Radioactivity assessment of selected samples of foodstuffs in the local market

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ABSTRACT

The research aims to evaluate the radioactivity of samples of foodstuffs Consumables in the local markets thirteen items were selected which are rice, tea, drinking water, lentils, chickpeas, flour, red bean, crushed chickpeas and milk powder where the concentrations of the specific activity of the chains of uranium (^{238}U), thorium (^{232}Th) and potassium (^{40}K) were measured using a gamma ray spectra analysis system with a high purity germanium (HPGe) detector using a program (Genie 2000) developed, where the results showed that potassium concentrations are clear, and the measurements showed low values for the concentrations of uranium and other natural isotopes, and no values were indicated for the presence of the industrial isotope cesium (^{137}CS), where it was found that the specific activity, which is measured by the unit (Bq/kg) of potassium ((^{40}K) in The studied samples ranged from (BDL -397.977 $\pm$ 25.894) with a rate of (143.559 $\pm$ 10.616), and for uranium ^{238}U (BLD -7.114 $\pm$ 0.877) with a rate of (1.904 $\pm$ 0.214) and thorium (^{232}Th) B.L.D (Below the detection level) the radium equivalent Raeq, which is measured by the unit (Bq/kg) whose value ranges from (BDL -37.758) and the rate of (12.959), and the internal hazard index Hin, which is measured by the unit (Bq/kg) (BDL -0.121) was calculated and with rate (0.040), and the annual effective dose of potassium (40K) measured in µSv/y whose values range (BDL - 1357.102) and an average (489,539) as a result of eating these foodstuffs that were within the permissible level per person in the general public during a year and according to the recommendations of the committee UNSCEAR, where the permissible exposure per person is (1mSv/y).

Introduction

Since the middle of the twentieth century, pollution has been one of the most important global environmental problems, which has attracted great attention from governments around the world. These industries have recently taken a dangerous trend represented in the emergence of diversity of, and some complex, industries, and these industries are often accompanied by serious pollution that leads to the deterioration of the biosphere and the irregularity of the environment.

Pollution is defined as the presence of a species in a concentration higher than the permissible concentration in the local and international environmental standards, which causes damage.

In human life, whether war or peace, the increase in the use of radioactive sources and isotopes for different purposes has increased the chance of radioactive contamination. After the Chernobyl accident in 1986, the boom of nuclear facilities and the tendency to use nuclear energy as a source of energy generation, special studies were conducted on the possibility of environmental pollution caused by radioactive materials [1].

The food chain is considered one of the most critical and important paths in the speed of transmission of radioactive pollutants, as different groups of organisms in the food chain are contaminated with radioactive materials such as plants, animals and their products, and the proportion of radioactive materials

in the water and the food chain increases as a result of human uses of these materials for peaceful and non-military purposes [2].

During the second Gulf wars in 1991 and the occupation of Iraq in 2003, the environment in Iraq was exposed to a new generation of radioactive weapons called depleted uranium shells. Accordingly, the need to measure radioactivity in the components of the environment has increased to determine the extent of the damage caused by the use of materials with dangerous radioactivity.

Nuclear explosions and nuclear accidents produce a large amount of atomic dust carrying strontium (^{90}Sr), cesium (^{137}Cs), and plutonium (^{239}Pu), which are radioactive isotopes whose radioactivity persists for a long time (in addition to the short-lived iodine-131I). Soil causes pollution of water, air and food, enters the food cycle and is transmitted to insects, birds and animals, and eventually to humans. The food chain is considered one of the most important and critical paths in the rapid transmission of radioactive pollutants from the components of the environment to humans [3].

Natural radioactive isotopes have been present in rocks, soil and water since the formation of the earth. Because some of these isotopes have very long decay half-lives, large amounts of these nuclides are still present on the earth today[4].

