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Calculation of Risk Indicators for Radioactivity in the Soil of Region Hammam Al-Alil, Nineveh Governorate, Iraq

Mayan I. Khalil
Department of Physics/ College of Sciences/ University of Mosul

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corresponding author:
Mayan I. Khalil
mayanibraheem@uomosul.edu.iq

ABSTRACT

Ten soil samples were collected from different areas on Hammam Al-Alil Township, located in the city of Mosul within the Nineveh Governorate / Iraq. The specific activity of natural radionuclides (^{238}U, ^{232}Th, ^{40}K and ^{137}Cs) were measured, and the results showed that the values of radioactivity concentration of the mentioned nuclides for soil samples ranged between (BDL, BDL, 3.52, BDL) Bq/ kg to (3.12, 6.05, 73.85, 2.02) Bq/ kg with an average (0.87, 3.13, 27.2 and 0.75) Bq/ kg, respectively, and the activity of the radium equivalent measured and its average value was (10.03) Bq/ kg. As well as absorbed dose in the air, which was the average value (3.42) nGy/ h. The average annual dose in the outside and inside were (0.004 mSv/y, 0.016 mSv/y) respectively, and the average internal and external hazard indicators were found, and its value was (0.02, 0.02) respectively.
Finally, the lifetime risk of developing cancer was determined utilizing the risk factors for Ionizing radiation's biological effects are discussed by the International Committee on Radiation Protection. All values of soil samples are less than the global limit.

Keywords: soil, radium equivalent activity, external and internal hazard index, NaI (TI).

INTRODUCTION

Soil, besides being the main source of ongoing radiation exposure to humans, also serves as a transporter for radionuclide to biological environments, making it the primary predictor of environmental radiological pollution (AL-Hamarne and Awadallah, 2009). The background radiation is the radioactivity level from natural radionuclides, which is dependent on the quantity of radioactive contaminants in environment. If the environment is contaminated, by man-made or natural activities, background radiation may be high. It may also be high in areas where natural resources, such as uranium or phosphate, are abundant. The weathering of rocks and soil formation are two processes that can bring radio materials from the deposit to the surface soil (Mohammed and Mazunga, 2013). The bulk Gamma radiation harm to the human body results from both internal and exterior exposure. released due to naturally occurring radioactive contaminants is present in all soils (UNSCEAR, 2000). About 85% of the radiation is considered to be caused by the environment. exposure obtained by people (WNA, 2009). some anthropogenic behaviors the levels of these doses have been seen to rise. Physics in health is crucial for rising along with the requirement for radiation safety and population safety.

For designing radiation protection policies. It can be useful to do research on how radionuclides are distributed in the environment and the doses that go along with them. Safety laws including rules (Al-Mashhadani *et al*., 2015). Several studies have been done performed over the world and in a variety of geographical Ordered formations to assemble references evidence for naturally occurring exposure to environmental radioactivity (Karahan *et al*., 2020; Tawfiq *et al*., 2017). This research's objective was to evaluate the activity concentrations of the naturally occurring radionuclides (^{238}U, ^{232}Th, ^{137}Cs and ^{40}K) Scintillation detector usage NaI (Tl), and examine some of the radiation hazard indicators for ten soil samples in Hammam Al-Alil Township in Nineveh Governorate, Iraq.

MATERIALS AND METHODS

The study sample was taken from the Hammam Al-Alil Township, located 27 km southeast of the city of Mosul / Nineveh Governorate in Iraq. Fig. (1) and (Table 1) show the sample collection sites and its type from Hammam Al-Alil Township.

