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A Study of Radon Concentration in Different Brands Tobacco Cigarette in Iraqi Market, Influencing Factors and Lung Cancer Risk

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ABSTRACT

In the present study ten different brands tobacco cigarette were collected from Iraqi market. Sealed can technique using CR-39 plastic track detector strippable has been used in order to measure radon concentrations to calculate annual effective dose and lung cancer cases per year per million person. Etching was done with 6.25 M NaOH and optical microscope was used with the purpose of counting of alpha particle tracks. Measurements of radon concentrations in tobacco cigarette are important from the health protection point of view, so simple and reliable analytical methods must be available. 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. 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 227.856 Bq/m^3 to777.877 Bq/m^3 with an average 432.304 Bq/m^3, while the radon induced lung cancer risks was found to vary from 103.473 to 353.203 with an average value of 196.317 per million person, respectively. Excellent correlation has been observed between radon concentration and lung cancer cases per year per million person for different brands tobacco cigarette.

Keywords: *Radon, tobacco, effective dose, lung cancer, CR-39, nuclear track detectors.*

1. INTRODUCTION

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 [1]. Radon is a carcinogen [2], which doesn't come as a surprise knowing that it is radioactive. When radium decays into radon it emanates from the rock and goes off into the air. Higher concentrations of radon are gathered in enclosed spaces such as mines and houses. Radon mainly enters houses from the soil under the house [1], and to a lesser degree through building materials and water [3]. Being a noble gas radon it is somewhat difficult to stop (though not impossible as we will soon find out). The usual method is instead to employ extra ventilation. Radon decays with a half-life of about four days. Its daughters (decay products) on the other hand are much shorter lived with half-lives of between a few milliseconds up to about half an hour. The decay chain comes to a pause with lead (^{210}Pb) which, with a half-life of 22.3 years, can almost be considered stable. This lead isotope can be accumulated in the body to significantly measurable levels [4]. The decay finally stops with another lead isotope, namely ^{206}Pb, which is stable.

Currently about 3000 people die from lung cancer every day [5]. Fortunately we know pretty well what the most common causes for lung cancer are; 90% of all lung cancer cases are due to tobacco usage [6]. The second largest cause for 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 [2]. 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 [7]. 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 [8]. Apart from this lead is also known to be neurotoxic to humans [9].

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 [10]. 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 [11] which clearly proved the connection between tobacco smoking and lung

cancer. In 1986 the International Agency for Research on Cancer published a monograph [12] 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 [6]. The World Health Organization estimates that every year as many as 5 million people die from tobacco use [13]. As it turns out, radon affects smokers more than non-smokers [14, 7, 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 being 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 [15].

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) [16]. 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 [17-19].

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 [20-24]. Numerous cohort, case-controlled, and experimental studies have established the carcinogenic potential of radon [25-27]. Prolonged exposure to radon may cause a negative effect on human health, causing lung cancer and bronchial tissue damage. Indoor radon and its decay products usually come from soil, building materials, and water supply. Because the decay products carry high electric charges, they readily attach themselves to indoor dust particles [28,29]. Subsequent inhalation of radon and its short-lived decay products is considered an etiological factor for lung cancer [28,30,31]. 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 [32].

Radon (^{222}Rn) in air is ubiquitous. Radon is a form of ionizing radiation and proven carcinogen [29]. Lung cancer is the only known effect on human exposure to radon in air [33]. Lubin et al. [34] 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 [33,34]. 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 [25,26].

Radon is the number one cause of lung cancer among nonsmokers, according to EPA estimates [35]. Overall, radon is the second leading cause of lung cancer. Radon is responsible for about 21,000 lung cancer deaths every year. About 3,000 of these deaths occur among people who never smoked. Exposed to 0.481 nBq/L (the average indoor radon level) never-smokers have a 2 in 1,000 chance of dying from lung cancer, while smokers exposed to same level have a 20 in 1,000 chance. The World Health Organization (WHO) says radon causes up to 15% of lung cancers worldwide [36].

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 [26]. 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 [25,26].

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 [35].

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 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 [29,31].

