Heliyon 10 (2024) e30454

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Evaluation of radioactivity concentration in farm fresh milk and concomitant dose to consumer

Shikha Pervin [a,*], Md Minhaz Kabir [b], Md Jafor Dewan [b], Mayeen Uddin Khandaker [c,d], Selina Yeasmin [a]

[a] Health Physics Division, Atomic Energy Centre, Dhaka, 1000, Bangladesh Atomic Energy Commission, Bangladesh
[b] Department of Nuclear Engineering, University of Dhaka, Dhaka, 1000, Bangladesh
[c] Applied Physics and Radiation Technologies Group, CCDCU, School of Engineering and Technology, Sunway University, Bandar Sunway, 47500, Selangor, Subang Jaya, Malaysia
[d] Faculty of Graduate Studies, Daffodil International University, Daffodil Smart City, Birulia, Savar, Dhaka, 1216, Bangladesh

ARTICLE INFO

Keywords:
Cow raw milk
Gamma-ray spectrometry
Activity concentration
Annual effective dose
Dhaka city

ABSTRACT

In this study, activity concentrations of natural radionuclides in 28 raw milk samples collected from different dairy farms in Dhaka city of Bangladesh were measured using a high-purity germanium (HPGe) detector for the first time. The activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K in the investigated fresh milk samples ranged from BDL (Below detection level) to 26 ± 1.6 Bq/kg, BDL to 11.7 ± 3.3 Bq/kg and 101 ± 17 to 384 ± 32 Bq/kg, respectively. No artificial radionuclides were found in the investigated samples. Present results show inline within the range of available data in the literature. Annual committed effective doses were estimated following the consumption characteristics of raw milk by city population, values are found within the limiting range recommended by international organizations due to consumption of foodstuffs. Additionally, real-time gamma-ray dose rate in the farms/sampling locations was found in the range of 0.12 ± 0.01–0.20 ± 0.01 μSv/h by using a digital gamma survey meter (Gamma Scout) and the calculated maximum annual effective dose due to outdoor absorbed dose was found to be 0.25 mSv/y, which shows lower than the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) recommended limit of 2.4 mSv/y. This study indicates that the concentration of radionuclides in the farm fresh milk of Dhaka city does not pose any unwanted risk to public health, and it is safe to consume by both children and adults with the current intake level.

1. Introduction

Natural radioactivity is ubiquitous in soil, water, air and other media comprising the earth and environment [1]. The presence of various amounts of naturally occurring radioactive materials such as uranium, thorium, and their decay products, as well as singly occurring ^{40}K are the major sources of natural radiation in our dwelling environment [2].In addition, the background radiation is contributed to by the interaction of cosmic rays with the atmospheric particles, as well as the applications of radiation in medicine, industry, nuclear weapons testing, etc [3]. Human beings are always exposed to radiation released from the radionuclides available in the environment. The concentration of radionuclides in the environment is generally relatively low. The ultimate mechanism for the

* Corresponding author.
E-mail address: shikha.pervin@yahoo.com (S. Pervin).

https://doi.org/10.1016/j.heliyon.2024.e30454
Received 22 November 2023; Received in revised form 3 April 2024; Accepted 26 April 2024
Available online 26 April 2024

release of primordial radionuclides into the soil is the weathering of the earth's crust. Plants uptake these radionuclides through their roots or absorb them through leaves, and animals accumulate them through the direct consumption of plants, plant-derived foodstuffs, phosphate-based mineral-fortified foods, etc. [4]. The three primary routes by which the human body can be exposed to hazardous radiation are ingestion, inhalation, and skin contact [5]. Among these, ingestion is the most prevalent and practically inevitable route for radiation exposure to humans. In fact, food and water intake are the primary routes through which radionuclides enter the human body. Radionuclides are easily incorporated into soft human tissues after consumption, resulting in complex health-threatening disorders that could last a lifetime. Furthermore, long-term low-intensity radiation exposure may result in various types of cancers. Milk and milk-based meals are regarded as crucial sources of nourishment for human health. Moreover, milk is a significant ingredient in many recipes, including cookies, curds, ice cream, yogurt, chocolate, and many more that are part of the average person's day-to-day diet. It is also the primary source of nutrition for newborns, children, and teenagers, and it can be preserved and used appropriately [6]. Milk is among the few foods that are produced in large amounts and gathered daily. Its composition is nearly identical everywhere in the world, and a typical sample that can be examined in liquid or dried form is simple to acquire. Contamination of milk may occur even when cows are confined indoors due to inhalation of radionuclides or ingestion of radionuclides via drinking water and consuming the contaminated feedstuffs [7]. Furthermore, milk is an important indicator of pollution in the food chain since it can be a significant transporter of radionuclides and heavy metals from the environment to humans. As a result, measuring radioactivity levels in milk is a critical step in this process [8].Studies related to the activity concentrations in different food items including milk and milk-based products were conducted in many countries in the world and reported a varying amount of radioactivity [9]. Although, some studies related to the measurement of natural radioactivity in a range of food items were performed in recent decades but none was performed for the measurement of natural radionuclides in raw milk in Bangladesh [10].Bangladesh is a small country adjacent to India and geographically very close to China and Pakistan. On the other hand, all three countries have numerous nuclear power plants in operation. In addition, all these neighboring countries possess nuclear weapons and associated nuclear technologies. As a result of these facts, Bangladesh is at risk of ^{137}Cs proliferation. Milk is a very important dietary item for the inhabitants of Dhaka city, as well as it are an essential foodstuff for infants and children. Observing the regular consumption of fresh milk by the city population, it is important to assess of the radiological content of raw milk produced by various farms in Dhaka city of Bangladesh. As Dhaka is the most populous city in the country having 21 million people, this study is of great importance regarding the health of the city population. Therefore, this study aims to assess the natural radioactivity in farm fresh milk and the associated effective dose to the consumers of Dhaka city, along with assessing the safety of foodstuffs. Furthermore, this study may help in creating guidelines and regulations to protect against the harmful effects of natural radiation via the intake of foodstuffs.

