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Assessment of radiological risks of gamma emitters in some milk samples available in Iraqi markets

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Abstract. Milk is a staple food consumed worldwide. Milk is a vital source of vitamins for human health. It can become contaminated with nuclear materials because of radioactivity from the cow's feed and water. This study aimed to measure levels of 232Th,238U, and 40K radioactivity that comes from nature and to calculate the annual effective dose from the ingestion of milk powder samples gathered from community markets located within the Najaf Governorate, Iraq. Natural radioactivity in samples was detected using a NaI (Tl) radioactive spectrometer. The mean specific activities detected in milk samples for 238U, 232Th, and 40K were determined (15.28±1.95) Bq/kg, (5.57±1.09) Bq/kg, and (286.86±19.79) Bq/kg, respectively; meanwhile, the corresponding total annual effective doses from powdered milk consumption were (0.171 mSv y^{-1}) for children (ages 7-12) and (0.055 mSv y-1) for adults (>17 years), respectively. Based on UNSCEAR, the measured specific activity and annual effective dose values for all samples in the study were lower than the worldwide median values. Hence, the tested milk samples pose no significant radiological risk.

1 Introduction

Radiation and radioactivity originate from many sources in the environment. There are naturally occurring radionuclides that belong to the decay series of 238U and 232Th as well as isolated radionuclides such as 40K, which are unevenly distributed over the Earth's surface as well as throughout its atmosphere. More than 80% of human exposure to radiation originates from natural radioactive elements, including those ingested through food [1]. The distribution of natural radioactive elements is not uniform but varies from one site to another depending on local geological conditions.

Stringent regulation of environmental releases of radioactive materials is crucial to ensure adequate protection for public and worker safety [2]. Radionuclides in soil can be taken up

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by plants: they get into human food directly or indirectly (through animal fodder) [3]. Numerous studies have investigated the contamination of food with radioactive substances in the environment and the methods by which it is transmitted to plants, animals, and humans. Dietary intake is the main pathway through which humans are exposed, leading to internal radiation doses from radioactive elements [4]. Milk is one of the most significant of all nutritional foods for humans; as it contains all macronutrients – proteins, carbohydrates, lipids – as well as vitamins (groups A, D, and B) and trace elements such as zinc, selenium, magnesium, phosphate, and calcium [5]. Milk and other dairy products are among the main sources of radionuclides in the human diet. Owing to its nutritional value and storage stability, milk powder finds applications in making cookies as well as ice cream, yogurt, chocolate, and beverages based on chocolate powder. The contamination is most severe when cows graze on grass and soil during rainfall [6]. Even if kept indoors, milk can be contaminated by breathing in radioactive materials or via ingestion through potable water and tainted animal feed. Due to the grazing habits of goats and sheep, milk should be checked regularly.

The measurement of radioactivity in the environment and in food, especially milk powder, is of extreme importance in controlling the levels of radiation. In addition to naturally occurring radionuclides, ecosystems have been contaminated by anthropogenic radionuclides, primarily released through historical atmospheric nuclear weapons testing and nuclear reactor accidents. Consequently, importing foodstuffs from regions contaminated by nuclear accidents poses an indirect public health risk to consumers worldwide. [1]. In Iraq, baseline measurements of radioactivity in canned food have not been carried out; likewise, baseline levels of natural and anthropogenic radioisotope concentrations have not been established. Therefore, determining the radioisotope concentrations will provide meaningful data for assessing population exposure and establishing baseline levels [6]. While numerous studies have quantified natural radioactivity in milk across various countries [7-12], data specific to Iraq remain scarce. This study therefore aims to determine the activity concentrations of radionuclides in powdered milk available in the Najaf Governorate, Iraq, using a NaI(Tl) gamma-ray spectroscopy, and to assess the associated radiological risk for adults and children. A further objective was to estimate the annual effective dose resulting from milk consumption for different age groups.

