Lung Cancer Risk Due to Radon in Different Brand Cigarette Tobacco in Iraqi Market

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ABSTRACT--- ***Sealed can technique using CR-39 plastic track detector strippable has been used in order to measure radon concentrations to calculate the annual effective dose and lung cancer cases per year per million person for twenty different brand tobacco cigarette were collected from Iraqi market. Lung cancer is the leading cause of cancer-related deaths worldwide. Radon exposure is the second leading cause of lung cancer, following tobacco smoke. Radon is not only an independent risk factor; it also increases the risk of lung cancer in smokers.***

It has been observed that tobacco smoking increases the risks of radon-induced lung cancer. Radon and cigarette smoking have synergistic, multiplicative effect on lung cancer rates. People who inhale tobacco smoke are exposed to higher concentrations of radioactivity. Ever since studies on the relation of smoking to cancer, particularly the lung cancer has been established, there had been a great interest in studies concerned with the monitoring of the alpha radioactivity in tobacco. The results showed that the ^{222}Rn concentrations in cigarette tobacco samples ranged from (156.450 to 403.087) Bq/m^3 with an average 284.751 Bq/m^3, while the radon induced lung cancer risks was found to vary from 71.047 to 183.049 with an average value of 129.3107 per million person, and standard deviation 83.529 and 37.932, respectively. Excellent correlation has been observed between radon concentration and lung cancer cases per year per million person for different brand tobacco cigarettes.

Keywords--- Radon, tobacco, lung cancer, CR-39 nuclear track detectors

1. INTRODUCTION

Currently about 3000 people die from lung cancer every day [1]. Fortunately, we know pretty well what the most common causes for lung cancer are. 90% of all lung cancer cases are due to tobacco use [2]. The second largest cause of lung cancer is radon. Among non-smokers, radon is the largest cause for lung cancer. People exposed to radon have an increased risk of lung cancer [3]. The reason for this is that the radon and its daughter nuclei follow the air into the lung where they can decay and deposit their radiation [4].

The cigarette is increasingly becoming a crutch for many in this pressure-laden world, and they opt for this easy way out despite the hard facts of it is hazardous. It is not only them, but also the people near them, who sometimes pay dearly for this habit. Studies after studies have confirmed that this is a dangerous habit. Tobacco smoke has toxic, genotoxic, and carcinogenic properties and has been linked to fatal pregnancy outcomes [5].

Tobacco smoke contains more than 4000 different chemicals, most of which are generated during the combustion process. More than 40 compounds are carcinogenic, which include some radionuclides such as polonium (^{210}Po) and lead (^{210}Pb) [6].

Smoking cigarettes greatly increases your chance of developing lung cancer if you are exposed to radon and radon progeny at the same levels as people who do not smoke. Because tobacco is naturally sticky, many of the radon decay products actually sticks to tobacco products. Therefore, when tobacco is smoked or otherwise used, these radon products may also enter your system. Breathing in other substances that cause lung cancer may also increase your chance of developing lung cancer from exposure to radon progeny [7].

Radioactivity in cigarette smoke was measured by several authors, and it was suggested that ionizing radiation from cigarette smoke could originate a meaningful exposure of lung tissues. Smokers are 10 times at greater risk of developing lung cancer than that of nonsmokers [8-10].

Radon and its progeny are the greatest sources of natural radioactivity. It has been estimated that inhalation of short-lived radon progeny accounts for more than half of the effective dose from natural sources [11-15].

Radon (^{222}Rn) is a radioactive noble gas that results from the decay of radium (^{226}Ra). It is part of the decay chain of uranium (^{238}U) (sometimes called the radium decay chain) and is thus naturally occurring wherever uranium can be found. At room temperature, it is a colorless, odorless gas [16].

Radon can damage the respiratory epithelium (the cells that line the lung) through the alpha-particle emissions. The damage to epithelial cells of the lung occurs when radiation interacts either directly with DNA in the cell nucleus or indirectly through the effect of free radicals [17,18]. Radon is the number one cause of lung cancer among nonsmokers, according to EPA estimates [19]. Overall, radon is the second leading cause of lung cancer. Radon is responsible for about 21000 lung cancer deaths every year. About 3000 of these deaths occur among people who never smoked. Exposed to 1.3 pCi/L (the average indoor radon level) never-smokers have a 2 in 1000 chance of dying from lung cancer, while smokers exposed to same level have a 20 in 1000 chance. The World Health Organization (WHO) says radon causes up to 15% of lung cancers worldwide [20].

