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The Effect of Tobacco Smoking On Concentration of ^{222}Rn Indoor Air and the Annually Received Effective Dose

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ABSTRACT

^{222}Rn is a radioactive gas which can injure the DNA of lung cells while being decomposed and emit alpha particles. It would finally lead to lung cancer. Smoking is on the rise in societies worldwide. Therefore, the present research seeks to investigate into the effect of the smoke induced by tobacco consumption on ^{222}Rn concentration. Concentration of ^{222}Rn was measured via RTM1688−2 in two circumstances once with and once without tobacco consumption in summer and winter. Moreover, the received effective dose was measured among individuals with regard to the concentration of ^{222}Rn along with the exposure time, again once with and once without the consumption of tobacco in summer and winter. the 24-hour average of ^{222}Rn concentration with and without tobacco consumption were measured $93.5 \pm 2.8\ Bq/m^3$ and $90.5 \pm 2.7\ Bq/m^3$, respectively. Then Annual Effective dose was calculated 2.54 ± 0.07 and $2.28 \pm 0.06\ mSv/y$. The smoke produced by tobacco consumption has no effect on the concentration of ^{222}Rn and effective dose. In winter, in closed spaces due to low ventilation compared to summer, ^{222}Rn concentration and effective dose is higher in indoor air.

Keywords: radon222 (^{222}Rn), tobacco consumption, effective dose, ventilation

INTRODUCTION

^{222}Rn Is a color and odorless radioactive element with a half-life of 3.8 days produced as a result of the decay of ^{235}U and ^{234}Th series. ^{222}Rn is dangerous due to the emission of alpha particles during decomposition. Long-term inhaling of high concentration ^{222}Rn could lead to an increase in the received effective dose and eventually lead in lung cancer [1, 2]. $1.3 mSv/y$ of the annually received effective dose has its root in the natural radiation ($2.4 mSv/y$) of ^{222}Rn [3, 4]. The Environmental Protection Agency of America [EPA] along with World Health Organization [WHO] proposed the standard ^{222}Rn concentration of the indoor air residential areas to be $148\ Bq/m^3$ and $100\ Bq/m^3$ respectively [5]. The International Commission for Radiological Protection [ICRP] proposed the standard concentration of ^{222}Rn in residential areas and working places to be $500\ Bq/m^3$ and $1000\ Bq/m^3$ respectively [6]. The global average of ^{222}Rn concentration in indoor and outdoor air are $48\ Bq/m^3$ and $15\ Bq/m^3$, respectively [7]. WHO has announced that 15% of lung cancer is due to ^{222}Rn [8]. The United Nations Scientific Committee on the Effects of Atomic Radiation [UNSCEAR] has reported the standard effective dose induced by ^{222}Rn to be $1\ mSv/y$ [9]. The main sources of emitting ^{222}Rn in indoor air are soil, construction materials and water [10]. Among the effective factors on ^{222}Rn concentration in indoor air ventilation is more important. An increase in ventilation would lead to a decrease of ^{222}Rn concentration in indoor air [11]. The smoke produced by tobacco consumption contains 4000 chemical compounds which can be toxic, genotoxic or cancerous [1, 12]. 40 of these compounds including radioactive ^{210}Po and ^{210}Pb are cancerous in nature too. Smokers are ten times as prone to lung cancer as non-smokers [13-16]. Research has indicated that smoking in areas where ^{222}Rn concentration is high increases the probability of affliction with lung cancer [12, 17]. ^{222}Rn Response for 21,000 mortalities caused by lung cancer. About 3,000 cases are among non-smokers. Generally ^{222}Rn could be regarded as the second

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reason for the development of lung cancer. Among non-smokers and smokers exposed to $48\ Bq/m^3$, the mortality rate due to lung cancer has been reported to be 0.002 and 0.02, respectively [12]. Tobacco consumption can increase the concentration of aerosol particles in air. On the other hand the ^{222}Rn of the air can, through connecting to aerosol particles spread by smoking, penetrate the inner parts of lungs and increase the risk of affliction with lung cancer [18, 19]. That is why lung cancer induced by ^{222}Rn is more prevalent among smokers than non-smokers [7, 20]. A great body of research has revealed that the smoke produced by cigarettes can increase the probability of ^{222}Rn induced lung cancer through producing aerosol in the air [19]. Little research has been conducted on the direct effect of smoke produced by tobacco consumption on ^{222}Rn concentration in the air indoors. In the present study, therefore, it has been attempted to delve into the above mentioned effect with regard to other effective variables.

