Estimation of Radiological Hazards due to Natural Radioactivity in Shampoo Samples Used in Iraqi Markets.

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Abstract. In this work, the levels of natural radioactivity (²³⁸U, ²³²Th and ⁴⁰K) in (25) samples of shampoo have been measured. The radioactivity of these samples were determined using Gamma–ray spectrometry with (NaI ((Tl)) detector. The specific activity of the radionuclides varied from (67.00±5.86) Bq Kg⁻¹ to (163.00±17.42) Bq Kg⁻¹ for ⁴⁰K with a mean of (108.76±15.11) Bq Kg⁻¹, from (1.84±0.38) Bq Kg⁻¹ to (8.64±2.42) Bq Kg⁻¹ for ²³⁸U having a mean of (4.80±0.87) Bq Kg⁻¹ and also for ²³²Th activity ranged from (0.23±0.03)Bq Kg⁻¹ to Bq Kg⁻¹ with a mean of (1.34±0.43) Bq Kg⁻¹. The equivalent activity of radium(Raₐq) and external hazard index(Hₑₓ) for the sample of the study have normal values ranging around (15.109)Bq kg⁻¹ and (0.0408), respectively. The values of (Rₐ) and (Hₑₓ) in the present work were below the action level which is recommended around (370Bq/kg and 1). This safe level is considered by Organization for Economic Cooperation and Development and International Commission on Radiological Protection. It is found that the radiation levels of the samples studied from shampoo used in local markets were within natural rates of permissible limits and don’t cause any danger to human different uses.

Keywords: Natural radioactivity, Radiological Hazards, Shampoo, gamma –ray spectrometry and Iraqi Markets.

1. Introduction

Natural and non-industrial radioactivities represent the two major causes of exposure to the radiation[1]. Radiation control is justified and an inevitable result of some human activities that pollute the environment such as the extraction of gas or oil and mining process. These processes may elevate the levels of radioactivity of materials which have natural radionuclides to high values [2]. In nature, the terrestrial radionuclides and cosmogenic radionuclides act as the basic sources of radiation exposure and these, in turn, lead to external and internal radiation exposure.

In nature, three are important radionuclides Uranium-238, Thorium-232 with their dissolution chains and radioactive analog of Potassium-40, ²³⁸U, ²³²Th with their decay products and ⁴⁰K form the major sources of external gamma radiation, while the in charge for the greater proportion of the internal dose a person receives from naturally occurring radionuclides is ²³⁸U rather than ²²⁶Ra and
their daughters products [3]. Despite the high concentrations of these radionuclides is extensively found in nature. [4].

Emitted alpha and beta (as the natural radionuclides) are accounted as the most significant with regard to potential internal radiation exposure for human, especially during eating and ingestion of food and water [1]. It represents around twenty percent of $^{226}\text{Ra}$ isotopes associated with 10–15 % for pb isotopes that be decay products of $^{238}\text{U}$ and $^{232}\text{Th}$ [5]. As a result, the extreme risk from an external source may be derived from penetrating radiation such as gamma rays, X-rays, neutrons or beta particles [6]. The detergent products like shampoo products may make the person exposed for natural radioactivity directly, and thus exposure externally, and this may be due to contents of those products at origin structure materials which are radioactively contaminated [7]. Since many studies have shown that water contains a percentage of radionuclides. Since water is one of the raw materials involved in the installation and manufacture of shampoo. It has become necessary to study the specific activity in the shampoo. There are many previous studies in Iraq about the activity of exposure and radioactive contamination in water and shampoo, so we will review some of them. In 2016, Saman K. Ezzulldin and others had been calculated the concentration of $^{238}\text{U}$, $^{232}\text{Th}$, $^{137}\text{Cs}$ and $^{40}\text{K}$ Radionuclides in Drinking Water Resources, collected from 25 locations in region-Erbil in Iraqi Kurdistan. They had found (ND to 2.95) Bq/liter for $^{238}\text{U}$, (0.06 to 0.24) Bq/liter for $^{232}\text{Th}$, (0.01 to 0.14) Bq/ liter for $^{137}\text{Cs}$, and (0.29 to 2.32) Bq/ liter for $^{40}\text{K}$ respectively[8].In 2015, Jabbar H. Jebur and others estimated the Level of Radionuclide Contents in Surface Water, measure the radionuclide’s concentrations level for 17samples of surface water taken from Shutt – Alarab River, in the Southern - East of province in Basrah governorate. They found the average radon inhalation effective dose was 0.005 mSv/y and average radium ingestion effective dose was 1.153 mSv/y[9]. In 2016, Ali A Abojassim and others have measured the Natural Radioactive Contamination in Shampoo and Dishwashing Samples Used in Iraq, the specific activity of samples for $^{238}\text{U}$, $^{232}\text{Th}$ and $^{40}\text{K}$ were (3.50 ± 0.60) Bq/kg, (1.77 ± 0.22) Bq/kg and (119.60 ± 7.27) Bq/kg, respectively[10].In 2014, Ali A. Abojassim and others Study of radioactivity levels in detergent samples in Iraq, and was found that the $^{238}\text{U}$ specific activities had been varied from (11.489 ± 2.089) Bq/kg to (36.062 ± 2.478) Bq/kg, while the $^{232}\text{Th}$ specific activities have varied from (1.411 ± 0.609) Bq/kg to (9.272 ± 1.642) Bq/kg and $^{40}\text{K}$ were varied from (8.189 ± 2.339) Bq/kg to (91.888 ± 4.164) Bq/kg[11]. The purpose of this work is to evaluation the level of radionuclides $(^{238}\text{U}, ^{232}\text{Th}, ^{40}\text{K})$ in different types of (shampoos) that available in Iraq markets. As well as to estimate the parameters which specify the radiological levels as radium equivalent activity and external exposure.