2. Materials and methods

2.1. Sample collection and preparation

To determine the concentration of radioactive elements in raw milk, a total of 28 samples were collected from different farms located in and around Dhaka city of Bangladesh. Dhaka is the capital of Bangladesh [11]. Samples were collected during the year 2022. Milk samples were stored in a refrigerator under -4 °C to avoid any kind of bacterial interference. No preservatives, such as formalin or sodium azide was added to prevent souring. The collection date of the sample was recorded as the reference date for sampling as farm-fresh milk was collected from the sampling points. The samples were then transported, stored and processed at the sample preparation laboratory of Atomic Energy Centre Dhaka (AECD). The samples were transferred to cylindrical plastic containers of 7 cm in height and 5.5 cm in diameter and the weights of the samples were recorded using an electrical balance. The sample-filled plastic containers were sealed tightly with caps and wrapped with thick vinyl tape around their necks; marked individually with identification number, date of preparation, net weight and then stored for about 30 days to assume secular equilibrium between ^{238}U and ^{232}Th parents and their short-lived progenies. The whole procedure was completed following the International Atomic Energy Agency (IAEA) technical report series [12].

2.2. In situ gamma dose rate

GAMMA SCOUT is a digital portable radiation survey meter that is used to measure the gamma-ray dose rate at the sampling area. It is equipped with a Geiger-Moller tube and is calibrated from the secondary standard dosimetry laboratory (SSDL) of the Bangladesh Atomic Energy Commission. The dose rate is measured by placing GAMMA Scout at 1meterabove the sampling points (different milk farms), where the milk sample has been taken.

2.3. Gamma-ray spectrometry system

In the present study, the spectral analysis of the milk samples has been performed in the Health Physics Division of Atomic Energy Centre Dhaka (AECD) using a gamma spectrometer equipped with a high-purity germanium detector (HPGe) and associated electronics. The detector was contained in a cylindrical lead shielding arrangement with a sliding cover and a fixed bottom to reduce interference from the environment. In this study, the gamma-ray emitting reference sources Cs-137, Co-60, and K-40 were used for energy calibration due to a wide range of gamma-ray energies emitted over the entire energy range of interest. In order to determine the detector's efficiency, a standard source was made by mixing Eu-152 of known activity with the Al_2O_3matrix. With a relative efficiency of 30 %, it was found that the energy resolution of the 1.33 MeV peak for ^{60}Co was 1.69 keV at full-width half-maximum

(FWHM). More in-depth information regarding efficiency calibration is available elsewhere [13,14].

2.4. Measurement of activity

The net count of the sample is obtained by subtracting a linear background distribution of the pulse spectra from the corresponding peak energy area. From the sample net counts,the radioactivity of the samples was calculated using the formula [15]:

$$A = \frac{CPS}{\varepsilon \times P\gamma \times W} \tag{1}$$

Where, A is the activity of the sample in $Bqkg^{-1}$, cps is the net counts per second, which is equal to the CPS for the sample - CPS for the background value, ε is the counting efficiency of the HPGe detector, P_γ is the absolute intensity of the gamma-ray energy, and W is the net weight of the sample (in kg).The measured activity concentrations of ^{226}Ra and ^{232}Th were determined from their short-lived daughter nuclides by assuming secular equilibrium for the different isotopic activities in decay chains. By combining the varied activity concentrations of several progenies, the weighted mean technique was used to compute the final activity concentrations of the radionuclides ^{226}Ra and ^{228}Ra [16,17]. The activity concentrations of ^{40}K are determined directly by measurement of the gamma-ray transitions at 1460.8 keV. The errors in the measurement have been expressed in terms of standard deviation (±σ), where σ is expressed as [18],

$$\sigma = \sqrt{\left[\frac{N_s}{T_s^2} + \frac{N_b}{T_b^2}\right]} \tag{2}$$

Where, N_s is the counts measured in time T_s and N_b is the background counts measured in the T_b. The standard deviation (±σ), in cps, was converted into activity in $Bqkg^{-1}$.

The minimum detectable activity (MDA) concentration was calculated by using the following equation [19]:

$$MDA = \frac{2.71 + 4.65 \times \sqrt{B}}{\varepsilon \times p \times T \times W}\ (\mathrm{Bq/kg}) \tag{3}$$

where, B is background counts in the region of the radionuclide key-gamma line energy, ε is the uncorrected counting efficiency, p is the gamma-ray abundance, T is the difference between sampling date and data acquisition date.

2.5. Measurement of annual effective dose

The annual effective dose, D to individuals due to the intake of the radionuclides can be estimated using the following equation [3,20],

$$D_{eff} = A \times I \times E \tag{4}$$

Where, D_{eff} is the annual effective dose due to ingestion of milk in Sv/y, A is the activity of radionuclides in milk samples in Bq/kg, *I* is the annual intake of milk in kg/y, E is the conversion factor from activity to dose in Sv/Bq [3,21].

