International Journal of Physical Research, *8 (2) (2020) 60-66*

International Journal of Physical Research

Website: www.sciencepubco.com/index.php/IJPR

Research paper

Radiological risk assessment of some consumed cigarettes and hookah in Iraq

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Abstract

The main purposes of the research are to assess the radiological risk due to smoking cigarettes and hookah and their impacts on the people health. Radon levels were measured in 28 consumed brands of cigarettes and 10 brands of hookah consumed Iraq using CR-39 solid state nuclear track detectors (SSNTDs). The results showed that the 222Rn concentration in cigarette tobacco samples ranged from 138.9 to 781.2 Bqm-3 with average value of 318.0 Bqm-3. The radon concentrations emerged from 11brands of the investigated samples was significantly higher than the recommended value. While, its concentration in hookah ranged from 633.6 Bqm-3 to 416.6 Bqm-3 with average value of 509.5 Bqm-3. The Potential Alpha Energy Concentration (PAEC) in terms of (WL) units, Exposure to radon progeny (EP), and the annual effective dose (AED) in terms of (mSv/y) units were also obtained. Lung cancer cases per year per million people (CPPP) are also evaluated with an average value of 144.4 per million people. The result indicates that the average values of PAEC, EP and AED were within the recommended range values given by UNSCEAR, NCRP and ICRP respectively. The radioactive impact of smoking is considered as a risk factor for lung cancer.

Keywords: *Cigarettes; CR-39; Hookah; Radioactivity; Radon.*

1. Introduction

Tobacco is a cultivation production prepared from green leaves of plants in the genus Nicotania. Tobacco also consists of small amount of radioisotopes that cause a radiation exposure hazard to smokers and passive smokers. Most humans became aware that the smoke of cigarette and tobacco has many toxic substances for example tar, arsenic, nicotine and cyanide. The common risks of cigarettes have been recognized for years. Yet, few humans realize that tobacco also contains radioactive materials: polonium-210 and lead-210. The combination of the toxic and radioactive materials in cigarettes hurt smokers. They also hurt persons subjected to secondhand smoke.

The radioactive isotope, Polonium-210, in cigarettes rests in “hot spots” in the lungs is one of the reasons which cause cancer [1]. Polonium is an alpha emitter which has a very damaging impact on lungs tissues. Alpha particles are a double positive charge which has very high ionizing energy that expended in the lung tissues and travels a limited range in the materials which it interacts with [2]. During its movement through the lung tissues it can produce a great numbers of ion pairs which in turn may cause cancer and may lead to thousands of deaths a year.

Since alpha particles can be stopped by the dead layer of the skin, then they are much less harmful than when they inter the blood stream, breathed in or ingested [3].

Smokers have the most serious danger of lung malignant growth. The danger of lung malignant growth increases with the length of smoking period and number of cigarettes consumed in a day. If they stopped smoking for a long time, they can lower the probability of malignant growth [4].

As indicated by the BEIR IV report of the US National Academies of Sciences and as per Pennsylvania Department of Environmental Protection, smokers were 10 and 6 times probable to get lung cancer than non-smokers, respectively. So, being a smoker is one of the factors that increase the possibility of developing radon induced lung cancer [5, 6].

Radioactive material from tobacco smoke is considered as the 2^{nd} major reason of global death as reported by World Health Organization (WHO). In whatever the way of consuming tobacco will result in different amounts of radioactive material to be entered the smoker's bloodstream. This causes the smoker to be exposed to a level of radioactive material that in a time can lead to different type of diseases like cancer, ulcer, leukemia and many other ailments [7]. Therefore, many countries impose strict conditions such as a minimum smoking age, adjust the purchasing and using of tobacco merchandise.

Hence, the perspective goals of this research are: (1) determination of radioisotopes level in most consumed brands of cigarettes in Iraq. (2) Calculation of risk indices such as (The Potential Alpha Energy Concentration (PAEC) in terms of (WL) units, radon progeny exposure (RP), and the annual effective dose (ED_A)). (3) To point up conclusions on hazardous impact of radioactivity due to smoking cigarettes and hookah.

