Measuring the level of Radioactive contamination of selected samples of Sugar and Salt available in the local markets in Najaf governorate / Iraq

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Abstract. Natural radioactivity has attracted a lot of attention in the world due to its crucial role in human safety. Sugar is compound, which is the generic name for sweet, soluble carbohydrates, many of which are used in food while salt is commonly used as a condiment and food preservative. Sugar and salt are very important for human beings, as well as their proven benefits to the general health of human beings. Therefore, the measurement of natural radioactivity is a critical because of its direct impact on human safety. In this research, quantification has been made of natural radionuclide concentrations using NaI(Tl) gamma-ray spectrometry. The analyses of samples reveal the mean activity concentrations of $^{226}$Ra, $^{232}$Th, $^{40}$K and $^{Ra}_{eq}$ are found to 5.83±1.008, 5.92±0.721 ,138.65±0.826, and 24.98(Bq.Kg⁻¹), respectively .also, calculated $I_\alpha$, $I_\gamma$ and $H_{in}$ the values were less than one, it was clear that the ratio of these nuclides concentrations were higher than internationally allowed limits. The estimated annual gonadal equivalent dose (AGED) resulting with an average 86.32*10⁻³(mSv.y⁻¹) were lower than globally limits. The data were statistically processed and Pearson's factor with p-value were calculated for concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K with annual ingestion dose for these nuclides where correlations of $^{226}$Ra were more a high increase statistical significance, direct, and positive with other parameters .The consumption of sugar and salt for adult, children and infant , where found the maximum value of cancer risk (ELCR) 0.2421*10⁻³ in adult for consumption of sugar while the minimum value 0.0005*10⁻³in infant from consumption of salt ,which is less than the global value 2.5*10⁻³ that assessed by the united nations scientific committee on the effects of atomic radiation to be due to food and water intake.

keywords: Hazard indices , AGED , ELCR , sugar ,salt.

1.Introduction

Natural radionuclide concentrations in environmental samples varies according to geographical and geological factors radionuclide's are found throughout nature and it exist in the soil ,water and food ,these radionuclide's have half-lives that are approximately Earth's age or greater ( about four to five billion year) [1]. The radioactivity present on air or in the agricultural land and soil may moves to the crops grown on it .However, that an amount of some radioactive elements find their way directly to human[2]. Most importantly for the ingestion dose comes from the radionuclides and their progeny. Ingestion involves the intake of the radionuclides through water and food (considering that sugar and salt are found in most foods) [3]. Where sugar is found in the biscuit cakes, candy and other sweets also it is added to many processed products foods such as ketchup, processed meats, biscuits, bread, soups, cereals ...etc. either for infant most processed foods contain sugar or lactose where naturally present in milk and dairy products[4]. There is no constant dietary for sugar in infants and children due to the varied desire of them to eat sugars. Also, some foods always contain a high percentage of salt because of the way they are made, while others, such as bread and breakfast cereals, contribute to a lot of salt in the food, and this is not because these foods are always rich in salt but daily consumption is much[5]. The ingested radionuclides which concentrated in certain parts of the body , for examples, $^{226}$Ra accumulated in human kidney , $^{232}$Th in liver and skeleton tissues and $^{40}$K in muscles. Sedimentation of large quantities of these radio nuclide in particular organs will affect the
health condition of human such as weakening the immune system[6] , induce various types of diseases and finally the increase in mortality rate the radionuclide present the most risk to human health , so it is important to understand effects of radionuclide movable through foods and drinks[7]. Sugar and salt intake varies widely across the globe, depending on environment, food quality and cultural dietary preferences, moreover, accurate estimates of sugar and salt consumption are not easy to obtain since there are considerable individual variations, as well as many seasonal foods and many regional consumption differences[8]. The reference dose level (RDL) of the committed effective dose was estimated to be 0.3 (mSv.y) by UNSCEAR in its guidelines for ingestion in food and water[9, 10]. The 0.3 (mSv) (RDL) is also equivalent to 30 % of the dosage level (1 mSv) recommended by both the International Commission on Radiological Protection (ICRP, 1991) and the International Basic Safety Standards (IAEA, 1996) for members of the population[11]. Therefore, there are many studies on sugar and salt because the issue is of great importance to investigate the possible radionuclides consumed in different parts of the world for example, a study of radionuclide concentrations and risk factors for different salt samples in Egypt[12]. This work investigates the natural and man-made radionuclides in foodstuff material as sugar and salt consumed by Iraqi Kurdistan region population Erbil. The measurements were carried out by using a high efficiency NaI(Tl) gamma-ray spectrometer [13]. Some different salt samples were collected from the local markets in Iraq for the purpose of identifying the most radioactive species using a detector NaI (Tl) [14]. Important objectives of this study were to quantify the presence of natural radionuclide in some samples of sugar and salt in markets of Najaf / Iraq, since sugar and salt are famous among all ages, therefore, sugar and salt concentrations must be carefully measured to predict any potential danger to humans. The primary purpose of this study is to determine the natural specific activity and to estimate the radiation hazard indices namely radium equivalent activity (Ra eq), representative level index (I γ), (I α), effective dose rate (D eff), internal hazard index (I H ), Pearson's correlation with P-value, annual Gonadal equivalent dose (AGED) and cancer risk (ELCR) in sugar and salt samples.

