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Comparison of Excess Lifetime Cancer Risk for Different Age Groups for Selected Flour Samples

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Abstract. Flour is a powder made from grains which rich in starch, where is the main raw material in making basic foods such as bread. because of the increased incidence of cancer, this study was conducted to assess the average concentration of ^{226}Ra, ^{232}Th, ^{40}K% radionuclide in (ppm) units and Radium equivalent activity Raeq (Bq.kg^{-1}) was (0.703, 5.874, 2.869 and 109.615) respectively, also calculate the ratio (^{232}Th - ^{226}Ra, ^{40}K - ^{226}Ra, ^{40}K - ^{232}Th) were measured in 15 flour samples using a gamma ray spectrometer with average values (4.097**,** 152.045 and 56.889) respectively. From the result we found that the ratio (^{40}K - ^{226}Ra) and (^{40}K - ^{232}Th) were higher than the average worldwide. Annual gonadal equivalent dose AGED (mSv.y^{-1}),it included a rise above the universally accepted health limit, the average of total annual committed effective dose AACED (mSv.y^{-1}) was higher than limits permissible globally for adult , children and infant. Finally WE found Excess lifetime cancer risk (ELCR) for adult, children and infant which were (0.004, 4.638E-05 and 1.60354E-05) , which does not fall within the limits permissible globally for adults , while it is universally accepted for children and infants. We can consider this study as a baseline for future studies.

Keywords: Annual gonadal equivalent, (AGED), cancer risk, ppm, flour.

INTRODUCTION

Natural radioactive materials (NORM) are found in soil, air, water, plants, and food. There are two main sources of radionuclides in food: the first is natural and the second is synthetic. Important natural radionuclides are terrestrial in origin and are found in all elements of the environment. Terrestrial radionuclides consist of natural chains like uranium and thorium and non-chain like potassium. They are usually long-lived with a half-life in excess of one hundred million years. It is found in varying amounts in air, water, vegetables, animals, soil, plants, and in the human body itself[1]. The presence of NORM in the environment is known to be responsible for a significant exposure of humanity to radiation. Radionuclides may emit either alpha or beta particles and may enter the body by ingestion or inhalation. This could lead to an increase in indoor exposures. Plants acquire these radionuclides through the roots and leaves, while animals acquire radionuclides through consuming these plants[2]. There are two different mechanisms for transporting radionuclides to plants, either by uptake by roots or directly through atmospheric precipitation. In some cases, the increase in radionuclide levels is due to inhalation and ingestion of air, food and water. This increase in the effective internal dose may be; Hence, there are many studies conducted regarding the concentration of radioactivity in food and meat products. The main methods of transporting radionuclides to the food chain are air and water[3]. For example, a food chain can absorb radionuclides through water in the same way as an absorption of minerals. Therefore, when animals drink this water, some of these radionuclides will remain inside their bodies. Plants and animals that will eventually turn into human food products provide a pathway for radionuclides to travel through the environment to humans. Therefore, the main objective of the current study is to measure the concentration of radionuclide activity in frozen red meat samples available in the Iraqi market[4]. The annual effective

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dose was also estimated and compared to the permissible dose. Many studies have been conducted to calculate the radioactive risk factors for flour as a basic food ingredient and it is eaten for all age groups, and among these studies, calculate the specific activity and radiation risk of radionuclides in wheat flour samples[5]. It has also been studied commonly used medicinal plants have been chosen to find out the radioactivity concentration and their annual effective dose for 10 samples in Iraq[6]. It has also been studied level of natural radioactivity in the banks of the Euphrates River was evaluated of four sites for the passage of the Euphrates (Al Kufa, Abu Sukhair, Al Mishkhab and Al Qadisiyah)[7]. There was a study on the concentrations of radionuclides in salt and sugar in Iraq[8]. Radiation risk indicators were measured for some types of local and imported flour in Iraq[9]. Calculating the risk coefficients of flour for the population of Iraqi Kurdistan. Another study in Karbala, Iraq, to assess the concentration of synthetic and natural radionuclides in wheat, measure the radioactivity in flour in Basra Governorate, Iraq, and assess gamma dose rates, radiation risk indicators, effective dose ingestion, and cancer risk over a specified period of time Excessive age. Since cereal flour is an essential commodity for making various types of food, it is important to create databases for the concentration of long-lived radionuclides in wheat flour and products to ensure that radiation levels are within safety limits. These databases can be useful as basic values for estimating the radiation risk indicators of grain flour among the different brand names in Iraq, given the importance of this nutrient and its frequent consumption, the aim of this study is to establish a baseline for the radiation parameters resulting from eating grain flour.