Secondhand smoke (referred to as environmental tobacco smoke) is the third leading cause of lung cancer and responsible for an estimated 3,000 lung cancer deaths every year. Smoking affects nonsmokers by exposing them to secondhand smoke. The lung cancer risk from secondhand smoke exposure is 20%–30% higher for those living with a smoker [18]. The epidemiological and biochemical evidence on exposure to environmental tobacco smoke (ETS) provides compelling confirmation that breathing other people's tobacco smoke is a cause of lung cancer. When evidence from various studies is combined, they indicate that exposure to ETS increases the number of lung cancers detected in nonsmokers. Nonsmoking coworkers of smokers have a relative risk of approximately 1.39 [17,18]. Radon and several of its daughters give off alpha-radiation as they decay. This radiation can severely damage the lungs and if the DNA is injured, this might lead to cancer. It is also possible that the heavy metal radon daughters (such as lead) can contribute to the overall increase in lung cancer risk through chemical impact. Inorganic lead has been classified as “probably carcinogenic to humans” by the International Agency for Research on Cancer [20]. Apart from this lead is also known to be neurotoxic to humans [21].

Chemical analysis of tobacco smoke is not easy. The curing, filtering and all the additives in commercial cigarettes differ from one brand to another. All in all tobacco smoke consists of several thousand chemical compounds [22]. Several of these are potent carcinogens. Some important constituents of tobacco smoke are polycyclic aromatic hydrocarbons (PAH) and these are in fact also found in other types of smoke. Other constituents are more unique to tobacco smoke, such as nicotine and tobacco specific nitrosamines. In 1950 Doll and Hill published an article [23] which clearly proved the connection between tobacco smoking and lung cancer. In 1986 the International Agency for Research on Cancer published a monograph [24] that concludes that tobacco smoking is carcinogenic to humans. By the year 2000 smoking had either peaked or declined in all developed countries, but it continued to rise in the developing world. Still today cigarette smoking is the leading cause of lung cancer [25]. The World Health Organization estimates that every year as many as 5 million people die from tobacco use [26]. As it turns out, radon affects smokers more than non-smokers [27, 28, 29].

Radon and its progeny are the greatest sources of natural radioactivity. It has been estimated that inhalation of short-lived radon progeny accounts for more than half of the effective dose from natural sources [12-15, 30]. Numerous cohort, case-controlled, and experimental studies have established the carcinogenic potential of radon [17,18,31]. Prolonged exposure to radon may cause a negative effect on human health, causing lung cancer and bronchial tissue damage. Indoor radon and its decay product usually come from soil, building material and water supply. Because the decay product carries high electric charges they readily attach themselves to indoor dust particle [32,33].

Subsequent inhalation of radon and its short-lived decay products is considered an etiological factor for lung cancer [32,34,35]. Lung cancer is the leading cause of cancer-related deaths worldwide. Lung cancer kills thousands of Americans every year. Smoking, radon, and secondhand smoke are the leading causes of lung cancer. Smoking is the leading cause of lung cancer. Smoking causes an estimated 160 000 cancer deaths in the United States every year. And the rate among women is rising. A smoker who is also exposed to radon has a much higher risk of lung cancer [36].

Radon (^{222}Rn) in air is ubiquitous. Radon is a form of ionizing radiation and proven carcinogen [33]. Lung cancer is the only known effect on human exposure to radon in air [37]. Lubin et al. [38] reported that, in the United States, exposure to radon progeny may account for 10% of all lung cancer deaths and 30% of lung cancer deaths in nonsmokers, while an estimate from the National Academy of Sciences BEIR VI committee suggests 21,800 lung cancer cases annually, resulting from radon exposure with uncertain bounds from 3,000 to 33,000, making this the second leading cause of lung cancer in the United States [37,38]. Radon can damage the respiratory epithelium (the cells that line the lung) through the alpha-particle emissions. The damage to epithelial cells of the lung occurs when radiation interacts either directly with DNA in the cell nucleus or indirectly through the effect of free radicals [17,18].

The U.S. Environmental Protection Agency (EPA) states that exposure to tobacco smoke, especially directly from smoking, but also from secondhand smoke, when coupled with exposure to radon gas, can significantly increase the risk of lung cancer, when compared to either smoking or radon exposure alone. In fact, most radon related lung cancer cases occur in individuals who also smoke, demonstrating a synergistic effect between tobacco smoke and radon. The synergistic effects of radon gas and smoking have been well documented through years of research and scientific studies [39].