2. Methodology

2.1. Sample Collection and Preparation

This study was conducted on sugar and salt consumed by the overall public in Najaf governorate, Iraq. Sixteen types of sugar and salt (local and imported), as shown in table (1). To determine the concentration of radionuclides in the sugar and salt, samples were immediately brought to the laboratory for preparation and storage. Each sample was with weight (500 gm), placing the samples in a tightly closed plastic container, then storing them separately for (35) day to allow a radiative equilibrium between 226Ra and then 232Th and short-lived degradation products[15]. Radionuclides of 226Ra, 232 Th and 40K were measured in as sugar and salt samples using NaI (Tl) gamma ray spectrometer detector.

| ID | Name of the sample(Sugar) | origin | ID | Name of the sample(Salt) | origin |
|----|---------------------------|--------|----|--------------------------|--------|
| Su01 | Iraq                      | Iraq   | Sa01 | Nawras                   | Turkey |
| Su02 | Khazra                    | Iraq   | Sa02 | Zer                      | Turkey |
| Su03 | Alosra                    | Saudi  | Sa03 | Al-Ameen                 | Iraq   |
| Su04 | Kasih                     | Jordan | Sa04 | Solt                 | Saudi  |
| Su05 | Alrahmoun                 | Syria  | Sa05 | Korjia                   | Turkey |
| Su06 | Safa                      | Emirates | Sa06 | Salva                  | Iran   |
| Su07 | Top-Top                   | Saudi  | Sa07 | Al-mansour              | Iraq   |
| Su08 | Etihad                    | Iraq   | Sa08 | Pousan                  | Iran   |

2.2. Statistical Analysis
Statistical descriptions were performed using SPSS by the Windows system, standard version 20.0. Analysis of the data was carried out by frequency distributions (Pearson correlation) to assess the statistical significance depending on P-value in all parameters measured in the three nuclides in sugar and salt samples.

2.3. Gamma spectrum analysis

The concentration of radioisotopes present in the sugar and salt such as and $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ were determined using the gamma ray spectroscopy technique on the high ability of this radiation to penetrate different materials. This spectrometer consists of a NaI(Tl) luster detector with crystal dimensions (3"x 3"), supplied by Alpha spectra, Inc.-12I12/3, and equipped with a multi-channel analyzer (MCA) (ORTEC-Digi base) with a range of 4096 channel connected to ADC (analog to digital converter), through the interface. Measurements and spectroscopy are calculated using the MAESTRO-32 software on a Windows computer. An energy calibration for this detector was performed with standard sources $^{22}\text{Na}$, $^{60}\text{Co}$ and $^{137}\text{Cs}$. To reach the lowest radiation background, the detector was protected by a cylindrical lead shield as shown in figure (1).

![Figure 1. System detector gamma ray spectroscopy (3 "x 3") NaI (Tl)](image)

3. Calculation of concentration of radionuclide and Hazard indices

3.1. Concentration of radionuclides

The radionuclide concentrations of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ were calculated in a unit of (Bq.kg$^{-1}$) using the equation (1) [16]:

$$A_n = \frac{(C_n - C_b)}{t \epsilon \gamma I_{\gamma} m_s}$$

Where $A_n$ is the specific activity of each radionuclide in (Bq.kg$^{-1}$), $C_n$ is the count rate in CPS for sample, $C_b$ is the count rate in CPS for background, $t$ is the checking time, $\epsilon_{\gamma}$ is the detection efficiency, $I_{\gamma}$ is emission probability of $\gamma$-ray, $m_s$ is the mass of the sample in (Kg).

3.2. Hazard Indices
The relationship between natural radionuclides can be determined $^{226}$Ra, $^{232}$Th, and $^{40}$K and the risks resulting from them by a set of indicators. In this study, excess life-time cancer risk (ELCR), annual gonadal equivalent dose (AGED) and nine hazard indicators were calculated as follows:

### 3.2.1. The radium equivalent: activity ($Ra_{eq}$)

It is used to describe gamma output from different mixtures of Radium, Thorium and Potassium in substances. It was calculated using special equation depending on activity concentrations $\mathcal{A}_{Ra}, \mathcal{A}_{Th}, \mathcal{A}_{K}$ for $^{226}$Ra, $^{232}$Th, and $^{40}$K respectively [16].

