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Determination of the Natural Radioactivity and Hazard Factors Available of the Soft Drinks in the Markets of the Thi-Qar Province, Iraq

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***Abstract*— In this research, the radioactivity of a group of soft drinks available in the markets of Thi-Qar Governorate (southern Iraq) was measured. Seven samples were selected, the most available and consumed by people. The idea of the research is to use a gamma spectrometer NaI (Tl) system to study the presence of radioactivity in these seven samples packaged in glass bottles and their counterparts packaged in metal cans for comparison. The results show that the specific activity values for the bottle samples ranged between 15.787 - 20.160 Bq.kg^{-1} for K-40, while ranging between (0.112 - 1.194) Bq.kg^{-1} for U-238. As for the third nuclide Th-232, its values were 0.098 - 0.200 Bq.kg^{-1}. On the other hand, the symmetric radioactivity for the can samples was recorded between 17.888 - 20.885 Bq.kg^{-1}, 0.185 - 1.406 Bq.kg^{-1}, and 0.218 - 0.272 Bq.kg^{-1} for the corresponding three radioactive nuclides K-40, U-238, and Th-232, respectively. The results of the hazard factors show that the maximum value studied was for (Sprite) sample, while the minimum value was for (Seven Up), each for bottle samples. Concerning to the can samples, the maximum value of these hazard factors studied was for the Fanta sample, while the minimum value was for (Dew). Furthermore, all these values of the hazard factors studied were higher for the can samples than for the symmetric bottles, but with a very small increase. All the radioactive factors studied in them were lower than the global limits, which proved safe for human use. Thus, this study will contribute to creating a radioactive guide for what humans consume, especially in Thi-Qar province.**

***Keywords*— Radioactivity, Soft Drinks, NaI(Tl) Detector, Hazard Factors, Thi-Qar province.**

I. INTRODUCTION

As a result of the increasing globalisation of the food supply and the rise in food intake, including fast food, soft drinks, and snacks, soft drink consumption has expanded dramatically over the past few decades. The blend of contemporary, trendy substances with a variety of properties, such as mood regulation and health advantages, is astounding [1,2]. The phrase "soft drinks" needs to be defined carefully because it can be interpreted in many ways. Tea, coffee, etc., and milk-based drinks are typically excluded. In addition, fruit juices and fruit nectars (apart from the lime juice), which are commonly described as soft drinks [3,4], are typically made of water, sweeteners, flavours, acids, colours, and preservatives[5]. Today's soft drinks are available in a vast array of varieties. Target markets for functional drinks are diverse, and products are regularly tailored to fit the needs of particular demographics, such as age or gender, with a growing emphasis on the elderly, women, and children [6]. Few people drink soft drinks for their taste or other reasons; most people do it for refreshment [7]. The demand for soft drinks is influenced by several factors. Since soft drink demand is comparatively price-elastic, price is the primary determinant. This indicates that, in relation to the price change, demand declines more when soft drink prices rise. Additionally, the demand for soft drinks is relatively income-elastic, which means that a fall in consumer income corresponds to a greater degree of decrease in soft drink demand and vice versa. Soft drink demand is also influenced by consumer choices and lifestyles. The demand for soft drinks, especially RTD goods, may rise due to the decreased emphasis on family meals and the rise in convenience food and takeout cravings. Soft drink products are packaged to cater to this grab-and-go lifestyle. Similarly, people are becoming busy and searching for energy-boosting and rejuvenating soft drinks, which is driving growth in the functional beverage categories. Although this is a chance, it is not anticipated to outweigh the other reasons that are now adversely affecting the market for soft drinks [8].
There could not have come up with a more perfect mechanism for weight gain than adding a liquid carbohydrate that contains calories partially offset by raising satiety. As a relatively recent addition to the human diet, liquid calories may not yet be recognized for what they are by the human satiety circuit.

A six-ounce bottle was the typical serving size for a soft drink fifty years ago. Thanks to the big size of soda fountain drinks that are available at most stores and restaurants, soft drinks are now sold in twenty-ounce bottles and are consumed in much larger quantities. Sugar-sweetened soft drinks account for 7.1% of total energy consumption. As few as one or two soft drinks a day can raise your risk for several health issues, according to scientific studies. Obesity, diabetes, dental decay, osteoporosis, inadequate nutrition, heart disease, and numerous neurological illnesses are a few of these health issues [9]. Away from these harms to the human body, the current study determined level of radioactive activity of the soft drinks manufactured in Iraqi factories and exist in the

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markets of the Thi-Qar province, according to what is available.