The conversion factor E varies with both the radioisotope and the age of the individual. I depend strongly on a given age group. The calculation of the annual ingestion dose has been done for different age groups: such as infants, children and adults. Effective dose conversion coefficients for different ages of people are given in Table 1.

2.6. Radiological risk analysis

Risk assessment for ingestion of radionuclide through raw milk was estimated for different age groups using the calculated annual effective dose. The following equation was used for the calculation of excess lifetime cancer risk [22]:

$$\mathrm{ELCR} = \text{Annual effective dose} \times \text{risk factor} \times \text{duration of life} \tag{5}$$

For low doses, the ICRP (2006) reported a fatal cancer risk factor of 0.05 Sv^{-1} [23] and duration of life is 70 years.

Table 1
Effective dose rate coefficients for different age groups [3].

Dose Conversion Coefficients ($\mu Sv Bq^{-1}$)				^{40}K
Age	**^{238}U**	**^{232}Th**	**^{137}Cs**	
Infant	0.96	2.5	0.011	0.042
Children	0.8	2.3	0.0098	0.013
Adults	0.38	0.69	0.013	0.0062

3. Results and discussion

External gamma-ray exposure at 1 m above the ground in each sampling location was measured in order to understand the outdoor gamma-ray dose rates. Four readings were taken at every sampling point using the 'Gamma Scout' radiation survey meter. Then the average and the standard deviation were obtained for each sampling location (see Table 2).

Table 2 shows that the highest dose rate is found to be 0.20 ± 0.01μSv/h for MK6 sampling point and the lowest value is 0.12 ± 0.01μSv/h for MK12. The calculated annual effective dose from outdoor absorbed dose rate ranged from 0.14 to 0.25 mSv/y. Real-time gamma dose rate measurement is very important in sample collection because it indicates whether the information of any artificial radionuclides is released or not to our surroundings from artificial radiation sources [24]. It is also prime important for environmental radiation and radioactivity monitoring purposes as well as for constructing the baseline data.

The activity concentrations of ^{226}Ra, ^{232}Th, ^{137}Cs and^{40}K radionuclides in the samples are given in Table 3.

From Tables 3 and it has been seen that the obtained radionuclides concentration was found lowest for ^{137}Cs and highest for ^{40}K compared to ^{226}Ra and^{232}Th for all fresh milk samples. Miah et al., 1998 [25] measured anthropogenic radionuclides,^{137}Cs and naturally occurring radionuclides ^{40}K and ^{226}Ra in the soil of Dhaka city as a result of the fallout of radioactivity from the atmosphere following the nuclear power plant accident at Chernobyl. They reported ^{137}Cs in the soil of Dhaka city in Bangladesh ranged from 3 ± 1 to10 ± 1 Bq/kg and primordial radionuclides^{40}K ranged from 402 ± 111 to 750 ± 82Bq/kg with an average value of 574 ± 111Bq/kg and ^{226}Ra concentration was 21±6to 43 ± 7 Bq/kg [25].The activity concentration of ^{226}Ra, ^{232}Th and^{40}K in the investigated fresh milk samples ranged from BDL to 26 ± 1.6, BDL to 11.7 ± 3.3Bq/kg and 101 ± 17to 384 ± 32Bq/kg, respectively. The artificial radionuclide, ^{137}Cs was found from 0.12 ± 0.07 Bq/kg in MK6 fresh milk sample, and for the other samples, the results were found below the detection limit. The highest ^{226}Ra, ^{232}Th and ^{40}Kconcentrationswere found in MK18, MK7 and milk samples, respectively. The lowest activity concentration of ^{40}K was found in MK23 milk sample. It is observed that^{40}K is the leading radionuclide in all investigated fresh milk samples. This is because, ^{40}K is one of the major radionuclide elements in soil which is present everywhere in the environment and also present in humans and plants, animals. The transfer process from soil to grass and grass to milk is also the reason to become ^{40}K a dominant radionuclide compared to other radionuclides. Radionuclide uptake in organisms occurs through the food chain. This may explain the observed variation in ^{226}Ra content in milk samples. Higher levels in some samples could be attributed to radium concentrations in surrounding areas. Radium is likely transferred to milk via the grass-cow-milk pathway. Additionally, the soil-plant biological system and specific dietary intake (silage vs. roughage) by cows can influence the radioactivity levels in milk consumed by infants. Food preparation and processing practices may also contribute to the redistribution of radionuclides within the milk [19]. Though it may be taken into consideration for future research, the radioactivity level in the powdered milk sample is not examined in this study.

All results of the concentration of the radionuclides are found below the world average value [3].The values of radionuclide concentration found in the present work are compared with the literature data reported from various countries in the world (Table 4).

Table 2
Outdoor gamma-ray dose rate at the studied sampling locations.

