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Measurement of Radioactivity in Flour and Macaroni Consumed in Basrah Governorate, Iraq and Evaluation of Gamma Dose Rates, Radiological Hazard Indices, Excess Life Time Cancer Risk and Ingestion Effective Dose

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Abstract:

The radioactivity levels of^{238}U, ^{232}Th, ^{40}K and ^{137}Cs were determined in 17brands offlour (6 brands) and macaroni(11 brands) consumed in Basrah, Iraq.This papershowed a comparison of the gamma absorbed dose rates (D),annual effective dose equivalent (AEDE)and the excess lifetime cancer risk (ELCR)for various types offlour and macaroni measured by SAM940-2G operating with BNC 2″x2″ gamma-ray NaI(Tl) detector along withthe thermoluminescencetechnique. For flour samples, the minimum specific activity values of ^{238}U, ^{232}Th, ^{40}Kand ^{137}Cs were 0.238±0.002 Bq/kg (at sample F1), 0.117±0.001 Bq/kg(at sample F4), 3.529±0.001 Bq/kg(at sample F4) and 0.040±0.007 Bq/kg(at sample F3) respectively, while the maximum values of the same isotopes were 0.325±0.002 Bq/kg(at sample F3),1.469±0.002 Bq/kg(at sample F5),102.348±0.001 Bq/kg(at sample F6) and0.179±0.003 Bq/kg(at sample F2) respectively. For macaroni samples, the minimum specific activity values of ^{238}U, ^{232}Th, ^{40}Kand ^{137}Cs were 0.195±0.002 Bq/kg(at sample M2),0.029±0.004 Bq/kg(at sample M1),40.390±0.001 Bq/kg(at sample M6)and0.01±0.008 Bq/kg(at sample M11)whereas the maximum values of the same isotopes were 1.430±0.002 Bq/kg(at sample M3),2.629±0.002 Bq/kg(at sample M11),294.495±0.001 Bq/kg(at sample M10) and0.566±0.002 Bq/kg(at sample M4).Various radiation hazard indices including the radium equivalent activity (Ra_{eq}), the ingestion effective dose ($H_{T,r}$), the internal hazard index (H_{in}), the external hazard index (H_{ex}), the gamma index (I_{γ}) andthe alpha index (I_{α}) have been determined for all 17 samples. Allachieved results have been found to be undertheinternationallimit standards. Thus, selected flour and macaronitypes are safe to be consumed in Basrah governorate. The findings of thisstudycould be used as a first step to create radiological baseline data of the hazard radiation in basic foodstuffsconsumed in Basrah/Iraq.

Keywords: Radioactivity, Dosimetry, Thermo-luminescence(TL), SAM940, Flour,Macaroni, Basrah governorate

Introduction

In Health Physics, radiation dosimetry is defined as the measurement of radiation levels that impact onhuman health[1,2]. The world population is subjected to different types of radiation sources including artificial radiation (15%)and natural radiation (85%) which contains food and drinks (11%). This may give a chance to the contamination of radioactive materials [2,3]. Natural occurring radioactive matter (NORM) is found in soil. In fact, NORM can be moved from soil to plants. Thus, each sort of food may have some amount of radioactivity in it. Most types of food have the following isotopes and their daughter products; uranium-238 (^{238}U), thorium-232(^{232}Th) and potassium-40 (^{40}K) [4]. However, foodstuffs radioactivity can also be affected by man-made radiation. Caesium-137 (^{137}Cs) which is made through nuclear accidents and processes is an example of anthropogenic radionuclides [5]. Flour and macaroniareclassified as foodstuffs daily consumed by inhabitants of Basrah. Safe foodstuffs and consumer protection are the responsibility of governments in all over the world [6,7].This study is critical in determining the risk of radiation on humans and is essential in creating rules and procedures involving radiation protection. It is critical for measuringthe radiation levelsthat affect Iraqi population. That is because there is always a risk of excessive exposure to radiation. That is why the study is significant to be done.Radioactivity measurements in foodstuffs are extremely significant for monitoring radiation risks onhuman health[8]. This paper aims to create radiological baseline data of the hazard radiation in involved foodstuff(flour and macaroni)samples in Basrah/Iraq. To achievethis aim,the radioactivity levels and radiation hazard indicesofconsumedflour and macaroni types in Basrah, Iraq are calculated and investigated.

Materials and Methods

Sample collections and preparations

Seventeenfoodstuff samples including six (one localand five imported) samples offlour and elevenimported samples of macaroni were selected and then all samples were collected from local markets in Basrah governorate as shown in Table 1.

