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Concentrations and Radiation Hazard Indices of Naturally Radioactive Materials for Flour Samples in Baghdad Markets

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Abstract:

In the present work, Uranium (²³⁸U), Thorium (²³²Th) and Potassium (⁴⁰K) specific activity concentration in (Bq/kg) was measured in five different types for wheat flours that are available in the Iraqi markets. The gamma spectrometry method with an NaI (TI) detector has been used for radiometric measurements. Calculations of radium equivalent activity, annual effective dose equivalent, external hazard index (H_{ex}), internal hazard index (H_{in}), representing gamma index and gamma dose rate in all flour samples were 17.98132 Bq/kg, 0.0100334, 0.04502, 0.04857, 0.06872, 0.125883 and 8.181244 respectively. It is found that the average of specific activity concentration of wheat flour samples for ²³⁸U, ²³²Th and ⁴⁰K are 7.4564 Bq / kg, 6.27962 Bq / kg and 20.0658 Bq / kg respectively. This study proves that the natural radioactivity and radiation hazard indices were lower than the safe.

Key words: Environmental, Pollution, Radioactivity, Wheat flour.

Introduction:

Because of geographical and geological conditions, the natural radionuclide concentrations in environmental samples can be significantly various. Natural radioactivity can be classified into two types, cosmogenic and primordial, named naturally occurring radioactive materials, commonly mentioned as (NORM). Some instances of natural radioisotopes are potassium isotopes ⁴⁰K, uranium (²³⁸U and glycolysis chain), and thorium (²³²Th and glycolysis series). These radionuclides are generally available in air, soil, and water in diverse magnitudes, in addition to their long- lasting period (for about 1010 years) (1- 3). In order to provide enough food to the increasing populations, several states have utilized phosphate fertilizers; these activities have triggered a substantial alteration in potassium in the soil, which makes significant changes to these agricultural activities. By means of the soil and phosphate utilizers, natural radioactive elements transfer through the food chain to humans. In order to avoid consumer vulnerability to radiation, it was substantial to measure the radioactivity of some food samples in order to identify the anticipated radiation doses. As well-known, potassium is

deemed to be one of the bulk substantial fundamental elements admitted into the cellular tissues, so ⁴⁰ K is one of the bulk substantial physical radionuclides (4). About 87% of the radiation dose sucks by humanity is from natural radiation according to UNSCEAR 2000 (5). Wheat flour is considered as one of the substantial foods in Iraqis daily lives. It is appropriate to compose a national baseline of radioactivity exposure from various type wheat flour samples available in Iraq markets. Wheat flour is produced from grinding wheat used for human consumption. Wheat flour has been a fundamental staple to human presence across the centuries and is currently the more broadly expendable staple food. Additionally, several studies have been performed worldwide to inquire the natural radionuclides in food consumer in various areas of the world (6-9). By spectroscopic analysis, the concentration of natural radionuclides (⁴⁰K, ²³²Th, ²²⁶Ra) is computed in diverse foods for human depreciation in the Abyan Delta in Yemen and it was found that the modified concentrations of radionuclides of ²²⁶Ra, ²³²Th, and ⁴⁰K in the selected specimens were 1.11 ± 0.08 , 1.00 ± 0.05 and 108.86 ± 3.49 , respectively. It was

remarked that the modified concentration of ^{40}K activity in foods was substantially of a superior activity to the modified concentrations of ^{226}Ra and ^{232}Th in all the samples (10-12).

The aim of the current work is measuring natural radioactivity concentrations for flour samples; Besler, Zer, Paten, Flour provided by government and barley in the local markets of Baghdad city in 2019, three samples of each type for flour were taken. Also, it calculated radium equivalent activities, annual effective dose equivalent, external and internal menace indices, representing extent index, and the gamma dose rate using a gamma spectrometry, NaI (TI) detector. Then, it estimated the radioactivity and its effect on human health. This study is necessary in the standpoint radiation protection and discusses natural radioactive elements in food coverage by the humans.

