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Determination of ^{40}K concentration in milk samples consumed in Tehran-Iran and estimation of its annual effective dose

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Background: Since ^{40}K is the most important natural radionuclide in the environment, its concentration was measured for all milk and milk powder samples consumed in Tehran-Iran. Milk was chosen, since because it is a reliable indicator of the general population intake of certain radionuclide, and many environmental programs have been applied for its safety. ***Materials and Methods:*** Measurements was done using a CANBERRA gamma spectrometer Model No. S100. Forty one milk and milk powder samples were choosen for the gamma spectroscopy analysis. ***Results:*** The average activity concentrations for ^{40}K in the samples were calculated, 31.0 ± 6.1 and 17.1 ± 3.3 $Bq.kg^{-1}$, in milk and milk powder respectively. These data correspond to the effective dose of 14 $\mu Sv.year^{-1}$ for adults and in the range of 6.4-15.9 $\mu Sv.day^{-1}$ for children. ***Conclusion:*** Considering the obtained data from liquid milk samples, an almost uniform distribution of ^{40}K can also be obtained. Furthermore, the calculated effective doses were too low to induce important health hazards; however, the data useful for monitoring. **Iran. J. Radiat. Res., 2009; 7 (3): 159-164**

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INTRODUCTION

A large fraction of natural radiation exposure is due to ingestion of food containing natural radionuclides such as ^{40}K, ^{226}Ra, ^{210}Po and ^{210}Pb [1-5]. Among these, ^{40}K, which is an important radionuclide from the health physics point of view, is the largest contributor to the dose received by humans due to of its wide spread distribution in environment and living organisms [1].

The half-life of ^{40}K is 1.3 billion years and it decays to ^{40}Ca by emitting a beta particle with no attendant gamma radiation (89% of the times) and the gas ^{40}Ar by electron capture with emission of an energetic gamma ray (11% of the times). So ^{40}K can present both external and internal health hazards. The strong gamma radiation (E_γ = 1.46 MeV) makes the external exposure to this radioisotope a concern; while in the body ^{40}K poses a health hazard from the beta particles ($E_{\beta Max}$ = 1.35 MeV) and gamma rays which associate with cell damage and general potential for subsequent cancer induction [6-8].

The concentration of potassium as an essential element for the body is under homeostatic controls and one can find about 2 g of this element in one kg of the body mass which is used to sustain biological process. With regards to the average natural abundance of ^{40}K, which is about 0.012%, and its transfer factor to the body, the normal average activity of this radionuclide in humans, eliminated from the body by a biological half-life of 30 days, is reported 60 $Bq.kg^{-1}$. The accumulated activity of this radioisotope in body can cause an absorbed dose which ranges from 100 µGy to 270 µGy in the thyroid gland and bone marrow respectively [8-10]. Moreovre, in normal situations ^{40}K and to a lesser extent other dietary sources of primordial radionuclide produce an average effective dose rate

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~400 μSv/yr (40 mrem/yr), or ~13% of natural background [11].

Among different kinds of foodstuffs milk is a reliable indicator of the general population intake of certain radionuclides, since fresh milk is consumed by a large segment of the population, and contains several biologically significant radionuclides [12]. By these considerations, the aim of the present study has been to determine the activity concentration of ^{40}K, as a soluble radionuclide, in different milk samples used in Tehran-Iran, and to estimate its effective ingestion dose. Tehran is the capital city of Iran with a population of about 12 million.

MATERIALS AND METHODS

Sampling and sample preparation

The location of the sampling site (the capital city of Iran; Tehran) is shown on a map presented in figure 1. An effort was made to ensure adequate sampling to identify all milk and milk powder samples of Tehran from 30 different milk samples of local diary product distributors, and 11 milk powder samples from drug stores. Some of the milk powder samples were imported to Iran from foreign countries such as France, Germany, USA and Sweden.

Raw unprocessed milk samples were transferred into an uncontaminated special empty cylindrical plastic container called marinelli beaker, which our system was calibrated on its geometry. In case of milk powder samples, 100 g of each sample was dissolved in 1 litter of distilled water in order to reach the same concentration as liquid milk samples. So, the concentration of ^{40}K in distilled water was also measured and ignored since it was below the detection limit (BLD) of the system.

Radioactivity determination

Gamma spectrometry was performed using a CANBERRA spectrometer (Model No. S100). This system had a high purity germanium (HPGe) detector with a relative efficiency of 25% and the FWHM of the system for 1332 keV of ^{60}Co was 2 keV. This proved the system to be capable of distinguishing the gamma ray energies of ^{40}K. The photopeack at 1487.9 keV was used for the measurement of the radionuclide. The detector was shielded by 10 cm lead on all sides and cadmium-copper in the inner