2. Collection of Samples.

In the present work, (25) selected samples of the most used shampoos were studied in the local market based on the Gamma measurement system using NaI (TI) in the determination of the specific activity of natural radionuclides $^{238}\text{U}, ^{232}\text{Th}$ and $^{40}\text{K}$ were listed in Table (1), With its trade name and its origin being disclosed using the technique above. One litter of polyethylene marinelli beaker was accounted as a container for sampling and Measuring. Firstly, by a dilute hydrochloric acid, the containers are washed and followed with rinsing by distilled water. Each sample of (400 to 600)gm of weight is packed inside a standard marinelli beaker which was sealed hermetically. Each sample was measured during an accumulating time of 18,000s.
### Table 1: Types and Origin of Shampoo Samples

| No | Sample Code | Sample Name     | Country of Origin |
|----|-------------|-----------------|-------------------|
| 1  | Sh1         | Pert Plus       | K.S.A             |
| 2  | Sh2         | New Silky       | Lebanon           |
| 3  | Sh3         | Sunsilk         | Egypt             |
| 4  | Sh4         | Hair            | Turkey            |
| 5  | Sh5         | Palmolive       | Morocco           |
| 6  | Sh6         | Johnson’s       | Italy             |
| 7  | Sh7         | Vatica          | U.A.E             |
| 8  | Sh8         | Luxx            | Turkey            |
| 9  | Sh9         | Garnier Fructis | India             |
| 10 | Sh10        | head & shoulders| U.S.A             |
| 11 | Sh11        | Dove            | Germany           |
| 12 | Sh12        | Kodomo          | Thailand          |
| 13 | Sh13        | Happy Baby      | Bulgaria          |
| 14 | Sh14        | Perfect Purity  | Canada            |
| 15 | Sh15        | Aqua therapy    | England           |
| 16 | Sh16        | Healthy         | P.R.C             |
| 17 | Sh17        | Plant Yingli    | P.R.C             |
| 18 | Sh18        | Qinbao          | P.R.C             |
| 19 | Sh19        | TEA             | P.R.C             |
| 20 | Sh20        | Blue earth PRO-V| P.R.C             |
| 21 | Sh21        | Vitam Yingli    | P.R.C             |
| 22 | Sh22        | Plants          | P.R.C             |
| 23 | Sh23        | Blue earth 2in1 | P.R.C             |
| 24 | Sh24        | Linken          | P.R.C             |
| 25 | Sh25        | Tea Seed 3in1   | P.R.C             |

**Experimental measurement.**

A scintillation detector NaI(Tl) with (3"×3") crystal dimension (ORTEC company), represent the gamma-ray spectrometer. Provided by (Alpha Spectra, Inc.- 12112/3), attached with a multi-channel analyzer (MCA) (ORTEC –Digi Base) with a range of 4096 channel, desperation energy (FWHM) in the peak 1.33 KeV for $^{60}$Co was 7% [12]. Energy calibration and efficiency calibration of gamma spectrometer were carried out using (Co-60, Cs-137, Na-22) calibration sources in 1 L marinelli beaker covering the energy from 25 KeV to 2500 KeV. The standard source put over the detector with a geometric match exactly to the geometrical sample form and with same distance between the sample and the detector.