Material and Methods:

Specific activity concentration

The specific activity concentration is the relationship between the mass of the material and its radiation efficiency in Bq/Kg, which is the number of anomalies that occur per second in radionuclide, it is given by Eq. 1(13, 14):

$$S.A=C= A / M \quad 1$$

Terms A is the activity which is identified directly from the screen of the system in Bq, M is the mass of sample in Kg.

Samples like Besler, Zer, Paten, Flour are provided by government and barley in the local markets of Baghdad city in 2019 .Gamma spectroscopy with Sodium iodide (NaI (TI)) (3" X 3") detector was adjusted for a period of 3600 seconds, and completely insulated by lead shield (13) used to determine NORM concentrations, in flour powdered samples. The weight of each samples are is Kg. Because the NaI (TI) detector is characterized by poor efficiency in energy resolution, radionuclides daughter was selected to determine radioactivity concentration for two series of ^{238}U and ^{232}Th where nuclide ^{226}Ra was chosen to indicate the radioactivity for a series of ^{238}U , which have been determined through radioactive isotope ^{214}Pb (352keV). Moreover, a series of ^{232}Th through a radioactive isotope ^{212}Pb (239keV) was determined. As regards ^{40}K (1460.8 keV), it can be detected directly by the detector (4, 13, 14).

Radium Equivalent Activity (Ra_{eq})

Radium equivalent activity Ra_{eq} which is the equivalent concentration value of the radium element is used to study the risk concentration caused by ^{226}Ra , ^{232}Th and ^{40}K (Bq/Kg). In

addition, the radiation hazards associated with them were taken into account and can be calculated from the following relationship as show in Eq.2 (15).

$$Ra_{eq} = C_{(Ra)} + 1.43 C_{(Th)} + 0.077 C_{(K)} \quad 2$$

Where $C_{(Ra)}$, $C_{(Th)}$ and $C_{(K)}$ represented radioactivity concentration in (Bq/Kg) for ^{238}U , ^{232}Th and ^{40}K , respectively.

Annual Effective Dose Equivalent (AEDE)

Dose equivalent receipt by the external member was computed from the absorbed dose rate through implementing the dose conversion of 0.7 (Sv/Gy) and the internal and external occupancy factor will be 0.2(5/24) and 0.8(19/24), respectively (13, 15). AEDE is determining by the Eqs.3 and 4.

AEDE (external)

$$(mSv/y) = \text{Absorbed dose (nGy/h)} \times 8760(h/y) \times 0.7(Sv/Gy) \times 0.2 \times 10^{-6} \quad 3$$

AEDE (internal)

$$(mSv/y) = \text{Absorbed dose (nGy/h)} \times 8760(h/y) \times 0.7(Sv/Gy) \times 0.8 \times 10^{-6} \quad 4$$

External Hazard Index (H_{ex})

This hazard can be quantified by the external hazard index (H_{ex}) (13, 15, 16). which is determined by Eq. 5:

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad 5$$

The value of this index should be lower than one unit for the radiation hazard to be minimal. H_{ex} equals to unity that is symmetrical for the high limit of Ra_{eq} , 370 (Bq/Kg) (13).

Internal Hazard Index (H_{in})

This hazard can be quantified by the internal hazard index (H_{in}) (13, 15, 16). This is given by Eq. 6:

$$H_{in} = \frac{C_{(Ra)}}{185} + \frac{C_{(Th)}}{259} + \frac{C_{(K0)}}{4810} \quad 6$$

The value of this index should be lower than one unit for the radiation hazard to be minimal.

