The Annual Inhalation Radiation Effective Dose Estimations for Hookah Tobacco Smoking of Baghdad's Publics

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Abstract: It's known that tobacco has many chemical, biological, and etc. dangerous but there are little studies about the radioactivity hazards of tobacco, especially smoking of hookah tobacco. In this work, tobacco used in shisha and available in local markets in Baghdad has been measured against natural occurring radioactive materials (NORM), which are U-238, Th-232, and K-40. The obtained overall average results of those isotopes were 5.29, 2.97, 84.89 Bq/kg, receptively. The annual inhalation radiation effective dose (AIRED) has been estimated according to two models. The overall average estimations of AIRED were 3.537 mSv/y for 1st method and 0.430 mSv/y for 2nd method. However, both methods, although have big difference, have values higher than the recommended values that limited by international agencies.

1 Introduction

Tobacco smoke (either by cigarettes or hookah) has toxic, genotoxic, and carcinogenic properties and has been linked to fatal pregnancy outcomes [1]. The consumption of tobacco products and the number of smokers have been increasing steadily throughout the world, and Iraq is no exception to this. 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 (210Po) and lead (210Pb) [2]. 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 [3-8].

Lung cancer is the leading cause of cancer-related deaths worldwide. Smoking, radon, and secondhand smoke are the leading causes of lung cancer. Smoking is the leading cause of lung cancer. A smoker who is also exposed to radon has a much higher risk of lung cancer [9]. Moreover, 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 1.3 pCi/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 [10]. The World Health Organization (WHO) says radon causes up to 15% of lung cancers worldwide [11]. It has been known for over 20 years that all types of tobacco contain radioactive 210Po (T1/2 = 138.38 d) which emits alpha particles and radioactive 210Pb (T1/2 = 22.3 y) which emits beta particles and it's a precursor of 210Po. There is a degree of consensus about how tobacco becomes radioactive [3].

A hookah is a water pipe that is used to smoke flavored and sweetened tobacco. Other names for hookah are narghile, water-pipe, shisha, hubble-bubble, and goza. The pipe is usually quite large with one or more flexible tubing stems that allow multiple smokers to inhale at the same time. Hookah tobacco is often flavored with molasses, fruit pulp, or honey with additional flavor added, like coconut, fruit flavors, mint, or coffee.
Flavorings sweeten the taste and aroma of the tobacco, making it more appealing to young people, especially. The tobacco chamber in a hookah consists of a bowl containing burning charcoal that is placed on top of the flavored tobacco. It has been estimated that daily hookah smokers absorb approximately the same amount of nicotine and other chemicals as they would if they smoked 10 cigarettes a day.

The aim of the present work is to measure the activity concentration of naturally occurring radioactive materials (NORM) isotopes in the Iraqi markets locally used hookah tobacco samples of different origin that famous from smokers in Baghdad city using gamma spectroscopy with NaI(Tl) detector. The second mean goal is to assessment the annual effective dose due to inhalation of NORM concentration from hookah tobacco samples for adults (smokers).

2 Experimental work

Due to the health risks associated with the exposure to inhalation of NORM isotopes in the smoke of tobacco, many governmental and international bodies such as the International Commission on Radiological Protection (ICRP), United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR) [12-14] have adopted strong measures aimed at minimizing such exposures. In this context, limits have been set on the concentrations of radionuclides in various materials and the use of materials with abnormally high levels of radioactivity has been banned.

In order to evaluate the levels of natural radioactivity in the Iraqi markets tobacco, seven samples of locally used tobacco collected from deferent Iraqi market.

The sample preparation depends on type of samples under investigation. The tobacco samples were sampled by cutting it to very small piece. Then, samples were milled and grinded by placing each sample in an oven for drying at a temperature of 110 °C for one hour until complete removal of any residual moisture and ensuring that a constant weight was reached. After that, the dried samples were pulverized into a fine powder and passed through a standard 1 mm mesh size. The homogenized samples were filled into 1 L Marinelli beakers to measure the radioactivity. For all samples, 1kg of sample mass was used and stored for at least one month prior to measurements in order to attain radioactive secular equilibrium between $^{226}$Ra and $^{228}$Ac and their short-lived progeny. NORM isotopes were measured using NaI(Tl) coaxial detector gamma spectroscopy with standard setup. In addition, radiation background was measured and automatically (by using some options in gamma spectroscopy system) subtracted from the obtained spectrum.

The energy resolution and efficiency was measured using Eu-152 isotope in order to adjust gamma system. The specific activity, in terms of the activity concentration, is defined as the activity per unit mass of the sample. After measurement and subtraction of the background, the activity concentrations were calculated [15] as follow;

(a) $^{226}$Ra concentration was determined by measuring the 295.1 (19.2 %) and 352 (37.1 %) keV γ-rays from $^{214}$Pb and the 609.3 (46.1%) and 1120.3 (15%) keV γ-rays from $^{214}$Bi. The $^{226}$Ra concentration was calculated by averaging over the measured concentrations for $^{214}$Pb and $^{214}$Bi.