2 Materials and methods

2.1 Sample collection

As can be seen in Table (1), the powdered milk tests used in this study were obtained from the local markets in Iraq. These samples included sixteen various kinds of milk that originated from a variety of countries, the majority of which were imported.

Table 1. Samples of powdered milk in the present study.

No.	Name of sample	Code of sample	Country of origin	Date of production
1	FALCON	P1	New Zealand	2022
2	Al Walad Al Zakey	P2	New Zealand	2023
3	Anchor	P3	New Zealand	2022
4	Dielac	P4	New Zealand	2023
5	Almarai	P5	New Zealand	2023
6	ANGELA	P6	New Zealand	2023
7	Almaleka	P7	Arbil, Iraq	2022
8	ISHTAR	P8	Jordan	2022
9	SamaMilk	P9	Holland	2023

Continuation of Table 1.

No.	Name of sample	Code of sample	Country of origin	Date of production
10	JANNATFull fat	P10	Holland	2023
11	JANNAT low fat	P11	Holland	2023
12	AL Mudhish	P12	Sultanate of Oman	2023
13	Fresh	P13	Sultanate of Oman	2022
14	Nido	P14	Dubai /United Arab Emirates	2023
15	MAHMOOD	P15	Dubai /United Arab Emirates	2023
16	DANO	P16	Denmark	2023

2.2 Sample preparation

The milk samples were collected from various local markets in Iraq, and then transported to the Radiation Measurement Laboratory within the Department of Physics, Faculty of Science, University of Kufa. In the present study, 1-liter Marinelli beakers made of polyethylene were used as sample and measurement containers. Before use, the containers were cleaned with water. To remove moisture prior to analysis, the samples were dehydrated and baked for four hours. To remove air from the samples, they were pressed with the light cover of the Marinelli cup. Each net weight was measured and noted on a high-sensitivity digital scale with ±0.01% accuracy. Amounting to around 1000 grammes of every specimen was then placed into a standard Marinelli cup, sealed, and weighed dry.

2.3 NaI (TI) gamma ray spectroscopy

Gamma-ray spectra were acquired using a NaI (TI) scintillation detector from ORTEC with a dynamic region of "3x3" inches, with an energy resolution of 7.9% at 662 KeV. The gamma spectrometer was calibrated for energy and efficiency using 60Co, 137Cs, 22Na and 54Mn. The standard source is placed above the detector with a geometry that exactly matches the geometry of the sample furthermore, the spatial separation between the sample and the detector remains constant. In certain instances, there may exist radioactive sources other than the one being measured in the counting area (what is commonly referred to as a natural background radiation). Therefore, shielding should be utilized to decrease the levels of radioactive background. The protective covering that was utilized in this investigation is composed of two layers: the first layer is constructed of stainless steel and measures 30 millimeters in width, and the second layer is built of lead and measures 100 millimeter in width.

The specific activity of 238U and 232Th was measured using property of secular equilibrium with their decay products such as transition lines of 214Bi (1765 KeV) and 208Tl (2614 KeV), respectively. While 40K were measured directly from the photo peak at 1460 KeV [11, 12]. The measuring time for all samples under study was 24 hours.

2.4 Mathematical formula and data analysis

The specific activity (A_r) for each identified photopeak was calculated in Bq/kg using the following equation [13, 14]:

$$A_r\left(\frac{Bq}{kg}\right) = \frac{N-N_o}{I_\gamma \varepsilon m t} \tag{1}$$

where $\mathbf{A_r}$ is the radionuclide's particular activity inside the sample, **N** is the sample's net numbers of a particular peak, N_o describes the backdrop of the specified peak, $\mathbf{I_\gamma}$ is the amount of gamma rays released during a disintegration, **ε** is the effectiveness of the detector at the particular gamma-ray energy of interest, **m** is the sample mass that was measured (fresh weight expressed in kilograms) and **t** is the amount of time that the sample was measured for. In this study, we also calculated the annual effective dose from the ingestion of milk powder. The dose was estimated using the following equation, which is based on the human metabolic model established by the International Commission on Radiological Protection (ICRP) [15]:

$$D_f\left(\frac{Sv}{y}\right) = \Sigma(C_r A_{rf}) * \; R_f (2)$$

where D_f is the effective annual dose, C_r corresponds to the nuclide's(r) effective dose conversion factor, A_{rf} nuclear activity refers to the particular activity of a nuclide (r) in the consumed meal (f, $Bq.kg^{-1}$, fresh weight), and R_f rate of consumption of the food item (f, $kg.y^{-1}$).