Fig. 1: Geologic map of studies locations

Table 1: Soil samples from Hammam Al-Alil Township with their sample ID, names, latitude, and longitude lines

Samples ID	Latitude N	Longitude E
S1	4007931.02	339258.95
S2	4007727.6	339107.57
S3	4007443.58	338907.27
S4	4007084.91	338910.27
S5	4007141.93	338522.22
S6	4007280.96	338797.22
S7	4006701.78	338933.02
S8	4006638.34	338746.22
S9	4006592.84	338983.49
S10	4006668.11	339094.03

Experimental Procedures:

Ten soil samples were collected in Hammam Al-Alil Township in February 2023, the specimens were dried through placed the specimens in an oven at a temperature of 110^{o} for 4 hours to ensure it was free of moisture. The dry samples were ground into a fine powder and run through a 1 mm mesh size standard. All specimens were weighed 1 Kg and then the samples were stored for at least 4 weeks to achieve a permanent balance between the radionuclides and their daughters.

The specimens were analyzed using gamma ray spectroscopy with a 3"x3" voltage (750V) detector made of sodium iodide scintillation NaI (Tl) from Canbera USA (Al-hankawi and Tawfiq, 2023), efficiency (60%) as well as an energy discernibility between (8.56- 6.5%) for the energy (1173, 1332 and 661 MeV). To lessen the laboratory's radiation background, a 15 cm lead encircles the NaI (Tl) detector. Using a multi-radionuclide standard source with energies of (88.34, 59.53, 1333.1173 and 661.7) KeV ^{109}Cd for ^{214}Am, ^{60}Co, and ^{137}Cs, respectively, the efficiency of the system before measurement was estimated put in front of the detector for 1080 seconds.

Analysis of Samples:

To calculate the activity concentration (^{238}U, ^{232}Th, ^{40}K and ^{137}Cs) of the soil samples in unit Bq/kg, The following standard equation was used (Alikulac *et al*., 2016):

$$A\left(\frac{\mathrm{Bq}}{Kg}\right)=\frac{N-B}{I\ \varepsilon_{ff}M\ t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where A represents the concentration of the measured activity of a radionuclide Bq/ kg, N net area value, B background, ε_{ff} the absolute efficiency, (I) gamma ray intensity, M: the sample's mass in kg, and t is the measurement time (7200 s).

One of the most important and widely used risk indicators is radium equivalent activity, which is calculated through the relationship (2). Assuming that the same rate of gamma radiation can be generated from 370 Bq/kg from ^{226}Ra, 4810 Bq / kg from ^{40}K and 259 Bq / kg from ^{232}Th. (Abdel-mageed *et al*., 2011) (Dhahir *et al*., 2020):

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

where A_{Th}, A_K and A_U are the activity concentrations of (^{232}Th, ^{40}K, and ^{238}U) Bq / kg respectively.

The external and internal hazard indices can, be calculate by the equation (3), the equation (4) was used to determine the internal radiation danger index.

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots.(3)$$

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots.(4)$$

The values of internal and external risk indicators must be less than or equal to one. (Farrag, 2016).

For the uniform distribution of naturally occurring radionuclides (^{238}U, ^{40}K, and ^{232}Th) and depending on the standards set by UNSCEAR (Al-ghamdi and Alrissa, 2014). At a height of 1 m above the ground, the gamma dose values that were absorbed as a result of gamma radiation were calculated. Depending on the conversion settings, which are specific exercise for each unit in Bq / kg (dry weight), which correspond to 0.462 nGy / h for ^{238}U, 0.0417 nGy / h for ^{40}K, and 0.604 nGy / h for ^{232}Th, the gamma dose rate absorbed (D) in air may be determined (Harb *et al.*, 2010) (Abd El-azeem and Howaida, 2021):

$$D\gamma \text{ (nGy /h)} = 0.462A_U + 0.604\ A_{Th} + 0.0417A_K \quad \ldots\ldots\ldots\ldots\ldots\ \ldots..(5)$$

