Indoor Radon-222 Concentration Levels Measurements and Exhalation Rates Calculations in Some Offices and Rooms of AAUJ during the Winter and the Spring of 2014

[1]Mohammad Abu-Samreh*, [1]Anan Hussain, [2]Mithqual Daraghmeh , [1]AbdelRahman Abulebdeh
[1]Physics Department, Faculty of Sciences, Arab American University Jenin, Palestine
[2]Mathematics Department, Faculty of Sciences, Arab American University Jenin, Palestine
Mohammad.Samreh@aauj.edu

Abstract

In this study, we report on the radon concentration levels, the radon exhalation rate, and the annual effective dose equivalent in 10 buildings of AAUJ during the winter and the spring of 2014 using the CR-39 track detectors. The inspected facilities include 46 offices, 24 labs, seven storage rooms, nine coffee rooms, a cleaning room, eight bathrooms, four Xeroxing rooms, and three meeting rooms. The indoor radon concentration levels were found to vary from 26 to 258 Bq/m^3, with an arithmetic mean and standard deviation of 76.6 and 16.2. In general, the bathrooms and stores were found to have a significant higher radon concentration levels. The estimated effective dose to the population was found to vary from 0.69 to 2.12 mSv/yr, with a mean of 1.15 mSv/yr. The exhalation rates values were found to vary from 1.92 to 5.20 mBq/m^2.hr.

The average of the obtained indoor radon concentration was below the indoor radon concentration action level (148 Bq·m^{-3}) as recommended by Environmental Protection Agency (EPA). Moreover, the effective dose to the population and the exhalation rates, which are 15% and 14% respectively, are higher than the accepted values, In general, most of the measurements were found to be within the internationally accepted concentration levels of ICRP and hence no remedial action is required.

Keywords: *CR-39 detectors; ^{222}Rn concentration levels; Dosimeter, Exposure, Isotopes radon Exhalation; Activity.*

Introduction

Radon-222 (^{222}Rn) as well as its natural isotopes such as ^{219}Rn and ^{220}Rn naturally emerged from the earth's crust that contains cores of uranium, thorium and their progenies in secular equilibrium (Nero and Nazaroff, 1984; UNSCEAR, 1993). On one hand, ^{222}Rn gas emanates from soil, building materials, water supplies, and natural gases of terrestrial origin (Hassan, 1996; Kullab, 1997; Camplin et al., 1988). On the other hand, it is entering houses from soil through cracks in concrete floors and walls, floor drains, construction joints, and tiny cracks or pores in hollow-block wall (Kunz et al., 1981). It is well known that ^{222}Rn isotope ($t_{1/2}$=3.82 days, E_{α}=5.49 MeV) as well as other isotopes (^{218}Po, ^{214}Po and ^{210}Po, half-lives vary from 0.2 ms – 26.8 min) are all alpha emitters and represent the main source of the natural radiation exposures to humans (Aytekin et al., 2005; Abumurad et al., 2005). Based on the the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reports data, these isotopes account for approximately 55% of the effective dose equivalent produced by natural ionizing radiation (UNSCEAR, 1988).

Over the past four decades, exposure to ^{222}Rn, especially indoors, has been classified to be an important factor that resulted in developing a health hazard, especially increasing the risk of lung cancer (Alexander, 1995). Accordingly, radon problems have been identified in almost every state of the world. In most of the developed countries, the radon problems have been taken seriously. Radon references and action levels have been set (Khan, 2005; Khattak, 2015). According to the International Commission on Radiological Protection (ICRP), the recommended indoor action level for the public is ranged between 150 and 600 Bq/m^3 (ICRP, 1994; Gonzalez, 1993). The arithmetic mean for most countries varies from 12 to 140 Bq/m^3 (UNSCEAR, 1993). The indoor radon level of 148 Bq/m^3, which corresponds to a yearly indoor effective average dose of 1.30 mSv/y, has been adopted in USA as a reference point before making any action (EPA, 1988). The indoor radon concentration average of 39 Bq/m^3 and its corresponding "yearly" effective dose population-weighted average value of about 1 mSv have been assigned as the world reference data to the indoor concentrations according to UNSCEAR report (UNSCEAR, 2000; Anastasiou et al., 2003).

It is of great importance to assess the exposure to ^{222}Rn and its progeny in dwellings, especially houses, offices, schools, and universities for the purposes of quality control. Assessment of the risk can only be done with accurate information on the radon concentration levels to which the people are exposed (Magalhaes et al., 2003; Alenezy, 2014). Investigations of natural radiation have received particular attention worldwide and led to extensive surveys in many countries (Kobal et al., 1987; Popovic et al., 1996; UNSCEAR, 2000; Al-Bataina, 2000; Popovic and Todorovic, 2006; Rahman et al., 2006).