### 3.2.2. The internal hazard indices ($H_{in}$)

It is one of the internal risk factors and calculate from activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K. values of ($H_{in}$) should be less than unity in order not to pose a threat of the population [17].

### 3.2.3. Representative Alpha index ($I_{\alpha}$)

The excess Alpha radiation due to the Radon inhalation originating from the sugar and salt samples were assessed through Alpha index, must be little than one. Alpha index ($I_{\alpha}$) was calculated as follow [16, 18, 19]:

\[ I_{\alpha} = \frac{\mathcal{A}_{Ra}}{200} \quad (2) \]

### 3.2.4. Representative gamma index ($I_{\gamma}$)

This indicator was used to calculate the risk arising from gamma radiation associated with radioactive natural nuclei in the studied samples and calculated from equation depending on activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K [16]. Its value must be less than one in order not to causes any risk to human health.

### 3.2.5. The annual effective dose

Equivalent from outdoor terrestrial gamma radiation was [16, 20]:

\[ D_{eff} = \text{Outdoor dose (nGy.h$^{-1}$)} \times 0.7 (\text{Sv.Gy}$^{-1}$) \times 8760 (\text{h.y}$^{-1}$) \times 0.2 \quad (3) \]

While for indoor exposure, by using an occupancy factor of 0.8, the annual effective dose equivalent was:

\[ D_{eff1} = \text{Indoor dose (nGy.h$^{-1}$)} \times 0.7 (\text{Sv.Gy}$^{-1}$) \times 8760 (\text{h.y}$^{-1}$) \times 0.8 \quad (4) \]

### 3.2.6. Annual Gonadal Equivalent Dose (AGED)

The gonads, the bone marrow and the bone surface cells are considered as organs of one of the important things that UNSCEAR has attached great importance because of their sensitivity to radiation. An increase in (AGED) has been known to affect the bone marrow, causing destruction of the red blood cells that are then replaced by white blood cells, The equivalent annual dose of gonads (AGED) from ($\mathcal{A}_{Ra}, \mathcal{A}_{Th}, \mathcal{A}_{K}$) activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K, respectively, then we would must calculate annual gonadal equivalent dose for sugar and salt samples [21].

### 4. Annual ingestion dose and Excess lifetime cancer risk
The annual ingestion dose ($E_{ING}$) for human was coming from consumption of sugar and salt, the ($E_{ING}$) was calculated using following equation given by [22, 23]:

$$E_{ING} = A_I \times I_P \times FDC_{ING}$$  \hspace{1cm} (5)

Where $E_{ING}$ is the annual ingestion dose (mSv.Bq$^{-1}$), $A_I$ is the activity concentration (Bq.Kg$^{-1}$) of the investigated radionuclides in the sugar and salt, $I_P$ is the consumption rate (Kg.y$^{-1}$) and $FDC_{ING}$ is the ingestion dose coefficient of the $^{226}$Ra, $^{232}$Th and $^{40}$K which was represented in table(7) UNSCEAR(2000).

Cancer risk due to radiation effects which is called excess lifetime cancer risk (ELCR) can be calculated from the following equation [24].

$$ELCR = AEDE \times LS \times RF$$ \hspace{1cm} (6)

$AEDE$: The average Annual Effective Dose Equivalent.

$LS$: is a mean life span for adult (50 years), for children (10 years) and infant (less than 2 year).

By offsetting these variables we will get the (ELCR) of $^{226}$Ra, $^{232}$Th and $^{40}$K in the sugar and salt samples. The value of risk factor (RF) for stochastic effects in the population is 0.05 per Sievert as recommended by ICRP [25]. By using equation (6) to estimate the risk cancer for an adult, children and infant in sugar and salt samples.

5. Result and Discussion

The concentration activity of $^{226}$Ra, $^{232}$Th and $^{40}$K sixteen samples of sugar and salt available in the Iraqi market were measured using NaI(Tl) gamma-ray spectrometry. The results of the natural radioactivity are presented in table(2), the maximum concentration activity of $^{226}$Ra, $^{232}$Th were found in (Su03) from 22.373±2.385 (Bq.Kg$^{-1}$), 10.049±0.971 (Bq.Kg$^{-1}$), respectively, which was the Saudi sugar Alosra (white sugar), it could be that the additives are used to filter the sugar from impurities. In addition to the nature of the soil where sugar cane is grown, while the maximum concentration activity of $^{40}$K was found 239.981±8.150 (Bq.Kg$^{-1}$) from in (Sa08) Iranian Pousan salt, the reason may be the method of treating salt extracted from mines (mineral salt) and using it to produce food salt by dissolving it in water and the degree of purification from the sediments. The minimum value of $^{226}$Ra was found in (Sa02) Zer Turkish salt, and minimum value of $^{232}$Th, $^{40}$K were found in the Iraqi Khazra sugar (Su02) and the Saudi Top -Top sugar (Sa07), respectively. Concentrations of radionuclides found in sugar and salt samples do not exceed the internationally recommended limits.

