دراسة المواد المشعة طويلة الأمد في الأرز المستهلك في الكويت

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الملخص:

في هذا البحث، تمت دراسة المواد المشعة طويلة الأمد في الأرز المستهلك في الكويت. ركزت الدراسة على النظائر المشعة الطبيعية مثل 40K ، 238U و 232Th والنظير المشع الغير طبيعي 137Cs من خلال هذه الدراسة، وجد بأن تقييم الجرعة التأثيرية السنوية نتيجة استهلاك الأرز كانت 33 ميكرو سيفرت و 60 ميكرو سيفرت للبالغين والأطفال على التوالي. إن هذه القيم هي أقل بكثير من المعدل العالمي للإشعاع الهضمي الناتج عن الإشعاعات الطبيعية والذي حدد بـ 6210 ميلي سيفرت. الجدير بالذكر بأن النظير المشع الغير طبيعي 137Cs رصد في عينة واحدة فقط من ضمن الواحد وعشرين عينة قيد الدراسة بحيث وجد بأن نشاطها الإشعاعي مساوي إلى 0.1 بكورل/كغ وهو أقل بكثير من الحد المسموح به. بناءً على هذه الدراسة والنتائج فإن استهلاك الأرز في الكويت يعد آمناً إشعاعياً.
Radioactivity of long lived gamma emitters in rice consumed in Kuwait

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Available online 11 November 2012

Abstract A study of long-lived gamma emitting radionuclides in rice consumed in Kuwait was performed. The study targeted the natural radionuclides 238U, 232Th, and 40K, in addition to the anthropogenic radionuclide 137Cs. Annual effective doses from rice consumption were estimated to be 33 and 60 lSv for the adult and child age groups respectively. These values were found to be of several orders of magnitude less than the 0.29 mSv year"u1 world average of the ingestion exposure from natural sources reported in the literature. Moreover, the anthropogenic radionuclide 137Cs was detected in one sample only, out of the 21 samples measured, with an activity concentration of 0.1 Bq kg"u1. This small value is four orders of magnitude less than the guideline limit. Hence, rice consumption in Kuwait is radiologically safe for the presence of the investigated radionuclides.

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1. Introduction

Radioactivity in the environment originates from natural and anthropogenic (man-made) sources. Natural radionuclides include isotopes of potassium (40K), uranium (238U and its decay series), and thorium (232Th, and its decay series). These natural occurring radioactive materials (NORM) are long-lived (in the order of 1010 year) and are typically present in environmental samples.

Anthropogenic radionuclides are products of nuclear processes in industrial, medical, and military applications. Releases to the environment can be either controlled (regulated discharges) or uncontrolled (accidents). For example, it was estimated that 9 \times 10^{16} Bq of the cesium isotope 137Cs, were released to the environment from the Chernobyl accident (IAEA, 2006). The presence of anthropogenic radionuclides in environmental samples is an indicator of a previous contaminating event.

Natural and anthropogenic radionuclides are found in terrestrial and aquatic food chains, with subsequent transfer to humans through ingestion of food. Therefore, there is a global interest in human radiation exposure due to radionuclide intake from food (Ababneh et al., 2009; Al-Azmi et al., 1999; Alrefae, 2012; Alrefae et al., 2012; Hosseini et al., 2006; IAEA, 1989, 2006, 2009; ICRP, 1996; Yu and Mao, 1999).

Among the types of food that are commonly consumed worldwide is rice. Hence, studies on the radioactivity of rice have been performed in various regions across the globe (Hosseini et al., 2006; Saeed et al., 2011; Yu and Mao, 1999). Results of these studies helped in establishing baselines of radiation exposure to people from consumption of rice.
A thorough literature search reveals a small number of studies on the radionuclide content of food consumed in Kuwait (Al-Azmi et al., 1999; Alrefae, 2012; Alrefae et al., 2012). Such scarcity was the main motive to conduct the current study, in order to meet the important national requirement of establishing a baseline of radioactivity exposure to the general public from food consumption. For a systematic approach, this study focused on one type of foodstuff that is widely consumed by various age groups in Kuwait, namely rice. Hence the aim of this study was to quantify the presence of long-lived gamma emitters in rice consumed in Kuwait, and to estimate annual effective doses to the general public due to this consumption.