For compute analogous to the yearly effective dose outdoor and indoor was used the equations (6), (7), where a human dose that is effective equivalence was created with an indoor exposure level of 80% using the absorbed dose rate, and an outdoor exposure level of 20% using a factor of 0.7 SvG/y (Hadad and Mokhtari, 2015) (Marie and Najam, 2022):

$$\text{outdoor (mSv / y)} = \text{AD (nGy/h)} \times 8760\text{ h} \times 0.2 \times 0.7\text{ Sv/Gy} \times 10^{-6} \ \ldots\ldots\ (6)$$

$$\text{indoor (mSv / y)} = \text{AD (nGy/h)} \times 8760\text{ h} \times 0.8 \times 0.7\text{ Sv/Gy} \times 10^{-6} \quad \ldots\ldots\ (7)$$

The ELCR is a gauge of the likelihood that radiation exposure will increase the incidence of cancer in any population, and if we use Average longevity is 70 years. for humans, we may determine (ELCR) using Eq. (8) (Shabana and Kinsara, 2014).

$$\text{ELCR} = \text{AEDE} \times \text{DL} \times \text{RF} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots\ (8)$$

where DL is for average life span, which is predicted to be 70 years, and Annual Effective Dose Equivalent is what AEDE stands for. the risk factor is RF (SV^{-1}), which, according to Sievert, increases the probability of dying from cancer.

The ICRP 60 utilizes values of 0.05 for the public exposure for low dose background radiations that are thought to cause stochastic effects (Shabana and Kinsara, 2014). We may use this useless unit, which reflects the likelihood of cancer incidence, to derive the equation above.

RESULTS AND DISCUSSION

Radionuclide activity results from the ten soil samples collected in the Hammam Al-Alil Township of the Nineveh Governorate, as shown in (Table 2), in sample S4 The outcomes ^{214}Pb (3.12) Bq/kg was found to be present at the maximum concentration during the particular activity of ^{238}U, while in the samples (S2, S5, S8 and S9) the BDL's lowest concentration with average (0.87) Bq/kg as depicted in figure 2. A concentration of activity of ^{232}Th had the greatest quantity of 228Ac actinium (6.5) Bq/kg in sample S1, as opposed to the lowest concentration (BDL) Bq/kg in S3 with average (3.13) Bq/kg, as shown in Figure 3. In S9 found maximum level of concentration of ^{40}K (73.85) Bq/kg, as opposed to a low level of concentration (3.52) Bq/kg was discovered in S6, with average (27.2) Bq/kg as shown in Fig. (4). The maximum concentration of ^{137}Cs was (1.7) Bq/kg. seen in S3, while a low level of concentration (0.09) Bq/kg was seen in S5 on average (0.75) Bq/kg, as shown in Fig. (4). So, the global limit was not reached for any average values. (EPA:US,1992), (Mohammed *et al*., 2020). The current findings indicate that values of specific activity of soil samples in Hammam Al- Alil Township less than the international limit in value. Specific activity of ^{238}*U*,^{232}Th ,^{40}K and ^{137}*Cs* in soil samples from Hammam Al-Alil Township.

Table 2: Specific Activity of ^{238}*U*,^{232}Th ,^{40}K and ^{137}*Cs* in soil samples from Hammam Al- Alil Township

Simps ID	Activity ^{238}U(^{214}Pb) (Bq/kg)	Activity ^{232}Th(^{228}Ac) (Bq/kg)	Activity ^{40}K (Bq/kg)	Activity ^{137}Cs (Bq/kg)
S1	1.41	6.50	40.95	1.02
S2	BDL	5.64	25.45	0.98
S3	0.98	BDL	28.36	2.021
S4	3.12	1.24	42.58	0.25
S5	BDL	4.85	17.20	BDL
S6	1.50	0.63	3.52	0.86
S7	0.59	0.89	14.25	0.10
S8	BDL	5.51	9.254	0.60
S9	BDL	3.01	73.85	1.03
S10	1.12	2.99	16.61	0.70
Min	BDL	BDL	3.52	BDL
Max	3.12	6.50	73.85	2.02
Average	0.87	3.130	27.207	0.75