The ratios were used to provide a simple explanation of the relationship between the three natural radionuclide concentrations. The ratios of ($^{232}$Th - $^{226}$Ra) in table (3) show that there is a convergence between the values of Thorium and Radium at a rate of 4.862 but both are lower than concentration of $^{40}$K concentrations due to the large increase in Potassium concentration. Also, the ratio between the concentrations of ($^{40}$K - $^{226}$Ra) Radium is found to be much lower than potassium, also the ratio ($^{40}$K - $^{232}$Th) is confirm the big difference between concentrations Potassium and Thorium, concentration ratios are ($^{232}$Th - $^{226}$Ra), ($^{40}$K - $^{226}$Ra) and ($^{40}$K - $^{232}$Th) with an average 4.862, 98.204 and 36.422 respectively. Where all three ratios were well above the average worldwide UNSCEAR(2000).

From table(4), we find that the highest values of $\alpha$, $\gamma$ and $Ra_{eq}$ in Sample (Su03) with values 0.111, 0.384 and 52.303 (Bq.Kg$^{-1}$) respectively, but the lower value of $\alpha$, $Ra_{eq}$ were found in Sample (Su02) with value 0.084, 10.142 (Bq.Kg$^{-1}$) respectively, and the lower value of $\gamma$ in sample (Sa05). Also we note the highest values at the sample (Su03), which is the Saudi sugar Alosra (white sugar), and as we mentioned earlier, the reasons may be the additives for the purpose of liquidation, all values
for these three indicators were less than the permissible limit, note that the relationship between $I_\gamma$ and $I_\alpha$ is shown in figure (2).

![Figure 2. Comparison between Alpha index ($I_\alpha$) and Gamma index ($I_\gamma$)](image)

Table (5). All parameters; annual ingestion dose of ($^{226}$Ra, $^{232}$Th and $^{40}$K), $H_{int}$ have a maximum value at the sample (Su03), which is the Saudi sugar Alosra (white sugar) with values (0.0281, 0.064698 and 0.035065) (mSv.y$^{-1}$), 0.201, respectively. While the minimum values of annual ingestion dose of $^{226}$Ra, $^{232}$Th were found in (Sa05) with values 5.01E-05, 0.002413(mSv.y$^{-1}$), respectively, and the minimum value of annual ingestion dose of $^{40}$K 0.001079 (mSv.y$^{-1}$) in sample (Sa03) while the minimum value for internal hazard indices $H_{int}$ in sample (Su02) with values 0.029.

It is important to point out that the gonads has a sensitivity to radiation, an increase in (AGED) causing negative health complications so it is necessary to calculate the annual the equivalent annual dose of gonads (AGED) from $^{226}$Ra, $^{232}$Th and $^{40}$K concentration, and found its maximum value in (Su03) equal to 174.587(mSv.y$^{-1}$) while the minimum value 39.520*10$^{-3}$ (mSv.y$^{-1}$) in sample (Su02), these values were safe and within the global recommended limits[21].

Table (6) explains the relationship between analysis of laboratory data and natural radionuclide concentrations and hazard indicators for the studied sugar and salt samples. Where we found Pearson's correlation was very direct strong relation and positive between the Potassium, Radium and Thorium concentrations with their counterparts. While Pearson's correlation showed significant middle positive where it was statistically significant (p-value < 0.05) it turns out that there is a high increase statistical significance between ($^{40}$K, $^{226}$Ra) also ($^{226}$Ra $^{40}$K), while Pearson's correlation for ($^{40}$K, $^{232}$Th) variables indicates was non-significant which mean high decrease statistical significance (p-value = 0.986), inverse relationship. There is no relationship between $^{226}$Ra and $^{232}$Th there is non-significant which mean high decrease statistical significance (p-value > 0.05), the relationship between $^{232}$Th and $^{226}$Ra direct positivity is weak and there is non-statistical significance. Show up annual ingestion dose of $^{40}$K a positive relationship is weak with concentration activity of $^{40}$K and $^{226}$Ra while the relationship is inverse with $^{232}$Th and there is non-statistical significance (p-value > 0.05) with these nuclides. Which relationship among annual ingestion dose of $^{226}$Ra a positive direct and weak with $^{40}$K and $^{232}$Th and there is non-statistical significance (p-value > 0.05) with these nuclides, while the
relationship is positive direct strong with $^{226}\text{Ra}$, high increase statistical significance, which relationship among annual ingestion dose of $^{232}\text{Th}$ a positive direct and very weak and non-statistical significance ($p$-value $>0.05$).