Collection and Preparation Samples

Fifteen samples of flour wheat were selected from the market. The samples were divided into groups according to sample code and trademark as shown in TABLE 1. After that the flour samples were selected, the natural radioactivity level was measured directly without heating, the homogeneity and then weighed by (600gm) each one. Then the samples were kept into one-liter Marinelli beakers and of constant volume to ensure geometric homogeneity. After the collection process, they were stored in container for one month in order to get a good statistical importance, and to balance between ^{226}Ra and ^{222}Rn according to equation 1.

$$t_m = \frac{\ln(\lambda_2 - \lambda_1)}{\lambda_2 / \lambda_1} \qquad (1)$$

Where t_m is the activity balance time, and λ_1 and λ_2 represent the decay constants of ^{226}Ra and ^{222}Rn radionuclides, respectively. After that, the samples were examined using a detector Sodium iodide thallium-denatured, and the examination time was five hours.

Spectroscopy and Spectrum Analysis

For the purpose of determining the amount and type of radioactive nuclei, the method for measuring the gamma sray was gamma spectrometry system from ORTEC, armed with scintillation detector NaI (Tl), has resolve 8% at ^{137}Cs (661.7 keV) and is rummage-sale to measure the activity concentration in cereal flour samples. The calibration of energy and efficiency was achieved using the normal sources from (IAEA),and the background spectra are continuously measured at the same circumstances of the samples. The ^{238}U activity concentration was assessed directly by gamma line 1765 keV. also, ^{40}K was intended using 1460 KeV gamma lines (^{214}Bi), and of ^{232}Th was originate by using gamma lines 2614keV (^{208}Ti).

Specific Activity Measurement

According to the results of gamma-ray spectra, the specific activity value of ^{226}Ra, ^{232}Th and ^{40}K were calculated in a unit of (Bq.kg^{-1}) was measured using Equation below[10]:

$$A_n = \frac{(G-B)}{t\varepsilon_\gamma I_\gamma m_s} \qquad (2)$$

Where $\mathcal{A}_n$ is the specific activity(S.A) of radionuclide in the samples, G is the count rate in (CPS) for samples, B is the count rate in (CPS) for background, t is represent the time of spectra acquisition, ε_γ is detection efficiency, I_γ is emission probability of γ ray and m_s , mass in (Kg) where the results of (S.A) was Fixed by Research Published [9, 11, 12].

RESULTS AND DISCUSSIONS

Calculations

^{226}Ra, ^{232}Th and ^{40}K% Elemental Concentration

The result for the elemental concentration of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K after calculated[9, 11, 13], for flour samples, it's been converted into total elemental concentrations of ^{232}Th, ^{238}U (in ppm) and ^{40}K% respectively as in TABLE 1[14].

Radium Equivalent Activity (Ra_{eq})

This parameter is used to describe gamma output from different mixtures of 226-Radium, 232-Thorium and 40-Potassium in substances. It was calculated using special equation depending on activity concentrations for ^{226}Ra, ^{232}Th,and ^{40}K respectively[7, 8, 11, 12, 15], as shown in TABLE 1, Its average value was (109.615) Bq.Kg^{-1} which was less than the global permissible value (370 Bq.Kg^{-1}).

