Measurement of Natural Radioactivity in different cigarettes samples by using (HPGe) detector

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Abstract. Twelve samples of cigarettes have been collected from local markets of different types and origins by using (HPGe) detector, and measurement of the specific activity for series U²³⁸ and series Th²³² in addition to K⁴⁰ in order to estimate the health risk of cigarettes their by smokers, the results shown that highest specific activity value were be (12.8±6.3 Bq/kg, 8.4±5.8 Bq/kg, 125.16±58.3 Bq/kg), respectively, in the sample (MAC) MacBeth type cigarettes in Brazilian origin, this paper reports data such as (specific activity of K⁴⁰, series U²³⁸, series Th²³² and some parameters hazard indices) on the radioactivity of tobacco leaves so as to know contaminate those cigarettes in natural radioactivity and Suitability of its use by smokers.

Keywords. Natural radioactivity, HPGe detector, cigarettes samples.

1. Introduction
Tobacco contains minute amounts of radioactive isotopes, for example (Th²³² series, K⁴⁰ and U²³⁸ series), that are radioactive carcinogenic and could be found in smoke from consuming tobacco. Individuals who intentionally or passively inhale tobacco smoke are exposed to higher concentrations of radioactivity than nonsmokers. Deposits of radioactive isotopes in the lungs of smokers, delivered to sensitive tissues for long periods of time, generating confined radiation exposures, may induce cancer both alone and synergistically with non-radioactive carcinogens. In a number of studies, inhalation of some naturally occurring radionuclides via smoking has been viewed as one of the most critical reasons for lung cancer [1]. This study aimed at assessment of radioactivity content in tobacco products to provide the important information to evaluate the conceivable wellbeing impacts of tobacco smoking.

2. Preparation and Collection of the sample
Twelve most every smoked brands of tobacco were picked. Samples were gathered haphazardly from those accessible on the Iraqi markets. The samples were dried at 60 °C for one hour to guarantee that any dampness was removed from the tests. So as to acquire uniform molecular sizes, a (500 μm) mesh work was utilized, from that point onward, the samples were weighted almost (one kg) Each sample has been (200 cigarettes) and transferred to a Marinelli beaker. The (HPGe) system which was utilized in the present work is a (3×3) inch, see Fig. (1). A fundamental prerequisite to estimate a gamma producer is the character of photo peaks showed in the spectrum made by the detector system. Calibration of energy was done by utilizing a standard source of Marinelli beaker of Eu-152 source, set up with energies (411. 1, 344. 3, 1408, 964, 444. 6, 778. 9, 1085. 8, 121. 8, 1112. 0 and 244. 7 keV).

3. Determination of activity Concentration and some Parameters Hazard Indices
1- Activity Concentration [2]:

\[ A = \frac{NET}{\varepsilon \cdot I_y \cdot m \cdot t} \]

(1)

Where:
A: activity concentrations. \( \varepsilon \): Energy efficiency.
m: mass of sample 
t: time measurement (7200 s.).

Radium Equivalent (\( Ra_{eq} \)) [2].
\( Ra_{eq} = 0.077A_k + 1.43A_{Th} + A_U \)

Where \( A_k, A_{Th}, A_U \) activity concentration of a series of (Th\(^{232}\), K\(^{40}\) and U\(^{238}\)) respectively
Absorbed Dose Rate (Dy) [3].

\[ D_y = 0.604 \text{A}_{\text{Th}} + 0.0417 \text{A}_{\text{K}} + 0.462 \text{A}_{\text{U}} \]

The Annual Effective Dose (AED in, AED out) [4].

\[ (\text{AED})_{\text{in}} = 0.80 \times (0.7 \text{ Sv/Gy}) \times D_y \times (\text{nGy/h}) \times 10^{6} \times 8760 \text{ h/y} \]
\[ (\text{AED})_{\text{out}} = 0.20 \times (0.7 \text{ Sv/Gy}) \times D_y \times (\text{nGy/h}) \times 10^{6} \times 8760 \text{ h/y} \]

### Internal and External Hazard Index (H_i, H_e)[5].

\[ H_i = \frac{A_{\text{Ra}}}{185} + \frac{A_{\text{Th}}}{259} + \frac{A_{\text{K}}}{4810} \leq 1 \]
\[ H_e = \frac{A_{\text{Ra}}}{370} + \frac{A_{\text{Th}}}{259} + \frac{A_{\text{K}}}{4810} \leq 1 \]

### Activity Concentration Index (I_y)[6].

\[ I_y = \frac{A_{\text{U}}}{300} + \frac{A_{\text{Th}}}{200} + \frac{A_{\text{K}}}{3000} \]

### 4. Results and Discussion

The specific activity of radionuclide in tobacco cigarettes is very different depending on the soil type of where tobacco is planted and the quality of phosphate fertilizers rich in uranium, the measurements of twelve sample of cigarette tobacco available in Iraqi markets of the most consumed kinds cigarettes and from different origins using (HPGe) detector.