II. EXPERIMENTAL METHODS

a) Sample Preparation

Fourteen samples of soft drinks were collected from different markets of the Thi-Qar province, which were made in Iraq. These collected samples were seven soft drinks bottles and another seven as cans corresponding to the same kind, according to what is available and most consumed (Table 1 and Figure 1). After that, each sample was sealed in a one-litre Marinelli beaker, and radioactive equilibrium was reached by waiting 30 days.

TABLE I. Samples and their codes.

No.	Bottle		Can	
	Sample Name	**Code**	**Sample Name**	**Code**
1	Pepsi Cola	P1	Pepsi Cola	P2
2	Miranda	M1	Miranda	M2
3	Seven Up	SE1	Seven Up	SE2
4	Coca Cola	C1	Coca Cola	C2
5	Sprite	SP1	Sprite	SP2
6	Fanta	F1	Fanta	F2
7	Dew	D1	Dew	D2

Fig. 1: Soft drinks samples (up: bottle, down: can)

b) Gamma Spectroscopy

Digital multi-channel analyser NaI(Tl) detector with the specifications "model Bmca with a crystal of (3×3) inch2, model 12/12/3, manufactured in the United States" was used to estimating the natural radioactive nuclides of K-40, Bi-214, and Tl-208. It examines 4096 channels of the gamma spectrum for gamma rays. Using the IAEA's standard point Europium source (Eu-152), the detector's calibration is confirmed [10]. Energy calibration may simply mean the relationship between the channel number (MCA) and the energy (KeV) of the point radioactive source absorbed by the detector, as illustrated in Figure 2.

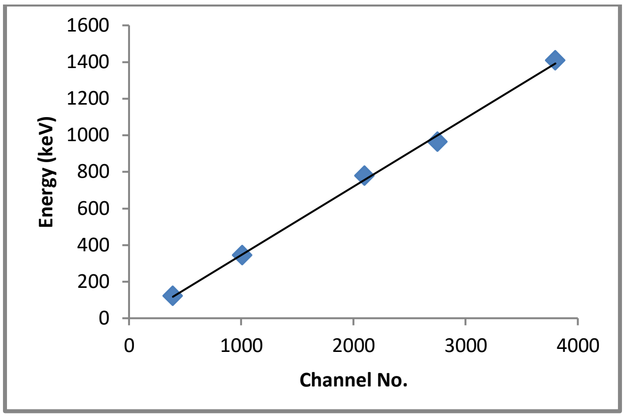

Fig. 2: Energy calibration curve.

In this work, the specific activity of the three main radionuclides mentioned above was primarily assessed in Bq/kg unit, with a peak at energy Eγ provided by [11, 12].

$$A(E_\gamma) = \frac{N}{\mathcal{E}(E\gamma)\times I_\gamma(E\gamma)\times t\times M} \qquad (1)$$

The net peak area under the specified peak, adjusted for the background count rate, is denoted as N (N=Ns-NBG) [13]. The measurement time, t, is expressed in seconds, while Iγ(Eγ) is the energy abundance. Ɛ(Eγ) refers to the detection efficiency at energy Eγ, and M represents the mass of the material that was measured (1 kg), which is equivalent to one liter Marinelli beaker. The measurement time of each sample was 24 hours (86400 sec) [14].

The following gamma information was used to calculate the activity concentration of the current radionuclides: (1460.8 keV, Iγ = 10.67%) for K-40, (1764.5 keV, Iγ = 15.30%) for U-238, and (2614.5 keV, Iγ = 99.75%) for Th-232.

c) Hazard Factors

Six main hazard factors were calculated in this work were listed as follows [15–20]:

- Radium equivalent Activity ($Ra_{eq.}$)

$$Ra_{eq.}(Bq.kg^{-1}) = A_U + 1.43A_{Th} + 0.077A_K \quad \leq 370 \qquad (2)$$

Where A_U, A_{Th}, and A_K represent the specific activity concentrations corresponding to the three main mentioned radionuclides U, Th, and K in $Bq.kg^{-1}$ unit, respectively.