In this study, we are mainly concerned with investigating the indoor radon concentration levels in the building of the Arab American University in Jenin using Solid State Nuclear Track Detectors (SSNTDs). The main purpose of these measurements was to find whether the workers and the students at AAUJ are exposed to elevated concentrations of radon gas. The study is motivated by several considerations, one of which is no information or data about radon gas concentration has been reported before for this region. Therefore, this study is expected to provide some data and information about the radon concentration levels concerning the radon exposures to the general public. Besides, some bases for radiation protection countermeasures are recommended too. This includes action level recommendations for the existing houses and for future housing architectural designs. Moreover, by this study we aim to create an interest and raise the public awareness the radon hazard in the community.

Study Area

The campus of AAUJ is situated in the southeastern part of Jenin province, in the north of the West Bank. The AAUJ area is located at longitudes between 35°30´ E and 35°00´ W, and latitudes between 35°15´ and 35°30´ at a height of about 350 m above sea level (Figure 1). The area is covered with 1–5 m soil cover. The soil cover is composed of Kaolinite, Mica, Quartz, and some Montmorillonite (Arrej, 2009).

Figure 1: General Geological Map of the West Bank Showing the Investigated Area Enclosed by a Blue Circle (http://www.infoplease.com/atlas/country/westbank.html)

Experimental Details

During the period of about six months in the winter and the spring of 2014, the indoor radon concentration levels in 10 various buildings of AAUJ were performed using passive radon measurement technique with alpha track detectors CR-39 (Somlai et al., 1997). Typical dosimeters composed of detectors each of sides 1cm × 1cm were used and fixed to the bottom of plastic cylinder cups by blue tag in a vertical position as shown in Figure 2 (Amrani, 2000; Leghrouz et al., 2007). The top of each dosimeter was covered with lids to prevent dust particles from entering the cups (see Figure 2) (Furuta *et al*., 2002; Leghrouz et al., 2007).

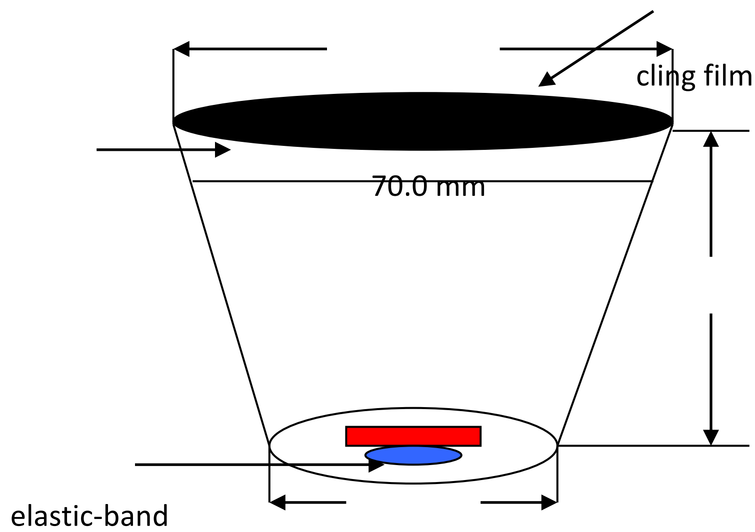

Figure 2. Typical CR-39 Dosimeter

The plastic cup had a dimension of 70.0 mm diameter orifice, 50.0 mm diameter base and 65.0 mm deep. The top of the cup was covered with a permeable cling film (Polyethylene foil) to allow only ^{222}Rn gas to pass through the film and to exclude radon daughters from entering the dosimeter (Leghrouz at el., 2013). The number was also engraved on the detector. The dosimeters were hung on the walls of the rooms at heights that vary from 0.5 to 1 m from the ground. 123 detectors were installed in 102 offices, lab rooms, hallways, kitchens, bathrooms, storage rooms and meeting rooms of AAUJ. These detectors were installed in January 2014 at various places of the university and collected in June 2014. After an exposure of almost 180 days, only 113 CR-39 detectors were collected, then taken out from the specified dosimeters, and chemically etched in 6.25 N-solution of NaOH at a temperature of 70 ± 1 °C for 8 hours (Durrani and Bull, 1987; AL-Sharif et al., 2001). The rest of the distributed dosimeters were lost. The etched detectors were then washed with distilled water and dried prior to microscope inspection. The etched tracks were then counted randomly under an optical microscope at a magnification of 150 × to calculate the track density (tracks/cm^2). Ten fields of view were selected at random for each detector (See Figure 3).

