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^{210}Po Radioactivity in Tobacco and Smoke Inhalation Effective Dose Estimation

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Abstract

In this study, ^{210}Po radioactivity in tobacco and effective dose estimation from smoke inhalation were investigated. 14 most frequently used cigarette brands in Turkey were used for this purpose. ^{210}Po average radioactivity in tobacco was found to be 25.4 ± 2.0 Bq/kg. ^{210}Po mean annual effective dose was found to be 181.8 μSv/y.
Keywords — ^{210}Po radioactivity, tobacco, inhalation effective dose

1. Introduction

The origin of the tobacco is leaves of the Nicotania plant. Tobacco is the highly popular product in many countries and the health consequences vary depending on the consumption types. Cigarette, narghile, pipe etc. is the types of the consumption of the tobacco. Tobacco contains radionuclides and considerable quantity of the toxic chemical compound. These radionuclides and elements considered cause of lung cancer [1]. Radiological importance of the tobacco consumption is internal radiation exposure as a result of the inhalation of the tobacco smoke.

Different radionuclides of natural and artificial origin are present in tobacco. Natural and artificial radionuclides (^{238}U, ^{232}Th decay series ^{40}K and ^{137}Cs) present in the soil. As a result of the food chain, this radionuclide passes into the tobacco [2]. Radioactivity concentrations of these radionuclides in soil are low. Due to the mineral contents, there are some soils have high activity concentrations. Additionally industrial activities and fertilization may elevate radioactivity concentrations of these radionuclides [3,4].

^{210}Pb and ^{210}Po is the important radionuclides in the tobacco. Principal mechanism of the incorporation of the ^{210}Pb and ^{210}Po in tobacco is direct deposition on the leaves (rain, snow, dust etc.), uptake into the root as a result of the food chain and use of the fertilizers. ^{210}Po is a member of the ^{238}U -series and one of the relatively long-lived radionuclides of radon decay products.^{210}Po has a physical half-life time of 138 days. ^{210}Po in cigarettes is volatilized at the temperatures (600-800 ºC) for burning cigarettes and inhaled into the lung along with the cigarette smoke [5].

According to the The World Health Organization report, cigarettes will kill 10 million people pear year by 2020[6]. In Turkey, according to the report of the Turkish Public Health Constitution (Türkiye Halk Sağlığı Kurumu) in 2014, cigarette use rate in Turkey is 31.2% [7]. Therefore, determination of the radionuclide contents of the tobacco samples is important. In this study, ^{210}Po radioactivity in tobacco and effective dose estimation from smoke inhalation were investigated. 14 most frequently used cigarette brand in Turkey were used for this purpose.

2. Materials and methods

2.1 Gamma-ray spectrometric analysis

Samples were collected from markets. Samples were separately labeled and brought into the laboratory. In order to remove moisture, tobacco samples were dried in a drying oven at 80°C until constant mass was obtained.

The samples were ground and homogenized in the laboratory. Adequate samples were put into cylindrical plastic analysis containers. Plastic analysis containers had a 6 cm diameter and 5 cm height. Then samples were weighed and sealed. Then each sample was measured and the values were given in Bq kg^{-1} dry weight.

Radioactivity measurements were performed by using a gamma spectrometer. The spectrometer was n-type reverse electrode closed-end coaxial high-purity germanium detector. The detector has 20% relative efficiency and 46:1 peak-to-compton ratio. The energy resolutions of the detector are 1.80 keV for ^{60}Co at 1332.5 keV and 0.97 keV for ^{57}Co at

Celal Bayar University Journal of Science
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122 keV. Before the measurements, energy calibration was done by using peaks of ^{241}Am, ^{137}Cs and ^{60}Co radionuclides of the standard point radioactive source.

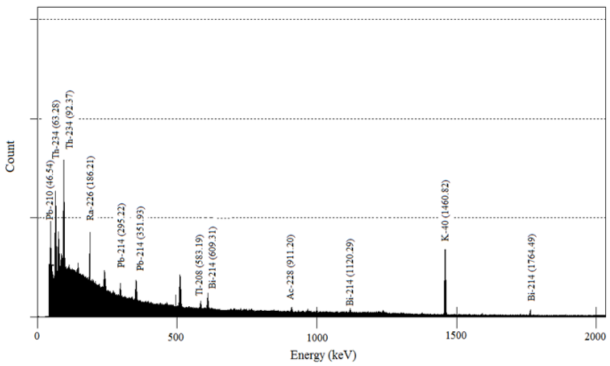

Figure 1. A spectrum of the Tobacco sample

The efficiency calibration of gamma spectrometry system was performed using 79829-839 coded certified standard volume source. The efficiency calibration source had vegetation matrix and 13 radionuclides that have the energy range of 59.5–1836.1 keV. Before the measurements an empty plastic sample container was counted in the same manner as the samples for the determination of the background effects. After measurements and subtraction of the background, the activity concentrations were determined.
The activity concentrations are calculated by the following formula [8].