2. Materials and methods

Twenty-eight different brands of cigarettes and10 hookah flavor samples were collected from cigarettes shops. Tables 1and 2 illustrate the coding of the studied cigarette and hookah flavor samples.

Table 1: Investigated Tobacco Brands and Their Production Country

No	Brand	Code	Production Country
1	Jewels Chocolate	JW	
2	OSCAR (Ice cold)	OS1	USA
3	Senator (Red)	SR1	Russia
4	Marlboro	MB	USA
5	Master	MS	USA
6	ESSE (blue)	ES1	Korea
7	P&S (balck)	PS1	USA
8	mond	MO	UAE
9	Akhtamar	AK	Armenia
10	Maxico (Red)	MX	
11	Titan	TT	
12	MT BLUE	MT	Armenia
13	OSCAR (silver)	OS2	USA
14	West (fusion black)	WT2	Germany
15	MAC	MC	Denmark
16	Senator (green)	SG2	Russia
17	Pine	PN	Korea
18	West (silver) fusion white	WT1	Germany
19	P&S (Silver)	PS2	USA
20	Gauloises (gold)	GL1	France
21	ESSE (silver)	ES3	Korea
22	Royale	RO	India
23	GAULOISES compact (red)	GL2	France
24	ESSE (Black)	ES2	Korea
25	Sumer	SU	Iraq
26	Bond	BO	USA
27	Craven "A"	CR	UK
28	Philip Morris (blue)	PM	USA

Table 2: Investigated Hookah Brands and Their Production Country

No	Brand	Code	
1	Mazaya, natural lemon molasses	MZ1	Jorden
2	Mazaya, natural lemon with mint molasses	MZ2	Jordan
3	Mazaya, natural kiwi with lemon molasses	MZ3	Jordan
4	Al Fakher, orange mint	FR	UAE
5	Adalia, Lemon mint	AD	Turkey
6	Al Fakhamah, lemon mint	FM	UAE
7	Al Amasi, lemon mint	AM	Jordan
8	Zain, castro	ZC	Jordan
9	Razan, Lemon mint	RZ	Jordan
10	Debaj, GUM	DJ	UAE

Five grams of each tobacco samples was put in plastic containers while the weight of each hookah flavor samples was 10 grams also put in plastic containers. The height of the container was 7.5 cm and 6.5 cm in diameter. A piece of CR-39 detector with area (1 x 1) cm^2 was sticked on the inside face of the container's cover (Figure 1). Each sample was replicated 3 times.

The containers were left at room temperature for two months exposure time. During this time alpha particles from the decay of radon, and its daughters fall on the CR-39 nuclear track detectors. Then, after the exposure time, alpha tracks on CR-39 detectors were developed using 6.25N NaOH etching solution at temperature 70°C for 5 h. After chemical etching Cr-39 pieces were washed with distilled water and prepared for counting the tracks with an optical microscope.

Alpha tracks recorded on CR-39 detector represent ^{222}Rn component, so the concentration of ^{222}Rn was assumed as directly proportional to the track density [8-10]

The calculated ^{222}Rn concentrations in the study brand tobacco and hookah samples (C) in ($Bq.m^{-3}$) were according to the equation (1) [11]:

$$C = \frac{\text{Track density}(\text{Tr.cm}^{-2})}{\text{Calibration factor}\times\text{Exposure time}} = \frac{\rho}{kt} \tag{1}$$

Where k was found experimentally to be equal to (0.04891Track cm^{-2} d^{-1}/Bq m^{-3}) [12].