Indoor cigarette smoking enhances the air concentration of submicron particles, which trap radon decay products. It has been reported that radon decay products that pass from room air through burning cigarettes into mainstream smoke are present in large, insoluble smoke particles that selectively deposited at the bronchial bifurcation of the inhabitant [28-30] where the attached radon progeny undergo substantial radioactive decay before clearance. Consequently, in addition to the traditional implication of smoking cigarette in lung cancer, the high incidence of lung cancer in cigarette smokers and nonsmokers may be attributed to the cumulative effect of alpha radiation dose from indoor radon and thoron progenies generated and/or trapped by tobacco and its smoke [32-34].

The purpose of this study, to estimate the number of people who may be exposed to lung cancer from inhaling radon emitted from tobacco cigarettes available in the Iraqi market.

2. MATERIALS AND METHODS

In this study, twenty one different brand tobacco cigarettes imported collections from the Iraqi market have been measured through “Sealed cup technique” containing CR-39 solid state nuclear detector as shown in Figure 1. Then drying the samples by exposing them to air and sunlight to get rid of the moisture. After that milled samples and became the powder form was then screened using a very small standard sieve to obtain a fine powder and free of impurities and large objects. In this technique, the same weight of the tobacco cigarette sample was placed in an emanation chamber, which was then closed for a period of four weeks in order to get equilibrium between radium and radon. After that, remove the cover and quickly put the lid last detector installed nuclear effect for the purpose of maintaining the status of the radiation equilibrium.

The use of SSNTDs is a convenient technique for low activity measurements since it is of low cost, is a simple operation, has high registration sensitivity, and has the possibility of use for long period exposures without any fading. CR-39 is very useful in the detection of alpha particles from disintegration of radon and radon daughters [12,33,35,40]. The concentration and exhalation rate of radon can be measured using CR-39 detectors because of their capability to register tracks at different levels of registration sensitivity. The CR-39 detectors used in this work were supplied by charleswater.co.uk and Vermason.co.uk, USA, in the form of large sheets that were cut into 1 x 1 cm^2. Cigarettes of 21 different brands were purchased from local markets in Iraq. A fixed amount (10g) of tobacco sample was placed in plastic containers. The container was 6.5 cm in height and 3.5 cm in diameter. The cups were left at room temperature for 60 days exposure time. During this time alpha particles from the decay of radon and their daughters bombarded the CR-39 nuclear track detectors in the air volume of the cup. After exposure the detectors were etched chemically in 6N NaOH solution at 70°C for 8 h to reveal the tracks. The tracks were counted using an optical microscope with magnification 100X.

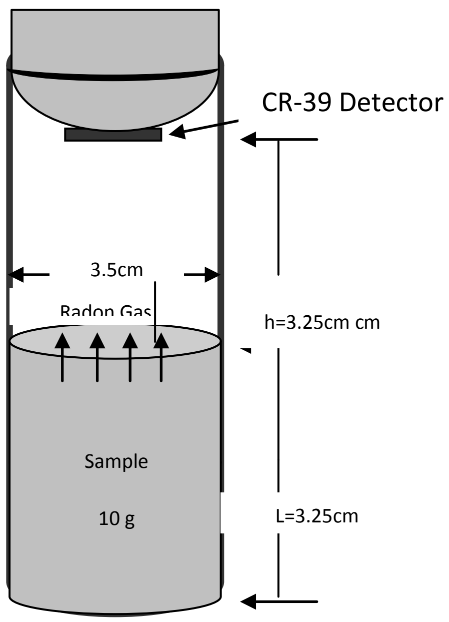

Figure 1: A schematic diagram of the sealed-cup technique.

3. RESULTS AND DISCUSSION

For the purpose of calculating ^{222}Rn concentration levels in the various brand tobacco samples, the radon concentration (C) in the can air above the samples were determined by measuring the track density on the detector according to the following relation [41]:

$$C\ (Bq/m^3) = \frac{\rho}{k.t} \qquad (1)$$

Where *C* is the ^{222}Rn concentration in the test tube above the sample measured in (Bq/m^3), ρ is the surface density of tracks on the exposed detectors(Tr/cm^2), *t* is the exposure time(60 day) and (k) is the calibration factor which was found experimentally to be equal to (0.223 ∓ 0.011 track.cm^{-2}/ Bq.d.m^{-3}) [42].