**3. Measurement Of Radioactivity.**

3.1. **Calculation of specific activity.** The Activity Concentration (Ac) which can be determined a specific activity as the follows [13]:

$$Ac = \frac{C - E}{\varepsilon \% \times \text{M}}$$

$$ \text{.........(1)} $$

Where Ac is represents the specific activity, C shows the area that located under the photo peaks, $\varepsilon \%$ the efficiency percentage of energy, Iy the probability of gamma-emission for the radionuclide under consideration, t: the accounting time, M is the mass of sample, and BG represents the background.
3.2. Radium Equivalent Activity (Ra$_{eq}$)

For representing or assessing the radiological hazards attendant with the three different radiations belong to $^{238}$U, $^{232}$Th and $^{40}$K, a single quantity. A public operator known as radium equivalent activity, (Ra$_{eq}$), is designed. It is mathematically distinct by followed equitation [14].

$$\text{Ra}_{eq} \ (\text{Bq/kg}) = A_U + 1.43 A_{Th} + 0.077 A_K \hspace{1cm} (2)$$

where $A_U$, $A_{Th}$ and $A_K$ are the specific activities of Uranium, Thorium and potassium respectively. The maximum value of Ra$_{eq}$ must be less than the acceptable safe limit of 370 Bq/kg.

3.3. External Hazard Index (H$_{ex}$)

The presence of natural radionuclides lead to the emission of gamma-ray in the environment. The external hazard index (H$_{ex}$) is considered to approximate the biological hazard of the natural gamma radiation and shown by the following equation [14]:

$$\text{H}_{ex} = \frac{A_U}{3} + \frac{A_{Th}}{2} + \frac{A_K}{4} \leq 1 \hspace{1cm} (3)$$

where $A_U$, $A_{Th}$, and $A_K$ are the specific activities (Bq/kg) of $^{226}$Ra, $^{232}$Th and $^{40}$K, respectively. The value of this index must be less than unity in order to keep the radiation hazard insignificant. The maximum value of (H$_{ex}$) equal to unity corresponds to the Higher limit of radium Equivalent activity (370 Bq Kg$^{-1}$)[15].

4. Results and discussion.

After calculating the specific activity of radionuclides $^{238}$U, $^{232}$Th and $^{40}$K, radium equivalent and external hazard index, the lowest, highest and average values were determined for all the results shown in (25) samples of shampoo used in Iraq. Table (2) shows the specific activity of $^{238}$U, $^{232}$Th and $^{40}$K, Table (3) Show the radium equivalent and the external hazard index using equations (2) and (3).

To statement the state of variation in the specific activity values, the radium equivalent and the external hazard index of the radionuclides for the shampoo samples. After studying Tables (2) and (3), and obtaining the results of the specific activity of radionuclides, radium equivalent and the external hazard index of the shampoo samples studied and after comparing them with the universally permissible values to the worldwide average recommended by UNSCEAR 2000 which are (32, 35 and 400) Bq kg$^{-1}$ for $^{238}$U, $^{232}$Th and $^{40}$K, respectively [1], its found the highest value for the specific activity of uranium ($^{238}$U) was $(8.64 \pm 2.42)$ Bq kg$^{-1}$ in model (Sh2) which represents a New Silky sample originating from (Lebanon), and the lowest value was $(1.84 \pm 0.38)$ Bq kg$^{-1}$ in model (Sh12) which is a sample of the shampoo (Kodomo) origin (Thailand). The average of these values $((4.80 \pm 0.87)$ Bq kg$^{-1}$). For Thorium ($^{232}$Th), the highest value for specific activity was $(2.86 \pm 0.35)$ Bq kg$^{-1}$ in the model (Sh22) which is represented a sample of (plants) of origin (P.R.C), and the lowest value was $((0.23 \pm 0.03)$ Bq kg$^{-1}$ in the model (Sh12) which is a sample of the shampoo (Kodomo) origin (Thailand). The average of these values $(4.80 \pm 0.87)$ Bq kg$^{-1}$. For $^{40}$K, the highest value of the specific activity was $(163.00 \pm 17.42)$ Bq kg$^{-1}$ in the model (Sh14) which represents the (Vitam Yingli) shampoo sample of origin of (P.R.C) and the lowest value was $(67.00 \pm 5.86)$ Bq kg$^{-1}$ in the model (Sh10) which represents the (head & shoulders) of origin (U.S.A). The average of these values $(108.76 \pm 15.11)$ Bq kg$^{-1}$. 