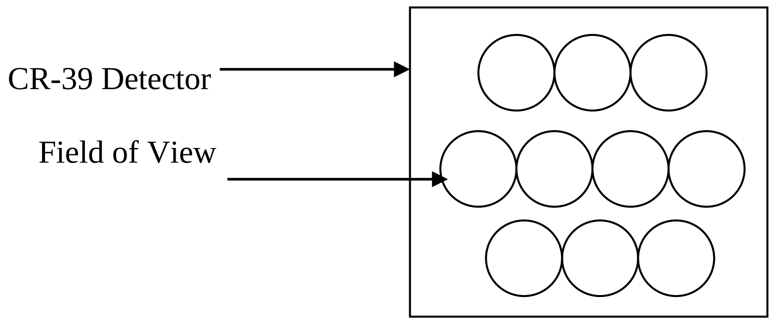

Figure 3. Schematic Representation of Field View on the Surface of the Detector

The general procedure for counting the number of tracks was summarized by dividing the CR-39 detector surface area into several assigned field of view each had an area of 7.4×10^{-5} cm^{-2} [$= \pi r^2 = \pi\ (4.85\times10^{-3})^2$, where r was the radius of field of view] as shown in Figure 3. Then, the number of tracks in each area was counted and the average of the measurements was obtained. Typical nuclear track etches picture are displayed in Figure 4 as a field microscopic view magnified 150 times.

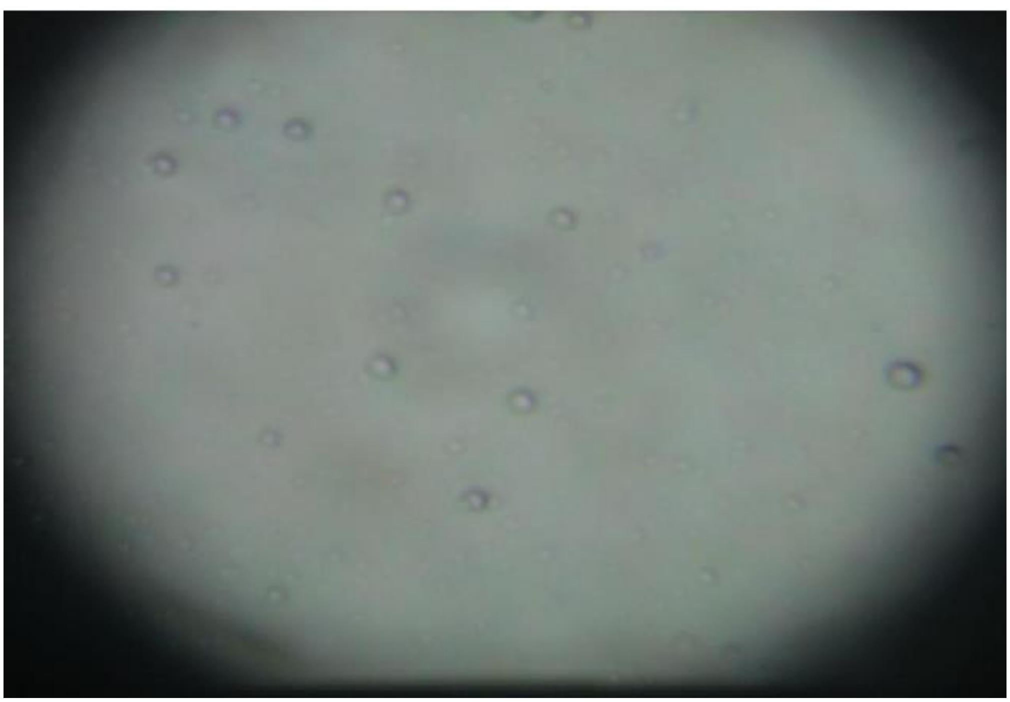

Figure 4. Tracks of Alpha Particles Emitted by Radon in a CR-39 Detector Magnified 200 Times, which was Exposed for Six Months in the Third Floor of Engineering Building.

In this study, ten field of views were chosen arbitrary to be representative of the whole surface of each detector, and the number of tracks per centimeter-squared was calculated. The obtained average of tracks of the ten fields of views for each detector was used to calculate the radon concentration, C_{Rn}, in units of Bq/m^3.

Calculations

The Radon Concentration

In calculating the radon concentration levels, C_{Rn}, we have adopted the calibration formulae used by the researchers at Yarmouk University based on Bristol university measurements. Accordingly, C_{Rn} can be calculated using the following equation (Kullab et al.,1997; Al-Bataynehl, 2005):

$$C_{Rn} = \frac{C_0 t_0 d}{d_0 t} \tag{1}$$

Where C_o (90 kBq/m^3) is a radon concentration in calibration chamber (Kullab et al., 1997), t_o (48 hours) is the exposure of detector in radon chamber; d is the density of nuclear tracks measured in units of tracks/cm^2; d_o is the density of nuclear tracks measured after calibrated, which equals 3.3×10^4 tracks/cm^2, and t is the detectors exposure time to indoor radon, which is about six months of durations (4320 hrs).