The aftereffects of the present work were outlined in Table (1) it tends to be seen that: The most elevated estimation of \text{A}_{\text{U}} in sample 6 which was equivalent (30.61 Bq/kg) which is Macbeth (Brazilian origin), while the least estimation of \text{A}_{\text{U}} was found in sample 10 which was equivalent (2.97 Bq/kg) which is Graven (Turkish origin), see Fig. (2), with a average estimation of (12.8 ±6.3 Bq/kg). The present outcomes have demonstrated that estimations of \text{A}_{\text{U}} in tobacco cigarettes were minimum than the recommended value of (35 Bq/kg) [7].

The aftereffects of the present work were outlined in Table (1) it tends to be seen that: The most elevated estimation of \text{A}_{\text{Th}} was found in sample 6 which was equivalent (24.39 Bq/kg) which is Macbeth (Brazilian origin), while the least estimation of \text{A}_{\text{Th}} was found in sample 10 which was equivalent (BDL) which is Graven (Turkish origin), see Fig. (2), with a average estimation of (8.41±5.8 Bq/kg). The present outcomes have demonstrated that estimations of \text{A}_{\text{Th}} in tobacco cigarettes were minimum than the recommended value of (30 Bq/kg) [7].

The aftereffects of the present work were outlined in Table (1) it tends to be seen that: The most elevated estimation of \text{A}_{\text{K}} was found in sample 6 which was equivalent (275.59 Bq/kg) which is Macbeth (Brazilian origin), while the least estimation of \text{A}_{\text{K}} was found in sample 11 which was equivalent (54.34 Bq/kg) which is Oscar Silver (American origin), see Fig. (2), with a average estimation of (125.16±58.3 Bq/kg). The present outcomes have demonstrated that estimations of \text{A}_{\text{K}} in tobacco cigarettes were minimum than the recommended value of (400 Bq/kg) [7].

Table (2) it tends to be seen that: The most elevated estimation of \text{Ra}_{\text{eq}} was found in sample 6 which was equivalent (86.708 Bq/kg) which is Macbeth (Brazilian origin), while the least estimation of \text{Ra}_{\text{eq}} was found in sample 10 which was equivalent (8.680 Bq/kg) which is Graven (Turkish origin), with an average estimation of (34.445±16.6 Bq/kg). The present outcomes have demonstrated that estimations of \text{Ra}_{\text{eq}} in tobacco cigarettes were minimum than the recommended value of (370 Bq/kg) [7].

The most elevated estimation of Dy was found in sample 6 which was equivalent (40.365 nGy/h) which is Macbeth (Brazilian origin), while the least estimation of Dy was found in sample 10 which was equivalent (4.465 nGy/h) which is Graven (Turkish origin), with a average estimation of (16.20±7.7 nGy/h). The present outcomes have demonstrated that estimations of Dy in tobacco cigarettes were minimum than the recommended value of (55 nGy/h) [7].
The most elevated estimation of \((\text{AED})_{in}\) was found in sample 6 which was equivalent \((0.198 \text{ mSv/y})\) which is Macbeth (Brazilian origin), while the least estimation of \((\text{AED})_{in}\) was found in sample 10 which was equivalent \((0.022 \text{ mSv/y})\) which is Graven (Turkish origin), with a average estimation of \((0.079\pm0.03 \text{ mSv/y})\). The present outcomes have demonstrated that estimations of \((\text{AED})_{in}\) in tobacco cigarettes were minimum than the recommended value of \((\text{one mSv/y})\) [7].