From table (8) we note that the maximum value of the risk cancer ($ELCR$) due to consumption of sugars for adults as a result of the daily use of sugar in their diet where it is known that adults eat sugar in different foods such as drinks and sweets where we Where we noted that the risk of cancer for adults > children> infants), also we noticed the lowest value of the risk of cancer is in the salt for infants, and that is because the infants are mainly dependent on mother's milk or formula milk and eating salt with foods like soups is relatively few. Where we noted that the risk of cancer for adults > children> infants). Finally we found the maximum value of cancer risk $0.2421\times10^{-3}(\text{mSv.y}^{-1})$ in adult for consumption of sugar while the minimum value $0.0005\times10^{-3}(\text{mSv.y}^{-1})$ in infant, from the results that we obtained that the risk cancer of developing is less than the internationally recommended limits therefore, sugar and salt samples are healthy for consumers.

6.Conclusion

The present study estimated the natural radionuclides of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ by means of gamma ray spectrometry in different samples of sugar and salt that are regularly consumed by the population of Najaf governorate/ Iraq. From our results are confirm that the relatively high concentrations of $^{40}\text{K}$ in sugar and salt samples from Najaf markets are still considered very low from a radiological protection perspective. Annual gonadal equivalent dose (AGED) was calculated to evaluate the radiation hazard of natural radioactivity it was within the permissible limits . Also estimated value of cancer risk was significantly less than the ICRP $2.5 \times 10^{-3}$ based on annual dose limit of 1(mSv) for general public. Which mean the average values of all samples is safe healthy, which confirmed from the average radiation dose of 0.29 (mSv.y$^{-1}$) received per capita world through ingestion of natural radionuclides of consumption of food reported by UNSCEAR (2000), as well as it has been much below the dose limit of $(250–400)\times10^{-3}$ (mSv.y$^{-1}$), recommended by WHO [20]. Finally we can say, sugar and salt samples pose practically no radiological health concern.

Table 2. Specific Activity (Bq.Kg$^{-1}$) in some types of sugar and salt studied

| ID   | $^{226}\text{Ra}$ | $^{232}\text{Th}$ | $^{40}\text{K}$ |
|------|-------------------|-------------------|-----------------|
| Su01 | 2.033±0.719       | 6.950±0.807       | 163.862±6.734   |
| Su02 | 0.762±0.440       | 0.657±0.248       | 109.611±5.508   |
| Su03 | 22.373±2.385      | 10.049±0.971      | 202.061±7.478   |
| Su04 | 5.908±0.859       | 5.071±0.690       | 124.557±5.871   |
| Su05 | 5.593±1.1925      | 6.292±0.768       | 110.44±5.528    |
| Su06 | 8.847±1.219       | 2.066±0.440       | 192.649±7.302   |
| Su07 | 7.562±0.440       | 6.950±0.807       | 64.216±4.216    |
| Su08 | 4.067±1.016       | 2.629±0.496       | 94.110±5.103    |
| Su09 | 2.796±0.843       | 5.729±0.733       | 87.190±9.128    |
| Su10 | 0.508±0.359       | 5.823±0.739       | 89.404±9.746    |
| Su11 | 0.542±0.216       | 8.547±0.895       | 79.44±6.689     |
| Su12 | 18.814±2.187      | 4.977±0.683       | 197.078±7.385   |
| Su13 | 5.08±0.024        | 4.790±0.670       | 198.73±7.416    |
| Su14 | 0.762±0.440       | 8.922±0.915       | 106.56±5.431    |
| Su15 | 19.577±2.230      | 9.674±0.953       | 158.60±6.625    |
| Su16 | 7.881±1.415       | 5.635±0.727       | 239.98±8.150    |
| Max. | 22.373±2.385      | 10.049±0.971      | 239.98±8.150    |
| Min. | 0.508±0.359       | 0.657±0.248       | 64.21±6.216     |
| Ave. | 5.833±1.008       | 5.922±0.721       | 138.65±0.826    |
### Table 3: The ratio of $^{226}$Ra, $^{232}$Th and $^{40}$K in the sugar and salt samples under study

