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# Determination of radionuclide concentrations in cigarette tobacco by using Thallium-doped NaI (TI) scintillate technique

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## ABSTRACT

This study includes the determination of natural and industrial radionuclides concentrations in different samples of cigarette tobacco. The radionuclides are $U^{238}$, $Th^{332}$ series and $K^{40}$, as well as industrial radionuclides of $Cs^{137}$.Radiation risk coefficients were calculated. The results showed that the specific activity rates of $Ra^{226}$, $Bi^{207}$, $Ac^{228}$, $K^{40}$, and $Cs^{137}$ were within the global limit. The radiological hazard radium equivalent $Ra_{eq}$ , intake dose ($D_{\gamma}$), annual effective dose for external and internal exposure ($AEDE_{out}$ and $AEDE_{in}$), health risk external and internal hazard indices data ($H_{ex}$ and $H_{in}$) and gamma risk radiation were all lower than the allowable global limits.

## Introduction

The environment is defined as the total external conditions that affect the life, growth and survival of the organism. It is also known that the natural environment depends on three main elements: air, water and soil which considered the basics of life. The ecosystem is characterized by a balance between its elements. Therefore, the presence of radiation activity in a certain environment above the allowable limits harmful to humans and living organisms. Generally, the environment in which radiation activity is high is classified as radioactive environment [1].

There are many developments that have occurred and produced polluted environment. Pollution, however, is defined as the introduction of pollutants into the environment that cause disruption in the ecosystem. The pollutants either be exotic substances to the environment or natural substances exceeded the permissible level.

On the other hand, smoking is a widespread phenomenon on a global scale. Moreover, the risk of smoking on humans and the environment are increasing day by day, as tobacco smoke produces large amounts of pollutants. These pollutants are more threatening to human health than that produced by the burning of diesel fuel or the exhaust of cars especially in places such as lactation [2].

When organisms, including humans, are exposed to nuclear radiation, a huge chemical changes occur in the tissues of these living organisms, resulting in a significant damage. This damage or chemical change may occur only after a period of time known as the incubation period and may not appear in the person exposed to radiation directly. Otherwise, a change may occurs in the genetic composition of future generations [3].

The radioactive materials existed on the surfaces of soils and rocks, water and air, and reach into the human body by means of many ways. First, eating plants and animal's meat, which in its turn absorbed these radioactive materials from the soil. Second, by drinking water and air breathing contaminated with radon gas located in the ground, which is the main source of radioactive that reaches the human body [4].

Studies on alpha or beta as well as gamma radiation have demonstrated the presence of a lot of radioisotopes in all types of cigarettes. Smoking is a type of practice that helps swallowing and inhaling these radioactive isotopes through the mouth and nose.

The inhaled radiotherapy, consequently, reaches the lungs as well as the rest of the upper respiratory tract and the gastrointestinal tract. Smokers are expected to show radioactivity accumulation over time, which results in increasing the risk of oral, lung and respiratory cancers. whereas, no evidences have been found for the lung cancer among nonsmokers. A team of scientists at Boston University, indicates that the smoking is a change in the structure of lung cells which exposes smokers to increased risk of developing lung cancer [5] [6].

Radon and its dissociation products can enter the human body through both the respiratory system and the digestive system. For the digestive system, it is not dangerous because the presence of food in the stomach, even with a thickness of up to a millimeter, can stop most of the alpha particles resulting from the breakdown of radon and its neonates. The in halation of neonates suspended by air into the respiratory system may adheres to the wall of the lungs. Studies have shown that the dose that the lungs receive as a result of exposure to radon is 2 to 3 times higher than that received by the stomach. While more recent studies revealed that radon is the main cause of lung cancer after smoking [7].

The study aims to measure the concentration of radionuclides for 20 samples of cigarette from different origins. Thallium-doped NaI (TI) scintillator detector is used to determine the specific radiological activity of the natural radioactive elements (uranium $U^{238}$, thorium $Th^{232}$, and potassium K40). and cesium $Cs^{137}$, and the radium equivalent and the air intake rate and the internal and external risk rates.

## Materials and Methods

A total of 20 samples of cigarette of different types were collected from the most wide spread cigarette in the local markets. The samples were then dried under sunlight for two days, then grinded in an electric mill to obtain a fine and homogeneous powder. For the purpose of measurement, a quantity of 210gm of each sample was placed in a sealed can to prevent contamination. Later, the samples were transferred into measuring container of a suitable volume (not less than 250gm) to measure radionuclides concentrations. Thallium-doped NaI (TI) detector was used to detect the gamma radiation in the studied samples. The Measurement was performed at Baghdad University - Faculty of Science - Physics Department.