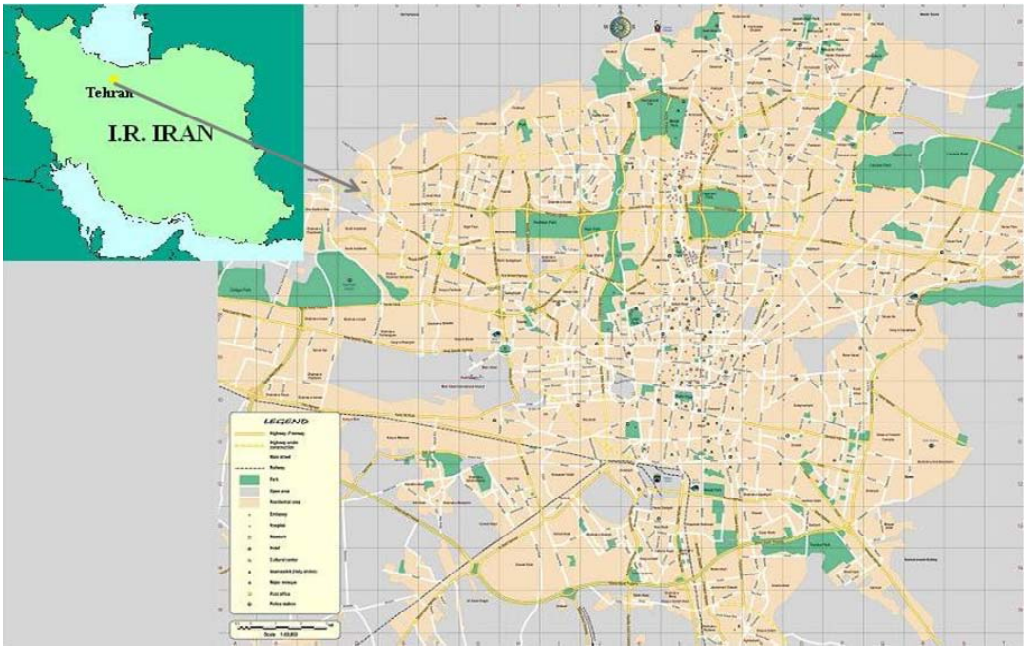

Figure 1. Map of Tehran-Iran which shows the location of study.

side. The instrument's performance was enhanced by the flexibility of the software which allowed the operator to define a unique assay protocol (count time, geometry reports, etc.) on a sample by sample basis.

Samples were counted for 60 000 seconds, which was a proper time for low level activity determination. The background spectra were also collected for the same period of time and, it was subtracted from the sample spectra. Marinelli standard mix source (CERCA HM 395) from France was also used for efficiency calibration.

Activity concentrations

The activity concentration in the samples was obtained using the following expression [13-15].

$$C = C_n/\varepsilon P_\gamma M_s \qquad (1)$$

Where C (Bq.kg^{-1}) is the activity concentration of ^{40}K in the milk samples, C_n is the primary count rate under the photo peak which was calculated by the system, ε is the detector efficiency for the ^{40}K specific gamma ray, P_γ is the absolute transition probability of the ^{40}K specific gamma ray and M_s is the mass of the sample (kg).

Assessment of the effective dose due to ingestion

To estimate radiological hazard form ^{40}K which can occur due to milk ingestion, we had to calculate the effective dose. Effective dose is based on the risks of radiation induced health effects and the use of the International Commission on Radiological Protection (ICRP) metabolic model that provides relevant conservation factors to calculate effective dose from the total activity concentration of radioisotope measured in the food samples [13, 16, 17]. Estimation of the radiation induced health effects associated with the intake of radionuclide in the body is proportional to the total dose delivered by the radionuclide while residing in the various organs. Thus, according to Till and Moor [18] the ingested effective dose can be calculated by the dose delivered by taking in radioactivity in food which is worked out by measuring how much is in the food (Bq.kg^{-1}), and multiplying this by the amount of food is eaten in a period of time (e.g. kg.year^{-1}), and then by a physical factor which tells what does is caused by this number of Bq in the body (Sv.Bq^{-1}). This can be summarized in the following equation:

$$H_{T,r} = U \times C_r \times g_{T,r} \qquad (2)$$

Where the coefficients U and C_r denote the consumption rate per year (kg) and activity concentration of the radionuclide (Bq), respectively, and $g_{T,r}$ is the dose coefficient for intake by ingestion of radionuclide r (here is potassium-40).

RESULTS

To determine the activity concentrations of ^{40}K in the samples, Equation 1 was used. Using this equation the data was normalized for one Kg mass of each sample (the primary analyzed mass in the sampling process ranged between 950 - 1150 g). Primary count rate under the photopeak was also calculated by the system. Finally, the calculated data which indicated the ^{40}K activity concentration (Bq.kg^{-1}) of milk and milk powder samples are presented in tables 1 and 2. The 2σ standard deviation uncertainties in these two tables are combined uncertainties in the counting measurements. As shown, the values of radioactivity vary from 11.4 Bq.kg^{-1} to 42.8 Bq.kg^{-1} for fresh/liquid milk samples and 11.1 Bq.kg^{-1} to 32.3 Bq.kg^{-1} milk powder samples. It should be noted that the activity concentration of ^{40}K, measured for each sample, presented the amount of radioactivity but they do not indicate the radiological hazard to individuals directly. So, there should be additional factors to be considered.