Representative Gamma Index ($I_{\gamma r}$)

The representative gamma index is given by Eq.7 (17):

$$I_{(\gamma r)} = \frac{C_{(Ra)}}{150} + \frac{C_{(Th)}}{100} + \frac{C_{(K)}}{1500} \quad 7$$

Value of $I_{\gamma r} \leq 1$ complies to an annual effective dose, of lower than or equal to 1.0 (mSv), while the $I_{\gamma r} \leq 0.5$ complies to annual effective dose lower or equal to 0.3 (mSv) (17, 5)

Gamma Dose Rate

The gamma dose rate in the external air at 1.0m above the ground level can be calculated using Eq. 8 (17).

$$D \text{ (nGy/h)} = 0.462C_{(Ra)} + 0.621C_{(Th)} + 0.0417C_{(K)} \quad (8)$$

Results and Discussion:

^{238}U , ^{232}Th and ^{40}K are naturally occurring elements. Their nuclei of radioactive elements are unstable, meaning they are transformed into other elements, typically by emitting particles. Uranium decays mainly by alpha-particle emission to become nonradioactive lead and it has very long half-lives. In the case of ^{40}K , it undergoes beta decay to stable species (^{40}Ca) and for ^{232}Th they undergo alpha-decay to stable species (^{208}Pb) (13). The specific activity concentration due to ^{238}U , ^{232}Th and ^{40}K in various types of wheat flour samples has been measured as shown in Table 1 and Fig.1. The specific activity concentration of ^{40}K was found in the range of 22.587 Bq/Kg in barley flour to the 16.468 Bq/Kg in flour provided by government with an average value 20.0658 Bq/Kg, ^{232}Th from 9.769 Bq / Kg in Barley flour to 4.3101 Bq/Kg in zer flour with an average 6.27962 Bq / Kg and ^{238}U from 9.329 Bq/Kg in flour provided by government to 6.109 Bq/Kg in zer flour. The results obtained shows that, the concentration of specific activity for ^{238}U , ^{232}Th and ^{40}K in all samples for flour was lower than the recommended limit of UNSCEAR 2000 which is 30, 45 and 420 Bq.kg⁻¹, respectively (5). The value of radium equivalent activities, annual effective dose equivalent, external and internal menace indices, representing extent index, and the gamma dose rate for all flour samples are listed in Table 2. The maximum value of radium equivalent activities, annual effective dose equivalent, external and internal menace indexes representing level index, and the gamma dose rate was found in barley flour sample and the minimum value of these indexes was found in zer flour

sample. The results were lower than the recommended limit of UNSCEAR 2013 (18) which is 0.17 mSv y⁻¹ for ^{40}K and 0.12 mSv y⁻¹ for Uranium and Thorium. High intake of ^{232}Th , ^{238}U , ^{40}K and their decay products may lead to harmful effects in human beings. An exposure of about 0.1 mg.Kg⁻¹ form body weight of soluble natural Uranium, Thorium and Potassium results in transient chemical damage to the kidneys (19). All the results obtained from this study are in agreement with the previous studies (4, 20).

Table 1. The specific activity concentration for ^{232}Th , ^{238}U , and ^{40}K isotopes in all samples.

Samples number	Samples name	The specific activity concentration (Bq/Kg)		
		^{232}Th	^{238}U	^{40}K
1	Besler flour	4.796	6.309	18.486
2	Zer flour	4.3101	6.109	20.302
3	Paten flour	5.791	7.214	22.486
4	Flour provide by government	6.732	9.329	16.468
5	Barley flour	9.769	8.321	22.587
Average		6.27962	7.4564	20.0658

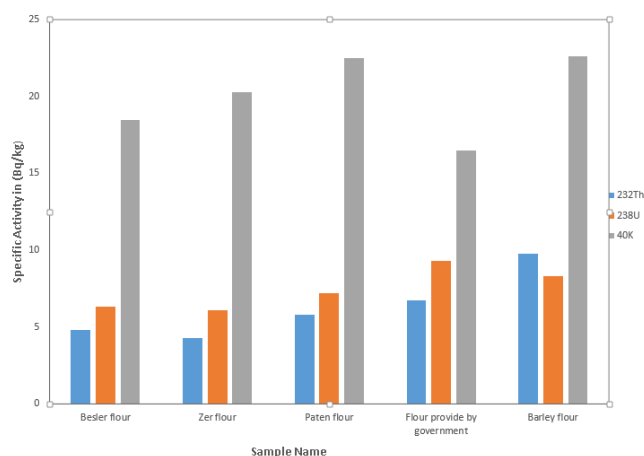


Figure 1. Specific Activity concentration for ^{238}U , ^{232}Th and ^{40}K in (Bq/Kg)

Table 2. Hazard indices in all samples are studied.