2. Materials and methods

Rice samples were collected from the Kuwaiti local market. The collection took place between January and June of 2010. To ensure a comprehensive and a wide-spread representation, 21 different brands that originated from 5 different countries were selected. Since rice is not produced locally in Kuwait, all samples were imported. Prior to measurement, each sample was powdered and placed in a Marinilli beaker. After being sealed, the sample-filled containers were left for a period of at least 4 weeks to reach secular equilibrium between parent radionuclides and their daughters. Measurements were performed using a high purity germanium (HPGe) p-type detector with an active diameter of 61 mm and a length of 46 mm. The low background Canberra system, had an energy resolution of 1.75 keV FWHM at the 1.33 MeV 60Co photopeak. This counting system of 30 percent relative efficiency was connected to a multi-channel analyzer. Energy calibration for the detector was performed using a set of point sources. As for efficiency calibration, it was performed over the energy range of 46.5–2000 keV using a standard, certified multinuclide source. As for efficiency calibration, it was performed over the energy range of 46.5–2000 keV using a standard, certified multinuclide source. Energy calibration for the detector was performed using a set of point sources. As for efficiency calibration, it was performed over the energy range of 46.5–2000 keV using a standard, certified multinuclide source. Energy calibration for the detector was performed using a set of point sources. As for efficiency calibration, it was performed over the energy range of 46.5–2000 keV using a standard, certified multinuclide source. Energy calibration for the detector was performed using a set of point sources. As for efficiency calibration, it was performed over the energy range of 46.5–2000 keV using a standard, certified multinuclide source.

To reduce statistical counting error, the samples were counted for a period of 86,400 s (one full day). An empty container was also counted under the same conditions to determine the background counts. For spectrum analysis, Gennie software was used, where the photopeaks considered were those of 238U progenies (295, 352, 609, 1120 and 1765 keV), 232Th progenies (238, 338, 583 and 911 keV), 137Cs (662 keV), and 40K (1460 keV). The activity concentration \( A \) (Bq kg\(^{-1}\)) of each radionuclide in each sample was calculated from the formula (IAEA, 1989)

\[
A = \frac{N}{\epsilon P_i t m}
\]

where \( N \) is the net counts of the corresponding photopeak, \( P_i \) is the emission probability per disintegration (IAEA, 1989), \( \epsilon \) is the the detector efficiency obtained from Eq. (1), at this specific gamma line, \( t \) is the counting time in seconds and \( m \) is the mass of the sample in kg. For radionuclides of decay series, namely 238U and 232Th, quantifying the activity was performed by applying Eq. (2) for the relevant photopeaks, then taking the average value.

3. Results

A gamma spectrum is shown in Fig. 1, where the gamma lines indicate the presence of radionuclides in the measured sample.

Table 1 presents the activity concentrations for 238U, 232Th, 40K, and 137Cs in the rice samples. 238U was detected in 9 out of the 21 samples with a maximum value of 0.91 ± 0.35 Bq kg\(^{-1}\) (a sample from India), a minimum value of 0.41 ± 0.19 Bq kg\(^{-1}\) (a sample from India), and an all-brand average of (±SD) 0.62 ± 0.19 Bq kg\(^{-1}\).

As for 232Th, it was detected in all samples with a maximum value of 0.61 ± 0.027 Bq kg\(^{-1}\) (a sample from India), a minimum value of 0.32 ± 0.093 Bq kg\(^{-1}\) (a sample from France), and an all-brand average of (±SD) 0.48 ± 0.10 Bq kg\(^{-1}\).

40K was detected in all samples with a maximum value of 100.00 ± 2.00 Bq kg\(^{-1}\) (a sample from Germany), a minimum value of 32.8 ± 0.63 Bq kg\(^{-1}\) (a sample from Pakistan), and an all-brand average of (±SD) 48.60 ± 18.34 Bq kg\(^{-1}\).

As for 137Cs, it was detected in one sample only (a sample from Germany) with a value of 0.1 ± 0.019 Bq kg\(^{-1}\).

4. Discussion

The presence of natural radionuclides in rice samples was expected. Specifically, detection of 40K in all samples was anticipated due to its natural abundance. As for 238U, its detection in some samples (in about 50 percent of the total samples) does not necessarily imply its absence in others. It is well understood that background levels and system detection limits could conceal minor photopeaks (Knoll, 2000). In fact, the infrequency of 238U detection in food samples was reported by various authors (Ababneh et al., 2009; Hosseini et al., 2006).