The effective dose was calculated according to the equation 2 by substituting the reported value of $g_{T,r}$ (5.9×10^{-9} Sv.Bq^{-1}) for this radionuclide [16, 17], average consumption rate and activity concentration of the samples. Since all milk samples which

Table 1. Potassium-40 activity concentration (Bq.kg^{-1}) measured in milk samples ± SD.

Sample ID	^{40}K activity concentration (Bq.kg^{-1})	Sample ID	^{40}K activity concentration (Bq.kg^{-1})
M 1	33.9 ± 7.2	M 16	25.0 ± 6.1
M 2	27.0 ± 6.1	M 17	27.3 ± 6.1
M 3	35.8 ± 7.2	M 18	28.5 ± 6.1
M 4	36.2 ± 7.1	M 19	32.6 ± 6.4
M 5	33.8 ± 6.1	M 20	28.8 ± 6.1
M 6	33.3 ± 6.1	M 21	30.3 ± 6.0
M 7	29.2 ± 6.1	M 22	25.9 ± 7.1
M 8	27.8 ± 6.1	M 23	31.3 ± 6.2
M 9	34.6 ± 6.1	M 24	33.6 ± 6.1
M 10	32.4 ± 6.3	M 25	37.0 ± 6.9
M 11	38.7 ± 5.3	M 26	32.6 ± 6.2
M 12	34.9 ± 6.4	M 27	42.8 ± 6.1
M 13	12.1 ± 2.4	M 28	36.1 ± 6.7
M 14	33.0 ± 7.1	M 29	37.1 ± 6.1
M 15	25.8 ± 5.8	M 30	11.4 ± 2.3

Table 2. Potassium-40 activity concentration (Bq.kg^{-1}) measured in milk powder samples ± SD.

Sample ID	^{40}K activity Concentration (Bq.kg^{-1})
MP 1	11.1 ± 2.2
MP 2	12.4 ± 3.0
MP 3	11.4 ± 2.2
MP 4	12.0 ± 2.2
MP 5	13.3 ± 2.5
MP 6	32.3 ± 5.2
MP 7	11.7 ± 2.3
MP 8	30.5 ± 5.1
MP 9	27.4 ± 6.3
MP 10	12.0 ± 3.0
MP 11	14.4 ± 2.8

are used in this study were not merely consumed in their production areas, the average activity concentrations was applied for ^{40}K in milk and milk powder samples which were 31.0 ± 6.1 and 17.1 ± 3.3 Bq.kg^{-1}, respectively. The average consumption rates of milk for Iranians were about 75 kg year^{-1} which was reported by the milk industry bodies of Iran. These values were 63 g day^{-1} for milk powders consumption in children at the breast younger than 5 months old, and 158 g day^{-1} for children at breast feeding, older than 5 months old. By these considerations the effective dose due to milk consumption was equal to 14 µSv.year^{-1} for adults. This value for children was in the range of 6.4 - 15.9 µSv.day^{-1}.

DISCUSSION

^{40}K behaves in the environment the same as other potassium isotopes, being assimilated into the tissues of all plants and animals through normal biological processes. It is the predominant radioactive component in human tissues and in most food. For example, milk contains about 2 000 pCi/L of natural ^{40}K [19, 20].

Ingestion of contaminated foods is one of the routes of uptake of potentially dangerous radionuclides for man and dairy products in particular due to importance in human diets [20]. In the present study, the concern has mainly been focused on analyzing the amount of ^{40}K in milk samples in the most populated city of Iran, Tehran. ^{40}K was chosen because of its importance. This radionuclide is one of the most important long-lived radionuclide on earth crust and its concentration in environmental samples can be an indicator for long-term radiation of this element because of its high solubility and ease of transfer. Considering the high transfer factor of this radionuclide form soil to food chain, and by comprising the data by natural ^{40}K in milk (2 000 pCi/L), at the first glance to the data obtained in this investigation, some aspects of radiological conditions from the studied area will be determined, and one can note that the area has a low background radiation from ^{40}K decay. Furthermore, the amount of ^{40}K in milk samples, collected from different areas, was not varied significantly (11.4 Bq.kg^{-1} to 42.8 Bq.kg^{-1}) and showed an almost; uniform dispersion of this radio isotope in Tehran. However, could be to monitor the concentration of this radionuclide in different soil samples to get more accurate results.

The acquired data also provided an opportunity to verify any impact from the ingestion of this radionuclide in the living organisms including human. Considering the health physics limitations, the amount of effective dose calculated in this study (1.4×10^{-5} Sv.year^{-1} for adults) showed that the dose received by milk ingestion was too low to induce health hazards. The calculated effective dose for children varies between 6.36×10^{-6}-15.9×10^{-6} Sv.day^{-1}. This was not critical too but the variation mainly refered to the variatiety in consumption rate which was 63 g.day^{-1} in children at the breast younger than 5 months old and 158 g.day^{-1} for children at the breast older than 5 months old.

Finally, although the investigation showed no significant hazard, the obtained data was so useful for monitoring programs in particular situations such as uncontrolled use of fertilizers and other human manipulations in the environment; since, together with nitrogen and phosphorous, potassium is a major soil fertilizer and levels of ^{40}K in soils are strongly influenced by fertilizer usage.

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