Estimated the concentration of $^{238}$U, $^{232}$Th and $^{40}$K in flour samples of Iraq markets

Shaymaa Awad Kadhim(1), Shatha F. Alhous(2), Ahmed shaker Hussein (3), Hayder H. Hussein(4), Azhar S. Alaboodi(5)
(1,4,5)Department of Physics /Faculty of Science/ University of Kufa/Iraq
Department of Physics /Faculty of education for girls / University of Kufa/ Najaf/Iraq (2)
Department of basic science-college of dentistry-university of Babylon –Iraq (3)

*1 Email: shaymaa.alshebly@uokufa.edu.iq
*2 Email: shathaf.alfatlawi@uokufa.edu.iq
*3 Email: ahmed.alduami67@gmail.com
*4 Email: hayder.alshibana@uokufa.edu.iq
*5 Email: azhers.hamza@uokufa.edu.iq

Abstract. Flour is a nutritious type of food that is widely consumed by various age groups in Iraq. This study investigates the presence of long-lived gamma emitters in different type of flour in Iraqi market. Uranium ($^{238}$U), Thorium ($^{232}$Th) and Potassium ($^{40}$K) specific activity in (Bq.kg$^{-1}$) were estimated in (15) unique kinds of flours that are accessible in Iraqi markets. The gammaspectrometry method with a NaI(Tl) detector has been utilized for radiometric measurements. Likewise right now have determined the internal hazard index. It is found that the specific activity in Flour samples were varied from ($13.73\pm1.89$) Bq.kg$^{-1}$ to ($2.60\pm0.30$) Bq.kg$^{-1}$ with an average ($8.75$) Bq.kg$^{-1}$ for $^{238}$U. For $^{232}$Th From ($67.79\pm0.44$) Bq.kg$^{-1}$ to ($9.96\pm0.14$) Bq.kg$^{-1}$ with an average ($21.88$) Bq.kg$^{-1}$ and for $^{40}$K from ($2680.7\pm23.60$) Bq.kg$^{-1}$ to ($283.70\pm3.41$) Bq.kg$^{-1}$ with an average ($133.09$) Bq.kg$^{-1}$. Also, it is found that the Outdoor and indoor annual effective absorbed dose equivalent also (Hin) hazard indices was ($0.302\pm0.014$) and average annual committed effective dose ($0.2205\pm0.030$) mSv.y$^{-1}$ in the flour samples. This study proved that the natural radioactivity and radiation danger records were low also estimated cancer risk has no significant health hazard in Iraqi Flour.

Keywords: Hazard indices, Gammaspectrometry, Flour, Iraq.

1. Introduction

Characteristic radioactivity is brought about by the nearness of Natural occurring radioactive matter (NORM) in the environment. Instances of normal radionuclides incorporate isotopes of Potassium ($^{40}$K), Uranium ($^{238}$U and its decay series), and Thorium ($^{232}$Th and its decay series). In Health Physics, radiation dosimetry is characterized as the estimation of radiation levels that sway on human health[1]. The world population is subjected to different types of radiation sources including artificial radiation (15%) and natural radiation (85%) which contains food and drinks (11%). This may give a...
chance to the contamination of radioactive materials [2]. In fact, NORM can be moved from soil to plants. Thus, each sort of food may have some amount of radioactivity in it[3]. The world population is subjected to different types of radiation sources including artificial radiation, these radionuclides are commonly present in air, soil, and Flour in various sums and levels of movement [4]. Normal radionuclides are found in earthly and oceanic evolved ways of life, with consequent exchange to people through ingestion of nourishment. As such, worldwide endeavors were united cooperatively to apply sufficient strategies in researching radionuclides in food [5], and to set basic rules to secure against elevated levels of inner presentation that might be brought about by food consumption [6].