The Annual Effective Dose

The annual mean effective dose H_y ($mSvy^{-1}$) to general public due to radon and its progeny is calculated according to the following empirical formulae (UNSCEAR, 2000):

$$H_y = C_{Rn} \times F \times O \times T \times D = 12614.4\times10^{-6}\ C_{Rn} \tag{2}$$

Where F stands for equilibrium equivalent concentration (EEC) factor, O for occupancy factor, T for time (8760 $h.y^{-1}$), and D for dose conversion factor (9×10^{-6} $mSvh^{-1}/Bqm^{-3}$) (UNSCEAR, 2000). According to UNSCEAR report 2000, the values of F and O are mentioned separately for indoor and outdoor environments and we have used the same values of F (F_{in} = 0.4 and F_{out} = 0.6); whereas the values of O have been modified. The values of O in the present case have been selected based on the time spent by the students in the campus. It should be noted that **a** person spends 12 hours at the university campus at the most Out of these 12 hours, the person spends about 80% time indoors and 20% outdoors. The values of O were therefore taken as 0.4 and 0.1 for indoors and outdoors, respectively. For the residential area the values of O were the same as mentioned in UNSCEAR report 2000.

The Exhalation Rate

The increase in radon concentration levels in air of the room is as a result of radon exhalation from all the inner space of the room. The exhalation rate, E_x (in mB/m^2.hr), was calculated using the following empirical equation (Hayam, 2006):

$$E_x = \frac{C_{Rn} V \lambda}{A\left[T + \frac{1}{\lambda\left(e^{\lambda T} - 1\right)}\right]} \qquad (3)$$

where V is the effective volume of the cup in m^3; λ (λ=7.6×10^{-3}hr^{-1}) is the decay constant for radon; T is the exposure time in hrs; A is the area of the cup in m^2.

Results and Discussion

The present radon concentration levels data were obtained from113 dosimeters collected after a period of almost 6 months.

The indoor radon concentrations levels were calculated using equation (1).The main buildings, the number of detectors, N, and the range and the frequency of radon concentration levels of 99 rooms were presented in Table 2.

The results indicate that radon concentration levels in kitchens, bathrooms, and store rooms are significantly higher than the radon concentration levels measured in other rooms and accommodations. The lowest values were found in spacious offices. The obtained high concentration levels may be attributed to several factors. The main factors include the poor ventilation, the natural gas used in cooking, heating, supplying kitchens and bathrooms with water originated from underground sources (Kenawy et al., 2000; Hayam, 2006; Khattak, 2015). The differences between concentration levels obtained for different buildings are probably due to the geological characteristics of the soil (Kobeissi, 2014).

Table 1: The Range and the Frequency of Radon Level Concentrations of 10 Buildings of AAUJ During the Period from January to June 2014.

Main Building	N	Range (Bq/m^3)				
		0-50	51-100	101-150	151-200	Above 200
		Frequency	Frequency	Frequency	Frequency	Frequency
Faculty of Arts and Sciences	17	4	5	3	3	2
Faculty of Allied Medical Sciences	20	5	6	5	3	1
Faculty of Engineering and IT*	15	3	4	4	2	2
Faculty of Administration and Finance	8	3	2	3	--	---
Faculty of Dentistry	10	2	2	2	3	1
Faculty of Student Affairs	13	4	3	3	3	--
Language(s)(del) Center	10	2	4	4	--	---
Faculty of Law	7	3	4	--	---	---
Hassib Sabagh	7	1	2	2	2	---
Accommodation	6	---	2	2	2	---
Total	113	27	34	28	18	6

IT= Information Technology

Statistical methods were employed to analyze the collected data. A summary of minimum (Min) and maximum (Max) average (Av), the annual effective dose equivalent to the population (H_y), and the exhalation rate, E_x, of the measured indoor radon concentrations for each monitored zone Dura district is exhibited in Table 2. Equations (2) and (3) were employed to calculate H_y and E_x.

