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Hazard Indices and Age Group Parameters of Powder Milk Consumed in Iraq

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Abstract: The specific activities of natural and artificial radionuclides in powder milk consumed by adult and infant were measured using gamma ray spectroscopy (HPGe detector). The radium equivalent activity (Ra_{eq}), internal hazard index (H_{in}) were also calculated together with the parameters dependent on the age group such as; annual effective dose from ingested foods (E_{ing}), and excess lifetime cancer risk (ELCR). Five radionuclides (^{212}Pb, ^{214}Pb, ^{228}Ac, ^{40}K, ^{137}Cs) were detected in the studied samples, with low specific activates ranged from (B. D. L) to (5.44±2.33, 2.37±1.53, 1.85±1.36, 284.87±16.87, 3.99±1.99) Bq/kg respectively, besides some samples didn't have any radionuclide or have one only. All the calculated values are less than the average worldwide, except the annual effective dose from ingested foods. In general, the results showed good agreement with the previous studies. This is meant that the analyzed milk is safe for human consumption because their levels of radioactivity are less than the global limits.

Keywords: Milk, Radionuclides, Hazard Indices, Specific Activity, Age Group, HPGe Detector

1. Introduction

Milk and milk products are important components of diet in many countries. Milk is one of the few foods produced over large areas and collected on a daily basis. Its composition is almost identical all over the world, and it is easy to collect a representative sample that can be analyzed in the liquid or dried form [1]. Milk is likely to be contaminated by radioactive ^{131}I and ^{137}Cs within the first days after a release of volatile radionuclides. 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. Milk from goats and sheep, because of their grazing habits, should be checked periodically over a longer period [2]. In addition, milk is one of the principal food for individual nutrition and includes each the carbohydrates, macronutrients namely protein, fat, vitamins (A, B groups and D) and trace elements particularly phosphate, calcium, zinc, magnesium, and selenium [3]. Milk is the basic foodstuffs for the babies particularly for babies less than one year because they usually consume more milk on body weight basis than adults. Therefore, the evaluation of radioactivity and heavy metals levels in the powdered infant's milk and the related doses are of crucial importance for controlling the radiation levels and necessary in establishing rules and regulations relating to radiation protection [4]. It is additionally vital to know the behavior of natural radionuclides and heavy metals in the environment because such information can be utilized as the associated parameter values for radiological evaluation [5]. Also, Potassium is an essential constituent of cellular tissue, ^{40}K is one of the most important natural radionuclides. In addition, the heavy metals such as Zn,

Fe, Mn, Cu, and Pb are essential at very low concentrations for the survival of all forms of life [6]. In the Arab World (Iraq), no studies of radioactivity in powdered infant's milk have been carried out and no baselines of the concentration of natural and artificial radioisotopes have been reported. Therefore, the establishment of radioisotope concentrations will prove important information that can add to the knowledge of population exposure and to the setting up of original baseline [7]. The aim of this research is to evaluate the concentrations of the natural and artificial radioactivity in milk samples, as well as the calculation of the radium equivalent activity (Ra_{eq}), internal hazard index (H_{in}). Moreover, the age group parameters dependent such as annual effective dose from ingested foods (E_{ing}) and excess lifetime cancer risk (ELCR).

2. Methods

Twelve imported milk powder samples belong to infant and adult consuming, were collected, prepared, and coded as shown in the Table 1.

The samples were fully mobilized and sealed in the Marinelli beakers for 30 days before the examination, in order to reach the secular equilibrium for both ^{238}U and ^{232}Th radionuclides with their daughter products.

The radioactivity was measured by a gamma ray spectroscopy of (HPGE) detector of crystal dimension 3"x3", efficiency of 40% and operation voltages 4000V. A mixed standard source of ten radionuclides with mass (985.0gm) and activity of (40kBq) was used to calibrate the efficiency of the detector.