1. Method:

1.1. Measuring ^{222}Rn concentration:

One of the indoor public places of Tehran City was selected for this research, where smoking cigarettes and hubble-bubble was prevalent. According to the protocol proposed by EPA for measuring ^{222}Rn concentration in the inside air using portable instruments, a whole duration of 24 continuous hours was compulsory [21]. First of all, ^{222}Rn [outdoor] background concentration [beside the entrance door] was measured for 24 hours continuously using the portable radon meter $RTM\ 1688-2$. Its concentration was recorded in Bq/m^3 [figure1]. Three 24-hour concentrations of ^{222}Rn without tobacco consumption along with three 24-hour concentrations with tobacco consumption were measured from 7 a.m. to 7 a.m. of the next day in summer and winter, 2011.

1.2. Measuring air ventilation:

One of the significant factors highly affecting indoor air pollutants is air ventilation. In order to determine the degree of its effect on concentration, while measuring ^{222}Rn concentration, the degree of ventilation was also measured. Through measuring airflow speed in Cm/s using a flow meter PCE-TA and also calculating the arithmetic area of the open part of the door and window, the amount of ventilation in summer and winter was measured in m^3/h as in the following equation [22]:

$$Q_{air} = V \times A \times 36 \quad (1)$$

In this equation, Q_{air} is the air flow in m^3/h; V is the speed of air flow in Cm/s; A is the arithmetic area of the open part of the window in m^2 and 36 is the conversion coefficient in m^3/h.

Fig. 1: The portable radon-meter RTM 1688-2 used to measure ^{222}Rn and ^{220}Rn concentration in water, soil and air, manufactured by Sarad Co. in Germany.

2. Measuring the annually received effective dose:

In order to measure the annually received effective dose, equation 2 proposed by UNSCEAR [2000] was utilized. In this equation, C_{Rn} is ^{222}Rn concentration in Bq/m^3; F is the balance factor; T is the exposure time in hours and D is the conversion coefficient of ^{222}Rn concentration to the effective dose.

$$ED = C_{Rn} \times F \times T \times D \times 10^{-6} \quad (2)$$

For the conversion factor of $9nSv/y$ for each Bq/m^3 and for the indoor balance factor, .4 was pre-set. Therefore, the received effective dose in a closed area was measured in mSv/y [23, 24].

Results:

^{222}Rn Concentrations in indoor air both in summer and winter in circumstances with and without tobacco consumption are presented in tables 1 and 2. The 24-hour range and average of ^{222}Rn concentration in indoor air in summer are $55 \pm 3.85 - 80 \pm 5.63\ Bq/m^3$ and $63.5 \pm 4.49\ Bq/m^3$. Without tobacco consumption, they are reported to be $48\pm3.34-82\pm5.74$ Bq/m^3 and 65.5 ± 4.55 Bq/m^3. In winter, the 24-hour range and average of ^{222}Rn concentration in indoor air are 115.8 ± 8.8 Bq/m^3 and 123.4 ± 8.68 Bq/m^3. The average ^{222}Rn concentrations in summer and winter are 101 ± 3.4 Bq/m^3.

Table 1: ^{222}Rn concentration in indoor air, background and ventilation in summer.

ventilation (m^3/hr)	background (Bq/m^3)	Without tobacco consumption (Bq/m^3)	With tobacco consumption (Bq/m^3)	time (hr)
99	25±1.75	55±3.85	53±3.69	8
80	24±1.68	61±4.27	52±3.64	9
68	28±1.96	56±3.92	50±3.50	10
80	34±3.35	60±4.22	55±3.85	11
91	27±1.89	61±4.25	56±3.92	12
84	24±1.68	59±4.15	62±4.35	13
77	24±1.68	62±4.36	58±4.11	14
0	24±1.68	64±4.48	67±4.70	15
0	26±1.82	66±4.62	65±4.55	16
73	15±1.05	61±4.27	65±4.55	17
48	20±1.4	62±4.36	62±4.30	18
38	31±2.17	59±4.13	63±4.46	19
39	35±2.45	57±3.97	55±3.87	20
0	35±2.45	66±4.60	53±3.71	21
0	37±2.59	66±4.60	48±3.34	22
0	34±2.38	64±4.48	55±3.87	23
0	34±2.38	67±4.69	76±5.32	24
0	35±2.45	70±4.88	64±4.50	1
0	35±2.45	80±5.62	75±5.25	2
0	36±2.52	80±5.62	79±5.53	3
0	29±2.03	79±5.51	82±5.74	4
0	28±2.96	76±5.35	76±5.34	5
0	28±1.96	73±5.09	75±5.27	6
0	27±1.89	69±5.85	74±5.15	7
32.4	29±2.08	65.5±4.55	63.5±4.49	average