Most of the results range between (26-258) Bq/m^3. As it can be seen from Table 3, the minimum indoor radon concentrations of about 26 Bq/m^3 has been found in a spacious office in administrative and finance building while the highest radon concentration level of 258 Bq/m^3 has been recorded in storage rooms in the Faculty of Medical Allied Sciences buildings. Very high radon concentrations have been also reported in storage rooms and closed rooms in the Faculty of Engineering and Information Technology, where a radon concentration of 250 is detected in a closed Store in the basement. However, this store is not a working place. This is because the rooms were closed and had poor ventilation.The concentration of radon in stores was relatively higher than that in the other category of rooms because these stores are occasionally opened

Table 2: Max, Min, Ave Radon Concentration Levels (Bqm^{-3}) and Annual Effective Dose Equivalent to the Population (H_y) and The Exhalation Rate (E_x) of AAUJ Buildings.

Main Building	Radon level concentrations (Bq/m^3)				H_y (mSv/y)	E_y(mB/m^2hr)
	N	Min	Max	Ave		
Faculty of Arts and Sciences	17	35	250	123	1.56	4.74
Faculty of Allied Medical Sciences	20	47	258	110	1.39	4.21
Faculty of Engineering and IT*	15	27	224	126	1.59	4.83
Faculty of Administration and Finance	8	26	112	78	0.98	3.04
Faculty of Dentistry	10	78	214	128	1.61	4.88
Faculty of Student Affairs	13	34	118	72	0.91	2.82
Languages Center	10	46	92	65	0.82	2.54
Faculty of Law	7	54	88	67	0.85	2.64
Hassib Sabagh	7	40	118	73	0.92	2.85
Accommodation rooms	6	56	111	82	1.03	3.17
Total	113	34	258	83	1.05	3.23

The elevated radon concentrations in these rooms resulted mainly from poor ventilation that reduces air exchange rates. On the other Hand, very low radon concentrations have been found in large, well-ventilated rooms. Radon concentration was found to be the lowest in the corridors of the building since corridors are open and well-ventilated. In general, values of the radon concentrations that exceed the hazardous set values were found in the poorly ventilated basements with concrete unpainted walls .This might be due to the reduction of air flow rates which increases radon concentrations. This confirms the importance of ventilation in order to avoid radon accumulation to the unaccepted hazardous level.

The variation of concentration at different locations in the same room was also investigated. This was accomplished by placing two sets of dosimeters at two different positions in some living rooms for some dwellings. The results showed that the radon concentration levels obtained from detectors placed near the windows were lower than those obtained from detectors placed far away from the windows. The difference in concentration levels is probably due to the air exchange near the windows which reduces the radon concentrations near them.

It was found that the average indoor radon concentrations in the monitored buildings were lower than 150 Bq/m^3 in general (see Table 3). The overall regional average of radon concentration levels of all buildings was about 76.6 Bq/m^3, and with a standard deviation of 15.7 Bq/m^3. This value is below the radon reference levels that range from 200-600 Bq/m^3 as recommended by ICRP (ICRP, 1994), IAEA (Gonzalez, 1993), in EU and Australia (200 Bq/m^3) and in Canada and Scandinavia countries (800 Bq/m^3) (Popovic et al., 2006) and the USA assigned radon level of 150 Bq/m^3 (EPA, 1988; EPA, 2003). In less than 4% of the monitored rooms, the radon concentration levels were in excess of 200 Bq/m^3 where an action is recommended by ICRP report (ICRP, 1994). It was found that about 90 % of the investigated rooms have indoor radon concentrations below 100 Bq/m^3. Thus, the investigated area has radon concentration level below the international assigned values, and no harm is expected for the peoples of this university, since the exposure time is limited for them.

In order to compare between the indoor radon concentrations results in rooms located in different floors, about 54 rooms and offices were inspected in different floors. The average indoor radon concentrations and the annual effective dose equivalents received by people in the buildings of AAUJ are summarized in Table 4. The indoor radon concentrations in the four buildings are clearly within normal values (Table 4). By examining the obtained results of rooms, a significant difference in the mean radon concentrations between the floors has been noticed (Table 4). It was found that the radon concentration levels are considerably scattered from one floor and another, where the ground floor has shown the most scattered results and variations. Besides, great variations within concentration values for rooms in the same floor have also been observed. Clearly, the main reason behind such variations is the poor ventilation. The annual effective dose equivalent received by people in the investigated zones was found to vary from 0.69 mSv/yr to 2.12 mSv/yr. The average effective dose equivalent to population for the monitored zones about 1.15 mSv/yr in total. This is almost equal to the world mean dose from environmental ^{222}Rn of 1.15 mSv/yr (UNSCEAR,200). As seen from Table 4, the annual effective dose is mainly depending on the occupancy factor (Bunditz,1974; Gonzalez and Anderer,1989; Gonzalez,1993;). For the residents of the university, the estimated dose value is large as compared with the dose to the students who spend less time of the daytime in the university.