- Internal Hazard Indices ($H_{in.}$)

$$H_{in.} = \frac{A_U}{185\ Bq.kg^{-1}} + \frac{A_{Th}}{259\ Bq.kg^{-1}} + \frac{A_K}{4810\ Bq.kg^{-1}} \quad \leq 1 \qquad (3)$$

- External Hazard Indices ($H_{ex.}$)

$$H_{ex.} = \frac{A_U}{370\ Bq.kg^{-1}} + \frac{A_{Th}}{259\ Bq.kg^{-1}} + \frac{A_K}{4810\ Bq.kg^{-1}} \quad \leq 1 \qquad (4)$$

- Absorb Gamma Dose Rate (D_γ)

It is the energy absorbed per mass unit from any ionising radiation. The units of absorbed dosage are rad and Gray, with 1 Gy which equal 100 rad [22]. Based on guidelines issued by UNSCEAR, the absorbed dose rates Outdoors

(Dγ) for the uniform distribution of naturally occurring radionuclides due to gamma radiations in the air at one meter above the ground surface were estimated.

$$D_{\gamma}(nGy.h^{-1}) = 0.462A_{u} + 0.621A_{Th} + 0.042A_{K} \qquad (5)$$

- Annual Effective Dose Equivalent

The outdoor absorbed dose (Dγ out) is used to estimate the annual effective dose rate in air (AEDE). Keep in mind that the conversion coefficient between the effective dose that adults get and the absorbed dose in the air is 0.7 $Sv.Gy^{-1}$, and the occupancy factor for AEDE equals 0.2 [21]. The following equation can be used to determine the yearly effective dose equivalent:

$$AEDEout\ (mSv.y^{-1}) = D\gamma\ (nGy.h^{-1}) \times 10^{-6} \times 8760\ (h.y^{-1}) \times 0.20 \times 0.7 (Sv.Gy^{-1}) \qquad (6)$$

- Excess Lifetime Cancer Risk (ELCR)

This relates to the lifetime risk of acquiring cancer at a specific exposure level, which is given as:

$$ELCR = AEDE \times DL \times RF \qquad (7)$$

Where DL is the life expectancy (70 years), while RF is the risk factor, which is defined as the fatal cancer risk per Sievert, with 0.05 Sv^{-1} being the value supplied by ICRP for low-level radiations, random effects, and the general public [22].

III. RESULT AND DISCUSSION

a) Specific Activity

First, by using eq. 1, the specific activity values of the three main radioactive nuclides K-40, U-238, and Th-232 were obtained; then, their results were put in the following table.

TABLE II.: Natural three radionuclides levels of the soft drinks for both bottle and can samples ($Bq.kg^{-1}$).

No.	Bottle				Can			
	Code	**K-40**	**U-238**	**Th-232**	**Code**	**K-40**	**U-238**	**Th-232**
1	P1	18.141	0.401	0.323	P2	20.030	0.581	0.521
2	M1	15.787	0.646	0.765	M2	17.888	0.746	0.835
3	SE1	19.516	0.222	0.098	SE2	20.600	0.211	0.218
4	C1	17.978	0.466	0.433	C2	19.278	0.661	0.604
5	SP1	18.669	1.194	0.379	SP2	19.859	1.406	0.340
6	F1	20.160	0.691	0.519	F2	20.885	0.841	0.799
7	D1	19.310	0.112	0.200	D2	19.333	0.185	0.272
Global limit average [22]						400	35	30

As shown in Table 2, the specific activity for bottle samples ranged between (15.787 - 20.160) $Bq.kg^{-1}$ for K-40, while ranged between (0.112 - 1.194) $Bq.kg^{-1}$ for U-238. As for the third nuclide Th-232, its values were (0.098 - 0.200) $Bq.kg^{-1}$. On the other hand, the symmetric radioactivity for can samples was recorded between (17.888 - 20.885) $Bq.kg^{-1}$, (0.185 - 1.406) $Bq.kg^{-1}$, and (0.218 - 0.272) $Bq.kg^{-1}$ for the corresponding three radioactive nuclides K-40, U-238, and Th-232 respectively. All these results were less than the Global limits [21].

These results show that the values of each radioactive nuclide were close to each other for all samples, for the same type of samples bottle or can. The specific activity values of the can samples were higher than their corresponding values of the bottle samples. It is likely due to the presence of preservatives in the can samples [23].

b) Hazard Factors

TABLE III.: Hazard Factors of the soft drinks for the bottle samples.

