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Radioactivity Measurement of ^{238}U, ^{232}Th, ^{40}K, and ^{137}Cs in soil of AL-Amara city - Missan governorate-Iraq

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Abstract: The activity of the radionuclides namely ^{238}U, ^{232}Th ,^{40}K and ^{137}Cs are measured in soil samples collected from different locations of AL-Amara city- Missan governorate-Iraq.Using HPGe detector, based on high-resolution gamma and an energy resolution of (≤1.8 keV) for the 133 MeV gamma transition of ^{60}Co. The range of concentrations of ^{238}U, ^{232}Th, ^{40}K, and ^{137}Cs in the samples varies from(9.659±0.733-34.912±5.611)Bq/kg, (11.714±1.287-21.337±1.588) Bq/kg, (212.953±13.071-471.154±22.871) Bq/kg and (B.D.L -3.940±0.393) Bq/kg with overall mean values of 18.882±2.138 Bq/kg, 16.313±1.468 Bq/kg, 369.025±19.447 Bq/kg and 0.896±0.23 Bq/kg, respectively.The radium equivalent rate (Ra_{eq}) calculated from concentration of ^{238}U, ^{232}Th, ^{40}K, and ^{137}Cs ranges between (48.757- 91.420) Bq/kg with mean value 70.625 Bq/kg.The absorbed dose Rate (D_γ) for the soil samples in the study area ranges from (23.046 -43.879) nGy/h with an average value of 33.965 nGy/h. The annual effective dose rate $(AED)_{\text{in range}}$ (0.113-0.215) (mSv/y) with an average value of 0.166 (mSv/y). The annual effective dose rate $(AED)_{\text{out range}}$ (0.028-0.053) (mSv/y) with an average value of 0.041 (mSv/y). The internal hazard index (H_{in}) range (0.165-0.319) with an average value of 0.241**.** The external hazard index (H_{ex}) range (0.131-0.246) with an average value of 0.190. The gamma Index (I_γ) range (0.364-0.690) with an average value of 0.534.The values of the specific activity of (^{238}U, ^{232}Th, ^{40}K and^{137}Cs), radium equivalent activity, indoor and outdoor annual effective dose rates, internal and

external hazard indices, and gamma index, all were found to be lower than their corresponding allowed limits.

Keywords: Natural radioactivity, γ-spectrometry, Radium-equivalent activities, External hazard index, Internal hazard index, annual effective dose rate (AED), Gamma Index.

INTRODUCTION

Radiation and radioactivity in the environment have natural and man-made sources. Exposure to natural radiation represents the most significant part of the total exposure to radiation in the environment Tso, and Leung[1]. Only natural radionuclides with half lives compared to the age of the Earth or their corresponding decay products existing in terrestrial material such as ^{232}Th, ^{238}U, ^{235}U and ^{40}K are of great interest. The levels of these radionuclides are relatively distributed in soil based on the nature of its geological formations Orabi *etal*[2].

Human activities like mining and milling of mineral ores, processing and enrichment, nuclear fuel fabrications, and handling of the fuel cycle tail end products cause the release of additional amounts of natural radionuclides into the environment Saleh[3]. Human beings are exposed outdoors to the natural terrestrial radiation that originates predominantly from the upper 30 cm of the soil only Chikasawa[4]. Knowledge of their distribution in soil and rock plays an important role in the field of radiation protection Rani, and Singh[5].

Man-made radionuclides are produced from nuclear industry activities, nuclear power plant accidents, or military uses. Radionuclides produced from nuclear activities are dispersed into the environmental ecosystems depending on the physicochemical characteristics of the radionuclides and the environmental prevailing conditions Saleh[3]. ^{137}Cs ($T_{1/2}$ = 30.17 years) is a man-made radionuclide released from nuclear fission and activation processes. The latitude and rate of precipitation are the main factors affecting the distribution of ^{137}Cs on the Earth's surface Ritchie and McHenry[6].AL-Amara city are located in the southeastern part of Iraq,about 300 km from Baghdad government and within Alluvial plain, it lies between longitudes (47 ° 07`-47 ° 12`) and latitudes (31 ° 48`-31 ° 53`) Essmael[7].