The Total of Annual Committed Effective Dose (AACED)

The average total of annual committed effective dose (AACED) due to ingestion of naturally occurring radioactive materials(NORMs) in food was estimated for human consumed of the samples due to the intake of ^{238}U, ^{232}Th and ^{40}K in any food product can be determined using the formula of UNSCEAR2000 and another researches [8, 16].

$$\text{AACED} = A_i * C_R * C_F \qquad (3)$$

A_i is the concentration of radionuclides in the ingested sample (Bq.kg^{-1}), C_R is the annual consumption of cereal flour for adults, it was 90 kilograms per year (Iraqi ministry of trade). As for children under the age of ten, a field study was conducted for more than 300 children in order to estimate the annual consumption rate after taking into account the quantities of bread, cakes and other foods that enter the flour In its manufacture, the value was 70 kilograms per year. As for infant less than two years, the annual consumption rate was estimated after a statistic of more than 300 infants, taking into account biscuits, ready-made cereal meals and others, so the annual consumption rate was about 11 kilograms per year, C_F is the ingestion dose coefficient of the radionuclide, which equal for adults (0.045, 0.23 and 0.0062) and for kids (0.068, 0.29 and 0.013), and for infant (0.12, 0.45, 0.04) with unite (μSv Bq$^{-1)}$ for ^{238}U, ^{232}Th and ^{40}K, respectively as established by ICRP [17].

The risk of Annual Gonadal Equivalent dose is associated with the risk of genetic effects for the entire population, It is estimated at about 20 cases per 10,000 people per Sv, and the overall damage rate to a dose of gonad is estimated at (3 - 4%) (ICRP2007). Whereas, UNSCEAR paid great attention to the gonads and bone marrow due to their sensitivity to radiation, the increase in (AGED) affects the bone marrow and thus leads to the destruction of red blood cells. The annual gonadotropin equivalent dose (AGED) is calculated from the activity concentrations ($\mathcal{A}_{\text{Ra}}.\mathcal{A}_{\text{Th}}\mathcal{A}_{\text{K}}$) for ^{226}Ra, ^{232}Th, and ^{40}K, respectively [17]. DNA damage in human body cells after exposure to radiation is of critical importance for cancer development, therefore, the practical radiation protection system recommended for doses less than 100 (mSv) confirms that any dose increase will result in a directly proportional increase. In the likelihood of cancer or the genetic effects ascribed to radiation. This dose response model is generally known as "linear non-threshold" or LNT. This view is consistent with the view presented by UNSCEAR (2000). Where the estimates were that Presented by various national organizations, some of which align with UNSCEAR's view as (NCRP, 2001, NAS / NRC, 2006) through the French academies report (2005) which supports the practical threshold for risk of radiation cancer [18](ICRP 2007) [17].

Excess أ (ELCR)

Cancer risk due to radiation effects which is called excess lifetime cancer risk (ELCR) can be calculated from equation below [8, 9, 19, 20]:

$$ELCR = \text{AACED} * LS * RF \qquad (4)$$

Where LS is a mean life span which for adult (seventy years),for children (ten years) and infant (less than two year).By offsetting these variables we will get the (ELCR) of ^{226}Ra, ^{232}Th and ^{40}K in the cereal flour samples. The value of risk factor (RF) for stochastic effects in the population (adult, children and infant) is 0.055 per Sievert as recommended by ICRP[17].

TABLE 1. The concentration (ppm) of ^{226}Ra, ^{232}Th, ^{40}K % and Ra$_{qe}$ (Bq.kg^{-1}) in the samples under study.

