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Determination of Natural Radionuclides for Ground Shapes in Tar Al-Najaf , Iraq

*** Heiyam Najy Hady** **Zahraa Mohammed Mashkor**

Department of Physics, Faculty of Education for Girls, University of Kufa, Najaf, Iraq.

*Corresponding Author E-mail: hiyamn.alkhafaji@uokufa.edu.iq

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ABSTRACT

The natural radioactivity of the earth formations of Tar Al-Najaf region in Al-Najaf Al-Ashraf governorate has been studied , which is considered one of the most important archaeological areas in the province. As Tar Al-Najaf is one of the natural phenomena prominently present in the governorate, as it cuts sharply to form a rocky cliff, as well as overlooks from the southern end of a plateau Al-Najaf and on the sea of Al-Najaf, in a clear and surprising way, Al-Najaf flew, by selecting 30 sites to take soil samples from the region, and spectral measurements were made using gamma-ray spectroscopy (NaI(Tl)) (3 " × 3"). It was found that the specific activity of ^{238}U, ^{232}Th and ^{40}K in the studied ranged between (27.644 ± 1.505) $Bq.kg^{-1}$to (6.530 ± 0.509) $Bq.kg^{-1}$with average (15.955) $Bq.kg^{-1}$, (31.06 ± 1.73) $Bq.kg^{-1}$ to (8.356±1.013) $Bq.kg^{-1}$with average (21.728) $Bq.kg^{-1}$and (475.391 ± 7.870) $Bq.kg^{-1}$to (95.173 ± 1.994) $Bq.kg^{-1}$ with average (281.197) $Bq.kg^{-1}$respectively. As per radium equivalent, it was between (101.084) $Bq.kg^{-1}$to (37.576)$Bq.kg^{-1}$ with average (68.678) $Bq.kg^{-1}$, and the activity concentration index ranged between (0.756) $Bq.kg^{-1}$to (0.272) $Bq.kg^{-1}$with average (0.510)) $Bq.kg^{-1}$, while the external hazard index ranged from (0.272) $Bq.kg^{-1}$ to (0.101) $Bq.kg^{-1}$, with rate (0.184)$Bq.kg^{-1}$. Comparing the present results with the globally considered values, it was found that the radiation levels of the studied samples are within the permissible limits.

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تحديد النويدات المشعة الطبيعية للأشكال الأرضية في طار النجف – العراق

هيام ناجي هادي **زهراء محمد مشكور**

قسم الفيزياء -كلية التربية للبنات- جامعة الكوفة- النجف- العراق

الكلمات المفتاحية:

النشاط الإشعاعي الطبيعي

الـــخُـــلاصـــة

تم دراسة النشاط الاشعاعي الطبيعي للتشكيلات الارضية لمنطقة طار النجف في محافظة

النجف الاشرف والتي تعد من أهم المناطق الأثرية في المحافظة إذ يعد طار النجف من الظواهر الطبيعية الموجودة بشكل بارز في المحافظة، حيث يقطع الهضبة بصورة حادة لتكون الجرف الصخري، وكذلك يطل من الطرف الجنوبي من هضبة النجف وعلى بحر النجف بصورة واضحة ليكون طار النجف وذلك من خلال اختيار 30 موقعا لأخذ عينات التربة من المنطقة وأجريت القياسات الطيفية باستعمال منظومة كاشف يوديد الصوديوم المنشط بالثاليوم $NaI\ (TI)$ (3″×3″). وجد ان الفعالية النوعية لكل من اليورانيوم ^{238}U و الثوريوم ^{232}Th و البوتاسيوم ^{40}K في النماذج المدروسة تتراوح بين (27.644±1.505)$Bq.kg^{-1}$ الى (6.530±0.509) $Bq.kg^{-1}$ وبمعدل (15.955)$Bq.kg^{-1}$ و (31.060±1.730 $Bq.kg^{-1}$ الى (8.356±1.013) $Bq.kg^{-1}$ وبمعدل (21.728)$Bq.kg^{-1}$ و (475.391±7.870)$Bq.kg^{-1}$ الى (95.173±1.994) $Bq.kg^{-1}$ وبمعدل (281.197)$Bq.kg^{-1}$ على التوالي. كما حسب مكافئ الراديوم وكان يتراوح بين (101.084) $Bq.kg^{-1}$ الى (37.576)$Bq.kg^{-1}$ وبمعدل (68.678) $Bq.kg^{-1}$، ومعامل تركيز الفعالية تراوح بين (0.756) $Bq.kg^{-1}$ الى (0.272)$Bq.kg^{-1}$ وبمعدل (0.510) $Bq.kg^{-1}$ ، اما معامل الخطورة الخارجي فقد تراوح بين (0.272)$Bq.kg^{-1}$ الى (0.101) $Bq.kg^{-1}$ وبمعدل (0.184) $Bq.kg^{-1}$.
ومن مقارنة النتائج الحالية مع النتائج المحسوبة عالميا وجد ان مستويات الاشعاع للنماذج المدروسة تقع ضمن الحدود المسموح بها .

مكافئ الراديوم
مؤشرات الخطورة
كاشف $NaI\ (TI)$
طار النجف

1. INTRODUCTION

The concentration of radionuclide activity in soil is a major determinant of natural background radiation. More than 60 radionuclides can be found in nature, and they can be classified into three general categories, Space and human produced. Radionuclides are found naturally or manufactured by man. The radioactive ones are heavy elements. Each element with an atomic number of more than eight has radioactive isotopes and is subject to disintegration. As for the stable, it is indissoluble, and these isotopes are radioactive [1]. Radioactive isotopes have provided countless services in the field of soil research, and other fields such as medicine, agriculture and industry that have benefited humans, and despite their great benefits, they lead to damage to living organisms and the environment [2]. Radioactivity can be defined as the process in which the unstable nucleus gets rid of excess energy by releasing particles and electromagnetic radiation, and familiar radiation is alpha particles, beta particles, and gamma rays [3]. This study aims to estimate the natural radionuclides in the natural formations of Tar Al-Najaf region by taking 30 soil samples from different locations in this region in order to assess the level of radioactive background from which they arise and calculate the external hazard factors that are integrated with current and future studies, and then compare the obtained results with the allowed global average.

2. STUDY AREA

Tar al-Najaf is considered one of the most important historical archaeological areas in the province, as it is considered one of the natural phenomena prominently present in the province, as it cuts the plateau sharply to form the rocky cliff, as well as overlooking the southern end of the Najaf plateau and the sea of Najaf in a clear and sudden way to be Tar al-Najaf [4]. The study area consisted of rock formations, including the formation of Injanah (Upper Miocene) and the hole formed (Middle Miocene), as well as the tor of Najaf is clearly visible as the tor extends from the eastern, northeastern and northern edge of the al-Najaf sea depression from the west of the city of Abi Sakhir from the intersection of the point ($31^o\ 54'N - 44^o\ 29'E$) and heads northwest and parallel to the Abu Sakhir - Najaf road to the west of the holy city of Najaf, specifically at the shrine of Safi al-Safa, where it takes the form of an arc heading towards the west at the point $(31^o\ 59'N\ -\ 44^o\ 18'E\ )$and its length at this point is (21) km, and then it descends south at the point($43^o\ 50'.32^o\ 07'$)and its length is (68.5) km, and the road and its hills end at the point $(43^o\ 48'.32^o\ 06')$, and the total length of the AL Tar is (74.5) km, Figure (1)

Figure (1): Landforms of the Tar Al-Najaf area - Al-Najaf Al-Ashraf [5].