Sample code	Name of the farm	Dose rate (μSv/y)	Annual effective dose (mSv/y)
MK1	Mahima Dairy Farm	0.13 ± 0.01	0.16
MK2	Krishibid Dairy Farm	0.15 ± 0.02	0.19
MK3	Alraba Dairy Farm	0.15 ± 0.02	0.19
MK4	Heritage Dairy and Agro Limited	0.16 ± 0.02	0.20
MK5	Ayan Agro Dairy Farm	0.16 ± 0.01	0.19
MK6	Silk Dairy	0.20 ± 0.01	0.25
MK7	Asma Dairy Farm	0.18 ± 0.01	0.22
MK8	Alam Dairy Farm	0.14 ± 0.01	0.17
MK9	Abdulliah Dairy Farm	0.14 ± 0.02	0.17
MK10	Toobaa Dairy Farm	0.17 ± 0.02	0.21
MK11	Hazi Dairy Farm	0.18 ± 0.0	0.22
MK12	Hawaladar Dairy Farm	0.12 ± 0.01	0.14
MK13	Saudi Dairy Farm	0.15 ± 0.01	0.18
MK14	Nehal Dairy Farm	0.15 ± 0.02	0.18
MK15	Gazi Dairy Farm	0.15 ± 0.02	0.19
MK16	Masud Dairy Farm	0.14 ± 0.01	0.18
MK17	Faizuddin Dairy Farm	0.19 ± 0.01	0.23
MK18	Goran Dairy Farm	0.17 ± 0.02	0.20
MK19	Shilaidaha Dairy Farm	0.15 ± 0.02	0.18
MK20	Salam Dairy Farm	0.16 ± 0.02	0.19
MK21	North Bengal Dairy Farm	0.13 ± 0.01	0.16
MK22	Polashi Dairy Farm	0.16 ± 0.01	0.20
MK23	AZ Dairy	0.16 ± 0.02	0.20
MK24	Atul Dairy Farm	0.13 ± 0.02	0.21
MK25	Sarkar Dairy Farm	0.17 ± 0.03	0.18
MK26	Farm Direct Dairy &Agro	0.15 ± 0.01	0.16
MK27	Mim Dairy Enterprise	0.13 ± 0.0	0.18
MK28	Pure Dairy Farm	0.15 ± 0.01	0.17

Table 3
Activity concentration of radionuclides in cow milk samples.

Sample ID	^{226}Ra	^{232}Th	^{137}Cs	^{40}K
MK1	6.6 ± 3.3	3 ± 0.2	BDL	150 ± 25
MK2	19 ± 4.4	7.6 ± 4.2	BDL	286 ± 20
MK3	10.8 ± 5.7	7.1 ± 3.0	BDL	265 ± 30
MK4	12 ± 5.1	8.1 ± 4.1	BDL	196 ± 30
MK5	5.97 ± 6.0	6.8 ± 4.7	BDL	287 ± 23
MK6	15.1 ± 4.2	6.4 ± 3.4	0.12 ± 0.07	215 ± 30
MK7	10.3 ± 5.0	11.7 ± 3.3	BDL	217 ± 25
MK8	17.7 ± 3.6	5.6 ± 1.6	BDL	230 ± 29
MK9	8.2 ± 5.8	2.4 ± 0.7	BDL	155 ± 33
MK10	15.3 ± 2.8	2.4 ± 0.1	BDL	384 ± 32
MK11	14.3 ± 1.9	3.2 ± 0.1	BDL	220 ± 24
MK12	BDL	BDL	BDL	245 ± 20
MK13	14.4 ± 1.8	2.8 ± 0.2	BDL	315 ± 21
MK14	BDL	BDL	BDL	365 ± 40
MK15	13.4 ± 3.4	3.5 ± 1.4	BDL	234 ± 17
MK16	BDL	BDL	BDL	240 ± 16
MK17	20 ± 1.4	8.5 ± 0.3	BDL	139 ± 12
MK18	26 ± 1.6	7.5 ± 2.6	BDL	117 ± 21
MK19	25 ± 4.9	9.7 ± 2.7	BDL	180 ± 32
MK20	BDL	BDL	BDL	250 ± 18
MK21	12.1 ± 0.5	4 ± 2.6	BDL	224 ± 12
MK22	13.4 ± 1.4	BDL	BDL	117 ± 17
MK23	BDL	BDL	BDL	101 ± 17
MK24	8.5 ± 0.8	4.6 ± 0.2	BDL	132 ± 20
MK25	BDL	BDL	BDL	148 ± 19
MK26	15.4 ± 2.4	2.4 ± 0.1	BDL	112 ± 4
MK27	BDL	BDL	BDL	307 ± 19
MK28	BDL	BDL	BDL	128 ± 18
Average	7.6 ± 3.4	5.4 ± 1.9	BDL	150 ± 22

[a]BDL means below detection limit.

Table 4 shows the comparison of activity concentration of ^{226}Ra, ^{232}Th, ^{137}Cs and^{40}K in this work with other studies of the world. It has been observed that the values of ^{226}Ra and^{232}Th in the present study are higher than the other studies of the world. For artificial radionuclides, ^{137}Cs were found lower than Tehran, Iran, Vietnam, Brazil, Algeria, Jordan, Selangor, Malaysia, Tunisia and Egypt. On the other hand, the values of Saudi Arabia and Australia are nearly the same. For ^{40}K, the results of the present study were found lower than Tehran of Iran, Vietnam, Brazil, Jordan and Egypt. The data of ^{40}K was found higher than the Vizag of India, Saudi Arabia, Algeria, Australia, Selangor of Malaysia, Tunisia and Argentinean. The activity concentration of ^{226}Ra, ^{232}Th ^{137}Cs and ^{40}K in fresh milk samples of the present study and other countries around the globe showed variation. It may be due to the variation of local geology, feedstuffs, environmental factors, etc. The annual effective dose due to ingestion of fresh milk for ^{226}Ra, ^{232}Th and ^{40}K for three different age groups of people are presented in Fig. 1-3, respectively.