The radon concentration in the various brand tobacco samples (C_{Rn}) in the test tube was calculated by using a model proposed by Somogyi [43]. According to this model, the number of radon atoms exhaled from the sample surface is equal to the number of radon atoms in the can air above the various brand tobacco samples multiplied by the probability of decay, which can be written in the following form [43, 44]:

$$C_{Rn}(Bq/m^3) = \frac{C.\lambda.h.t}{L} \qquad (2)$$

Where, *λ: decay* constant for (^{222}Rn) , *h:* distance from the powder surface to the detector = 3.25 cm., *t:* exposure time = 60day, *L:* depth of the powder (3.25cm).

The Potential Alpha Energy Concentration (PAEC) in terms of (WL) units was obtained using the relation [45-47] :
PAEC (WL) = F × C / 3700 (3)

Where (F) is the equilibrium factor between radon and its progeny and it is equal to (0.4) as suggested by (UNSCEAR, 2000) [48].

Exposure to radon progeny (EP) is then related to the average radon concentration C by following expression [49]:
EP (WLM Y^{-1}) = 8760 × n × F × C / 170 × 3700 (4)

Where C is in Bq.m^{-3} , n is the fraction of time spent indoors, which is equal to (0.8) ,8760 is the number of hours per year ,170 is the number of hours per working month.

The annual effective dose (AED) in terms of (mSv/y) units was obtained using the relation [50-52] :
AED (m Sv/y) = C × F × H × T × D (5)

Where (H) is the occupancy factor which is equal to (0.8), (T) is the time in hours in a year, (T=8760 h/y), and (D) is the dose conversion factor which is equal to [9×10^{-6} (m Sv) / (Bq.h.m^{-3})] .

The lung cancer cases per year per million person (CPPP), was obtained using the relation [45,53,54]:
(CPPP) = AED × (18×10^{-6} mSv^{-1}.y) (6)

In the present work radon concentrations, were measured in different for 21 different brand tobacco cigarette in the Iraqi market. Table 1 summarizes the results obtained in the present work for radon gas concentrations in brand tobacco cigarette in the Iraqi market, it can be noticed that, the highest radon concentration in the can air above the brands tobacco cigarette samples was found in PI (Pin- Korea) which was (403.087 Bq/m^3), while the lowest radon concentration was found in MA (Marlboro-Turkey) which was (156.450Bq/m^3), with an average value of (284.751 Bq/m^3) and standard deviation 83.529, which is less than even the lower limit of the recommended range (200-300 Bq/m^3) (ICRP, 2009) [55].

The dissolved radon concentration of the brands tobacco cigarette samples varies between 1.702×10^3 Bq/m^3 to 4.387Bq/m^3 with an average 3.099×10^3 Bq/m^3 and standard deviation 0.909×10^3.

The highest value of the potential alpha energy concentration (PAEC) was found in PI (Pin- Korea) which was (43.576 mWL), while the lowest value of the potential alpha energy concentration was found in MA (Marlboro-Turkey) which was (16.913mWL) with an average value (46.735 mWL) and standard deviation 9.030. All results of the potential alpha energy concentration (PAEC) in for 21 different brand tobacco cigarette in Iraqi market lower than the recommended value of (53.33 mWL) reported by the (UNSCEAR, 1993) [56]. The highest value of exposure to radon progeny (EP) was found in PI (Pin- Korea) which was equal to (1.796 WLMY^{-1}), while the lowest value of (EP) was found in MA (Marlboro-Turkey) which was equal to (0.697 WLMY^{-1}), with an the average value of (1.269 WLMY^{-1}) and standard deviation 0.732. All results of (EP) in for 21 different brand tobacco cigarette in Iraqi market were lower than the even the lower limit of the recommended range (1-2 WLMY^{-1}) (NCRP, 1989) [45]. Also from Table (1), it can be noticed that, the annual effective dose (AED) received by the residents of the for 21 different brand tobacco cigarette in Iraqi market varies from (3.947 mSv /y) to (10.196 mSv/y) with an average value of (7.183 mSv/y) and standard deviation 2.107. In all the for 21 different brand tobacco cigarette in Iraqi market surveyed in the present work, the annual effective dose is less than even the lower limit of the recommended range (3-10 mSv/y) (ICRP, 1993) [57].