Table 2: ^{222}Rn concentration in indoor air, background and ventilation in winter.

ventilation (m^3/hr)	background (Bq/m^3)	Without tobacco consumption (Bq/m^3)	With tobacco nsumption (Bq/m^3)	time (hr)
0	27±1.89	108±7.58	140±9.80	8
0	35±2.45	92±6.44	104±7.28	9
0	28±1.96	83±5.81	98±6.80	10
0	31±2.17	99±6.91	104±7.30	11
0	28±1.96	96±6.7	101±7.05	12
0	20±1.40	116±8.1	115±8.05	13
0	25±1.75	128±8.9	119±8.33	14
0	20±1.40	133±9.3	120±8.04	15
0	20±1.40	136±9.5	122±8.56	16
0	18±1.26	109±7.6	120±8.42	17
0	22±1.54	113±7.9	118±8.24	18
0	24±1.68	106±7.4	105±7.86	19
0	20±1.40	108±7.5	112±7.95	20
0	28±1.96	117±8.2	115±8.06	21
0	30±2.10	120±8.3	125±8.70	22
0	31±2.17	116±8.1	124±7.50	23
0	35±2.45	117±8.2	127±8.90	24
0	38±2.66	128±8.9	133±9.30	1
0	34±2.38	129±9.1	144±10.06	2
0	36±2.52	124±8.6	144±10.06	3
0	35±2.45	128±8.9	144±10.06	4
0	35±2.45	131±9.1	145±10.15	5
0	35±2.45	128±8.9	145±10.15	6
0	30±2.10	115±8.03	138±9.66	7
0	28.5±1.93	115.8±8.8	123.4±8.68	average

3. *Discussion:*

In summer, the 24-hour ^{222}Rn average concentrations in indoor air with and without tobacco consumption are 57.1% and 55.8% lower than the EPA standard [148], respectively. They are also 34.5% and 36.5% lower than the standard set by WHO (148 Bq/m^3). In winter, they are respectively 16.7% and 22.3% lower than the EPA standard and 23.4% and 15.8% higher than the standard set by WHO [figure 2].

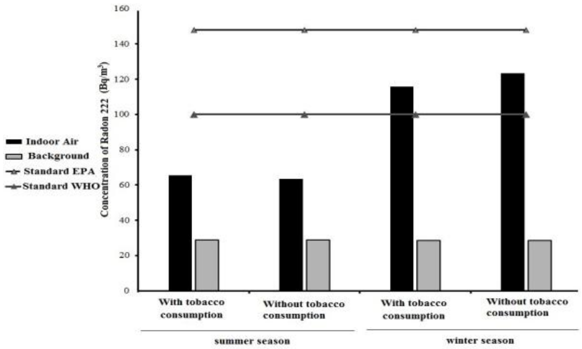

Fig. 2: The average background concentration of ^{222}Rn with and without tobacco consumption in summer and winter.

The ratio of ^{222}Rn concentration of background [outdoor] and indoor air in winter and spring are respectively 44% and 30%. The P-value<0.01 between ^{222}Rn concentration of indoor and outdoor [background] air in summer and winter is indicative of a significant difference between these two variables. The $P_{value} > 0.05$ between ^{222}Rn concentration of indoor air with and without tobacco consumption in winter and spring shows no significant difference between these two variables. The average ^{222}Rn concentrations in indoor air in winter with and without tobacco consumption are respectively 76.6% and 94.3% higher than summer. The higher ^{222}Rn concentration in summer could be due to less indoor ventilation in winter compared to summer.

Variations in ^{222}Rn concentration in indoor air compared to ventilation variations are shown in figures 3 and 4. In summer and winter, between 2 to 4 p.m. and 9 p.m. to 7 a.m. ^{222}Rn concentration in indoor air is higher due to no ventilation since the doors and windows are often closed. For the same reason, the highest ^{222}Rn concentration can be observed between 1 to 6 a.m... P_{value} Between ^{222}Rn concentration and air ventilation is equal to 0.008. Since P_{value} is lower than 0.05, a significant correlation can be said to exist between these two variables. An increase in ventilation leads to a decrease in ^{222}Rn concentration.

