Journal of the Association of Arab Universities for Basic and Applied Sciences (2013) **13**, 24–27

University of Bahrain

Journal of the Association of Arab Universities for Basic and Applied Sciences

www.elsevier.com/locate/jaaubas
www.sciencedirect.com

دراسة المواد المشعة طويلة الأمد في الأرز المستهلك في الكويت

طارق الرفاعي[1,2]، تيروفاتشي ناتارجان ناقشوان[2]

[1] قسم الفيزياء، كلية العلوم، جامعة الكويت

[2] مركز ابحاث الإشعاع البيئي، كلية العلوم، جامعة الكويت

الملخص:

في هذا البحث لقد تمت دراسة المواد المشعة طويلة الأمد في الأرز المستهلك في الكويت. ركزت الدراسة على النظائر المشعة الطبيعية مثل ^{40}K , ^{238}U, ^{232}Th و النظير المشع الغير طبيعي ^{137}Cs من خلال هذه الدراسة وجد بأن تقدير الجرعة التأثيرية السنوية نتيجة استهلاك الارز كانت 33 ميكرو سيفرت و 60 ميكرو سيفرت للبالغين والأطفال على التوالي. إن هذه القيم هي أقل بكثير من المعدل العالمي للتعرض الإشعاعي الهضمي الناتج عن الاشعاعات الطبيعية والذي حدد بـ 0.29 ميللي سيفرت. الجدير بالذكر بأن النظير المشع الغير طبيعي ^{137}Cs رصد في عينة واحدة فقط من ضمن الواحد وعشرين عينة قيد الدراسة بحيث وجد بأن نشاطها الاشعاعي مساوي إلى 0.1 بكورل/كغ وهو أقل بكثير من الحد المسموح به. بناء على هذه الدراسة والنتائج فإن استهلاك الأرز في الكويت يعد آمناً اشعاعياً.

Journal of the Association of Arab Universities for Basic and Applied Sciences (2013) **13**, 24–27

University of Bahrain

Journal of the Association of Arab Universities for Basic and Applied Sciences

www.elsevier.com/locate/jaaubas
www.sciencedirect.com

ORIGINAL ARTICLE

Radioactivity of long lived gamma emitters in rice consumed in Kuwait

Tareq Alrefae [a,b,*], **Tiruvachi N. Nageswaran** [b]

[a] *Physics Department, Faculty of Science, Kuwait University, Kuwait*
[b] *Center of Research in Environmental Radiation, Faculty of Science, Kuwait University, Kuwait*

Available online 11 November 2012

KEYWORDS

NORM;
Rice;
Foodstuff;
Radioactivity;
Dose;
Kuwait

Abstract A study of long-lived gamma emitting radionuclides in rice consumed in Kuwait was performed. The study targeted the natural radionuclides ^{238}U, ^{232}Th, and ^{40}K, in addition to the anthropogenic radionuclide ^{137}Cs. Annual effective doses from rice consumption were estimated to be 33 and 60 μSv 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^{-1} world average of the ingestion exposure from natural sources reported in the literature. Moreover, the anthropogenic radionuclide ^{137}Cs was detected in one sample only, out of the 21 samples measured, with an activity concentration of 0.1 Bq kg^{-1}. 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.

1. Introduction

Radioactivity in the environment originates from natural and anthropogenic (man-made) sources. Natural radionuclides include isotopes of potassium (^{40}K), uranium (^{238}U and its decay series), and thorium (^{232}Th, and its decay series). These natural occurring radioactive materials (NORM) are long-lived (in the order of 10^{10} 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 9×10^{16} Bq of the cesium isotope ^{137}Cs, 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.

* Corresponding author. Address: Physics Department, Faculty of Science, Kuwait University, Firdous St., Khaldia, Kuwait.
E-mail address: tareq.alrefae@ku.edu.kw (T. Alrefae).

Peer review under responsibility of University of Bahrain.

ELSEVIER Production and hosting by Elsevier

1815-3852 © 2012 University of Bahrain. Production and hosting by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.jaubas.2012.07.005

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 ^{60}Co 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 of similar geometry and density to those of the rice samples. Efficiency (ϵ) of each gamma energy specified in the calibration source was calculated using the formula (IAEA, 1989)

$$\epsilon = \frac{N}{AP_\gamma t} \tag{1}$$

where N is the net counts of the corresponding photopeak, A is the activity in Bq, P_γ is the emission probability per disintegration (IAEA, 1989), and t is the counting time in seconds.

