University of Bahrain
Journal of the Association of Arab Universities for Basic and Applied Sciences
www.elsevier.com/locate/jaaubas
www.sciencedirect.com

دراسة النشاط الاشعاعي طويل الامد في الاطعمة البحرية المعلبة المستهلكة في الكويت

طارق الرفاعي[1,2]، تيروفاتشي ناقشواران[2]، طاهر الشمالي[2]

[1] قسم الفيزياء، كلية العلوم، جامعة الكويت
[2] مركز أبحاث الإشعاع البيئي، كلية العلوم، جامعة الكويت

الملخص:

أجريت دراسة للمواد المشعة طويلة الأمد في الاطعمة البحرية المعلبة المستهلكة في دولة الكويت. لقد كان مصدر الاطعمة البحرية من اربع دول مختلفة وكانت الدراسة تستهدف النظائر المشعة في الطبيعة مثل، ^{232}Th، ^{226}Ra و ^{40}K.

لقد وجد بأن الجرعة التأثيرية السنوية نتيجة استهلاك الاطعمة البحرية المعلبة هي 5 ميكرو سيفرت، وهذه القيمة هي اقل بكثير من 0.29 ميللي سيفرت وهو المعدل العالمي للتعرض الإشعاعي من مصادر الاشعاع الطبيعية. وبالتالي فان استهلاك الاطعمة البحرية المعلبة في دولة الكويت يعتبر امنا من الناحية الإشعاعية للنظائر المشعة قيد الدراسة.

Journal of the Association of Arab Universities for Basic and Applied Sciences (2014) 15, 6–9

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 canned seafood consumed in Kuwait

Tareq Alrefae [a,b,*], **Tiruvachi Natarajan Nageswaran** [b], **Taher Al-Shemali** [b]

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

Received 21 January 2013; revised 9 March 2013; accepted 10 April 2013
Available online 13 May 2013

KEYWORDS
NORM;
Seafood;
Foodstuff;
Kuwait;
Gamma spectrometry

Abstract A study of long-lived gamma emitting radionuclides in canned seafood consumed in Kuwait was performed. The canned seafood samples originated from four different countries. The study targeted the natural radionuclides ^{232}Th, ^{226}Ra, and ^{40}K. The annual effective dose from canned seafood consumption was estimated to be 5 μSv. This value was found to be several orders of magnitude less than the 0.29 mSv year^{-1} world average of the ingestion exposure from natural sources. Hence, canned seafood consumption in Kuwait is radiologically safe for the presence of the investigated radionuclides.

1. Introduction

Radioactivity in the environment originates mainly from natural sources. Natural radionuclides include isotopes of potassium (^{40}K), uranium (^{238}U and its decay series), and thorium (^{232}Th and its decay series). In addition to being long-lived (in the order of 10^{10} years), these naturally occurring radioactive materials (NORM) are normally present in environmental samples with varying quantities. Consequently, NORM are typically found in terrestrial and aquatic food chains, with subsequent transfer to humans through ingestion of food. In other words, internal radioactive exposure to the general public is directly related to the amount and type of food consumed. This firm relation raised global interest and concern toward radioactivity exposure from food intake (Al-Masri et al., 2004; Chau and Michalec, 2009; FSA, 2004; Gharbi et al., 2010; IAEA, 1989; Venturini and Sordi, 1999; WHO, 2006).

A thorough literature search reveals a relatively small number of studies on the radionuclide content of food consumed in Kuwait (Al-Azmi et al., 1999; Alrefae, 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 food that is widely consumed by various age groups, namely canned seafood. Hence, the aim of this study was to quantify the content of ^{232}Th, ^{226}Ra, and ^{40}K in canned seafood consumed in Kuwait, and to estimate annual effective doses to the general public of various age groups due to this consumption.

2. Materials and methods

Canned fish samples were collected from the Kuwaiti local market. The collection took place between January and June

* Corresponding author at: Department of Physics, Faculty of Science, Kuwait University, Khaldia, Kuwait. Tel.: +965 24987780; fax: +965 24846498.
E-mail address: tareq@washington.edu (T. Alrefae).

