Measurement of Natural Radionuclides Levels and their Aannual Effective Doses in Different Types of Powdered Milk Consumed by Infants in Jordan

Ala'a A. Tawalbeh[1*], Khaild M. Abumurad[2], Eyad S. M. Abu-Nameh[3], Ali M. Qaisi[4]

[1]Department of Physics, Faculty of Science, Al-Balqa Applied University, Al-Salt, Jordan

[2]Department of Physics, Faculty of Science, Yarmouk University, Irbid, Jordan

[3]Department of chemistry, Faculty of Science, Al-Balqa Applied University, Al-Salt, Jordan

[4]Department of Pharmaceutical Sciences, Faculty of Pharmacy, The University of Jordan, Jordan

ABSTRACT

In this study, fourteen samples of different types of imported and locally produced powdered milk consumed by infants in Jordan were analyzed using gamma-ray spectrometry system equipped with a High Purity Germanium (HPGe) detector. The activity concentrations of the natural radionuclides ^{238}U, ^{232}Th and ^{40}K present in the studied samples were measured. The measurements indicted that the radioactivity concentrations for: ^{238}U ranged from 0.23±0.10 $Bq.kg^{-1}$ to 2.03±0.74 $Bq.kg^{-1}$ with an average of 1.1±0.3 $Bq.kg^{-1}$, for ^{232}Th ranged from 0.12±0.08 $Bq.kg^{-1}$ to 0.68±0.29 $Bq.kg^{-1}$ with an average of 0.42±0.13 $Bq.kg^{-1}$ and for ^{40}K ranged from below detection limit to 479±27.1 $Bq.kg^{-1}$ with an average of 346±19.6 $Bq.kg^{-1}$. The annual effective dose rate that infants may experience as a result of the consumption of powdered milk (the study samples) and the contents of the above-mentioned radioactive elements were approximately 268 µs per year. This total is way less than the permissible value of 1 $mSvy^{-1}$ for public. The obtained results were compared with the international accepted values, and found to be within the acceptable limits. Therefore, according to the findings of this study, the investigated powdered milk samples does not pose any significant health hazard and is considered radiologically safe for infants consumption in Jordan.

Keywords: ^{238}U, ^{232}Th and ^{40}K, Naturally Occurring Radionuclides, Powdered Milk, Infants, Radioactivity Concentrations, Annual effective Dose (AED)**.**

INTRODUCTION

The sources of ionizing radiation are found everywhere in the environment of the human being. They include Naturally Occurring Radioactive Materials (NORM) contained in the earth, building materials, air, food, water and cosmic rays[1]. NORM include cosmogenic radionuclides such as ^{14}C and ^{3}H, primordial radionuclides, including the series of ^{238}U, ^{235}U, ^{232}Th, and some independent nuclides such as ^{40}K[2]. External dose from primordial radionuclides due to gamma radiation depends mainly on the geological and geographical environmental conditions, and appear at different levels in the soils of each region in the world[3, 4]. Basically, radionuclides in water and food are from natural sources. This natural radioactivity can be transferred from rocks and mineral present in the soil to plants. When animal eat the plant, this radionuclides can be transferred and remained in different organs of their bodies. Accordingly, throughout of chain food, plants and animals that will become food for people. Thus, provide a pathway for radionuclides to move from environment to people who live in places surrounded by NORM [5]. The world is naturally radioactive and around 90% of human exposure arises from natural sources [6,7,8]. Therefore, assessment of the gamma radiation dose from natural sources is

* abunameh@bau.edu.jo.
Received on 4/3/2018 and Accepted for Publication on 27/2/2019.

important as it is the biggest contributor to the external dose of the world population[9]. The ingested radionuclides could be concentrated in certain organs of the body. For example, ^{238}U is accumulated in human lungs and kidney, ^{232}Th in lungs, liver and skeleton tissues, and ^{40}K in muscles[10]. Depositions of large quantities of these radionuclides in particular organs will affect the health condition of the human such as weakening the immune system, induce various types of diseases, and finally increase in mortality rate[11].

The major foodstuffs contributing to the radiation ingestion dose will be those in which the radionuclides have large transfer rates or those consumed in large quantities. Such as milk (fresh/ powdered). Milk and its products are important components of diet in many countries, especially in the underdeveloped countries; people in these countries tend to use this product extensively in the diets of their children[12]. Milk is consumed in significant amount, particularly by infants < 2 years old, since its minerals and proteins are essential for their growth. Apart from this, infant formula is produced from purified cow's milk and other protein sources. Contamination of milk will be greatest when cows are grazing during the fallout period. But even when cows are kept indoors, contamination of milk may occur by inhalation of radionuclides or ingestion of radionuclides in drinking water and contaminated feed. Since the first year of life is a very sensitive period in the development of human nervous, reproductive, digestive, and immune systems, detail study on the composition of baby foods (especially concentration of radionuclides) is crucial to ensure the safety and suitability of these foods[13].

