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Measurement of Natural Radioactivity in Selected Soil Samples from the Archaeological of Babylon City, Iraq

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Abstract: The specific activity of natural radionuclides in 10 soil samples collected from the antiquity's area of the archaeological of Babylon city. Experimental results were obtained by using a Gamma ray spectrometer analysis system consists of a scintillation detector NaI(Tl) of (3"×3") crystal dimension. The results have shown that, the specific activity, for U-238 ranged between (9.060 Bq/kg) to (21.220 Bq/kg), with the average value (15.485 Bq/kg), the specific activity of Th-232 was ranged between (11.590 Bq/kg) to (19.040 Bq/kg), with the average value of (15.505 Bq/kg), while the specific activity of K-40 was ranged between (122.250 Bq/kg) to (232.540 Bq/kg), with the average value of (170.206 Bq/kg). All soil samples of the archaeology of Babylon city were found to be lower than the recommended values given by (UNSCEA Rreports). In order to assess the radiological hazards of the radioactivity in soil samples of the archaeological of Babylon city, (Ra_{eq}, D_{γ}, AED_{in}, AED_{out}, EAD, I_{γ}, H_{in} and H_{ex}) have been calculated, and all the obtained results were found to be less than the allowed limits given by (UNSCEAR reports), the originality in the paper consider is the first study in Iraq to measured specific activity for Babylon archaeological for the first time as far as authors know.

Keywords: Natural radioactivity, Specific activity, NaI (Tl) detector, Archaeological, Babylon.

1 Introduction

Babylon is unquestionably one of the most important archaeological sites in the world. It was the capital city of two of the most famous kings of antiquity, Hammurabi (1792-1750 BC) who introduced one of the world's first law codes, and Nebuchadnezzar (604-562 BC) who built the Hanging Gardens of Babylon, one of the Seven Wonders of the World. Alexander the Great chose Babylon as his new capital, but died before he could implement this plan. The existence of Babylon is first mentioned in cuneiform texts of the Akkadian period (2371-2230 BC), but the city did not become significant until the time of Hammurabi. The archaeological site of Babylon governorate is situated (90 km) south of Baghdad governorate. It belongs to the municipal area of al-Hillah and the governorate "Babil". The Inner city covers an area of (2.99 km^2) and the outer walls which surround the city east and west of the Euphrates encloses an area of (9.56 km^2) [1].

It is well known that traces of radionuclides are found in (air, soil, water and human bodies), we inhale and ingest radionuclides every day of our lives and radioactive materials have been ubiquitous on earth since its creation. The presence of natural radioactivity in soil results in internal and external exposure to humans. Radioactive nuclides which can be found in nature are generally categorized in two distinct families, namely of arising from either "Cosmogenic" or "Terrestrial" origin. The most commonly encountered radionuclides that irradiate the human body through external exposure (primarily by gamma radiation) are ^{238}U, ^{235}U and ^{232}Th and their subsequent radioactive decay products and 40K [2-7].

The aim of the present work is to determine the specific activity concentrations of (^{238}U, ^{232}Th, and ^{40}K and the associated radiation hazards such as radium equivalent activity, absorbed gamma dose rate, indoor and outdoor annual effective dose equivalents, external annual effective dose, activity concentration index, internal and external hazard indices soil samples from the Archaeological of Babylon City, Iraq.

2 Experimental Section

Soil samples were collected from 10 locations from depth 0-10 cm in the antiquity's area of the archaeological of Babylon city see figure (1) in the Babylon governorate in the central of Iraq. The samples were ground into a fine powder with a particle size less than 200μm and then dried in a temperature controlled furnace at 100°C for 24 h to remove moisture. Each sample stored in a sealed polyethylene marinelli beaker for 30 days to achieve the

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secular equilibrium. Marinelli beaker was used as sampling and measuring container [8-11].

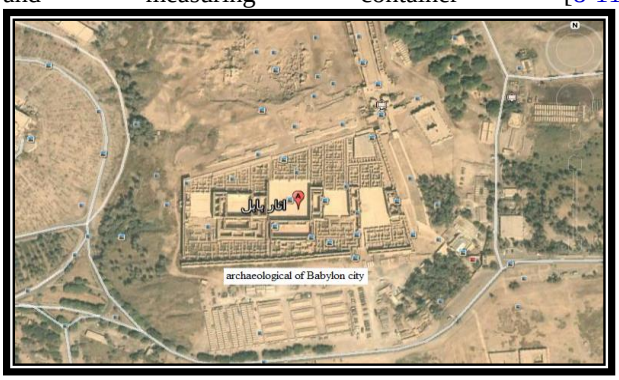

Figure (1) the antiquities area of Babylon city.