Samples	Ra_{eq} (Bq/kg)	D(nGy/h)	H_{ex}	H_{in}	$I_{(yr)}$	AEDE external	AEDE internal
Besler flour	14.5907	6.66394	0.03941	0.05646	0.102344	0.008172	0.032691
Zer flour	13.8357	6.34552	0.03737	0.05388	0.097362	0.007782	0.031129
Paten flour	17.22655	7.86674	0.04653	0.06602	0.120994	0.009647	0.038591
Flour provide by government	20.2238	9.17728	0.05462	0.07984	0.140492	0.011255	0.04502
Barley flour	24.02987	10.85272	0.06490	0.08739	0.168221	0.013309	0.053239
Average	17.98132	8.181244	0.04857	0.06872	0.125883	0.0100334	0.040134

Fig. 2 shows the average value of Ra_{eq} of gamma dose rate for all samples were determined using Eq.2. The maximum value of gamma dose rate was 24.02987 Bq/Kg in barley flour and the minimum value of radium equivalent activities was 17.98132 Bq/Kg in zer flour sample.

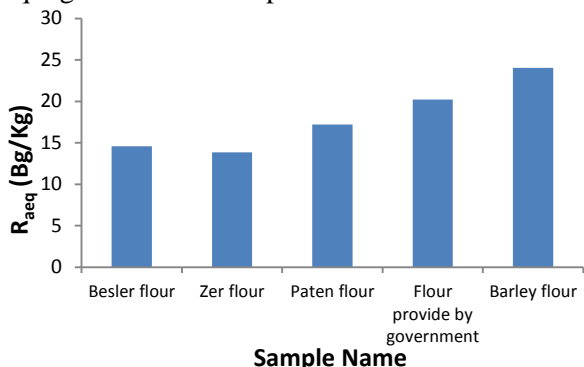


Figure 2. The Ra_{eq} for flour samples.

The average values of the (AEDE), calculated using Eqs.3,4 in units of mSv/y. by using 0.8 for the outdoor occupy factor, which implies 20% of time is spent outdoors, while for the indoor occupy factor 0.2 is used, which is suggested by UNSCEAR 2013 respectively (18). The average value of the AEDE reason to wilderness gamma radiation internal and external received for flour models was 0.04013 and 0.01003 (mSv/y). The maximum value for AEDE internal was 0.05324 (mSv/y) in barley flour samples and for AEDE external was 0.01331(mSv/y) in barley flour samples. The minimum value for AEDE internal was 0.03113 (mSv/y) in the zer flour samples and for AEDE external was 0.00778 (mSv/y) in the zer flour samples, as shows in Figs. 3 and 4.

