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Survey on differences in effective dose radon 222 with Thoron indoor air in masonry workshops

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Abstract: *Radon 222 and Thoron (Radon 220) are of colorless, odorless and radioactive gases that can be emitted from igneous rocks such as granite. A sources of granite rocks is masonry workshops. In this cross-sectional study, concentrations of radon 222 and Thoron in the indoor and outdoor air in the masonry workshop in Minab city by portable radon detector RTM1688-2 model were measured in two levels. Also Effective dose received by radon 222 and Thoron was calculated by UNSCEAR equations. Finally, comparing the effective dose of radon 222 and Thoron was performed by statistical Pair sample t test. The mean and mean concentration of radon 222 and indoor air of masonry workshop 1 is 76-186 Bq/m^3 and 120±29, respectively. Also, the range and mean concentrations of radon 222 in indoor air of masonry workshop 2 is 95-214 Bq/m^3 and 148±38Bq/m^3. Range and mean concentration of Thoron indoor air in the workshop masonry 1 is 27-65 Bq/m^3 and 42±10Bq/m^3. Also, the range and mean concentration of Thoron indoor air in the masonry workshop 2 is 33-75 Bq/m^3 and 52±13Bq/m^3. The mean effective dose of radon 222 and Thoron in the workshop is1.26±0.31 and 0.02±0.1 mSv/y. Effective dose received by radon 222 and Thoron in workshop 1 and 2 as well as the sum of the two is less than the ICRP standard limit. Effective dose received by radon 222 is much greater than the dose Thoron (8.8 times more) and the share of dose received by Thoron out of the total dose is only 10% (P value <0.05). Thoron measurement and calculation of effective dose does not have much impact on increasing the accuracy of measuring the total effective dose (Radon 222 and Thoron) in the masonry workshops.*
Keywords: *Radon 222, Thoron, workshops masonry, effective dose*

I. Introduction

One of the international concern about indoor air quality are radon 222 and Thoron gases [2 ,1]. Radon 222 and Thoron gases are colorless, odorless radioactive half-life of 3.28 days and 56 seconds which can be emitted from water, soil, stones and rocks [5-3]. Radon 222 is the result of radium 226 decay in chain of uranium 238 and Thoron and the decay of radium 224 in the chain of thorium232 [6]. Based on information provided by National Radiation Protection Board (NRPB), 85% of the effective dose received by humans is from natural exposure to radon (Radon 222, Thoron and daughters) [8 ,7]. Radon 222, Thoron and daughters have allocated 1.4 mSv of the annual effective dose received from natural exposure (2.4 mSv) that is more than 50% [10 ,9]. The alpha radiation emitted by radon in the long term can damage the DNA of lung cells and eventually cause lung cancer [11 ,6].The World Health Organization (WHO) has approved direct relationship with the prevalence of lung cancer with radon indoor air [6]. The International Committee for Radiation Protection (ICRP) reported that the maximum annual effective dose received by staff from indoor air radon is 20mSv/y [12]. Concentrations of radon and indoor air Thoron is mainly due to emissions from building materials, soil and water resources [14 ,13]. Studies have shown that although the half-life of Thoron (56 seconds) is less than radon 222 (3.82 days), its risks, particularly in enclosed spaces (storage, etc.) can be overlooked [15 ,2]. In recent years, several studies on emissions of radon 222 and Thoron from building materials such as granite, marble, etc. is done. These studies suggest that granite and marble than many other materials emit more radon at level unit to air [19-16]. In recent years, less attention has been paid to the difference between the effective dose received by staffs due to inhalation of radon 222 with Thoron indoor air storage and cutting stock of these the materials. Therefore, in this study we attempted to compare and evaluate effective dose difference caused by inhaling radon 222 with Thoron in masonry workshop staffs.

II. Materials and methods

2.1. Measurement concentrations of radon 222 and Thoron

First, two masonry workshops in Minab city were selected. Both of these plants have a total area of 20 m^2 and 2.5 meter height. Since the winter is mild in Minab city, the entrance is open for air conditioning [20].

Measurements were carried out in 2 step from December to October 2012 (one stage per every month). Concentration Radon 222 and Thoron indoor air as well as outdoor for 24 and 6 hours respectively was measured by portable radon detector RTM1688-2 model construction made in Germany SARAD Company. Measurement of radon concentration in outdoor air was conducted from the hours 7 PM to 13AM. According to measurements instruction provided by SARAD Company, in continuous measurement of more than 2 hours, the machine must be in a slow state to reduce statistical error and doubling the measurement accuracy [22 ,21]. The device was placed 1 meter in height and in the center of the cutting room. At each stage of each barn, one 24-hour measurement and one 4-hour measurement was performed. From each stone-cutting center, two 24-hour concentrations and Radon 222 and Thoron was measured. Also, two 4-hour concentrations of Radon 222 and Thoron outdoor air was measured from each masonry workshop.