The radionuclides in the soil are taken up by plants and thus become available for further distribution within the food chains. These plants may become included directly in human food or indirectly as animal feed [5]. Levels of radionuclides in foods vary and depend on several factors. These factors include the type of food and the geographical area where these materials were produced. The common radionuclides in foodstuffs are potassium (^{40}K), radium (^{226}Ra) and thorium (^{232}Th).

Potassium (^{40}K) is one of the most common natural radioactive isotopes in foodstuffs and is found mainly in milk, but also in meat, bananas and other potassium-rich products. In other natural radioactive isotopes, they are found in lower concentrations and stem from the decay of uranium and thorium chains.

Also, potassium (^{40}K) is an important radionuclide from the point of view of health physics, given that Because it is the largest contributor to the dose received by humans, it is widely distributed in the environment and living organisms [6].

Among the local scientific studies and research conducted at the Atomic Energy Organization is University of Baghdad and the Center for Radiation Protection for the years 2000, 2001 and 2005, which dealt with many local and imported foodstuffs and ration card items, and indicated the emergence of the potassium isotope (^{40}K) in all food models with concentrations ranging from Becquerel/kg to approximately 1000 Becquerel / kg. Yet, the consumption of local and imported foods during these years did not cause radiation doses exceeding the

internationally recommended limits known (2000), [7,8]. A study of the effective dose equivalent to potassium (^{40}K) in the milk of cows in Salah El-Din Governorate examines radioactivity in different types of milk using the NaI (Ti) reagent. Another study also examines natural radiation levels in some milk samples in the local markets in Babylon Governorate and a study of radioactivity materials Local and imported foodstuffs, in addition to the ration card items. All these studies proved that the natural radioactivity, risk factors and annual effective doses for milk and food intake were low and within the permissible limits, except for some potassium values [9,10,11].

The current study aims to measure the radioactivity in local and imported foodstuffs using the spectroscopic technique of a highly purified germanium detector.

Calculation of Specific Activity

According to [12]. the specific effectiveness concentration can be calculated as shown in Table (1) and through the following equation.

$$A = \frac{N_{net}}{\varepsilon.I_\gamma.m.t} \pm \frac{\sqrt{N_{net}}}{\varepsilon.I_\gamma.m.t}(Bq/kg)........(1)$$

Nnet represents the area under the curve after subtracting the background radiation and is measured in (c.s^{-1}).

ε :is the efficiency of the detector.

I_γ is the concentration factor of effectiveness.

M :is the block of the model.

t : Measurement time.

Radium Equivalent (Ra$_{eq}$)

The value of the radium equivalent concentration (Raeq) is used to estimate the concentration risk caused by the effectiveness of ^{40}K, ^{232}Th and ^{238}U. It is measured in units of Bq./kg and calculated from the following equation [13].

Ra$_{eq}$ (Bq/ kg) = A$_U$ + 1.43A$_{Th}$ + 0.077A$_K$ .... (2)

(A$_K$, A$_{Th}$, A$_U$) represent the Specific activity for uranium, thorium, and potassium, respectively.

Internal Hazard Index (H$_{in}$)

The inhalation of alpha particles emitted by short-lived isotopes such as radon and thoron, which are accompanied by gamma rays of different energies can be expressed in terms of the internal hazard coefficient and calculated by the following equation [14].

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

The Annual Effective Dos

The annual radiation dose resulting from the intake of potassium isotope (^{40}K) present in foods is calculated using the formula developed by the United Nations Scientific Committee.

$$D = C*CF*M.........(4)$$

Here D represents the effective annual dose and is measured in (Sv/y). C is the rate of radionuclide concentration in the food materials and is measured in (Bq/kg) and CF stands the conversion factor of radionuclides and is measured in (Sv/Bq) where it is determined The value of the conversion factor (CF)

according to each of the radioactive isotopes and the age of the individual, M: represents the mass of a particular type of food and the intake per year and is measured in units (kg/y) [15].