The concentration of radon in the study cigarette brand samples (C_{Rn}) was calculated by utilizing equation (2) suggested by Somogyi et al. [1986]. They proposed that the number of radon atoms emitted from the sample is equal to the number of radon atoms in the air above the sample times the decay probability, which can be written in the following form [13], [14]:

$$C_{Rn}(Bq/m^3) = \frac{C\lambda ht}{L} \tag{2}$$

Where: λ: decay constant for (^{222}Rn) , h: sample surface to detector distance (cm), t: time of exposure = 60 day, L: height of the sample (cm).
The Potential Alpha Energy Concentration (PAEC) in terms of (WL) units was calculated utilizing equation (3) [15-17]:

$$\text{PAEC (WL)} = \text{F} \times \frac{\text{C}}{3700} \tag{3}$$

UNSCEAR (2000) proposed that (F) is the equilibrium factor between radon and its progeny and it is = 0.4.
Equation (4) shows the relation between the exposures to radon progeny (EP) with the average radon concentration C [18]:

$$\text{EP (WLMY}^{-1}) = 8760 \times \text{n} \times \text{F} \times \frac{\text{C}}{170 \times 3700} \tag{4}$$

Where C is in $Bq.m^{-3}$, n = 0.8 (the fraction of time spent indoors), 8760 = hours / year, 170 = number of hours /working month.
Furthermore, the annual effective dose (AED) in units of (mSv/y) was also calculated using equation (5) [19-21]:

$$\text{AED (mSv.y}^{-1}) = \text{C} \times \text{F} \times \text{H} \times \text{T} \times \text{D} \tag{5}$$

Where H = 0.8 (the occupancy factor), T=8760 $h.y^{-1}$, and D = 9×10^{-6} mSv / ($Bq.h.m^{-3}$) (the dose conversion factor).
Then (CPPP), which is the number of lung cancer cases per year per million people, was calculated using the following equation [16], [22], [23]:

$$\text{CPPP} = \text{AED} \times (18 \times 10^{-6}\ \text{mSv}^{-1}.\text{y}) \tag{6}$$

3. Results and discussion

3.1. Tobacco samples

Table 3 displays the calculated values of C, C_{Rn}, PAEC, EP, AED and CPPP in the measured tobacco cigarette samples.
Table 3 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 persons (CPPP)

Table 4: Radon Gas Concentration (C) in the Can Air above the Samples,

Code	C $Bq.m^{-3}$	C_{Rn} $Bq.m^{-3}$	PAEC (mWL)	EP ($WLM.y^{-1}$)	AED ($mSv.y^{-1}$)	CPPP $\times10^{-6}$
JW	208.3	18.5	22.5	0.928	5.255	94.6
SR1	243.0	21.6	26.3	1.083	6.131	110.4
SG2	538.1	47.7	58.2	2.398	13.577	244.4
MB	277.7	24.6	30.0	1.238	7.007	126.1
MS	486.1	43.1	52.5	2.166	12.263	220.7
ES1	347.2	30.8	37.5	1.547	8.759	157.7
ES2	277.7	24.6	30.0	1.238	7.007	126.1
ES3	243.0	21.6	26.3	1.083	6.131	110.4
PS1	138.9	12.3	15.0	0.619	3.504	63.1
PS2	208.3	18.5	22.5	0.928	5.255	94.6
MO	347.2	30.8	37.5	1.547	8.759	157.7
AK	191.0	16.9	20.6	0.851	4.817	86.7
MX	225.7	20.0	24.4	1.006	5.693	102.5
TT	173.6	15.4	18.8	0.774	4.379	78.8
MT	295.1	26.2	31.9	1.315	7.445	134.0
OS1	486.1	43.1	52.5	2.166	12.263	220.7
OS2	416.6	37.0	45.0	1.857	10.511	189.2
MC	364.5	32.3	39.4	1.625	9.197	165.5
PN	364.5	32.3	39.4	1.625	9.197	165.5
WT1	329.8	29.3	35.7	1.470	8.321	149.8
WT2	138.9	12.3	15.0	0.619	3.504	63.1
RO	399.3	35.4	43.2	1.779	10.073	181.3
GL1	781.2	69.3	84.5	3.481	19.708	354.7
GL2	347.2	30.8	37.5	1.547	8.759	157.7
SU	277.7	24.6	30.0	1.238	7.007	126.1
BO	277.7	24.6	30.0	1.238	7.007	126.1
CR	260.4	23.1	28.2	1.160	6.569	118.2
PM	260.4	23.1	28.2	1.160	6.569	118.2
Average	318.0	28.2	34.4	1.417	8.024	144.4
Min	138.9	12.3	15.0	0.619	3.504	63.1
Max	781.2	69.3	84.5	3.481	19.708	354.7
Allowable value	200-300 [24]		53.33 [25]	1-2 [28]	3-10 [18]	170-230 [18]

