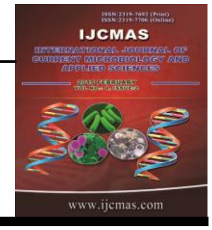

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Original Research Article

Assessment Risk of Lung Cancer from Inhalation of Radon 222 and Thoron (Radon 220) of Indoor Air in Staff Cement Storage Warehouses; Minab city, Iran

Yadolah Fakhri[1], Amir Hossein Mahvi[2], Seyed Mohsen mohseni[3], Bigard moradi[4], Ghazaleh langarizadeh[5], Yahya Zandsalimi[6], Saeedeh Jafarzadeh[7] and Maryam Mirzaei[8]*

[1]Social Determinants in Health Promotion Research Center, Hormozgan University of Medical Sciences, Bandar Abbas, Iran
[2]Department of Environmental Health Engineering, Faculty of Health, Tehran University of Medical Sciences, Tehran, Iran
[3]Department of Environmental Health Engineering, School of Public Health, Qom University of Medical Sciences, Qom, Iran.
[4]Department of Health Public, Kermanshah University of Medical Sciences, Kermanshah, Iran
[5]Food and Drugs Research Center, Bam University of Medical Sciences, Bam, Iran
[6]Environmental Health Research Center, Kurdistan University of Medical Sciences, Sanandaj, Iran
[7]Research Center for non-communicable disease, Fasa University of Medical Sciences, Fasa, Iran
[8]Research Center for non-communicable disease, Msc of Critical Care Nursing, Jahrom University of Medical Sciences, Jahrom, Iran
**Corresponding author*

Keywords

Radon 222, Thoron, Effective dose, Black cement and Risk lung cancer

A B S T R A C T

Radon is a colorless, odorless radioactive gas that can be emission from different materials such as black cement. Inhaling Radon gas over a long period may increase the effective dose received and the subsequent increase in lung cancer among humans. In this cross-sectional-descriptive study, Radon 222 and Thoron concentrations was measured in five warehouse centers of black cement by RadonMeter portable devices model RTM1688-2 in three stages. In total, 30 concentrations of 24 hours of local air and 30 concentrations of 4 hours of Radon 222 and Thoron of the outdoor air were measured. Then, effective dose received and the risk of lung cancer in Staff was calculated by UNSCEAR and ICRP equations, respectively. The Mean of radon 222 and Thoron indoor air in 5 warehouses of cement were 133.6±33.2and 21.8±10 Bq/m^{3}and outdoor air were 29.6±3.3 and 5.8±2Bq/m^3, respectively. The mean concentration of Radon (Radon 222 and Thoron) of indoor air is 155.4±27 Bq/m^3. The mean effective dose received by Staff from Radon at 8 and 16 working hours are1.46±0.36 and2.91±0.72mSv/y, respectively. Also the mean risk of lung cancer at 8 and 16 hours are 26±6 and 52±13, respectively. Black cement storage warehouse is an important source of Radon gas emission. Effective dose received and the risk of lung cancer among Staff in black cement warehouse at 8 and 16 working hours is lower than the standard ICRP. By the simultaneous measurement of the concentration of Radon 222 and Thoron, the effective dose received and the risk of lung cancer can be precisely calculated.