Table 1. *Type, Code, Mass, Exporting country, and Age group of the samples.*

No.	sample name	Code	Mass (gm)	Exporting country	Age group
1	Diealac	Die	465.23	New Zealand	
2	Fresh	Fre	460.92	Sultanate of Oman	
3	Walad AlDhakey	Wal	487.72	New Zealand	
4	Almuneish	Alm	486.48	United Arab Emirates	Adult
5	Alqarya	Alq	503.87	Jordan	
6	Awladi	Awl	457.45		
7	Al-Mudhish	Al-M	385.4	Sultanate of Oman	
8	Aptamil	Apt	557.75	Holland	
9	Hero Baby	Her	385	Switzerland	
10	Similac Gain	Sim	565.96	Ireland	Infant
11	Nutrawiz	Nut	577.16	Australia	
12	Sunny baby	Sun	391.5	France	

3. Calculations

3.1. Specific Activity $A_i(E_\gamma)$

The specific activity for i radionuclide, at energy peak E_γ, is given by [8]:

$$A_i(E_\gamma) = \frac{N}{t \times I_\gamma(E_\gamma) \times \varepsilon(E_\gamma) \times m} \quad (1)$$

Where N is the net area under the peak, t is the time of measurement, I_γ is the abundance at energy E_γ, ε is the detection efficiency, and (m) is the mass of the sample.

3.2. Radium Equivalent Activity (Ra_{eq})

The activity due to ^{226}Ra, ^{232}Th, and ^{40}K are represented by a single quantity, which takes into account the radiation hazard may cause by a general index called the radium equivalent activity, and defined as [9].

$$Ra_{(eq)} = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad (2)$$

3.3. Internal Hazard Index (H_{in})

The index is utilized to analyze the specific activities of foodstuffs containing various concentrations of ^{226}Ra, ^{232}Th, and ^{40}K.

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (3)$$

For the safe use, the maximum value of H_{in} should be less than unity [10].

3.4. Estimation of Annual Effective Dose from Ingested Foods (E_{ing})

The Ingestion effective dose due to the intake of ^{226}Ra, ^{232}Th and ^{40}K in foods can be evaluated using the following expression [11].

$$E_{ing} = \sum_i (A_{ig} \times C_{i,r}) \times g_{T,r} \quad (4)$$

Where i denotes the food group, the coefficients A_{ig} and $C_{i,r}$ denotes the consumption rate (kg/y) and specific activity of the radionuclide r of interest respectively, and $g_{T,r}$ is the dose conversion coefficient for ingestion of radionuclide r in tissue T. For individual, the recommended dose conversion coefficient $g_{T,r}$ for ^{40}K, ^{226}Ra (^{238}U), and ^{232}Th, are 6.2×10^{-9}, 2.8×10^{-7}, and 2.2×10^{-7} respectively.

3.5. Excess lifetime Cancer Risk (ELCR)

The risk incurred by a population is estimated by assuming

a linear dose-effect relationship with no threshold as per ICRP practice. For low doses, ICRP fatal cancer risk factor is ($0.05Sv^{-1}$). The risk factor states the probability of a person dying of cancer increases by 5% for a total dose of (1Sv) received during his lifetime. Therefore, the probability of death from cancer due to 'natural incidence' increases from about 25% to 30% following a total lifetime exposure of (Sv). To estimate cancer risk for person using the following relationship

$$ELCR = C_d \times R_f$$

Where: R_F is a risk factor, fatal cancer risk. For stochastic effects, ICRP uses values of 0.05 for the public. C_d is the life time effective dose, which is a measure of the total effective dose received over an average lifetime of (50y) following ingestion of a radionuclide, was calculated using [12]:

$$C_d = 50 \times E_{ing}$$

$$ELCR = R_f \times E_{ing} \times 50 \quad (5)$$

Where E_{ing} is the total effective dose to an individual.

4. Results and Discussion

Five radionuclides were detected in these studied samples they are (^{212}Pb, ^{214}Pb, ^{228}Ac, ^{40}K, ^{137}Cs). The lead (^{214}Pb) appears at two energy peaks (295.21 and 351.92) keV, it's one of the decay product of the uranium-238 chain. (^{228}Ac and ^{212}Pb) were found at the energy of (911.16, and 238.63) keV respectively, they belong to the thorium-232 chain, the single radionuclide ^{40}K is appeared at (1460.80 keV), and the artificial is appeared at ^{137}Cs at (661.61 keV).

