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Measurement of Natural Radioactivity Concentrations in Local and Imported Truffle Samples

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***Abstract*— In this study, gamma spectroscopy with NaI(Tl) was used to measure the specific activity of natural radio nuclides uranium, thorium, uranium potassium, radium equivalent, annual effective dose, and excess lifetime cancer risk (ELCR) of truffles from the north of Iraq to the south and from the east to the west, as well as samples that were brought in from other countries. The average concentrations of ^{226}Ra, ^{238}U, ^{232}Th, and ^{40}K were 1.32±0.089 Bq/kg, 1.37±0.092 Bq/kg, 1.56±0.119 Bq/kg, and 23.31±0.958 Bq/kg, respectively. It was found that the gamma ray hazard scores and the extra lifetime cancer risk were about the same as the world average.**

Keywords*— NaI (Tl), Activity concentration, Effective dose, Truffles, Merilani beaker.

I. INTRODUCTION

People are constantly being exposed to ionizing radiation because of background radiation. Uranium, thorium, their daughter, and potassium are the main sources of ionizing radiation in the Earth's crust, and people are constantly exposed to them [1-4]. Earth has these radionuclides since the beginning of Earth formation [5]. Recently, studies have shown that, in normal situations, over 70% of the total nuclear dose that people receive each year comes from natural sources of ionizing radiation. Five-fourths of this amount is due to breathing in or eating the naturally radioactive gas radon ^{222}Rn and its byproducts. Long-term exposure to radon through breathing it in in caves, small rooms, or open air that is full of radon gas is the cause of about 10% of all lung cancer deaths [6-7]. ^{222}Rn is one of three naturally occurring isotopes of radon (^{222}Rn is an inert radioactive gas with a half-life of 3.82 days and belongs to the radioactive Uranium series. ^{220}Rn is called Thoron, and belongs to the ^{232}Th decay series with a half-life of 55.5 sec). ^{219}Rn is called Actinon, and belongs to the ^{235}U decay series with a half-life of 4 sec. It is produced directly from^{226}Ra, which is a child of ^{238}U. Because its half-life is pretty long (3.82 days), it can travel a long way before breaking down, and you can find it in soil gas layers all over the world. Radium concentration is also a significant hazard to human health, because it decays promptly after creation by emitting gamma rays. However, it is interesting to study other gamma emitters present in the environment, and they are: ^{232}Th, ^{228}Ra, ^{238}U, and ^{40}K. These radioactive isotopes are a matter of investigation by many researchers; in soil gas, building materials, water, and even atmospheric air [8-12]. In order to give a full analysis of background radiation in the environment and its effect on human health, we measured gamma concentration emitted by natural radioactive sources using a NaI(Tl) instrument. Truffles are a type of fungus belonging to the truffle family. They grow on the ground and vary in size based on the differences in species. Truffles belong to the genus of tubers that grow under the surface of the ground or on or near the roots [13]. Truffles grow underground at a depth of between 5-10 cm, and when they are mature, they are collected by skilled specialists. Truffles grow in arid or semi-arid desert areas, and their distribution varies due to different environmental conditions and the presence of plants with which they coexist Truffles do not consist of seeds or roots. They are fungal nitrogenous complexes of nitrogen and hydrogen gas present in the atmosphere, which combine under an electric spark (lightning). This fungus does not germinate until after the occurrence of lightning and thunder accompanying rainstorms, as lightning increases the formation of nitrogen oxide in the air to combine with water droplets falling from the sky to the ground, and then an amino compound is formed that rotates in a rapid motion that collects the salts and minerals present in the soil, forming types of Among the fungi are truffles, which are equivalent to meat in terms of content, benefit and taste [14]. Because of the importance of this food substance, which is of natural origin and is found in soil that has been exposed to radioactive pollutants through the wars that Iraq has experienced in recent decades, it was imperative for us to conduct such studies. The aim of this study is to measure the level of natural radioactivity in samples of local and imported truffles using gamma spectroscopy.