2.2. Calculating annual effective dose

1.2.2. Effective dose received from radon 222

The annual effective dose received from radon 222 indoor air was calculated by Equation 1 presented by UNSCEAR;

Equation1 $E_{Rn}=C_{Rn}\times0.4\times T\times9\times10^{-6}$

In this equation, E_{Rn} is annual effective dose received (mSv/y), C_{Rn} ; Geometric mean concentrations of radon 222 (Bq/m^3), 0.4 the equivalent factor, T; daily working time is 8 hours (2920h/y), 9 ; conversion factor concentration of radon 222 to annual effective dose received (nSv/Bq.m^3.h) and 10^{-6}; conversion factor nano Sievert to mili Sievert [23]. Staff masonry in winter were working from 8 to 13 pm and from 16:30 to 20:30 pm. As a result, the mean time of 8 hours a day was considered as the time of exposure.

2.2.2 Effective dose received by the Thoron

The annual effective dose received by the Thoron 220 Indoor Air was also calculated by equation presented by UNSCEAR (2);

Equation 2 $E_{Tn}= C_{Tn}\times0.02\times T\times40\times10^{-6}$

In this equation, E_{Rn}; annual effective dose received (mSv/y), C_{Rn}; Geometric mean concentrations of Thoron (Bq/m^3), 0.02 the equivalent factor, T; daily working time is 8 hours (2920h/y), 40 conversion factor concentration of Thoron to annual effective dose received (nSv/Bq.m^3.h) and 10^{-6} is nano conversion factor nano Sievert to mili Sievert [23].

3.2. Statistical analysis

To determine the difference between the effective dose received by radon 222 with Thoron masonry workshops, Pair sample statistical test in software SPSS16 was statistically analyzed. P value<0.05was considered as the significant level (α=5%).

III. Results

The range and mean concentration of radon 222 of indoor air workshop masonry 1 is 76-186 Bq/m^3 and 120±29Bq/m^3. The mean concentration of radon 222 in indoor air night and day is 135 and 105 Bq/m^3. Also, the range and mean concentration Radon 222 indoor air in Masonry workshop 2 is 95-214 Bq/m^3 and 148±38Bq/m^3. The mean concentration of radon 222 in indoor air day and night is 167 and 129 Bq/m^3 (Table 1).

Table 1.The concentration of Radon 222 Indoor air of two masonry workshops

	MW1			MW2			MEAN
Time	Step 1	Step 2	MEAN	Step 1	Step 2	MEAN	
9	125	122	124	155	144	150	137
11	103	109	106	130	122	126	116
13	92	105	99	120	111	116	107
15	135	125	130	169	154	162	146
17	96	78	87	132	115	124	105
19	76	96	86	100	95	98	92
21	89	102	96	121	108	115	105
23	108	111	110	142	127	135	122
1	135	124	130	178	154	166	148
3	154	138	146	182	173	178	162
5	179	143	161	207	198	203	182
7	186	155	171	214	205	210	190
Mean	123±36	117±22	120±29	154±36	142±35	148±38	134±33
Day	105	106	105	134	124	129	117
Night	142	129	135	174	161	167	151

The mean and concentration of Thoron of indoor air day and night in masonry workshop 1 is 27-65 Bq/m^3 and 42±10Bq/m^3. The mean concentration of Thoron indoor air at night and day is 47 and 37 Bq/m^3. Also, the mean and mean concentration of thoron indoor air in Masonry workshop 2 is 33-75 Bq/m^3 and 52±13Bq/m^3. The mean concentration of thoron indoor air day and night is 59 and 45 Bq/m^3 (Table 2).