Since Flour is one of the essential food that is consumed in Iraqis daily lives, the longing to build up a national standard of radioactivity exposure from various kinds of Flour types that available in Iraq markets is very critical, Flour is a powder made from the grinding of wheat used for human consumption. Also, the "Staff of Life", has been an essential commodity to human existence through the centuries and is currently the most widely consumed staple food[7]. Moreover, numerous studies were conducted worldwide to research natural radionuclides in food consumed in various pieces of the world[8, 9]. Another study on vegetables .The annual effective dose due to intake of these radionuclides through ingestion of vegetable samples was estimated to assess radiological risks, the average annual effective dose was found as 213.27 μ Sv y⁻¹[10] .Radioactivity measurements in staples are very important for checking radiation hazards on human health. Where the another study in Iraq found the dose due to consumption of fish by the public has also been determined and it has been below the dose limit recommended by World Health Organization [11, 12]. This paper aims to create radiological baseline data of the hazard radiation in involved foodstuff (Flour samples in Najaf/Iraq). To achieve this aim, the radioactivity levels and radiation hazard indices of consumed Flour types in Najaf, Iraq are calculated and investigated. Since Flour is famous among all ages, the present study centers around limited the natural radioactive in this nourishment

2.Materials and Methods

collection and Preparation (15) samples of the most available kinds of Flour were gathered from the local markets in Iraq to measure natural activity. The types of samples are listed in Table (1) where was the Wight of each sample was 600gm. After collection, each Flour sample was kept in a plastic bag and marked by its name. After collection, these samples were packed in a 1 L polyethylene plastic container of constant volume to arrive at a geometric homogeneity around the Detector, then the respective net weights were measured and recorded with a high sensitive digital weighing balance with a percent of ±0.01%. the plastic container were sealed with adhesive tape, the samples were kept in container for one month to confirm the radioactive equilibrium to take place between the series $^{222}$Rn and their short lived progenies [10].
Table 1. The Characteristics of Flour samples available in markets of Iraq

| Sq. | Name of Samples     | Code | Origin   |
|-----|---------------------|------|----------|
| 1   | Zero flour          | F₁   | Turkey   |
| 2   | Aqeelah             | F₂   | Iran     |
| 3   | Ard shiraz star     | F₃   | Iran     |
| 4   | Alzamord            | F₄   | Iran     |
| 5   | Al Ihasan           | F₅   | Iraq     |
| 6   | Flour company       | F₆   | Iran     |
| 7   | Al Haidariya        | F₇   | Iraq     |
| 8   | Barka zain company  | F₈   | Iraq     |
| 9   | Al rahab company    | F₉   | Iraq     |
| 10  | Soft                | F₁₀  | Turkey   |
| 11  | Kush                | F₁₁  | Iran     |
| 12  | Barley flour        | F₁₂  | Turkey   |
| 13  | Ameen               | F₁₃  | Turkey   |
| 14  | Zer                 | F₁₄  | Turkey   |
| 15  | Warameen            | F₁₅  | Iran     |

Characteristic radioactivity levels were estimated utilizing a gamma spectrometer which incorporates gamma multichannel analyzer outfitted with NaI(Tl) indicator of crystal dimension (3” * 3”). The gamma spectra were analyzed using the ORTEC Maestro-32 information procurement and analysis system. The detector had coaxial closed-facing geometry with the following specifications. The calculated resolution is 7.9% for energy of (661.66 keV) of ¹³⁷Cs standard source. Relative efficiency at (1.33 MeV) ⁶⁰Co was 22.2% and at (1.27 MeV) ²²Na was 24.4%. The detector was shielded by a cylindrical lead shield in order to achieve the lowest background level. An energy calibration for this detector was performed with a set of standard ¹³⁷Cs, ⁶⁰Co, ⁵⁴Mn, and ²²Na sources. In this study, the concentration of ⁴⁰K was determined directly from the peak areas at (1460 keV). The activity concentration of ²³⁸U and ²³²Th were calculated assuming common balance with their decay products. The gamma transition lines of ²¹⁴Bi (1765 keV) were used to calculate concentration of radioisotope in the ²³⁸U-series. The activity concentration of radioisotope in the ²³²Th-series were determined using gamma transition lines of ²⁰⁸Tl (2614 keV). The checking time for each sample was 5 hours.
Calculation of Activity. Since the counting rate is proportional to the amount of the radioactivity in a sample, $A_n$ is the Activity Concentration of each radionuclide in Bq.kg$^{-1}$, which can be determined as a specific activity as follows [13]:

$$A_n = \frac{(C_n - C_b)}{t \varepsilon \gamma I \gamma m_s} \tag{1}$$

where $A_n$ is the specific activity of each radionuclide in Bq.kg$^{-1}$, $C_n$ the count rate in cps for sample, $C_b$ the count rate in cps for background, $\varepsilon \gamma$ and $I \gamma$ are detection efficiency and emission probability of $\gamma$-ray, $t$ is the checking time and $m_s$ is the mass of the sample in Kg.