II. MATERIALS AND METHODS

A. Sampling

The study included several areas from the north of Iraq to the south and from the east to the west, as well as imported samples for the purpose of measuring and comparing them with the samples of this study in terms of the amount of natural radioactivity for each of them due to the exposure of these areas during the wars on Iraq 1990 and 2003, which is believed that some of these

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locations were bombed with bombs containing depleted uranium. 16 samples of truffles (each sample 600 g) were collected in Table 1. The samples were dried by heating them in the oven at 110 degrees Celsius, then ground and placed in the Merilani beaker. They were left for a month for the purpose of radioactive equilibrium, after which they were the gamma rays emitted by the radioactive isotopes (^{226}Ra, ^{238}U, ^{232}Th, and ^{40}K) present in the truffle samples were then measured using a sodium iodide detector.

TABLE 1. TRUFFLES SAMPLES INFORMATION

S.N	Sample location
T_1	Safuan, Basrah
T_2	AL-Zebair, Basrah
T_3	AL-Bitera, Measan
T_4	Said-Ahmed, Measan
T_5	Druga, Smawa
T_6	AL-Jfir, Smawa
T_7	Shibcha, Najaf
T_8	Rabeah, Mosal
T_9	Mkhul, Slah-ALDean
T_{10}	AL-Dibs, Slah-ALDean
T_{11}	AL-Nama, Slah-ALDean
T_{12}	AL-wrar, AL-Anber
T_{13}	AL-Rtba, AL-Anber
T_{14}	Syria
T_{15}	Iran
T_{16}	China

B. Gamma Ray Spectroscopy

A 3"x3" NaI(Tl) detector that is well -regulated and highly shielded was used for gamma-ray spectroscopy in this work. A lead shield 5cm thick surrounds the detector to cut down on unwanted noise. The instrument was manufactured by an American company (Alpha SpectraInc, Mai 3*3) and includes a computer-based multichannel scanner for data collection and software to control data collection. Standard ^{57}Co, ^{60}Co, and ^{137}Cs sources were used to calibrate the system, and a Merilani beaker blank was used to measure the background radiation for 7,200 seconds. Fig. 1 represents the gamma-ray spectrum of a truffle sample. The count rate (area under the peak) for each peak was found, using Spectrum Techniques (Windows R and Macintosh R) Software and operating Manuals Code 040813.

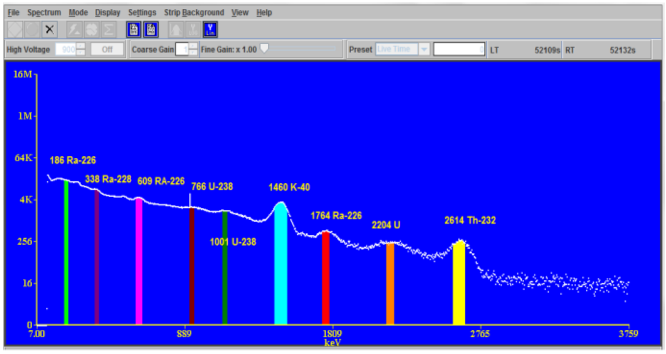

Fig. 1: Truffles sample gamma spectrum measured by NaI(Tl).

The following equation was used to find the activity concentration of each natural isotope [15];

$$A = \frac{Net\ count}{\varepsilon \times I_\gamma \times M \times t} \quad ......(1)$$

A is the specific activity (Bq/kg). The absolute gamma peak efficiency of the detector at the specific gamma-ray energy is given by ε. I_γ is the decay intensity for the specific energy peak, which includes information on the decay branching ratio. M is the sample's mass in kg, and t is the measurement's counting time in seconds. The following method is used to figure out the variance in the activity concentration [16].

$$\Delta A = A\left[\left(\frac{\Delta N_C}{N_C}\right)^2 + \left(\frac{\Delta\varepsilon}{\varepsilon}\right)^2 + \left(\frac{\Delta I_\gamma}{I_\gamma}\right)^2 + \left(\frac{\Delta M}{M}\right)^2\right]^{\frac{1}{2}} \quad ....(2)$$