Table 3: Summary of Radon Concentration Levels, Effective Doses and Exhalations Rates in AAUJ Buildings

Main Building	Floor	Radon concentration levels (Bq/m^3)				H_y (mSv/y)	E_x
		N	Min	Max	Ave		
Faculty of Arts and Sciences	Ground	5	59	250	165	2.08	6.24
	First	5	42	182	115	1.45	4.46
	Second	5	35	214	88	1.11	3.45
	Third	2	49	123	86	1.09	3.38
Faculty of Allied Medical Sciences	Ground	8	64	258	135	1.71	5.15
	First	7	53	165	106	1.34	4.05
	Second	5	47	108	82	1.03	3.19
Faculty of Engineering and IT*	Ground	3	90	224	167	2.12	6.36
	First	5	37	217	116	1.46	4.52
	Second	4	42	131	94	1.19	3.68
	Third	3	28	90	68	0.86	2.67
Faculty of Administration and Finance	Ground	1	112	--	112	1.41	4.37
	First	3	34	88	68	0.86	2.67
	Second	2	26	84	55	0.69	2.14
	Third	2	14	54	34	0.43	1.33
Faculty of Dentistry	Ground	1	214	--	214	2.70	8.10
	First	5	68	124	112	1.41	4.37
	Second	4	78	112	88	1.11	3.44
Faculty of Student Affairs	First	2	54	118	86	1.09	3.38
	Second	7	46	98	68	0.86	2.67
	Third	4	34	82	62	0.85	2.64
Languages Center	First	4	62	92	74	0.93	2.88
	Second	4	56	78	63	0.78	2.41
	Third	2	46	68	58	0.73	2.26
Faculty of Law	First	2	56	88	72	0.91	2.82
	Second	4	54	84	62	0.78	2.42
	Third	1	64	--	64	0.81	2.51
Hassib Sabagh	First	5	51	118	82	1.03	3.19
	Second	2	40	90	65	0.82	2.54
Accommodations Building	First	3	48	96	74	0.93	2.88
	Second	2	44	68	56	0.71	2.20
	Third	1	42	--	42	0.53	1.64

The calculated values of radon exhalation rate are summarized in Tables 2 to 4. The obtained values of exhalation rate were found to vary from 1.33 to 8.10 $mBq/m^2.hr$

Conclusions

The results presented in this study represent measurements of radon concentration levels, exhalation rate and annual effective dose equivalent in 100 compartments of 10 buildings of the AAUJ. The obtained results for the indoor radon concentration levels in AAUJ indicate that not all the investigated buildings are of high concentration levels. In addition, the overall average radon concentration levels in the monitored buildings were found to be of the order76.6 Bq/m^3. This corresponds to an overall average dose to population value of 1.15 mSv/y, which is equal to the average value set by the environmental protection agency (ICRP, 1994). The estimated effective dose to the population was also found to vary from 0.69 to 2.12 mSv/yr. Moreover, the exhalation rates values were found to vary from 1.92 to 5.20 mBq/m^2.hr.

The maximum among the average values of radon concentration was found to be in closed places. Generally speaking, poor ventilation is the main reason for having higher radon concentration levels in closed places, which is the case at AAUJ in winter. Improving ventilation of these places will increase air exchange rates with the outside, thereby resulting in reducing radon concentration levels. Accordingly, remedial efforts should be focused mainly on reducing the radon concentration levels as well as effective consideration to improve the ventilation and adopt the mitigation technique to reduce the concentration of radon from the buildings.

In conclusion, the measured radon concentration levels as well as radon exhalation rates were found to be less than the reference levels set by various radiation protection agencies. Accordingly, radon cannot be considered as a major radiological risk for inhabitants at the Arab American University in Jenin (AAUJ).

Acknowledgments

The authors would like to thank Mr. Sakher Abu-Zahra for facilitating the use of the microscope and Yousif Abu-AlShawarib for performing the detectors etching in the chemistry labs.

The authors are grateful to the AAUJ administration for allowing them to conduct this type of research at the university campus.