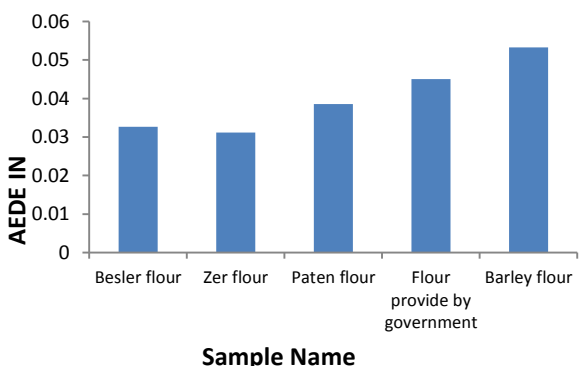


Figure 3. The AEDE (internal) for flour samples

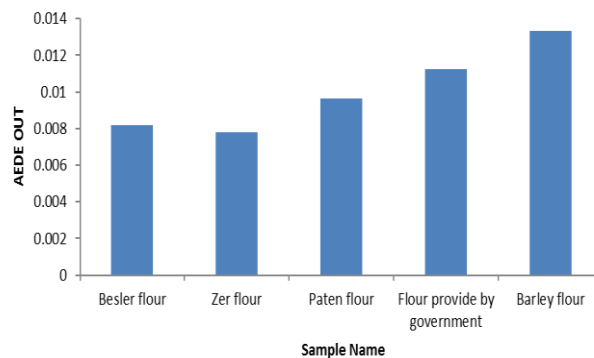


Figure 4. The AEDE (external) for flour samples.

Figures 5 and 6 shows the average value of the H_{ex} and H_{in} , which is 0.04857 and 0.0687 respectively. By using Eqs. 5, 6 the maximum value of H_{ex} was 0.0649 in barley samples and the minimum value was 0.03737 in zer samples. And the maximum value of H_{in} was 0.08739 in barley samples and the minimum value was 0.05388 in zer samples. The all result values for H_{ex} and H_{in} have the regular extent and it's under unity.

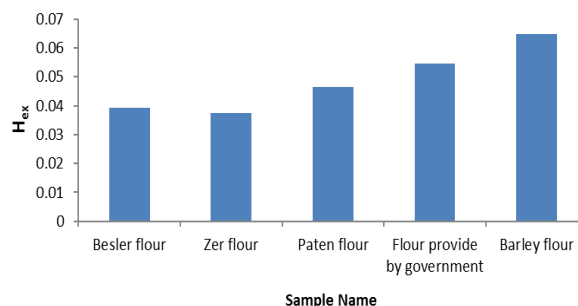


Figure 5. The external and hazard indexes for flour samples.

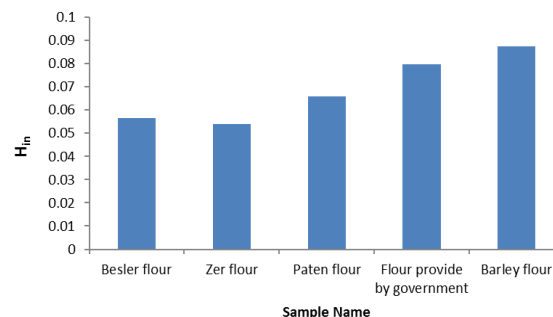


Figure 6. The internal and hazard indexes for flour samples.

The average value of the represented extent index I_{yr} for all samples was 0.12588 specifies by using eq. 7 whereas the maximum value was 0.1682 in barley samples, and the minimum value was 0.09736 in zer samples. Fig.7 describes the

represented extent indexes, $I_{\gamma r}$ and the dose rate in nGy/h.

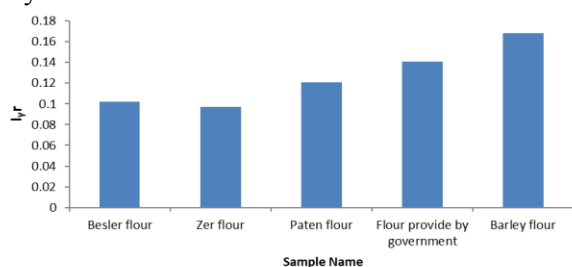


Figure 7. The level index $I_{\gamma r}$ indexes for flour samples.

Fig.8 shows the average value of the gamma dose rate (D) for the all samples were existed to be 8.18124(nGy/h) that was calculate used eq.8. The maximum value was 10.85272(nGy/h) for barley flour and the minimum value was 6.34552(nGy/h) for zer flour.

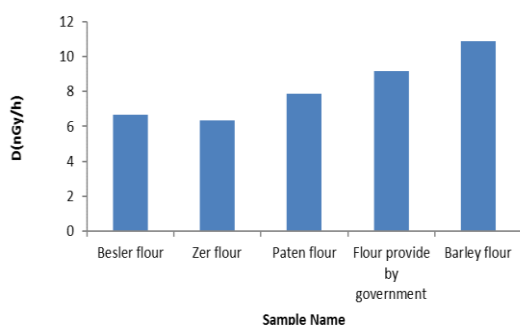


Figure 8. The gamma dose rate indices for flour samples.