M is the sample's mass in kg, and t is the measurement's counting time in seconds. The radium equivalent activity (Raeq) is used to determine the dangerous things that contain ^{226}Ra, ^{232}Th, and ^{40}K in Bq kg^{-1}. Since 370 Bq kg^{-1} of ^{226}Ra, 260 Bq kg^{-1} of ^{232}Th and 4810 Bq kg^{-1} of of ^{226}Ra, 260 Bq kg^{-1} of ^{232}Th and 4810 Bq kg^{-1} of ^{40}K all give off the same amount of γ dose, this is possible. The following equation can be used to find out what a sample's Raeq is in Bq kg^{-1} [17-18]:

$$Ra_{eq} = (A_{Ra}) + (A_{Th} \times 1.43) + (A_K \times 0.077) \quad ....(3)$$

Raeq has said that 370 Bq kg^{-1} is the highest number that can be used [19,20]. The exterior and internal hazard indices are used to measure the danger of natural gamma radiation. The main purpose of this measure is to keep the radiation dose below the allowed dose equivalent limit of about 1mSvy^{-1}. To judge this score, you can use the following relationships [12].

$$H_{ex} = \left({A_{Ra}}/{370} + \left({A_{Th}}/{259} + \left({A_K}/{4810}\right)\right)\right) \quad ....(4)$$

$$H_{in} = \left({A_{Ra}}/{185} + \left({A_{Th}}/{259} + \left({A_K}/{4810}\right)\right)\right) \quad ....(5)$$

This takes into account the fact that the soil's highest radium-equivalent activity level of 370 Bq/kg is the same as the gamma radiation danger that comes from the outside. To determine the yearly effective dose rate in air, you need to know the conversion coefficient between the dose that is absorbed in the air and the absorbed dose that an adult receives. The number given here is 0.7 SvGy-1 for moderately energetic gamma radiation exposure in the environment. This value was reported in UNSCEAR 2000 and UNSCEAR 1993. The occupancy rate for open areas is about 0.2. The following method can be used to find the annual effective dose equivalent [19]:

$$AEDE_{oo}\left({mSv}/{y}\right) = D\left({nGy}/{h} \times 8760\left({h}/{y}\right)\right) \times 0.2 \times 0.7\left({Sv}/{Gy} \times 10^{-6}\right)$$

...(6)

When measuring inside, the population factor is about 0.8, which is also true for building materials. Because of this, equation 6 looks like this:

$$AEDE_{in}\left(\frac{mSv}{y}\right) = D\left(\frac{nGy}{h}\right) * 8760\left(\frac{h}{y}\right) * 0.8 * 0.7\left(\frac{Sv}{Gy}\right) * 10^{-6} \quad ...\ (7)$$

The average yearly effective dose equivalent (AEDE) of gamma radiation from sources inside or outside the Earth is 0.560 mSv/y [21].

TABLE 2.The specific activity of natural radioactive isotopes of uranium, thorium, radium, and potassium in truffle samples

S. N	Regin Name	^{226}Ra (Bq/kg)	^{238}U (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)
1	Safuan, Basrah	1.842±0.129	1.881±0.131	1.7012±0.126	317.110±1.381
2	AL-Zebair, Basrah	1.784±0.124	1.761±0.122	1.311±0.097	278.482±1.211
3	AL-Bitera, Measan	1.873±0.132	1.441±0.099	1.601±0.118	252.711±1.098
4	Said-Ahmed , Measan	1.425±0.098	1.612±0.11	1.323±0.097	259.351±1.126
5	Druga,Smawa	1.412±0.097	1.481±0.101	1.312±0.096	229.752±0.997
6	AL-Jfir, Smawa	1.491±0.102	1.682±0.114	2.371±0.173	135.663±0.588
7	Shibcha, Najaf	1.423±0.097	1.561±0.105	1.452±0.105	256.822±1.113
8	Rabeah, Mosal	1.042±0.071	1.101±0.074	1.201±0.086	285.461±1.237
9	Mkhul, Slah-ALDean	0.681±0.046	0.972±0.065	0.951±0.068	219.944±0.953
10	AL-Dibs, Slah-ALDean	0.931±0.062	1.041±0.069	1.794±0.121	262.573±1.137
11	AL-Nama, Slah-ALDean	0.824±0.045	0.992±0.065	0.962±0.064	271.442±1.176
12	AL-wrar, Anber	1.022±0.067	1.212±0.079	2.073±0.182	276.871±1.199
13	AL-Rtba, Anber	1.273±0.083	1.325±0.086	1.055±0.091	253.05±1.096
14	Syria	1.822±0.117	1.412±0.091	1.014±0.087	234.972±1.017
15	Iran	1.373±0.089	1.532±0.099	1.732±0.149	242.191±0.918
16	China	1.062±0.068	1.071±0.069	2.981±0.256	257.454±0.975
Max.		1.873±0.132	1.881±0.131	2.981±0.256	317.110±1.381
Min.		0.681±0.046	0.972±0.065	0.951±0.068	135.663±0.588
Ave.		1.277±0.089	1.426±0.098	1.966±0.162	226.386±0.984

