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RESEARCH PAPER

Assessment of radiological hazards in cooking liquid oil, used in Kurdistan region-Iraq

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A B S T R A C T:

In this study, the cooking liquid oil as a principal foodstuff element in meals of Kurdistan region population has been examined for radioactivity assessment. The activity concentration of natural and artificial radionuclides in twenty one oil types available in Kurdistan region markets were calculated using NaI(Tl) gamma-ray spectrometer. The results indicates that the activity concentration of ^{238}U, ^{232}Th and ^{40}K radionuclides were ranged in Bq/L from 0.167- 0.207, 0.148-0.613 and 0.184-12.018, respectively. For ^{137}Cs artificial radionuclide, the activity concentration was below the detection limit. The radiological parameters derived from the primordial radionuclides of radium equivalent $Ra_{eq,}$, Indoor Absorbed Gamma Dose Rate (D_{in}), Indoor Annual Effective Dose Rate (E_{in}), Annual Committed Effective Dose, Representative Level Index (RLI) and Excess Life Time Cancer Risk were calculated to be well below the recommendation values suggested by UNSCEAR 200. Thus, it's concluded that the usage of the 21 studied oil samples do not create any radiological risks and safe for consumptions.

KEY WORDS: Cooking oil, Radioactivity, NaI (Tl), Hazard Indices, Cancer risk.
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1.INTRODUCTION :

All living organisms are continually exposed to natural gamma radiation. Different kind of organs and cell has a different sensitivity on the dose radiation received. The main health concern for consumers in the long term due to high radiation exposure is development of cancer [Podgorsak, 2003]. Ionizing radiation acts on the cells of the human body. If the cells do not repair themselves permanent effects of radiation damage can be seen as biological changes in tissues and organs. These changes may be showed as medical symptoms which are classified into stochastic or deterministic effect [Podgoršak, 2006].

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All food contains natural radionuclide. The background levels of radionuclides in food differ and are dependent on several factors, including the type of food and the geographic region were the food has been produced. The common radionuclides in food are (^{40}K), (^{232}Th) and (^{238}U) with their associated progeny. Food also contaminated with artificial radioactive Martials such as (^{137}Cs) which originates from nuclear emergency such as Chernobyl accident [Morino, Ohara and Nishizawa, 2011].

Different routes exist to transfer of radionuclides from earth's crust to human beings; one of them can be regarded as a major pathway is Soil-plant-food chain-man [Cherry, Sorenson and Phelps, 2012].

Both natural and artificial radionuclides can be found in foodstuffs, and are contributed to the increase in the internal effective dose. Long lived radionuclides of single decay source of ^{40}K with decay series of both ^{232}Th and ^{238}U are regarded the main source of human exposure and the artificial radionuclide of ^{137}Cs are released and fall out to the environment from nuclear fission products and contribute to the total annual effective dose. The contributions of foodstuffs to the natural source exposure nearly about one eighth of the total annual effective dose [UNSCEAR 2000; Hammood, and Al-Khalifa, 2011].

The extent of exposure if significant and above the critical limited value causes to some remarkable health effects. Exposure contact above the critical safety limit causes to both genetic and somatic effects that destructive the cell and finally leads to the death [Awudu, et al., 2011].

The main reasons for the measurement of radioactivity level in cooking liquid oils available in Kurdistan region are: first due to its usage role as a principal foodstuff element, and second because of its importing mechanism from different countries which do not obey to any radioactive control or assessment.

So, the radioactivity originates from primordial radionuclides and artificial ^{137}Cs in cooking oil samples and the radiological hazard parameters derived from these radio nuclides were calculated.

This work provides a base line data in the Kurdistan region for comparison and future radioactivity measurements.

2. Materials and methods

2.1. Sample collection and preparation techniques

Twenty one of cooking liquid oil samples was collected from local Erbil markets. No need the prior treatment. The oil samples were inserted in one liter of Marinelli plastic beaker, sealed and sored for about eight times of the half-life of ^{222}Rn to ensure reach of secular equilibrium between parent and progeny. The information about oil samples are given in Table 1.