(b) $^{232}$Th activity was determined from the γ-peaks of 238.6 (43.6%) keV from $^{212}$Pb and 338.4 (12%), 911.2 (29%) and 969 (17%) keV from $^{228}$Ac and583.0 (86%) keV γ-rays from $^{208}$Tl.

(c) $^{40}$K activity concentration was measured from its 1460 (10.7%) keV γ-line. The activity concentrations for the natural radio- nuclides in the measured samples were computed using the following relation

$$S.A. = \frac{C_a}{\epsilon P_\gamma M_S} ... ... 1$$

where $S.A.$ is the specific activity in $(Bq/kg)$, $C_a$ is the net counting rate of γ-ray (counts per second), $\epsilon$ the detector efficiency of the specific γ-ray, $P_\gamma$ the absolute transition probability of γ-decay and $M_S$ the mass of the sample (kg).

3 Results and Discasions

3.1 NORM Activity Concentrations in Hookah Tobacco samples

Uranium, thorium and their daughter products are significant sources of natural radioactivity in the environment. Human population is always exposed to ionizing radiations from natural sources present in earth’s crust. Natural uranium has higher abundance in earth crust than other toxic elements such as Sb, Cd, Bi, Hg, etc.

The present data obtained for hookah tobacco samples have also been compared with the data existing in the literature of other Iraqi works.

The resulted data are presented in Table (1). This table illustrates the specific activities of NORM isotopes; $^{238}$U, $^{232}$Th, and $^{40}$K of the hookah tobacco samples. The specific activities of $^{238}$U are ranged from 29.78 Bq/kg in S4 sample to 41.04 Bq/kg in S3 sample with an overall average value of 35.29 Bq/kg, whereas $^{232}$Th ranging from...
2.32 Bq/kg in S7 sample to 3.4 Bq/kg in S6 with an average value of 2.29 Bq/kg. The maximum value of ⁴⁰K was measured in sample S6 with value 94.66 Bq/kg, and the minimum value was registered in sample S4 with value 78.25 Bq/kg, while the overall average value was 84.89 Bq/kg. However, Ref. [6] measured uranium activity concentrations using kinetic phosphorescence analysis (KPA), which is a very excellent method, for all smoked types of cigarettes by Iraqi’ publics. He obtained that the overall average activity concentration of all measured types was 57 Bq/kg. A comparison between this value and our estimated value, which is 35.29 Bq/kg, directly proved that the uranium contents in hookah tobacco are less than that in cigarettes’ tobacco. In addition, figure (1) showed that the statistical variation between all investigated samples is within the range of the overall average.

Table 1: The specific activity (S.A) (in Bq/kg) for NORM (²³⁸U, ²³²Th, and ⁴⁰K) isotopes of hookah tobacco

| Sample | U-²³⁸ Bq/kg | Th-²³² Bq/kg | K-⁴⁰ Bq/kg |
|--------|-------------|--------------|------------|
| S1     | 33.93       | 2.75         | 79.39      |
| S2     | 37.58       | 3.23         | 87.24      |
| S3     | 41.04       | 3.12         | 83.76      |
| S4     | 29.78       | 2.97         | 78.25      |
| S5     | 36.19       | 3.02         | 82.16      |
| S6     | 38.66       | 3.40         | 94.66      |
| S7     | 29.83       | 2.32         | 88.77      |
| Overall Average | 35.29   | 2.97         | 84.89      |

Figure 1: the specific activity S.A. of the investigated Tobacco samples

3.2 The Annual Inhalation Radiation Effective Dose
Hookah tobacco contains minute quantities of radioactive isotopes such as uranium, that is radioactive carcinogenic and could be found in smoke from burning tobacco. People who intentionally or passively inhale tobacco smoke are exposed to higher concentrations of radioactivity than nonsmokers [2]. Deposits of radioactive isotopes in the lungs of smokers, delivered to sensitive tissues for long periods of time, generating localized radiation exposures, may induce cancer both alone and synergistically with non-radioactive carcinogens. Inhalation of some naturally occurring radionuclides via smoking has been considered to be one of
the most significant causes of lung cancer. Therefore, it’s important to estimation the effective dose from NORM activity concentration in hookah tobacco, that dose consumed from smoker widely in Iraq. This dose must be compared with the average worldwide exposure as given by UNSCEAR (2001) report [16]; the committed effective dose has been estimated to be 0.24 mSv per year based on the assumption that a smoker smoking 30 cigarettes per day and that 20% of $^{210}$Po and $^{210}$Pb are inhaled by the smoker. Although it is a rough estimate even then it indicates that cigarette smoking could be a considerable part of the global dose resulting from an avoidable exposure to natural radioactivity.