ID	Name of the sample	Origin	^{226}Ra	^{232}Th	^{40}K %	Ra$_{eq}$
FL$_1$	Zero flour	Turkey	0.744	3.060	1.104	53.576
FL$_2$	Aqeelah	Iran	0.871	3.340	1.163	58.188
FL$_3$	Ard shiraz star	Iran	1.097	3.044	1.064	56.877
FL$_4$	Alzamord	Iran	0.961	3.192	1.068	56.149
FL$_5$	Alhasan	Iraq	0.470	2.865	0.967	45.768
FL$_6$	Flour company	Iran	0.762	2.608	0.960	47.702
FL$_7$	Al haidariya	Iraq	0.934	3.090	1.092	55.815
FL$_8$	Baraka zain company	Iraq	0.762	2.831	0.906	47.701
FL$_9$	Al rahab company	Iraq	0.445	2.451	8.565	226.157
FL$_{10}$	soft	Turkey	0.441	16.678	6.946	269.795
FL$_{11}$	kush	Iran	1.113	6.625	3.035	125.384
FL$_{12}$	Barley Flour	turkey	0.384	8.200	3.424	134.927
FL$_{13}$	Ameen	Turkey	1.113	9.428	4.013	165.258
FL$_{14}$	Zer	Turkey	0.326	4.239	1.670	68.924
FL$_{15}$	Warameen	Iran	0.211	9.080	3.331	135.667
Max.			1.113	16.678	8.565	269.795
Min.			0.211	2.451	0.906	45.768
Average			0.703	5.874	2.869	109.615
Worldwide	[21]					370

TABLE 2. The ratio of specific activity among ^{226}Ra, ^{232}Th and ^{40}K in the cereal flour samples

ID	The ratio of specific activity of 226Ra, 232Th and 40K		
	232Th - 226Ra	40K - 226Ra	40K - 232Th
FL1	1.354	37.598	27.772
FL2	1.263	33.847	26.800
FL3	0.913	24.581	26.911
FL4	1.094	28.165	25.753
FL5	2.008	52.177	25.990
FL6	1.128	31.964	28.342
FL7	1.089	29.639	27.212
FL8	1.224	30.177	24.656
FL9	1.813	487.941	269.087
FL10	12.447	399.150	32.067
FL11	1.961	69.156	35.271
FL12	7.038	226.287	32.152
FL13	2.790	91.453	32.776
FL14	4.280	129.869	30.341
FL15	14.170	400.239	28.246
Max.	14.170	487.941	269.087
Min.	0.913	24.581	24.656
Average	4.097	152.045	56.889
Worldwide[22]	0.86	11.43	13.33

TABLE 3. The total average annual committed effective dose(AACED) and Excess lifetime cancer risk for whole population flour samples

ID	AGED*10^{-3} (mSv.y^{-1})	Whole population					
		adult		children		infant	
		AACED (mSv.y^{-1})	ELCR	AACED (mSv.y^{-1})	ELCR	AACED (mSv.y^{-1})	ELCR
FL_1	188.859	0.705	0.002	1.081	5.407E-05	0.3182	3.5002E-05
FL_2	204.240	0.730	0.003	1.209	6.044E-05	0.3489	3.83748E-05
FL_3	198.124	0.796	0.003	1.313	6.564E-05	0.3581	3.93926E-05
FL_4	195.823	0.727	0.003	1.232	6.159E-05	0.3439	3.78284E-05
FL_5	161.671	0.535	0.002	0.837	4.184E-05	0.2588	2.84661E-05
FL_6	167.727	0.665	0.002	1.015	5.076E-05	0.2906	3.19653E-05
FL_7	195.473	0.720	0.003	1.212	6.059E-05	0.3419	3.76071E-05
FL_8	166.231	0.601	0.002	1.018	5.091E-05	0.2873	3.16039E-05
FL_9	900.371	3.038	0.011	2.949	1.475E-04	1.3458	0.000148041
FL_{10}	982.863	1.908	0.007	3.660	1.830E-04	1.3975	0.000153726
FL_{11}	453.263	1.566	0.005	2.180	1.090E-04	0.7172	7.88895E-05
FL_{12}	490.495	1.511	0.005	1.917	9.586E-05	0.7102	7.81174E-05
FL_{13}	597.051	1.404	0.005	2.690	1.345E-04	0.9151	0.000100657
FL_{14}	248.633	1.157	0.004	1.051	5.255E-05	0.3694	4.06287E-05
FL_{15}	489.711	0.647	0.002	1.844	9.220E-05	0.6919	7.61084E-05
Max.	982.863	3.038	0.011	3.660	1.830E-04	1.3975	0.000153726
Min.	161.671	0.535	0.002	0.837	4.184E-05	0.2588	2.84661E-05
Average	399.122	1.193	0.004	1.747	8.737E-05	0.6089	6.69765E-05
Worldwide [22, 23]	300μSv.y^{-1}	290 μSv.y^{1}	2.5*10^{-3}	290 μSv.y^{-1}	2.5*10^{-3}	290 μSv.y^{-1}	2.5*10^{-3}