Peer review under responsibility of University of Bahrain.

Production and hosting by Elsevier

1815-3852 © 2013 Production and hosting by Elsevier B.V. on behalf of University of Bahrain.
http://dx.doi.org/10.1016/j.jaubas.2013.04.001

of 2010. To ensure a wide-spread representation, 15 different brands were selected, that covered five different types, crab, salmon, sardine, squid, and tuna (Table 1).

Prior to measurement, each sample was prepared in accordance to standard procedures (IAEA, 1989). The preparation included a freeze-drying process that removed the moisture, while preserving essential contents. Such process lasted 4–5 days for each sample. Then, the freeze-dried samples were powdered and placed in cylindrical containers. Dimensions of the containers were 30 mm in radius and 60 mm in height. After being sealed, the sample-filled containers were left for a period of at least 4 weeks to reach a secular equilibrium between parent radionuclides and their daughters. Measurements were performed using a high purity germanium (HPGe) p-type detector. The low background Ortec system, had an energy resolution of 1.75 keV FWHM at the 1.33 MeV ^{60}Co photopeak. This counting system of 80% relative efficiency was connected to a multi-channel analyzer. The detector had a cylindrical geometry with a radius of 37 mm and a height of 88 mm. Energy calibration for the detector was performed using a set of point sources. Efficiency calibration was done using a reference material (IAEA-414) with a cylindrical geometry with the same dimensions as the samples' containers. Because this reference material is made from fish, it has the same density as the investigated samples. Hence, efficiency values (ε) were calculated using the formula (Knoll, 2000).

$$\varepsilon = \frac{N}{AP_\gamma tm} \tag{1}$$

where N is the net counts of the corresponding photopeak after subtracting the background counts. P_γ is the emission probability per disintegration at this specific gamma line. A is the activity concentration of the targeted radionuclide obtained from the reference sheet that came with the reference material. t is the counting time in seconds, and m is the mass of the sample in kg.

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, Gamma Vision software was used, where the photopeaks considered were 609 keV (^{226}Ra), 911 keV (^{232}Th), and 1460 keV (^{40}K). The activity concentration A (Bq kg^{-1}) of each radionuclide in each sample was calculated from the formula (IAEA, 1989).

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

The minimum detectable activity (MDA) was calculated using the formula (Currie, 1968)

$$\text{MDA} = \frac{2.71 + 4.66S_b}{\epsilon P_\gamma tm} \tag{3}$$

where S_b is the standard error in the net background count for the photo-peak. The MDA values for the counting system were calculated to be 0.32, 0.29, and 3.67 Bq kg^{-1} for ^{226}Ra, ^{232}Th, and ^{40}K, respectively.

3. Results

Fig. 1 and 2 present the activity concentrations for ^{226}Ra and ^{40}K, respectively, in the canned seafood samples. ^{226}Ra was detected above the MDA in 14 samples with a maximum value of 2.12 ± 0.17 Bq kg^{-1} (sardine sample) and a minimum value of 0.36 ± 0.07 Bq kg^{-1} (tuna sample). The average activity concentration was (±SD) 0.97 ± 0.1 Bq kg^{-1}.

As for ^{40}K, it was detected in all samples. The maximum value was 41.56 ± 0.57 Bq kg^{-1} (tuna sample) and the minimum value was 4.69 ± 0.19 Bq kg^{-1} (crab sample). The average activity concentration was (±SD) 26.47 ± 0.46 Bq kg^{-1}.

^{232}Th activity concentrations were below the MDA in all samples. Hence, these values were not reported (see Fig 3).

4. Discussion

The presence of the natural radionuclides in canned seafood samples was expected. Specifically, detection of ^{40}K in all samples was anticipated due to its natural abundance. As for ^{226}Ra and ^{232}Th, their undetection in samples does not necessarily imply their absence. It is well understood that background levels and system MDA could conceal minor photopeaks (Knoll, 2000). In fact, the infrequency of ^{226}Ra and ^{232}Th detection in food samples was reported

Table 1 Brand names of types of samples investigated in this study.