Figure 1 illustrates the results of C which perceives that the highest radon concentration was found in GL1 (Gauloises (gold) - France) with a value of (781.2 Bq.m^{-3}), while the lowest radon concentration was (138.9 Bq.m^{-3}) in WT2 (West (fusion black) - Germany) and PS1(P&S (black) USA), with an average value of (318.0 Bq.m^{-3}), which is higher than the recommended range (200-300 Bq.m^{-3}) [24]. Twelve out of twenty-eight cigarette samples are higher than the allowable value given by ICRP [24].
The dissolved radon concentration of the brands tobacco cigarette samples varies between 12.3×10^{3} Bq.m^{-3} to 69.3×10^{3} Bq.m^{-3}with an average value of 28.2×10^{3} Bq.m^{-3}.

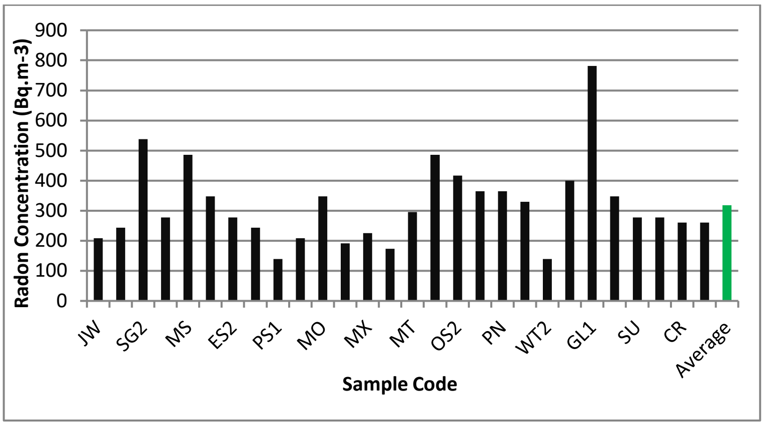

Fig. 1: Radon Gas Concentration in Different Brand Tobacco Samples.

The highest value of PAEC was equal to (84.5 mWL), while its lowest value was equal to (15.0mWL) with an average value (34.4 mWL). In all 28 different tobacco cigarettes investigated samples, the results of PAEC were lower than (53.33 mWL) the recommended value reported by the [25] except GL1 and SG2 with values of 84.5 and 58.2 mWL, respectively.
The values of EP were ranged from the highest value (3.481 WLM y^{-1}) to the lowest value (0.619 WLM.y^{-1}), with a mean value of (1.416 WLM.y^{-1}). All results of EP in the study brand tobacco were lower than the recommended range (1-2 WLM.y^{-1}) (NCRP, 1989) except SG2 (2.398 WLM.y^{-1}), MS and OS1 (2.166 WLM.y^{-1}) and GL1 with value (3.481 WLM.y^{-1}).
The annual effective dose (AED) received by the residents ranged from (3.504 mSv.y^{-1}) to (19.708 mSv.y^{-1}) with a mean value of (8.024 mSv.y^{-1}). AED in all measured tobacco samples were lower than the recommended range (3-10 mSv.y^{-1}) (ICRP, 1993) except SG2 (13.577 mSv.y^{-1}), MS and OS1 (12.263 mSv.y^{-1}) and GL1 with value (19.708 mSv.y^{-1}). The results are shown in Figure 2.