The activities of the three natural radionuclides (U-238, Th-232 and K-40) in the samples were determined by gamma rays spectrometry NaI(Tl) of (3"×3"). The spectrometer has been calibrated for energy by acquiring a spectrum from three radioactive elements point source in order to calibrate the system (^{133}Ba, ^{137}Cs and ^{60}Co), as shown in table (1).

Table (1) the radioactive isotopes details used in energy and efficiency calibration.

Isotope	A_o (μCi)	$t_{1/2}$ (y)	E (keV)	I (%)
Ba-133	10.8	10.51	81.00	34.06
			365.02	62.05
Cs-137	1	30.07	661.66	85.10
Co-60	1	5.27	1173.24	99.97
			1332.50	99.99
			2505.69	2×10^{-6}

2.1 The Measurements

2.1.1 Activity Concentration

Since all the elements of radioactive chains effective in the case of late balance so it is possible to calculate the concentration of an element in the series in terms of the concentration of another element, it has been the focus of effectiveness of a series of Uranium account ^{238}U (Radium ^{226}Ra) by focusing effectively account for nuclide Bismuth ^{214}Bi (1764 keV), as well as in Thorium ^{232}Th series has been the focus of effectiveness of the radioactive nuclide Thallium ^{208}Tl (2614 keV), which represents the concentration of thorium ^{232}Th account, and then the concentration of Potassium ^{40}K account radioactive nuclide (1460 keV), the specific activity concentrations of radionuclides in soil archaeological of Babylon city samples were obtained by using the equation [12]:

$$A = (Net\ \ Area - B.G)/M \times I_{\gamma}(E\gamma) \times eff \times T \quad \ldots (1)$$

where:

B.G: Background activity.

A: specific activity concentrations of the radionuclides measured in (Bq/Kg) units.

eff: efficiency of the detectors at energy E_γ.

M : mass motor oil samples (0.5 Kg) .

I_γ (E_γ): is the abundance at energy E_γ.

T: time of measurement which was equal to (10800 s)

2.1.2 Radium Equivalent Activity (Ra_{eq})

To represent the activity concentrations of (U-238, Th-232 and K-40) by a single quantity, which takes into account the radiation hazards associated with them, a common radiological index has been introduced. The index is called radium equivalent activity (Ra_{eq}) which is used to ensure the uniformity in the distribution of natural radionuclides (U-238, Th-232 and K-40) is given by the expression [12]:

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

Where: A_U, A_{Th} and A_K are the specific activities concentrations of (U-238, Th-232 and K-40) in (Bq/kg) respectively.

2.1.3 Absorbed Gamma Dose Rate (D_γ)

Outdoor air gamma absorbed dose rate (D_γ) in (nGy/h) due to terrestrial gamma rays at (1 m) above the ground surface which can be computed from specific activities A_U, A_{Th} and A_K of (U-238, Th-232 and K-40) in (Bq/kg) respectively using the following relation [13]:

$$D_\gamma\,(nGy/h) = 0.462A_U + 0.604A_{Th} + 0.0417A_K \quad \ldots (3)$$

2.1.4 Annual Effective Dose Rate (AED)

The estimated annual effective dose equivalent received by a member was calculated by using a conversion factor of (0.7 Sv/Gy), which was used to convert the absorbed rate to human effective dose equivalent with an outdoor occupancy of (20 %) and (80 %) for indoors [14]:

$$(AED)_{in}(mSv/y) = D_\gamma(nGy/h)\times10^{-6}\times8760h/y\times0.80\times0.7Sv/Gy \ldots (4)$$

$$(AED)_{out}(mSv/y) = D_\gamma(nGy/h)\times10^{-6}\times8760h/y\times0.20\times0.7Sv/Gy \quad (5)$$

2.1.5 External Annual Dose (EAD)

The external annual effective dose was calculated by using the following equation [7]:

$$EAD = (0.92A_U + 1.1A_{Th} + 0.08A_K)\times(10^{-9}Gy/h)$$

× (0.7Sv/Gy)×(24×365) h/y×0.8 ……..(6)