Introduction

One of the major global concerns in the indoor air quality is colourless and odourless of Radon gas and its decay products (Al-Khateeb, Al-Qudah et al; 2012, Ju, Ryu et al; 2012, Taylor-Lange, Stewart et al; 2012). Radon222 (^{222}Rn) is resulting from the decay of radium-226 (^{226}Ra) in the chain of uranium-235 (^{235}U) and Thoron (^{220}Rn) is resulting from the decay of radium-224 (^{224}Ra) in the chain of Thoron 232 (^{232}Th) (Cothern and Smith; 1987, Cohen, Xiong et al; 1998). Based on the information presented by the National Radiation Protection Board (NRPB) (NRPB), 85% of the effective dose received by humans is from natural radiation and 15% is from synthetic radiation (man-made) (Green, Lomas et al; 1991). Radon 222 gas, Thoron and their girls allocates 1.4 mSv of the annual effective dose received from natural radiation measurement (2.4 mSv) (over 50%) (Richard;1987, Magill and Galy; 2005). The alpha radiation emitted by the Radon222 and the girls (^{218}Po and ^{214}Po) in the long term can damage the DNA of lung cells and eventually cause lung cancer (Zeeb and Shannoun; 2009, Kávási, Somlai et al; 2010). Studies have also shown that there is a direct relationship between cardiovascular disease and long-term exposure to high levels of indoor air Radon (Bajwa and Virk; 1997) . The World Health Organization (WHO) has approved a statistically significant relationship of Lung cancer prevalence with indoor air Radon (Torres-Durán, Barros-Dios et al; 2014). Environmental Protection Agency (EPA) in America has announced the mortality rate caused by indoor air Radon nearly 21,000 people annually which is 10 times higher than deaths from air pollution (EPA; 2010). EPA and WHO proposed indoor air Radon as 148 Bq/m^3 and 100 Bq/m^3 standard concentrations (WHO; 2009, EPA; 2010). The global mean concentration of indoor and outdoor air Radon is 48 and 15 Bq/m^3, respectively (FARID; 2012). The maximum annual effective dose received by the Staff of the indoor air Radon is 20 mSv/y (ICRP; 1994). Indoor air Radon concentration is mainly related to emissions from building materials, the surrounding soil and water resources (Ramasamy, Dheenathayalu et al; 2004). All building materials have radioactive substances although in small amounts. Many studies have shown that cement (black and white powder, plaster, concrete, etc.) can emit radioactive materials, especially ^{226}Ra, Radon 222 and Thoron compared to other building materials (Petropoulos, Anagnostakis et al; 1999, Petropoulos, Anagnostakis et al; 2002, Ju, Ryu et al; 2012). Long-term studies suggests that the effective dose from indoor air Thoron cannot be overlooked (Janik, Omori et al; 2015). Hence, this study was an attempt to measure Radon 222 and Thoron concentration indoor air in 5 important warehouses of the storage and distribution of black cement at Minab city. Then the risk of lung cancer from inhalation of Radon (Radon 222 and Thoron) was calculated and evaluated.

Materials and Methods

Measurement concentration of Radon 222 and Thoron

First, 5 major and important warehouse of black cement storage at Minab city were selected. The measurement was done at three stages from February 2013 to April 2013 (one step per month). According to the instructions provided by the EPA, concentration measurement of indoor air Radon measurements should be taken at least 24 hours (EPA; 2010). Hence, the concentration of Radon 222 and Thoron indoor air and the background (outdoor) air was measured for 24 and 4 hours, respectively by Radon Detector portable RTM1688-2 model made in SARAD German companies (Figure 1). The sensitivity of this device in 150 minutes of continuous measurement is 6.5cts/min×KBqm^{-3}(Ursulean, COREŢCHI et al; 2012). High sensitivity with alpha spectrometry analysis leads to a short response time even at low concentrations. According to measurement instructions provided by the SARAD Company, in the continuous measurement of more than 2 hours, to reduce the statistical error and double precision, the device must be in a slow mode (Ursulean, COREŢCHI et al; 2012, GmbH June; 2007). Along with concentration measurement of radon 222 and thoron , relative humidity (%), temperature (℃) and pressure (mbar) is continuously measured and recorded by the device. In each warehouse of black cement storage, the device was placed at a height of 1 meter and in the centre of warehouse. At every stage of the warehouse, two 24-hour measurements and two 4-hour measurements was done. In total of three stages of 5 storage warehouse, 30 concentration of Radon 222 and Thoron 24-hour indoor air and 30 concentration of Radon 222 and Thoron 4-hour of background air were measured.

Calculation of the annual effective dose received by Staff

Effective dose received by the Radon 222

The annual effective dose received by the Radon222 indoor air was calculated by Equation 1 presented from UNSCEAR;

Equation 1

$$E_{Rn}=C_{Rn} \times 0.4\times T\times 9\times 10^{-6}$$

In this equation; ERn is annual effective dose received, (mSv/y) is geometric mean concentration of Radon 222 (Bq/m^3), 0.4 balancing factor, T; daily working time that is 8 hours (2920 h/y) and (5840 h/y)16 h, 9 is conversion coefficient concentration of Radon 222 to the effective dose received, (nSv/Bq.m^3.h) and 10^{-6} is Nano-Sivert conversion ratio to the mili-Sivert (UNSCEAR; 2000).