From Table 2 which lists the types of the studied samples and the detected radionuclides with the specific activities in each of them, we observed a difference in the number of the nuclides detected in the samples, ranging from five to zero.

The highest number of nuclides was found in (Al-Mudhish), imported from Sultanate Oman which was contain with type (Fresh) imported from the same country on the artificial nuclide ^{137}Cs, the nuclide which did not appear in the most studied samples. This means that environment of this country, thus plants and animals are radioactively contaminated.

It's shown that one of the samples (Hero Baby) imported from the European country Switzerland and used for infant consume doesn't contain any natural or artificial radionuclide, this result may attribute to the soil type and the clean and healthy environment of this country, In addition to being far from battle fields, and facilities where the nuclear explosions took place. It is also interesting to note that Diealac type the commonly used milk by adult contains four nuclides one of them is ^{137}Cs.

Table 2. *Nuclides and the specific activities of the milk samples.*

Code	Uranium series products			Thorium series products			Single radionuclides	
	^{214}Pb Bq/kg		average Bq/kg	^{212}Pb Bq/kg	^{228}Ac Bq/kg	average Bq/kg	^{40}K Bq/kg	^{137}Cs Bq/kg
	295.22 keV	351.93 keV		238.63keV	911.16 keV			
Die	-	1.53±1.23	1.53±1.23	1.31±1.41	-	1.31±1.41	212.49±14.57	2.30±1.51
Fre	-	-	-	-	-	-	-	2.08±1.44
Wal	-	-	-	-	-	-	273.75±16.54	-
Alm	-	-	-	-	-	-	117.14±10.82	-
Alq	-	-	-	1.67±1.29	-	1.67±1.29	271.90±16.48	-
Awl	-	-	-	-	-	-	113.90±10.67	-
Al-M	2.37±1.53	-	2.37±1.53	0.67±0.81	1.85±1.36	1.26±1.12	284.87±16.87	3.99±1.99
Apt	-	-	-	-	-	-	11.26±3.35	-
Her	-	-	-	-	-	-	-	-
Sim	-	-	-	0.87±0.93	0.97±0.98	0.92±0.95	-	-
Nut	-	-	-	0.73±0.85	1.62±1.27	1.17±1.08	149.52±12.22	-
Sun	-	-	-	5.44±2.33	-	5.44±2.33	166.36±12.89	-
Max.	2.37±1.53	1.53±1.23	1.53±1.23	5.44±2.33	1.85±1.36	5.44±2.33	284.87±16.87	3.99±1.99
Min.	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L
Avg.	2.37±1.53	1.53±1.23	3.9±1.97	1.78±1.33	1.48±1.21	1.96±1.40	177.91±13.33	2.79±1.67
World wide average [13]	___		35	___		30	400	14.8

Note: (-): B.D.L. or below the detection limit.

The values of the specific activity for the detected radionuclides in the ^{238}U and ^{232}Th chain, and for ^{40}K, and ^{137}Cs radionuclides in all samples can be shown in figure 1.