Among the types of food that are commonly consumed worldwide is milk powder. Hence, studies on the radioactivity of milk powder were performed in various regions across the globe [14-21]. In Jordan, several studies were performed to measure the level of radioactivity in environmental samples[22-25]. These studies mostly concentrated on measuring the radioactivity from soil and radon in limited regions of the country. A thorough literature search reveals that there are insufficient data on the subject and a small number of studies on radionuclides content of food consumed in Jordan[26,27]. The lack of information about the level of radioactivity in the powdered milk has persuaded one to initiate such studies[12,28]. The levels in some type of powdered milk consumed by infants in Jordan need to be established in order to forecast any possible radiological risk associated with the consumption of the powdered milk. Thus, the main objectives of this research are**: i)** to quantify the presence of natural radionuclides in some powdered milk consumed by infants in Jordan, and **ii)** to estimate the average annual effective dose equivalent for ingestion of NORMS in milk powder samples. The collected data also can be used as baseline data on powdered milk radioactivity in Jordan for future reference.

MATERIALS AND METHODS

Materials

Six types of different brands of infant's powdered milk were taken as the samples. All samples used were both local and imported powdered milk and were purchased from local markets. The name of the powdered milk samples and their numbers are as follows: Jordanian samples (3), Ireland samples (3), France samples (2), Switzerland samples (3), Holland samples (2) and Dubai samples (1).This makes the total number of samples collected as fourteen. Table 1 lists the country of origin, Brand names, code No., age group consumers and production date of the powdered milk samples used in the present study.

Sample Preparation

The samples were prepared for the natural radioactivity concentration measurements. Each powdered sample was weighted (500 g) and sealed in 500 ml marinelli beakers. The samples were kept at room temperature (25℃) for at least 30 days, before counting, to allow reaching the secular equilibrium of radium isotopes coming from natural radioactive series (^{238}U and ^{232}Th) with their respective decay products, in which the activities of all radionuclide within each series are nearly equal.

Natural radioactivity measurement

The measurements were conducted at Physics Department/ Yarmouk University**,** Irbid-Jordan**,** using a Canberra p-type high purity germanium (HPGe) gamma spectrometer with 25% relative efficiency and resolution of 1.9 keV at 1.33 MeV of ^{60}Co gamma ray peak. The detector was connected to a computer with MCA card (Accuspec B) and Genie-2000 Analysis software of Canberra Industries, USA. A100-mm thick lead bricks shielded the detector from the background radiation from the radionuclides in the environment and cosmic rays. The calibrations of the energy and relative efficiencies for the detector were carried out using a multi-gamma ray reference standard source (MGS-5, Canberra, USA), which emits gamma rays in the range of 60 -1461 keV. The samples were counted for 86000 s to reduce the statistical counting error and quality control tests were performed using standard reference materials (IAEA-321 Powdered milk). An empty beaker was also counted under the same conditions to determine the background. The activity concentrations of each sample for the radionuclides of interest were determined from their respective gamma lines or gamma lines emitted by their progenies. The gamma lines used were 609 keV for ^{238}U (^{214}Bi), with emission percentage of 44.6, 238 keV for ^{232}Th (^{212}Pb), with emission percentage of 43.5 and 1461 keV for ^{40}K with emission percentage of 10.66

Determination of radioactivity concentration:

The activity concentration, $\boldsymbol{A_i}$ measured in Bq.kg^{-1}, of a radionuclide of interest in each sample was evaluated; ^{238}U concentration was calculated from ^{214}Bi (energy 609.3 keV , yield = 44.6%), ^{232}Th concentration was calculated from ^{212}Pb (energy 238.6 keV, yield = 43.5%) and ^{40}K concentration was calculated from its own gamma photopeaks (energy 1461, yield = 10.7%). using the following equation[29,30].

$$A_i = \frac{C_i}{\varepsilon(E)\, m\, p_\gamma(E,i)} \quad (1)$$

where C_i is the net count rate of nuclide *i*, $\mathcal{E}(E)$ is the detector efficiency at energy *E*, *m* is the mass of the sample in kilograms, and $p_\gamma(E,i)$ is the emission probability of radionuclide *i* at energy *E*.