| ID   | $^{232}$Th - $^{226}$Ra | $^{40}$K - $^{226}$Ra | $^{40}$K - $^{232}$Th |
|------|-------------------------|------------------------|------------------------|
| Su01 | 3.417                   | 80.565                 | 23.577                 |
| Su02 | 0.861                   | 143.714                | 166.835                |
| Su03 | 0.449                   | 9.031                  | 20.105                 |
| Su04 | 9.967                   | 244.805                | 24.560                 |
| Su05 | 1.124                   | 19.745                 | 17.552                 |
| Su06 | 0.353                   | 32.944                 | 93.233                 |
| Su07 | 9.112                   | 84.195                 | 9.239                  |
| Su08 | 0.646                   | 23.134                 | 35.785                 |
| Sa01 | 2.048                   | 31.176                 | 15.218                 |
| Sa02 | 11.451                  | 175.819                | 15.353                 |
| Sa03 | 15.769                  | 146.568                | 9.294                  |
| Sa04 | 0.494                   | 8.101                  | 16.394                 |
| Sa05 | 9.419                   | 390.831                | 41.490                 |
| Sa06 | 11.698                  | 139.722                | 11.943                 |
| Sa07 | 0.494                   | 8.101                  | 16.394                 |
| Sa08 | 0.715                   | 30.448                 | 42.585                 |
| Max. | 15.769                  | 390.831                | 166.835                |
| Min. | 0.0                      | 0.0                    | 9.239                  |
| Ave. | 4.862                   | 98.204                 | 36.422                 |
| Worldwide[22] | 0.86                     | 11.43                   | 13.33                  |

### Table 4: Radiation hazard indices of Gamma and Alpha rays in the sugar and salt samples under study

| ID   | $I_\alpha$(Bq.Kg$^{-1}$) | $I_\gamma$(Bq.Kg$^{-1}$) | $Ra_{eq}$(Bq.Kg$^{-1}$) |
|------|---------------------------|---------------------------|--------------------------|
| Su01 | 0.010                     | 0.192                     | 24.590                   |
| Su02 | 0.003                     | 0.084                     | 10.142                   |
| Su03 | 0.111                     | 0.384                     | 52.303                   |
| Su04 | 0.002                     | 0.137                     | 17.352                   |
| Su05 | 0.027                     | 0.173                     | 23.096                   |
| Su06 | 0.029                     | 0.188                     | 23.636                   |
| Su07 | 0.003                     | 0.117                     | 15.646                   |
| Su08 | 0.020                     | 0.116                     | 15.075                   |
| Sa01 | 0.013                     | 0.134                     | 17.703                   |
| Sa02 | 0.002                     | 0.121                     | 15.719                   |
| Sa03 | 0.002                     | 0.142                     | 18.847                   |
| Sa04 | 0.094                     | 0.306                     | 41.107                   |
| Sa05 | 0.0020                    | 0.183                     | 22.661                   |
| Sa06 | 0.003                     | 0.165                     | 21.727                   |
| Sa07 | 0.097                     | 0.332                     | 45.623                   |
| Sa08 | 0.039                     | 0.268                     | 34.418                   |
| Max. | 0.111                     | 0.384                     | 52.303                   |
| Min. | 0.0020                    | 0.084                     | 10.142                   |
| Ave. | 0.0291                    | 0.190                     | 24.980                   |
| Worldwide[27] | < 1                      | < 1                       | < 370                    |

Note: error range was in most cases within 6%
Table 5. The annual ingestion dose, the annual gonadal equivalent dose and the internal hazard indices in sugar and salt Samples under study

| ID   | $^{226}$Ra (mSv·y$^{-1}$) | $^{232}$Th | $^{40}$K (mSv·y$^{-1}$) | AGED*10$^{-3}$ | $H_{int}$ |
|------|--------------------------|------------|-------------------------|---------------|-----------|
| Su01 | 0.0025                   | 0.044742   | 0.028436               | 86.788        | 0.071     |
| Su02 | 0.0009                   | 0.00423    | 0.019022               | 39.520        | 0.029     |
| Su03 | 0.0281                   | 0.064698   | 0.035065               | 174.587       | 0.201     |
| Su04 | 0.0006                   | 0.032649   | 0.021615               | 61.881        | 0.048     |
| Su05 | 0.0070                   | 0.040506   | 0.019166               | 78.262        | 0.077     |
| Su06 | 0.0073                   | 0.013302   | 0.033432               | 87.198        | 0.079     |
| Su07 | 0.0009                   | 0.044744   | 0.011144               | 51.572        | 0.044     |
| Su08 | 0.0051                   | 0.01693    | 0.016332               | 53.113        | 0.051     |
| Sa01 | 0.0002                   | 0.002886   | 0.001184               | 59.967        | 0.055     |
| Sa02 | 5.01E-05                 | 0.002933   | 0.001214               | 53.985        | 0.043     |
| Sa03 | 5.34E-05                 | 0.004305   | 0.0001079              | 62.345        | 0.052     |
| Sa04 | 0.0018                   | 0.002507   | 0.002676               | 140.825       | 0.161     |
| Sa05 | 5.01E-05                 | 0.002413   | 0.002698               | 83.997        | 0.062     |
| Sa06 | 7.52E-05                 | 0.004494   | 0.001447               | 73.115        | 0.060     |
| Sa07 | 0.0019                   | 0.004873   | 0.002154               | 150.731       | 0.176     |
| Sa08 | 0.0007                   | 0.002839   | 0.003258               | 123.263       | 0.114     |
| Max. | 0.0281                   | 0.064698   | 0.035065               | 174.587       | 0.201     |
| Min. | 5.01E-05                 | 0.002413   | 0.001079               | 39.520        | 0.029     |
| Ave. | 0.0036                   | 0.0180     | 0.012495               | 86.321        | 0.0715    |