Table 1: Significant information about all flour and macaroni samples involved in this study

Sample number	Sample code	Sample commercial name	Sample mass(gm)	Sample origin country
1	F1	Whole Wheat	500	Kuwait
2	F2	Patent	500	Kuwait
3	F3	Ration Card System (RCS)	500	Iraq
4	F4	Iranian	500	Iran
5	F5	Zero	500	Turkey
6	F6	Aya super	500	Ukraine
7	M1	Tiffany	500	Italy
8	M2	Pastazara	500	Italy
9	M3	San Marco	500	Italy
10	M4	Korjia	500	Turkey
11	M5	Azar	500	Iran
12	M6	Macroni	500	Kuwait
13	M7	pasta hat	500	UAE
14	M8	Antonio Amato	500	Italy
15	M9	Divella	500	Italy
16	M10	Zer	500	Turkey
17	M11	Tak	500	Iran

Sample preparation was made by putting each foodstuff sample in an oven for drying at a temperature of 105^{o}C (24hour) until a constant weight was reached, thus ensuring complete removal of any residual moisture. The pulverization of dried samples was made by a grinder. The crushed samples were passed through a 0.5-mm sieve to have homogenized foodstuff samples [4]. The homogenizedfoodstuff samples were divided into two groups. Each group has 0.5 kg of each foodstuff sample and both groups transported for sampling to the ThermoluminescenceLaboratory and Nuclear Physics Researches Laboratory at the University of Basrah.In Thermoluminescence Laboratory, each 0.5 kg of homogenized foodstuff sample was filled into plastic cylinder-shaped beaker with a dimension of 17 cm in length and 10 cm in diameter. Three of annealed TLD-200 dosimeters were positioned in the middle of the filled beaker. Labeled beakers were kept in refrigeration at a range of temperature of (-10 and 10) ^{o}C for 3 months prior to measurement in order to collect adequate amount of gamma radiation [4,9,10].In Nuclear Physics Researches Laboratory, each 0.5 kg of homogenized foodstuff sample wasweighed and put in 0.5 kg polyethylene plastic Marinelli beakers and properly stored in the nuclear physics researches laboratory. The storage period of labeled samples was for at least one month prior to measurement in order to reach radioactive secular equilibrium between parents and their daughter [4,11].

Measurementtechniques

Themeasurements of foodstuff samples were carried out by using two different techniques which are: thermo-luminescence (TL) technique using the dosimeters of calcium fluoride dysprosium, CaF_2:Dy (TLD-200) and SAM940-2G device operating with NaI(Tl) gamma-ray detector. The lower detection limit (D_{ldl}) of TLD-200equals to 0.291705(arbitrary units). The calibration equation of TLD-200 is indicated as[12]:

$$D_X = \left(\frac{\bar{M}_x - \bar{B}}{\bar{M}_c - \bar{B}}\right) D_C \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

It is found that $\bar{M}_C - \bar{B} = 118.684$ (arbitrary units), and D_C = 75.8 mrad. Equation 1 is used to convert the light emission obtained during the readout of TLD to the absorbed dose (D_X) of foodstuff sample[12]. On the other hand, SAM940-2G operating with BNC 2″x2″ gamma-ray NaI(Tl) detectorhas 256 channels, voltage operation of 600 volts, coarse gain=1 and fine gain=1.1386.The energy calibration, resolution calibration and efficiency calibration of a BNC 2"x2" NaI (Tl) detector were determined experimentally for (32.90, 661.7, 31.63, 80.90, 356.01, 1173.20 and 1332.50)keV. The calculation of the activity level and presence of ^{238}U and ^{232}Thin all foodstuff sampleswas derived by the arithmetical average of activities obtained from the peaks of their daughtersin the foodstuff spectrum.^{238}U derived from ^{214}Bi (609.32 keV) and ^{214}Pb(295.21 and 351.92keV).^{232}Th derived from^{212}Pb, ^{208}Tl and ^{228}ACat energies of238.63,583.19 and 911.16keV respectively.The activity values of ^{40}Kin all foodstuff samplesweredetermined from the singlepeak ofpotassium at 1461keV.In the present study, the activity values and existence of Caesium-137 (^{137}Cs)in all foodstuff samples at energy of 661.61keVare determined.The acquisition time for each sample was 1800 seconds.

Specific activity

The specific activity (A_s) of individual radioactivity isotope is defined as the activity per the unit of sample mass and it was calculated using the following equation [4,13]:

$$A_s\left(\frac{Bq}{Kg}\right) = \frac{N}{(\varepsilon_f)(P_\gamma)(m)(t_s)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 2$$

Where, N = count per second (cps) equals measured count rate (N_p)in the foodstuff sample spectrum minus background count rate (N_{BGR})in the background spectrum, ε_f = the efficiency at the peak energy, t_s = the live time of the foodstuffsample spectrum (1800 seconds), m = the sample mass (0.5kg) and P_γ = the emission probability of gamma-ray related to the peak energy.