Effective dose received from Thoron

The annual effective dose received by indoor air Thoron was also calculated by Equation 2 presented by UNSCEAR;

Equation 2

$$E_{Tn}= C_{Tn} \times 0.02\times T\times 40\times 10^{-6}$$

In this equation E_{Tn}; annual effective dose received (mSv/y), CRn is geometric mean concentrations of Thoron (Bq/m^3), 0.02, balance factor, T; daily working time that is 8 hours (h/ y 2920) and 16 hours (5840 h/y); 40 is conversion coefficients of Thoron concentration to the effective dose received (nSv/Bq.m^3.h) and 10^{-6} is the conversion coefficients of Nano-Sivert conversion ratio to the mili-Sivert (UNSCEAR; 2000).

Risk of lung cancer

To calculate the probability of a lung cancer cases per year per million people (CPPP) caused by effective dose received from Radon, Equation 3 was used (Samet; 1989).

Equation 3

$$CPPP = E_{Rn}\times 18$$

Statistical Analysis

The difference in indoor and background air Radon concentration at five cement storage center were statistically analyzed by One way ANOVA method in SPSS16 software.

P value <0.05 (α = 5%) was considered as significant level.

Result and Discussion

The mean concentration of indoor air Radon (Radon 222 and Thoron) is 155.4±27 Bq/m^3. The mean concentration of indoor air Radon (M ±SD)[1] in black cement warehouse BCW1, BCW2,BCW3, BCW4 and BCW5 is 158.33±28, 183.67±32, 111.25±19, 199.67±35 and 123.33±22Bq/m^3(Table 1). The concentration range of indoor air Radon in BCW1, BCW2, BCW3, BCW4 and BCW5are 211±37-103±18,239±42-127±22, 158±28-50±9, 261±46-156±27 and 172±30-86±15Bq/m^3, respectively (Table 1). The order of cement warehouse given the Radon concentration is BCW3>BCW5> BCW1> BCW2>BCW4, respectively. Also, the meanoutdoor air Radon concentration in BCW1, BCW2,BCW3, BCW4 and BCW5is 39±11 ,41.6±7.15, 15.4±4.2, 36.7±8.5 and 28.2±2.7Bq/m^3, respectively (Table 2).

The mean indoor air concentration of Radon 222 black cement warehouse BCW1, BCW2,BCW3, BCW4 and BCW5 are 122.33±56,160.67±17,96.33±26,175.67±27 and 113.33±28 Bq/m^{3}and also the mean indoor air Thoron is 36.33±10,23.33±4 , 14.67±4,24.33±11 and 10.33±23 Bq/m^3. The mean indoor air concentration of Radon 222 in five cement storage warehouse is 33.2±133.6 and 21.8±10 Bq/m^{3}and thoron indoor air is 29.6±3.3 and 5.8±2 Bq/m^3, respectively (Table 2).

Effective dose received by the Staff caused by indoor air Radon in black cement warehouses BCW1, BCW2,BCW3, BCW4 and BCW5 in 8 working hours are 1.9, 1.05, 1.74, 1.37 and 1.22 mSv/yas well as 16 working hours is 2.74, 3.49, 2.09,3.81and2.43 mSv/y. Effective dose received by Staff from the radon 222 and thoron indoor air in 8 working hours is 1.4±0.3 and 0.05±0.02 mSv/y, respectively and in 16 working hours is 2.81±0.7 and 0.10±0.05 mSv/y. The mean effective dose from Radon Staff at 8 and 16 hours are 1.46±0.36 and 2.91±0.72 mSv/y, respectively (Table 3). Like concentration of Radon, cement warehouses in terms of effective dose received are BCW3>BCW5>BCW1>BCW2>BCW4.

The risk of lung cancer (lung cancer per million people) in the cement warehouses are BCW1, BCW2,BCW3, BCW4 and BCW5 respectively in 8 working hours are 25, 31, 19, 34 and 22, respectively and in 16 working hours are 49, 63, 38, 69 and 44. Also the risk of lung cancer at 8 and 16 hours is 26±6 and 52±13, respectively (Table 3).

