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Seasonal variation measurements of indoor Radon concentrations in the city of Benghazi- Libya

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Highlights

- **Indoor radon concentrations were measured in selected locations in the city of Benghazi.**
- **Seasonal variation for the summer and winter seasons were studied.**
- **Exhalation rates and annual effective doses were also calculated.**

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ABSTRACT

Indoor concentrations of radioactive radon gas were determined experimentally in fifteen selected locations within the grounds of the University of Benghazi, Benghazi city–Libya. Detection and registration of radon gas were achieved by means of CR-39 plastic detectors (SSNTD) attached to stainless steel cups that contain the samples using the method known as can technique or sealed-cup technique. Forty-five samples within the fifteen selected locations were counted for ninety days interval in the summer season and repeated for the winter season. Radon concentrations were determined for three different sample types in each of the fifteen locations. The three samples are defined as a brick wall, ceramic flooring and marble ledge in the faculty of Science building. Results showed that radon concentrations for all sample types and in all locations were below the ICRP action level limits in both seasons and their magnitudes are seasonal dependent, with high radon concentrations attained in the winter season. Exhalation rates and annual effective doses from all samples were also calculated and showed the familiar linear relationship with radon concentration.

1. Introduction

Radon has many isotopes, radon 222 (^{222}Rn) is the most prominent isotope ($t_{1/2}$= 3.8 d) and result from the nuclear decay of Uranium and Thorium atoms. These parent nuclei atoms are naturally radioactive and found in the environment that human live in. Small amounts of these radioactive substances can be found in the materials that people use in their living places which render them to be a source of radioactive radon gas that permeate into the living space of dwellings and working sites and then find their way into the lungs of the inhabitants which increase the risk of lung cancer (ICRP, 1978). Statistical data showed that radon cancer cases make up about 40% of all cancer cases.

In light of these important facts, many researchers directed their effort in studying, measuring and reporting radon and its risks (Durani, 1993). The International Commission on Radiological Protection (ICRP) recommended that radon concentration values to be in the range 500-1500 Bqm^{-3}and an action level value of 200-600 Bqm^{-3} is set for both working sites and dwellings making them risk-free for both workers and inhabitants (ICRP-1993).

Experimental measurements of radon concentrations in indoor areas have been given worldwide attention and have been reported in the literature by various researchers in different countries naming few examples; Austria (Friedmann, 2002), Yemen (Khayrat *et al.*, 2003), Mexico (Espinosa *et al.*, 1999). A previous study has been conducted in some working places at the University of Benghazi campus, which determined the radon concentration during the summertime (Saad *et al.*, 2010). However, the current study concentrates on the measurement of radon concentration in the winter season in the same working places and then try to establish whether there is a seasonal variation dependence or not. These studies and others will, hopefully, serve as the beginning of the national survey baseline of radon measurements in Libya.

2. Materials and Method

The measurement of radon concentration is carried out by the common method known as sealed-can technique (Saad *et al.*, 2010; Fleischer *et al.*, 1980; Abu–Jarad *et al.*, 1980; Somogyi *et al.*, 1984). A cup made of steel is placed on top of the sample and a plastic detector is fixed on the inside ceiling of the cup. The cup is then isolated from the surroundings by a sealant applied around its edges. The plastic detector used here is CR-39 solid state nuclear track detector (SSNTD) of size 1.5 cm×1.5 cm manufactured by Intercast Europe Co., Parma, Italy (Saad *et al.*, 2010).

Forty-five cups were prepared and placed in fifteen locations in the faculty of science building within the grounds of the University of Benghazi. Three cups were used in each location for a brick wall, ceramic floor and marble edge samples respectively. Locations were selected to include seven departments, three floors, offices, laboratories and teaching rooms. All detectors were labeled according to the above criteria.

