Annual Average Internal Dose Based on Alpha Emitters in Milk Sample

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Abstract. Natural radioactivity is common in the environment. As well as in geological formations such as soil, rock, air, water and plants. Which required extensive researches in many countries are due to the global interest in exposure to natural radioactivity. Ten different samples of milk collected from Iraqi markets were evaluated for concentration of alpha radioactivity (uranium concentration, effective radium content and radon concentrations) using CR-39. After exposure, the detectors were etched in a (NaOH) solution of normality (6.25 N) at a temperature of 70 °C for 8 hours. The tracks were calculated by the microscope track-counting system. At a rate of 0.171 ppm, uranium concentrations ranged between 0.079 – 0.263 ppm. While, the effective radium content varied from 53.724 - 178.47 mBq/kg with an arithmetic rate of 116.096 mBq/kg. The variation of the radon exhalation values for the mass unit and for the area unit was also observed between 0.406 - 1.349 mBq/kg.h and 3.076 - 10.217 mBq/m².h, at a mean rate of 0.943 mBq/kg.h and 6.646 mBq/m².h, respectively. The average of annual average internal effective dose (AAIED) due to ingestion of 222Rn in milk samples in children and adults has been found 0.60 nSv/y and 0.2 nSv/y respectively, there are excellent correlation between radium concentrations and radon exhalation rate and uranium concentration(R²=1). Thus, the results of this study do not constitute a health hazard to the lives of people because they are within the limits allowed internationally.

Keywords: Alpha radioactivity; sealed can technique; CR-39; milk

1. Introduction

Heavier than air, Radon gas is called radium emission. Since radon gas has no colour, no odour, no taste and no sight, appropriate detectors should be used to detect its presence. Radon-222 is the natural radioactive gas resulting from the decay of radium-226 in the uranium-238 series. Radium resides in soil rocks and ocean waters sediments. Alpha particles with 5.486 MeV of energy are emitted as the radon atoms decay to produces polonium isotopes “(Po-218 and Po-214)” [1]. In developing radiation protection rules and regulations, it is necessary to know how human exposure to natural and industrial radiation sources is carried out, so many studies on radiation levels and the distribution of radionuclides in the environment are conducted to extract vital radioactive information [2]. The earth contains rudimentary radionuclides, including uranium and radium. Radionuclides are highly important in the nuclear fuel cycle. They are decomposed by three groups of distinct radionuclides such as uranium-238, uranium-235, and thorium-232. They do not only exist in the human body but can be inhaled by gas inhalation from certain nutrients. Radium-226 (half-life of 1600 years), radium-224 and radium-228 (half age have 3.6 days and 5.8 years, respectively, are usually mixed with
uranium ore). Because radium chemically behaves like calcium in the bone, surfaces of metal metabolism, these nuclei are radioactive [3]. Radium-226 concentrations, which are widely dispersed in the environment, vary depending on the sources in which they are presented, with concentrations varying in water, soil, and food [4]. Most substances are excreted rapidly, when radium is ingested. However, because of the similarity of the chemical of radium and calcium, the blood-absorbing radium from the gastrointestinal tract or lungs follows calcium disposal and is deposited mainly in the bones [5]. Radium from radionuclides in the environment is the origin of radon, since it generates alpha rays and has a prolonged half-life is one of the deadliest radionuclides [6]. Milk powder is one of the most important foods that young people and adults eat as an important food meal after mixing it with warm water or water to drink it as liquid at different times of the day. The importance of this food is to study the activity of the natural radiation for α-particles emitted in ten samples of Iraqi powdered milk markets (Karbala governorate) for various brands. This research is aimed at determining uranium concentrations, effective radium content, radon exhalation rate of the mass and surface unit in ten samples of powdered milk to know the health risks associated with the alpha radioactivity emitted from different milk samples.

2. Experimental details

Ten samples for various types of milk available at Iraqi market were collected for this study, where the samples were dried and grinded in the form of soft powder. 90 gm of powder milk samples were taken, and were stored for 30 days to arrive of secular equilibrium. The sealed can technique was used, as shown in Figure 1. To measure effective radium content and exhalation rates of radon in different milk samples, the CR-39 was used with a thickness of 500 μm and dimensions (1.5 x 1.5 cm2) to estimate alpha concentrations emitted from radon-222 [7,8] in ten samples of milk available in Iraqi local markets. 90 grams of each milk sample were taken and placed in the bottom of the cylindrical cup with a height of 6.5 cm and a diameter of 12.3 cm. The distance between the sample surface and the detector surface was 9.3 cm. The detector is installed in a double-sided adhesive on the inner surface of the cup lid. After the exposure (108 day) was completed, the detectors were retrieved and etched for eight hours in 6.25N NaOH solution maintained at a temperature of 70 ± 1 °C in a constant temperature water bath to reveal the tracks. The detectors were washed and dried. Subsequently, α-tracks were calculated using an optical microscope (kruss-mbl 2000) at a magnification of 100X.