Calculation of Average "Annual effective Dose" (AED):

The average annual effective dose equivalent for ingestion of NORMS in milk powder samples were evaluated using the following expression[31]:

$$AED\left(\frac{mSv}{a}\right) = \sum_i I\,(DCF)_i A_i \quad (2)$$

where *I* is the consumption rate from intake of NORMS in milk powders, A_i is the specific activity of radionuclide *i* in the milk samples and $(DCF)_i$ is the dose conversion factor of radionuclide *i* for certain group age. For infants, $(DCF)_U$ = 960 nSv/Bq, $(DCF)_{Th}$ = 450 nSv/Bq and $(DCF)_K$ = 42 nSv/Bq[32].

RESULTS AND DISCUSSION

The measured activity concentration of ^{238}U, (^{226}Ra), ^{232}Th, and ^{40}K in Bqkg^{-1} present in each brand are displayed in Table 2. For the powdered milk it is shown that ^{238}U and ^{232}Th were detected in all samples and displayed relatively low activity concentrations ranged from 0.64 ± 0.58 to 1.64 ± 0.63 Bqkg^{-1} and 0.14 ± 0.09 to 0.55 ± 0.34 Bqkg^{-1}, respectively. On The other hand, ^{40}K was measured above the detection limit in eleven brands and varied between 197 ± 13.12 Bqkg^{-1} and 479 ± 27.1 Bqkg^{-1}. This variation in the activity concentrations is not significantly large from one brand to another. The average values of the activity concentration of the ^{238}U (^{226}Ra), ^{232}Th, and ^{40}K in Bqkg^{-1} are displayed in Table 2. The average concentrations of ^{238}U, ^{232}Th, and ^{40}K were 1.1 ±

0.3, 0.42 ± 0.13 and 346 ± 20 Bq/kg, respectively. Figure (1) shows that the highest average concentration of ^{238}U was found in Holland samples, while the lowest average concentration was found in Dubai samples. ^{238}U average concentration for all samples (1.1 ± 0.3 $Bqkg^{-1}$**)** is comparable with the world average and lies within the acceptable value, which is less than 35 $Bqkg^{-1}$ for infant's safe consumption[11]. The average value concentration of ^{232}Th was 0.42 ± 0.13 $Bqkg^{-1}$**.** The results indicate that the maximum concentration of ^{232}Th occurred mainly in Ireland samples (0.55 $Bqkg^{-1}$) and the minimum in Holland samples (0.14 $Bqkg^{-1}$). It was also observed that the average concentration of ^{238}U in Jordanian milk samples was higher than the average concentration of ^{232}Th. This is due to high concentration of ^{226}Ra in Jordanian soil compared to the concentration of ^{228}Ra[22,24]. In general the measured average concentration value of ^{232}Th (0.42 ± 0.13 $Bqkg^{-1}$**)** lies within the acceptable values as was reported by UNSCEAR (United Nation Scientific Committee on the Effects of Atomic Radiation) which is 30 $Bqkg^{-1}$ [11]. Potassium is a very soluble in water and an essential element in metabolism of living organism. The highest activity concentration of ^{40}K was found in Ireland samples-Pro3 (479 ± 27.1 $Bqkg^{-1}$), followed by Jordanian samples-Fo3 (387 ± 21.7 $Bqkg^{-1}$) and Holland samples-Be2 (360 ± 20.3 $Bqkg^{-1}$). The lowest concentration was found in Switzerland samples with a value of 197 ± 13.9 $Bqkg^{-1}$. ^{40}K grand average concentration in the studied samples was (346 ± 20 $Bqkg^{-1}$). This average is less than the internationally recommended upper limit (400 $Bqkg^{-1}$) for the safe use[11].

The contribution of ^{238}U, ^{232}Th and ^{40}K into the annual effective dose (*AED*) was calculated using equation (2). Figure (2) shows the results of these calculations. *AED* due ^{40}K was the largest, 247 μSvy^{-1}, while *AED* from ^{232}Th was the smallest, 3.1 μSvy^{-1} and *AED* from ^{238}U was 18.12 μSvy^{-1}. However, the total of *AED* was 268 μSvy^{-1}. This total is way less than the permissible value of 1 $mSvy^{-1}$ for public[33, 34].

