α-particle tracks in the unused detectors. Therefore, only 56 detectors were analyzed (see Table 1). Detectors were placed between one to two meters above ground level, except in few cases in which the height was less than a meter. The time and date of placing the detectors were noted. They were left in place for (40-59)days through August to October, 1993. The detectors were then etched using a 6.25N- solution of NaOH at (98±2)C for 60 min. During etching the solution was stirred constantly. Detectors were then thoroughly rinsed with tap water and dried. Each detector was manually read using an optical microscope with a magnification of ×100 . In some cases where a large number of tracks were observed ×400 magnification was employed.

Ten to twenty fields of view were selected at random for each detector. The size of each field of view at ×100 magnification was(2.377± 0.028)mm^2 and at ×400 magnification was(0.170± .007)mm^2. The counts obtained for all fields of view were averaged and converted to a count per cm^2. The track density can be converted to radon concentrations (in $Bq.m^{-3}$) using the calibration factor obtained at Bristol University.

5. Results and Discussions

The average indoor radon concentrations and the annual effective dose equivalents received by people in the four buildings of Hebron University are summarized in Table 2. Figure 2 shows the frequency histogram of radon concentrations in the four buildings. The details of the measurements are shown in Tables 3 through 6.

Table 2: Summary of radon concentrations and effective doses in Hebron University Buildings.

Building	No. of Detectors	Radon concentrations Bq/m^3 Minimum Maximum Average			Effective dose mSv/y Level Building	
Main building:						
Ground floor	20	5.8	54.3	27.9	1.47	
First Floor	7	9.7	15.4	13.2	0.66	1
Research center:						
First Floor	4		31.9	24.9	1.24	
Second Floor	3	9	22.3	17.2	0.86	1
		3				
Science:						
Ground Floor	7	6.4		43.0	2.15	
First Floor	4	2.4	5	34.6	1.7	0
			4			
Agriculture						
Ground Floor	3		72.6	43.7	2.65	
First Floor	5	5	60.8	38.9	1.95	2
		3				

Average radon concentration (without chemical store) = 29.8 Bq/m^3

Effective dose equivalent = 1.49 mSv/y

The indoor radon concentrations in the four buildings are clearly(see Table 2) within normal values. These concentrations vary from 13.2 Bq/m^3 in the first floor in the Main Building to 43.7 Bq/m^3 in the ground floor, Agriculture Building. The average radon concentration in the four buildings is 29.8 Bq/m^3 . In calculating this average, the radon concentration in the chemical store in the Faculty of Science has been ignored.

Fig 2

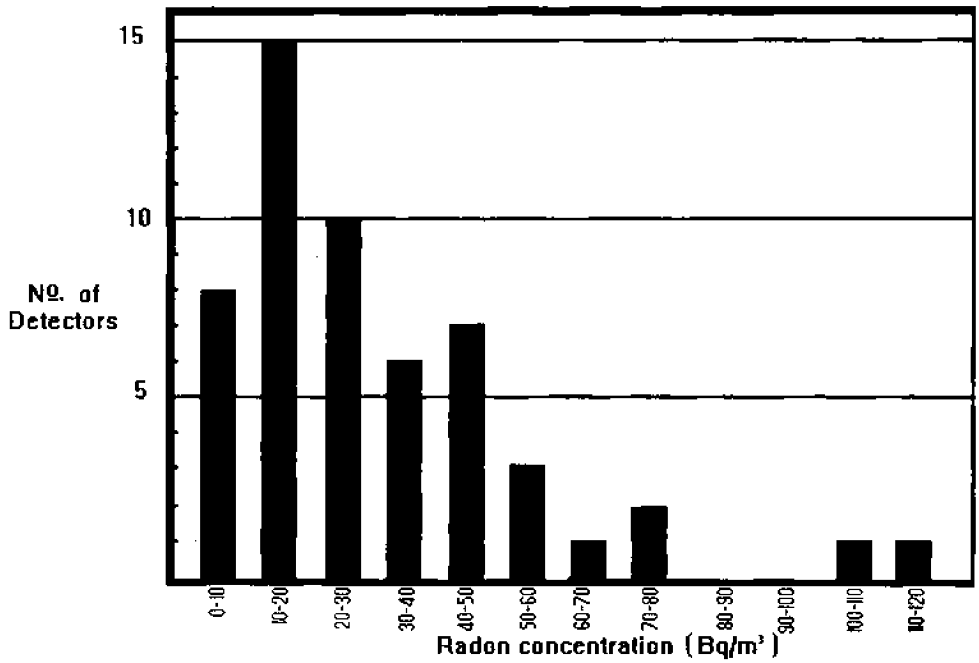

Fig 2:Frequency histogram of radon concentrations.