The aim of the present work is to determine the specific activity of (^{238}U, ^{232}Th, ^{40}K and ^{137}Cs), radium equivalent activity, absorbed gamma dose rate, indoor and outdoor annual effective dose rates, external annual effective dose, activity concentration index, internal and external hazard indices in surface soil samples in some selected regions in AL-Amara city by using high purity germanium (HPGe) detector

Experimental Method: A total of 15 surface samples at 0-5 cm depth level was collected by using GPS from AL-Amara city (as shown in figure 1). After transporting the samples to the laboratory, all sails were dried at 80C° for two hours, pulverized, homogenized, and sieved through 75μm. The sieved soil samples were transferred to Marinelli beakers (500 ml capacity) for radio nuclide analysis. The soil samples were weighed, placed in labeled plastic cases, and stored for 30 days to allow secular equilibrium of ^{226}Ra with its decay products in the uranium series. The activity of ^{214}Bi and^{214}Pb in equilibrium was assumed to represent the ^{238}U activity Begy etal[8].

Gamma-spectrometry analysis of samples was made with HpGe (Canberra- P-type) with 62 mm crystal diameter and 60 mm crystal length. The detector has a photo peak relative efficiency of ≥40 %. To reduce the gamma-ray background, the detector is shielded in 10 cm thick lead, And enveloping

Detector from the inside with a thin layer of cadmium thick (1.6 mm) and thin layer of copper thickness (0.4mm) to attenuation X-ray resulting of interaction gamma rays with a lead material. The energy calibration efficiency of the detector was carried out using Multi- Gamma source that contained (Am-241, Cd-109, Ce-139, Co-57, Co-60, Cs-137, Sn-113, Sr-85, Y-88) emitting gamma rays in the energy range between 59.54 MeV and 1836.08 MeV. Sample measuring times ranged within 3600 Sec.