The results reported here are compared with those obtained by other studies worldwide (Table3). As can be seen from the table, the ^{40}K activities are, on an average lower by almost 25% [14-21] of the global value. As for ^{232}U (^{226}Ra) and ^{232}Th (^{228}Ra), the data available in the literature are not enough to allow for an exhaustive comparison because in most cases these isotopes were not detected[14-18]

Analysis of Variance

Table 4 shows the descriptive statics of activity concentration of ^{238}U, ^{232}Th, and ^{40}K of different countries. The variation in the levels of radionuclides activity concentrations were mainly due to the geological formation of the country of origin. Milk powder imported from Ireland showed high concentration of radionuclide as the country consists of granitic rock and sediments and experienced many volcanic activities[14]. The milk powder imported from Switzerland show low level of radionuclide concentration as the country has a clean and healthy environment which also being far from any battle fields and facilities where nuclear explosions took place[15]. The radiation dose could vary also due to differential bioaccumulation of radionuclide by organisms, contamination of food through processing and preparation techniques and feeding habits by a particular population [16,31].

CONCLUSION

In this research, 14 samples of different types of imported and locally produced powdered infant milk in central zone of Jordan were examined and evaluated. The gamma-ray spectrometry system equipped with a high Purity germanium (HPGe) detector was used in this study. The results have shown that the grand average activity concentrations of natural radionuclides of ^{238}U, ^{232}Th, and ^{40}K (1.1±0.3 $Bqkg^{-1}$, 0.42±0.13 $Bqkg^{-1}$, 346±20 $Bqkg^{-1}$, respectively) in samples of different types of imported and locally produced powdered milk consumed by infants in Jordan are relatively lower than the world recommended limits (35 $Bqkg^{-1}$, 30 $Bqkg^{-1}$ and 400 $Bqkg^{-1}$ for ^{238}U, ^{232}Th and ^{40}K, respectively)[11]. The calculated total average annual effective dose (AED = 68.3 $\mu Sv.y^{-1}$) from these natural radioactive nuclides (^{238}U, ^{232}Th and ^{40}K) due to the ingestion of powdered milk by infant (less than two years) were found to be less than the WHO recommended limit and ICRP for radiological safety[33,34]. As far as we concerned, this study is the first in the country for the estimation of AED from the radionuclide concentration in infant's milk powder. The data reported here might be useful to establish a baseline and help to develop future guidelines in the country for radiological protection.

Acknowledgement

The authors wish to thank the staff members of Gamma Ray Spectroscopy laboratory at Yarmouk University, Irbid, Jordan specially Mr Mohammad Gharaibeh. Also I will not forget to thank Nurse Amera Tawalbeh from King Talal Hospital in Mafraq, Jordan for their help and support during the undertaking of this project.

Table 1. The country of origin, Brand names, code No., age group and production date of the powdered milk samples used in the present study.

Origin	Brand name	Code No.	Age group (months)	Production date(dd/mm/yy)
Jordan	Sahha	Sa_1	0-6	20/8/2017
	Sahha	Sa_2	6-12	23/7/2017
	Formelac	Fo_3	12-24	18/7/2017
Ireland	S-26 Promil	Pro_1	0-6	21/6/2017
	Similac Gain	Si_2	6-12	21/11/2016
	S-26 Progress	Pro_3	12-24	18/7/2017
Switzerland	Nan	Na_1	0-6	/6/2016
	Nan	Na_2	6-12	22/4/2017
	Primalac	Pri_3	12-24	2/2/2016
France	Nidina	Ni_1	0-6	/6/2017
		Ni_2	6-12	/6/2017
Holland	Bebelac	Be_1	0-6	28/3/2017
		Be_2	6-12	18/4/2017
Dubai- U.A.E	Nido	Nid_3	12-24	/9/2017

Table 2. Origin, code no (CN) of samples, activity concentrations and their averages for ^{238}U, ^{232}Th and ^{40}K in powdered milk samples (Bq/kg) used in the present study.