2.1.6 Gamma Index (I_γ)

The gamma index (I_γ) for soil samples was calculated by using the following equation [15]:

$$I_\gamma = \frac{A_U}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \leq 1 \text{……(7)}$$

2.1.7 External (H_{ex}) and Internal (H_{in}) Hazard Indices

The external hazard index is obtained from (Ra_{eq}) expression through the supposition that its allowed maximum value (equal to unity) correspond to the upper limit of Ra_{eq} (370 Bq/kg). The external hazard index (H_{ex}) can then be defined as [16]:

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad \text{…… (8)}$$

Internal exposure to ^{222}Rn and its radioactive progeny is controlled by the internal hazard index (H_{in}) as given below [17-18]:

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad \text{…… (9)}$$

This index value must be less than unity in order to keep the radiation hazard to be insignificant.

3 Results and Discussion

From table (2) it can be noticed that, the specific activity of U-238 was ranged between (9.06 Bq/kg) to (21.22 Bq/kg), with the average value (15.48 Bq/kg), the specific activity of Th-232 was ranged between (11.590 Bq/kg) to (19.040 Bq/kg), with the average value of (15.505 Bq/kg), while the specific activity of K-40 was ranged between (122.25 Bq/kg) to (232.54 Bq/kg), with the average value of (170.21 Bq/kg), from table (2), it can be seen that the specific activity values in all soil samples of archaeological of Babylon city were less than the global limit average (35 Bq/Kg) for U-238, (30 Bq/Kg) for Th-232 and (400 Bq/Kg) for K-40 [19]. Also from the table (2) it can be noticed that, Ra_{eq} was ranged between (36.47 Bq/Kg) to (64.09 Bq/Kg), with the average value of (50.76 Bq/Kg). It can be seen be that the Ra_{eq} values for all soil samples of the archaeological of Babylon city were less than the recommended maximum value (370 Bq/Kg) [19], see Figure (2).

Table (2) specific activities of radionuclides for all the soil samples of the archaeological of Babylon city.

Sample Code	^{238}U (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	Ra_{eq} (Bq/kg)	D_γ (nGy/h)	(A.E.D) (mSv/y)		EAD (mSv/y)	I_γ	Hazard index	
						Indoor E_{in}	Outdoor E_{out}			H_{in}	H_{ex}
S_1	12.450±3.5	11.590±3.4	122.250±11.0	38.437	17.850	0.088	0.022	0.167	0.140	0.137	0.104
S_2	9.060±3.0	12.480±3.5	124.260±11.1	36.474	16.905	0.083	0.021	0.157	0.134	0.123	0.099
S_3	11.580±3.4	15.340±3.9	162.372±12.7	46.019	21.386	0.105	0.026	0.199	0.169	0.156	0.124
S_4	18.060±4.2	11.760±3.4	151.760±12.3	46.562	21.775	0.107	0.027	0.205	0.170	0.175	0.126
S_5	14.390±3.7	17.340±4.1	166.770±12.9	52.027	24.076	0.118	0.030	0.224	0.190	0.179	0.141
S_6	18.810±4.3	15.630±3.9	134.250±11.5	51.498	23.729	0.116	0.029	0.222	0.186	0.190	0.139
S_7	17.430±4.1	19.040±4.3	203.340±14.2	60.314	28.032	0.138	0.034	0.261	0.221	0.210	0.163
S_8	19.580±4.4	17.480±4.1	192.652±13.8	59.411	27.637	0.136	0.034	0.258	0.217	0.213	0.160
S_9	12.270±3.5	15.820±3.9	232.540±15.2	52.798	24.921	0.122	0.031	0.232	0.198	0.176	0.143
S_{10}	21.220±4.6	18.570±4.3	211.870±14.5	64.089	29.855	0.146	0.037	0.279	0.234	0.230	0.173
Ave.	15.485	15.505	170.206	50.763	23.617	0.116	0.029	0.220	0.186	0.179	0.137
Min.	9.060	11.590	122.250	36.474	16.905	0.083	0.021	0.157	0.134	0.123	0.099
Max.	21.220	19.040	232.540	64.089	29.855	0.146	0.037	0.279	0.234	0.230	0.173
Global limit[18]	35	30	400	370	55	1	1	1.5	1	1	1