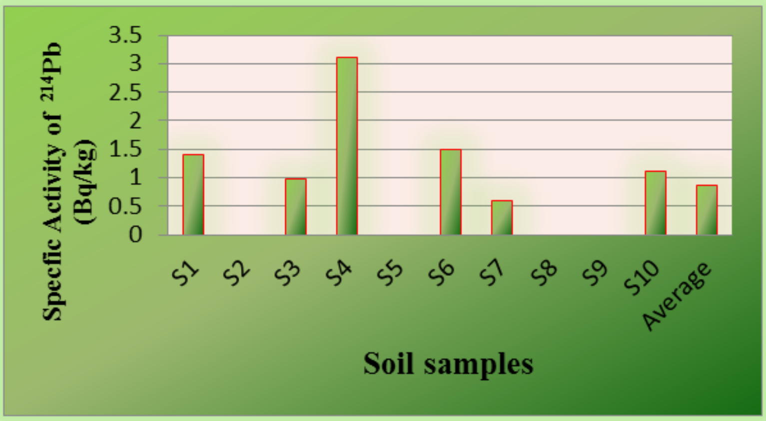

Fig. 2: Specific activity of ^{238}U (214Pb) in soil samples

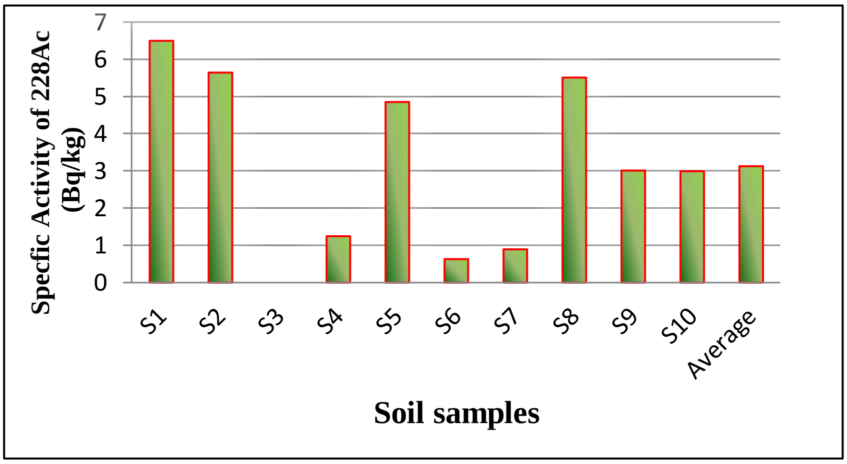

Fig. 3: Specific activity of ^{232}Th (^{228}Ac) in soil samples

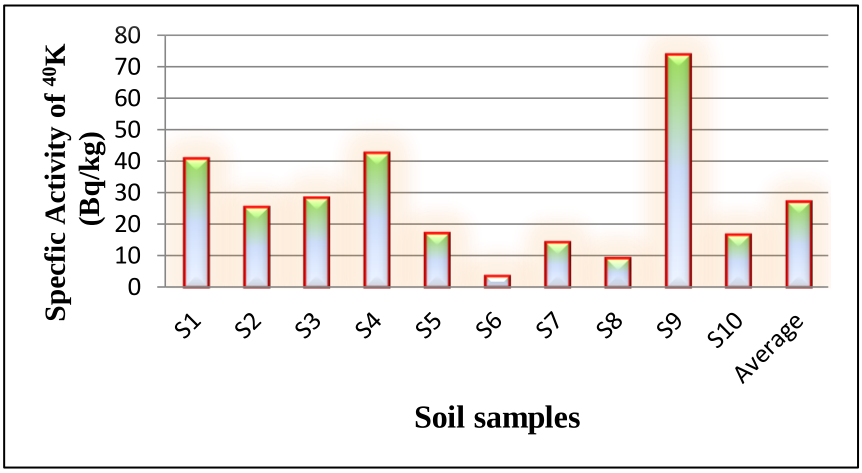

Fig. 4: Specific activity of ^{40}K in soil samples

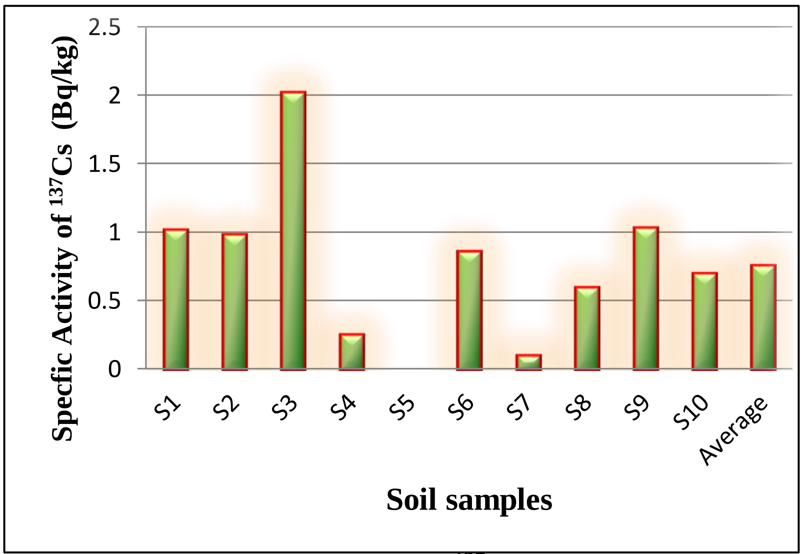

Fig. 5: Specific activity of ^{137}Cs in soil samples

Fig. (6) shows the relative contribution of radionuclides of ^{232}Th(^{228}Ac), ^{238}U (^{214}Pb), ^{40}K, and ^{137}Cs in soil samples for Hammam Al- Alil Township, the ^{40}K constitutes the largest proportion, which is 85% (because its presence in nature in abundance), followed by ^{232}Th (^{228}Ac) in a proportion 10%, the proportion of ^{137}Cs is equal (2%) and ^{238}U (^{214}Pb) is equal 3%.

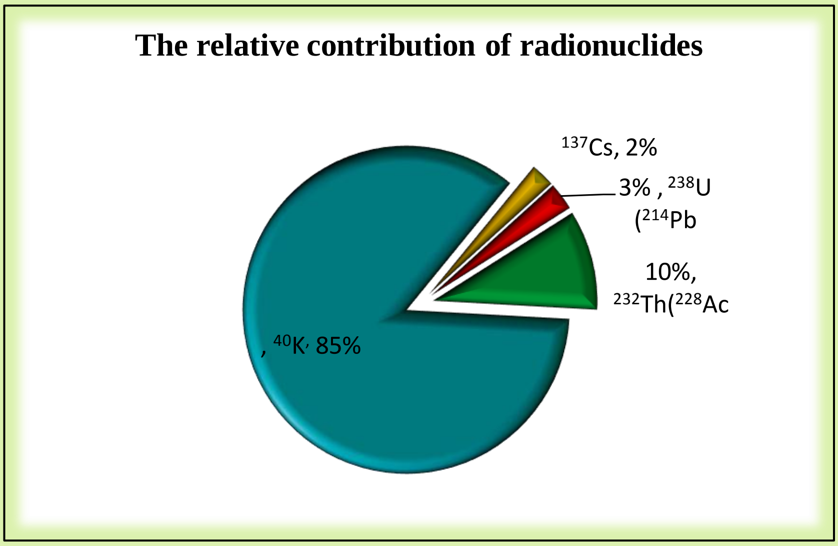

Fig. 6: The relative contribution of radionuclides of $^{232}Th(^{228}Ac)$, ^{238}U (^{214}Pb), ^{40}K, and ^{137}Cs in soil samples for Hammam Al- Alil Township.