Figure 2 shows the annual effective dose(AED) in different brand tobacco samples in the Iraqi market. The radon induced lung cancer risks for 21 different brand tobacco cigarette in Iraqi market was found to vary from (71.047) to (183.049) with an average value of (129.310) per million person and standard deviation 37.932. These values are less than the lower limit of the range (170-230) per million person recommended by the (ICRP, 1993) [57]. Finally, we can say that all the results obtained in this study is less than the results obtained by some researchers earlier study conducted on some of the samples tobaccos used in the Iraqi market [58]. Excellent correlation has been observed between radon concentrations and lung cancer per year per million person In all the for 21 different brand tobacco cigarette in Iraqi market shown in figures 3 .

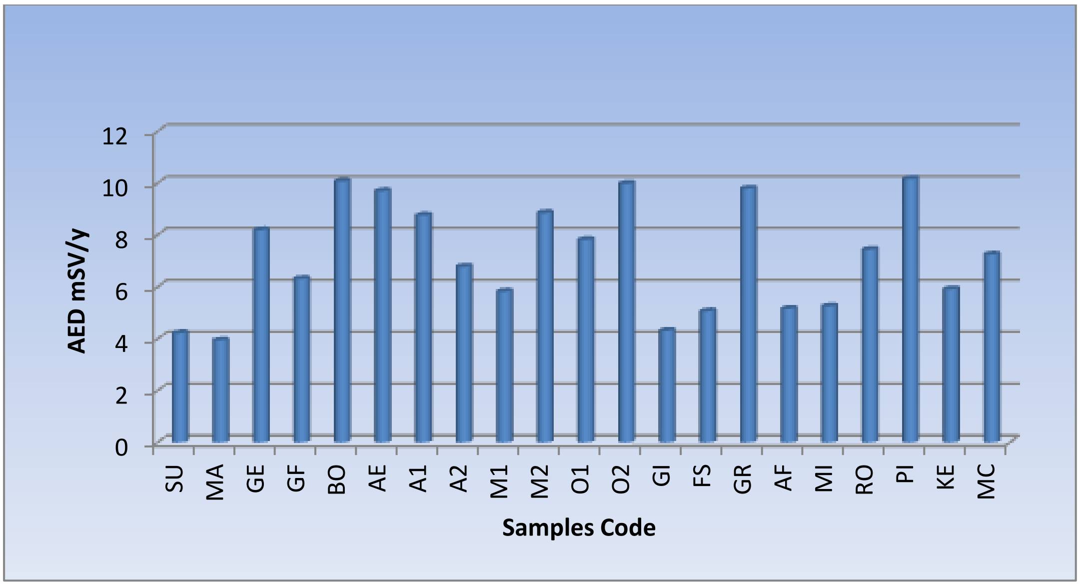

Figure 2: The annual effective dose(AED) in different brand tobacco samples in Iraqi market.

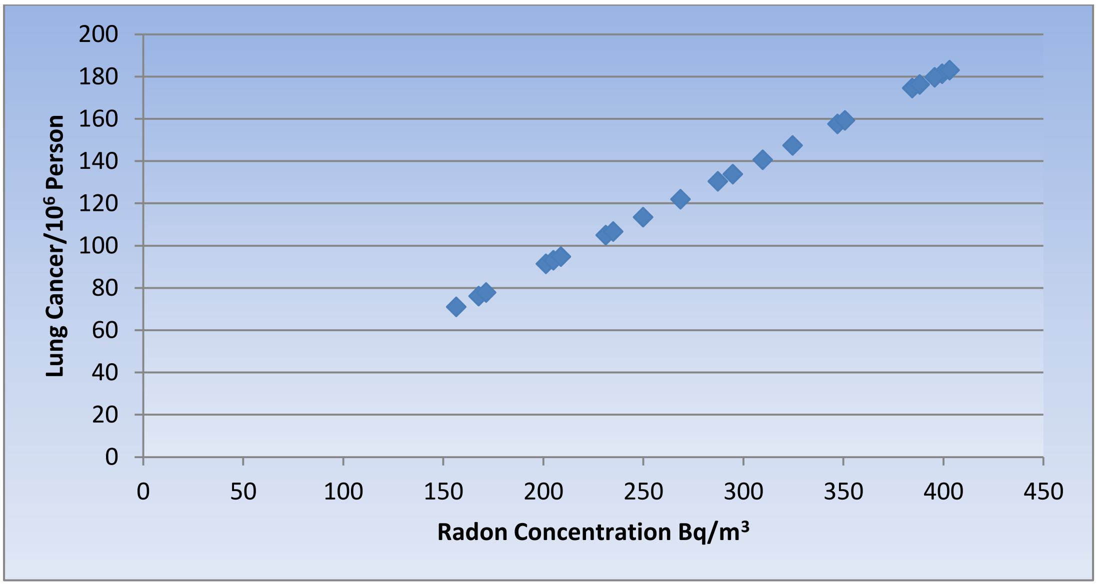

Figure 3: Correlation between radon concentration and lung cancer per year per million person.