Note: error range was in most cases within 5%

Table 6. Pearson Correlation with its P-value for all parameters studied

| Laboratory data |
|-----------------|
| **Variables**   | **Correlations** | **$^{40}$K** | **$^{226}$Ra** | **$^{232}$Th** |
| $^{40}$K        | Pearson Correlation | 1               | 0.563*          | -0.005         |
|                 | P value             | 0.023           | 0.986           |                |
| $^{226}$Ra      | Pearson Correlation | 0.563*          | 1               | 0.376          |
|                 | P value             | 0.023           | 0.151           |                |
| $^{232}$Th      | Pearson Correlation | -0.005          | 0.376           | 1              |
|                 | P value             | 0.986           | 0.151           |                |
| Annual ingestion dose of $^{40}$K | Pearson Correlation | 0.224          | 0.147           | -0.205         |
|                 | P value             | 0.404           | 0.588           | 0.447          |
| Annual ingestion dose of $^{226}$Ra | Pearson Correlation | 0.338          | 0.611*          | 0.277          |
|                 | P value             | 0.201           | 0.012           | 0.298          |
| Annual ingestion dose of $^{232}$Th | Pearson Correlation | 0.007          | 0.200           | 0.311          |
|                 | P value             | 0.979           | 0.459           | 0.241          |

* Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).**

**Table 7.** Dose convection factors for different radionuclides in (nSv.Bq⁻¹) [UNSCEAR 2000]

| Nuclides | infant | children | adult |
|----------|--------|----------|--------|
| ⁶⁰K      | 42     | 13       | 6.2    |
| ²²⁶Ra    | 960    | 800      | 280    |
| ²³²Th    | 450    | 290      | 230    |

**Table 8.** Consumption rate and cancer risk in sugar and salt samples for adult, children and infant

| sample Categories | Age    | Consumption rate [28] | cancer risk (mSv)*10⁻³ |
|-------------------|--------|------------------------|------------------------|
|                   |        | (Kg.y⁻¹)               | (tsp.y⁻¹)              |
| Sugar             | Adult  | 27.99                  | 6997.51                | 0.2421                |
| Sugar             | Children | 9.125               | 2281.25                | 0.0337                |
| Sugar             | Infant | 1.095                 | 273.75                 | 0.0014                |
| Salt              | Adult  | 2.19                   | 547.5                  | 0.0232                |
| Salt              | Children | 1.468               | 365                    | 0.0065                |
| Salt              | Infant | 0.365                 | 91.25                  | 0.0005                |

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**References**

1. Whicker, F.W. and V. Schultz, *Radioecology: nuclear energy and the environment*. Vol. 1. 1982: CRC press Boca Raton, FL.
2. Oliver, M., *Soil and human health: a review*. European Journal of soil science, 1997. 48(4): p. 573-592.
3. El-Arabi, A.M., ²²⁶Ra, ²³²Th and ⁴⁰K concentrations in igneous rocks from eastern desert, Egypt and its radiological implications. Radiation Measurements, 2007. 42(1): p. 94-100.
4. Cubadda, F., et al., *Dietary exposure of the Italian population to inorganic arsenic: The 2012–2014 Total Diet Study*. Food and chemical toxicology, 2016. 98: p. 148-158.
5. Drewnowski, A. and B.M. Popkin, *The nutrition transition: new trends in the global diet*. Nutrition reviews, 1997. 55(2): p. 31-43.
6. Njinga, R.L., V.M. Tshivhase, and F.B. Yusuf, *The natural radioactivity in some tropical fruit juices in Lapai metropolis by gross alpha and gross beta measurements*. 2016.
7. Covello, V.T. and M.W. Merkhoher, *Risk assessment methods: approaches for assessing health and environmental risks*. 2013: Springer Science & Business Media.
8. Mennella, J.A. and N.K. Bobowski, *The sweetness and bitterness of childhood: Insights from basic research on taste preferences*. Physiology & behavior, 2015. 152: p. 502-507.
11. Rožmarić, M., et al., Radiological characterization of tap waters in Croatia and the age
dependent dose assessment. Chemosphere, 2014. 111: p. 272-277.