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 ^{238}U progenies (295, 352, 609, 1120 and 1765 keV), ^{232}Th progenies (238, 338, 583 and 911 keV), ^{137}Cs (662 keV), and ^{40}K (1460 keV). The activity concentration A (Bq kg^{-1}) of each radionuclide in each sample was calculated from the formula (IAEA, 1989)

$$A = \frac{N}{\epsilon P_\gamma tm} \tag{2}$$

where N is the net counts of the corresponding photopeak. P_γ is the emission probability per disintegration (IAEA, 1989). ϵ 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 ^{238}U and ^{232}Th, 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 ^{238}U, ^{232}Th, ^{40}K, and ^{137}Cs in the rice samples. ^{238}U 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 ^{232}Th, 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}.

^{40}K 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 ^{137}Cs, 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 ^{40}K in all samples was anticipated due to its natural abundance. As for ^{238}U, 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 ^{238}U detection in food samples was reported by various authors (Ababneh et al., 2009; Hosseini et al., 2006).

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

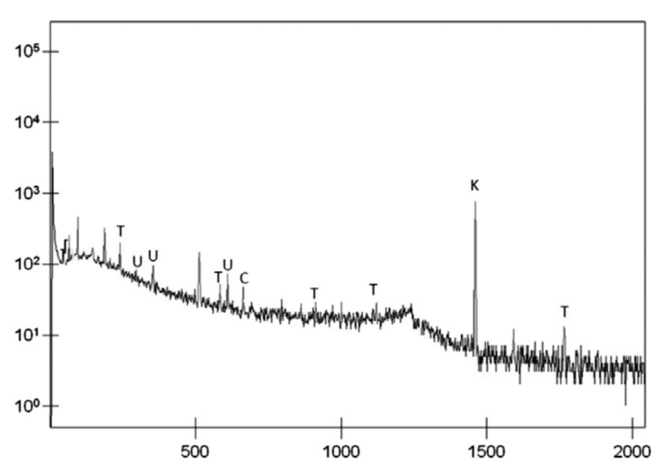

Figure 1 Gamma spectrum of sample 4. U = ^{238}U lines. T = ^{232}Th lines. C = ^{137}Cs line. K = ^{40}K line.

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

Sample No.	Brandname	Origin	^{238}U	^{232}Th	^{40}K	^{137}Cs
1	Kuwaitania rice	Egypt	0.77 ± 0.57	0.60 ± 0.18	36.20 ± 0.71	ND
2	Lataste	France	ND	0.32 ± 0.14	51.15 ± 1.00	ND
3	Natural and organic	Germany	ND	0.37 ± 0.067	87.53 ± 1.73	ND
4	Rapunzel	Germany	ND	0.53 ± 0.063	101.00 ± 1.98	0.10 ± 0.012
5	Alwazzan	India	ND	0.43 ± 0.073	33.16 ± 0.65	ND
6	Coop	India	0.41 ± 0.19	0.55 ± 0.071	40.61 ± 0.65	ND
7	Country	India	ND	0.47 ± 0.093	51.59 ± 1.01	ND
8	Dawat	India	ND	0.53 ± 0.094	42.16 ± 0.83	ND
9	Gazell	India	0.44 ± 0.14	0.36 ± 0.091	42.24 ± 0.80	ND
10	Gold seal	India	0.71 ± 0.043	0.45 ± 0.081	48.00 ± 0.94	ND
11	Hamsa	India	0.55 ± 0.022	0.56 ± 0.031	39.61 ± 0.77	ND
12	India gate	India	0.84 ± 0.27	0.44 ± 0.093	42.87 ± 0.82	ND
13	Malek	India	ND	0.50 ± 0.017	43.65 ± 0.67	ND
14	Dr. Moosa	India	0.42 ± 0.014	0.62 ± 0.027	81.16 ± 1.62	ND
15	Rozan	India	ND	0.54 ± 0.03	43.30 ± 0.86	ND
16	Shaker	India	ND	0.49 ± 0.083	47.31 ± 0.90	ND
17	Sunwhite	India	0.91 ± 0.35	0.44 ± 0.062	47.67 ± 0.82	ND
18	Tilda	India	0.55 ± 0.21	0.54 ± 0.04	41.49 ± 0.92	ND
19	VeeTee	India	ND	0.46 ± 0.073	40.36 ± 0.79	ND
20	Alquaem	Pakistan	ND	0.43 ± 0.09	32.90 ± 0.63	ND
21	Alzehan	Pakistan	ND	0.46 ± 0.096	37.72 ± 0.74	ND

ND = not detected.

Table 2 Activity concentrations (Bq kg^{-1}) of ^{238}U, ^{232}Th, ^{40}K, and ^{137}Cs in rice samples investigated in this study, compared with those reported in the literature.