The maximum value of the radium equivalent ($Ra_{eq}$) and external hazard index ($H_{ex}$) radionuclide were (21.417) Bq kg$^{-1}$ and (0.057) respectively, in the (Sh22) model, which represents the (Plants) of origin (P.R.C). The minimum value were (8.781) Bq kg$^{-1}$ and (0.023) in the (Sh1) model which represents the (Pert Plus) of origin (K.S.A). The average values of ($Ra_{eq}$) and ($H_{ex}$) were (15.1097) Bq kg$^{-1}$, (0.0408) respectively. Accordantly to our results, it was observed the radioactivity in shampoo samples healthy and not harmfully in human different uses.

Table 2: Specific Activity of $^{238}$U, $^{232}$Th and $^{40}$K in the shampoo samples

| Sample Code | Specific activity in (Bq Kg$^{-1}$) |
|-------------|-----------------------------------|
|             | K-40     | U-238    | Th-232    |
| Sh1         | 69.00±7.83 | 2.01±0.84 | 1.02±0.70 |
| Sh2         | 102.00±14.50 | 8.64±2.42 | 1.34±0.06 |
| Sh3         | 99.00±10.41 | 3.1±0.09  | 1.51±0.29 |
| Sh4         | 78.00±10.37 | 7.89±0.93  | 2.00±0.80 |
| Sh5         | 120.00±10.69 | 7.09±1.73   | 1.39±0.35 |
| Sh6         | 132.00±19.09 | 4.08±0.51   | 0.98±0.16 |
| Sh7         | 89.00±14.98 | 6.23±0.28   | 1.01±0.56 |
| Sh8         | 122.00±22.29 | 5.18±1.30   | 1.20±0.20 |
| Sh9         | 155.00±11.74 | 2.33±0.66   | 2.72±1.00 |
| Sh10        | 67.00±5.86 | 3.89±1.09   | 1.46±0.49 |
| Sh11        | 70.96±4.58 | 8.38±1.27   | 1.59±0.62 |
| Sh12        | 133.00±8.58 | 1.84±0.38   | 0.57±0.39 |
| Sh13        | 109.00±24.60 | 6.87±0.64   | 1.09±0.78 |
| Sh14        | 163.00±17.42 | 6.03±1.51   | 0.87±0.25 |
| Sh15        | 120.07±9.05 | 3.56±0.07   | 0.78±0.19 |
| Sh16        | 101.00±12.20 | 7.67±0.33   | 1.63±0.47 |
| Sh17        | 98.00±21.38 | 6.15±1.60   | 1.25±0.38 |
| Sh18        | 154.00±14.82 | 4.32±1.37   | 2.31±0.93 |
| Sh19        | 68.00±20.27 | 2.87±0.96   | 1.23±0.38 |
| Sh20        | 75.00±19.09 | 3.42±0.11   | 0.59±0.04 |
| Sh21        | 129.00±20.77 | 1.98±0.26   | 0.23±0.03 |
| Sh22        | 134.00±22.45 | 7.01±1.89   | 2.86±0.35 |
| Sh23        | 145.00±12.91 | 4.10±0.19   | 1.51±0.15 |
| Sh24        | 78.00±22.40 | 3.09±0.78   | 1.12±0.96 |
| Sh25        | 108.00±19.65 | 2.43±0.58   | 1.46±0.44 |
| **Average ± S.D** | **108.76±15.11** | **4.80±0.87** | **1.34±0.43** |

Table 3: Radium equivalent activity and External hazard Index in shampoo samples.

| Sample Code | $Ra_{eq}$ (Bq kg$^{-1}$) | $H_{ex}$ |
|-------------|-------------------------|--------|
| Sh1         | 8.781                    | 0.023  |
| Sh2         | 18.410                   | 0.049  |
| Sh3         | 12.882                   | 0.034  |
| Sh4         | 16.756                   | 0.045  |
| Sh5         | 18.317                   | 0.049  |
| Sh6         | 15.645                   | 0.042  |
| Sh7         | 14.527                   | 0.039  |
| Sh8         | 16.29                    | 0.043  |
| Sh9         | 18.154                   | 0.049  |
| Sh10        | 11.136                   | 0.030  |
| Sh11        | 16.117                   | 0.043  |
| Sh12        | 12.896                   | 0.034  |
| Sh13        | 16.821                   | 0.045  |
| Sh14        | 19.825                   | 0.053  |
5. Conclusions.

The average values of radioactivity in the shampoo samples which available in Iraqi local markets and the most widely used (current study), also values of the radium equivalent and the external hazard index were within the internationally permissible limits according to the UNSCEAR and the International Commission on Radiation Protection (ICRP), for measurement samples.

6. Acknowledgements.

We present our thanks for Department of physics specially staff of nuclear physics laboratory also we thanks Dr. Ali Abid Abojassim for useful discussions.

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