3 Result and discussion

Table (2) shows the results of activity for naturally occurring radioactive substances such 40K, 232Th, and 238U in the milk samples. The observed activity concentrations of 238U in most samples exhibit variability (3.0±1.0) $Bq.kg^{-1}$ to (28.6±3.1) $Bq.kg^{-1}$ with mean value of (15.28±1.95) $Bq.kg^{-1}$. For 232Th detected activity values in most samples range between (1.0±0.3) $Bq.kg^{-1}$ to (13.2±1.3) $Bq.kg^{-1}$ with mean value of (5.57±1.09) $Bq.kg^{-1}$. For 40K the majority of samples' measured activity concentrations range between (120.95±6.6) $Bq.kg^{-1}$ to (392.90±11.9) $Bq.kg^{-1}$ with mean value of (286.86±19.79) $Bq.kg^{-1}$.

Table 2. Results of the specific activity (Bq/kg) of powder milk in the present study.

No	Sample code	Uranium-238		Thorium-232		Potassium-40	
		Mean	S. D	Mean	S. D	Mean	SD
1	P1	7.6	1.6	1.3	0.4	217.92	8.8
2	P2	10.8	1.9	2.2	0.5	238.31	9.2
3	P3	10.5	1.9	9.5	1.1	327.77	10.8
4	P4	26.3	2.9	2.4	0.5	291.27	10.2
5	P5	14.8	2.2	2.1	0.5	257.28	9.6
6	P6	21.4	2.6	10.3	1.1	419.38	12.3
7	P7	3.0	1.0	1.1	0.4	120.95	6.6
8	P8	28.6	3.1	3.5	0.7	342.09	11.1
9	P9	23.0	2.7	1.0	0.3	319.18	10.7
10	P10	19.4	2.5	7.0	0.9	392.90	11.9
11	P11	20.0	2.6	12.3	1.2	282.69	10.1
12	P12	6.9	1.5	1.7	0.5	152.08	7.4
13	P13	15.1	2.2	13.2	1.3	384.67	11.7
14	P14	8.2	1.6	3.6	0.7	254.77	9.5
15	P15	23.7	2.8	5.5	0.8	319.90	10.7
16	P16	5.3	1.3	12.5	1.2	268.73	9.8
Mean ± SD		15.28±1.95		5.57±1.09		286.86±19.79	

It was observed that the activity concentrations of the three radionuclides varied from one sample to another. This variation can be attributed to differences in the transfer factors of these radionuclides: from soil to food, water and air to animals. Moreover, the particular activity values of 214Bi (238U series), 208Ti (232Th series), and 40K in food are determined to be below the maximum permittable values globally of 33 $Bq.kg^{-1}$, 45 $Bq.kg^{-1}$, and 420 $Bq.kg^{-1}$ according to UNSCEAR [14], respectively.

Analysis of the annual effective dose rates (AED) from powdered milk consumption by children (ages 7-12), showed the following: for 238U: between (0.060) $mSv.y^{-1}$ to (0.358) $mSv.y^{-1}$ with mean value of (0.246±0.025) $mSv.y^{-1}$, 232Th : between (0.022) $mSv.y^{-1}$ to (0.076) $mSv.y^{-1}$ with mean value of (0.052±0.003) $mSv.y^{-1}$ and 40K: between (0.004) $mSv.y^{-1}$ to (0.054) $mSv.y^{-1}$ with mean value of (0.022±0.004) $mSv.y^{-1}$ in (Table 3).

Table 3. Results of the AED of powdered milk in the present study for children (ages 7-12).