where

$$D\left(\frac{nGy}{h}\right) = 0.0417A_K + 0.462A_{Ra} + 0.606A_{T_h} \ldots\ldots\ldots\ldots\ldots \quad \ldots(8)$$

III. RESULTS AND DISCUSSION

The specific activity of ^{226}Ra, ^{238}U, ^{232}Th, and ^{40}K in Bq kg^{-1} is shown in Table 2. The specific activity of ^{226}Ra. Ranged from 0.68±0.046 Bq/kg to 1.87±0.13 Bq/kg, with a mean value of 1.32±0.089 Bq/kg, which is below the safe limit of 50 Bq/kg [22]. Different parts of the world don't have the same amounts or locations of these radioactive isotopes.

The average value of ^{238}U is 1.37±0.092 Bq/kg, which is less than the 50 Bq/kg that UNSEAR a safe place should have. It takes between 0.97±0.065 Bq/kg and 1.88±0.131 Bq/kg of ^{238}U to be exact. ^{232}Th specific Activity ranged from 0.95±0.068 Bq/kg to 2.98±0.256 Bq/kg, with average 1.56± 0.119 Bq/kg being the mean number. The percentage of ^{40}K varies from 135.66±0.588 Bq/kg to 317.11±1.38 Bq/kg, with average of 236.31± 0.958 Bq/kg, which is less than the average value of 500 Bq/kg around the world [20]. Figure 2 shows the specific activity of radioactivity (in Bq/kg) compared to the number of statistically significant truffle samples.

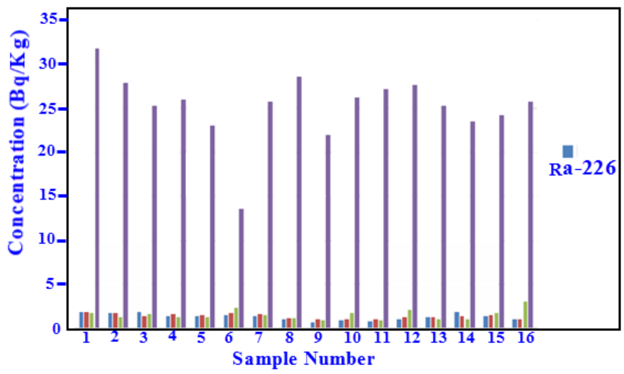

Fig. 2: The radioactivity concentrations in Bq/kg as a function of truffle sample numbers.

As shown in Figures 3-5 and Table 3, the radium equivalent activity Raeq is linked to both the external gamma dose and the internal dose to radon and its daughters. The study found that the Raeq ranged from 15.32 Bq/kg to 28.69 Bq/kg, with 22.97 Bq/kg being the average. The safe amount for UNSCEAR is 370 Bq/kg, which is below this figure. As it should be, the numbers of internal and external hazards are not all the same in all cases. The average effective dose (AEDE) for outside and inside is 0.02 mSv/y and 0.06 mSv/y, respectively. Both of these values are less than 0.56 mSv/y [22]. The calculated of gamma dose rat D(nGy/h) varied from 7.78 nGy/h to 15.1 nGy/h and average 12.07 nGy/h and this also less than 55 nGy/h , It is the highest value for the recommended dose rate worldwide [23].

TABLE 3. Radiation hazard parameters.