The size of the detector system is (3 X 3)inch and operates at 750 Volt, also has a high efficiency of up to 60%. The detector base surrounded with a thick shield of lead to reduce the risk of radiation background in the laboratory.table:1 shows the sample code and type.

**Table1: shows the sample code and type**

| No. | Sample code | Sample type |
|---|---|---|
| 1 | D1 | Rothmans |
| 2 | D2 | Zumerret |
| 3 | D3 | Milano |
| 4 | D4 | Pleasure |
| 5 | D5 | M.M |
| 6 | D6 | Royale club |
| 7 | D7 | Dunhil |
| 8 | D8 | Winston |
| 9 | D9 | Oscar |
| 10 | D10 | Kent |
| 11 | D11 | Miami |
| 12 | D12 | Summer |
| 13 | D13 | Prestige |
| 14 | D14 | Pine |
| 15 | D15 | Vecory |
| 16 | D16 | Camil |
| 17 | D17 | Classic gold |
| 18 | D18 | Gauloises |
| 19 | D19 | Aspin |
| 20 | D20 | Gitanes |

For the purpose of calibration of both energy and efficiency of the used detector, a multi-energy source ($Co^{60}$, $Cs^{137}$ and $Am^{242}$) was placed in front of the detector for a period of 3600sec. the energy and efficiency values of the radioactive elements used in the calibration process of tobacco models. Genie 2000 program was employed to draws the relationship between calculating relative efficiency of each energy recorded.

Where the calculation of radiation hazard indicators for gama rays

Radium Equivalent Activity (Raeq)

Radiation coefficient is used to ensure uniform distribution of radionuclides, represented by radium $Ra^{226}$, thorium $Th^{232}$ and potassium $K^{40}$ and measured in units (Bq / kg) and can be calculated by the following equation [8]:

$A=Cps/(\varepsilon_{ff} I_{\gamma} t\ m)$

A: activity , cps :count per second ,E:efficiency , $I_{\gamma}$ : intensity % ,t: time measurement 3600sec , m: sample mass 220gm

$Raeq = ARa + 1.43ATh + 0.077Ak$

Whereas ARa, ATh and Ak are the efficiency of $Ra^{226}$, $Th^{232}$ and $k^{40}$ in Bq / kg, respectively, and the highest value of Raeq should be less than the globally allowed limit of 370Bq / kg.

Dose Rate in Air (Dγ Absorbed):

The rate of absorbed dose of Kama rays in the air Dγ at 1m above ground level in nGy/ h can be calculated using the specific activity of radionuclides for radium $Ra^{226}$ for thorium $Th^{232}$ and potassium as in the following equation [8]:

$D\gamma = 0.462\ ARa + 0.604\ ATh + 0.0417\ Ak \leq 1$

(0.462,0.604,0.0417):- are the conversion factors used to calculate the ratio of the air absorbed dose to natural radionuclides (uranium $^{238}_{92}U$, thorium $^{232}_{90}Th$ and potassium $^{40}_{19}k$).

Outdoor Hazard Index:

Radiation coefficient is used to determine the risk of natural Kama radiation and can be calculated from the following equation [9]:

$Hex = ARa / 370 + ATh / 259 + Ak / 4810 \leq 1$

Indoor Hazard Index (Hin)

It can be calculated from the following equation [9]:

$Hin = ARa / 185 + ATh / 259 + Ak / 4810 \leq 1$

* The external and internal risk index should be less than one [8].

Annual Effective Dose (AEDE) Equivalent:

To calculate the annual effective dose, the conversion factor from the absorbed dose to the active dose should be taken into account. The factor of occupancy is 0.7Sv / Gy as a conversion factor from the air absorbed dose to the annual received dose. The following [8]:

AEDEin (mSv/y) = D (nG / h) x0.7Sv / Gyx0.8x8760 h / y ≤1

The equivalent annual effective external dose is calculated from the following equation [9]:

AEDEout (mSv/y)=D (nG / h) x0.7Sv/Gyx0.2x8760 h / y ≤1

Activity Concentration Index (Iγr):

Radiation coefficient from which to estimate the risk levels of gama rays associated with natural radionuclides in the samples, can be calculated from the following equation [8]:

$I\gamma r = ARa / 300 + ATh / 200 + Ak / 3000$

## Results and Discussion

Table: 2 shows the result of radionuclides concentration in tobacco, The acquired results revealed that the specific activity levels of radium ($Ra^{226}$) were between (33.40-3.64) Bq/kg and (18.52) Bq/kg on average. These results, however, were less than the allow able limit which is 35Bq/kg [10]. While for $Bi^{207}$, the specific activity levels were below detection limits (B.D.L) which is 35 Bq/kg. The specific activity levels of $Ac^{228}$were within B.D.L (33.45Bq/kg) and within the global limits ,and for potassium $K^{40}$werebetween (4.08 Bq/kg) to (390.31 Bq/kg) and (197.195 Bq/$m^3$) on average [10]. The results appeared less than the global limit (400 Bq/kg). The specific activity levels for $Cs^{137}$ were between B.L.D and (9.56 Bq/kg), where some of the results appeared close to global allowable limits(14.8 Bq/kg) , while Figure 1 illustrates the specific activity of the radionuclides $Ra^{224}$, $Ac^{228}$, and $K^{40}$in the studied tobacco samples.