The sealed cups were left for an exposure time of ninety days during the summer season in order to obtain good statistics and the process was identically repeated for the winter season. After the detectors in the cups were exposed to radon and its decay daughters, alpha particles emitted from the decay will form tracks in the detector material medium. The SSNTDs were then removed from

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the cups and etched chemically in 6.25 M NaOH solution at 70±1 °C for 8 hours to display and enlarge the latent alpha tracks.

The etched tracks on the detectors were counted manually using an optical microscope at 400x magnification (Saad *et al*., 2010). The area of one field of view was accordingly calculated by stage micrometer and the track density was calculated in terms of tracks per cm^2. The background track density was determined by processing a blank detector under the same etching condition. The background was then subtracted from the measured track density. In order to obtain a realistically good statistics of tracks, 100 fields of view were selected randomly on the detector surface. The track densities were then converted into radon concentration by applying the calibration factor for Intercast CR-39 detectors as 0.239±0.008 tracks cm^{-2} equal to 1 Bq m^{-3} of radon (Saad, 2008).

Thus, radon concentration levels were calculated from the observed track densities using this calibration factor of 0.239±0.008 tracks cm^{-2}/Bqm^{-3} (Saad, 2008). Radon exhalation rate (E_x) and annual effective dose (E_p) were estimated according to the following equations respectively (Saad *et al*., 2010):

$$E_x = \frac{\lambda_v V_r \ C_{Rn}}{S_r} \tag{1}$$

C_{Rn} is radon concentration (Bq m^{-3}), V_r is room volume (m^3), λ_v is air exchange rate (h^{-1}), and S_r is sample surface area.

$$E_x = \frac{A_o \, \lambda \quad V}{S} \tag{2}$$

Where A_0 is radon concentration recorded by the detector from the sample in the emanation cup, λ is the activity of the sample (h^{-1}), V is the volume of the emanation cup ($0.423\pm10^{-3} m^3$), and S is the total surface area of the building material sample ($0.385\pm10^{-2} m^2$).

The annual effective dose (Ep) is given by:

$$E_P(WLM/Y) = \frac{8760 \ n \ F \ C_{Rn}}{170x \ 3700} \tag{3}$$

Where n is the fraction of time spent indoors, F is the equilibrium factor, 8760 is the number of hours per year, 3700 is the conversion factor from unit (Bq/m^3) to working level (WL), and 170 is the number of hours per working month. n=0.8 and F=0.42 were used to calculate E_p. A conversion factor of 6.3mSv/WLM was used to estimate the effective dose from working level month (WLM) values (ICRP, 1987).

3. Results and Discussion

Comparisons of all the values of radon concentration, exhalation rate, and annual effective dose for the summer and winter seasons are shown in Table 1. Comparisons of minimum, maximum and average indoor radon concentration levels observed for all samples and for each sample type of brick wall, ceramic floor, and marble ledge are also shown in Table 2. The results in Table 2 showed that radon concentration levels for the winter season have clearly higher levels than the summer season across the board. Marble ledge samples produced the highest average radon concentration levels for both seasons, while ceramic floor samples produced the lowest average value in the summer season compared to a brick wall, which produced the lowest average value for the winter season. However, the average radon concentration levels for both seasons from sample types were all within the range of the internationally recommended ICRP action level value for working places (500–1500 Bqm^{-3}).

Seasonal comparison of minimum, maximum and average indoor radon concentration levels observed for different locations are given in Table 3. The average radon concentration level from the first floor was the highest for the summer season, whereas in the winter season the highest average value was from the second floor.

The minimum, maximum and average values for the radon exhalation rate and the annual effective dose from the brick walls, ceramic flooring, and marble ledge samples are shown in Table 4. The results showed that the average radon exhalation rates ranged from 0.110–0.131Bq m^{-2} h^{-1} for the summer season compared to the range of 0.413–0.504 Bq m^{-2} h^{-1} in the winter season. For the estimation of the expected annual effective dose to be received by the workers in the university campus due to radon and its progeny, a conversion factor by which 1 Bqm^{-3} of radon corresponding to yearly effective dose equivalent of 0.05 mSv was used as recommended by the Commission of the European Communities (CEC). Using CEC recommended conversion factor, minimum, maximum and average annual effective doses were also compared for the summer and winter seasons as shown in Table 4. The average values of annual effective dose from all samples within all working places showed higher winter doses compared to summer doses as expected since it follows the familiar linear relationship with the level of radon concentration.