The absence of the anthropogenic radionuclide 137Cs in most rice samples was expected, since this substance does not naturally exist in the environment. Nonetheless, the detection

Figure 1 Gamma spectrum of sample 1. U = 238U lines. T = 232Th lines. C = 137Cs line. K = 40K line.
of this man-made radionuclide in one sample (from Germany) was not surprising. The Chernobyl accident fallout, which contained $^{137}$Cs, is still being uptaken by vegetation (IAEA, 2006). It is noteworthy, however, that the $^{137}$Cs amount found in the German rice sample was four orders of magnitude less than the guideline level (UNSCEAR, 2000).

The results from the present study were compared to those reported in the literature. Table 2 shows the values of the activity concentration of the present study agreeing in some cases with those reported in the literature. Such agreement is evident in the $^{40}$K range overlap of rice samples from Pakistan of the present study with the range of values reported in the literature for the same region. In other cases, however, the activity concentrations in the present study exhibit higher values than those reported in the literature for the same region. For example, $^{232}$Th activity concentration of rice samples from Pakistan is one order of magnitude higher in this study than those reported in the literature. Nevertheless, similar variability in food samples has been previously reported by others (Ababneh et al., 2009; Hosseini et al., 2006).

The annual effective dose from consumption of rice was calculated using the following formula (UNSCEAR, 2000)

$$D = AEI$$

where $D$ is the annual effective dose (Sv year$^{-1}$), $A$ is the activity concentration for the radionuclide (Bq kg$^{-1}$), $E$ is the dose conversion factor for the radionuclide (Sv Bq$^{-1}$), and $I$ is the annual intake of rice (kg). Since $E$ is age-dependent, the calculation for the annual effective dose $D$ was performed for both age groups separately. Values for $E$ (Table 3) were selected based on the International Commission on Radiological Protection (ICRP) classifications (ICRP, 1996), namely adults and children (10 years old). Values of $I$ were taken to be 75 kg year$^{-1}$, in accordance to the official gazette data of ration distributed to Kuwaiti households (Kuwait Government, 2009). The results of the annual effective dose $D$ are presented