Gamma absorbed dose rates

The mean specific activity values of ^{238}U (^{226}Ra), ^{232}Th, and ^{40}K (Bq.kg^{-1}) in the foodstuff samples were used to calculate the gamma absorbed dose rate (D). The specific activity of ^{238}U equals to the specific activity of ^{226}Ra because of achieving secular equilibrium between the parent radionuclide and its daughter. The calculation of the relation of the gamma absorbed dose rate which is measured by (nGy/h) is suggested by the UNSCEAR 2000 as [14]:

$$D\left(\frac{nGy}{h}\right) = 0.461\,A_U + 0.623\,A_{Th} + 0.0414 A_K \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 3$$

Where, A_U, A_{Th}, and A_K are the specific activities of ^{238}U,^{232}Th, and ^{40}K in Bq kg^{-1} respectively.

Annual effective dose equivalent

The annual effective dose equivalent(AEDE) from^{238}U (^{226}Ra), ^{232}Th, and ^{40}K is obtained by using the following equations [14]:

$$AEDE_{outdoor}\left(\frac{mSv}{y}\right) = D \times 8760 \times 0.7 \times 0.2 \times 10^{-6} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 4$$

$$AEDE_{indoor}\left(\frac{mSv}{y}\right) = D \times 8760 \times 0.7 \times 0.8 \times 10^{-6} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 5$$

Where, D is absorbed dose rate measured in nGy/h.The number of 0.2 refers to outdooroccupancy factor, 0.8is indoor occupancy factor. 0.7 Sv/Gyis conversion factor.

Excess lifetime cancer risk

The risk of cancer due to radiation effects which is called excess lifetime cancer risk (ELCR) can be calculated from the following equation [15]:

$$ELCR = AEDE \times DL \times RF \quad \ldots \; 6$$

Where, AEDE, DL and RF are the annual effective dose equivalent, the average duration of human life (70 years) and risk factor respectively. The value of risk factor in the public is 0.05 per Sievert as recommended by ICRP for stochastic effects [5,15].

The radium equivalent activity

The activity levels of ^{238}U, ^{232}Th and ^{40}K are not uniformly distributed in the foodstuff samples. Hence, the foodstuff samples were examined by radium equivalent activity (Ra_{eq}). The Ra_{eq} which is measured in Bq/Kg can be calculated by the following equation [13]:

$$Ra_{eq}\left(\frac{Bq}{Kg}\right) = A_U + 1.43\,A_{Th} + 0.077\,A_K \quad \ldots \; 7$$

Where, A_U, A_{Th} and A_K are the specific activity of ^{238}U, ^{232}Th and ^{40}K in $Bq.kg^{-1}$, respectively. The acceptable maximum value of the radium equivalent activity is 370 $Bq.kg^{-1}$[14]. The Ra_{eq} is assumed that 370 Bq/kg of ^{226}Ra, 259 Bq/kgof ^{232}Th and 4810 Bq/kgof ^{40}K yield the same gamma dose rate [4,14].

The internal and external hazard indices

The internal (H_{in}) and external hazard (H_{ex}) indices to gamma ray radiation in foodstuff samples were calculated using the following equations [6,14,16]:

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad \ldots \; 8$$

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad \ldots \; 9$$

Where, A_U, A_{Th} and A_K are the specific activity of ^{238}U, ^{232}Th and ^{40}K in $Bq.kg^{-1}$, respectively.

The gamma index

The gamma radiation hazard index (I_γ), which is also called the representative level index, is calculated for foodstuffsamples by the following equation[17]:

$$I_\gamma = \frac{A_U}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \quad \ldots \; 10$$

Where, A_U, A_{Th} and A_K are the specific activity of ^{238}U, ^{232}Th and ^{40}K in $Bq.kg^{-1}$, in the foodstuff samples, respectively. The maximum value of the gamma index is unity as reported by ICRP [15].

Alpha Index

Alpha index (internal index) deals with the extraordinary level of alpha radiation. This internal index is rising because of the radon inhalation. In the current study, the alpha index was calculated by using the following equation[18] :

$$I_\alpha = \frac{A_{Ra}}{200} \quad \ldots \; 11$$

Where, A_{Ra} are the specific activity of ^{226}Ra supposed in equilibrium with the specific activity of ^{238}U. The maximum value of the alpha index is unity [15].

Ingestion effective dose

The Ingestion effective dose ($H_{T,r}$) due to the intake of ^{238}U, ^{233}Th and ^{40}K in foodstuff samplesis considered as radiological hazard for human health and it can be evaluated using the following expression [13,15]:

$$H_{T,r} = \sum_i \left(U_i \times A_{i,r}\right) \times g_{T,r} \quad \ldots \; 12$$

where, i indicates a food type, the coefficients U_i and $A_{i,r}$represent the rate of consumption ($kg.\,y^{-1}$) and the specific activity of the radionuclide (r) of interest ($Bq.\,Kg^{-1}$), respectively, and $g_{T,r}$ is the conversion coefficient of dose for ingestion of radionuclide r ($Sv.\,Bq^{-1}$) in tissue (T). For the public, the adult conversion coefficient of dose $g_{T,r}$ for ^{40}K, ^{226}Ra (^{238}U), ^{232}Th, and ^{137}Cs are 6.2 $\times10^{-9}$, 2.8×10^{-7}, 2.2×10^{-7} and 1.3×10^{-8} Sv/Bq respectively [4,13]. The average consumption rate of flour for Iraqi adults is 108 kg/y whilethe average consumption rate of macaroni for Iraqi adults is only 3 kg/y[19].