Origin	CN	Activity Concentration, Bq/kg		
		^{232}U	^{238}Th	^{40}K
Jordan	Sa1	1.34 ± 0.57	0.42 ± 0.26	BDL
	Sa2	1.41 ± 0.62	0.37 ± 0.29	333 ± 18.89
	Fo3	0.46 ± 0.31	0.4 ± 0.29	387 ± 21.7
	Average	1.1	0.4	360
Irland	Pro1	1.43 ± 0.75	0.46 ± 0.35	BDL
	Si2	0.52 ± 0.2	0.68 ± 0.29	445 ± 24.7
	Pro3	0.23 ± 0.1	0.51 ± 0.39	479 ± 27.1
	Average	0.73	0.55	462
Switzerland	Na1	2.03 ± 0.74	0.45 ± 0.2	197 ± 13.12
	Na2	0.61 ± 0.2	0.41 ± 0.29	327 ± 18.60
	Pri3	0.9 ± 0.58	0.53 ± 0.28	BDL
	Average	1.2	0.47	262
France	Ni1	1.26 ± 0.75	0.57 ± 0.45	295 ± 17.4
	Ni2	1.42 ± 0.64	0.37 ± 0.29	333 ± 18.85
	Average	1.34	0.47	317
Holland	Be1	1.41 ± 0.64	0.15 ± 0.09	307 ± 17.6
	Be2	1.86 ± 0.62	0.12 ± 0.08	360 ± 20.3
	Average	1.64	0.14	334
Dubai	Nid3	0.64 ± 0.58	0.5 ± 0.27	327 ± 18.3

BDL: Below Detection Limit.

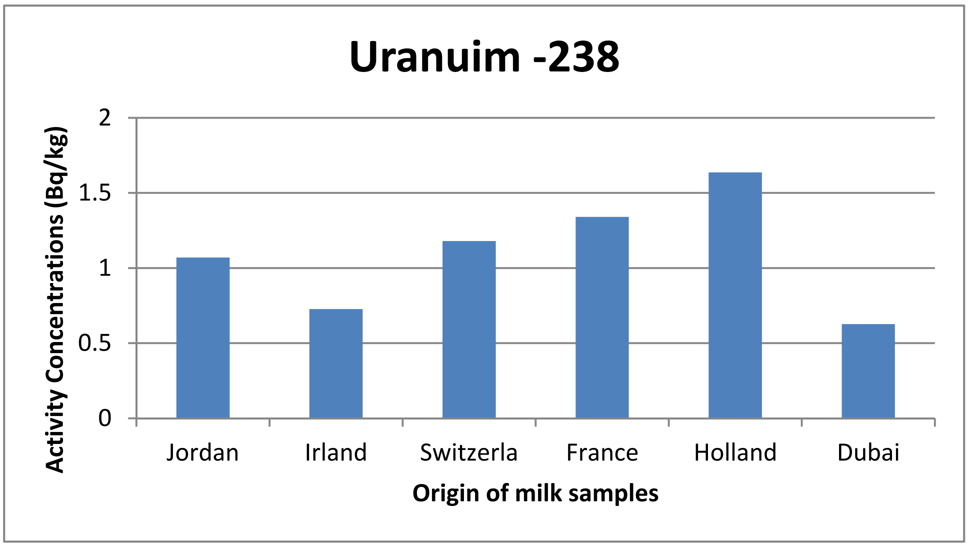

Figure 1: Average activity concentrations of U-238 in milk samples from different country (an example from Anova outcome)

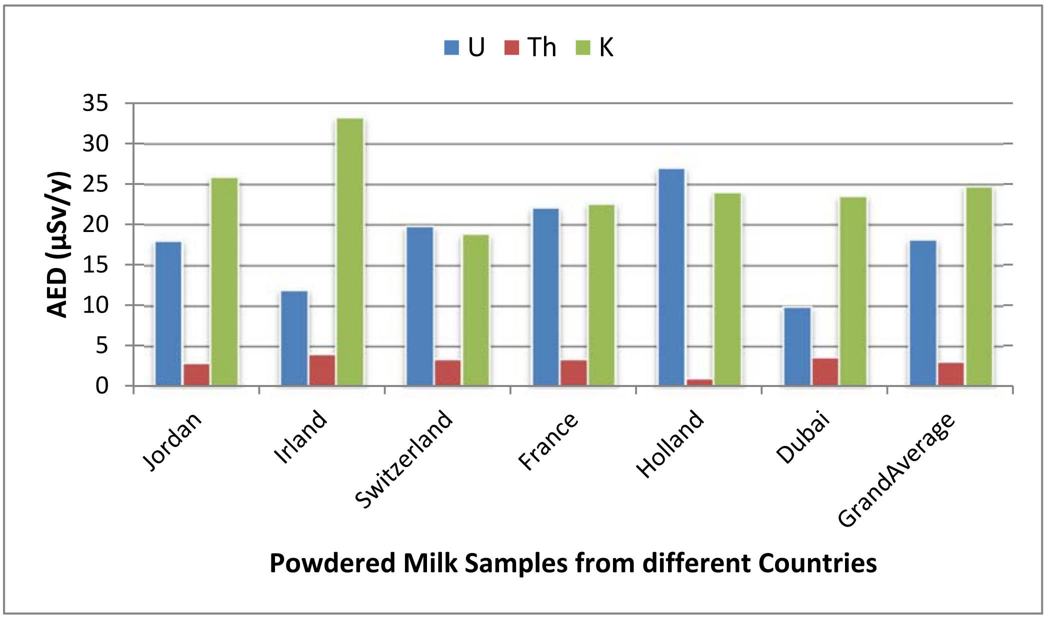

Figure 2: Shows the annual effective dose of U-238, Th-232 and K-40 due to ingestion of milk samples from different countries. Values of ^{40}K must be multiplied by 10.