The most elevated estimation of \((\text{AED})_{out}\) was found in sample 6 which was equivalent \((0.050 \text{ mSv/y})\) which is Macbeth (Brazilian origin), while the least estimation of \((\text{AED})_{out}\) was found in sample 10 which was equivalent \((0.005 \text{ mSv/y})\) which is Graven (Turkish origin), with a average estimation of \((0.02\pm0.009 \text{ mSv/y})\). The present outcomes have demonstrated that estimations of \((\text{AED})_{out}\) in tobacco cigarettes were minimum than the recommended value of \((\text{one mSv/y})\)[7].

The most elevated estimation of \(I_{\gamma}\) was found in sample 6 which was equivalent \((0.316 \text{ mSv/y})\) which is Macbeth (Brazilian origin), while the least estimation of \(I_{\gamma}\) was found in sample 10 which was equivalent \((0.031 \text{ mSv/y})\) which is Graven (Turkish origin), with a average estimation of \((0.061\pm0.006 \text{ mSv/y})\). The present outcomes have demonstrated that estimations of \(I_{\gamma}\) in tobacco cigarettes were minimum than the recommended value of \((\text{one mSv/y})\)[7].

The most elevated estimation of \(H_{in}\) was found in sample 6 which was equivalent \((0.317 \text{ mSv/y})\) which is Macbeth (Brazilian origin), while the least estimation of \(H_{in}\) was found in sample 10 which was equivalent \((0.035 \text{ mSv/y})\) which is Graven (Turkish origin), with a average estimation of \((0.055\pm0.005 \text{ mSv/y})\). The present outcomes have demonstrated that estimations of \(H_{in}\) in tobacco cigarettes were minimum than the recommended value of \((\text{one mSv/y})\)[7].

The most elevated estimation of \(H_{ex}\) was found in sample 6 which was equivalent \((0.234 \text{ mSv/y})\) which is Macbeth (Brazilian origin), while the least estimation of \(H_{ex}\) was found in sample 10 which was equivalent \((0.023 \text{ mSv/y})\) which is Graven (Turkish origin), with an average estimation of \((0.045\pm0.004 \text{ mSv/y})\). The present outcomes have demonstrated that estimations of \(H_{ex}\) in tobacco cigarettes were minimum than the recommended value of \((\text{one mSv/y})\)[7].

The present outcomes have demonstrated that estimations of \(I_{\gamma}\), \(H_{in}\), \(H_{ex}\), \(A_{\text{U}}\), \(A_{\text{Th}}\), \(A_{\text{K}}\) in all cigarette's samples.

5. Conclusions

The eventual outcomes of the present work concerning values of the \(A_{\text{U}}, A_{\text{Th}}, A_{\text{K}}\) in all cigarettes samples and determination the parameters \([R_{aeq}, D_{\gamma}, \text{ (AED)}_{in}, \text{ (AED)}_{out}, I_{\gamma}, H_{in} \text{ and } H_{ex}]\) which was less than their corresponding allowed limits.
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Appendix

Table 1. Radionuclides of U²³⁸ Series, Th²³² Series and K⁴⁰ and A₆, A₉, A₁₅ of all cigarette's samples.

| No. | Country of Origin | Cigarette name | Ra-226 Bq/kg | Bi-214 Bq/kg | Pb-214 Bq/kg | Pb-212 Bq/kg | Th-208 Bq/kg | Ac-228 Bq/kg | Th²³² Bq/kg | K⁴⁰ Bq/kg |
|-----|------------------|----------------|--------------|-------------|-------------|-------------|-------------|-------------|-------------|--------------|
| 1   | America          | Miami          | 12.43        | 2.921       | 1.56        | 5.64        | BDL         | 12.43       | 5.82        | 6.08         | 54.90       |
| 2   | England          | Arden          | 13.44        | BDL         | 9.45        | 7.63        | 3.08        | BDL         | 19.00       | 7.36         | 100.97      |
| 3   | British          | Kent Silver    | 14.18        | 14.15       | 24.40       | 17.58       | 2.62        | BDL         | BDL         | 0.87         | 72.30       |
| 4   | Germany          | Aspen          | 23.32        | BDL         | 15.04       | 12.79       | 12.42       | BDL         | BDL         | 4.14         | 125.41      |
| 5   | Iraq             | Sumer          | BDL          | 12.24       | 13.41       | 8.55        | 14.92       | 14.45       | 23.02       | 17.46        | 145.27      |
| 6   | Brazil           | Macheth        | 53.24        | 15.13       | 23.45       | 30.61       | 26.56       | 11.40       | 35.21       | 24.39        | 275.59      |
| 7   | Korea            | Pine Silme     | 21.22        | 18.03       | 15.95       | 11.33       | 16.47       | 10.27       | 17.64       | 14.79        | 250.41      |
| 8   | Germany          | Davidoff       | 38.84        | 15.36       | 15.47       | 23.22       | 10.81       | 13.24       | 12.42       | 12.16        | 179.01      |
| 9   | America          | Mikado         | 05.16        | 15.25       | 13.03       | 18.08       | 46.1        | BDL         | BDL         | 0.49         | 80.10       |
| 10  | Turkey           | Graven         | 4.42         | 2.71        | 1.78        | 2.97        | BDL         | BDL         | BDL         | 74.16        |
| 11  | America          | Oscar Silver   | BDL          | BDL         | 14.43       | 4.81        | 75.3        | 14.52       | BDL         | 6.39         | 54.34       |
| 12  | Germany          | Gold Seal      | 86.23        | BDL         | 63.6        | 10.16       | 44.2        | 85.2        | 15.06       | 6.79         | 89.53       |
|     | Min.             | BDL            | 1.56         | 2.97        | BDL         | BDL         | BDL         | 0           | 54.34       |              |
|     | Max.             | 53.24          | 15.25        | 24.40       | 30.61       | 26.56       | 14.52       | 35.21       | 24.39       | 275.59       |
Table 2. Radiation Hazard indices for all cigarettes samples.