Results

The specific activities due to^{238}U,^{232}Th, $^{40}K$and ^{137}Cs in 6 samples of flour and 11 samples of macaronihave been calculated using equation 2 and their results are presented in

Table **2**. Comparison of average specific activity values of ^{238}U, ^{232}Th, $^{40}K$and ^{137}Cs in flour samples along with macaroni samples is shown in Table **3**.The minimum specific activity values of ^{238}U, ^{232}Th, $^{40}K$and ^{137}Cs in flour samples were0.238±0.002 Bq/kg(at sample F1), 0.117±0.001 Bq/kg(at sample F4), 3.529±0.001 Bq/kg(at sample F4) and0.040±0.007 Bq/kg(at sample F3) respectively, while the maximum values of the same isotopeswere0.325±0.002 Bq/kg(at sample F3),1.469±0.002 Bq/kg(at sample F5),102.348±0.001 Bq/kg(at sample F6) and0.179±0.003 Bq/kg(at sample F2) respectively. On the other hand, the minimum specific activity values of ^{238}U, ^{232}Th, $^{40}K$and ^{137}Cs in macaroni samples were0.195±0.002 Bq/kg(at sample M2),0.029±0.004 Bq/kg(at sample M1),40.390±0.001 Bq/kg(at sample M6)and0.01±0.008 Bq/kg(at sample M11)whereas the maximum values of the same isotopeswere1.430±0.002 Bq/kg(at sample M3),2.629±0.002 Bq/kg(at sample M11),294.495±0.001 Bq/kg(at sample M10) and0.566±0.002 Bq/kg(at sample M4). Thegamma absorbed dose rates measured by TL technique (using equation 1) and SAM940 (using equation 3) for flour sampleswere(0.282-0.346)and (0.002-0.039)mSv/yrespectively, and for macaroni samples were (0.298-0.374) and (0.004-0.109) mSv/y respectively, as presented in Table 4. The average gamma absorbed dose rates measured by TL technique are higher than those measured by SAM940 for all samplesas shown in Figure 1. The outcomes obtained appear to be lower than the world average absorbed dose rates. The estimated world average absorbed dose rate of 1 mSv/y reported in UNSCEAR 2000 [24].The annual effective dose equivalent (AEDE) values and excess lifetime cancer risk (ELCR) valuesfor outdoor and indoor gamma exposures were determined by TL technique and SAM940 for the flour samples and macaroni samples. The mathematical calculations of these quantities were carried out using equations 4, 5 and 6. For the flour samples, the average values of $AEDE_{outdoor}$,$AEDE_{indoor}$, $ELCR_{outdoor}$ and $ELCR_{indoor}$ measured by TL technique were (0.045±0.003)mSv/y, (0.179±0.012)mSv/y, (0.157±0.011) $x10^{-3}$ and (0.627±0.043) $x10^{-3}$ respectively and those values measured by SAM940 were (0.002±0.002) mSv/y, (0.007±0.007) mSv/y, (0.006±0.006)$x10^{-3}$ and (0.024±0.025)$x10^{-3}$ respectively as presented inTable 5. For the macaroni samples, the average values of $AEDE_{outdoor}$,$AEDE_{indoor}$, $ELCR_{outdoor}$ and $ELCR_{indoor}$ measured by TL technique were (0.047±0.004)mSv/y, (0.188±0.015)mSv/y, (0.165±0.013) $x10^{-3}$and(0.660±0.052) $x10^{-3}$respectively and those values measured by SAM940 were (0.011±0.004) mSv/y, (0.042±0.018) mSv/y, (0.037±0.015)$x10^{-3}$and (0.147±0.062)$x10^{-3}$ respectively as presented in Table 6. These results show that the AEDE and ELCR obtained byTLDs arehigher than that measured using the SAM940 measurements. The results obtained show that the AEDE and ELCR in all foodstuff samples appear to be lower than the world average values. The estimated world average outdoor and indoor annual effective dose equivalent are0.07 mSv/y and0.34 mSv/y respectively, as recommended by UNSCEAR 2000 [14]. The estimated world average $ELCR_{outdoor}$ of 0.29×10^{-3} and $ELCR_{indoor}$ of 1.4×10^{-3} is reported in UNSCEAR 2000[5,14].