4. Conclusion

A Survey of radon gas levels was performed at the University of Benghazi campus. Results showed that the levels of concentration of radon gas of all selected working places were within the range of the ICRP action level limits in both seasons (summer and winter) and the levels of indoor radon concentrations are seasonal dependent, with higher radon levels found to be in the winter season, as expected. The higher winter concentration levels may be due to several factors among them are the lack of ventilation and weather parameters such as temperature and humidity, which may cause higher radon emanation during the winter season. The average exhalation rates and annual effective dose due to radon gas from all samples within all working places showed the familiar linear relationship with radon levels as expected. Based on the result of this survey of seasonal variation it is concluded that the campus is safe for its occupants because the construction materials used to build the campus buildings are not a source of hazardous levels of radiation.

Based on this study, this work can be extended to survey indoor radon levels in the city of Benghazi and other areas in Libya, which will contribute to the safety and protection of public health.

References

Abu –Jarad, F., Fremlin, J. H., Bull, R. (1980) 'A study of radon emitted from construction materials using plastic α-track detectors', *Phys. Med. Biol*., 25, pp. 483-694.

Durrani, S. A. (1993) 'Radon as health at home: what are the facts?', *Nucl. Tracks Radiat. Meas*., 22, pp. 303-317.

Espinosa, G., Golarri, J.I., Richards, R., and Gammage, R.B. (1999) 'Distribution of indoor radon levels in Mexico', *Radiat. Meas*., 31, pp. 355-358.

Fleischer, R. L., Giard, W. R., Mogro-Campero, A., Turner, L. G., Alter, H. W. and Gingrich, J. E. (1980) 'Dosimetry of Environmental Radon: Methods and Theory for Low-dose, Integrated Measurements', *Health Physics*, 39, pp. 957-962.

Friedmann, H. (2002) Radon in Austria. In: Bukart, W., Shorabi, M., Bayer, A. (Eds.), Proceedings of Fifth International Conference on High Levels of Natural Radiation and Radon Areas: Radiation dose and health effects. Munich, Germany, 4th-7th September 2000, p. 162.

ICRP "International Commission on Radiological Protection" (1979) Lung Cancer Risks From Indoor Exposure to Radon Daughters, Report 50, Vol. 17, No. 1.

ICRP "International Commission on Radiological Protection" (1993) Protection against Rn-222 at Home and at Work. Annals of the ICRP 65. Pergamon, Oxford.

Khayrat, A. H., Al-Jarallah, M. I., Fazal-ur-Rehman, X., and Abu –Jarad, F. (2003) 'Indoor radon survey in dwellings of some regions in Yemen', Radiation Measurements, 36, pp. 449-451.

Saad, A. F. (2008) 'Radium activity and radon exhalation rates from Phosphate ores using CR-39 on-line with an electronic radon gas analyzer "Alpha GURAD", *Radiation Measurements*, in press

Saad, A. F., Abdall, Y. K., Hussein, N. A., I. S. Elyaseery, I. S. (2010) 'Radon exhalation rate from building materials used on the Garyounis University Campus, Benghazi, Libya', *Turkish J. Eng. Env. Sci.*, 3, pp. 67-74.

Somogyi, G., Paripas, B. and Varga, Zs. (1984) 'Measurement of Radon, Radon Daughters and Thoron Concentrations by Multi-detector Device', *Nuclear Tracks and Radiation Measurements.*, 8, pp. 423-427.

Table 1

Radon Concentration (C_{Rn}), Radon Exhalation Rate per unit area (E_x) and Annual Effective Dose (E_p) for the summer and winter seasons from the various sample locations within the university campus. Departments: P physics, C-chemistry, G-geology, B-botany, Z-zoology, S-statistics, A-administrative. Sample type: W brick wall, F ceramic floor, M marble edge, Floor level: I Ground Floor GF, II First Floor FF, III Second Floor SF. 1-14 stands for locations.