S.N	Regin Name	Ra_{eq} (Bq/kg)	H_{ex}	H_{in}	D (nGy/h)	$AEDE_{in}$ (msv/y)	$AEDE_{out}$ (msv/y)
1	Safuan, Basrah	28.690	0.080	0.082	15.100	0.070	0.020
2	AL-Zebair, ,Basrah	25.107	0.075	0.073	13.236	0.062	0.026
3	AL-Bitera, Measan	23.615	0.064	0.075	12.374	0.064	0.024
4	Said-Ahmed –Measan	23.284	0.063	0.063	12.273	0.063	0.023
5	Druga, Smawa	21.253	0.062	0.064	11.141	0.052	0.012
6	AL-Jfir, Smawa	15.321	0.042	0.052	7.780	0.040	0.010
7	Shibcha-AL-Najaf	23.272	0.063	0.072	12.242	0.064	0.024
8	Rabeah, Mosal	24.737	0.073	0.075	13.113	0.062	0.023
9	Mkhu, Slah-ALDean	18.982	0.052	0.052	10.061	0.054	0.012
10	AL-Dibs, Slah-ALDean	23.716	0.064	0.074	12.463	0.062	0.021
11	AL-Nama, Slah-ALDean	23.092	0.066	0.061	12.285	0.065	0.022
12	AL-wrar, Anber	25.306	0.072	0.074	13.276	0.071	0.024
13	AL-Rtba, Anber	22.252	0.061	0.061	11.772	0.075	0.012
14	Syria	21.345	0.065	0.064	11.246	0.063	0.014
15	Iran	22.493	0.063	0.063	11.782	0.067	0.016
16	China	25.154	2 0.07	0.072	13.037	0.062	0.027
Max.		28.690	0.080	0.082	15.100	0.070	0.020
Min.		15.321	0.042	0.052	7.780	0.040	0.010
Vae.		22.005	0.061	0.067	11.440	0.055	0.015

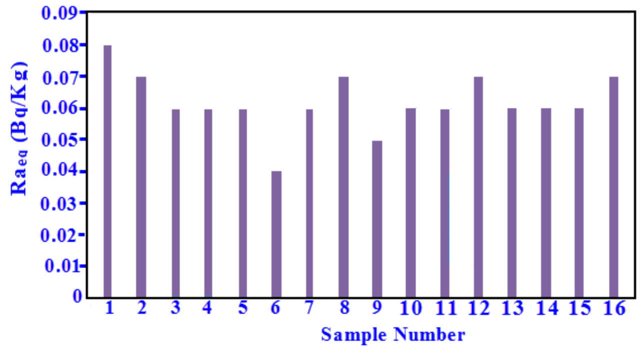

Fig. 3: The distribution of the value of Ra_{eq} in Bq/kg as a function of sample number

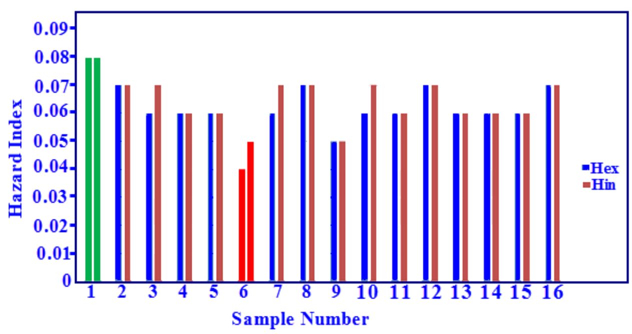

Fig. 5: The values of external H_{ext} and internal H_{in} hazard as a function of sample number.

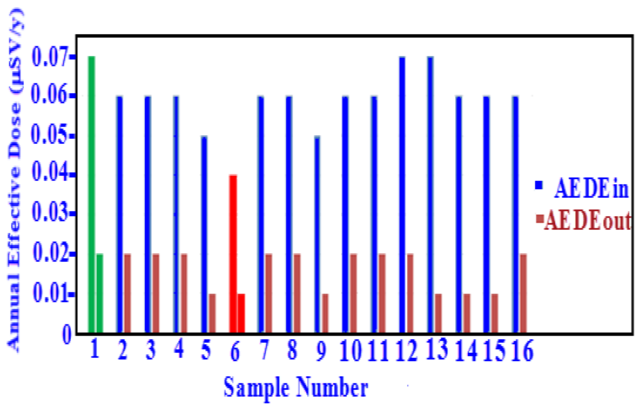

Fig. 4: The values of the annual effective dose in the unit of mSv/y as a function of sample number.