The aims of the present study are to determine radon level in Different Brands Tobacco Cigarette in Iraqi Market and to calculate potential alpha energy concentration (PAEC), exposure to radon progeny (EP), annual effective dose (AED), and lung cancer cases per year per million person (CPPP).

2. MATERIALS AND METHODS

In the present work, ten different brands of imported tobacco cigarette were sampled from the Iraqi market and measured through "Sealed cup technique" containing CR-39 solid state nuclear detector as shown in Figure 1. The samples were then dried by exposing them to air and sunlight to get rid of moisture. The open dried samples were then milled into powder form and sieved using a very small standard sieve to obtain a fine powder and free of impurities and large objects.

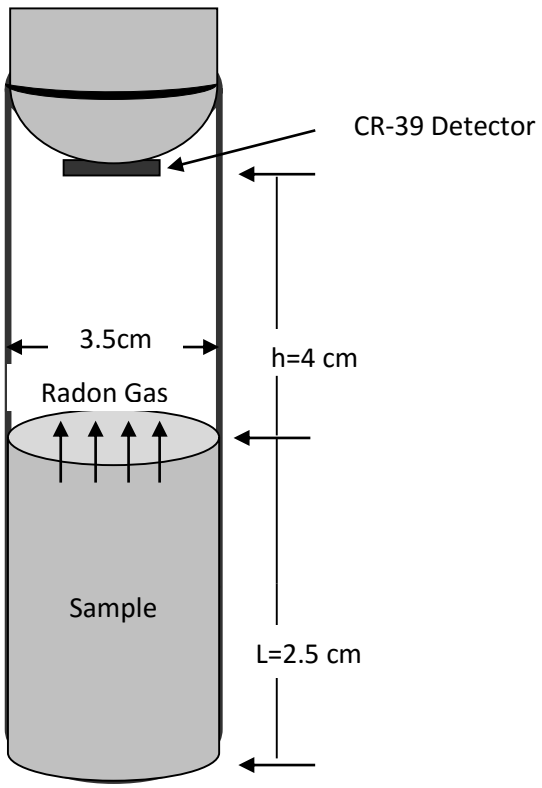

Figure 1: A schematic diagram of the sealed-cup technique.

In this technique, the same weight of the tobacco cigarette samples 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, the cover was removed 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 [21, 29, 31, 37]. 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 Pershore Mouldings, UK, in the form of large sheets that were cut into 1 x 1 cm^2. Cigarettes of 10 different brands were purchased from local market in Iraq.

A fixed amount (7.2g) 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 57 day 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 6 M NaOH solution at 70°C for 8 h to reveal the tracks. The tracks were counted using an optical microscope with magnification 100X.

For the purpose of calculating ^{222}Rn concentration levels in the various brand tobacco samples, the radon activity density (C) in the can air above the samples were determined by measuring the tracks density on the detector according to the following relation [38]:

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

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(57 day) and (k) is the calibration factor which was found experimentally to be equal to (0.045987 $track.cm^{-2}/Bq.d.m^{-3}$) [39].

The radon activity density in the various brand tobacco samples (C_{Rn}) in the test tube was calculated by using a model proposed by Somogyi [40]. 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 sample multiplied by the probability of decay, which can be written in the following form [40, 41]:

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

where,

λ: decay constant for (^{222}Rn) , *h:* distance from the powder surface to the detector = 0.045 m., *t:* exposure time = 57day, *L:* depth of the powder (2.5cm).

The Potential Alpha Energy Concentration (PAEC) in terms of (WL) units was obtained using the relation [42-44]:

$$PAEC\ (WL) = F \times C / 3700 \quad (3)$$

where (F) is the equilibrium factor between radon and its progeny and it is equal to (0.4) as suggested by (UNSCEAR, 2000) [45].

Exposure to radon progeny (EP) is then related to the average radon concentration C by following expression [46]:

$$EP\ (WLM\ Y^{-1}) = 8760 \times n \times F \times C / 170 \times 3700 \quad (4)$$

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 [47-49]:

$$AED\ (m\ Sv/y) = C \times F \times H \times T \times D \quad (5)$$

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 [42,50,51]:

$$(CPPP) = AED \times (18\times10^{-6}\ mSv^{-1}.y) \quad (6)$$

3. RESULTS AND DISCUSSION

In the present work, radon concentrations were measured in 10 different imported brands of tobacco cigarette in the Iraqi market. Table 1 summarizes the results obtained in the present work for radon gas concentrations in brands tobacco cigarette in Iraqi market.