Radium equivalent activity (Ra_{eq}) in (Table 3) shows the highest value in soil was discovered in S1 which was equivalent to (13.86) Bq/kg, whereas lowest value recorded in S6 which was equivalent to (2.67) Bq/kg with an average (10.03) Bq/kg. Show the current results average values of radium equivalent of soil samples in Hammam Al-Alil Township less than the maximum global value, which is equivalent to (370) Bq / kg (UNSCEAR,2000).

The largest value of absorbed gamma dose rate (D), indoor annual effective dose rate (AEDEin), outdoor annual effective dose rate (AEDout), hazard indecies Hin, Hex, and excess lifetime cancer risk (ELCR) in soil samples was between (1.22 nGy / h, 0.0059, 0.0014 mSv / y, 0.009, 0.007 and 0.02x10^{-3}) to (6.28 nGy / h, 0.03, 0.007 mSv / y, 0.041, 0.037 and 0.107967 x10^{-3}) on average (3.42 nGy / h, 0.016, 0.0042 mSv / y, 0.02, 0.02, 0.058x10^{-3}) respectively

Table 3: Shows radiological hazard indices of soil samples in Hammam Al-Alil Township.

Sample ID	Ra_{eq} (Bq/kg)	D (nGy/h)	$AEDE_{in}$ (mSv/y)	$AEDE_{out}$ (mSv/y)	H_{ex}	H_{in}	ELCR×10^{-3}
S1	13.8	6.28	0.03	0.007	0.03	0.04	0.10
S2	10.0	4.47	0.02	0.005	0.02	0.02	0.07
S3	3.16	1.63	0.008	0.002	0.008	0.01	0.02
S4	8.18	3.97	0.01	0.004	0.02	0.03	0.06
S5	8.27	3.65	0.01	0.004	0.02	0.02	0.06
S6	2.67	1.22	0.005	0.001	0.007	0.01	0.02
S7	2.97	1.41	0.006	0.001	0.008	0.009	0.02
S8	8.59	3.71	0.01	0.004	0.02	0.02	0.06
S9	9.99	4.90	0.02	0.006	0.02	0.02	0.08
S10	6.68	3.02	0.01	0.003	0.01	0.02	0.05
Min	2.67	1.22	0.005	0.001	0.007	0.009	0.02
Max	13.8	6.28	0.030	0.007	0.037	0.04	0.10
Averag	10.0	3.42	0.016	0.004	0.020	0.02	0.05

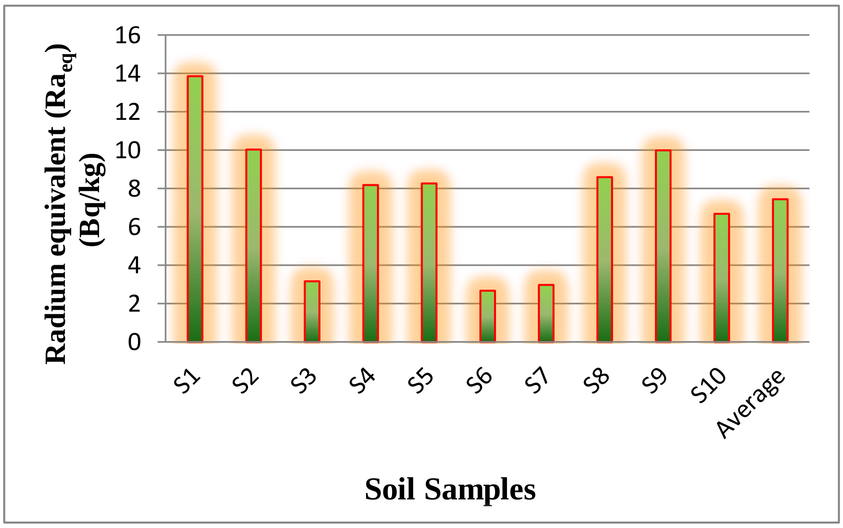

Fig. 7: Ra_{eq} for all Hammam Al-Alil Township soil sample

Table 4: A comparison of the specific activity levels (Bq/Kg) of ^{238}U, ^{232}*Th*, ^{40}*K* and ^{137}Cs measured in the current study with other studies