Table 3. Measured average concentration activity of ^{238}U, ^{232}Th and ^{40}K in powdered milk samples (Bq/kg); in compared with the literature.

Origin of sample manufactured (number of sample)	Activity Concentration, Bq/kg			Reference
	^{232}U	^{238}Th	^{40}K	
This study	**1.1 ± 0.3**	**0.42 ± 0.13**	**346 ± 19.6**	
Jordan	1.24± 0.77	1.11± 0.20	348.30 ± 26.03	12
Malaysia	-	0.82 ± 0.08	238.71 ± 1.04	14
Iraq	3.90 ± 1.97	1.96 ± 1.40	177.91± 13.33	15
Brazil	-	-	464.96 ± 34.68	17
Venezuela	-	-	401.71 ± 13.45	17
Nigeria	-	BDL	39.60 ± 12.6	18
Saudi Arabia	-	0.29 ± 0.02	210.70 ± 2.26	19
Germany	-	0.09 ± 0.03	610.00 ± 18.30	20
France		0.14 ± 0.03	434.10 ± 13.00	20
New Zealand		0.15 ± 0.04	605.550 ± 12.10	20
Iran	BDL	BDL	254.78 ± 3.38	21
Spain	0.35 ± 0.02	BDL	241.16 ± 3.38	21
World average	**35**	**30**	**400**	**11**

BDL: Below Detection Limit.

Table 4. One way Anova output of ^{238}U activity concentrations in milk samples from different countries

Anova: Single Factor for Th-232

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Jordan	3	1.19	0.396667	0.000633
Irland2	3	1.65	0.55	0.0133
Switzerland	3	1.39	0.463333	0.003733
France	2	1.41	0.47	0.01
Holland	2	0.41	0.136667	0.000233
Dubai	1	1.92	0.64	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.442161	5	0.088432	19.01768	2.5E-05	3.105875
Within Groups	0.0558	12	0.00465			
Total	0.497961	17				

REFERENCES

(1) National Council on Radiation Protection and Measurements. Ionizing radiation exposure of the population of the United States. Bethesda, MD: National Council on Radiation Protection and Measurements; NCRP Report No. 160; 2009.

(2) Quan, W., Hongada, Z., Tiqiang, F. & Qingfen, L. Re-Estimation of internal dose from natural radionuclides for Chinese adult men. *Radiation Protection Dosimetry* 2008;130: 434- 441.

(3) Diab, H., Nouh, S., Hamdy, A. & El-Fiki, S. Evaluation of natural radioactivity in acultivated area around a fertilizer factory. *Nuclear and Radiation Physics*. 2008; 3(1):53-62

(4) Yasir, M., Ab Majid A. & Yahaya, R. Study of natural radionuclides and its radiation hazard index in Malaysia building materials. *Radio analytical and Nuclear Chemistry* 2007; 273:539-541.

(5) Turner, J.E., (1995) *Atoms, Radiation, and Radiation Protection*. 2nd ed., John Wiley &Sons.

(6) Rani, A. & Singh, S. Natural radioactivity levels in soil samples from some areas of Himachal Pradesh, India using gamma ray spectrometry. *Atmospheric Environment*. 2005;39:6306-6314.

(7) Jabbar, T., Akhter, P., Khan, K., Jabbar, A. & Saleem, K. Radiological impact of composite food served at PINSTECH. *Food and Chemical Toxicology,* 2009; 47:1205-1208.

(8) Desideri, D., Meli, M., Feduzi, L., Roselli, C., Rongoni, A. & Saetta, D. ^{238}U, ^{234}U, ^{226}Ra, ^{210}Po concentrations of bottled mineral waters in Italy and their dose contribution. *Journal of Environmental Radioactivity.* 2007; 94:86-97.

(9) Rahman, S., Faheem, M. & Matiullah. Natural radioactivity measurements in Pakistan. *Journal of Radiological Protection*. 2008; 28:443-452.