| No. | Country of Origin | Cigarette name | Ra<sub>eq</sub> (Bq/kg) | D<sub>y</sub> (nGy/h) | Annual effective dose Equivalent (mSv/y) | I<sub>fr</sub> | Hazard index |
|-----|-------------------|----------------|--------------------------|---------------------|-----------------------------------------|-------------|--------------|
|     |                   |                |                          |                     | (AEDE)<sub>n</sub> (AED)<sub>ext</sub>  |             |              |
| 1   | American          | Miami          | 18.562                   | 8.567               | 0.042                                   | 0.011       | 0.068        | 0.065 | 0.050 |
| 2   | England           | Arden          | 25.929                   | 12.181              | 0.060                                   | 0.015       | 0.096        | 0.091 | 0.070 |
| 3   | British           | Kent Silver    | 24.391                   | 11.662              | 0.057                                   | 0.014       | 0.087        | 0.113 | 0.066 |
| 4   | Germany           | Aspen          | 28.367                   | 13.639              | 0.067                                   | 0.017       | 0.105        | 0.111 | 0.077 |
| 5   | Iraq              | Sumer          | 44.704                   | 20.554              | 0.101                                   | 0.025       | 0.164        | 0.144 | 0.121 |
| 6   | Brazil            | Macbeth        | 86.708                   | 40.365              | 0.198                                   | 0.050       | 0.316        | 0.317 | 0.234 |
| 7   | Korea             | Pine Silme     | 51.761                   | 24.610              | 0.121                                   | 0.030       | 0.195        | 0.170 | 0.140 |
| 8   | Germany           | Davidoff       | 54.393                   | 25.537              | 0.125                                   | 0.031       | 0.198        | 0.210 | 0.147 |
| 9   | American          | Mikado         | 24.948                   | 11.989              | 0.059                                   | 0.015       | 0.089        | 0.116 | 0.067 |
| 10  | Turkey            | Graven         | 8.680                    | 4.465               | 0.022                                   | 0.005       | 0.035        | 0.031 | 0.023 |
| 11  | American          | Oscar Silver   | 18.132                   | 8.348               | 0.041                                   | 0.010       | 0.066        | 0.062 | 0.049 |
| 12  | Germany           | Gold Seal      | 26.764                   | 12.528              | 0.061                                   | 0.015       | 0.098        | 0.100 | 0.072 |
|     | Min.              |                | 8.680                    | 4.465               | 0.022                                   | 0.005       | 0.035        | 0.031 | 0.023 |
|     | Max.              |                | 86.708                   | 40.365              | 0.198                                   | 0.050       | 0.316        | 0.317 | 0.234 |
|     | Ave.              |                | 34.445±                  | 16.204±             | 0.079±                                  | 0.020±      | 0.061±       | 0.055±| 0.045± |
|     |                   |                | 16.6                     | 7.7                 | 0.03                                    | 0.009       | 0.006        | 0.005 | 0.004 |

Worldwide Ave. [7]

| Ave. | 370 | 55 | 1 | 1 | 1 | 1 | 1 |