![Figure 1. Sealed can technique.](image)
3. Theoretical calculations

The dissolve radon concentration in milk was calculated using the following equation [9-11]:

\[
C_{Rn} = \frac{C_a \lambda T}{L}
\]

(1)

where \(C_a\) = radon concentration in ambient air (Bq/m\(^3\)), \(\lambda\) = decay constant for radon (d\(^-1\)), \(h\) = the distance from the surface of milk to detector (m), \(T\) = time of exposing and \(L\) = the depth of the sample (m).

Effective radium content in milk samples is calculated using the following formula: [12, 13]:

\[
C_{Ra}(mBq/kg) = \frac{hA}{KT_wM}
\]

(2)

where, \((\rho)\) is track density on the surface detectors, \((K)\) is the calibration factor equal to (0.223 Tracks.cm\(^2\).day\(^-1\)/Bq.m\(^3\)) [14] and \((M)\) mass of sample.

The effective exposure time \((T_e)\) with the real exposure time \((T)\) and \(^{222}\text{Rn}\) decay constant \((\lambda)\) are related to the following relationship [15, 16]:

\[
T_e = T - \frac{T}{T} \left(1 - e^{-\lambda T}\right)
\]

(3)

Area exhalation rate of radon \([E_A\ (mBq/ m^2.h)]\) is calculated from the next equation [12, 17]:

\[
E_A(mBq/ m^2.h) = \frac{CV_A}{AT_e}
\]

(4)

here \((A)\) the area of the tube, \(V\) is the effective volume of the can.

Mass exhalation rate of radon\([E_M(mBq/ kg.h)\) \] is calculated by using equation [12, 17]:

\[
E_M(mBq/ kg.h) = \frac{CV_A}{MT_e}
\]

(5)

where, \(M\) is the mass of the milk sample, \(C\) represents the integrated radon exposure (Bq.m\(^-3\).d),

Uranium concentration \((C_u)\) in the powder milk samples can be defined as the ratio between the weight of the uranium in the sample\((W_u)\) and the weight of the sample\((W_s)\) itself according to the following formula and measured in unit of part per million (ppm) [18,19]:

\[
C_u(ppm) = \frac{W_u}{W_s}
\]

(6)

The annual average internal dose (AAIED) by an ingestion of radionuclides has been calculated according to the equation [20,21]:

\[
AAIED(\frac{Sv}{y}) = C_{Rn} \left(\frac{Bq}{kg}\right) \times I^n \left(\frac{Kg}{y}\right) \times C_f \left(\frac{Sv}{Bq}\right)
\]

(7)

where, \(C_{Rn}\) is the activity concentration of radon inside of the ingested sample (Bq/Kg), \(I^n\) is the annual intake of powdered milk (Kg/y) which depends on a given age [22,23] and \(C_f\) is the effective dose conversion factor of the radioactive element (nSv/Bq) \(C_f\) is the ingested dose conversion factor for radionuclides (Sv/Bq), as mentioned in the UNSCEAR2000 report [24]. The average consumption rate of milk for children, in different age groups [22,25,26].

4. Results and Discussion

In the present study, ten samples of powdered milk were selected from various brands available in the Iraqi market. For the purpose of measuring of alpha radioactivity emitted from the milk samples, using CR-39 detector. The values of \(\rho, CS, E_M, E_A,\) and \(C_u\) as well as sample name with origin country are summarized Table 1 to ten different samples of powdered milk in present study. The results of the samples were arranged upward of these results, effective radium content were found to range from 53.724±3.2 to 178.470±8.7 mBq/kg, at an average of 116.096 mBq /kg. While the radon exhalation rate for the mass unit and the area unit was 0.406±0.01 to 1.349±0.09 mBq/kg.h and 3.076±0.09 to 10.217±0.20 mBq/m\(^3\).h. With an average of 0.943 mBq /kg .h and 6.646 mBq /m\(^3\).h, respectively. It was also observed that the highest \(C_u\) was 0.263±0.009 ppm in the sample Li-Vie and the lowest concentration was 0.079±0.001 ppm in the sample AL-Mudhish, at an average of 0.171ppm. The values of AAIED based on ingestion of radon-222 from samples of milk in different age groups such as a children and adults respectively are shown in Figures 2 and 3. From Figure 2, it is found that, the range value of AAIED by ingestion of radon-222 in children groups was 0.266 nSv/y to 0.882 nSv/y.
with an average value of 0.60 nSv/y, while the range of AAIED in adult groups was between 0.091nSv/y and 0.302nSv/y with an average value of 0.20 nSv/y (see Figure 3). In Figure 4, it is found that the percentage of AAIED in children and adults were 75% and 25% respectively. Therefore, AAIED consumption by children is larger than the dose from consumption by adults. This larger value for children is due to the high sensitivity of tissues of children body. They indicate that the AAIED in all milk samples was lower than the action level of 0.29 mSv/y recommended by UNSCEAR in regard to the ingestion exposure that occurred by natural sources [20,21,24]. In this study, we can say that all the results were similar to that of other Iraqi researchers for different food items (dates, rice, vegetables) [18,27,28]. Therefore, there is no danger to human health from the point of view of radiation. In addition, the concentration of uranium in all milk samples for this study was lower than that of milk products in the United States [29] and some Asian countries such as China [30], India [31] and Japan [32], as well as European countries, namely Poland [33] and the United Kingdom [34]. The value of $C_{Ra}$ in the milk under study was higher than the products by America [29], China [30], Japan [32], Italy [35], Poland [33,36] and Romania [37,38] and were within the limits of permitted levels in Germany [39,40] and the United Kingdom [34]. From the concentration of uranium and radium concentrations obtained from that study with levels of uranium and radium concentrations in the United States and many European and Asian countries in milk products, therefore, it can say that these samples do not dangerous on the health of people life because the concentrations of nuclei studied within the levels allowed internationally.