The practical part

Collection and preparation of forms:

Thirteen samples of different types of food were collected from the local markets in Baghdad city to calculate the levels of radioactivity. Tables of food samples were made according to the name of the sample and the country of origin, and a special code was set for each sample as shown in Table (1). To measure the radioactivity of the samples, the sample must be free of moisture because the measurement of the specific effectiveness depends on the weight of the sample, and to get rid of this moisture, the samples must be dried by placing them in the oven. In this research, gamma ray spectroscopy using a high purity germanium detector (HPGe) and the advanced (Genie 2000) program was used. It is based on a basic rule represented in the interaction of radiation with the detector material. This system consists of a crystal of high purity germanium (HPGe) detector, which is a semiconductor and its size is (3×3) inches. This crystal needs liquid nitrogen to cool it at a

temperature of (-196 ℃) and it has a separation energy of (2kev) at (1332.5kev)) for cobalt isotope (^{60}Co), detector efficiency (40%) and voltage (2500Volt), the sample to be measured is placed in a Marinelli Beaker container whose dimensions are proportional to the dimensions of the detector crystal in the measuring system, the detector is placed inside a protective barrier that consists of three layers: lead, aluminum and copper, respectively, this technique was used in the past, but it developed a lot, especially when the electronic calculator was discovered, and work with it developed in detecting radionuclides and measuring the level of radioactivity in various environmental samples, especially the isotopes of uranium and thorium sequences that are present in most of them, as well as the presence of potassium-40 (natural) and cesium-137 (Result of nuclear tests). Dickson et al 1976 measured the natural radioactivity in the Irish surface soil, and they used the germanium detector Li (Ge) and at different depths under the surface of the earth, extending from (10cm) to (1m). It was possible to determine the average radioactivity of uranium -238, thorium-232, potassium-40, in addition to cesium-137 [16].

Table 1: Specific activity of U-238, Th-232 and K-40 for food samples

No.	Code Sample	Model name	Origin	^{238}U Bq/kg	^{232}Th Bq/kg	^{40}K Bq/kg
1	S1	filtered drinking water	Iraqi	B.D.L	B.D.L	B.D.L
2	S2	Mahmoud's rice	Turki	B.D.L	B.D.L	42.715±6.27
3	S3	red kidney bean	Turki	B.D.L	B.D.L	16.296±5.44
4	S4	Ambr rice	Iraqi	2.258±0.303	B.D.L	21.805±6.22
5	S5	Lentils	Turki	B.D.L	B.D.L	276.667±14.207
6	S6	Zir flour	Turki	3.241±0.312	B.D.L	12.646±5.618
7	S7	Local flour ration	Iraqi	2.75±0.375	B.D.L	32.962±7.277
8	S8	Chickpeas	Indian	4.666±0.485	B.D.L	24.552±7.388
9	S9	Perfume tea	Sri Lanka	4.731±0.427	B.D.L	274.301±13.489
10	S10	jihan tea	Sri Lanka	7.114±0.887	B.D.L	397.977±25.894
11	S11	crushed chickpeas	Turki	B.D.L	B.D.L	77.205±7.696
12	S12	Almudhish Milk Powder	Oman	B.D.L	B.D.L	380.54±20.998
13	S13	Dielac Dry Milk	New Zealand	B.D.L	B.D.L	308.61±17.512
	Min. value			B.D.L	B.D.L	B.D.L
	Max. value			7.114±0.887	B.D.L	397.977±25.894
	Av.			1.904±0.214	B.D.L	143.559±10.616
	permissible limits			32	45	412

Results and Discussion

Evaluation of levels of specific efficacy of foodstuffs:

Table (1) shows the results obtained for the levels of qualitative effectiveness of the different isotopes in food samples, which amounted to (13) samples selected from the local markets of the city of Baghdad. Levels of specific activity of thorium (^{232}Th) in all food samples (B.D.L.), which is less than the permissible limit of (1 Bq/kg) (a report issued by the Iraqi Ministry of Environment, 2012). The specific effectiveness of uranium (^{238}U) in the samples was in the range (7.114 ± 0.887 - BDL) Bq.kg-1, and an average of (1.904 ±0.214) Bq.kg-1. The current results show that the specific

effectiveness of uranium in the models is within the global average The specific activity of uranium - is (32)Bq.kg-1, shown in Figure (1) [17,18].