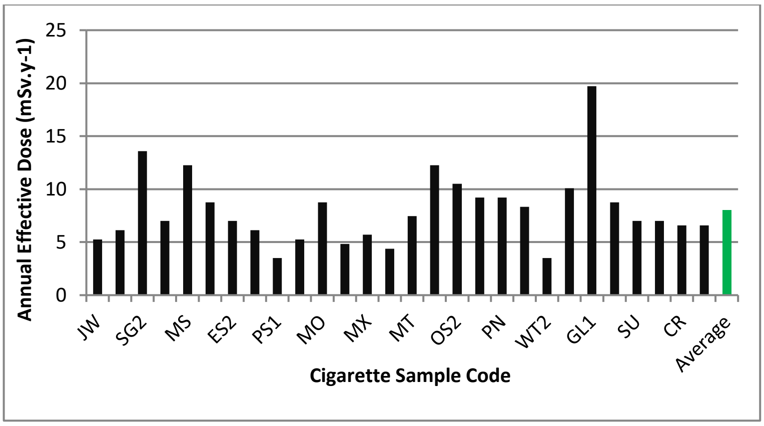

Fig. 2: The Annual Effective Dose (AED) in Different Brand Tobacco Samples.

As well radon concentrations are positively correlated with CPPP as shown in Figure 3.
Lastly, we can say that most of the obtained results presented in this study are comparable with the results given in previous studies made on some tobacco samples used in the Iraqi market [26], [27].

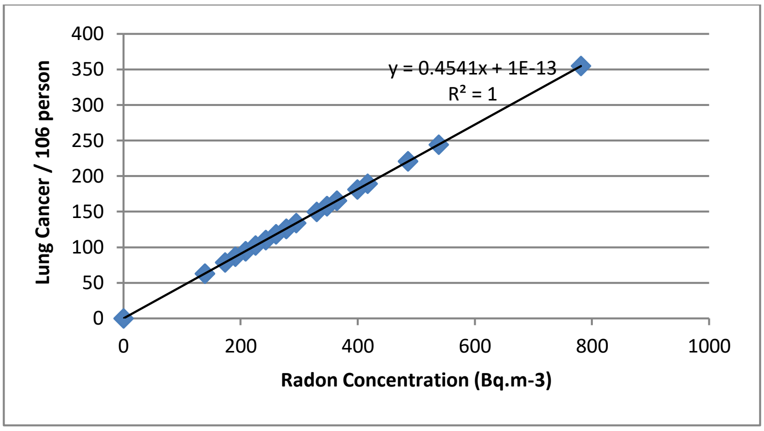

Fig. 3: Positive Correlation between CPPP and Radon Concentration for Tobacco Samples.

3.2. Hookah flavor samples

The measured values of C, C_{Rn}, PAEC, EP, AED and CPPP in the investigated tobacco cigarette samples are given in Table 4.
Table 4 Radon gas concentration in the various brand hookah 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 (CP PP).

Code	C $Bq.m^{-3}$	CRn $Bq.m^{-3}$	PAEC (mWL)	EP (WLM.y-1)	AED ($mSv.y^{-1}$)	CPPP $\times 10^{-6}$
MZ1	512.1	45.4	55.4	2.282	12.919	232.6
MZ2	460.0	40.8	49.7	2.050	11.606	208.9
MZ3	451.3	40.0	48.8	2.011	11.387	205.0
FR	442.7	39.3	47.9	1.973	11.168	201.0
AD	512.1	45.4	55.4	2.282	12.920	232.6
FM	598.9	53.1	64.7	2.669	15.109	272.0
AM	416.6	37.0	45.0	1.857	10.511	189.2
ZC	633.6	56.2	68.5	2.824	15.985	287.7
RZ	546.8	48.5	59.1	2.437	13.796	248.3
DJ	520.8	46.2	56.3	2.321	13.139	236.5
Average	509.5	45.2	55.1	2.271	12.854	231.4
Min	416.6	37.0	45.0	1.857	10.511	189.2
Max	633.6	56.2	68.5	2.824	15.985	287.7