**Table 1.** The results of $\rho$, CS, $C_{Ra}$, $E_M$, $E_A$, and $C_U$ for different milk samples under study.

| Code | Sample Name       | Country        | $\rho$ (Trak/cm$^2$) | CS (Bq/m$^3$) | $C_{Ra}$ (mBq/Kg) | $E_M$ mBq/kg.h | $E_A$ mBq/m$^2$.h | $C_U$ (ppm) |
|------|-------------------|----------------|----------------------|---------------|------------------|-----------------|-------------------|-------------|
| M1   | Al-Mudhish        | Oman           | 100±6.2              | 4.152±0.10    | 53.724±3.2       | 0.406±0.01      | 3.076±0.09        | 0.079±0.001  |
| M2   | AL-Munaish        | New Zealand    | 125.8±7.3            | 5.223±0.12    | 67.584±4.2       | 0.511±0.02      | 3.869±0.09        | 0.100±0.002  |
| M3   | AL-Ajeeb          | New Zealand    | 151.6±8.1            | 6.295±0.11    | 81.445±4.6       | 0.616±0.03      | 4.663±0.10        | 0.120±0.002  |
| M4   | Dielac 1          | Vietnam        | 177.4±7.8            | 7.366±0.13    | 95.306±4.9       | 720±0.04        | 5.456±0.12        | 0.141±0.003  |
| M5   | Rawdha-Al-Mudhish | New Zealand    | 203.2±9.0            | 8.437±0.14    | 109.166±5.1      | 0.825±0.05      | 6.250±0.14        | 0.161±0.004  |
| M6   | Happy Family      | New Zealand    | 229±10.2             | 9.508±0.15    | 123.027±6.7      | 0.930±0.06      | 7.043±0.16        | 0.181±0.005  |
| M7   | Rino              | UAE-Dubai      | 254.8±12.8           | 10.580±0.18   | 136.888±7.6      | 1.035±0.07      | 7.837±0.17        | 0.202±0.006  |
| M8   | Dielac 2          | Vietnam        | 280.6±13.7           | 11.651±0.19   | 150.748±7.9      | 1.139±0.08      | 8.630±0.18        | 0.222±0.007  |
| M9   | Al-Ryad           | UAE-Sharjah    | 306.4±16.8           | 12.722±0.2    | 164.609±8.2      | 1.244±0.09      | 9.424±0.19        | 0.243±0.008  |
| M10  | Li-Vie            | New Zealand    | 332.2±16.9           | 13.793±0.02   | 178.470±8.7      | 1.349±0.09      | 10.217±0.20       | 0.263±0.009  |
| Minimum |                   |                | 100                   | 4.152         | 53.724           | 0.406           | 3.076             | 0.079       |
| Maximum|                   |                | 332.2                 | 13.793        | 178.470          | 1.349           | 10.217            | 0.263       |
| Average |                   |                | 216.1                 | 8.972         | 116.096          | 0.943           | 6.646             | 0.171       |
Figure 2. Results of Annual average internal dose in children.

Figure 3. Results of Annual average internal dose in adults.
5. Conclusion

After studying of alpha radioactivity in ten samples of powdered milk, which is widely used in the Iraqi market and through the results we found that the highest concentrations of uranium concentration, effective radium content, radon exhalation rate for mass and surface in sample M10 (Li-Vie, New Zealand), while the lowest values for the same variables were in the sample M1 (Al-Mudhish, Oman). When comparing the results of this study with the results of researchers in previous studies, including different food items, it was found that there is similarity and convergence between these studies. It is conclude from this study that the results have not affected on the health of people because they are within the levels allowed internationally compared to concentrations of uranium and radium nuclei in milk products in many countries of the world, such as the United States of America as well as many European countries and Asia.

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