References

- Ahmed J. U.1994. Radon in the human environment: Assessing the picture. *IAEA Bulletin.*, 36, pp. 32-36.
- AL-Bataina B. A., and Lsataifeh M. S. 2000. Indoors Radon Levels During Autumn in AL-Karak District, Jordan. *Mu'tah Lil-Buhuth wad-Dirasat.*, 15(1), pp. 123-128.
- Alenezy, M. D. 2014. Radon Concentrations Measurement in Aljouf, Saudi Arabia Using Active Detecting Method. *Natural Science*. 6, pp. 886-896
- Alexander F.E. 1995. The search for causes of the leukemia's, *Eur. J. Canc.* 31, pp. 863-867.
- AL-Sharif A. and AbdelRahman Y. 2001. Factors affecting radon concentration in houses, *Turk.J.Phys*.,25, pp. 153-158.
- Amrani D. 2000. Dose assessment due to radon concentrations in schools and dwellings of Algiers. *Rad.Prot. Dos*. 87(2), pp.133-135.
- Anastasiou T., Tsertos H., Christofides H., Christodoulides G. 2003. Indoor radon concentration measurements in Cyprus using high-sensitivity portable detectors, *J. Enviro. Radio*., 68, pp.159-161.
- Applied Research Institute – Jerusalem (ARIJ). *GIS Database*. 2006-2009.
- Aytekin H., Baldik R.,Celebi N.,Ataksor B., Tasdelen M. and kopuz G. 2005. Radon measurements in the caves of Zonguldak (Turkey). *Rad. Prot .Dos*.,118, pp.117-121.
- Baxter, M. S. 1993. Environmental radioactivity: A perspective on industrial contributions. *IAEA Bulleti*n., 35(2), pp. 33-35.
- Bunditz R. G.1974. Radon-222 and its daughters, *Health Phys*., 26, pp.145-147.
- Camplin G. C., Henshaw D. L., Lock S., and Simmons Z. 1988. A national survey of background alpha particle radioactivity. *Phys. Educ*., 23, pp. 212-216.
- Durrani S.A., Bull R.K. 1987. *Solid State Nuclear Track Detection*. Pergamon Press, Oxford, pp.172-176.
- EPA. 2003. Indoor Air: Radon, U.S. Environment Protection Agency (*http://www.epa.gov./iaq/radon/pubs/*).
- EPA: USA. 1988. The national radon measurement proficiency (RMP) program, Washington, D. C.: Environmental protection Agency; EPA 520/1-88-025; pp. 32-36.
- Farid S. 1992. Measurements of concentrations of radon and its daughters in dwellings using CR-39 nuclear track detector. J. *of Islamic Academy of Science* 5(1), pp. 4-7.
- Furuta S., Ito K., Ishimori Y. 2002. Measurements of radon around closed uranium mines, *J. Environm. Rad.* 62, pp. 97-114
- Gonzalez A.J. 1993. Global levels of radiation exposure: Latest international findings. *International Atomic Energy Agency (IAEA) Bulletin.*, 35(40, pp. 49-53.
- Hassan F. I.1966. Indoor radon concentration measurements at Hebron University campus. *An-Najah University Journal for Research.*, 4(10), pp. 92-96.
- Hayam A. 2006. Variability of radon levels in different rooms of Egyptial dwelling. *Indoor and built Environ.* , 15, 2, pp.193-196.
- http://www.infoplease.com/atlas/country/westbank.html
- ICRP. 1994. Protection Against Radon- 222 at home and work, ICRP Publication 65, (Oxford: Pergamon press) UK, pp. 1- 262.
- Kenawy M., Ahmad M. and Abdel Ghany H. 2000. Measurements of radon daughter plateot. *Arab J. Nucl. Sci. Appl*., 34, pp. 79-86.