Season		Summer			Winter		
Sample No.	Sample Code	C_{Rn} (Bqm^{-3})	E_x (Bqm^{-2}h^{-1})	E_p (mSv y^{-1})	C_{Rn} (Bqm^{-3})	E_x (Bqm^{-2}h^{-1})	E_p (mSv y^{-1})
1	PWI1	192.8±6.5	0.146±0.005	9.6±0.3	559.7±18.7	0.424±0.014	28.0±0.9
2	PFI1	118.2±4.0	0.089±0.003	5.9±0.2	-	-	-
3	PMI1	166.2±5.6	0.126±0.004	8.3±0.3	642.8±21.5	0.486±0.016	32.1±1.1
4	PWI2	119.5±4.0	0.090±0.003	6.0±0.2	332.4±11.1	0.252±0.008	16.6±0.6
5	PFI2	94.8±3.2	0.072±0.002	4.7±0.2	-		
6	PMI2	279.2±9.3	0.211±0.007	14.0±0.5	623.3±20.9	0.472±0.016	31.2±1.0
7	PWI3	163.6±5.5	0.124±0.004	8.2±0.3	541.5±18.1	0.410±0.014	27.1±0.9
8	PFI3	233.7±7.8	0.177±0.006	11.7±0.4	-	-	-
9	PMI3	126.0±4.2	0.095±0.003	6.3±0.2	718.1±24.0	0.543±0.018	35.9±1.2
10	PWI4	254.5±8.5	0.193±0.006	12.7±0.4	958.4±32.1	0.725±0.024	47.9±1.6
11	PFI4	162.3±5.4	0.123±0.004	8.1±0.3	-	-	-
12	PMI4	207.8±7.0	0.157±0.005	10.4±0.3	590.9±19.8	0.447±0.015	29.5±1.0
13	PWI5	133.8±4.5	0.101±0.003	6.7±0.2	-	-	-
14	PFI5	87.0±2.9	0.066±0.002	4.4±0.1	1196.0±40	0.905±0.030	59.8±2.0
15	PMI5	119.5±4.0	0.090±0.003	6.0±0.2	720.7±24.1	0.545±0.018	36.0±1.2
16	PWII6	277.9±9.3	0.210±0.007	13.9±0.5	489.6±16.4	0.370±0.012	24.5±0.8
17	PFII6	148.0±5.0	0.112±0.004	7.4±0.2	-	-	-
18	PMII6	231.8±7.8	0.175±0.006	11.6±0.4	-	0.175±0.006	11.6±0.4
19	PWII7	142.8±4.8	0.108±0.004	7.1±0.2	477.9±7.80	0.362±0.012	23.9±0.8
20	PFII7	127.3±4.3	0.096±0.003	6.4±0.2	-	-	-
21	PMII7	221.4±7.4	0.168±0.006	11.1±0.4	915.5±30.6	0.693±0.023	45.8±1.5
22	PWIII8	141.5±4.7	0.107±0.004	7.1±0.2	1406.4±47.1	1.064±0.036	70.3±2.4
23	PFIII8	106.5±3.6	0.081±0.003	5.3±0.2	1109±37.1	0.839±0.028	55.5±1.9
24	PMIII8	113.0±3.8	0.085±0.003	5.6±0.2	953.2±31.9	0.721±0.024	47.7±1.6
25	AWI9	129.9±4.3	0.098±0.003	6.5±0.2	202.6±06.8	0.153±0.005	10.1±0.3
26	AFI9	105.2±3.5	0.080±0.003	5.3±0.2	702.5±23.5	0.532±0.018	35.1±1.2
27	AMI9	110.4±3.7	0.084±0.003	5.5±0.2	470.1±05.0	0.356±0.120	23.5±0.8
28	AWI10	153.2±5.1	0.116±0.004	7.7±0.3	-	-	-
29	AFI10	-	-	-	-	-	-
30	AMI10	-	-	-	-	-	-
31	CWII11	219.5±7.3	0.166±0.006	11.0±0.4	418.2±14.0	0.316±0.011	20.9±0.7
32	CFII11	171.4±5.7	0.130±0.004	8.6±0.3	435.0±14.6	0.329±0.011	21.8±0.7
33	CMII11	171.4±5.7	0.130±0.004	8.6±0.3	479.2±16.0	0.363±0.012	24.0±0.8
34	GWII12	139.0±4.7	0.105±0.004	6.9±0.2	540.2±18.1	0.409±0.014	27.0±0.9
35	GFII12	-	-	-	209.1±07.0	0.158±0.005	10.5±0.3
36	GMI12	298.7±10.0	0.226±0.008	14.9±0.5	-		-
37	BWI13	-	-	-	553.2±18.5	0.419±0.014	27.7±0.9
38	BFI13	275.3±9.2	0.208±0.007	13.8±0.5	361.0±12.1	0.273±0.009	18.1±0.6
39	BMI13	140.2±4.7	0.106±0.004	7.0±0.2	644.1±21.6	0.487±0.016	32.2±1.1
40	ZWII14	213.6±7.2	0.162±0.005	10.7±0.4	270.1±09.0	0.204±0.007	13.5±0.5
41	ZFII14	146.7±4.9	0.111±0.004	7.3±0.2	240.2±08.0	0.182±0.006	12.0±0.4
42	ZMII14	146.7±4.9	0.111±0.004	7.3±0.2	-	-	-
43	SWI15	107.8±3.6	0.082±0.003	5.4±0.2	346.7±11.6	0.262±0.009	17.3±0.6
44	SFI15	110.4±3.7	0.084±0.003	5.5±0.2	406.5±13.6	0.308±0.010	20.3±0.7
45	SMI15	100.0±3.3	0.076±0.003	5.0±0.2	568.8±19.0	0.430±0.014	28.4±1.0