No	Sample code	AED mSv/y			
		Uranium-238	**Thorium-232**	**Potassium-40**	**Total**
1	P1	0.130	0.040	0.005	0.085
2	P2	0.173	0.043	0.009	0.121
3	P3	0.216	0.060	0.039	0.118
4	P4	0.357	0.053	0.010	0.295
5	P5	0.221	0.047	0.009	0.166
6	P6	0.358	0.076	0.042	0.240
7	P7	0.060	0.022	0.004	0.034
8	P8	0.397	0.062	0.014	0.320
9	P9	0.320	0.058	0.004	0.258
10	P10	0.317	0.072	0.028	0.217
11	P11	0.325	0.051	0.050	0.224
12	P12	0.112	0.028	0.007	0.077
13	P13	0.293	0.070	0.054	0.169
14	P14	0.153	0.046	0.015	0.092
15	P15	0.346	0.058	0.022	0.265
16	P16	0.159	0.049	0.051	0.059
Mean ± SD		0.246±0.025	0.052±0.003	0.022±0.004	0.171±0.021

Analysis of the annual effective dose rates (AED) from powdered milk consumption by adults (>17 years), showed the following: for 238U: between (0.024) $mSv.y^{-1}$ to (0.358) $mSv.y^{-1}$ with mean value of (0.095±0.009) $mSv.y^{-1}$, 232Th : between (0.010) $mSv.y^{-1}$ to (0.034) $mSv.y^{-1}$ with mean value of (0.023±0.001) $mSv.y^{-1}$ and 40K: between (0.003) $mSv.y^{-1}$ to (0.039) $mSv.y^{-1}$ with mean value of (0.016±0.003) $mSv.y^{-1}$ in (Table 4).

Table 4. Results of the AED of powdered milk in the present study for adults (>17 years).

No	Sample code	AED mSv/y			
		Uranium-238	**Thorium-232**	**Potassium-40**	**Total**
1	P1	0.049	0.018	0.004	0.028
2	P2	0.065	0.019	0.007	0.039
3	P3	0.093	0.026	0.028	0.038
4	P4	0.126	0.023	0.007	0.096
5	P5	0.081	0.021	0.006	0.054
6	P6	0.142	0.034	0.031	0.078
7	P7	0.024	0.010	0.003	0.011
8	P8	0.142	0.028	0.010	0.104
9	P9	0.112	0.026	0.003	0.084
10	P10	0.123	0.032	0.021	0.071
11	P11	0.132	0.023	0.037	0.073
12	P12	0.042	0.012	0.005	0.025
13	P13	0.125	0.031	0.039	0.055
14	P14	0.061	0.021	0.011	0.030
15	P15	0.128	0.026	0.016	0.086

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16	P16	0.078	0.022	0.037	0.019
Mean ± SD		0.095±0.009	0.023±0.001	0.016±0.003	0.055±0.007

Subsequently evaluated radiological effects demonstrate that the annual effective dose levels in (μSv/y) units in powdered milk for children (ages 7-12) and adult (> 17 years) are found to be under the threshold of 1.0 mSv/y, the value that is suggested for the general population by the International Commission on Radiological Protection is equal to it [15].

In conclusion, the measured activity concentrations of natural radionuclides in the tested powdered milk samples are below international reference levels, indicating that their consumption poses no significant radiological risk to the population.

4 Conclusions

This study quantified the activity concentrations of naturally occurring radionuclides (238U, 232Th, and 40K) and the associated annual effective dose in powdered milk samples commonly consumed in Najaf, Iraq. The measured specific activities for all radionuclides were below the global average values reported by UNSCEAR. Furthermore, the estimated annual effective doses for adults and children were all lower than the safety limits recommended by the International Commission on Radiological Protection (ICRP) [15]. These findings indicate that the consumption of the tested milk powders poses no significant radiological health risk. Regular monitoring of radionuclides in milk and other foodstuffs remains essential to prevent their excessive accumulation in the food chain.

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