Where $A_{Ra}$, $A_{Th}$ and $A_K$ are the specific activity of $^{238}$U, $^{232}$Th and $^{40}$K respectively.

The internal ($H_{in}$) hazard indices was calculated using Equations (2) [14, 15].

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \tag{2}$$

The internal hazard index has to be less than one as well to provide safe radionuclide levels in all samples. In the event that the determined estimations of files are more prominent than solidarity, radioactivity may make hurt the populace.

The annual effective dose equivalent from outdoor terrestrial gamma radiation is [16]:

$$D_{eff} = \text{Outdoor dose (nGy h$^{-1}$)} * 0.7 (\text{Sv Gy$^{-1}$}) * 8760 (\text{h y$^{-1}$}) * 0.2 \tag{3}$$

For indoor exposure, using an occupancy factor of 0.8, the annual effective dose equivalent is:

$$D_{eff} = \text{indoor dose (nGy h$^{-1}$)} * 0.7 (\text{Sv Gy$^{-1}$}) * 8760 (\text{h y$^{-1}$}) * 0.8 \tag{4}$$

the average annual committed effective dose, $E_{ave}$, for ingestion of NORMS in the Flour were calculated using the expression in equation below [17].

$$E_{ave} = C_r \cdot DCF_i \cdot A_i \tag{5}$$

Where $DCFi$ is the dose convection factor for ingestion, for each radionuclide (i.e., $4.5 \times 10^{-5}$ mSv.Bq$^{-1}$, $2.3 \times 10^{-4}$ mSv.Bq$^{-1}$ and $6.2 \times 10^{-6}$ mSv.Bq$^{-1}$ for $^{238}$U, $^{232}$Th and $^{40}$K respectively for an adult (UNSCEAR 2000). $C_r$ is the consumption rate from intake of NORMS in Flour and $A_i$ is the activity concentration in the Flour sample. Subsequently, based on this data and the non-accessibility of an all-around accepted consumption rate for Flour (90) kg .y$^{-1}$ was assumed for all the Flour eating.

Average annual committed effective dose(AACED) measurements The AACED due to the ingestion of naturally occurring radioactive materials (NORMs) in was estimated according to Equation 9. AACED for an individual is directly proportional to the consumption rate of the
components of Flour. By using the same equation, the threshold consumption rate for a Flour was measured as follows [18].

\[ C_r = \frac{E_{ave}}{\sum_{i=1}^{3} (DCF_i \times A_i)} \]  

(6)

3. Result and Discussion

The specific activity of \(^{238}\text{U}\), \(^{232}\text{Th}\) and \(^{40}\text{K}\) in various types of Flour samples has been measured as appeared in Table (2) and Figures 1 - 3. The specific activity of \(^{238}\text{U}\) was found in the range of \((2.60\pm0.30)\) Bq.kg\(^{-1}\) to \((13.73\pm1.89)\) Bq.kg\(^{-1}\) with an average \((8.75\pm0.71)\) Bq.kg\(^{-1}\), \(^{232}\text{Th}\) from \((9.96\pm0.14)\) Bq.kg\(^{-1}\) to \((67.79\pm0.44)\) Bq.kg\(^{-1}\) with an average \((21.87\pm0.31)\) Bq.kg\(^{-1}\) and \(^{40}\text{K}\) from \((283.70\pm3.41)\) Bq.kg\(^{-1}\) to \((2680.73\pm23.60)\) Bq.kg\(^{-1}\) with an average \((820.20\pm10.14)\) Bq.kg\(^{-1}\).

**Table 2.** Activity concentration (Bq.kg\(^{-1}\)) \(^{40}\text{K}\), \(^{232}\text{Th}\) and \(^{238}\text{U}\) of Flour of present study.