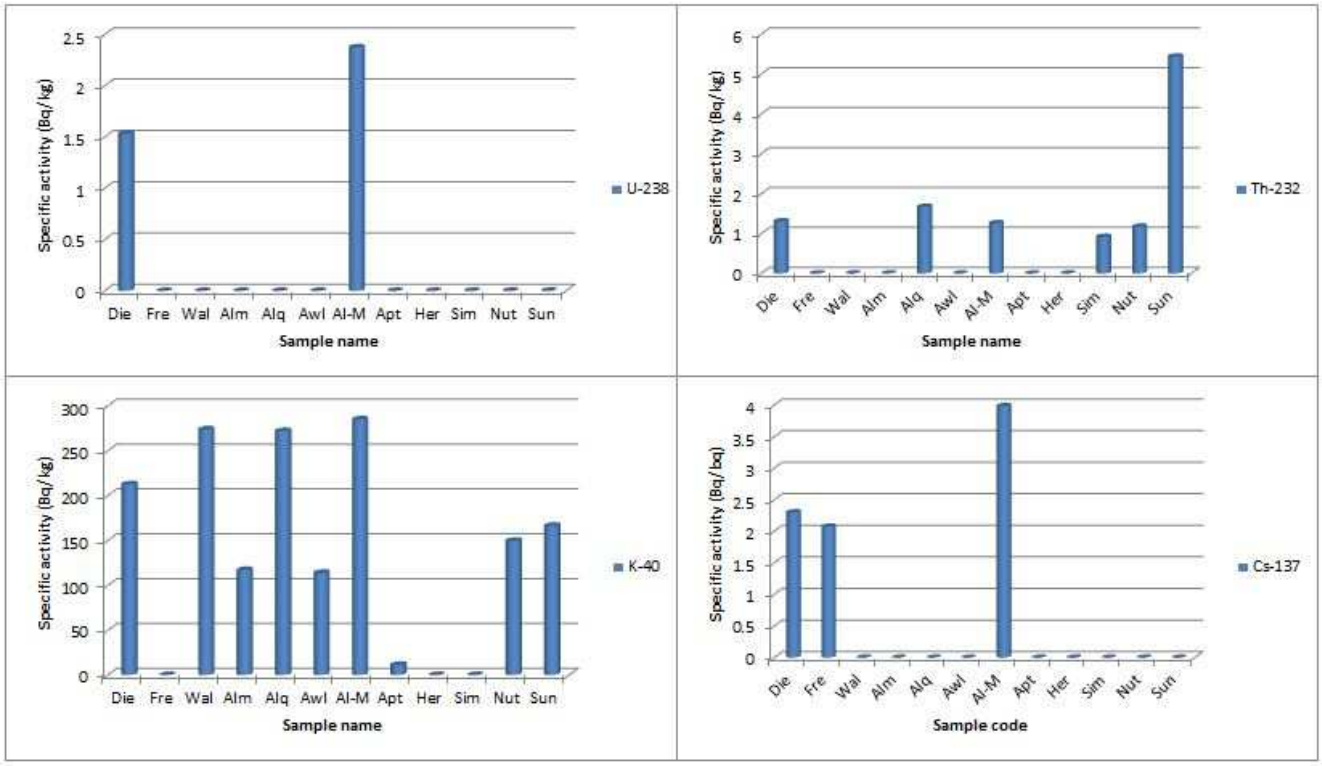

Figure 1. *The specific activities of radionuclides in studied milk.*

The radium equivalent activities Ra_{eq}, internal hazard index H_{in}, Annual effective dose from ingested foods E_{ing} for ^{238}U, ^{232}Th, and ^{40}K, and excess lifetime cancer risk ELCR for the infant and adults are listed in the Tables 3 and 4. Respectivly. All the radiation hazard indices are under the global limit values [14].

Table 3. *Hazard parameters in infant milk samples*

No.	Code	Ra_{eq} (Bq/kg)	H_{in}	E_{ing} ^{238}U (mSv/y)	E_{ing} ^{232}Th (mSv/y)	E_{ing} ^{40}K (mSv/y)	ELCE 10^{12}
1	Apt	0.87	0.002	-	-	8.4×10^{-3}	21
2	Her	-	B.D.L	-	-	-	-
3	Sim	1.31	0.004	-	0.024	-	61
4	Nut	13.19	0.036	-	0.031	0.11	36
5	Sun	20.59	0.056	-	0.144	0.12	67
Max.		20.59		-	0.144	0.12	67
Min.		B.D.L	B.D.L	-	-	-	-
Avg.		11.69	0.02	-	0.06	0.08	46
world wide average [14]		370	1	—	—	—	—