Table1. Types and origin of the studied liquid oil samples

Sample code	Types	Production country
S1	Sivan	Turkey
S1	Alin	Turkey
S3	Marjan	Azerbaijan
S4	Raz	Turkey
S5	Golden deer	Turkey
S6	Sor	Turkey
S7	Nawras	Turkey
S8	Aftab	Iran
S9	Family	Turkey
S10	Cihan	Turkey
S11	Altunsa	Turkey
S12	Sidra	Ukraine
S13	Final	Azerbaijan
S14	Safya	Turkey
S15	Hana	Turkey
S16	Belkis	Turkey
S17	Paris	Turkey
S18	Cana	Turkey
S19	Aldar	Iraq
S20	Tak	Turkey
S21	Zer	Turkey

2.2. Gamma-ray spectrometry analysis

The gamma spectrometer exists in the post graduate Nuclear Laboratory of the college of science, physics department at Salahaddin university- Erbil.The gamma ray spectrometer used consists of an active area 3″×3″ NaI (Tl) detector (SILENA type model 3S3), preamplifier, a shaping amplifier, multi-channel analyzer of 512 channels of (CASSY type and model 524058) and a high voltage power supply (521681 LYBOLD) model with the range and operating voltage of 0-1500 (800 Volt). The resolution of the scintillation detector obtained with help of the photo peak energy of ^{137}Cs.The detector is shielded by two layers in order to reduce the external background radiation, starting with lead (10 cm) and copper (20mm) for extra absorption of lead K X-rays.

A CASSY software program was used to acquire and analyze the spectrum. The energy calibration for NaI (Tl) gamma ray spectrometry was carried out using the point source of ^{226}Ra with their progenies: ^{214}Pb (242, 295 and 352 KeV) and

^{214}Bi (609 and 1120 KeV) and the full peak efficiency calibration was achieved using the three standard famous activity sources of ^{137} Cs, ^{60}Co and ^{152}Eu. The counting time of 21600 sec was depended as a sufficient time to produce the strong gamma peaks in oil samples spectra. The background spectrum was taken under the same conditions of the samples and subtracted to get the net sample spectra. The minimum detection limits for a counting time of 21600 sec were estimated to be 0.023 Bq/Kg for ^{238}U, 0.071 Bq/Kg for ^{232}Th and 0.254 Bq/Kg for ^{40}K. Fig. 1 shows the principal components of NaI (Tl) gamma-ray spectrometry system.

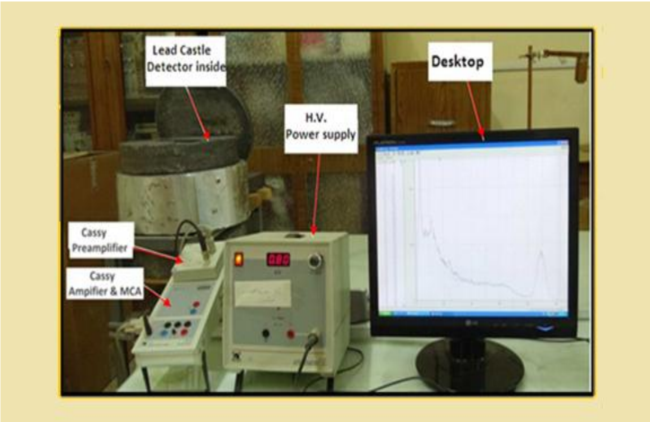

Fig. 1 Experimental set-up for the NaI(Tl) detector

3. Activity measurements

The activity concentration in oil liquid diet samples was calculated using the following equation (Ononugbo, Avwiri and Ikhuiwu, 2017).

$$A_s\left(\frac{Bq}{L}\right) = \frac{N_s}{\varepsilon_\gamma\, I_\gamma\, t\, V_s} \qquad (1)$$

where Ns is the net peak area at a specific energy, ε_γ is the absolute efficiency for a given nuclear energy, I_γ is the probability for decay of radionuclide, t is overall counting time and Vs represented the volume of liquid oil.