| No. | Sample code | \(^{40}\text{K}\) | \(^{232}\text{Th}\) | \(^{238}\text{U}\) |
|-----|-------------|-----------------|-----------------|-----------------|
| 1   | F\(_1\)     | 345.456±3.859   | 12.439±0.414    | 9.188±0.805    |
| 2   | F\(_2\)     | 363.892±3.776   | 13.578±0.404    | 10.751±0.970   |
| 3   | F\(_3\)     | 332.961±3.692   | 12.373±0.423    | 13.546±0.781   |
| 4   | F\(_4\)     | 334.155±3.776   | 12.976±0.386    | 11.864±0.734   |
| 5   | F\(_5\)     | 302.725±3.748   | 11.648±0.414    | 5.802±0.686    |
| 6   | F\(_6\)     | 300.504±3.442   | 10.603±0.442    | 9.401±0.757    |
| 7   | F\(_7\)     | 341.818±3.637   | 12.561±0.367    | 11.533±0.781   |
| 8   | F\(_8\)     | 283.706±3.692   | 11.507±0.423    | 9.401±0.686    |
| 9   | F\(_9\)     | 2680.738±3.415  | 9.962±0.141     | 5.494±0.734    |
| 10  | F\(_{10}\)  | 2174.022±11.661 | 67.797±0.442    | 5.447±1.894    |
| 11  | F\(_{11}\)  | 949.85±20.546   | 26.93±0.178     | 13.735±0.520   |
| 12  | F\(_{12}\)  | 1071.74±21.656  | 33.333±0.235    | 4.736±0.331    |
| 13  | F\(_{13}\)  | 1256.101±23.600 | 38.324±0.235    | 13.735±0.378   |
| 14  | F\(_{14}\)  | 522.82±20.546   | 17.232±0.160    | 4.026±0.355    |
| 15  | F\(_{15}\)  | 1042.586±21.101 | 36.911±0.178    | 2.605±0.307    |
|     | Average ±S.D| 820.205±10.143  | 21.878±0.318    | 8.750±0.715    |
|     | Average ±S.D[19]| 133.097     | 1.9465          | 6.6025         |
|     | Maximum value | 2680.738±3.415 | 67.797±0.442    | 13.735±0.378   |
|     | Minimum value | 283.706±3.692  | 9.962±0.141     | 2.605±0.307    |
There is a variety in the specific activity of radionuclides in different Flour samples, in the sample (F₉) which is Iraqi (Al rahab company) has height concentration for (⁴⁰K and ²³⁴Th) while (F₁₃) which is Turkish (Ameen) was height for (²³⁸U). The results obtained show that the specific activity of ²³⁸U, ²³⁴Th and ⁴⁰K in all Flour samples seemed lower than recommended limit of UNSCEAR (2008). we noted from our results that all average is higher than values in another publishers [6, 20].

The Outdoor annual effective dose equivalent, Indoor annual effective dose equivalent and the Total annual effective dose equivalent due to ²³⁸U, ²³⁴Th and ⁴⁰K in different kinds of Flour samples has been measured as shown in Table (3) and Figures 4 - 6 respectively. Where was in sample (F₁₀) Turkish(soft) was height in all this parameters while was low in sample (F₅) Iraqi (Al Ihasan).