(10) Samat, S. B. & Evans, C.J. Determination of radiation hazard arising from the ^{40}K content of bottled mineral water in Malaysia. *Sains Malaysiana*. 2011;40(12):1355-1358.

(11) United Nation Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing

radiation. UNSCEAR 2000. Report to General Assembly. (New York: United Nations) 2000.

(12) Zaid.Q. Ababneh, Abdalmajeid. M. Alyassin, Khaled.M.Aljarrah and Anas.M.Ababneh. Measurement of natural and artificial radioactivity in powder milk consumed in Jordan and estimates of the corresponding annual effective dose. *Radiation Protection Dosimetry*. 2009; 138(3):278-283.

(13) O.B.Uwatse, M.A.Olatunji, M.U.Khandaker, Y.M.Amin, D.A.bradley, M.Alkhorayef &K.Alzimami, Measurement of Natural and Artificial radioactivity in infant powdered milk and estimation of the corresponding annual effective dose. *Environmental Engineering Science*. 2015; 32(10):1-10.

(14) Priharti W., Samat S. B., Yasir M. S., Garba N. N. Assessment of Radiation Hazard Indices Arising from Natural Radionuclides Content of Powdered Milk in Malaysia. *J Radioanal Nucl Chem*, 2016; 307: 297-303.

(15) Hassan Abid-Al Ammer, Nada Farhan Kadhim, Mahmood Salim Karim, Ali Abdulwahab Ridha Hazard Indices and Age Group Parameters of Powder Milk Consumed in Iraq. *Higher Education Research*. 2017; 2(5): 117-122.

(16) Onosohwo Bemigho Uwatse, Michael Adekunle Olatunji, Mayeen Uddin Khandaker, Yusoff Mohd Amin, Bradley D. A., Alkhorayef M., and Alzimami K. Measurement of Natural Artificial Radioactivity in Infant Poedered Milk and Estimation of The Corresponding Annual Effective Dose. *Environmental Engineering Science*. 2015;32(10): 1-9.

(17) Melquiades F. L. & Appoloni C. R. Natural Radiation Levels in Powdered Milk Samples. *Recebido para publicação em*. 2004; 24(4): 501-504.

(18) Ademola A. K. Assessments of Natural Radioactivity and Heavy Metals in Commonly Consumed Milk in Oke-Ogun Area, Nigeria and Estimation of Health Risk Hazard to the Population. *Journal of Environmental & Analytical Toxicology.* 2014; 5(2): 1-5.

(19) Al-Zahrani J. H. Natural Radioactivity and Heavy Metals in Milk Consumed in Saudi Arabia and Population Dose Rate Estimates. *Life Sciences Journal.* 2012; 9(2): 651-656.

(20) Hosseni T., Fathivand A. A., Barathi H., Karimi M. Assessment of Radionuclides in Imported Foodstuff in Iran. *Iran J. Radiat. Res*. 2006; 4(3): 149-153.

(21) Alrefae T., Nageswaran T., Al-Failakawi A. and Al-Shemali T. Radioactivity of long lived gamma emitters in milk Powder consumed in Kuwait and estimates of annual effective doses. *Kuwait J. Sci. Eng.* 2012; 39:143-158.

(22) Al-Jundi. Population doses from terrestrial gamma Jordan. *Radiat. Meas.* 2002;35:23-28

(23) Kullab, M. Assessment of radon-222 concentration in building materials, water and soil in Jordan. *Appl. Radiat. Isot.* 2005; 62:765-773.

(24) Ajlouni, A.W., Abdelsalam, M., Abu-Haija, O. and Joudeh, B. New finding: avery high natural radiation area in Afra hot springs, Jordan. Radiat. Protect. Dosimetry. 2009; 133:115-118.

(25) Al-Jundi, J., Al-Ahmad, N., Shehadeh, H., Afaeh,f., Maghrabi, M., Gerstmann, U., Hollriegl, V. and Oeh, U. Investigations on the activity concentration of 238U, 226Ra, 228Ra, 210Po and 40K in Jordan phosphogypsum and fertilizers. *Radiat. Protect. Dosimetry*. 2008; 131:449-454.

(26) Ababneh, A.M., Masa'deh,M.S., Ababneh, Z.Q., Awawdeh, M.A., and Alyassin, A. M. Radioactivity concentrations in soil and vegetables from the northen Jordan Rift Valley and the corresponding dose estimates. *Radiat. Protect. Dosimetry*. 2009; 134: 30-37.