Sample no.	Country of origin	Brand name	Type	Wet sample weight (g)	Dried sample weight (g)
1	Japan	Geisha crab meat	Crab	510	100
2	Thailand	Chef's salmon spread	Salmon	370	100
3	Japan	Geisha sardines in tomato sauce	Sardine	645	85
4	Philippines	Ligo sardines in tomato sauce	Sardine	750	100
5	Philippines	Liyo sardines in chilli sauce	Sardine	750	74
6	Thailand	Liyo squids in natural ink	Squid	455	100
7	Thailand	Alwazzan white meat tuna	Tuna	620	100
8	Thailand	Americana white meat tuna	Tuna	370	95
9	Thailand	California garden white tuna	Tuna	370	100
10	Philippines	Century light tuna flakes hot n spicy	Tuna	720	100
11	Thailand	Dandy white meat tuna	Tuna	660	100
12	Thailand	Daniah white meat tuna in veg oil	Tuna	510	100
13	Japan	Geisha Tuna	Tuna	425	85
14	Italy	Rio Mare Light meat tuna in oil	Tuna	640	100
15	Thailand	Melek white meat tuna	Tuna	570	100

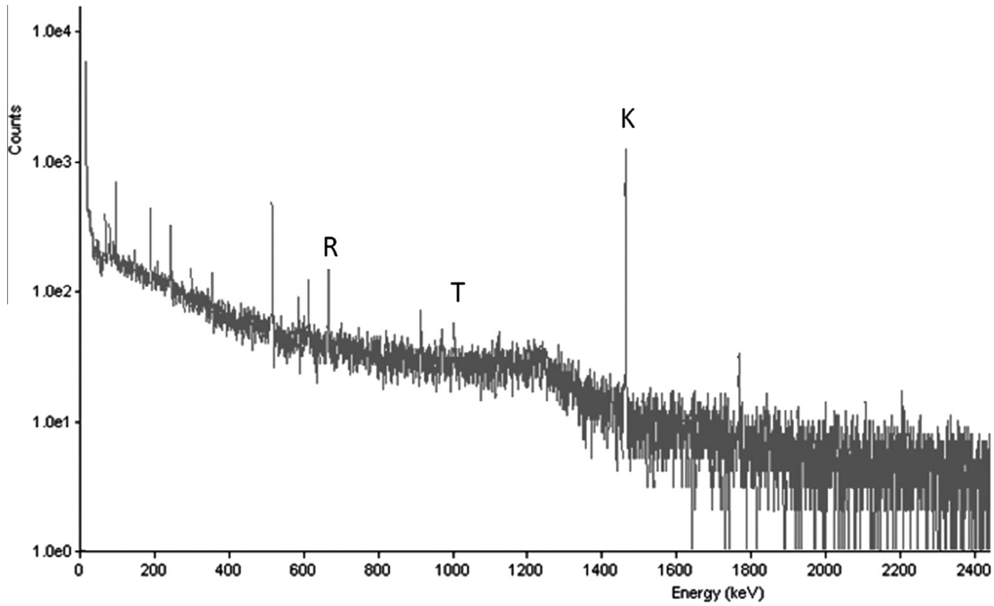

Figure 1 Gamma spectrum for a canned seafood sample, where R, T, and K indicate ^{226}R, ^{232}Th, and ^{40}K, respectively.