Origin	^{238}U	^{232}Th	^{40}K	^{137}Cs	Reference
Brazil	–	–	15	–	Venturini and Sordi (1999)
Egypt	0.77	0.60	36	–	(Present study)
France	–	0.32	51	–	(Present study)
Germany	–	0.4–0.5	87–101	0.1	(Present study)
China (Hong Kong)	–	–	15	0.26	Yu and Mao (1999)
India	0.41–0.91	0.36–0.62	36–81	–	(Present study)
Iraq	–	–	38	–	Hosseini et al. (2006)
Malaysia	18–25	35–65	65–110	–	Saeed et al. (2011)
Pakistan	–	0.06–0.08	7–50	0.02–0.04	Hosseini et al. (2006)
Pakistan	–	0.43–0.46	33–38	–	(Present study)
Thailand	–	0.02–0.3	22–23	0.081	Hosseini et al. (2006)

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)

$$D = AEI \tag{3}$$

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

Table 3 Dose conversion factors (nSv Bq^{-1}) of ^{238}U, ^{232}Th, ^{40}K, and ^{137}Cs, for the adult and child age groups (ICRP, 1996).

Age group	^{238}U	^{232}Th	^{40}K	^{137}Cs
Adult	45	230	6.2	13
Child	68	290	613	10

Table 4 Annual effective dose (μSv) from consumption of rice for the adult and child age groups.

Age group	^{238}U	^{232}Th	^{40}K	^{137}Cs	Total
Adult	2	8	23	0	33
Child	3	10	47	0	60

in Table 4. The activity concentration A used in Table 4 was the average for each radionuclide for each age group. Hence, the doses presented in Table 4 are the average annual effective doses, the total of which were found to be 33 and 60 μSv for adults and children respectively. These values were found to be of several orders of magnitude less than the 0.29 mSv year^{-1} world average of the ingestion exposure from natural sources reported in the literature (UNSCEAR, 2000). It is noteworthy that the annual effective dose from ^{137}Cs was considered to be negligible, since this radionuclide was detected in one sample only (originating from Germany). The ^{137}Cs activity concentration in this sample was four orders of magnitude less than the 1000 Bq kg^{-1} guideline limit (UNSCEAR, 2000), thus making it safe for consumption. Therefore, rice consumption in Kuwait is radiologically safe for the presence of investigated radionuclides.

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}U, ^{232}Th, ^{40}K, and ^{137}Cs. While ^{232}Th and ^{40}K were detected in all samples, ^{238}U was detected in some samples with varying quantities, and undetected in others. Interestingly, ^{137}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 the 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.

References

Ababneh, Z.Q., Alyassin, A.M., Aljarrah, K.M., Ababneh, A.M., 2009. Measurement of natural and artificial radioactivity in powdered milk consumed in Jordan and estimates of the corresponding annual effective dose. Radiation Protection Dosimetry 138, 278–283.

Al-Azmi, D., Saad, H.R., Farhan, A.R., 1999. Comparative study of desert truffles from Kuwait and other countries in the Middle East for radionuclide concentration. Biological Trace Element Research 7, 71–72.

Alrefae, T., 2012. Investigation of ^{238}U content in bottled water consumed in Kuwait and estimates of annual effective doses. Health Physics 102 (1), 85–89.

Alrefae, T., Nageswaran, T.N., Al-Failakawi, A., Al-Shemali, T., 2012. Radioactivity of long lived gamma emitters in milk powder consumed in Kuwait and estimates of annual effective doses. Kuwait Journal of Science and Engineering 39 (1A), 1–19.

Hosseini, T., Fathivand, A.A., Barati, H., Karimi, M., 2006. Assessment of radionuclides in imported foodstuffs in Iran. Iranian Journal of Radiation Research 4.

IAEA (International Atomic Energy Agency), 1989. Measurements of Radionuclides in Food and the Environment, Vienna.

IAEA (International Atomic Energy Agency), 2006. Environmental Consequences of the Chernobyl Accident and Their Remediation: Twenty Years of Experience, Vienna.

IAEA (International Atomic Energy Agency), 2009. Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Terrestrial and Freshwater Environments, Vienna.

ICRP (International Commission on Radiological Protection), 1996. Age-dependent Doses to Members of the Public from Intake of Radionuclides, ICRP Publication 72.

Kuwait Government, 2009. Kuwait Gazette, vol. 5. p. 10.

Knoll, G.F., 2000. Radiation Detection and Measurement. Wiley, New York.

Saeed, M.A., Wahab, N.A., Hossain, I., Ahmed, R., Abdullah, H.Y., Ramli, A.T., Tahir, B.A., 2011. Measuring radioactivity level in various types of rice using hyper pure germanium (HPGe) detector. International Journal of the Physical Sciences 6 (32), 7335–7340.

UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation), 2000. Sources and Effects of Ionizing Radiation, New York.

Venturini, L., Sordi, G.A., 1999. Radioactivity and comitted effective dose from some Brazilian foodstuffs. Health Physics 76, 311–313.

Yu, K.N., Mao, S.Y., 1999. Assessment of radionuclide contents in food in Hong Kong. Health Physics 77, 686–696.