10. Clark, R. US Environmental Protection Agency Radiation Protection Programs for Waste
Management and Site Cleanup. 2008. WM Symposia, 1628 E. Southern Avenue, Suite 9-332,
Tempe, AZ 85282 (United…

11. Verdun, F.R. and P. Schnyder, Reduction of radiation doses to staff during diagnostic X-ray
procedure. European Radiology Supplements, 2004. 14(1): p. 84-90.

12. Shabaan, D.H. Radioactivity measurements of different types of salt using SSNTD. in AIP
Conference Proceedings. 2018. AIP Publishing LLC.

13. Ahmed, A.H. and A.I. Samad, Measurement of radioactivity levels in daily intake foods of
Erbil city inhabitants. Journal of Zankoy Sulaimani Part A, 2014. 16(4): p. 111-121.

14. Alaboodi, A.S., A.M. Hassan, and A.A. Muhmood. Study the Health risk of Radioisotopes in
different samples of salt in markets of Iraq. in Journal of Physics: Conference Series. 2019.
IOP Publishing.

15. Makki, N.F., et al., Natural Radioactivity Measurements in different regions in Najaf city,
Iraq. International Journal of Computer Trends and Technology, 2014. 9(6): p. 286-9.

16. Hamza, Z.M., S.A. Kadhim, and H.H. Hussein. ASSESSMENT THE NORMS FOR
AGRICULTURAL SOILS IN GHAMMAS TOWN, IRAQ. Plant Archives, 2019. 19(1): p. 1483-
1490.

17. Little, M., et al., New models for evaluation of radiation-induced lifetime cancer risk and its
uncertainty employed in the UNSCEAR 2006 report. Radiation research, 2008. 169(6): p. 660-
676.

18. Salih, N.F., Determination of natural radioactivity and radiological hazards of 226Ra, 232Th,
and 40K in the grains available at Penang Markets, Malaysia, using high-purity germanium
detector. ARO-The Scientific Journal of Koya University, 2018. 6(1): p. 71-77.

19. Najam, L.A., N.F. Tawfiq, and F.H. Kitha, American Journal of Engineering Research
(AJER)

20. Rangaswamy, D., et al., Measurement of terrestrial gamma radiation dose and evaluation of
annual effective dose in Shimoga District of Karnataka State, India. Radiation Protection and
Environment, 2015. 38(4): p. 154.

21. Hassan, N.M., et al., Assessment of the natural radioactivity using two techniques for the
measurement of radionuclide concentration in building materials used in Japan. Journal of
radioanalytical and nuclear chemistry, 2010. 283(1): p. 15-21.

22. Charles, M., UNSCEAR Report 2000: sources and effects of ionizing radiation. Journal of
Radiation Protection, 2001. 21(1): p. 83.

23. Aswood, M.S., M.S. Jaafar, and N. Salih, Estimation of annual effective dose due to natural
radioactivity in ingestion of vegetables from Cameron Highlands, Malaysia. Environmental
Technology & Innovation, 2017. 8. p. 96-102.

24. Avwiri, G., C. Ononugbo, and I. Nwokeoji, Radiation Hazard Indices and Excess Lifetime
cancer risk in soil, sediment and water around mini-okoro/ogingba creek, Port Harcourt,
Rivers State, Nigeria. Comprehensive Journal of Environment and Earth Sciences, 2014. 3(1):
p. 38-50.

25. James, A. and A. Birchall, New ICRP lung dosimetry and its risk implications for alpha
emitters. Radiation Protection Dosimetry, 1995. 60(4): p. 321-326.

26. Talab, A.H.D., et al., Evaluation the effect of individual and demographic factors on
awareness, attitude and performance of radiographers regarding principles of radiation
protection. Al Am een J Med Sci, 2016. 9(2): p. 90-5.

27. Radiation, U.N.S.C.o.t.E.o.A., Sources and effects of ionizing radiation: sources. Vol. 1.
2000: United Nations Publications.

28. Fidler Mis, N., et al., Sugar in infants, children and adolescents: a position paper of the
European Society for Paediatric Gastroenterology, Hepatology and Nutrition Committee on
Nutrition. Journal of pediatric gastroenterology and nutrition, 2017. 65(6): p. 681-696.