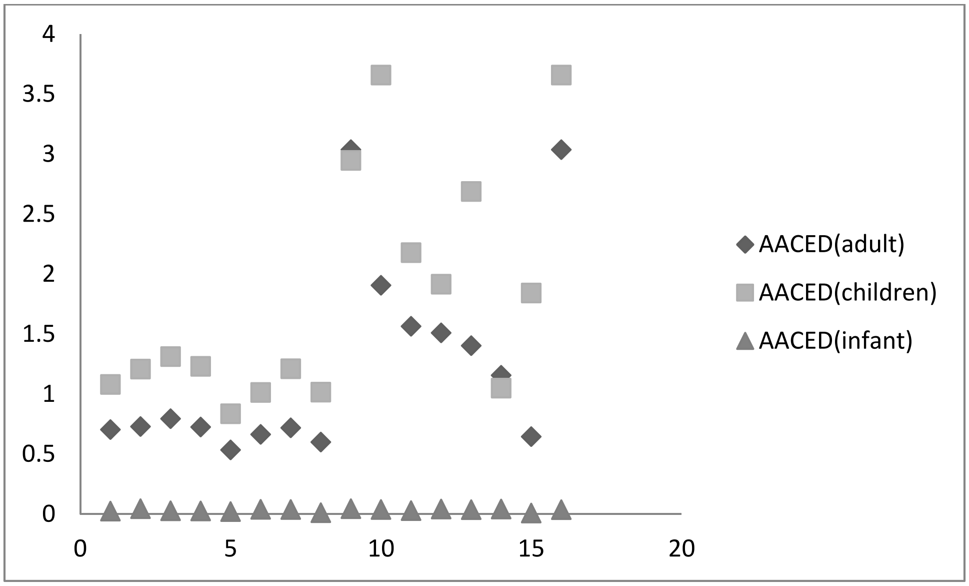

FIGURE 1. Comparison between AACED (mSv.y^{-1}) for (adult, children and infant)

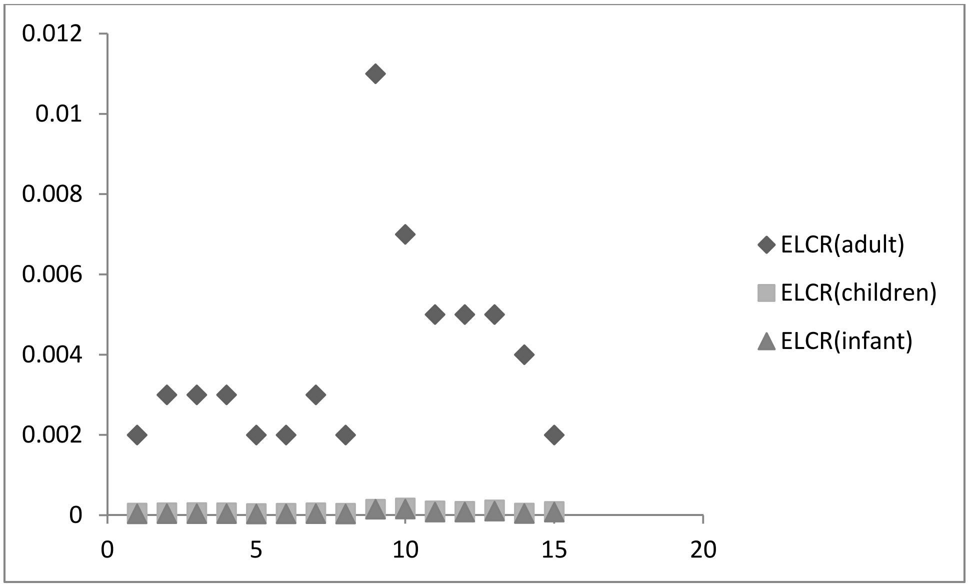

FIGURE 2. Comparison between ELCR for (adult, children and infant)