From Figs. 1–3, it has been seen that thecalculated annual effective dose due to radionuclides in milk is found higher for infants compared to other age groups. The maximum annual effective dose due to ^{226}Ra for infants, children and adults was found to be 369.41, 282.88 and 94.64μSv/y, respectively. Similarly, for^{232}Th, the respective values were found to be 432.9, 365.98 and 104.95 μSv/y, and for ^{40}K the values were found to be 238.69, 67.89 and 30.95μSv/y, respectively. This indicates that infants have a higher risk factor as compared with adults. All calculated doses for different age groups are within the typical worldwide range of annual effective dose (200–800 μSv/y) due to the ingestion of all-natural radionuclides as reported by UNSCEAR 2000 [3]. However, the largest contributor to the dose received from ingestion of milk is from ^{232}Th. It may be due to the dose coefficient factor. It has been

Table 4
Comparison between the activity concentrations of^{226}Ra,^{232}Th,^{40}K in farm fresh milk samples in Dhaka city with other countries.

Country	Source	^{226}Ra in Bq/kg	^{232}Th in Bq/kg	^{137Cs} in Bq/kg	^{40}K in Bq/kg	Reference
Dhaka, Bangladesh	farm fresh milk	BDLto 26	BDL to 11.7	BDL to 0.12	101–384	**Present Study**
Vizag, India	market milk (mBq/g)	2.58	1.11	–	8.78	[26]
Saudi Arabia	powdered milk	3.26–17.72	1.59–13.57	–	74.51	[27]
Saudi Arabia	liquid milk			0.12 ± 0.03	66 ± 4	[28]
Tehran, Iran	milk powder	0.05	0.142	3.2	434	[29]
Vietnam	fresh milk	0.91	1.98	1.45	371	[30]
Brazil	powdered milk	BDL	1.7–3.7	5.1–11.2	489	[31]
Algeria	powdered infant milk	1.19 ± 0.81	1.45 ± 0.96	0.18 ± 0.06	18.07 ± 3.42	[32]
Jordan	powdered milk	0.5–2.14	0.78–1.28	1.55	349–392	[33]
Selangor, Malaysia	infant powered milk	3.05 ± 1.84	2.55 ± 2.48	99.1 ± 69.5	0.27 ± 0.19	[34]
Tunisia	powdered milk	–	–	2.26 ± 0.5	160 ± 19	[35]
Egypt	infants powdered milk	0.91 ± 0.20	0.60 ± 0.11	0.42 ± 0.11	477 ± 25	[36]

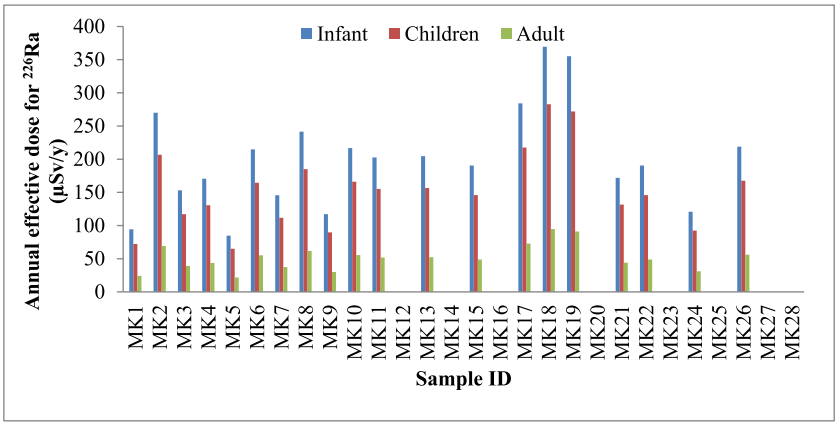

Fig. 1. Variation of annual effective dose among infants, children and adults due to ^{226}Ra.

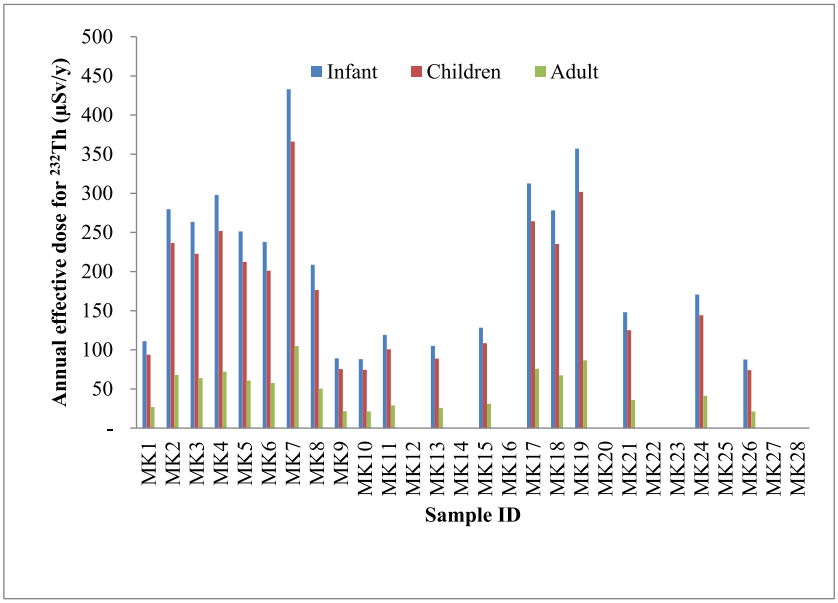

Fig. 2. Variation of annual effective dose among infants, children and adults due to ^{232}Th.

seen that all the annual effective doses due to^{226}Ra, ^{232}Th and ^{40}K and for different aged people, the annual effective dose is within 1mSv/y recommended by the International Commission on Radiological Protection (ICRP) in all ages [21].