However, the Annual Inhalation Radiation Effective Dose (AIRED) can be estimated by two methods. The first and old one, which is used by many previous works, can be illustrated as follow; Assuming 12.5 g of hookah tobacco per one using and a smoker is smoking 3 times the hookah per day or 37.5 g of hookah tobacco per day, and then the annual consumption of tobacco by cigarettes is estimated to be 13.6875 kg/y. Taking into consideration the data for the radionuclide activity concentrations (Bq/kg) in hookah tobacco fresh, the fraction of the radionuclide activity concentration that is recovered from hookah tobacco to cigarette smoke is 0.75 (75 %), as on the average, about 75 % of the radioisotope in the cigarette tobacco was contained in the hookah smoke, which is partially inhaled and deposited in the lung tissues and about 25 % was retained in the hookah filter (the water) and ash. The most recent dose conversion coefficients of the radionuclides (Sv/Bq) for the case of inhalation for adults (smokers) is presented in Table (2) [12], then measurements are derived for the AIRED (Sv/y), due to inhalation for adults (smokers), according to the equation:

$$\text{AIRED} = I_1 \times e_1 \times \ldots \times e_{2^n}$$

where $I_1$ (Bq/y) refers to intake from the inhalation cigarette smoke, $e_i$(Sv/Bq) refers to effective dose coefficients (or dose conversion factor) and its values are listed in table (2). The $I_1$ can be estimated as:

$$I_1 = 0.75 \times M_T \times (S.A)_i$$

where $M_T$ (kg/y) refers to the annual amount (in mass) of hookah tobacco consumed, $(S.A)_i$ (Bq/kg) refers to the specific activity concentration of the ith radionuclide.

Table 2: The effective dose coefficients (or dose conversion factor) for NORM isotopes [12]

| Nuclide | $e_i$(Sv/Bq) |
|---------|--------------|
| $^{238}U$ | $5 \times 10^{-7}$ |
| $^{232}Th$ | $1.1 \times 10^{-4}$ |
| $^{40}K$ | $2.1 \times 10^{-9}$ |

Nevertheless, this method (the first method) act such as ingested of hookah tobacco rather inhaled, but in real, the hookah tobacco is inhaled after burning. Therefore, one must be estimated AIRED from the inhaled smoking, which is the second method in this work.

Before listed the equations of the second method, the following information about the smoking of hookah must be given. A typical manufactured cigarette contains between 7 and 22 milligrams of nicotine, depending on brand, with about 1 mg being absorbed by the smoker [5]. An average hookah bowl contains as much nicotine as a pack of 20 cigarettes. Smokers inhale 500 to 600 ml of smoke in the 20 puffs it takes to smoke a cigarette. If they're smoking hookah, which is typically an event lasting 45 minutes to an hour, smokers inhale approximately 90,000 ml of smoke and take as many as 200 puffs on the water pipe. Therefore, every one kg of hookah tobacco gives 0.648 m$^3$ of smoke, and if one assumes that the smokers smoke the hookah three times per day, then and the inhalation per hour of the hookah tobacco by Iraqi smoker is 0.00000675, which is the inhalation intake rate. Consequently, the AIRED in Sv$\cdot$y$^{-1}$, to the hookah tobacco smoking public can be estimated by multiply this rate with the inhalation effective dose coefficients (or dose conversion factor) for NORM isotopes that illustrated in table (2). Finally, the calculated results of the AIRED by the two methods have been listed in table (4-3) and illustrated in figures (2) and (3).

The results showed higher differences between the two methods, and by comparing with the international value 0.24 mSv per year, one can directly note that the first method is the corrected one. Additionally, the overall average value was 0.432 mSv/y, and this indicates about the highly associated health hazard with smoking of the hookah from Iraqi smokers. Furthermore, the results of AIRED of the smoking hookah represents big part from the total international allowed annual effective dose (from ingestion and inhalation) that is 2.5 mSv/y. In other words, the smokers have more chance to injury by lung cancer.
Table 3: The annual inhalation radiation effective doses (AIRED) by the two methods for NORM ($^{238}$U, $^{232}$Th, and $^{40}$K) isotopes of hookah tobacco

| Sample | 1st method AIRED (mSv/y) | 2nd method AIRED (mSv/y) |
|--------|--------------------------|--------------------------|
| S1     | 3.282                    | 0.399                    |
| S2     | 3.840                    | 0.467                    |
| S3     | 3.734                    | 0.454                    |
| S4     | 3.507                    | 0.427                    |
| S5     | 3.597                    | 0.438                    |
| S6     | 4.036                    | 0.491                    |
| S7     | 2.778                    | 0.338                    |
| Overall Average | 3.537                               | 0.430                               |

Figure 2: 1st method for calculated AIRED (mSv/y).

Figure 2: 2nd method for calculated AIRED (mSv/y).
4 Conclusions
From the results of the NORM activity concentration measurements of hookah tobacco that smoked from Iraqi smokers and then from the annual inhalation radiation effective dose (AIRED), one can conclude that the obtained results are within the results of other Iraqi researchers and are higher than the limits of international agencies, which is 0.25 mSv/y. In addition, the obtained results showed small differences between all investigated hookah tobacco types that means all types gives a remarkable health hazard.

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