The results reveal that the highest radon concentration was found in ZC (Zain, Castro - France) with a value of (633.6 $Bq.m^{-3}$), while the lowest radon concentration was (416.6 $Bq.m^{-3}$) in AM (Al Amasi - Germany), with an average value of (509.5 $Bq.m^{-3}$), which is higher than the recommended range (200-300 $Bq.m^{-3}$) [24]. The obtained results are shown in Figure 4.
The values of C_{Rn} of the tobacco hookah samples were ranged between ($37.0\times10^{3)}$ $Bq.m^{-3}$ to (56.2×10^{3}) $Bq.m^{-3}$with a mean value of (45.2×10^{3}) $Bq.m^{-3}$.
PAEC values were ranged from the highest value (68.5 mWL) to the lowest value of equal to (45.0 mWL) with an average value (55.1 mWL). The results of (PAEC) for 6 hookah samples (MZ1, AD, FM, ZC, RZ and DJ) are higher than the (53.33 mWL) the recommended value given by the [25], while the results of the other 4 hookah samples (MZ2, MZ3, FR and AM) show lower values than the recommended value.
The average value of EP was (2.271 $WLM.y^{-1}$) where the greatest EP value was equal to (2.824 $WLM.y^{-1}$), while the lowest value of EP was equal to (1.857 $WLM.y^{-1}$). All EP values of the study hookah flavor samples were higher than the range (1-2 $WLM.y^{-1}$) recommended by NCRP [28] except for AM and FR which show lower values than the recommended range.

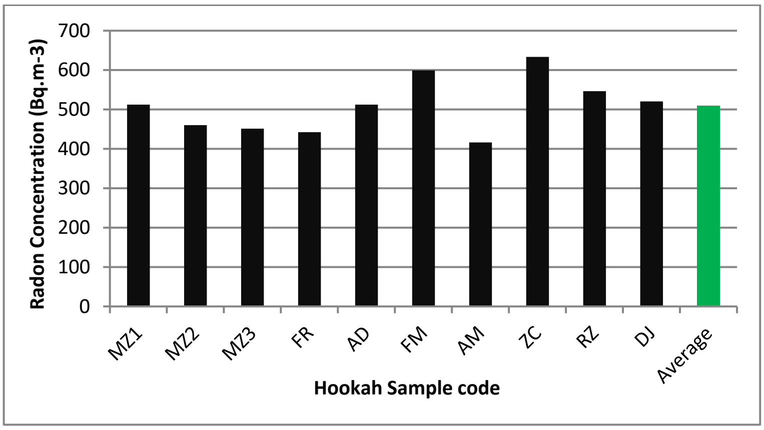

Fig. 4: Radon Gas Concentration in Study Brand of Hookah Flavor Samples.

The annual effective dose (AED) received by the residents varies from (10.511 $mSv.y^{-1}$) to (15.985 $mSv.y^{-1}$) with an average value of (12.854 $mSv.y^{-1}$). AED in all measured hookah flavor samples are higher than the recommended range (3-10 $mSv.y^{-1}$) [18]. The results of AED are shown in Figure 5.

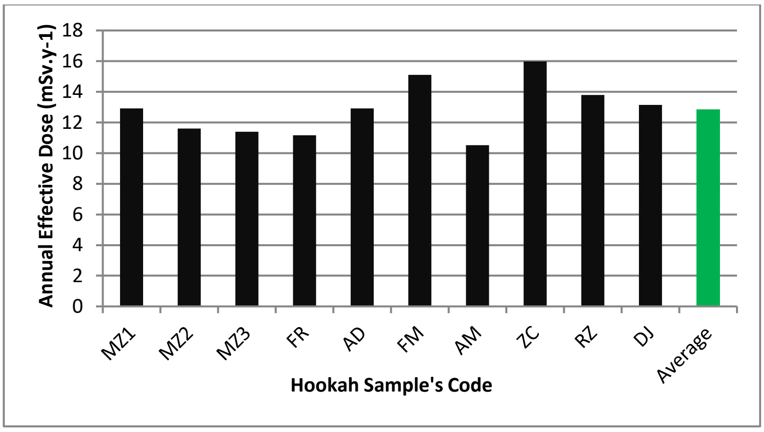

Fig. 5: The Annual Effective Dose (AED) in Study Brand of Hookah Flavor Samples.