**Table 2: shows the result of radionuclides concentration in tobacco.**

| Sample ID | Ra-226 Bq/ kg | Bi-207 Bq/ kg | Ac-228 Bq/ kg | k-40 Bq/ kg | Cs-137 Bq/ kg |
|---|---|---|---|---|---|
| D1 | 3.64 | 10.90 | 19.07 | 289.20 | B.L.D |
| D2 | 15.98 | 25.05 | 25.63 | 180.89 | 10.45 |
| D3 | 27.62 | 2.50 | 22.85 | 5.99 | 14.88 |
| D4 | 9.99 | B.L.D | B.L.D | 290.09 | B.L.D |
| D5 | 19.88 | B.L.D | B.L.D | 220.70 | 6.89 |
| D6 | 27.25 | 2.32 | 33.45 | 131.94 | 14.02 |
| D7 | 26.22 | 14.7 | 1.09 | 159.69 | B.L.D |
| D8 | 19.98 | 1.55 | 5.11 | 14.79 | B.L.D |
| D9 | 1.505 | B.L.D | B.L.D | 167.08 | 12.00 |
| D10 | 13.00 | 8.62 | B.L.D | 149.51 | B.L.D |
| D11 | 20.40 | 2.70 | 10.73 | 300.45 | B.L.D |
| D12 | 28.58 | 13.18 | B.L.D | 290.20 | B.L.D |
| D13 | 19.00 | 1.69 | 1.0 | 5.01 | 12.80 |
| D14 | 32.97 | 24.0 | 7.5 | 35.02 | 11.93 |
| D15 | 18.31 | 1.29 | 19.86 | 4.08 | 5.60 |
| D16 | 33.40 | 30.89 | 2.0 | 390.31 | B.L.D |
| D17 | 18.77 | 2.09 | 11.87 | 25.46 | 13.27 |
| D18 | 10.00 | 9.85 | 24.16 | 63.30 | B.L.D |
| D19 | 15.05 | 3.0 | 5.317 | 162.70 | 9.56 |
| D20 | 4.50 | 1.00 | 16.46 | 5.55 | B.L.D |
| W.A | 35 | 35 | 30 | 400 | 14.8 |

Lower permissible limit: B.L.D

International standard Value : W.A

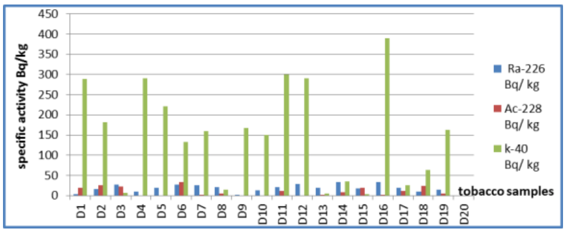


**Fig. 1: illustrates the specific activity of the radionuclides $Ra^{224}$, $Ac^{228}$, and $K^{40}$ for the tobacco samples.**

The data for radiological risk were as following: $Ra_{eq}$ (radium equivalent) has a values between 14.38-85.25 Bq/kg and 49.81 Bq/kg on average which in its turn lower than the average global allowable limit (370 Bq/kg) [11].The values for air intake dose were between (7.66-38.35 $nGyh^{-1}$) and the average value was (23.01 $nGyh^{-1}$) which is much lower than theaverage global allowable limit (84 $nGyh^{-1}$) [12]. The data for the annual external and internal effective dose (outdoor) were between(0.03-0.05 mSv/y) and an average value of (0.04 mSv/y) which is also less than the allowable global limit (0.07 mSv/y). While the annual effective dose (indoor) ranged between (0.04-0.16 mSv/y) with an average value of (0.1 mSv/y) which is lower than the global limit (0.5 mSv/y) [13]. The calculated external risk index shows a results between (0.386-0.043), whereas for one of the studied samples was bigger than the global limit. The observed average value was (0.2145) lower than the global limit (1). The internal risk index revealed a values between (0.373-0.039) and an average value of (0.206) lower than the global limit (1). The gamma risk indicator presented a values between (0.27-0.07) and an average value of (0.17) which also lower than the global limit of 1Bq/$m^3$[13]. And Table3: Indicates values for $Ra_{eq}$, air intake dose, annual affective dose, risk indexes and gamma risk indicator.