Due to the consumption of milk by the population during their life time, the maximum excess life time cancer risk for infants, children and adults was calculated. From Table 5, these risks were found 1.3×10^{-4}, 9.7×10^{-4}, and 3.3×10^{-4} for infants, children, and adults, respectively, from exposure to ^{226}Ra. Similarly, the risks from ^{232}Th were found 1.5×10^{-3}, 1.3×10^{-3}, and 3.7×10^{-4}, and from ^{40}K were found 8.4×10^{-4}, 2.4×10^{-4} and 1.1×10^{-4}. Notably, these values are significantly lower than the cancer risk factor of 2.5×10^{-3} recommended by the ICRP (2006).

4. Conclusion

The activity concentrations of radionuclides ^{226}Ra, ^{232}Th and ^{40}K in different milk samples were measured in 28 raw cow milk samples from different locations of Dhaka city using a HPGe detector. The real-time dose rate was measured in each sampling point using a digital gamma survey meter and the value ranges from 0.12 ± 0.01 μSv/h to 0.20 ± 0.01 μSv/h. The activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K in the investigated fresh milk samples ranged from BDL to 26 ± 1.6, BDL to 11.7 ± 3.3 Bq/kg and 101 ± 17 to 384 ± 32 Bq/kg, respectively. The calculated average value is lower than the respective world average values reported by UNSCEAR. The values of activity concentration show similar data compared to the values worldwide. The presence of artificialradionuclide^{137}Cs was not detected within all the investigated samples, it might be below the detection limit. The maximum annual effective dose rate was found 369.41 μSv/y for ^{226}Ra, 432.9 μSv/y for ^{232}Th and 238.69 μSv/y for ^{40}K. It was found that the maximum value of the annual

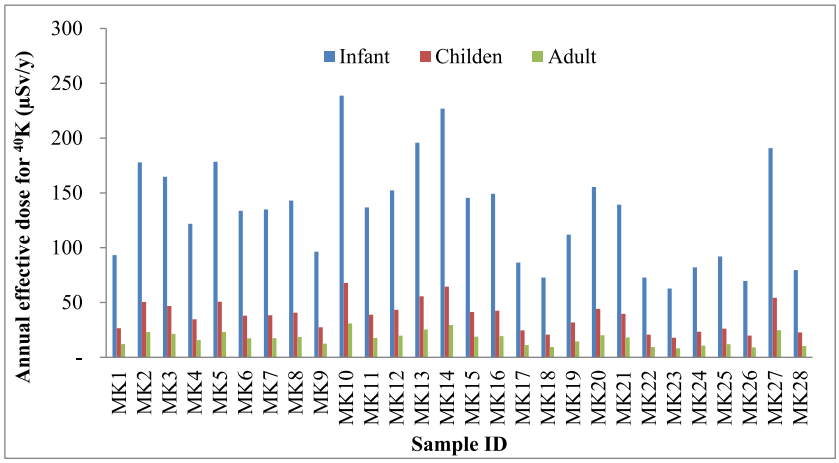

Fig. 3. Variation of annual effective dose among infants, children and adults due to ^{40}K.

Table 5
Excess life time cancer risk due to ^{226}Ra, ^{232}Th and ^{40}K for infant, children and adult.

Sample ID	ELCR × 10^{-3}								
	For ^{226}Ra			For ^{232}Th			For ^{40}K		
	Infant	Children	Adult	Infant	Children	Adult	Infant	Children	Adult
MK1	0.33	0.08	0.08	0.39	0.33	0.09	0.33	0.09	0.04
MK2	0.94	0.24	0.24	0.98	0.83	0.24	0.62	0.18	0.08
MK3	0.54	0.14	0.14	0.92	0.78	0.22	0.58	0.16	0.07
MK4	0.60	0.15	0.15	1.04	0.88	0.25	0.43	0.12	0.06
MK5	0.30	0.08	0.08	0.88	0.74	0.21	0.62	0.18	0.08
MK6	0.75	0.19	0.19	0.83	0.70	0.20	0.47	0.13	0.06
MK7	0.51	0.13	0.13	1.52	1.28	0.37	0.47	0.13	0.06
MK8	0.85	0.22	0.22	0.73	0.62	0.18	0.50	0.14	0.06
MK9	0.41	0.10	0.10	0.31	0.26	0.08	0.34	0.10	0.04
MK10	0.76	0.19	0.19	0.31	0.26	0.07	0.84	0.24	0.11
MK11	0.71	0.18	0.18	0.42	0.35	0.10	0.48	0.14	0.06
MK12	–	–	–	–	–	–	0.53	0.15	0.07
MK13	0.72	0.18	0.18	0.37	0.31	0.09	0.69	0.19	0.09
MK14	–	–	–	–	–	–	0.79	0.23	0.10
MK15	0.67	0.17	0.17	0.45	0.38	0.11	0.51	0.14	0.07
MK16	–	–	–	–	–	–	0.52	0.15	0.07
MK17	0.99	0.25	0.25	1.09	0.93	0.27	0.30	0.09	0.04
MK18	1.29	0.33	0.33	0.97	0.82	0.24	0.25	0.07	0.03
MK19	1.24	0.32	0.32	1.25	1.06	0.30	0.39	0.11	0.05
MK20	–	–	–	–	–	–	0.54	0.15	0.07
MK21	0.60	0.15	0.15	0.52	0.44	0.13	0.49	0.14	0.06
MK22	0.67	0.17	0.17	–	–	–	0.25	0.07	0.03
MK23	–	–	–	–	–	–	0.22	0.06	0.03
MK24	0.42	0.11	0.11	0.60	0.50	0.14	0.29	0.08	0.04
MK25	–	–	–	–	–	–	0.32	0.09	0.04
MK26	0.77	0.20	0.20	0.31	0.26	0.07	0.24	0.07	0.03
MK27	–	–	–	–	–	–	0.67	0.19	0.09
MK28	–	–	–	–	–	–	0.28	0.08	0.04