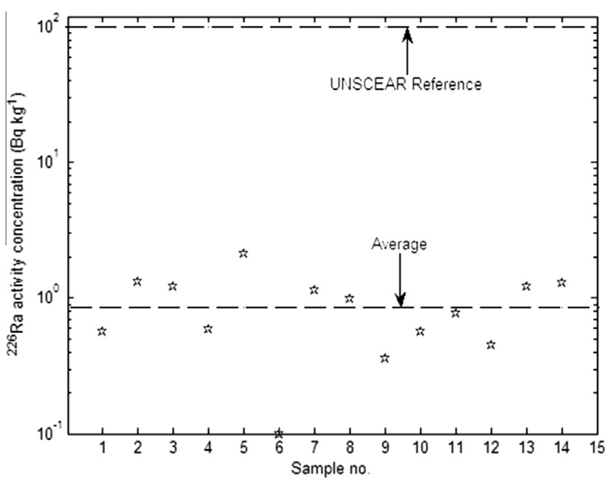

Figure 2 Activity concentration of ^{226}Ra.

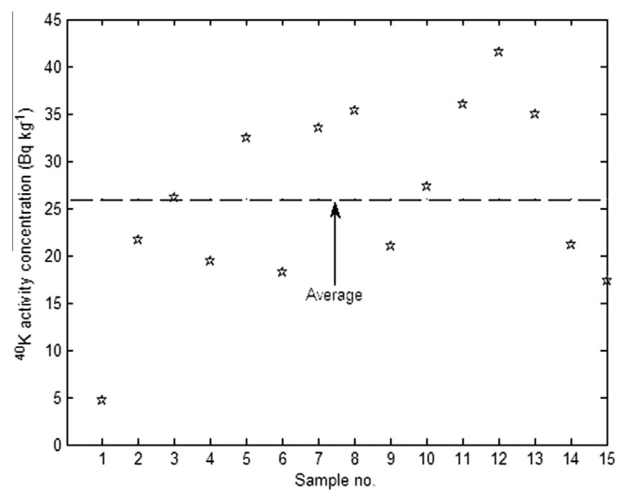

Figure 3 Activity concentration of ^{40}K.

by various authors (Ababneh et al., 2009; Hosseini et al., 2006; Jibiri and Okusanya, 2008; Yu and Mao, 1999).

The results from this study were compared with those reported in the literature. Table 2 shows the values of the present study agreeing with those reported in the literature. Such agreement is evident by the overlap of the activity concentration values of ^{40}K, as well as the below detection limit values of ^{232}Th.

Table 3 shows the activity concentration of the three targeted radionuclides in different food items that are reported in the literature. ^{232}Th is typically unreported due to its relatively low activity in food. This behavior is seen in the present study. Similarly, ^{226}Ra has relatively low activity in food. Again, this behavior is seen in the presented study. As for ^{40}K, it is clearly present in food items with various concentrations. Such variation in ^{40}K could be related to regional and food-type dependences.

Table 2 Activity concentrations (Bq kg^{-1}) of ^{232}Th, ^{226}Ra, and ^{40}K in seafood samples in this study, compared with those reported in the literature.

Origin	^{232}Th	^{226}Ra	^{40}K	Reference
Hong Kong	BDL		40–110	Yu et al. (1997)
Italy	BDL	1	21	(Present study)
Japan	BDL	0.6–1	5–35	(Present study)
Philippines	BDL	0.6–2	20–33	(Present study)
Thailand	BDL	0.4–1	17–42	(Present study)

BDL = below detection limit.

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

$$D = AEI \quad (4)$$

Table 3 Activity concentrations (Bq kg^{-1}) of ^{232}Th, ^{226}Ra, and ^{40}K in various foodstuffs reported in the literature.

Origin	Foodstuff	^{232}Th	^{226}Ra	^{40}K	Reference
Brazil	Beef			80	Venturini and Sordi (1999)
	Chicken			54	Venturini and Sordi (1999)
	Beans		1	434	Venturini and Sordi (1999)
Hong Kong	Beef			91	Yu et al. (1997)
	Chicken			76	Yu et al. (1997)
Syria	Cereals			300	Al-Masri et al. (2004)

