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# Radon Gas Concentration Measurement and Assessment of Health Risk in Tehran, Iran

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**ABSTRACT:** In recent years, technology development and using various tools have led to produce environmental contaminations. Radon (Rn-222) is one of the dangerous and fatal indoor air pollution. According to Environment Protection Agency (EPA) and many other international organizations, Radon is major cause of lung cancer after smoking. In present research, Radon measurements have been done in 30 dwellings of Tehran using AEOI devices. According to research achievements, the average Radon concentration in Tehran is measured 104 Bq/m$^3$. Maximum and minimum concentrations are 460.2 Bq/m$^3$ in west and 31 Bq/m$^3$ in north respectively. Risk assessment was done using EPA method. Results showed that independent of age, the lung cancer death rates and risk were 14 times or 12 times (for males and females respectively) greater for ever smokers than never smokers. In conclusion, females are more at risk than males. It was determined people who were older than 70 and also ever smokers are more at risk that must be followed up.

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## 1- Introduction

Radon is a colorless, odorless, with dew point of 62 ˚C and density of 8 times greater than air density. Radon exposure usually occurs primarily indoors [1]. Radon is known as the second cause of lung cancer and the first cause of cancer mortality in the world after tobacco smoking [2, 3]. About 90% of lung cancers occur among ever smokers [4]. Maximum radon level recommended by EPA[1] and WHO[2] is 200 and 100 Bq/m3 respectively; so that it will cause minimum health risks [5]. There is no maximum radon level definition in Iran; thus WHO standard will be used in this study to have minimum risks. Veloso et al. showed that 18-28% out of 8514 lung cancer-induced deaths were caused by radon in north of Portugal [6]. Singh et al. showed that the average inhalation dose in 90 dwellings located in 13 villages of India varies from 1.33 ± 0.31e3.36 ± 0.72 mSv/y that are within the reference level recommended by ICRP[3], 2011 [7]. Jafarizadeh et al. evaluated radon concentration in some Kashan dwellings by AEOI device. The average concentration was more in winter than in other seasons. Moreover, more than 95% of the dwellings had concentrations less than 300 Bq/m$^3$ (safe limit recommended by ICRP) [8]. Tavakol et al. measured radon levels in Tarom, Zanjan by SSNTD. Using 30 samples, results showed an average concentration of 130.57 Bq/m$^3$. 18 samples showed concentrations more than 100 Bq/m$^3$ [9].

Since the cancer rate is incredibly high in Iran, it is absolutely important to discover the main reasons and find practical solutions to reduce them. The main goal of this paper is to measure radon concentration as a lung cancer cause in city of Tehran in order to assess the risk of radon induced lung cancer which has not been done before.

## 2- Methodology

Penetrative Chamber, also known as AEOI, is a device to measure radon concentration designed by Atomic Energy Organization of Iran. AEOI uses a passive method to measure radon concentration. To calculate risk per WLM, there are four steps:

Step 1: Lung cancer death rates for male and female ES and NS:

$$h_{pop}(x) = (1 - p(x))\,h_{NS}(x) + p(x).h_{ES}(x) \quad (1)$$

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1 Environment Protection Agency
2 World Health Organization
3 International commission on radiological protection

where hNS(x), hES(x) and hpop(x) are the respective lung cancer death rates for NS, ES, and the general population. p(x) is the proportion of ES at age x.

Step 2: Choice of a relative risk model: EPA used a scaled concentration model for modeling the relative risks.

Step 3: Applying the chosen (concentration and duration) models: The concentration model used in BEIR VI specifies that the excess relative risk (ERR) depends on time-since exposure (w), rate of exposure (β*) and attained-age (x) according to the formula [10]:

$$ERR = \beta^* \left( w_{5-14} + 0.78 w_{15-24} + 0.51 w_{25+} \right) \quad (2)$$

$$\beta^* = 0.0760 \qquad x < 55y$$

$$\beta^* = 0.0438 \qquad 55y \le x < 65\,y$$

$$\beta^* = 0.0223 \qquad 65\,y \le x < 75y$$

$$\beta^* = 0.0069 \qquad x \ge 75y$$

Step 4: Calculating the average of the age-specific risks of lung cancer death: In order to yield the risk estimates for male and female ES and NS, weighted averages of the age-specific excess lung cancer death rates are calculated. Risk per WLM is obtained according to formula [6]:

$$RWLM = \frac{ERR_x \times N_{x,s}}{1 + ERR_x} \quad (3)$$

Where $N_{a,s}$ is total numbers of lung cancer-induced deaths at age a and gender s.