effective dose for ^{226}Ra, ^{232}Th and ^{40}K are lower than the recommended limit. The present result concludes that the dose incurred to children and adults is below the recommended limit. Also, the annual effective dose obtained from the real-time dose rate was within the recommended limit. The excess life time cancer risk due to the radionuclides for infant, children and adult are within the recommended limit. The data of this study reported here may help to establish a baseline for natural radioactivity in fresh milk in Dhaka city of Bangladesh and help to develop future guidelines in the country for radiological protection for the people.

Data availability statement

All data are within the manuscript.

Funding

No funding was obtained for this study.

CRediT authorship contribution statement

Shikha Pervin: Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Md Minhaz Kabir:** Writing – original draft. **Md Jafor Dewan:** Supervision. **Mayeen Uddin Khandaker:** Writing – review & editing. **Selina Yeasmin:** .

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

The author would like to thank the relevant personnel of the Health Physics Division and also grateful to the inhabitants for their support during sample collection.

References

[1] S.A. Oladele, Measurement of activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th for assessment of radiation hazards from soils of the southwestern region of Nigeria, Radiat. Environ. Biophys. 48 (2009) 323–332.
[2] N.I. Zakariya, M.T.E. Kahn, Review article benefits and biological effects of ionizing radiation, sch. Acad, J. Biosci. 2 (2014) 583–591.
[3] United Nations Scientific Committee on the Effects of Atomic Radiation, Sources and Effects of Ionizing Radiation, UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes, United Nations, New York, 2000.
[4] A.E. Shershaby, N.W. Dine, Assessment of Natural and Man –Made Radioactivity Levels of the Plant Leaves Samples as Bio- Indicators of Pollution in Hebron District- Palestine, 2009.
[5] H.A. Ammer, N.F. Kadhim, M.S. Karim, A.A. Ridha, Hazard indices and age group parameters of powder milk consumed in Iraq, Higher Education Research 2 (2017) 117–122, https://doi.org/10.11648/j.her.20170205.11.
[6] Y.F. Ali, F.A. Cucinotta, L. Ning-Ang, G. Zhou, Cancer risk of low dose ionizing radiation, Front. Physiol. 8 (2020) 234, https://doi.org/10.3389/fphy.2020.00234.
[7] J. Desimoni, F. Sives, G. Errico, J. Mastrantonio, Activity levels of gamma-emitters in Argentinean cow milk, Food Compos Anal. 22 (2009) 250–253.
[8] J. Elassaad, A. Thamer, Measurements of natural radioactivity in infant formula and radiological risk assessment, J. Radioanal. Nucl. Chem. 315 (2018) 157–161.
[9] A.S. Sahar, S.M.A. Mohammed, A. Rana, Assessment of natural radionuclides in powdered milk consumed in Iraq, Journal of Sciences Research Natural 6 (2016) 13.
[10] Technical Report Series 295, A Guidebook on Measurement of Radionuclides in Food and Environment, International Atomic Energy Agency, Vienna, 1989.
[11] S. Pervin, S. Banik, M.U. Khandaker, S. Yeasmin, Assessment of gross alpha/beta activity in tap water of Dhaka city using ZnS (Ag) scintillation detector and concomitant health hazard, Int. J. Environ. Anal. Chem. (2022).
[12] M.U. Khandaker, N.L.M. Nasir, N.S. Zakirin, H.A. Kassim, K. Asaduzzaman, D.A. Bradley, M.Y. Zulkifli, A. Hayyan, Radiation dose to the Malaysian populace via the consumption of bottled mineral water, Radiat. Phys. Chem. 140 (2017) 173–179.
[13] M.U. Khandaker, H. Haba, J. Kanaya, N. Otuka, Activation cross-sections of deuteron-induced nuclear reactions on natural iron up to 24 MeV, Nucl. Instrum. Methods Phys. Res. Sect. B Beam Interact. Mater. Atoms 316 (2013) 33–41.
[14] M.U. Khandaker, H. Haba, J, Kanaya N. Otuka, Excitation Functions of (d. x) Nuclear reactions on natural titanium up to 24MeV, Nucl. Instrum. Methods Phys. Res. Sect. B Beam Interact. Mater. Atoms 296 (2013) 14–21, https://doi.org/10.1016/j.nimb.2012.12.003.
[15] S. Pervin Md, J.D.A.M. Apon, M.M.M. Siraz, S. Yeasmin, Measurement of natural radioactivity and its health hazards associated with the use of different branded cement samples collected from different manufactures in Dhaka city using gamma spectrometry, J. Bangladesh Acad. Sci. 45 (2021) 95–104.
[16] M.U. Khandaker, N.A.B. Heffny, Y.M. Amin, D.A. Bradley, Elevated concentration of radioactive potassium in edible algae cultivated in Malaysian seas and estimation of ingestion dose to humans, Algal Res. 38 (2019) 101386, https://doi.org/10.1016/j.algal.2018.101386.
[17] M.U. Khandaker, O.B. Uwatse, K.A. Khairi, M.R.I. Faruque D.A. Bradley, Terrestrial radionuclides in surface (dam) water and concomitant dose in metropolitan Kuala Lumpur, Radiat. Protect. Dosim. 185 (2019) 343–350, https://doi.org/10.1093/rpd/ncz018.
[18] B. Monira, S.M. Ullah, A.S. Mollah, ^{137}Cs-uptake into wheat (Triticum vulgare) plants from five representative soils of Bangladesh, Environ. Monit. Assess. 104 (2005) 59–69, https://doi.org/10.1007/s10661-005-1601-0.
[19] B. Onosohwo, O.B. Uwatse, A.O. Michael, M.U. Khandaker, M.A. Yusoff, D.A. Bradley, M.M. Alkhorayef, K. Alzimami, Measurement of natural and artificial radioactivity in infant powdered milk and estimation of the corresponding annual effective dose, Environ. Eng. Sci. 32 (2015), https://doi.org/10.1089/ees.2015.0114.
[20] Y. Mei-Wo, Measurement of activity concentrations in powdered milk and estimation of the corresponding annual efective dose, J. Radioanal. Nucl. Chem. (2019).
[21] Age-dependent doses to members of the public from intake of radionuclides: Part 5, Compilation of ingestion and inhalation dose coefficients, Ann. ICRP 26 (1) (1996) 1–91, https://doi.org/10.1016/s0146-6453(00)89192-7. Erratum in: Ann ICRP. 2002 ;32(1-2):310. PMID: 8886253.
[22] R.M. Amin, F. Ahmed, Estimation of annual effective dose to the adult Egyptian population due to natural radioactive elements in ingestion of spices, Adv. Appl. Sci. Res. 4 (2013) 50–354.
[23] ICRP, Low-dose Extrapolation of Radiation-Related Cancer Risk. Publication 99, Elsevier, Amsterdam, the Netherlands, 2006.
[24] Y.L. Hae, M. Seongjin, J.P. Seong, H.L. Sang, Comparison of gamma absorbed dose rates in the air measured with a portable survey meter and the soil radioactivity measurements, Radiat. Protect. Dosim. 198 (2022) 1529–1539, https://doi.org/10.1093/rpd/ncac195.
[25] S. Miah, M. Roy, B. Touchiduzzaman, F.K. Alam, Distribution of radionuclides in soil samples in and around Dhaka City, Appl. Radiat. Isot. 49 (1998) 133–137, https://doi.org/10.1016/S0969-8043(97)00232-7.
[26] A.C. Patra, S. Mohapatra, S.K. Sahoo, P. Lenka, J.S. Dubey, V.K. Thakur, P.M. Ravi, R.M. Tripathi, Assessment of ingestion dose due to radioactivity in selected food matrices and water near Vizag, India, J. Radioanal. Nucl. Chem. 300 (2014) 903–910, https://doi.org/10.1007/s10967-014-3097-y.
[27] M.A. Zain, Assessment of natural radionuclides in powdered milk consumed in Saudi Arabia and estimates of the corresponding annual effective dose, Journal of American Science 9 (2013).