where D is the annual effective dose (Sv yr^{-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 canned seafood (kg). Values for E were selected based on the International Commission on Radiological Protection (ICRP) classifications (ICRP, 1996) 6.4 and 280 nSv Bq^{-1} for ^{40}K and ^{226}Ra, respectively. The value of I is taken to be 10.3 kg yr^{-1} (IAEA, 1999). It is noteworthy that this intake value covered all types of seafood, of which canned is one type. Thus, the actual intake value for canned type specifically is less. This study, however, took the conservative approach of using the relatively high intake values. The results of the annual effective dose D showed 3 μSv and 2 μSv from the ingestion of ^{226}Ra and ^{40}K, respectively. Thus the total annual effective dose from ingestion of long lived gamma emitters in canned seafood is 5 μSv, which is of several orders of magnitudes less than 0.29 mSv yr^{-1} world average of the ingestion exposure from natural sources reported in the literature (UNSCEAR, 2000). Therefore, canned seafood consumption in Kuwait is radiologically safe for the presence of the investigated radionulcides. It is important to note, however, that the activity concentration A used in dose calculations was the average for each radionuclide. Hence, the calculated doses are the average annual effective doses. Interestingly, this value of 5 μSv yr^{-1} is close to its counterpart of 6 μSv yr^{-1} reported in the literature (Yu et al., 1997).

5. Conclusion

Long-lived gamma emitters in canned seafood consumed in Kuwait were investigated. The samples, which were collected from the local market, originated from four different countries. The study targeted three radionuclides, namely ^{232}Th, ^{226}Ra, and ^{40}K. While ^{40}K was detected in all samples, ^{226}Ra was detected in almost all samples, and ^{232}Th was detected in none. In addition, the annual effective dose from the consumption of canned seafood was calculated for the three age groups.

The present study is the first at the national level to investigate the radioactivity of canned seafood. The findings of this study will help in establishing a baseline of radioactivity exposure to the general public from ingestion of foodstuff. However, canned seafood 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.

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. Radiat. Prot. 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. Biol. Trace Elem. Res. 71–72, 7.

Al-Masri, M.S., Mukallati, H., Al-Hamwi, A., Khalili, H., Hassan, M., Assaf, H., Amin, Y., Nashawati, A., 2004. Natural radionuclides in Syrian diet and their daily intake. J. Radioanal Nucl. Chem. 260, 405–412.

Alrefae, T., 2012. Investigation of 238U content in bottled water consumed in Kuwait and estimates of annual effective doses. Health Phys. 102, 85–89.

Chau, N.D., Michalec, B., 2009. Natural radioactivity in bottled natural spring, mineral and therapeutic waters in Poland. J. Radioanal Nucl. Chem. 279, 121–129.

Currie, L.A., 1968. Limits for qualitative detection and quantitative determination; application to radiochemistry. Anal. Chem. 40, 8.

FSA, 2004. Analysis of the natural radioactivity content of bottled waters. The Food Standards Agency, UK, London.

Gharbi, F., Baccouche, S., Abdelli, W., Samaali, M., Oueslati, M., Trabelsi, A., 2010. Uranium isotopes in Tunisian bottled mineral waters. J. Environ. Radioact. 101, 589–590.

Hosseini, T., Fathivand, A.A., Barati, H., Karimi, M., 2006. Assessment of radionuclides in imported foodstuffs in Iran. Iranian J. Radiat. Res. 4.

IAEA, 1989. Measurements of radionuclides in food and the environment, technical report series 295. IAEA, Vienna.

IAEA, 1999. Assessment of doses to the public from ingested radionuclides, Safety report series no. 14, Vienna.

ICRP, 1996. Age-dependent doses to members of the public from intake of radionuclides, ICRP publication 72.

Jibiri, N.N., Okusanya, A.A., 2008. Radionuclide contents in food products from domestic and imported sources in Nigeria. J. Radiol. Prot. 28, 405–413.

Knoll, G.F., 2000. Radiation detection and measurement. Wiley.

UNSCEAR, 2000. Sources and effects of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation United Nations, New York.

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

WHO, 2006. Guidelines for drinking water quality.

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

Yu, K.N., Mao, S.Y., Young, E.C., Stokes, M.J., 1997. A study of radioactivities in six types of fish consumed in Hong Kong. Appl. Radiat. Isot. 48, 515–519.