- KHAN S. A., ALI A., TUFAIL M. , QURESHI A.A .2005. Radon concentration levels in Fatima Jinnah women university Pakistan. *Radioprotection*. 40, (1), pp. 11- 27.
- Khattak, N. U., Khan, M.A., Shah, M.T., Javed, M.W. 2015. Radon concentration in drinking water sources of the Main Campus of the University of Peshawar and surrounding areas, Khyber Pakhtunkhwa, Pakistan. *J RADIOANAL NUCL CHEM* , pp. 1-13
- Kobal I., Smodis B., Burger J., and Skofljanec M. 1987. Atmospheric Radon-222 in Tourist Caves of Slovenia, Yugoslavia. *Health Phys*., 52(4), pp.473-475.
- Kobeissi, M. A., Omar El Samad, O., Zahraman , K., Rachidi, I. 2014. Assessment of Indoor and Outdoor Radon Levels in South LebanonInt. *J Disaster Risk Sci*. 5, pp. 214–226
- Kullab M., Al-Bataina B., Ismail A., Abumurad K. and Gaith A. 1997. Study of radon-222 concentration levels inside Kindergardens in Amman. Radiant. Meas. 28 (1-6), pp. 699 – 702
- Kunz E., Sevc J., Placek V., and Horacek J.1981. Lung Cancer in Man in Relation to Different Time Distribution of Radiation Exposure. *Health Phys*., 36, pp. 699-671.
- Leghrouz, A.A., Abu-Samreh, M. M., Shehadeh, A.K. 2013. Measurements of indoor radon concentration levels in dwellings in Bethlehem, Palestine. *Health Phys.* 104(2), pp. 163-167
- Leghrouz, Amin A., Abu-Samreh, M. M., and. Awawdeh, Karam M. Saleh, A. M., Abu-Taha, M. I., Kitaneh, R. M-L, and Darwish, S. M. 2007. Indoor radon-222 concentration measurements in some houses in the winter season of year 2000 in some houses and school of Hebron Province, *Rad. Prot. Dos*. 123 (2), pp. 226-233.
- Magalhaes M.,Amaral E.,Sachett I. and Rochedo E. 2003. Radon -222 in Brazil: an outline of indoor and outdoor measurements. *J.Environ. Radioactivity*. 67, pp.131 - 143.
- Nero, A. V., and Nazaroff, W. W. 1984. Characterizing the Source of Radon Indoors. *Radiat. Prot. Dosim*., 7(1- 4), pp. 23-25.
- Popovic D., Djuric G., and Todorovic D.1996. Radionuclides in building materials and radon indoor concentrations. *Radiat. Protect. Dosim*., 63(3), pp. 223-225.
- Popovic D.and Todorovic D. 2006. Radon indoor concentrations and activity of radionuclides in building materials in Serbia.Series. *Phys.,Chemis. And Techn*. ,4(1), pp.11-20.
- Somlai J., Knayor B., Lendvai Z.,Nemeth C. and Bodnar R. 1997. Radiological qualification of the coal by products used as building materials region of the city Ajka. *Magy.Kem. Foly*, 2, pp. 84 -88.
- United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR). 1988. Source: Effects and risks of ionizing radiation. (New York: United Nations).
- UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). 1993.Sources and Effects of Ionizing Radiation. Report to the General Assembly, with Scientific Annexes, United Nations, New York, NY. United Nations. pp. 45-56.
- UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). 2000. Sources, Effects, and Risks of Ionizing Radiation. Report to the General Assembly. New York, NY, United Nations, 165. Pp.68-71. (*http://www.unscear.org/reports/2000_1.html*).

قياس مستويات تركيز غاز الرادون -222 وحساب معدل الزفير في بعض المكاتب والغرف المغلقة في الجامعة العربية الامريكية خلال فصل الشتاء والربيع من العام 2014

محمد ابو سمرة [1] *، عنان حسين [1] ، مثقال دراغمة [2]، عبد الرحمن ابو لبده[1]

[1] قسم الفيزياء، كلية العلوم والآداب، الجامعة العربية الأمريكية، جنين، فلسطين.

[2] قسم الرياضيات، كلية العلوم والآداب، الجامعة العربية الأمريكية، جنين، فلسطين.

Mohammad.Samreh@aauj.edu

ملخص

اجريت هذه الدراسة لمعرفة مستويات تركيز غاز الرادون ومعدل زفيره وجرعته الفعالة السنوية في 5 مباني في الجامعة العربية الامريكية – جنين خلال فصل الشتاء والربيع من العام 2014 . تم الحصول على البيانات اللازمة لهذه الدراسة من خلال استخدام الكاشف CR-39 موزع في الاماكن المستهدفة. شملت الدراسة 46 مكتبا و 24 مختبرا و 7 غرف تخزين و 9 غرف لعمل قهوة ومخزن ادوات النظافة و8 حمامات و 4 غرف تصوير و3 قاعات إجتماعات . تم تسجيل مستويات تركيز غاز الرادون في الاماكن المغلقة من 26 الى 258 بيكريل/م3 ، وبمتوسط حسابي وانحراف معياري 76.6 و 16.2 على التوالي . بلغت اعلى مستويات تركيز غاز الرادون في الحمامات والمخازن. وتراوحت قيمة الجرعة الفعالة للعينات من 0.69 الى 2.12 mSv/y بمتوسط حسابي mSv/y1.15. وتراوح معدل الزفير من 1.92 الى 5.20 MBq/m2.hr.

اشارت النتائج الى ان متوسط تركيز الرادون في الأماكن المغلقة والتي تم الحصول عليها كانت اقل من القيمة الحقيقية (148 بيكريل/م3) والتي أوصت به وكالة حماية البيئة (EPA). علاوة على ذلك، كانت الجرعة الفعالة لعينات الدراسة ومعدل الزفير (15٪ و 14٪ على التوالي) أعلى من القيم المتوقعة. بشكل عام، كانت جميع النتائج ضمن مستويات التركيز المقبولة من اللجنة الدولية ICRP ، وبالتالي لا يلزم اتخاذ إجراءات علاجية.

كلمات دالة: *كاشفات CR-39، مستويات تركيز Rn222، الجرعات، التعرض، نظائر الرادون ، زفير، نشاطية.*