This store has a radon concentration of about 250Bq/m³. The store is a small room that is locked most of the time and has no means of ventilation. It is rarely used, and we do not consider this room as a suitable working place.

The annual effective dose equivalent received by people in the four buildings vary from 1.1 mSv/y in the Main Building and the Research Center to 2.2 mSv/y in the Agriculture Building. The average annual effective dose equivalent for the four buildings is 1.49 mSv/y. In calculating these doses we have used the Environmental Protection Agency(EPA)assumption that 20 Bq/m³ of radon is equivalent to an effective dose of 1 mSv/y (Budnitz,1974). The average dose in the buildings is slightly higher than the average global dose of 1.3 mSv/y (Gonzalez,1993;Gonzalez and Anderer,1989).

It is clear that (60%) of the radon concentrations (see Figure 2) are less than 30 Bq/m³. Only (17%) of the radon concentrations found are more than 50 Bq/m³. Radon concentrations of 100 Bq/m³ or more are very rare, and only (4%) of the detectors have this rather high concentration. This radon concentration is still much lower than the action level of 150 Bq/m³ in the United States.

The average indoor radon concentration reported ranges from 11 Bq/m³ in Australian homes(Langroo et al,1991) to 46 Bq/m³ in the US (Ahmed,1994) or an even higher value of 50 Bq/m³ in Sweden(Swedjemark and Makitalo,1990). In the UK an average value of 20 Bq/m³ has been reported(Sumner et al,1991,p.65).

Table 3: Radon concentration and doses in the Main Building.

Location	No. of detectors	Concentration	Dose equivalent	Average dose
Ground floor:				
Student council	2	35.7	1.78	
Store	1	21.3	1.07	
Education	1	17.5	0.87	
Arabic	1	16.5	0.82	
Workers Union	1	8.7	0.4	1.5
Admission Dept.	2	29.6	1.32	
Academic (Sharea)	2	8.3	0.4	
University	2	50.2	2.5	
President	2	43.7	2.18	
Vice-President	2	47.5	2.38	
President Assist.	2	29.3	1.47	
Arts, Dean of				
First Floor (Library)				
	1	14.2	0.71	
Information	1	14.6	0.73	
Periodicals	1	15.4	0.77	0.66
References	1	13.4	0.7	
Islamic Studies	1	12.6	0.6	
History	1	12.6	0.6	
Director	1	9.7	0.5	
Staff				
Third Floor :				
Academic(Arabic)	1	0.5	0.025	0.025

Ground Floor : Radon mean concentration = 27.9 Bq/m^3
Standard Deviation = 15.7 Bq/m^3
First Floor : Radon mean concentration = 13.2 Bq/m^3
Standard Deviation = 1.9 Bq/m^3

It is interesting that, in the Main Building, radon concentration tends to increase from the western part of the building towards the eastern part. In the western part, the concentrations vary from 8.7 Bq/m³ in the Workers Union (now School of Finance and Management) to about 21 Bq/m³ in the Book Store. The average radon concentration in this part of the building is about 16 Bq/m³. In the eastern part of the building the radon concentrations vary from 29.3 Bq/m³ to 50 Bq/m³ in the President's Office. The average radon concentration in this part is 42.7 Bq/m³. The radon concentrations in the ground floor are considerably scattered with an average of 27.9 Bq/m³ and a standard deviation of 15.7 Bq/m³.

In the first floor of the building(the University Library), the radon concentrations are less scattered and vary from 9.7 Bq/m³ to 14.6 Bq/m. The average radon concentration and the standard deviation are 13.2 Bq/m³ and 1.9 Bq/m³, respectively. Very little radon concentration is detected in the third floor of the building.

Table 4: Radon concentration and doses in the Research Center.