No.	**Sample Name**	**$Ra_{eq.}$ ($Bq.kg^{-1}$)**	**$H_{in.}$ × 10^{-3}**	**$H_{ex.}$ × 10^{-3}**	**D_{γ}($nGy.h^{-1}$)**	**$AEDE_{out}$ ($mSv.y^{-1}$) × 10^{-3}**	**ELCR × 10^{-3}**
1	Pepsi Cola	2.259	7.186	6.102	1.147	1.406	4.921
2	Miranda	2.955	9.727	7.981	1.436	1.761	6.163
3	Seven Up	1.864	5.635	5.035	0.983	1.205	4.217
4	Coca Cola	2.469	7.928	6.668	1.239	1.519	5.316
5	Sprite	3.173	11.798	8.571	1.571	1.926	6.741
6	Fanta	2.985	9.930	8.062	1.488	1.824	6.384
7	Dew	1.884	5.392	5.089	0.986	1.209	4.231
Global limit [22]		370	≤1	≤1	84	≤1	≤0.29

TABLE IV.: Hazard Factors of the soft drinks for the can samples.

No.	Sample Name	$Ra_{eq.}$ $(Bq.kg^{-1})$	$H_{in.} \times 10^{-3}$	$H_{ex.} \times 10^{-3}$	$D_{\gamma}(nGy.h^{-1})$	$AEDE_{out}$ $(mSv.y^{-1}) \times 10^{-3}$	$ELCR \times 10^{-3}$
1	Pepsi Cola	2.868	9.316	7.746	1.433	1.757	6.149
2	Miranda	3.317	10.975	8.959	1.614	1.979	6.926
3	Seven Up	2.108	6.264	5.694	1.098	1.346	4.711
4	Coca Cola	3.009	9.912	8.126	1.490	1.827	6.394
5	Sprite	3.421	13.041	9.241	1.694	2.077	7.269
6	Fanta	3.591	11.972	9.699	1.761	2.159	7.556
7	Dew	2.062	6.069	5.569	1.066	1.307	4.574
Global limit [22]		370	≤1	≤1	84	≤1	≤0.29

When examining the results of the tables 3, the maximum values of the hazard factors studied were for (Sprite) sample, while the minimum value was for (Seven Up), each of them for bottle samples. As for Table 4, the maximum values of these hazard factors studied were for Fanta sample, while the minimum value was for the Dew for can samples. The difference between these samples and their corresponding may belong to the difference in preservative rate in the can samples, as mentioned earlier.

Furthermore, it is clear that all these values of the hazard factors studied were higher for the can samples than for the symmetric bottles, but with a very small increase. Figure (3) represents a comparison between bottle and can sample for the values of the most important factor, Excess Lifetime Cancer Risk (ELCR). All the results show that soft drinks have radioactivity factors within the global normal limits, which are put in the last row of the table [21].

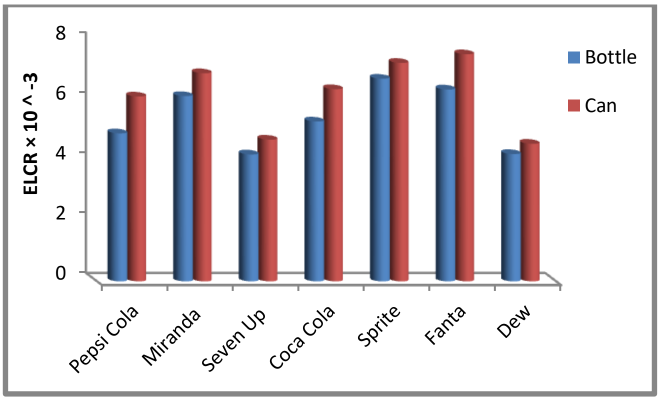

Fig. 3: Comparison between (ELCR) values for bottle and can samples.

Figure (3) shows that the minimum confirms that the maximum value of the excess lifetime cancer risk was for the can sample Fanta, while its minimum value was for the bottle sample Seven Up.

IV. CONCLUSIONS

Radioactivity has significant harm, the most important of which is cancer. This comes from the air that humans breathe or the food or drink they consume. Therefore, this study came to show the amount of radioactive harm in soft drinks, which proved to be safe for human use, as all the radioactive factors studied in them were lower than the global limits, whether for the bottle or the can. Thus, this study will contribute to creating a radioactive guide for what humans consume, especially in Thi-Qar province.

CONFLICT OF INTEREST

Authors declare that they have no conflict of interest.

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