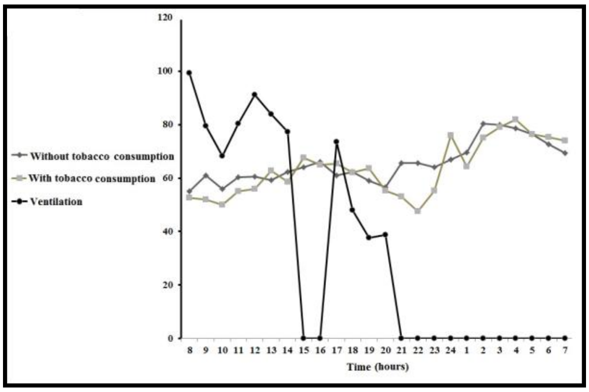

Fig. 3: Variations in ^{222}Rn concentration in indoor air and ventilation along 24 hours in summer.

The values of the received effective dose induced by ^{222}Rn are indicated in table 3. In summer these values in circumstances without and with tobacco consumption are respectively $1.65 \pm .04$ and $1.6 \pm .03$ mSv/y. In winter these values are $2.92 \pm .08$ and $3.48 \pm .1$ mSv/y. Considering the average ^{222}Rn concentration in summer and winter, the annually received effective dose without and with tobacco consumption are estimated to be $2.28 \pm .06$ and $2.54 \pm .07$ mSv/y, respectively.

^{222}Rn Induced effective dose which is received in summer without and with tobacco consumption are respectively 65% and 60% higher than the standard ^{222}Rn induced effective dose $(1\ mSv/y)$. In winter they are respectively 292% and 348% higher than the standard. Considering the average ^{222}Rn concentration in summer and winter, the annually received effective dose is estimated to be $2.54 \pm .07$ mSv/y which is 245% higher than the existing standard.

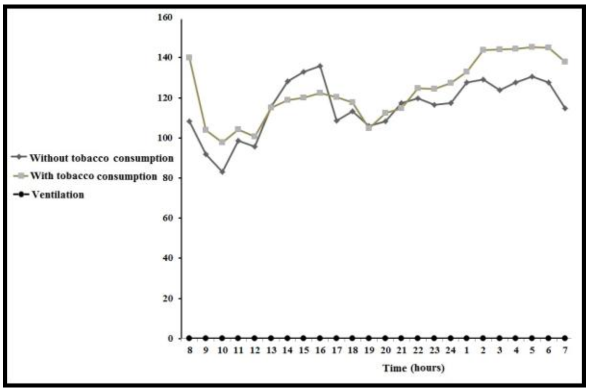

Fig. 4: Variations in ^{222}Rn concentration in indoor air and ventilation along 24 hours in winter.

Table 3: The annually received ^{222}Rn induced effective dose in summer, winter and annually.

		^{222}Rn concentration	Exposure time hr / year	Balance factor	Received effective dose mSv / y
summer	background	29 ± 2.08	1760	0.4	0.18 ± 0.01
	Without tobacco consumption	65.54 ± 4.45	7000	0.4	1.65 ± 0.04
	With tobacco consumption	63.5 ± 4.49	7000	0.4	1.6 ± 0.03
winter	background	28 ± 1.93	1760	0.4	0.19 ± 0.01
	Without tobacco consumption	115.81 ± 8.8	7000	0.4	2.92 ± 0.08
	With tobacco consumption	123.4 ± 8.68	7000	0.4	3.48 ± 0.1
Annual average	background	28.5 ± 0.85	1760	0.4	0.185 ± 0.01
	Without tobacco consumption	90.5 ± 2.7	7000	0.4	2.28 ± 0.06
	With tobacco consumption	93.5 ± 2.8	7000	0.4	2.54 ± 0.07

Conclusion:

The smoke produced by tobacco consumption was found to have no direct effect on ^{222}Rn concentration and annual effective dose. The 24-hour average of ^{222}Rn concentration [average summer and winter season] was lower than WHO and EPA standards. An increase in air ventilation can reduce ^{222}Rn concentration. In winter due to low ventilation compared to summer, ^{222}Rn concentration in indoor air is increased. Therefore, it is recommended to cut down on ^{222}Rn concentration through the provision of more and better air ventilation in closed spaces especially in winter. Accordingly, the effective dose received by people would be reduced as well.

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