Table 4. *Hazard parameters in adult samples.*

No.	Code	Ra_{eq} (Bq/kg)	H_{in}	E_{ing} U-238 (mSv/y)	E_{ing}Th-232 (mSv/y)	E_{ing}K-40-(mSv/y)	ELCE 10^{12}
1	Die	19.76	0.058	0.045	0.03	0.138	534
2	Fre	-	-	-	-	-	-
3	Wal	21.08	0.057	-	-	0.178	446
4	Alm	9.02	0.024	-	-	0.076	191
5	Alq	23.33	0.063	-	0.04	0.177	539
6	Awl	8.77	0.024	-	-	0.074	185
7	Al-M	26.11	0.077	0.07	0.03	0.185	711
Max.		26.11	0.077	0.07	0.04	0.185	711
Min.		B.L.D	B.L.D	-	-	-	-
Avg.		18.01	0.05	575×10^{-4}	0.03	0.118	434
world wide average [14]		370	1	6.3×10^{-3}	0.38×10^{-3}	170×10^{-3}	29×10^{7}

Figure 2 showd the radium equivalent activities Ra_{eq} and internal hazard index H_{in}, while Figure 3 showed the parameters depending on age grope for infants milk samples. The highest value of E_{ing} for both ^{232}Th and ^{40}K radionuclides and ELCR are found in (Sun) sample.

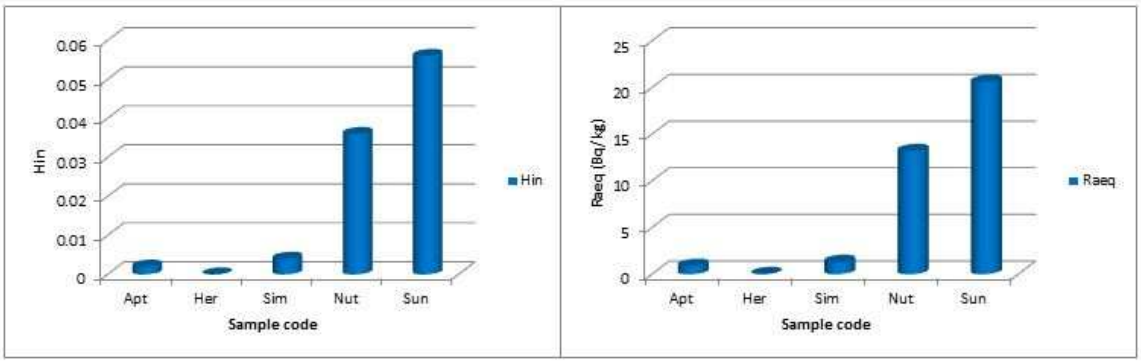

Figure 2. *The Ra_{eq} and $H_{in,}$ for infant milk samples.*

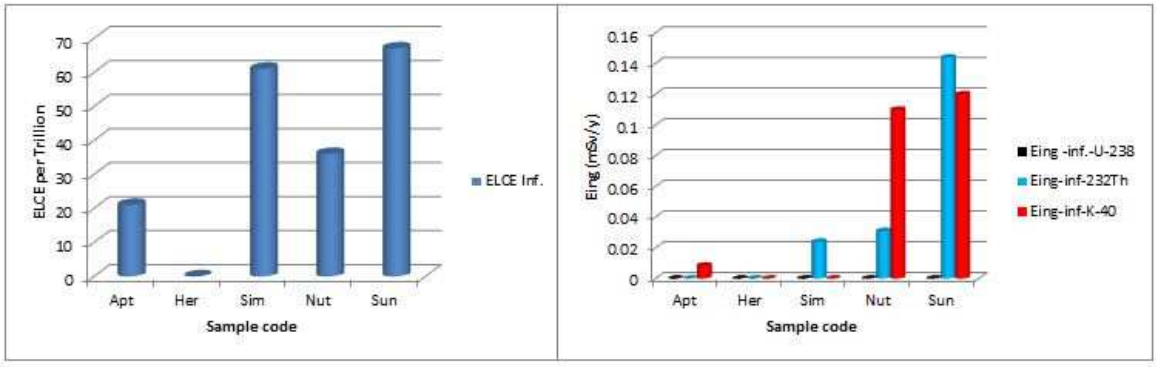

Figure 3. *The $E_{ing.}$ (^{238}U-^{232}Th-^{40}K) and ELCE in infant milk samples.*

Figure 4 showed the radium equivalent activities Ra_{eq} and internal hazard index H_{in}, while Figure 5 showed the parameters depending on age grope for adult milk samples. The E_{ing} values are higher than the world wide average in most samples for the ^{238}U, ^{232}Th and ^{40}K, the highest rate of excess lifetime cancer risk ELCR in (Al-M) sample.