The ratio of mean indoor air Radon concentration to EPA Standard in cement warehouses of BCW1, BCW2,BCW3, BCW4 and BCW5 are 106.7, 123.6,75,134.8 and 83.3%. The mean concentration of warehouses of BCW3 and BCW5 is lower and BCW1, BCW2 and BCW4 warehouses is higher than the EPA standard. Also, the ratio of mean indoor air Radon concentration to WHO standard in cement warehouses of BCW1, BCW2, BCW3, BCW4 and BCW5 are 158.3, 183.6,111.2, 199.6 and 123.3 . The mean indoor air concentration of Radon in all black cement warehouses are higher than WHO standard (Figure 1).

The ratio of mean concentration of Radon indoor air to outdoor air in cement warehouses of BCW1, BCW2,BCW3, BCW4 and BCW5 are 5.44, 7.2, 4.39, 4.05 and 4.36, respectively and totally 4.38(155.4/35.4) times more than outdoor air. The maximum and minimum Radon concentration of indoor air to outdoor air are

[1]Mean±standard deviation

related to BCW3 and BCW1 warehouses, respectively. ANOVA statistical analysis showed that there is a significant difference between indoor and outdoor air concentration of Radon in all cement warehouses (p value <0.05). Concentration of radon indoor air is higher than outdoor Hence it can be said that cement warehouses are a source of Radon. This difference in indoor air concentration of Radon in cement warehouses is caused by the difference in the air conditioning (natural and artificial), cement volume stored, the warehouse volume (air exchange) and the different brands of cement black (Perrier, Richon et al; 2004, Nain, Chauhan et al; 2006, Alsaedi, Almayahi et al; 2013). The higher the stored cement volume and consequently the less air conditioning and exchange, concentration of Radon in indoor air also increases (p value=0.21). Outdoor air Radon concentration in 5 warehouses of black cement storage (n=30) shows that there is no significant difference between outdoor air Radon concentration in 5 warehouses (p value >0.05). Effective dose received by Staff in 8 working hours (1.46±0.36 mSv/y) and 16 working hours (2.91±0.72 mSv/y) is lower than the ICRP standards for Staff (20mSv/y). The maximum and minimum effective dose received by Staff at 8 and 16 working hours relates to BCW3 BCW4 centre, respectively. (Figure 2 and 3).

Since increasing the exposure time increases the effective dose, thus the effective dose received in 16 working hours is 2 times more than 8 hours (UNSCEAR; 2000).High concentration of indoor air Radon 222 BCW4 compared to other warehouses can be resulted from less air conditioning, less space, difference in brands of cement stored or differences in building materials of warehouse body (Biira, Kisolo et al;2010 , Perrier, Richon et al; 2004, Alsaedi, Almayahi et al; 2013).Hence, the impact of each of these variables to be studied separately or together in further studies. Mean risk of lung cancer at 8 and 16 working hours are 26±6 and 52±13 humans, respectively that is much lower compared with standard ICRP (170-230 people) (Table 3))Protection and ICRP 1994(. The mean concentration Radon 222 in this study is more than Radon 222 concentration at indoor air in 7 cement companies in the study done by Beira et.al (96.6 Bq/m^3). The effective dose received in study by Beira et.al (2.43±0.1 mSv/y) is more than the mean effective dose at 8 working hours (1.46±0.36 mSv/y) and lower than the effective dose in 16 working hours (2.91 ± 0.72 mSv/y) (Biira, Kisolo et al;2010). Since the exposure time in the study of Beira et.al (7010 hours per year) is more than the one in this study (2920 hours per year for 8 working hours), hence despite the fact that there was less than 222 Radon concentration in study by Beira et.al, the effective dose was more. Despite the fact that Staff exposure time in 16 working hours (5840 hours per year) was less than in the study of Beira et.al (7010 hours per year), however, due to the higher concentration of Radon in our study, the effective dose received was more than the one received in the study of Beira et.al (19% more). Since Thoron allocates 16% (21.8/133.6) Radon concentration, hence more accurate effective dose can be received with simultaneous measurement concentration of Radon 222 and thoron.