The concentrations of the specific activity of potassium (^{40}K) in foodstuffs ranged between (397.977 ± 25.894-BDL)Bq.kg-1 in the two models (S10, S1), respectively, with an average of (143.559±10.616) Bq.kg-1, which is within the permissible limit. It is a scholar [19]. as shown in Figure (2).
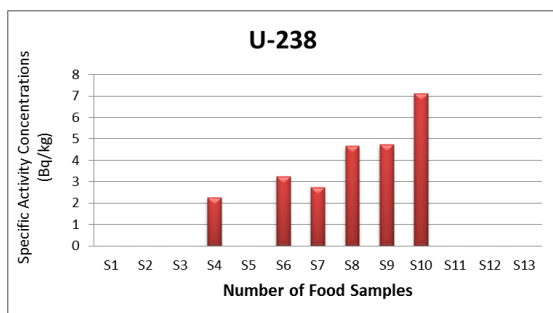
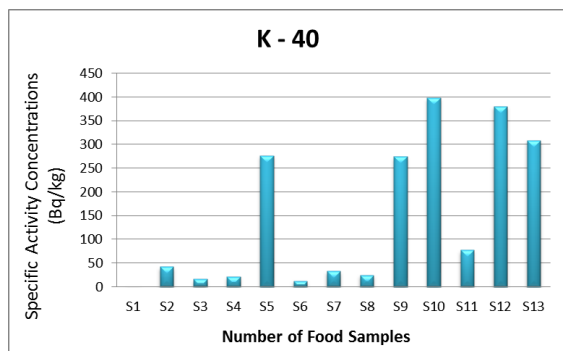**Fig. 1: Levels of specific activity of uranium-238 food samples**

Fig. 2: Specific activity levels of potassium-40 in food samples

Evaluation of radium equivalent, radiological hazard effect and annual effective dose of food samples Through table (2), we note that the radium equivalent, which was calculated through equation (2), ranged from (37.758 - 0) Bq. L^{-1} in the two models (S10 - S1), respectively, at a rate of (12.959) Bq.kg^{-1}. It is less than the permissible global limit of (412) Bq.kg^{-1} [4]. and the internal risk factor that was calculated through equation (3) ranged between (0.121 - 0) Bq.kg^{-1} in the two models (S10– S1) with a rate of (0.040) Bq.kg^{-1}, which is less than the internationally permissible limit of (1) Bq.kg^{-1}. The annual effective dose was calculated from equation (4) whose value ranged between (1357.102 - 0)μSv.y^{-1} in the two models (S10- S1), respectively, with a rate of (489,539) μSv.y^{-1},which is lower than the global permissible rate of (1000)μSv.y^{1} [20,4].

Table 2: Hazard coefficient values for each of the radium equivalent index (Raeq), the internal hazard (Hin), and the annual effective dose in selected food sample.

Effective Annual Dosage ^{40}K (μSv/y)	Inner risk factor H_i (Bq/kg)	EQ radium Ra_{eq} (Bq / kg)	Code sample
B.LD	B.LD	B.LD	S1
145.658	0.009	3.289	S2
55.569	0.003	1.255	S3
74.355	0.017	3.937	S4
943.434	0.058	21.303	S5
43.123	0.020	4.215	S6
112.400	0.022	5.288	S7
83.722	0.030	6.557	S8
935.366	0.083	25.852	S9
1357.102	0.121	37.758	S10
263.269	0.016	5.945	S11
1297.641	0.079	29.302	S12
1052.360	0.064	23.763	S13
0.000	0.000	0.000	Min.value
1357.102	0.121	37.758	Max. value
489.539	0.040	12.959	Av.
1000(μSv/y)	1(Bq/kg)	370(Bq/kg)	permissible value