[28] G.A. Alharshan, D.A. Aloraini, H. Al-Ghamdi, A.H. Almuqrin, K.M. El-Azony, A. S Alsalamah, Measuring the radioactivity concentration of 40K and 137Cs and calculating the annual internal doses from ingesting liquid and powdered milk, Radiochemistry 59 (2017) 98–103, https://doi.org/10.1134/S1066362217010131.
[29] T. Hosseini, A.A. Fathivand, H. Barati, M. Karimi, Assessment of radionuclides in imported foodstuffs in Iran, J. Radiat. Res. 4 (2006), 149-1.
[30] V.H. Duong, T.D. Nguyen, M. Hegedus, E. Toth-Bodrogi, T. Kovacs, Assessment of ^{232}Th, ^{226}Ra, ^{137}Cs, and ^{40} K concentrations and annual effective dose due to the consumption of Vietnamese fresh milk, J. Radioanal. Nucl. Chem. 328 (2021) 1399–1404.
[31] F.L. Melquiades, C.R. Appoloni, Radiation of powdered milk produced at Londrina, PR, BrazilRadiat, Phys. Chem. 61 (2021) 691–692.
[32] K. Benaissa, L.N. Seladji, A. Kadum, B. Dahmani, Radiation of powdered milk produced at Londrina, PR, BrazilRadiochemistry 62 (2020) 673–680, https://doi.org/10.1134/S106636222005015X.
[33] Q.A. Zaid, A.M. Alyassin, K.M. Aljarrah, A.M. Ababneh, Measurement of natural and artificial radioactivity in powdered milk consumed in Jordan and estimates of the corresponding annual effective dose, Radiat. Protect. Dosim. 138 (2010) 278–283.
[34] O.B. Uwatse, M.A. Olatunji, M.U. Khandaker, Y.M. Amin, D.A. Bradley, M. Alkhorayef, K. Alzimami, Environ. Eng. Sci. 32 (10) (2015) 2015, https://doi.org/10.1089/ees.2015.0114.
[35] R.E.L. Mestikou, E. Jemil, M. Mazouz, M. Benali, L. Ghedira, Determination of the activity level in powdered milk available in Tunisia and assessment of the radiological risks, J. Radioanal. Nucl. Chem. 317 (2018), https://doi.org/10.1007/s10967-018-5965-3.
[36] S.D. Khaled, Assessment of natural and artificial radioactivity in infants' powdered milk and their associated radiological health risks, J. Radioanal. Nucl. Chem. 324 (2020), https://doi.org/10.1007/s10967-020-07170-0.