3. Samples Collection and Preparation:

In this research thirty soil samples have been collected during the period from 20 Sep. 2022 to 30 Sep. 2022 were collected distributed along the study area, with a separation distance of (1 km) between one sample and another, and the coordinates of the sites were recorded using the GPS device (G.P.S).The samples have been taken to measure the amount of natural radioactivity in addition to the risk indicators. Through the specific activity of radioactive elements (238U, 232Th and 40K).

The samples have been transferred to the research laboratory in the Physics Department- College of Education for Girls- Kufa University. These samples have been dried until a stable weight has reached, crushed, and sieved to (0.5 mm) in order to obtain homogeneous samples, the samples weight ranged between (500 to 600) gm. After that, the soil samples have been packed in plastic bags, and the information on each sample has been recorded. In addition, the samples are filled in special measuring containers (Marinelli beakers), and these containers are tightly wrapped with adhesive tape and the samples have been left stored in these containers for 28 day to obtain a state of radioactive equilibrium between uranium−238 and thorium−232 and their radioactive daughters. Finally, the natural radioactivity of the isotopes ^{238}U, ^{232}Th and ^{40}K is measured for (18000sec) by a gamma-ray spectroscopy with scintillation detector NaI(TI), (3"× 3") from ORTEC with energy resolution (7.9)% and efficiency of (4.6) at energy 662 keV.

4. Data analysis and Mathematical equations:

When ^{238}U and ^{232}Th is balanced with their radioactive daughters, the activity of all elements of the two radiation chains is in balance, so it is possible to calculate the concentration of an element in any chain in terms of the concentration of another element, the concentration of ^{232}Th calculating by the activity concentration of thallium ^{208}Tl radionuclides with energy $(2614.511keV)$ and ^{238}U by calculating the activity concentration of bismuth nuclides ^{214}Bi with energy of $(1764.539keV)$, as well as calculating the concentration of potassium radioactive nuclide ^{40}K with energy of $(1460.822keV)$ through equation (1) [6].

$$A = \frac{N_{net}}{\varepsilon . I_{\gamma} . m . t} \pm \frac{\sqrt{N_{net}}}{\varepsilon . I_{\gamma} . m . t} \dots (1)$$

Where N_{net}: is the net area under the curve of the optical peak after subtracting the radioactive background from it

ε: the calculated efficiency of the photo peak at a given energy

I_{γ} : The intensity of the gamma rays

m : mass of the sample(kg)

t : measurement time (sec)

Depending on the activity concentrations of ^{238}U, ^{232}Th and ^{40}K, several coefficients of radioactive hazard were calculated:

4.1. Radium Equivalent Ra_{eq}:

The value of the equivalent concentration of radium, which is used to estimate the risk of the concentration caused by the activity of ^{238}U, ^{232}Th and ^{40}K, in $Bq.kg^{-1}$ units, is calculated from the following equation.

$$Raeq = A_U + 1.43\, A_{Th} + 0.077\, A_K \dots (2)$$

As A_U, A_{Th} and A_K are the active concentrations of uranium, thorium, and potassium respectively, and the highest Ra_{eq} value must be less than the internationally permissible limit (370 $Bq.kg^{-1}$) [7,8].

4.2. Activity Concentration Index (I_{γ}):

The Activity Concentration Index refer to the risk arising from gamma rays associated with natural radionuclides (uranium ^{238}U, thorium ^{232}Th and potassium ^{40}K) in the studied material. The Activity Concentration Index (Iγ) calculated from the following equation [9-10].

$$I_{\gamma} \frac{A_U}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \dots . (3)$$

4.3. External Hazard Index (H_{ex}):

External hazard index(H_{ex}) gives the assessment of the health risk associated with the

emission of gamma radiation by various natural radionuclides which calculated through the following equation [11,12].