In this study, a calculation was made the mean of elemental concentrations of ^{226}Ra, ^{232}Th , Radium equivalent activity (Raeq) and percentage of ^{40}k% in studies samples of flour, then we find the proportions between these concentrations for the purpose to provide a simple explanation of the relationship between the concentrations of the three natural radionuclides in the studied cereal flour samples as shown in TABLE (1).Ratios were used to provide a simple explanation of the relationship between the concentrations of the three natural radionuclides, The ratios (^{232}Th - ^{226}Ra) in TABLE (2) show that there is a convergence between the values of thorium and radium at a rate of 4.097 which was higher than the internationally recommended limits, Also, the ratio between the concentrations of (^{40}K - ^{226}Ra) was higher than the permissible limits globally and equals 152.045, also the ratio (^{40}K - ^{232}Th) confirms the big difference between the concentrations of potassium and thorium, which is equal to 56.889, which is much higher than the global average UNSCEAR (2000).From TABLE (3) the average annual gonadal dose (AGED) was calculated which was not within the internationally recommended limits(300µSv.y^{-1}), also show the highest value was in sample FL$_{10}$ (soft) of Turkish origin and the low value was in sample FL$_5$ (Rumman) of (Alhasan) Iraq with average (399.122*10^{-3} mSv.y^{-1}), and it is within not safe limits and does may be pose health threat.The total of average annual committed effective dose(AACED) calculated using Eq. (3). Based on the annual consumption rate, the annual ingestion dose was calculated which was compared with Brazilian National Commission of Nuclear Energy (CNEN) [23]. The results are shown in TABLE (3) and FIGURE (1) where total average ingestion dose calculated for ^{226}Ra, ^{232}Th and ^{40}K in adult, children and infant were found to be (1.193, 1.747 and 0.6089 (mSv.y^{-1}), respectively, which higher than worldwide (250 – 400)*10^{-3} (mSv.y^{-1}) for adult, children and infant that recommended by WHO[24], this is may be because the potassium concentration in samples FLl$_9$ and FL$_{10}$ was high, affecting the hazard values. From TABLE (3) and FIGURE (2) The values average total (ELCR) which was (0.004, 8.737E-05 and 6.69765E-05) for adult, children and infant respectively, We Noted that the difference between the ELCR value for adults, children and infant due to the risk factor where was higher for adult age while was less for (children and infant) compared with the world's average (2.5 × 10^{-3}) based on annual dose limit of 1(mSv) for which negligible risk of developing cancer has been stated [25].

CONCLUSION

Natural radioactivity value of elemental concentrations (ppm) (^{226}Ra, ^{232}Th), Radium equivalent activity (Raeq) which was less than the Permissible limits, and ^{40}K% in cereal flour were measured by gamma-ray spectrometry method. Results of the current study indicated that the ratio of ^{40}K - ^{226}Ra and ^{40}K - ^{232}Th were higher than the Global studies while the ratio of ^{232}Th - ^{226}Ra was less than the worldwide. The total average ingestion dose of these radionuclides is less than (0.3 msv.y^{-1}) for Infant category studied, While for adults and children, it was much higher than the permissible percentage. The comparison shows that the total ingestion dose in the present study is higher than the total ingestion dose reported by UNSCEAR (2000). The ELCR for cereal flour consumption was low than the world average (ICRP 2007) in infant and children but higher than $2.5*10^{-3}$ in adults. It appears that the absorption of fertilizers by cereal and materials that may be deposited in the soil or through water. The unknown pollutants are transported leading to an increase in the concentrations of radionuclides. Therefore, increased uptake of radionuclides by cereal. Consequently, it is necessary to investigate these changes in the future studies.

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