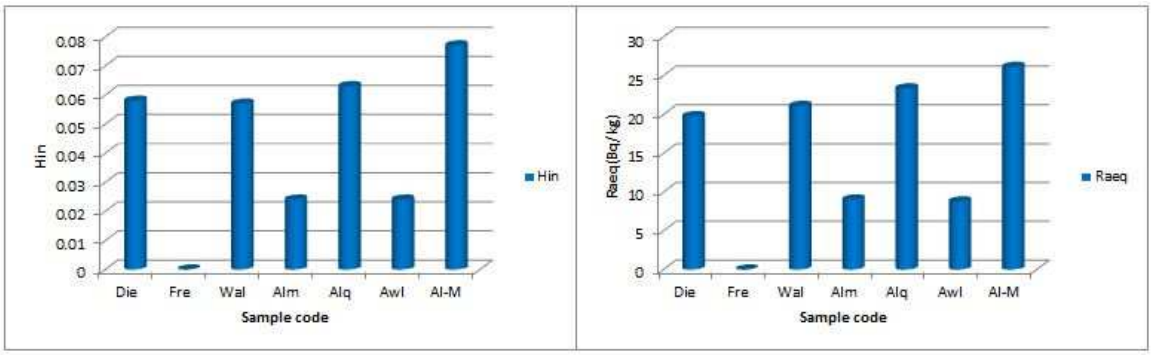

Figure 4. *The radium equivalent Ra_{eq} and $H_{in,}$ for adults samples.*

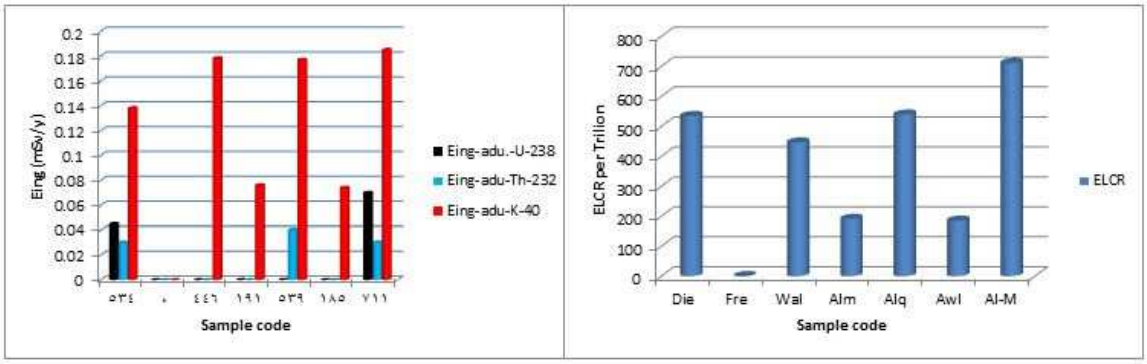

Figure 5. *The $E_{ing.}$ and ELCR in adults samples.*

5. Conclusions

1. Four natural radionuclides were detected; ^{214}Pb belong to uranium-238series; ^{212}Pb and ^{228}Ac belong to thorium-232series, natural single radionuclide ^{40}K, and artificial single radionuclide ^{137}Cs in milk samples.
2. The average values of the specific activities of the radionuclides of milk samples were under the world wide average recommended by UNSCEAR.
3. The values of the radiation hazard indices Ra_{eq} and H_{in} were under the global limit.
4. the parameters depending on age grope ELCR for adults were be under the world wide average, while the E_{ing} were higher than of worldwide average.
5. Hero Baby is best milk for babies because does not contain radioactive nuclides.

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