The age and gender specific data of Tehran population, the age and gender specific ES and NS deaths from lung cancer were derived from the Statistical Center of Iran and Ministry of Health, Treatment and Medical Education respectively for 2011.

## 3- Results and Discussion

In the present work, 30 numbers of AEOI devices were placed in 30 dwellings. Due to the fact that people frequently spend most of their time in indoors, samples were placed in dwellings.

Minimum and maximum radon were found in Shahid araqi (less than 31 Bq/m$^3$) and Shahid Baqeri Town (460.2) respectively. More than 100 Bq/m$^3$ radon concentration was measured in 38% of samples. Tables and figures 1 and 2 show the results.

**Table 1. Average radon concentrations in 5 areas (Bq/m$^3$)**

| Region | Average Concentration |
|---|---|
| north | 71.96 |
| south | 69.81 |
| east | 75.60 |
| west | 153.60 |
| center | 68.24 |

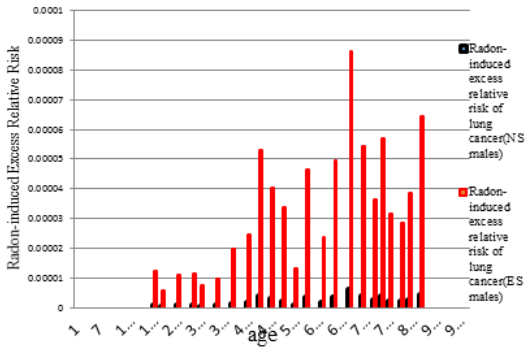


**Figure 1. Age-specific excess relative risks for ES (red) and NS(black) males (from a constant radon exposure at rate 0.327 WLM/y)**

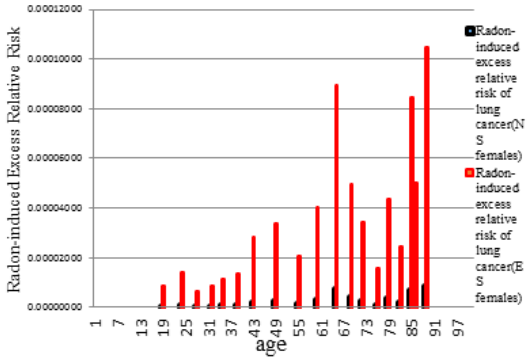


**Figure 2. Age-specific excess relative risks for ES (red) and NS(black) females (from a constant radon exposure at rate 0.327WLM/y)**

**Table 2. Maximum death rates and ERR for males and female ES and NS**

| Sex | Smoking Status | Max. Death Rates | Max. ERR |
|---|---|---|---|
| Male | ES | $6.3645\times10^{-4}$ | $8.6579\times10^{-5}$ |
| | NS | $4.546\times10^{-5}$ | $6.18\times10^{-6}$ |
| Female | ES | $1.0274\times10^{-3}$ | $1.0498\times10^{-4}$ |
| | NS | $8.5616\times10^{-5}$ | $8.7482\times10^{-6}$ |

## 4- Conclusions

It is concluded that the average radon exposure is maximum in west and minimum in center of the city. The center and are introduced as the most immune regions. Maximum rate of lung cancer death occurred for NS and ES males of age 88 years while the maximum radon-induced excess relative risk of lung cancer occurred for NS and ES males of age 70 years. Thus, the lung cancer death rate was 14 times greater for ES than NS among males. Also, Maximum rate of lung cancer death occurred for NS and ES females of age 89 years. The lung cancer death rate was 12 times greater for ES than NS among females. Eventually, the maximum radon-induced excess relative risk of lung cancer occurred for NS and ES

females of age 89 years; therefore, the excess relative risk was 12 times greater for ES than NS among females. In conclusion, danger of radon-induced lung cancer was more significant among ES females and at the age of 70≥.

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