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	ρ (Trac/cm^2)	C (Bq/m^3)	C_{Rn} (Bq/ m^3)	PAEC (mWL)	EP (WLM/Y)	AED (m Sv/y)	Lung cancer/10^6 person
BO	Bon	USA	1241.623	473.664	7836.735	51.207	2.111	11.950	215.099
AS	Aspen	Germany	961.764	366.901	6070.353	39.665	1.635	9.256	166.616
MA	Mastar	USA	1072.310	409.073	6768.089	44.224	1.823	10.320	185.767
GI	Gitanes	France	1220.458	465.590	7703.153	50.334	2.075	11.746	211.433
FI	Five star	Jordan	808.924	308.594	5105.677	33.362	1.375	7.785	140.138
GR	Graven	England	2038.801	777.778	12868.280	84.084	3.466	19.622	353.203
AF	Afaair	UAE	752.487	287.064	4749.462	31.034	1.279	7.242	130.361
MI	Miami	UAE	710.159	270.917	4482.301	29.288	1.207	6.835	123.028
RO	Royale	France	1928.254	735.605	12170.540	79.525	3.278	18.558	334.052
PI	Pine	Korea	597.284	227.856	3769.870	24.633	1.015	5.749	103.473
Mean			1133.206	432.304	7152.446	46.735	1.926	10.906	196.317
Maximum			2038.801	777.778	12868.280	84.084	3.466	19.622	353.203
Minimum			597.284	227.856	3769.870	24.633	1.015	5.749	103.473

An average value of 432.304 Bq/m^3 was recorded for the radon concentration in the can air above the brands tobacco cigarette samples (Table 1). The highest value was found to be 777.778 Bq/m^3 in GR (Graven), while the lowest radon concentration was found in PI (Pine) to be 227.856 Bq/m^3. Figure 2 shows the different concentrations of radon between the 10 different brands of tobacco cigarettes.

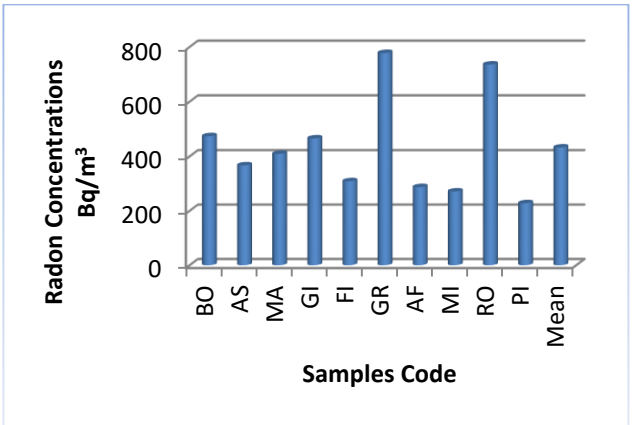

Figure 2: Radon Concentrations in the can air above the tobacco samples.

It can be said that the concentration of radon in the can air above the brands tobacco cigarette AF (Afaair), MI (Miami) and PI (Pine) identical with recommendations range (200-300 Bq/m^3) by ICRP [52]. However, the concentrations of radon in Tobacco cigarettes BO (Bon), AS (Aspen), MA (Master), GI (Gitance), FI (Five star), GR (Graven) and RO (Royale) higher than the concentrations of radon as recommended by ICRP [52].

The dissolved radon concentration for the brands tobacco cigarette samples varies between 3769.870 Bq/m^3 to 12868.280 Bq/m^3 with an average 7152.446 Bq/m^3. The highest value of the potential alpha energy concentration (PAEC) was found in GR (Graven) which was 84.084 mWL, while the lowest value of the potential alpha energy concentration was found in MI (Miami) which was 24.633mWL with an average value 46.735 mWL. All results of the potential alpha energy concentration (PAEC) in 8 of the different brands tobacco cigarette in Iraqi market were lower than the recommended value of 53.33 mWL reported by the UNSCEAR [53], while the result in the samples GR and RO were higher.