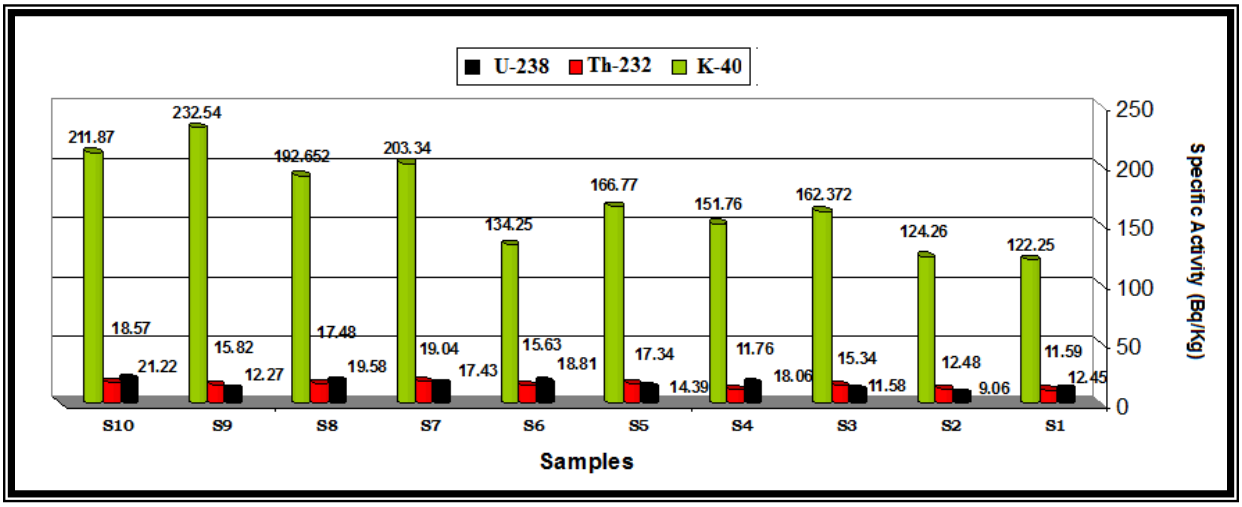

Figure (1) specific activity of (^{238}U, ^{232}Th and ^{40}K) for all the soil samples of the archaeological of Babylon city.

For D_γ one meter above the ground, indoor and outdoor annual effective dose was calculated and given in the table (2). The result shows that the lowest value of D_γ which was equal to (16.91 nGy/h), while the highest value of D_γ which was equal to (29.85 mSv/y), with the average value of (23.62 mSv/y). The values of D_γ for all soil samples of the archaeological of Babylon city were under limit the global limit value (55 nGy/h) [19].

The values of AED_{in} and AED_{out} was ranged between (0.08 mSv/y) to (0.14 mSv/y) and from (0.02 mSv/y) to (0.04 mSv/y) respectively, ,with the average value of (0.12 mSv/y) and (0.03 mSv/y) respectively, all values of AED_{in} and AED_{out} were less than (1 mSv/y) recommended by given [19].

The value of EAD was ranged between (0.157 mSv/y) to (0.279 mSv/y), with the average value of (0.220 mSv/y) ,the present results have shown that values of EAD for soil samples of the archaeological of Babylon city were less than the recommended value of (1.5 mSv/y) for the EAD given by [19].

The value of (I_γ) was ranged between (0.134) to (0.234), with the average value of (0.186), the present results have shown that values of (I_γ) for soil samples of the archaeological of Babylon city were less than the recommended value of (1) for the (I_γ) given by [19].

The values of H_{in} and H_{ex} was ranged between (0.123) to (0.230) and from (0.099) to (0.173) respectively, ,with the average value of (0.179) and (0.137) respectively, It can be seen that all the soil samples of the archaeological of Babylon city were less than the recommended value of (1) for H_{in} and H_{ex} given by [19].

The study under investigation is regarded as the first study in Iraq that deals with the effect of the contents of the radionuclides on levels of natural radiation in soil samples of the archaeological of Babylon city, in addition to being helpful in drawing of radiological maps for the area under study.

4 Conclusions

The environmental monitoring of natural background radiation using sodium iodide NaI(Tl) detector revealed the distribution of the natural radiation levels in all the samples of the archaeological of Babylon city. From the obtained result, one could see that the distribution was not uniform. Also, artificial radionuclide was not detected in any of the measured samples, the average specific activity of U-238, Th-232 and were found to be lower than the recommended values given by UNSCAIR, report and accepted with the radiation levels are within the permissible limits, and the radioactive hazard is low for human beings (employees or tourists) in this area.

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