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \dots (4)$$

5. Results and Discussion:

The specific activity of ^{238}U, ^{232}Th and ^{40}K radionuclides in thirty soil samples from Tar al-Najaf ground shapes have been calculated using equation (1) after preparing the samples for measurement with a gamma-ray spectroscopy $NaI\,(TI)$ (3 " × 3") detector from ORTEC with energy resolution (7.9)% and efficiency of(4.6) at energy 662 keV. The soil samples weight ranged between (500 to 800) gm. After that, the samples have been packed in plastic bags, and the information on each sample has been recorded. The samples are filled in special measuring containers (Marinelli beakers), and these containers are tightly wrapped with adhesive tape and the samples have been left stored in these containers for 28 day to obtain a state of radioactive equilibrium between uranium−238 and thorium−232 and their radioactive daughters. The radioactivity of the isotopes are measured for (18000). The specific activity of ^{238}U, ^{232}Th and ^{40}K have been explained in Table (1) and Figure (2), whereas the radium equivalent Ra_{eq}, activity concentration Index (I_{γ}) and external hazard Index (H_{ex}) have been shown in Table (2) . The obtained results were compared with the permissible global average they were within the acceptable worldwide limit [13-15].

Table (1): The specific activity of ^{238}U, ^{232}Th and ^{40}K radionuclides in thirty soil samples from Tar al-Najaf ground shapes with their locations.

No. Sample	Locations		Specific Activity Concentrations $Bq.Kg^{-1}$		
	Longitude	Latitude	^{238}U	^{232}Th	^{40}K

	(°E)	(°N)			
S1	44°20´19″	31°58´0.4″	15.048±0.819	18.069±0.893	163.513±2.767
S2	44°20´16″	31°58´05″	12.630±0.741	19.132±0.907	151.345±2.629
S3	44°20´12 ″	31°58´07″	8.639±0.635	18.990±0.936	140.288±2.621
S4	44°20´07″	31°58´09″	13.824±0.838	22.528±1.064	155.127±2.876
S5	44°20´08″	31°58´12″	6.649±0.514	16.783±0.813	130.351±2.333
S6	44°20´06″	31°58´11″	12.703±0.738	15.923±0.822	134.098±2.457
S7	44°20´04 ″	31°58´13″	13.582±0.718	14.981±0.750	116.961±2.160
S8	44°18´27″	31°59´20″	6.530±0.509	16.586±0.808	95.173±1.994
S9	44°18´26″	31°59´23″	8.240±0.594	20.041±0.922	152.155±2.617
S10	44°18´24″	31°59´25″	17.367±0.822	27.239±1.024	144.309±2.428
S11	44°17´12 ″	32°00´51″	17.501±0.754	18.281±0.767	124.273±2.059
S12	44°17´11 ″	32°00´53 ″	7.313±0.488	19.834±0.800	126.069±2.078
S13	44°17´09″	32°00´56″	19.219±1.256	30.960±1.586	411.147±5.952
S14	44°17´07″	32°00´58″	22.404±1.376	29.277±1.564	404.507±5.990
S15	44°17´05″	32°00´58″	27.644±1.505	28.650±1.524	387.227±5.773
S16	44°17´04″	32°01´00″	24.878±1.463	29.128±1.575	448.723±6.366
S17	44°17´04″	32°01´02″	25.264±1.470	22.962±1.394	460.688±6.433
S18	44°17´04″	32°01´03″	19.461±1.258	21.429±1.313	293.125±5.004
S19	44°17´00 ″	32°01´02″	19.877±1.302	22.620±1.381	330.284±5.437
S20	44°17´00″	32°01´11″	0.895 9.600±	17.840±1.213	343.962±5.488
S21	44°16´58″	32°01´13″	18.134±1.329	31.060±1.730	397.415±6.376
S22	44°16´55″	32°01´11″	14.293±1.239	27.007±1.694	145.681±4.052
S23	44°16´53 ″	32°01´13″	18.942±1.367	18.546±1.345	407.950±6.498
S24	44°16´56″	32°01´15″	9.396±0.996	18.803±1.401	378.087±6.471
S25	44°16´53″	32°01´17 ″	11.832±15.31	28.039±1.742	395.624±6.739
S26	44°16´50″	32°01´15 ″	20.499±1.572	23.741±1.682	443.065±7.487
S27	44°16´48″	32°01´17 ″	20.888±1.310	18.794±1.236	307.773±5.153
S28	44°16´50″	32°01´19 ″	14.897±1.250	25.534±1.628	395.944±6.601
S29	44°16´48″	32°01´21 ″	16.182±1.304	20.688±1.466	375.625±6.435
S30	44°16´45″	32°01´20 ″	21.735±1.643	8.356±1.013	475.391±7.870
Max.			**27.644±1.505**	**31.060±1.730**	**475.391±7.870**
Min.			**6.530±0.509**	**8.356±1.013**	**95.173±1.994**
Average			**15.955**	**21.728**	**281.197**
World . Average.			**33**	**45**	**420**
Global range			**(15-50)**	**(7-50)**	**(100-700)**