Figur 9 represents an experimental relationship between the radium equivalent activity and the internal hazard index, where it was observed that the H_{in} increased directly with the Ra_{eq} .

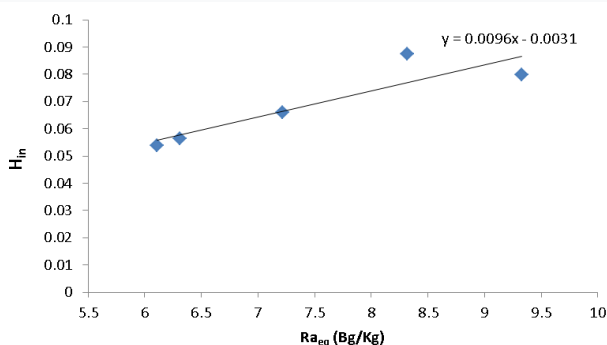


Figure 9. The relationship between Ra_{eq} and H_{in} .

Conclusions:

As commented on before, 87% of the radiation dose is due to natural radiation sources .Essential shareholders existed by the present work are ^{238}U

and ^{232}Th , that have activities in the same order as in the literature for ^{226}Ra and nearly twice as high for ^{232}Th . The world average values of ^{238}U , ^{232}Th and ^{40}K concentrations indicated for natural background areas are 30, 45 and 420 Bq.Kg⁻¹, respectively. The result values found are lower than the average values. Due to increasing employment of phosphate fertilizers in agriculture, potassium substance in soils can be changed and conveyed via food chain to man. As the metabolic balance maintains the ^{40}K body level irrespective of intake quantities, since the metabolic balance sustain the ^{40}K body level regardless of intake quantities, so the quantity of ^{40}K , which is $1.17.10^{-4}$ of the natural plethora, will be also approximately constant. The annual ^{40}K equivalent dose in tissues of the body is 165 $\mu Sv.y^{-1}$ for adults and the total ^{40}K effective dose from inhalation and ingestion is 170 $\mu Sv(5)$. Because of this, there is no trouble in swallowing cereal flour providing the activities levels existed in the present work.

Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in University of Baghdad.

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تركيزات ومؤشرات الخطر الإشعاعي للمواد المشعة طبيعياً لعينات الدقيق في أسواق بغداد

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الخلاصة:

العمل الحالي، تم قياس نشاط اليورانيوم ^{238}U ، الثوريوم ^{232}Th والبوتاسيوم ^{40}K في تركيز بيكريل/ كيلوغرام في خمسة أنواع مختلفة من دقيق القمح متوفرة في الأسواق العراقية. تم استخدام طريقة قياس طيف غاما باستخدام كاشف يوديد الصوديوم NaI (TI) لقياس القياسات الإشعاعية. أيضاً في هذه الدراسة قمنا بحساب النشاط المكافئ للراديو، المكافئ السنوي الفعال للجرعة، مؤشر الخطر الخارجي (H_{ex})، مؤشر الخطر الداخلي (H_{in})، مؤشر جاما الممثل ومعدل جرعة جاما في جميع العينات. وجد أن متوسط النشاط المحدد للتركيز في عينات دقيق القمح لـ اليورانيوم ^{238}U ، الثوريوم ^{232}Th والبوتاسيوم ^{40}K هو 7.4564 بيكريل / كغم و 6.27962 بيكريل / كغم و 20.0658 بيكريل / كغم على التوالي. أثبتت هذه الدراسة أن مؤشرات الإشعاع الطبيعي وخطر الإشعاع كانت أقل من أمانة.

الكلمات المفتاحية: بيئية، تلوث، نشاط إشعاعي، طحين ابيض .