Table 1: Radon gas concentration (C) in the can air above the samples, Radon gas concentration in the various brand tobacco samples (C_{Rn}), potential alpha energy concentration (PAEC), exposure to radon progeny (EP), annual effective dose (AED), and lung cancer cases per year per million person (CPPP).

Sample Code	Sample	Origin	$\rho\times10^3$ Trac/cm^2	C Bq/m^3	$C_{Rn}\times10^3$ Bq/ m^3	PAEC mWL	EP WLM/Y	AED m Sv/y	Lung cancer/10^6 person
SU	Sumer	Iraq	2.243	167.661	1.824	18.125	0.747	4.230	76.138
MA	Marlboro	Turkey	2.093	156.450	1.702	16.913	0.697	3.947	71.047
GE	Gauloises	European	4.343	324.611	3.533	35.093	1.447	8.190	147.412
GF	Gauloises	France	3.343	249.873	2.719	27.013	1.114	6.304	113.472
BO	Bon	USA	5.343	399.350	4.346	43.172	1.780	10.075	181.352
AE	Aspen	England	5.143	384.402	4.183	41.556	1.713	9.698	174.564
A1	Aspen 1	Germany	4.643	347.033	3.777	37.517	1.547	8.755	157.594
A2	Aspen 2	Germany	3.593	268.558	2.922	29.033	1.197	6.775	121.957
M1	Mastar 1	Armenia	3.093	231.188	2.516	24.993	1.030	5.833	104.987
M2	Master 2	Armenia	4.693	350.770	3.817	37.921	1.563	8.850	159.291
O1	Oscar 1	USA	4.143	309.664	3.370	33.477	1.380	7.812	140.624
O2	Oscar 2	USA	5.293	395.613	4.305	42.768	1.763	9.981	179.655
GI	Gitanes	France	2.293	171.398	1.865	18.529	0.764	4.324	77.835
FS	Five star	Jordan	2.693	201.293	2.190	21.761	0.897	5.078	91.411
GR	Graven	England	5.193	388.139	4.224	41.960	1.730	9.792	176.261
AF	Afaair	UAE	2.743	205.030	2.231	22.165	0.914	5.173	93.108
MI	Miami	UAE	2.793	208.767	2.272	22.569	0.930	5.267	94.805
RO	Royale	France	3.943	294.716	3.207	31.861	1.313	7.435	133.836
PI	Pine	Korea	5.393	403.087	4.387	43.576	1.796	10.169	183.049
KE	Kent	British	3.143	234.925	2.556	25.397	1.047	5.927	106.684
MC	Mac	Switzerland	3.843	287.242	3.126	31.053	1.280	7.247	130.442
Mean			3.809	284.751	3.099	30.783	1.269	7.183	129.3107
Maximum			5.393	403.087	4.387	43.576	1.796	10.169	183.049
Minimum			2.093	156.45	1.702	16.913	0.697	3.947	71.047
Standard Deviation			1.117	83.529	0.909	9.030	0.732	2.107	37.932

4. CONCLUSION

Radon is one of the largest causes for lung cancer in the world. In fact, it is second only to smoking. It has been observed that tobacco smoking increases the risks of radon-induced lung cancer, but there does not appear to be any theory that quantitatively describes why this is. Tobacco smoking is fatal in many ways and has severe health, economic, and social consequences. Although the natural radioactivity in tobacco could be one of the main reasons for the health impacts of tobacco smoking, there are very limited publications on natural radionuclides concentration in tobacco. The results of this study indicate the existence of a wide range of variations in ^{222}Rn we wish to emphasize on the urgent needs for more research on the activity concentration of natural radionuclides in tobacco and tobacco products, their behavior during smoking, and on their concentration in smoke and smoker's intake. Excellent correlation has been observed between radon concentrations and lung cancer per year per million person for all brand tobacco cigarette.

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