The highest value of exposure to radon progeny (EP) was found in GR with an estimated value of 3.466 WLMY^{-1}, while the lowest value of (EP) was found in PI to be 1.015 WLMY^{-1}, with an the average value of 1.926 WLMY^{-1}. The results of (EP) in for BO, GI, GR and RO brands tobacco cigarette in Iraqi market were higher than limit of the recommended range of 1-2 WLMY^{-1} by NCRP [54]. The remaining results of the samples were within allowable limits of the recommended values.

The annual effective dose (AED) as observed from Table (1), for the 10 different brands tobacco cigarette in Iraqi market varies from 5.749 mSv /y in PI to 19.622 mSv/y in GR with an average value of 10.906 mSv/y. In other words, The annual effective dose in the samples AS, FI, AF, MI and PI were within the allowable limits (3-10 mSv/y) recommended by range ICRP, whereas the doses in the other samples BO, MA, GI, GR and RO were higher than the allowable limits recommended [55].

The radon induced lung cancer risks for the 10 different brands tobacco cigarette in Iraqi market was found to vary from 103.473 in PI to 353.203 in GR with an average value of 196.317 per million person. These values are less than the lower limit of the range, 170-230 per million person recommended by the [55] except for the sample GR and RO which were higher than the recommended limit. Excellent correlation has been observed between radon concentrations and lung cancer per year per million person in all the 10 different brands tobacco cigarette in Iraqi market as shown in figures 3.

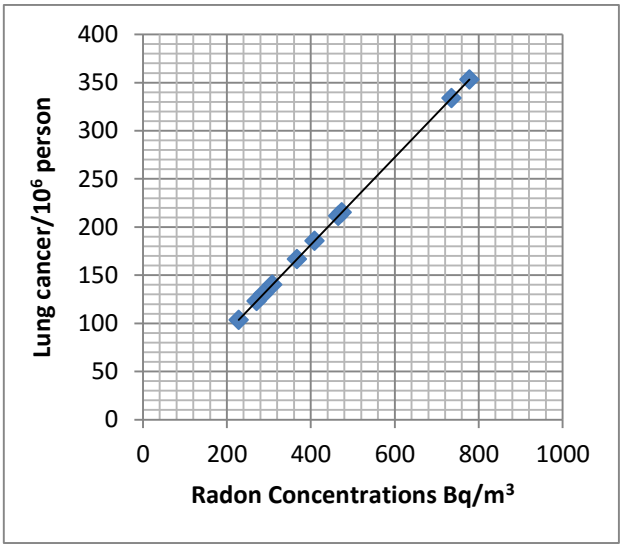

Figure 3: Correlation between radon concentration and lung cancer per year per million person.

4. CONCLUSION

Nearly 50% of annually radiation dose absorption of human is due to radon which is one of the main cancers cause at respiratory and digestion systems. The results showed that radon concentration in ten different brands tobacco cigarette samples were ranged between 227.856 Bq/m^3 to777.877 Bq/m^3 and the highest concentration was found in Graven cigarette, whereas the lower concentration was in the Pine cigarette. The annual effective dose to be committed by users of the 10 different brands tobacco cigarette in Iraqi market varies from 5.749 mSv /y to 19.622 mSv/y. The radon induced lung cancer risks was found to vary from 103.473 to 353.203 per million person, while the corresponding average values of radon concentration, the annual effective dose and the radon induced lung cancer risks per year per million person are equal 432.304 Bq/m^3, 10.906 mSv/y and 196.317, respectively.

Through the results of the study it can be argued that high radon concentration in sporulation cigarettes (Graven, Royal, Gitanes, Bon and Master) poses a significant risk to human health, leading to increased risk for lung cancer and

thus may lead to increased deaths due to high doses of radon.

Excellent correlation has been observed between radon concentrations and lung cancer per year per million person for all brands tobacco cigarette.

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