Table 2. The concentration of Thoron indoor air in two masonry workshops

	MW1			MW2			MEAN
Time	Step 1	Step 2	MEAN	Step 1	Step 2	MEAN	
9	44	43	43	54	50	52	48
11	36	38	37	46	43	44	41
13	32	37	34	42	39	40	37
15	47	44	46	59	54	57	51
17	34	27	30	46	40	43	37
19	27	34	30	35	33	34	32
21	31	36	33	42	38	40	37
23	38	39	38	50	44	47	43
1	47	43	45	62	54	58	52
3	54	48	51	64	61	62	57
5	63	50	56	72	69	71	64
7	65	54	60	75	72	73	67
Mean	43±13	41±8	42±10	54±13	50±12	52±13	47±11
Day	37	37	37	47	43	45	41
Night	50	45	47	61	56	59	53

The mean concentration of Radon 222 of indoor air at day and night is 315 and 105 Bq/m^3. The range and mean concentration of Radon 222 in indoor air masonry workshop is 214-95 Bq/m^3 and 148±38Bq/m^3. Also, the mean concentration of radon 222 in indoor air at night and day is 167 and 129 Bq/m^3 (Table 1).

The range and mean concentration of Thoron indoor air in the masonry workshop 1 is 27-65 Bq/m^3 and 42±10Bq/m^3. The mean concentration of Thoron in indoor air at night and day is 47 and 37 Bq/m^3. Also, the mean and mean Thoron concentration in indoor air in Masonry workshop 2 is 33-75 Bq/m^3 and 52±13Bq/m^3. The mean concentration of Thoron in indoor air day and night is 59 and 45 Bq/m^3 (Table 2).

In the step 1 mean concentration of Radon 222 of outdoor air in workshop masonry 1 and 2 is 37±2 Bq/m^3 and 23±3 Bq/m^3 and in step 2 is 21±3 and 29±5 Bq/m^3, respectively (Table 3). The mean concentration of Thoron in outdoor air in workshop masonry 1 and 2 is 6±2 and 13±4 Bq/m^3 and in level 2 is 10±5 and 9±3 Bq/m^3 (Table 2). The mean outdoor air Thoron of both workshops is 10±5 Bq/m^3(Table 4).

Table 3. The concentration of radon 222 outdoor air of masonry workshop

	Step 1						Step 2						MEAN
Time	MW1		Mean	MW2		Mean	MW1		MEAN	MW2		MEAN	
9	38	33		35	11	23	22	19	21	24	33	29	26
11	32	36	36	39	25	32	26	23	25	29	32	31	31
13	29	36	34	38	19	29	20	18	19	33	27	30	29
Mean	33±5	35±2	33±5	37±2	18±7	28±5	23±3	20±3	21±3	29±5	31±3	30±4	29±5

Table 4. The concentration of thoron in outdoor air in masonry workshop

	Step 1						Step 2						MEAN
Time	MW1		Mean	MW2		Mean	MW1		MEAN	MW2		MEAN	
9	11	ND[1]	6	13	5	9	8	21	15	13	9	11	12
11	8	5	7	19	9	14	ND	18	9	12	6	9	12
13	9	3	6	18	16	17	ND	11	6	14	ND	7	11
Mean	9±2	3±3	6±2	17±3	10±6	13±4	3±5	17±5	10±5	13±1	5±5	9±3	10±5

[1]Not Detected

The mean effective dose of Radon 222 and Thoron is 1.26±03 and 0.1±0.02 mSv/y. Also, total effective dose of Radon (Radon 222 and Thoron) is 1.36±0.33 mSv/y. Effective dose of Radon 222 and Thoron in the night is 1.42 and 0.11mSv/y, respectively and in the day is 1.1 and 0.09mSv/y, respectively (Table 5).

Table 5. The effective dose of radon 222 and Thoron in masonry workshop 1

	Concentration		Effective Dose		Sum
	Radon 222	Thoron	Radon 222	Thoron	
MW1	120	42	1.26	0.10	1.36
SD	29	10	0.30	0.02	0.33
Day	105	37	1.10	0.09	1.19
Night	135	47	1.42	0.11	1.53

The meanEffective Doseof radon 222 and thoron in workshop masonry 2 is 1.56±0.38and 0.12±0.03 mSv/y, respectively. The total effective dose of Radon (Radon 222 and Thoron) is 1.68±0.41 mSv/y. the effective dose of Radon 222 and Thoron in night is 1.89 and 0.14mSv/y and in the day is 1.46 and 0.11 mSv/y, respectively (Table 6).