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### Table 1 Activity concentrations (Bq kg$^{-1}$) of $^{238}$U, $^{232}$Th, $^{40}$K, and $^{137}$Cs in rice samples investigated in this study.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Brandname</th>
<th>Origin</th>
<th>$^{238}$U</th>
<th>$^{232}$Th</th>
<th>$^{40}$K</th>
<th>$^{137}$Cs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kuwaitania rice</td>
<td>Egypt</td>
<td>0.77 ± 0.57</td>
<td>0.60 ± 0.18</td>
<td>36.20 ± 0.71</td>
<td>ND</td>
</tr>
<tr>
<td>2</td>
<td>Lataste</td>
<td>France</td>
<td>–</td>
<td>0.32 ± 0.14</td>
<td>51.15 ± 1.00</td>
<td>ND</td>
</tr>
<tr>
<td>3</td>
<td>Natural and organic</td>
<td>Germany</td>
<td>–</td>
<td>0.37 ± 0.067</td>
<td>87.53 ± 1.73</td>
<td>ND</td>
</tr>
<tr>
<td>4</td>
<td>Rapunzel</td>
<td>Germany</td>
<td>ND</td>
<td>0.53 ± 0.063</td>
<td>101.00 ± 1.98</td>
<td>0.10 ± 0.012</td>
</tr>
<tr>
<td>5</td>
<td>Alwazzan</td>
<td>India</td>
<td>ND</td>
<td>0.43 ± 0.073</td>
<td>33.16 ± 0.65</td>
<td>ND</td>
</tr>
<tr>
<td>6</td>
<td>Coop</td>
<td>India</td>
<td>0.41 ± 0.19</td>
<td>0.55 ± 0.071</td>
<td>40.61 ± 0.65</td>
<td>ND</td>
</tr>
<tr>
<td>7</td>
<td>Country</td>
<td>India</td>
<td>ND</td>
<td>0.47 ± 0.093</td>
<td>51.59 ± 1.01</td>
<td>ND</td>
</tr>
<tr>
<td>8</td>
<td>Dawat</td>
<td>India</td>
<td>ND</td>
<td>0.53 ± 0.094</td>
<td>42.16 ± 0.83</td>
<td>ND</td>
</tr>
<tr>
<td>9</td>
<td>Gazell</td>
<td>India</td>
<td>0.44 ± 0.14</td>
<td>0.36 ± 0.091</td>
<td>42.24 ± 0.80</td>
<td>ND</td>
</tr>
<tr>
<td>10</td>
<td>Gold seal</td>
<td>India</td>
<td>0.71 ± 0.043</td>
<td>0.45 ± 0.081</td>
<td>48.00 ± 0.94</td>
<td>ND</td>
</tr>
<tr>
<td>11</td>
<td>Hamsa</td>
<td>India</td>
<td>0.55 ± 0.022</td>
<td>0.56 ± 0.031</td>
<td>39.61 ± 0.77</td>
<td>ND</td>
</tr>
<tr>
<td>12</td>
<td>India gate</td>
<td>India</td>
<td>0.84 ± 0.27</td>
<td>0.44 ± 0.093</td>
<td>42.87 ± 0.82</td>
<td>ND</td>
</tr>
<tr>
<td>13</td>
<td>Malek</td>
<td>India</td>
<td>ND</td>
<td>0.50 ± 0.017</td>
<td>43.65 ± 0.67</td>
<td>ND</td>
</tr>
<tr>
<td>14</td>
<td>Dr. Moosa</td>
<td>India</td>
<td>0.42 ± 0.014</td>
<td>0.62 ± 0.027</td>
<td>81.16 ± 1.62</td>
<td>ND</td>
</tr>
<tr>
<td>15</td>
<td>Rozan</td>
<td>India</td>
<td>ND</td>
<td>0.54 ± 0.030</td>
<td>43.30 ± 0.86</td>
<td>ND</td>
</tr>
<tr>
<td>16</td>
<td>Shaker</td>
<td>India</td>
<td>ND</td>
<td>0.49 ± 0.083</td>
<td>47.31 ± 0.90</td>
<td>ND</td>
</tr>
<tr>
<td>17</td>
<td>Sunwhite</td>
<td>India</td>
<td>0.91 ± 0.35</td>
<td>0.44 ± 0.062</td>
<td>47.67 ± 0.82</td>
<td>ND</td>
</tr>
<tr>
<td>18</td>
<td>Tilda</td>
<td>India</td>
<td>0.55 ± 0.21</td>
<td>0.54 ± 0.04</td>
<td>41.49 ± 0.92</td>
<td>ND</td>
</tr>
<tr>
<td>19</td>
<td>VecTee</td>
<td>India</td>
<td>ND</td>
<td>0.46 ± 0.073</td>
<td>40.36 ± 0.79</td>
<td>ND</td>
</tr>
<tr>
<td>20</td>
<td>Alquuem</td>
<td>Pakistan</td>
<td>ND</td>
<td>0.43 ± 0.09</td>
<td>32.90 ± 0.63</td>
<td>ND</td>
</tr>
<tr>
<td>21</td>
<td>Alquaem</td>
<td>Pakistan</td>
<td>ND</td>
<td>0.46 ± 0.096</td>
<td>37.72 ± 0.74</td>
<td>ND</td>
</tr>
</tbody>
</table>

ND = not detected.
Radioactivity of long lived gamma emitters in rice consumed in Kuwait

5. Conclusion

Long-lived gamma emitters in rice consumed in Kuwait were investigated. The rice samples originated from 5 different countries. The study targeted four radionuclides, namely $^{238}\text{U}$, $^{232}\text{Th}$, $^{40}\text{K}$, and $^{137}\text{Cs}$. While $^{232}\text{Th}$ and $^{40}\text{K}$ were detected in all samples, $^{238}\text{U}$ was detected in some samples with varying quantities, and undetected in others. Interestingly, $^{137}\text{Cs}$ was detected in one sample only. In addition, the annual effective dose from consumption of rice was calculated for the adult and child age groups. It was found that rice consumption in Kuwait is radiologically safe for the presence of investigated radionuclides.

The present study is the first at the national level to investigate the radioactivity of rice. The findings of this study will help in establishing a baseline of radioactivity exposure to the general public from ingestion of foodstuff. Rice, however, is only one dietary component and the focus of the present study was gamma emitters. To establish a more robust baseline, there is a need to investigate more types of foodstuffs, as well as targeting alpha and beta emitting radionuclides.

Acknowledgement

The authors thank Taher Al-Shemali for his help in sample preparation.

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