Conclusion

The natural radioactivity was measured in this study in food samples, which were the specific activity of thorium-232, the specific activity levels of potassium (^{40}K), and the specific activity of uranium-238. All results showed that all values are within the international permissible limit.Also, the rates of radiological hazard effects represented by the radium equivalent effectiveness, the internal hazard index, and the annual effective dose in food samples are less than the internationally permissible limit (Radiation *Protection Center, Radiation Control* Department., 2012).

Table 3: Concentrations of U, Th and K for some foodstuffs of regional countries. [21] [22]

Number	Sample name	U Bq/kg Th	Th Bq/kg	K Bq/kg
1	Flour	2.34	-------	28.43
2	Rice	2.88	3.32	33.83
3	beans	13.95	2.82	372.40
4	Lentils	*	1.88	302.43
5	dried chick peas	*	2.78	271.21
6	Powdered milk	4.10	2.36	352.63
7	Tea	2.88	2.61	559.99
8	Sugar	0.85	*	*
9	Dried crushed beans	13.95	2.82	372.40
10	Green Peas	34.89	36.59	455.54

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تقييم النشاط الاشعاعي لنماذج مختارة من مواد غذائية في السوق المحلية

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الملخص

يهدف البحث الى تقييم النشاط الاشعاعي لعينات من المواد الغذائية المستهلكة الموجودة في الاسواق المحلية تم اختيار ثلاثة عشر صنف وهي الارز والشاي ومياه الشرب والعدس والحمص والطحين والفاصوليا الحمراء والحمص المطحون ومسحوق الحليب حيث تركيزات محددة. نشاط حيث تم قياس تراكيز الفعالية النوعية لسلاسل اليورانيوم (^{238}U) الثوريوم (^{232}Th) والبوتاسيوم (^{40}K) باستخدام منظومة تحليل اطياف اشعة كاما مع كاشف الجرمانيوم عالي النقاوة (HPGe) باستخدام برنامج (Genie 2000) المتطور حيث اظهرت النتائج ان تراكيز البوتاسيوم واضحة واظهرت القياسات قيم واطئة لتراكيز اليورانيوم والنظائر الاخرى الطبيعية ولم يوشر اي قيم لوجود نظير السيزيوم الصناعي (^{137}CS) حيث وجد أنَّ الفعالية النوعية التي تقاس بوحدة (Bq/kg) للبوتاسيوم (^{40}K) في النماذج المدروسة تتراوح بين (B.D.L–397.977±25.894) وبمعدل (143.559±10.616) , ولليورانيوم ^{238}U (7.114±0.877 -B.L.D) وبمعدل (1.904±0.214) ولم تتحسس المنظومة تراكيز الثوريوم ^{232}Th (B.L.D) وهذه النتائج هي ضمن النتائج المسموح بها عالميا وكذلك تم حساب مكافئ الراديوم Ra_{eq} الذي يقاس بوحدة (Bq/kg) التي تتراوح قيمتها (B.D.L – 37.758) وبمعدل (12.959) ودليل الخطورة الداخلي H_{in} الذي يقاس بوحدة (Bq/kg) التي تتراوح قيمتها (0.121– B.D.L) وبمعدل (0.040) ، والجرعة الفعالة السنوية للبوتاسيوم (^{40}K) التي تقاس بوحدة µSv/y التي تتراوح قيمها (B.D.L – 1357.102) وبمعدل (489.539) نتيجة تناول هذه المواد الغذائية التي كانت ضمن مستوى المسموح به الفرد من عامة الناس خلال سنة وحسب توصيات اللجنة العلمية في الأمم المتحدة (UNSCEAR) حيث ان تعرض المسموح به للفرد هو (1mSv/y).