$$A = \frac{N}{\varepsilon\ \gamma t\ m} \tag{1}$$

where, N is the corrected net peak area of the corresponding photopeak. t is live time in seconds. ε is the efficiency at the related photopeak energy. m is the dried mass. γ is the emission probability.
The relative combined standard uncertainty of the activity concentration is given by the following formula [8]

$$u_c(A) = \frac{\sigma(A)}{A} = \sqrt{\left(\frac{\sigma(m)}{m}\right)^2 + \left(\frac{\sigma(N)}{N}\right)^2 + \left(\frac{\sigma(\gamma)}{\gamma}\right)^2 + \left(\frac{\sigma(\varepsilon)}{\varepsilon}\right)^2} \tag{2}$$

The activity concentrations of the samples were determined from radionuclide's own energies or gamma-ray photopic of their decay products. The activity concentration of the ^{210}Po was determined from ^{210}Pb activity. The activity concentration of ^{210}Pb was calculated from 46.5 keV photopeak energy. There were equilibrium between ^{210}Pb and daughter ^{210}Po. This equilibrium was determined and applied experimentally in the literature[5,9-11]. Time period between harvesting tobacco and production of the cigarettes generally six-seven half-lives of the ^{210}Po. Therefore ^{210}Pb in cigarettes reaches secular equilibrium. At the secular equilibrium, activity concentration of the ^{210}Po was calculated from the activity concentration of ^{210}Pb.

$$A_{Po} = 1.02\ A_{Pb} \tag{3}$$

2.2 Effective Dose Calculation
The effective doses were calculated using following equation [12]:

$$E\ =\ C\ \times M \times D \times F \tag{4}$$

where E_{ing} is the annual effective dose from inhalation of nuclide in tobacco (Sv/y). C_i is the radioactivity concentration of radionuclide (Bq kg^{-1}), D is the effective dose conversion factor (Sv/Bq). The values of effective dose conversion factor for adults is 3.3×10^{-6} Sv/Bq [12]. F is the transfer factor of the radionuclide from cigarette to smoke. The value of the transfer factor is 0.18 [13]. M is annual mass of the consumed tobacco (kg/y). In 2008 annual consumption of the tobacco per person in Turkey is 1508 cigarettes (12.06 kg/yr) [14].

3. Results and Discussions
The activity concentrations of ^{210}Po and the annual effective doses are given in the Table 1. The activity concentrations of ^{210}Po calculated using Equation 3. The mean activity concentration of ^{210}Po was found 25.4 ± 2.0 Bq/kg. The mean annual effective dose of the ^{210}Po was found 181.8 µSv/y.

Table 1. The activity concentrations of ^{210}Po and the annual effective doses.

Sample	Activity (Bq/kg)	Annual Effective Dose (µSv/y)
1	23.7 ± 1.9	169.5
2	25.2 ± 2.0	180.5
3	22.7 ± 1.8	162.9
4	36.8 ± 2.9	263.8
5	35.2 ± 2.8	252.1
6	12.8 ± 1.0	91.3
7	31.1 ± 2.5	222.9
8	11.1 ± 0.9	79.6
9	33.2 ± 2.7	237.5
10	25.8 ± 2.1	184.9
11	18.1 ± 1.4	129.3
12	33.8 ± 2.7	241.9
13	14.5 ± 1.2	103.8
14	31.5 ± 2.5	225.8
Mean	25.4 ± 2.0	181.8
Min.	11.1 ± 1.9	79.6
Max.	36.8 ± 2.0	263.8

For the Turkish tobacco, Dogru et el. [9] found that activity concentration of ^{210}Po ranged from 2.93 to 20.9 mBq.g^{-1}. Yaprak et el. [10] found that activity concentration of ^{210}Po ranged from 6.7 to 26.57 mBq.g^{-1}.

Khater [15] found that average activity concentration of ^{210}Po was 16.3± 3.2 mBq/g for Egyptian tobacco. Khater found that the annual effective was 193 µSv/y. For the Polish tobacco, Skwarzec et al. [16] found that average activity concentration of ^{210}Po was 20 mBq per cigarette. Skwarzec et.al found that the mean annual effective was 35µSv.

For the Brazilian tobacco, Peres et al. [17] found that activity concentration of ^{210}Po ranged from 10.9 to 27.4 mBq/g. Mandic et al. [15] found that average activity concentration of ^{210}Po 32.8± 9.5 Bq/kg for the Serbian tobacco. Mandic et al. [5] found that the mean annual effective was 724 µSv/y.

4. Conclusion

In this study, ^{210}Po radioactivity in tobacco and effective dose estimation from smoke inhalation were investigated. Maximum ^{210}Po radioactivity concentration was found to be 36.8 ± 2.0 Bq/Kg. The ^{210}Po radioactivity concentrations are in accordance with the other worldwide studies. Highest annual effective dose found as 263.8 µSv/y. The annual effective dose was much lower than the intervention exemption level of 1 mSv^{-1}. As tobacco contains harmful elements and other radionuclides, there is a need to evaluate effects of those elements and radionuclides to health.

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