4. Radiation hazards

4.1Radium Equivalent (Ra_{eq})

In order to associate the specific activities of elements and to evaluate the risks that related with material containing different concentrations of natural radionuclides of ^{238}U, ^{232}Th and ^{40}K, a single parameter of radium equivalent is designed from the following equation [Al-Hamidawi, Al-Gazaly and Al-Alasadi, 2013].

$$Ra_{eq} = A_U + 1.43A_{Th} + 0.077A_K \qquad (2)$$

where A_U, A_{Th} and A_K are the specific activities of ^{238}U, ^{232}Th and ^{40}K (in Bq/kg), defining a single parameter of Ra_{eq} activity that 1Bq/kg of ^{238}U , 0.7 Bq/kg of ^{232}Th and 13 Bq/kg of ^{40}K create the similar gamma ray dose rate [Al-Hamidawi, Al-Gazaly and Al-Alasadi, 2013].

4.2 Indoor External Doses Rate

The γ-ray dose (D_{in}) imparted by ^{238}U, ^{232}Th and ^{40}K existing in the indoor can be obtained from exchanging the absorbed dose to the effective dose via the conversion factors; 0.92 nGy.h^{-1} per Bq.kg^{-1} for ^{238}U, 1.1 nGy.h^{-1} per Bq.kg^{-1} for ^{232}Th and 0.081 nGy.h^{-1} per Bq.kg^{-1} for ^{40}K. By using the above declared conversion factors the following equation is used to obtained (D_{in}) [Ghamdi and Alzahrani, 2017].

$$D_{in}(\text{nGy}.h^{-1}) = 0.92A_U + 1.1A_{Th} + 0.081A_K \; (3)$$

4.3 Annual Indoor External Effective Dose

The (E_{in}) is the dose in which an individual takes in the indoor location. The (E_{in}) be determined from external indoor dose (D_{in}) that is the γ-ray dose inside the buildings construction, dose conversion parameter factor (CF that is 0.7 Sv Gy^{-1}) and the stay time in the indoor building (that is 80% of the year) (E_{in}) is obtained by the following equations [Adedokun et al. 2019].

$$\text{E}_{\text{in}}(mSv\, y^{-1}) = \text{D}_{\text{in}}(\text{nGyh}^{-1}) \times 80\% \text{ of } 8760\text{h} \times 0.7(\text{Sv.Gy}^{-1}) \qquad (4)$$

4.4 Annual Committed Effective Dose (E_{ing})

The annual effective dose rate due to the intake of of ^{226}Ra , ^{232}Th and ^{40}K in any of the food samples was calculated using the following formula

$$Eing(svy^{-1}) = I \times A \times C \times 365 \qquad (5)$$

Where E is the annual effective dose (Sv/y),I is the intake of nuts during one year , A is the specific activity of radionuclides in the ingested sample (Bq/kg), and C in the ingested dose conversion factor ,the values are $4.5*10^{-8}$ (Sv/y) for ^{238} U $2.3*10^{-7}$ (Sv/y) for ^{232}Th and $6.2*10^{-9}$ (Sv/y) for ^{40}K,The annual dose limit of (1mSv/year) for public exposure [WHO,2008 ; UNSCEAR,1993].

4.5 **Representative Level Index (RLI)**

The value of the representative level index is used to determine the safety limit of the gamma ray level that associated with natural radionuclides present in samples.

The (RLI) is defined as [Mamont-Ciesla et. al. 1982]:-

$$RLI = \frac{A_U}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \qquad (6)$$

When (RLI) value becomes greater than one (standard value), the destructive body cells may grow and thereby causing cancer.

4.6 Excess Life Time Cancer Risk (ELCR)

The (ELCR) due to consuming of foods are obtained from the annual effective gamma dose using the following equation; [Adedokun et al. 2019].

$$(ELCR)_{ing} = E_{ing} \times DL \times RF \qquad (7)$$

Where E_{ing} is the committed annual effective dose due to all of ^{238}U, ^{232}Th and ^{40}K, DL and RF are average duration of life time (70y) and fatal cancer risk (0.05) respectively.

5. Results and discussion

5.1 Activity concentration

The activity concentrations Standard deviations of Radionuclides of ^{238}U, ^{232}Th, ^{40}K, and ^{137}Cs in cooking liquid oil samples of Iraqi Kurdistan region are presented in Table 2.

Table 2 specific activities of ^{238}U, ^{232}Th , ^{40}K and ^{137}Cs radionuclides in cooking liquid oil samples.