Country	^{238}U	^{232}*Th*	^{40}*K*	^{137}Cs	Ref.
Iraq/ Mosul	19.8±0.998	13.65±1.02	213.71±8.896	--	(Marie and Najam,2022)
Iraq/ Mosul	9.86	23.05	232.91	--	(Wais and Najam,2021)
Iraq/ Mosul	11.5	23.95	266.6	--	(Wais and Najam,2021)
Iraq/ Mosul	32.52±6.48	20.30±5.36	378.93±123.29	8.17±5.55	(Najam *et al.*,2015)
Qatar	10	17	201	4	(Ahmed *etal.*,2019)
Egypt	35.53	23.59	266	---	(Gad etal.,2019)
Jordan	42	23	309	3.7	(Alomari *etal.*,2019)
Iraq/ Hammam Al-Alil	0.874	3.13	27.207	0.75	Present Study

CONCLUSION

In the lookup presented the consequences of unique specific activity in soil samples taken from Hammam Al-Alil Township in Nineveh Governorate. Measurement had been made of the concentrations of genuine activities of ^{238}U (^{214}*Pb*), ^{232}*Th* (^{228}*Ac*), ^{40}*K*, and^{137}Cs in the samples. Radium's equivalency, internal and external annual effective dose rates, absorbed gamma dosage rate, risk inequities, andlifelong cancer risk calculations. Each of their rates fell below the worldwide limit. Therefore Hammam Al-Alil Township is within the standard radiation concentration, it reduces the environmental and health risks posed by the soil radioactivity there. However, this data could serve as a baseline for future measures and analyses of potential radioactive hazards to the health of humans in the area under research and provide a general background level for the area under study. This indicates that there is no radioactive risk to people from the soil in the Hammam Al-Alil Township

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حساب مؤشرات الخطر للنشاط الاشعاعي في تربة منطقة حمام العليل، محافظة نينوى، العراق

ميان ابراهيم خليل
قسم الفيزياء/ كلية العلوم/ جامعة الموصل

الملخص

تم جمع عشر عينات من التربة من مناطق مختلفة لناحية حمام العليل الواقعة في مدينة الموصل في محافظة نينوى، العراق. تم قياس النشاط الاشعاعي للنويدات المشعة الطبيعية (^{238}U،^{232}Th و K40 و $^{137}C_s$) وبينت النتائج أن قيم تراكيز النشاط الاشعاعي للنويدات المذكورة لعينات التربة من (BDL،BDL ، 3.52 ،Bq/kg BDL) إلى (3.12، 6.05، 73.85 ، 2.02 Bq/kg) بمتوسط (0.87 ، 3.13 ،27.2 ، 0.75 Bq /kg) على التوالي. كذلك تمت دراسة نشاط مكافئ الراديوم وبلغ متوسط قيمته (10.03 Bq/kg). وايضا دراسة معدل الجرعة الممتصة في الهواء للعينات وكان متوسط قيمته (3.42955 nGy/h). وتبين ان نسب متوسط الجرعة الفعالة السنوية الخارجية (0.0042 mSv/y) ومتوسط الجرعة الفعالة السنوية الداخلية (0.016 **mSv**/y). في حين بلغ معدل مؤشر الخطورة الداخلية (0.022) ومتوسط مؤشر الخطورة الخارجية (0.02). وتم حساب خطورة الإصابة بالسرطان مدى الحياة باستخدام عوامل الخطر الخاصة باللجنة الدولية للحماية من الإشعاع والآثار البيولوجية للإشعاع المؤين، وكانت نتائج جميع عينات التربة أقل من المعدل العالمي.

الكلمات الدالة: التربة، النشاط المكافئ للراديوم، مؤشر الخطورة الخارجية والداخلية، **NaI** (TI)