Table (2): The radium equivalent Ra_{eq}, activity concentration Index (I_{γ}) and external hazard Index (H_{ex}) in $Bq.kg^{-1}$in thirty soil samples from Tar al-Najaf ground shapes.

No. Sample	Ra_{eq} $Bq.kg^{-1}$	I_{γ} $Bq.kg^{-1}$	H_{ex} $Bq.kg^{-1}$
S1	53.478	0.390	0.144
S2	51.642	0.376	0.139
S3	46.598	0.341	0.125
S4	57.984	0.420	0.156
S5	40.686	0.299	0.109
S6	45.799	0.333	0.123
S7	44.012	0.318	0.118
S8	37.576	0.272	0.101
S9	48.616	0.356	0.131
S10	67.431	0.484	0.182
S11	53.212	0.382	0.143
S12	45.385	0.331	0.122
S13	95.151	0.711	0.256
S14	95.418	0.711	0.257
S15	98.431	0.728	0.265
S16	101.084	0.756	0.272
S17	93.572	0.705	0.252
S18	72.676	0.539	0.196
S19	77.655	0.578	0.209
S20	61.597	0.471	0.166
S21	93.152	0.696	0.251
S22	64.130	0.462	0.173
S23	76.875	0.583	0.207
S24	65.397	0.502	0.176
S25	85.878	0.646	0.231
S26	88.565	0.669	0.239
S27	71.463	0.532	0.193
S28	81.899	0.618	0.221
S29	74.690	0.565	0.201
S30	70.289	0.545	0.180
Max.	**101.084**	**0.756**	**0.272**
Min.	**37.576**	**0.272**	**0.101**
Average	**68.678**	**0.510**	**0.184**
World . Average.	**370**	**1≤**	**1≤**