Figure 6 illustrates the positive correlation between the radon concentrations and CPPP for hookah samples. The present obtained results are higher than the results reported in the previous studies made on some hookah flavor samples used in the Iraqi market [29].

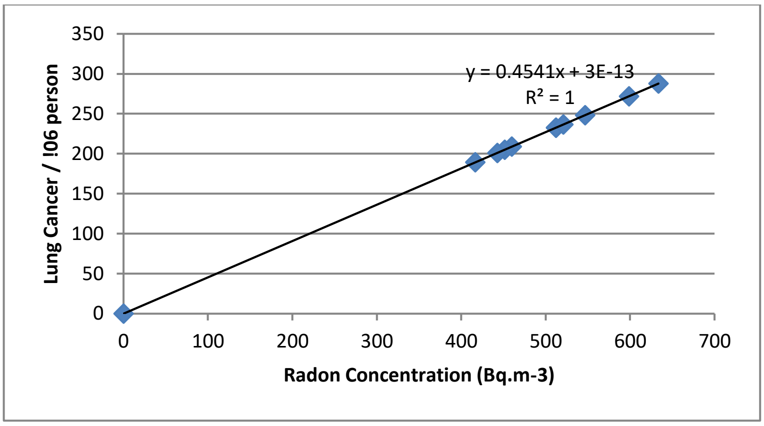

Fig. 6: Positive Correlation between CPPP and Radon Concentration for Hookah Flavor Samples.

4. Conclusions

Tobacco smoking is lethal from numerous points of view and it has genuine wellbeing, financial, and social outcomes. Despite the fact that the common radioactive materials in tobacco and hookah can be considered as one of the fundamental purposes behind the health effects of smoking cigarettes or hookah, there are very restricted published researches on the concentration of natural radioisotopes in tobacco. Moreover, the concentration of radioactive isotopes content in tobacco differs within the same brands of cigarette as well as same brands of hookah. Furthermore, the measured radon concentrations in both tobaccos of cigarettes or hookah samples are found greater than the recommended range given by ICRP.

The estimated radiological impacts indices calculated in this work such as PAEC, EP and AED in most tobacco cigarette samples were found to be lower than the recommended value. While only 6 samples of hookah tobacco were found to be lower than the recommended value.

The excess lifetime cancer risks values estimated were also lower than the recommended limits given by ICRP except GL1 and SG2 cigarette samples and FM, ZC, RZ and DJ hookah samples. This represents a genuine malignant growth hazard and some other radiation wounds to the smokers and passive smokers in the environment. So, It can then be deduced that various factors, for example, the planting area where the tobacco plant is grown, the cultivation of the tobacco, the size and composition of the filter, manufacturing procedures, age of the products and smoking habits govern the degree of exposure via the path way of tobacco.

From the present work we found that according to the International Commission of Radiological Protection, the results reveal that 16 of cigarette tobacco samples are within the allowable limits, while all the hookah tobacco samples are higher than the allowable limits. Hence, we can conclude that the radioactivity content in hookah products was higher than that of the cigarette products, so, hookah flavor may add risk of lung malignancy to that due to tobacco for smokers.

Acknowledgments

I would like to express my special thanks to Environmental Research Center- University of Technology for providing me with all facilities that were required in completing this project. As well as, I would like to thank all my colleagues in the Center for sharing their experience and for their support.

Conflict of interest

The author has no conflicts of interest to disclose.

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