Table 2: Specific activity results of^{238}U,^{232}Th,$^{40}K$and ^{137}Cs in flour and macaroni samples

Sample number	Sample code	Specific activity (A_s) in (Bq/Kg) (± Uncertainty)			
		^{238}U	^{232}Th	^{40}K	^{137}Cs
1	F1	0.238±0.002	0.848±0.000	ND	0.040±0.007
2	F2	0.249±0.006	0.436±0.001	ND	0.179±0.003
3	F3	0.325±0.002	0.122±0.002	35.684±0.001	0.040±0.007
4	F4	0.068±0.001	0.117±0.001	3.529±0.001	ND
5	F5	0.022±0.002	1.469±0.002	ND	ND

6	F6	0.211±0.001	0.117±0.001	102.348±0.001	ND
7	M1	0.436±0.000	0.029±0.004	281.162±0.001	ND
8	M2	0.195±0.002	0.108±0.001	272.535±0.001	ND
9	M3	1.430±0.002	0.425±0.007	194.108±0.001	ND
10	M4	1.051±0.009	ND	ND	0.566±0.002
11	M5	0.754±0.037	0.114±0.001	168.227±0.001	ND
12	M6	0.646±0.006	1.403±0.000	40.390±0.001	0.04±0.007
13	M7	1.216±0.002	ND	245.87±0.001	0.129±0.004
14	M8	0.960±0.002	ND	233.321±0.001	ND
15	M9	0.203±0.001	2.076±0.002	171.364±0.001	ND
16	M10	0.638±0.002	ND	294.495±0.001	0.149±0.004
17	M11	0.368±0.001	2.629±0.002	190.186±0.001	0.01±0.008

***ND: Not detected**

Table 3: Comparison of average specific activity values of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in flour samples along with macaroni samples

Isotopes	Flour samples			Macaroni samples		
	Minimum	**Maximum**	**Average±SD**	**Minimum**	**Maximum**	**Average±SD**
^{238}U	0.238±0.002	0.325±0.002	0.185±0.106	0.195±0.002	1.430±0.002	0.718±0.39
^{232}Th	0.117±0.001	1.469±0.002	0.518±0.499	0.029±0.004	2.629±0.002	0.969±0.987
^{40}K	3.529±0.001	102.348±0.001	47.187±41.154	40.390±0.001	294.495±0.001	209.166±71.125
^{137}Cs	0.040±0.007	0.179±0.003	0.086±0.065	0.01±0.008	0.566±0.002	0.179±0.2

Table 4: The results of gamma absorbed dose rates in foodstuff samples (Flour and Macaroni) measured by TL technique and SAM940

Sample number	Sample code	Gamma absorbed dose rates (D) in mSv/y	
		TL	**SAM940**
1	F1	0.333	0.006
2	F2	0.346	0.003
3	F3	0.340	0.015
4	F4	0.313	0.002
5	F5	0.282	0.008
6	F6	0.306	0.039
7	M1	0.346	0.104
8	M2	0.301	0.100
9	M3	0.386	0.078
10	M4	0.374	0.004
11	M5	0.337	0.065
12	M6	0.331	0.025
13	M7	0.331	0.094

14	M8	0.360	0.088
15	M9	0.319	0.074
16	M10	0.298	0.109
17	M11	0.320	0.085

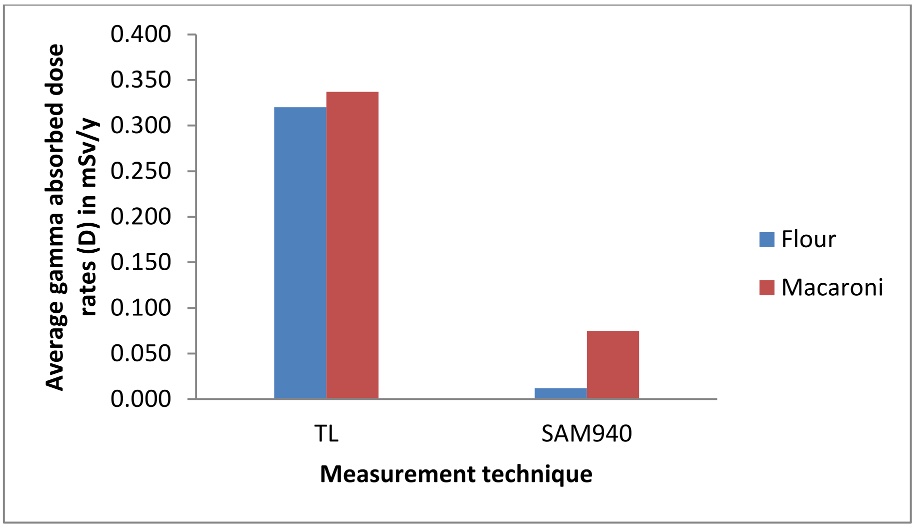

Figure 1: The average of gamma absorbed dose rates in foodstuff samples (Flour and Macaroni) measured by TL technique and SAM940