IV. EXCESS LIFETIME CANCER RISK

The following factors might be taken into consideration when evaluating the excess lifetime cancer risk, which is caused by gamma radiation effects [24-25].

$$ELCR = AEDE \times DL \times RF \qquad \text{....... (9)}$$

In this case, AEDE, DL , and RF. It indicates the annual effective dosage, standard age (D=70 years), and risk factor, respectively. As advised by the ICRP for stochastic impacts, the public's risk factor (RF) is 0.05 per Sievert [26]. The gamma ray spectroscopy approach was used to calculate the excess lifetime cancer risk (ELCR) and annual effective dose equivalent (AEDE) values for both indoor and outdoor gamma exposures. Equations 6, 7, 8, and 9 were used to perform the mathematical computations of these data as illustrated in Fig. 6 and Table 4. The ranges of $AEDE_{oo}$, $AEDE_{in}$, $ELCR_{in}$, and

$ELCR_{oo}$ measured by gamma ray spectroscopy were 0.01-0.02 mSv/y, 0.04 - 0.07 mSv/y, 0.14 - 0.245, and 0.035 - 0.07 with averages of 0.02 mSv/y, 0.06 mSv/y, 0.28 $x10^{-3}$ and0.075$x10^{-3}$ respectively as demonstrated in Table 4.

TABLE 4. Annual effective dose equivalent (AEDE), and excess lifetime cancer risk (ELCR)

S.N	Regin Name	$AEDE_{in}$ (msv/y)	$AEDE_{out}$ (msv/y)	$ELCR_{in}$ $x10^{-3}$ (msv/y)	$ELCR_{out}$ $x10^{-3}$ (msv/y)
1	Safuan, Basrah	0.073	0.021	0.245	0.070
2	AL-Zebair, Basrah	0.062	0.022	0.211	0.070
3	AL-Bitera , Measan	0.064	0.021	0.221	0.070
4	Said-Ahmed , Measan	0.061	0.021	0.211	0.070
5	Druga, Smawa	0.054	0.012	0.175	0.035
6	AL-Jfir,Smawa	0.042	0.011	0.124	0.035
7	Shibcha, Najaf	0.062	0.021	0.211	0.070
8	Rabeah, Mosal	0.063	0.022	0.221	0.070
9	Mkhul,Slah-ALDean	0.054	0.012	0.175	0.035
10	AL-Dibs,Slah-ALDean	0.061	0.021	0.211	0.070
11	AL-Nama,Slah-ALDean	0.065	0.022	0.231	0.070
12	AL-wrar, AL-Anber	0.073	0.021	0.245	0.070
13	AL-Rtba, AL-Anber	0.072	0.012	0.245	0.035
14	Syria	0.063	0.011	0.211	0.035
15	Iran	0.062	0.011	0.221	0.035
16	China	0.061	0.022	0.211	0.070
	Max.	0.073	0.022	0.245	0.070
	Min.	0.042	0.011	0.124	0.035
	Ave.	0.057	0.016	0.208	0.075

V. CONCLUSIONS

Based on the gamma ray spectroscopy used in this work, the concentrations of natural radioactive isotopes ^{226}Ra and U^{238} were measured in truffle samples, where 16 samples were measured، taken from several areas from the north of Iraq to the south and from the east to the west, as well as imported samples for the purpose of measuring and comparing them with the samples of this study in terms of the amount of natural radioactivity for each of them due to the exposure of these areas during the wars on Iraq 1990 and 2003. It is found that the study levels are considered within acceptable levels. The activity concentration of ^{226}Ra and U^{238} in truffle samples. The results obtained showed that the concentration of these isotopes is within the recommended safety limits, and no artificial radionuclides were detected in any sample measured. Finally, the results obtained regarding the natural radioactivity of the radioisotopes present in the truffle samples in this study were all below the internationally permissible limits as indicated.

CONFLICT OF INTEREST

Authors declare that they have no conflict of interest.

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