(27) Tawalbeh, A.A., Abumurad, K., Samat, S. & Yasir, M. A study of natural radionuclide activities and radiation hazard index in some grains consumed in Jordan. *The Malaysian Journal of Analytical Sciences* 2011;15(1):61-69.

(28) Al-Jarrah, Z. Use of X-ray fluorescence to study the milk components in Jordanian markets. *MSc Thesis*. Yarmouk University, Jordan. 1999.

(29) Tawalbeh, A.A., Samat, S. & Yasir, M. Radionnuclides level and its radiation hazard index in some drinks

consumed in the central zone of Malaysia. *Sains Malaysiana* 2013; 42(3) :319-323.

(30) Tufail, M., Akhtar N. and M.Waqas. Measurement of terrestrial radiation for assessment of gamma dose from cultivated and barren saline soils of Faisalabad in Pakistan. *Radiation Measurements* 2006;41:443-451.

(31) Prabhath, R., Sreejith, S., Nair, M. Rao, D. and Pradeepkumar, K. Determination of ^{210}Po concentration in commercially available infant formulae and assessment of daily ingestion dose. *Radiation Research and Applied Sciences*. 2015; 8:470-476.

(32) Abojassim A A, Al-Aasadi L A, Shitake A R, Al-Tememie F A, and Husain A A. Assessment of Annual Effective Dose for Natural Radioactivity of Gamma Emitters in Biscuit Samples in Iraq. *J Food Prot.*2015 Sep; 78(9):1766-1769.

(33) International Commission on Radiological Protection. Age-dependent doses to member of the public from intake of radionuclides. Part 5: Compilation of ingestion and inhalation coefficients. ICRP publication 72 (Oxford: Pergamon Press) (1996).

(34) International Atomic Energy Agency. Measurement of radionuclides in food and the environment. A Guidebook Technical Reports No. 295 (Vienna: IAEA) 1989.

قياس "مستويات النويدات المشعة الطبيعية" والجرعات الفعالة الخاصة بها في أنواع مختلفة من الحليب المجفف المستهلك من قبل الأطفال الرضع فى الأردن

آلاء طوالبه [1]، خالد أبو مراد [2]، إياد أبو ناعمة [3]، علي القيسي [4]

[1] قسم الفيزياء، كلية العلوم، جامعة البلقاء التطبيقية، السلط، الأردن.

[2] قسم الفيزياء، كلية العلوم، جامعة اليرموك، اربد، الأردن.

[3] قسم الكيمياء، كلية العلوم، جامعة البلقاء التطبيقية، السلط، الأردن.

[4] قسم العلوم الصيدلانية، كلية الصيدلة، الجامعة الاردنية، الأردن

ملخص

تم في هذا البحث تحليل اربع عشرة عينة من انواع مختلفة من الحليب المجفف المستورد والمنتج محليا والتي يستهلكها الرضع في الاردن باستخدام نظام قياس طيف اشعة جاما المجهز بكاشف جرمانيوم عالي النقاوة . تم قياس تراكيز النشاط من النويات المشعة الطبيعية الموجودة في العينات التي تم دراستها ، كما تم حساب معدل الجرعة الفعالة السنوية. لقد بينت القياسات ان متوسط تراكيز اليورانيوم-238 والثوريوم-232 والبوتاسيوم-40 هي كالتالي: 0.3 ±1.1، 0.13±0.42 و20± 343 بيكريل/كغم على التوالي. وكان معدل الجرعة الفعالة السنوية التي يمكن ان يتعرض لها الأطفال الرضع نتيجة استهلاك حليب البودرة (عينات الدراسة) وما تحويه من العناصر الطبيعية المشعة سالفة الذكر حوالي 268 ميكروسيفرت في السنة. ان هذه النتائج متواضعة جدا مقارنة مع المعايير الدولية المتفق عليها. ولقد قورنت نتائج هذه الدراسة مع نتائج دراسات مشابهة في مناطق أخرى من العالم وتبين انها تقع ضمن معدلات تلك الدراسات. لذلك فان عينات الحليب المجفف التي تم التحقق منها في هذه الدراسة لا تشكل اي خطر صحي وتعتبر آمنة اشعاعيا لاستهلاك الرضع في الاردن.

الكلمات الدالة: النويات المشعة التي تحدث بشكل طبيعي ، الحليب المجفف في الاردن، الرضع، تركيز ^{238}U، ^{232}Th، ^{40}K النشاط الاشعاعي، معدل الجرعة الفعالة السنوية..

تاريخ استلام البحث 2018/3/4 وتاريخ قبوله للنشر 2019/2/27.