Table 5: The annual effective dose equivalent values and the excess lifetime cancer risk valuesmeasured by TL technique and SAM940for flour samples

Sample code	**AEDE (mSv/y) measured by TL**		**AEDE (mSv/y) measured by SAM940**		**ELCR measured by TL**		**ELCR measured by SAM940**	
	Outdoor	**Indoor**	**Outdoor**	**Indoor**	**Outdoor $\times10^{-3}$**	**Indoor $\times10^{-3}$**	**Outdoor $\times10^{-3}$**	**Indoor $\times10^{-3}$**
F1	0.047	0.186	0.001	0.003	0.163	0.652	0.003	0.011
F2	0.048	0.194	0.000	0.002	0.169	0.678	0.002	0.007
F3	0.048	0.191	0.002	0.008	0.167	0.667	0.007	0.029
F4	0.044	0.176	0.000	0.001	0.154	0.614	0.001	0.004
F5	0.039	0.158	0.001	0.005	0.138	0.553	0.004	0.016
F6	0.043	0.172	0.005	0.022	0.150	0.601	0.019	0.076
Average	0.045	0.179	0.002	0.007	0.157	0.627	0.006	0.024
±SD	0.003	0.012	0.002	0.007	0.011	0.043	0.006	0.025

Table 6: The annual effective dose equivalent values and the excess lifetime cancer risk valuesmeasured by TL technique and SAM940for macaroni samples

Sample code	**AEDE (mSv/y) measured by TL**		**AEDE (mSv/y) measured by SAM940**		**ELCR measured by TL**		**ELCR measured by SAM940**	
	Outdoor	**Indoor**	**Outdoor**	**Indoor**	**Outdoor $\times10^{-3}$**	**Indoor $\times10^{-3}$**	**Outdoor $\times10^{-3}$**	**Indoor $\times10^{-3}$**
M1	0.048	0.194	0.015	0.058	0.169	0.678	0.051	0.204

M2	0.042	0.169	0.014	0.056	0.148	0.590	0.049	0.196
M3	0.054	0.216	0.011	0.044	0.189	0.756	0.038	0.154
M4	0.052	0.210	0.001	0.002	0.183	0.734	0.002	0.008
M5	0.047	0.189	0.009	0.036	0.165	0.660	0.032	0.127
M6	0.046	0.185	0.003	0.014	0.162	0.649	0.012	0.049
M7	0.046	0.185	0.013	0.053	0.162	0.649	0.046	0.184
M8	0.050	0.201	0.012	0.050	0.176	0.705	0.043	0.173
M9	0.045	0.178	0.010	0.042	0.156	0.625	0.036	0.146
M10	0.042	0.167	0.015	0.061	0.146	0.584	0.054	0.214
M11	0.045	0.179	0.012	0.047	0.157	0.628	0.042	0.166
Average	0.047	0.188	0.011	0.042	0.165	0.660	0.037	0.147
±SD	0.004	0.015	0.004	0.018	0.013	0.052	0.015	0.062

The radium equivalent activity, internal and external radiation hazard indices, the gamma index and alpha index were calculated by applying the equations 7, 8, 9, 10 and 11 respectively. There is a variation in the values of these radiation hazard indices in all foodstuff samples as shown inTable 7, Figure 2 and Figure 3. The results of all radiation hazard indices are less than acceptable world limit values. Last but not least, the equation 12 was applied to calculate the ingestion effective dose of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in flour and macaroni samples. The findings of ingestion effective dose are presented in Table 8 in units of (mSv/y). For the flour samples, the range of summation of the ingestion effective dose varied from (0.0072) mSv/y (at sample F4) to (0.0777) mSv/y (at sample F6) with an average (0.0338±0.0221) mSv/y. For the macaroni samples, the range of summation of the ingestion effective dose varied from (0.0009) mSv/y (at sample M4) to (0.0060) mSv/y (at sample M10) with an average (0.0046±0.0015) mSv/y. These results indicate that the ingestion effective dose in all foodstuff samples were less than the acceptable ingestion effective dose values of 1 mSv/y recommended by ICRP [13,15].

Table 7: The results of radium equivalent activity, radiation hazard(internal, external, gamma and alpha) indices in flour and macaroni samples

Sample number	Sample code	Ra_{eq} (Bg/Kg)	H_{in}	H_{ex}	I_γ	I_α
1	F1	1.451	0.005	0.004	0.005	0.001
2	F2	0.874	0.003	0.002	0.003	0.001
3	F3	3.248	0.010	0.009	0.014	0.002
4	F4	0.507	0.002	0.001	0.002	0.000
5	F5	2.124	0.006	0.006	0.007	0.000
6	F6	8.260	0.023	0.022	0.035	0.001
7	M1	22.127	0.061	0.060	0.095	0.002
8	M2	21.335	0.058	0.058	0.092	0.001
9	M3	16.984	0.050	0.046	0.072	0.007
10	M4	1.051	0.006	0.003	0.004	0.005
11	M5	13.871	0.039	0.037	0.059	0.004
12	M6	5.762	0.017	0.016	0.023	0.003
13	M7	20.148	0.058	0.054	0.086	0.006
14	M8	18.926	0.054	0.051	0.081	0.005
15	M9	16.367	0.045	0.044	0.068	0.001
16	M10	23.314	0.065	0.063	0.100	0.003
17	M11	18.773	0.052	0.051	0.078	0.002