**Table 3: Indicates values for $Ra_{eq}$, air intake dose, annual affective dose, risk indexes and gamma risk indicator.**

| Sample ID | $Ra_{eq}$ (Bq/kg) | Dγ (nGy/h) | $AEDE_{Outdoor}$ (mSv/y) | $AEDE_{Indoor}$ (mSv/y) | $H_{in}$ | $H_{ex}$ | Iγ |
|---|---|---|---|---|---|---|---|
| D1 | 60.44 | 28.65 | 0.03 | 0.14 | 0.163 | 0.193 | 0.22 |
| D2 | 75.63 | 34.55 | 0.04 | 0.17 | 0.204 | 0.272 | 0.27 |
| D3 | 60.76 | 26.81 | 0.03 | 0.13 | 0.960 | 0.163 | 0.20 |
| D4 | 32.33 | 16.71 | 0.02 | 0.08 | 0.090 | 0.114 | 0.13 |
| D5 | 36.87 | 18.38 | 0.02 | 0.09 | 0.099 | 0.154 | 0.14 |
| D6 | 85.24 | 38.35 | 0.05 | 0.19 | 0.229 | 0.303 | 0.3 |
| D7 | 40.1 | 19.43 | 0.02 | 0.09 | 0.108 | 0.179 | 0.15 |
| D8 | 28.43 | 12.95 | 0.02 | 0.06 | 0.076 | 0.130 | 0.11 |
| D9 | 14.38 | 7.66 | 0.01 | 0.04 | 0.039 | 0.043 | 0.07 |
| D10 | 24.51 | 12.24 | 0.02 | 0.06 | 0.066 | 0.101 | 0.09 |
| D11 | 58.87 | 28.43 | 0.03 | 0.14 | 0.158 | 0.213 | 0.22 |
| D12 | 50.93 | 25.3 | 0.03 | 0.12 | 0.137 | 0.215 | 0.19 |
| D13 | 20.82 | 9.60 | 0.01 | 0.05 | 0.056 | 0.108 | 0.07 |
| D14 | 46.39 | 21.22 | 0.03 | 0.1 | 0.125 | 0.215 | 0.16 |
| D15 | 47.01 | 20.62 | 0.03 | 0.1 | 0.127 | 0.177 | 0.16 |
| D16 | 66.31 | 32.92 | 0.04 | 0.16 | 0.179 | 0.269 | 0.25 |
| D17 | 37.7 | 16.9 | 0.02 | 0.08 | 0.149 | 0.201 | 0.13 |
| D18 | 49.42 | 21.85 | 0.03 | 0.11 | 0.133 | 0.160 | 0.17 |
| D19 | 35.18 | 16.94 | 0.02 | 0.08 | 0.096 | 0.136 | 0.12 |
| D20 | 28.47 | 12.25 | 0.02 | 0.06 | 0.373 | 0.386 | 0.10 |
| | | | | | | | |
| W.A | 370 | 84 | 0.07 | 0.5 | 1 | 1 | 1 |

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# ايوديد الصوديوم NaI(TI)

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*قسم الفيزياء ، كلية التربية للعلوم الصرفة ، جامعة تكريت ، تكريت ، العراق*

**الملخص**

تتضمن هذه الدراسة ايجاد تراكيز النويدات المشعة الطبيعية والمتمثلة بسلسلة اليورانيوم U238 وسلسلة الثوريوم Th232 والبوتاسيوم، K40 والنويدات المشعة الصناعية المتمثلة بالسيزيوم، Cs137 لعشرين عينة من تبغ السكائر المختلفة المنشأ, بأستخدام تقنية مطيافيه اشعة كاما كاشف ايوديد الصوديوم المطعم بالثاليوم، (NaI (TI)) وحساب معاملات الخطورة الاشعاعية في هذه النماذج واظهرت النتائج ان معدلات الفعالية النوعية للراديوم Ra226 والبزموث Bi 207 والاكتينيوم Ac228 والبوتاسيوم K40-والسيزيوم Cs137-في جميع النماذج ضمن الحدود المقبولة عالمياً. ومعدلات مؤثرات الخطورة الاشعاعية المتمثلة بفعالية الراديوم المكافئة (Raeq) ومعدل الجرعة الممتصة في الهواء (Dγ) والجرعة الفعالة السنوية للتعرض الخارجي (AEDEOUT) والجرعة الفعالة السنوية للتعرض الداخلي (ADEAin) ودليل الخطورة الخارجي (Hex) ودليل الخطورة الداخلي (Hin) ودليل الخطورة لأشعة كاما كانت جميعها اقل من الحدود المقبول بها عالميا .