The mean concentration of Radon in indoor air at black cement warehouses (155.4±27 Bq/m^3) is higher than the standard WHO and EPA. Effective dose received by Staff at 8 and 16 working hours is lower than the standard ICRP. Also the risk of lung cancer at 8 and 16 working hours is less than the standard ICRP. More accurate effective dose received and lung cancer can be calculated for humans with simultaneous measurement concentration of radon 222 and thoron. Black cement storage warehouses is one of radon gas emissions sources. It is therefore suggested that the effective dose received and the risk of lung cancer be reduced in Black cement storage warehouses with proper ventilation, reduction of working time and other methods.

Table.1 Mean total indoor air Radon concentration (Bq/m3) in 5 black cement warehouse during 24 hours.

Time (hr)	BCW1	BCW2	BCW3	BCW4	BCW5
10 : 30 AM	123±22	146±26	80±14	165±29	96±17
12	103±18	127±22	69±12	156±27	86±15
14	134±23	154±27	76±13	167±29	96±17
16	138±24	134±23	50±9	183±32	104±18
18	160±28	181±32	110±19	195±34	122±21
20	166±29	200±35	114±20	199±35	118±21
22	182±32	217±38	140±25	197±34	139±24
24	190±33	225±39	140±25	227±40	134±23
2 PM	196±34	233±41	156±27	240±42	152±27
4	211±37	239±42	158±28	248±43	172±30
6	163±29	190±33	143±25	261±46	157±27
8:30	134±23	158±28	99±17	158±28	104±18
M±SD	158.33[2]±28	183.67±32	111.25±19	199.67±35	123.33±22

Figure.1 Portable device for measurement of Radon meter, model RTM1688-2 for measure concentration of Radon 222 and Thoron in water, soil and air, made in SARAD Company of Germany

[2]Mean of 6 Concentration 24 hours radon222 and thoron 220

Table.2 Mean indoor and background air Radon 222 and Thoron (Bq/m3) in 5 black cement storage warehouse

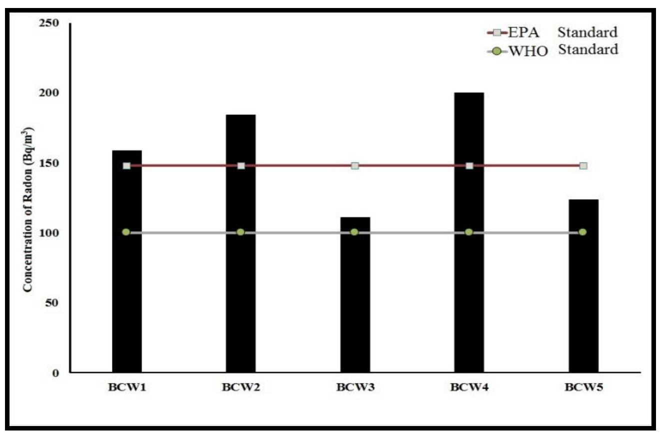
				(February, 2013) Step 1				Step 2 (March,3013)				Step 3(April, 2013)				Sum[3]			
				Indoor[4]		Background[5]		Indoor		Background		Indoor		Background		Indoor		Background	
Number	Humidity (%)	Pressure (mbar)	Tempture (C)	^{222}Rn	^{220}Rn	^{222}Rn	^{220}Rn	^{222}Rn	^{220}Rn	^{222}Rn	^{220}Rn	^{222}Rn	^{220}Rn	^{222}Rn	^{220}Rn	^{222}Rn	^{220}Rn	^{222}Rn	^{220}Rn
BCW1	76	998	31	86	27	14	4	94	46	33	4	187	36	54	8	122.33±56	36.33±10	33.67±20	5.33±2.3
BCW2	84	999	29	142	21	28	3	176	28	25	17	164	21	39	14	160.67±17	23.33±4	30.67±7	11.33±7.3
BCW3	69	997	29	69	14	28	2	122	19	37	2	98	11	21	3	96.33±26	14.67±4	28.67±8	2.33±0.5
BCW4	91	998	32	174	19	41	7	204	37	16	2	149	17	35	10	175.67±27	24.33±11	30.67±13	6.33±4
BCW5	56	998	34	142	11	19	3	86	7	28	4	112	13	27	4	113.33±28	10.33±23	24.67±5	3.67±0.5
[6]M±SD	75±14	998±1	31±2	123±44	18±6	26±10	4±2	136±52	27±15	28±8	6±6	142±37	20±10	35±13	8±4	133.6±33.2	21.8±10	29.6±3.3	5.8±2