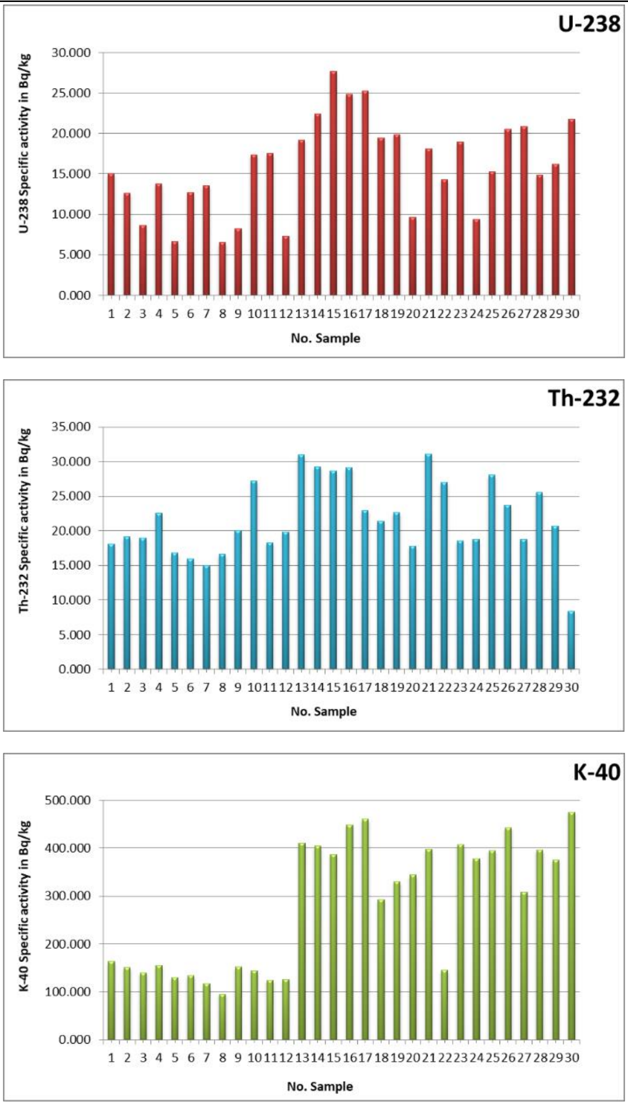

Figure (2): The specific activity of ^{238}U, ^{232}Th and ^{40}K radionuclides in thirty soil samples from Tar al-Najaf ground shapes.

The concentration of the radionuclides' have been varies from one location to another depending on the natural distribution of radionuclides, i.e. it is of random origin, and that the concentrations are within the global average[13-15], meaning that they do not pose a threat to human health, especially as they are considered archaeological and wonderful tourism areas that reflect the history of the formation of landforms within this region of the governorate Najaf, which could continue to be an important area for tourists. It is clear that the highest value of the specific activity of uranium ^{238}U, was $(27.644 \pm 1.505) Bq.Kg^{-1}$ in sample (15), and the lowest value was $(6.530 \pm 0.509)\ Bq.Kg^{-1}$ in sample (8) and the average of these values was $(15.955)\ Bq.Kg^{-1}$ It was found that the highest value of the specific activity of thorium ^{232}Th was $(31.060 \pm 1.730)\ Bq.Kg^{-1}$ in sample (21), and the lowest value was $(8.356 \pm 1.013)\ Bq.Kg^{-1}$ in sample (30), and the average of these values was $(21.728)\ Bq.Kg^{-1}$. For potassium ^{40}K, the highest value of specific activity was $(475.391 \pm 7.870)\ Bq.Kg^{-1}$ in sample (30), and the lowest value was $(95.173 \pm 1.994)\ Bq.Kg^{-1}$ in sample (8), and the average of these values was $(281.197)\ Bq.Kg^{-1}$. As for the highest value of Ra_{eq} radium equivalent, it was $(101.084)\ Bq.Kg^{-1}$ in sample (16), and the lowest value was $(37.576)\ Bq.Kg^{-1}$ in sample (8), and the average of these values was $(68.678)\ Bq.Kg^{-1}$. The highest value of the activity concentration Index (I_{γ}) was $(0.756)\ Bq.Kg^{-1}$ in sample (16), and the lowest value was $(0.272)\ Bq.Kg^{-1}$ in sample (8), and the average of these values was $(0.510)\ Bq.Kg^{-1}$ .The highest value of the external Hazard Index (H_{ex}) was $(0.272)\ Bq.Kg^{-1}$ in sample (16), and the lowest value was $(0.101)\ Bq.Kg^{-1}$ in sample (8), and the average of these values was $(0.184)\ Bq.Kg^{-1}$.

6. Conclusions :

The specific radioactivity values of the uranium, thorium, and potassium isotopes were distributed in varying proportions for the Tar Al-Najaf area, which is within the internationally permitted range, and most of the results of the radioactive hazard coefficients for each of the radium equivalent, activity concentration Index, and external risk coefficient for the soil samples were within the internationally permissible limit. The results do not pose a threat to humans and residents near this area.

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