Table 2

Comparison of radon concentrations (Bqm^{-3}) for different sample types in summer and winter seasons.

	Summer season				Winter season			
Concentration parameter	All samples	Ceramic Floor	Brick Wall	Marble Edge	All samples	Ceramic Floor	Brick Wall	Marble Edge
minimum	87	87	107.8	100	202.6	209.1	202.6	470.1
maximum	298.7	275.3	277.9	298.7	1406.4	1196	1406.4	953.2
average	163.6	145.1	170.7	173.7	596.3	582.4	545.9	666.1

Table3

Comparison of radon concentrations (Bqm^{-3}) for different samples according to the location of samples in summer and winter seasons

	Summer season			Winter season		
Concentration parameter	Ground Floor	First Floor	Second Floor	Ground Floor	First Floor	Second Floor
minimum	87	127.3	106.5	202.6	209.1	953.2
maximum	279.2	298.7	141.5	1196	915.5	1406.4
average	153.8	187.3	120.3	586.3	447.5	1156.2

Table4

Comparison of Radon exhalations rates and annual effective doses for different samples in summer and winter seasons.

parameter		Summer season				Winter season			
		All Samples	Floor	Wall	Marble Edge	All samples	Floor	Wall	Marble Edge
Exhalation Rate per unit area (Bqm^{-2}h^{-1})	*minimum*	0.066	0.066	0.082	0.076	0.153	0.158	0.153	0.356
	maximum	0.226	0.208	0.193	0.226	1.064	0.905	1.064	0.721
	average	0.123	0.11	0.129	0.131	0.451	0.441	0.413	0.504
Annual Effective Dose (mSv y^{-1})	*minimum*	4.4	4.4	5.4	5	10.1	10.5	10.1	23.5
	maximum	14.9	13.8	13.9	14.9	70.3	59.8	70.3	47.7
	average	8.2	7.3	8.5	8.7	29.8	29.1	27.3	33.3