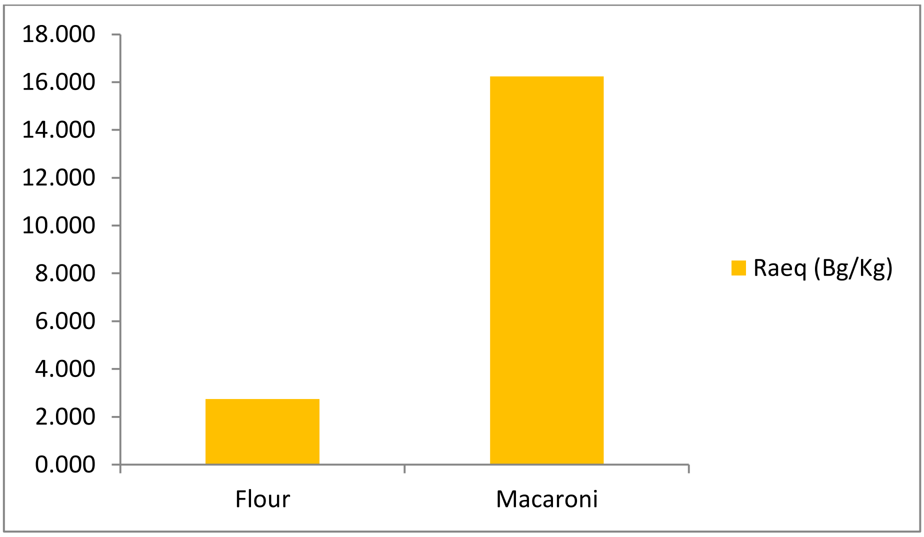

Figure 2: The average radium equivalent activity offlour and macaroni samples

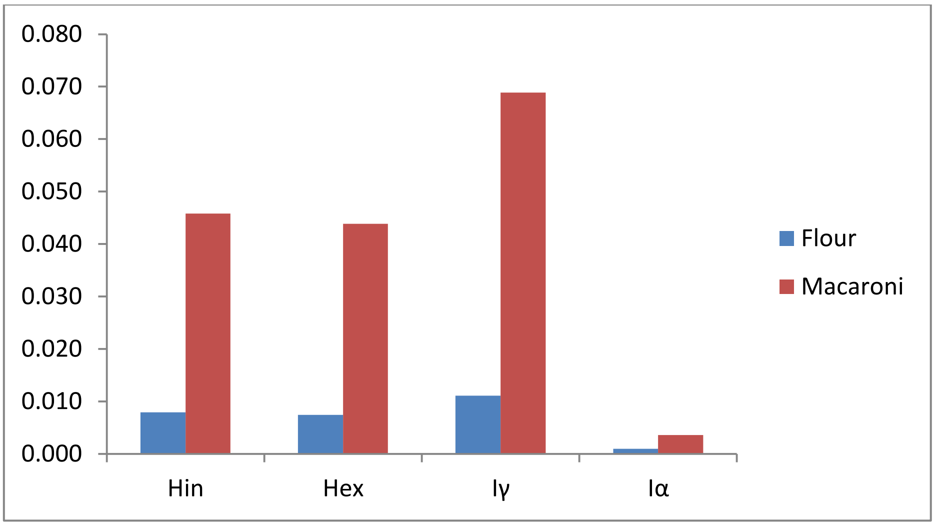

Figure 3: The averagevalues of radiation hazard (internal, external, gamma and alpha) indices in foodstuff samples

Table 8: The results of ingestion effective dose for adult in foodstuff samples

Sample number	Sample code	Ingestion effective dose (mSv/y)				Sum
		^{238}U	^{232}Th	^{40}K	^{137}Cs	
1	F1	0.0073	0.0205	0.0000	0.0001	0.0279
2	F2	0.0077	0.0106	0.0000	0.0003	0.0185
3	F3	0.0100	0.0030	0.0243	0.0001	0.0374
4	F4	0.0021	0.0028	0.0024	0.0000	0.0073
5	F5	0.0007	0.0356	0.0000	0.0000	0.0363
6	F6	0.0065	0.0028	0.0698	0.0000	0.0792
7	M1	0.0004	0.0000	0.0052	0.0000	0.0056
8	M2	0.0002	0.0001	0.0051	0.0000	0.0053
9	M3	0.0012	0.0003	0.0036	0.0000	0.0051
10	M4	0.0009	0.0000	0.0000	0.0000	0.0009
11	M5	0.0006	0.0001	0.0031	0.0000	0.0038
12	M6	0.0005	0.0009	0.0008	0.0000	0.0022