[3]Mean of 3 Steps
[4]Mean of 2 Concentration of 24 hours
[5]Mean of 2 Concentration of 4 hours
6 Mean± Standard Deviation

Table.3 Total concentration of radon 222and thoron indoor air, the effective dose received and the risk of lung cancer in Staff of 5 cement warehouses

				Effective Dose (mSv/y)		Effective Dose (mSv/y)		Work Time (h/d)		LCR[7]	
	Concentration of Radon (Bq/m^3)		Sum of ^{222}Rn and ^{220}Rn	Work time 8hr		Work time 16hr		8	16	Work time 8hr	Work time 16hr
	^{222}Rn[8]	^{220}Rn[9]		^{222}Rn	^{220}Rn	^{222}Rn	^{220}Rn	^{222}Rn+^{220}Rn	Rn+^{220}Rn^{222}		
BCW1	122.33	36.33	158.33±28	1.29	0.08	2.57	0.17	1.37	2.74	25	49
BCW2	160.67	23.33	183.67±32	1.69	0.05	3.38	0.11	1.74	3.49	31	63
BCW3	96.33	14.67	111.25±19	1.01	0.03	2.03	0.07	1.05	2.09	19	38
BCW4	175.67	24.33	199.67±35	1.85	0.06	3.69	0.11	1.90	3.81	34	69
BCW5	113.33	10.33	123.33±22	1.19	0.02	2.38	0.05	1.22	2.43	22	44
M±SD	133.6±33.2	21.8±10	155.4±27	1.4±0.3	0.05±0.02	2.81±0.7	0.10±0.05	1.46±0.36	2.91±0.72	26±6	52±13

Figure.1 Comparing the mean indoor air concentration of Radon (Radon 222 and Thoron) in 5 black cement warehouses with the EPA and WHO standards



7 Lung Cancer Risk (LCR)
8 Radon 222 (222Rn)
9 Thoron (220Rn)

Figure.2 Comparing the effective dose received by Staff with standard ICRP (8 working hours)

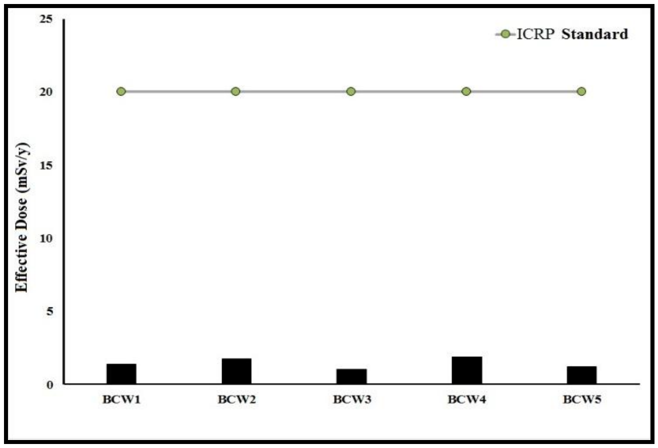
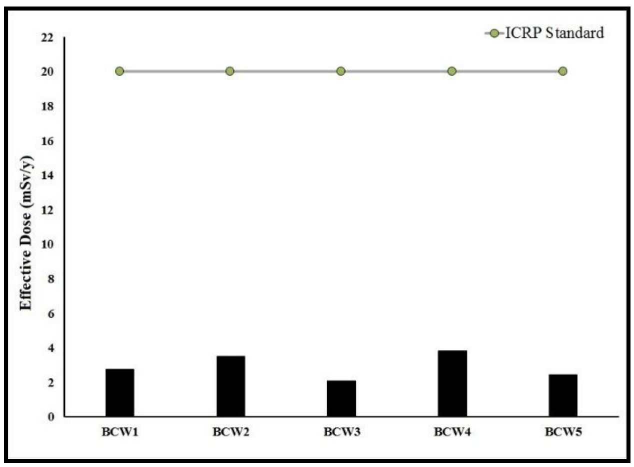


Figure.3 Comparing the effective dose received by Staff with ICRP standard (16 working hours)



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