Location	No. of Detectors	Radon Concentration Bq/m³	Dose Equivalent mSv/y	Average Dose mSv/y
First Floor :				
Secretary	1	31.9	1.6	
Corridor	1	25.5	1.3	1.24
Public Relation	1	26.1	1.3	
Meeting Hall	1	15.6	0.8	
Second Floor :				
Center Director	1	22.3	1.1	
Staff	1	13.3	0.7	0.86
Corridor	1	15.9	0.8	

Mean dose equivalent = 1.13 mSv/y
Radon mean concentrations = 21.5 Bq/m³
Standard deviation = 6.8 Bq/m³

In the Research Center(see Table 4), a maximum radon concentration of about 32 Bq/m^3 has been found in the first floor. A minimum radon concentration of about 13 Bq/m^3 has been found in the second floor. The mean radon concentration in this building is 21.5 Bq/m^3 and the standard deviation is 6.8 Bq/m^3.

Very high radon concentrations have been found in the Faculty of Science. An elevated radon concentration of 250 Bq/m^3 is

Table 5 : Radon concentration and doses in the Faculty of Science.

Location, office	No. of Detectors	Concentration	Dose equivalent	Average dose
Ground Floor:				
Dean	1	31.3	1.57	
Secretary	1	52.4	2.6	
Academic(Chemistry)	1	116.5	5.8	2.15
Corridor	1	9.8	0.5	
Mosque	1	41.4	2.1	
Toilet	1	6.4	0.3	
Store	1	253	12.7	
First Floor:				
Academic, Physics	1	21.8	1.1	
Physics	1	109.4	5.5	1.7
Chemistry lab.	1	2.7	0.1	
Biology lab.	1	4.5	0.2	

Average dose for the building = 2.95 mSv/y
Average dose for the building (without store) = 2.0 mSv/y
Radon mean concentration (without store) = 39.6 Bq/m^3

detected in the Chemical Store. However, this store is not a working place. Therefore, we have not used this value in our calculations. This is the only room in which the radon concentrations exceed the action level of 150 Bq/m³ in the US and even exceed the 200 Bq/m³ action level adopted in most countries(Ahmed,1994). A high radon concentration of 116.5 Bq/m³ is found in a small room that is used by academic staff. Also a high radon concentration of 109.4 Bq/m³ has been found in the Physics Laboratory. This laboratory is used for instruction purposes only. The elevated radon concentrations in these rooms result mainly from poor ventilation that reduces air exchange rates. On the other

Hand, very low radon concentrations have been found in large, well-ventilated laboratories. Radon concentrations of 2.7 Bq/m³ and 4.5 Bq/m³ have been measured in the Chemistry and Biology Laboratories, respectively. The radon concentrations in this building are very much scattered with a mean of about 39.6 Bq/m³ and a standard deviation of 42 Bq/m³ .

In the recently constructed Faculty of Agriculture, relatively high radon concentrations have been found(see Table 6). In the ground

Table 6 : Radon concentration and doses in the Faculty of Agriculture

Location, office	Detectors	Concentration	Dose equivalent	Average dose
Ground Floor:				
Academic, History	2	71.8	3.6	2.2
Academic, English	1	15.5	0.8	
First Floor:				
Secretary	1	22.3	1.1	
Academic, room 1	1	60.8	3.0	
Academic, room 2	1	42.3	2.12	1.94
Academic, room 3	1	42.0	2.1	
Academic, room 4	1	27.2	1.36	

Average dose equivalent = 2.0 mSv/y
Radon mean concentration = 40.0 Bq/m³
Standard deviation = 20.5 Bq/m³

floor, the radon concentrations in the north wing (71.8 Bq/m^3) have been found to be about five times higher than the radon concentrations in the south wing(15.5 Bq/m^3). In the first floor, one detector has measured a high radon concentration of 60.8 Bq/m^3). The height of this detector was about 45 cm. This may partially explain the high concentration measured , since radon is seven and a half time heavier than air. The mean radon concentration in the building is 40 Bq/m^3, which is much less than the action level of 150 Bq/m^3.

6. Conclusions

The main purpose of these measurements was to find whether workers in Hebron University are exposed to elevated concentrations of radon gas. The average radon concentration in the four university buildings was found to be 29.8 Bq/m^3. This concentration leads to an annual effective dose equivalent of 1.49 mSv/y. Although elevated radon concentrations have been detected in few working places, these radon concentrations are well below the United States EPA's action level of 150 Bq/m^3. We believe that poor ventilation is the main cause of these high concentrations. Improving ventilation of these places will increase air exchange rates with the out side, thereby resulting in reduced concentration.

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