13	M7	0.0010	0.0000	0.0046	0.0000	0.0056
14	M8	0.0008	0.0000	0.0043	0.0000	0.0051
15	M9	0.0002	0.0014	0.0032	0.0000	0.0047
16	M10	0.0005	0.0000	0.0055	0.0000	0.0060
17	M11	0.0003	0.0017	0.0035	0.0000	0.0056

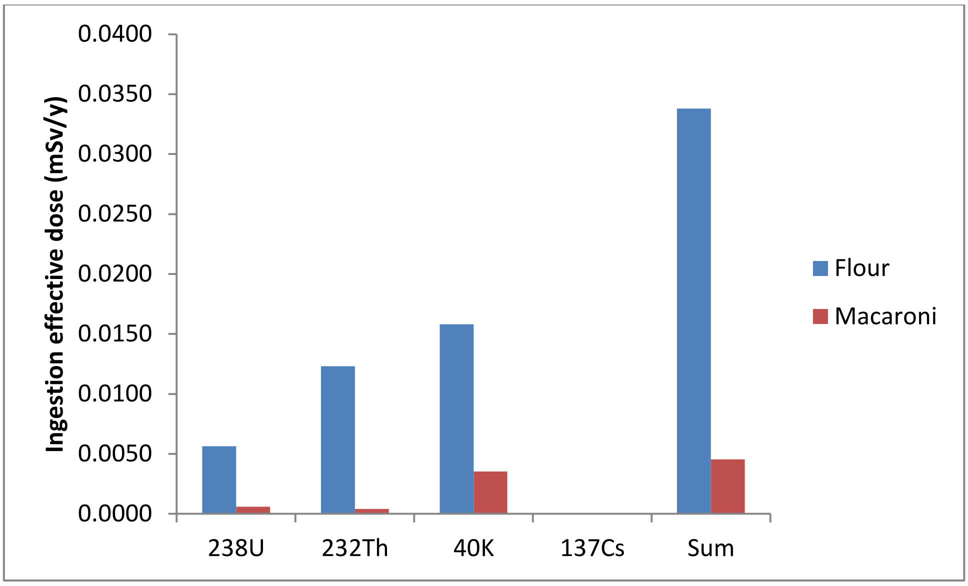

Figure 4:The average ingestion effective dosevaluesof ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs for adult in flour and macaroni samples

Discussion

The specific activity of^{238}U,^{232}Th, ^{40}K and ^{137}Cs in all foodstuff samples appear to be lower than the world average specific activity values.The world average specific activity values of ^{238}U, ^{232}Th, ^{40}K and^{137}Cs are 32 Bq/kg, 45 Bq/kg, 412 Bq/kg and 101 Bq/kg respectively [14,20].The higher averagespecific activity of ^{40}K compared with the average activity concentration of ^{238}U, ^{232}Thand ^{137}Cs was expected because of its natural presence and the extraordinary level of potassium isotope in the sample area which contains phosphate fertilizers in which a great amount of potassium. ^{238}U and ^{232}Th are found in all samples except 4 macaroni samples (M4,M7,M8 and M10) have no ^{232}Th . The levels ofbackground and the detection limits of technique may conceal minor peaksof ^{232}Th[21]. Previous studies reported that the detection of ^{232}Th is not necessary to be found in all food samples [11,22]. The existence of ^{137}Cs in some foodstuff samples may be due to the Chernobyl accident fallout, the usage of contaminated foodstuff bags and nitrate fertilizers [6,23].The difference between the results of TLDs and SAM940 techniques is because TLDs obtainthe gamma absorbed dose of all isotopes in foodstuff sample, while SAM940measuresonly the gamma absorbed dose of ^{238}U, ^{232}Th and ^{40}K in foodstuff samples. This is also clarifies the reason behind the difference between the results of AEDE and ELCR measured by TLDs and those measured by SAM940. The ingestion effective dose of all isotopes in flour samples is higher than those in macaroni samples because theaverage consumption rate of flour (108 kg/y) is much greater than this of macaroni (3 kg/y)for Iraqi adults[19]. The ingestion effective dose of^{137}Csis not found in all samples whereasthe ingestion effective dose of ^{40}K is presented as the highest one. These results are not surprising because the ingestion effective dose results are based on the results of specific activity of mentioned isotopes.

Conclusion

Radioactivity levels, gamma does rates, radiation hazard indices, excess life time cancer risk and ingestion effective dose in flour and macaroni were examined. The outcomes have been shown that consumed flour and macaroni in Basrah/Iraq are safe from any radiation risk. The present study recommends that other staple foodstuffs are needed to have similar study in order to create baseline data of consumed foodstuffs for preparing a radiological map of Basrah/Iraq.

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