Table 6. The Effective dose of radon 222 and Thoron in masonry workshop 2

	WMT2		Effective dose		Sum
	Radon 222	Thoron	Radon 222	Thoron	
Mean	148	52.00	1.56	0.12	1.68
SD	36.00	13.00	0.38	0.03	0.41
Day	129.00	45.00	1.36	0.11	1.46
Night	167.00	59.00	1.76	0.14	1.89

IV. Discussion

Staffs of masonry workshop are exposed to radon air during the day. Hence, the mean concentration of radon 222 and Thoron during the day (working hours) was considered as the basis for the effective dose calculation. The ratio of total effective dose received by radon 222 and Thoron (1.57 mSv/y) to the ICRP standard is equal to 7.8% (p value <0.05) [12]. Effective dose received by radon 222 and Thoron in workshop 1 and 2 and the mean of the two was less than the standards ICRP (Figure 1). Statistical pair t test showed that the mean indoor radon 222 and Thoron of masonry workshop 1 with masonry workshop 2 is not significantly different (p value>0.05). Therefore, no significant difference between the effective dose of the two workshops can be expected. There is a significant difference between radon 222 and Thoron radon indoor air with the outside air (p value <0.05). Radon 222 indoor air (148±38 Bq/m^3) to radon 222 outdoor air (29±5 Bq/m^3) is more than 5.1 times and indoor air (47±11 Bq/m^3) to outdoor air (10±5 Bq/m^3) is more than 4.7 times. It shows that masonry workshop is one of the sources of radon gas. The ratio of effective dose received by radon (radon 222 and Thoron) in the day than night in the workshop 1 and 2 is 77.7% and 77.2%,respectively. Although the statistical analysis does not show a statistically significant difference between the effective dose of the day than night (p value>0.05), the use of active devices such as radon detector RTM1688-2 than passive devices such as CR39 is more accurate [24 ,17].Active devices gives us the ability to measure concentrations of radon during doing work, but passive devices measure the day and night or monthly mean[26 ,25].

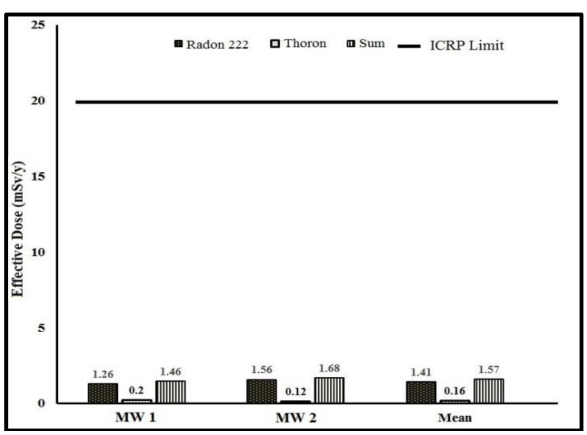

Figure 1. Comparing the effective dose received by radon 222, Thoron and the sum with the of ICRP standard limit

Table 7. Analysis of Paired Samples Test between effective dose of Radon 222 and indoor air Thoron in masonry workshop

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Radon – Thoron	1.30	0.33	0.0480	1.20	1.39	26.5	47	P<0.05

Statistical analysis of Paired Samples Test between the effective dose of Radon 222 and Thoron indoor air indicate that there are significant differences between these two variables (Table 7). Effective dose received of radon 222 is much greater than the Thoron dose (8.8 times more) and the share of total dose absorbed dose is only 10%.

Table 8. Comparison of radon 222 concentration to Thoron in Iran and other countries

Countries (City)	Unit	Radon 222	Thoron	Ratio	References
Palestine	Bq/kg	35.1	20.5	0.6	[27]
Saudi Arabia	Bq/kg	23	30	1.3	[28]
Brazil	Bq/kg	48.6	288.2	5.9	[27]
Hong Kong	Bq/kg	202	140	0.7	[27]
France	Bq/kg	90	80	0.9	[28]
Egypt	Bq/kg	32.46	47.76	1.5	[29]
Iran (Minab City)2	Bq/m3	50.1±17	23.2±14	0.5	[30]
Iran (Minab City)	Bq/m3	134±33	47±11	0.4	Present study

The higher emissions of Thoron from granite in some countries is due to higher thorium 232 in the ground layers of this state [6]. Thorn concentrations to radon 222 in Palestine, France and Iran (Minab, decorative stones storage) as in our study is more than the contribution of Radon 222. But in countries like Saudi Arabia, Brazil and Egypt, Thoron contribution is more (Table 8). It shows that when calculating the effective dose of radon, radon 222 and Thoron should be measured together because despite lower half-life of Thoron, Thoron concentration could be more from the Radon 222 concentration [15 ,2].

V. Conclusion

Effective dose received of radon 222 and indoor air Thoron of masonry workshops is less than ICRP standard limit. Measuring Thoron concentration along with radon 222, although increases effective dose measurement accuracy, accuracy is not significant (10 percent contribution). Using portable (active) devices will enhance measurement of concentrations of radon then effective dose received.

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