Name	Activity Concentration Bq/L			
	^{238}U	^{232}Th	^{40}K	^{137}Cs
S1	ND	0.201±0.037	9.305±0.485	ND
S1	0.168±0.017	0.338±0.048	10.928±0.52	ND
S3	ND	0.613±0.065	9.749±0.497	ND
S4	ND	ND	12.018±0.55	ND
S5	ND	ND	2.130±0.232	ND
S6	ND	0.331±0.048	1.978±0.223	ND
S7	ND	ND	0.811±0.143	ND
S8	ND	ND	2.874±0.284	ND
S9	ND	ND	4.107±0.322	ND
S10	ND	0.148±0.032	3.474±0.296	ND
S11	ND	ND	2.713±0.262	ND
S12	ND	ND	1.014±0.169	ND
S13	ND	ND	1.344±0.184	ND
S14	ND	ND	3.474±0.296	ND
S15	ND	ND	1.648±0.204	ND
S16	ND	ND	1.724±0.209	ND
S17	0.207±0.018	ND	2.992±0.275	ND
S18	ND	ND	2.561±0.254	ND
S19	ND	ND	3.309±0.289	ND
S20	ND	ND	3.905±0.314	ND
S21	ND	ND	0.963±0156	ND

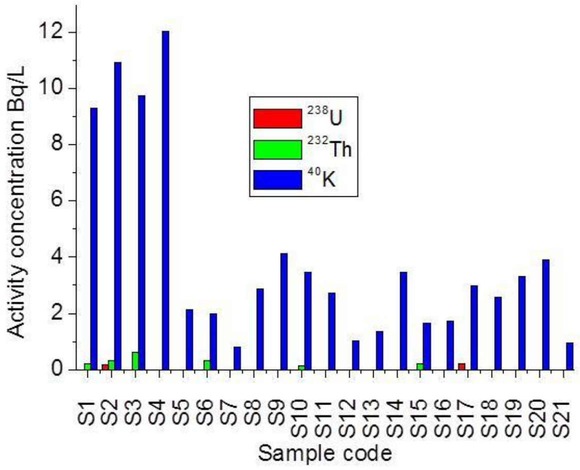

Fig. 2. Activity concentration of primordial radionuclides across sample codes

The specific activities of ^{238}U, ^{232}Th and ^{40}K were identified, but ^{137}Cs was below the detection limit. ^{238}U was noticed only in two samples with the low value of 0.168±0.017 Bq/L found in S2 and the high value of 0.207±0.018 Bq/L in S17. ^{232}Th was detected only in five samples ranged from a minimum value of 0.148±0.032 Bq/L found in S10 and the maximum value of 0.613±0.065 Bq/L in S3. ^{40}K was detected in all samples ranged from 0.811±0.143 Bq/L observed in S7 to 12.018±0.552 Bq/L in S4. The detection of ^{40}K in all samples was attributed to the fact that potassium is an essential element for living organisms.

Unfortunately there is no data found for the limit of natural radioactivity in cooking liquid oil in order to compare the results with the present work. But the results can be compared with the other researches in different country, the activity of ^{238}U, ^{232}Th and ^{40}K are in a good agreement with the previous results of 2.41, 0.85 and 8.87 Bq/l for ^{238}U, ^{232}Th and ^{40}K respectively reported by [Al-Ghamdi and Alzahrani, 2017] and BDL for ^{238}U, 1.61±0.21Bq/L for ^{232}Th and 76.873±77 Bq/L for ^{40}K reported by [Ononugbo, Avwiri and Ikhuiwu, 2017] for vegetable oils and higher than the values of 2.7±0.2 to 6.4±0.5 mBq/Lfor ^{238}U and 2.0±0.1 to 3.5±0.2 mBq/L for 232Th reported by [Misdaq, and Touti, 2012].

5.2 Hazard indices

The radium equivalent and radiological hazard indices of primordial radionuclides in liquid cooking oil samples are presented in column 2 of Table 3.

Table 3 The radium equivalent and radiological hazard indices of primordial radionuclides in liquid cooking oil samples.