| Sample code | Outdoor annual effective dose equivalent (mSv.y⁻¹) | Indoor annual effective dose equivalent (mS.y⁻¹) | Total annual effective dose equivalent (mSv.y⁻¹) | Internal radiation hazard, H_int | AACD (mSv.y⁻¹) |
|-------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|---------------------------------|----------------|
| F₁          | 0.172±0.005                                   | 0.033±0.0009                                  | 0.025±0.0059                                  | 0.17±0.012                      | 0.2320±0.031   |
| F₂          | 0.186±0.005                                   | 0.036±0.0010                                  | 0.222±0.0064                                  | 0.186±0.013                     | 0.2710±0.034   |
| F₃          | 0.18±0.004                                    | 0.035±0.0009                                  | 0.215±0.0058                                  | 0.19±0.011                      | 0.3410±0.030   |
| F₄          | 0.179±0.004                                   | 0.034±0.0008                                  | 0.213±0.0055                                  | 0.184±0.011                     | 0.2990±0.028   |
| F₅          | 0.148±0.004                                   | 0.028±0.0008                                  | 0.176±0.0053                                  | 0.139±0.011                     | 0.1460±0.027   |
| F₆          | 0.153±0.004                                   | 0.029±0.0009                                  | 0.182±0.0058                                  | 0.154±0.011                     | 0.2370±0.030   |
| F₇          | 0.178±0.004                                   | 0.034±0.0008                                  | 0.212±0.0055                                  | 0.182±0.011                     | 0.2910±0.029   |
| F₈          | 0.152±0.004                                   | 0.029±0.0008                                  | 0.181±0.0055                                  | 0.154±0.011                     | 0.2370±0.028   |
| F₉          | 0.792±0.004                                   | 0.152±0.0008                                  | 0.944±0.0053                                  | 0.625±0.010                     | 0.1380±0.028   |
| F₁₀         | 0.897±0.008                                   | 0.173±0.0017                                  | 1.07±0.0106                                   | 0.743±0.021                     | 0.1370±0.057   |
| F₁₁         | 0.412±0.007                                   | 0.079±0.0015                                  | 0.491±0.0093                                  | 0.376±0.018                     | 0.3460±0.028   |
| F₁₂         | 0.448±0.007                                   | 0.086±0.0015                                  | 0.534±0.0093                                  | 0.377±0.019                     | 0.1190±0.025   |
| F₁₃         | 0.544±0.008                                   | 0.105±0.0016                                  | 0.694±0.0101                                  | 0.483±0.020                     | 0.3460±0.027   |
| F₁₄         | 0.227±0.007                                   | 0.044±0.0013                                  | 0.271±0.0086                                  | 0.197±0.017                     | 0.1010±0.023   |
| F₁₅         | 0.449±0.007                                   | 0.086±0.0014                                  | 0.535±0.0087                                  | 0.373±0.017                     | 0.0660±0.023   |
| Average     | 0.341±0.006                                   | 0.066±0.0011                                  | 0.407±0.0072                                  | 0.302±0.014                     | 0.2205±0.030   |
| ±S.D        |                                              |                                              |                                              |                                 |                |
| Average     | 0.3213±0.1657                                 |                                              |                                              |                                 |                |
| ±S.D[12]    |                                              |                                              |                                              |                                 |                |
| Maximum     | 0.897±0.008                                   | 0.173±0.0017                                  | 1.07±0.0106                                   | 0.743±0.021                     | 0.3460±0.028   |
The values of all the radiation hazard indices in this study, Internal radiation hazard (H_{int}), Representative level index and average annual committed effective dose (AACD) are height in sample (F_{10}) Soft (Turkish) except (AACD) in sample( F_{11}) Kush (Irani) While lowest value in sample (F_{5}) Iraqi (Al Ihasan) except AACD in sample F_{15}(Warameen) Irani, which was arranged in (table 3) below and in Figures 7-8 respectively.

### 3.1 Excess lifetime Cancer risk:

The risk of cancer due to radiation effects which is called excess lifetime cancer risk (ELCR) can be calculated from the following equation [21]

\[
\text{ELCR} = (\text{AACD}) \text{ Sv.y}^{-1} \times \text{Rf (Sv}^{-1})
\]

Where, (AACD) the annual committed effective dose of the average duration for adult members of public and risk factor respectively. The value of risk factor (Rf) in the public is 0.05 per Sievert as recommended by ICRP for stochastic effects [22]. The average annual committed effective dose for the measured flour in this study, 0.2205 mSv, is used to estimate cancer risk for an adult person using the equation (11) above was estimated to be 0.0110 mSv, which gives a risk factor of 5.512*10^{-4}. The estimated values are significantly less than the ICRP cancer risk of 2.5 \times 10^{-3} based on annual dose limit of 1 mSv for general public. Which mean the average of all samples is saving healthy.
Figure 1. Activity concentrations of $^{40}$K in Flour samples

Figure 2. Activity concentrations of $^{232}$Th in Flour samples

Figure 3. Activity concentrations of $^{238}$U in Flour samples

Figure 4. the outdoor annual effective dose (nGy. h$^{-1}$) in Flour samples

Figure 5. the Indoor annual effective dose (nGy. h$^{-1}$) in Flour samples
Figure 6. The total annual effective dose (nGy h⁻¹) in Flour samples

Figure 7. Internal hazard index in Flour samples

Figure 8. Average annual committed effective dose (AACD) in Flour samples

4. Conclusions

The current study is significant at the national level to study radioactivity of Flour that is available in Iraqi markets. It is found that utilization of Flour as the staple is safe for all ages of individuals in Iraq. Potassium (⁴⁰K) specific activity in (Bq kg⁻¹) were very high compared with other studies [23], especially in sample F9 which may be because the type of soil or Fertilizers which added for soil containing potassium, this work will help in building up a gauge of radioactivity exposure to the public from ingestion of foodstuff. Also have been found the outdoor and indoor annual effective absorbed dose equivalent derived from activity Internal radiation hazard and average annual committed effective dose for Flour samples were the results fall within the permissible limits internationally that mean we estimated from this study the cancer risk has no significant health hazard and Iraqi Flour which used in markets are radiologically safe, as per international standards.
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