Sample code	Ra equivalent	Din ($nGyh^{-1}$)	Ein (mSv/y)	RLI	E_{ing} total (μSv/y)	$ELCR_{ing}*10^{-3}$
S1	1.003	0.974	0.005	0.008	3.790	0.013
S2	1.492	1.411	0.007	0.012	7.022	0.025
S3	1.627	1.463	0.007	0.013	7.348	0.026
S4	0.925	0.973	0.005	0.008	2.720	0.010
S5	0.164	0.173	0.001	0.001	0.482	0.002
S6	0.625	0.524	0.003	0.005	3.225	0.011
S7	0.062	0.066	0.000	0.001	0.184	0.001
S8	0.221	0.233	0.001	0.002	0.650	0.002
S9	0.316	0.333	0.002	0.003	0.930	0.003
S10	0.479	0.444	0.002	0.004	2.027	0.007
S11	0.209	0.220	0.001	0.002	0.614	0.002
S12	0.078	0.082	0.000	0.001	0.230	0.001
S13	0.103	0.109	0.001	0.001	0.304	0.001
S14	0.267	0.281	0.001	0.002	0.786	0.003
S15	0.439	0.374	0.002	0.003	2.205	0.008
S16	0.133	0.140	0.001	0.001	0.390	0.001
S17	0.438	0.433	0.002	0.003	2.795	0.010
S18	0.197	0.207	0.001	0.002	0.580	0.002
S19	0.255	0.268	0.001	0.002	0.749	0.003
S20	0.301	0.316	0.002	0.003	0.884	0.003
S21	0.074	0.078	0.000	0.001	0.218	0.001

The obtained Ra eq. ranges from 0.078 Bq/L in S21 to 1.623 Bq/L in S3. All values are under the declared level of 370Bq/L suggested by [UNSCEAR 2000].

The obtained D_{in} ranges from a minimum value of 0.078 $nGyh^{-1}$ found in S21 to the maximum value of 1.463 $nGyh^{-1}$ in S3, column 3 of Table 3. All magnitudes are below the reference level of 84 $nGyh^{-1}$, advised by [UNSCEAR 2000].

The measured range of E_{in} varied from 0 to 0.007mSv/y, column 4 of Table 3. All the obtained values are below the average recommendation value of 0.41 mSv/y declared by [UNSCEAR, 2000] for indoor annual effective dose rates, the annual effective dose is well below the recommendation values.

The representative level index (RLI) was calculated using eq. (6), and presented in column 5 of Table 3. The obtained range of RLI varied from 0.001-0.013. All the values of RLI are less than one, indicating that ingestion of cooking liquid oil are safe and not poses a radiological threat.

The committed effective dose due to ingestion of 100ml of daily intake of cooking oil over a lifetime (E_{ing}) was calculated using equation (7). The obtained values are presented in column 6 of Table 3. The measured range of estimated annual effective dose due to ingestion of oil varied from 0.184 (S7) to 7.348 (S8). The world average annual effective dose due to ingestion of all foodstuffs is 290 μSv/y (0.12 mSv/y for both ^{226}Ra and ^{232}Th and 0.17 for ^{40}K) reported by [UNSCEAR, 2000]. All samples are well below the recommended values.

As a consequence, the ingestion of cooking oil food do not create any radiological effects from the studied samples, the same behavior was reported by [Al-Ghamdi and Alzahrani, 2017] and [Ononugbo, Avwiri and Ikhuiwu, 2017].

Depending on the committed effective dose, the cancer risk from ingestion of oil $(ELCR)_{ing}$ was calculated using equations(8), column 7 of Table 3. If the value of the ELCR above the standard value, the likely of getting cancer is also increases. The range of $ELCR_{ing}$ varied from 0.001×10^{-3} (S7) to 0.026×10^{-3} (S3). All values are well below the average worldwide value of 1.45×10^{-3} suggested by (UNSCEAR, 2000). This reveals that the chance to get the cancer for consuming cooking liquid oil is insignificant.

6. Conclusions

The activity concentration of primordial radionuclides as well as the cesium artificial radionuclide were calculated using the NaI(Tl) detector. The ^{123}Cs activity was below the detection limits for all studied samples. The derived radiological parameters are all well below the recommended values reported by UNSCEACR2000. This study will establish the first baseline data for specific activities in the cooking liquid oil in Kurdistan region. The results showed that the consumption of cooking oil are safe for health and do not pose any radiological risks to the consumers.

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