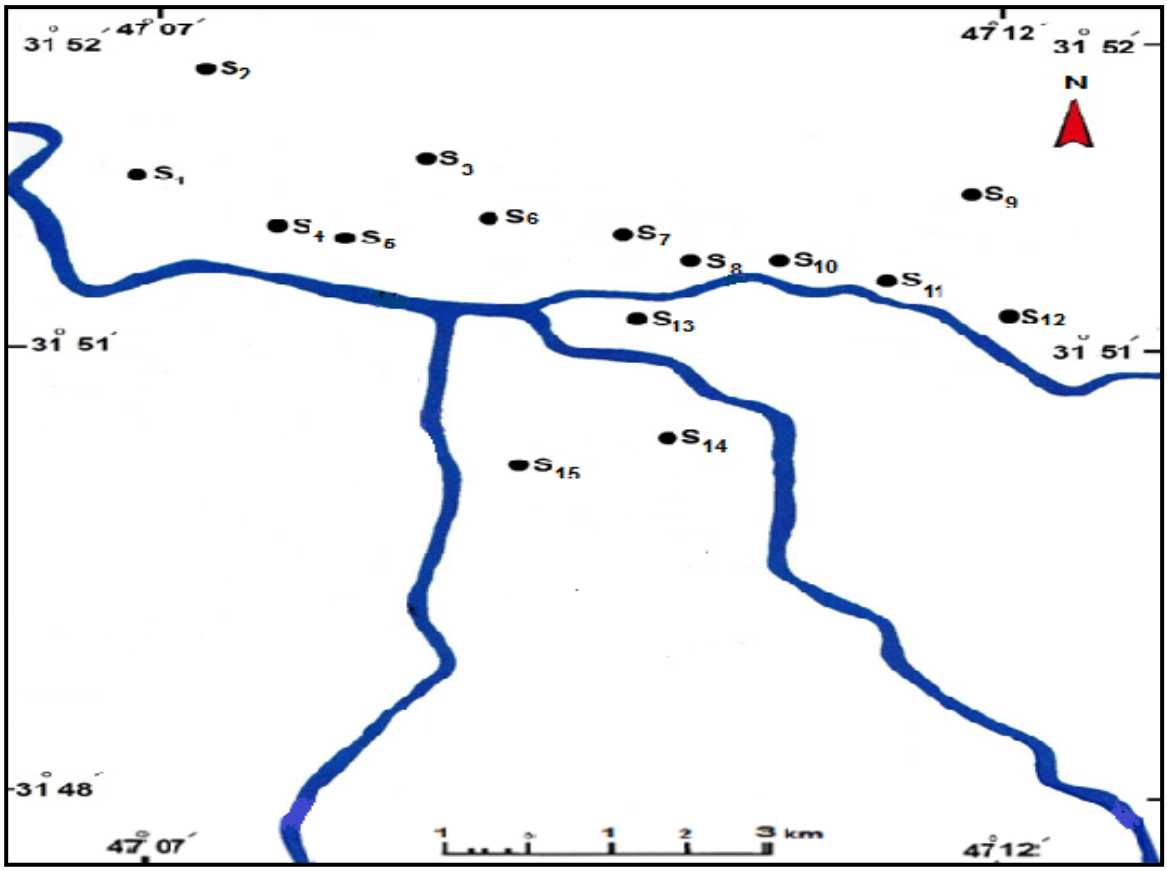

Figure 1: Map of the studied area with sampling location.

GAMMA RADIATION PARAMETERS

1-Radium Equivalent Activity (Ra_{eq}): To represent the activity concentrations of ^{238}U, ^{232}Th and ^{40}K 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 ^{238}U, ^{232}Th and ^{40}K and is given by the expression[9]:

$$Ra_{eq}\ (Bq/kg) = ARa + 1.43A_{Th} + 0.077A_K \quad \ldots (1)$$

Where ARa, A_{Th} and A_K are the specific activity concentrations of ^{226}Ra, ^{232Th} and ^{40}K in (Bq/kg) respectively.

2- Absorbed Gamma Dose Rate (D_γ): Outdoor air, gamma absorbed dose rate ($D_{\square}$) in (nGy/h) due to terrestrial gamma rays at (1 m) above the ground surface which can be computed from specific activities A_{Ra}, A_{Th} and A_K of ^{226}Ra, ^{232}Th and ^{40}K in (Bq/kg) respectively using the following relation Ramola etal[9]:

$$D\left(\frac{\text{nGy}}{\text{h}}\right) = 0.462\,A_{Ra} + 0.604\,A_{Th} + 0.0417\,A_K\ (nGy.h^{-1}) \quad \ldots (2)$$

3-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 Mehra etal[10]:

$$AEDE_{\ out}(mSv.y^{-1}) = D(nGy.h^{-1}) \times 8760h \times 0.7Sv.Gy^{-1} \times 0.2 \times 10^{-6} \quad \ldots (3)$$

$$\text{AEDE}_{\text{ in}}(\text{mSv.y}^{-1}) = \text{D(nGy.h}^{-1}) \times 8760\text{h} \times 0.7\text{Sv.Gy}^{-1} \times 0.8 \times 10^{-6} \quad \ldots (4)$$

4-External (Hex) and Internal (Hin) Hazard Indicies: The external hazard index is obtained from (Raeq) expression through the supposition that it's allowed maximum value (equal to unity) correspond to the upper limit of Raeq (370 Bq/kg). Internal exposure to ^{222}Rn and its radioactive progeny is controlled by the internal hazard index (H_{in}) as given below:

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad \ldots (5)$$

The external hazard index (H_{ex}) can then be defined as given below [9]:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad \ldots (6)$$

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

5-The Gamma Index (I_γ): The gamma index (I_γ) for soil samples was calculated by using the following equation Hossain ***etal*[11]*:***

$$I_\gamma = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \quad \ldots (7)$$

RESULTS AND DISCUSSION

From **Table (1)** it can be noticed that the highest value of specific activity of (^{238}U) was found in (Hai Al Sadir) region, which was equal to (34.912±5.611Bq/kg), while the lowest value of specific activity of

(^{238}U) was found in (Hai Al Ghadeer) region, which was equal to (9.659±0.733 Bq/kg), with an average value of (18.882±2.138 Bq/kg).

Table 1: Specific activity concentrations of (^{238}U, ^{232}Th, ^{40}K and ^{137}Cs), for soil samples in selected regions in AL-Amara city.

Number of samples	**Location**	Y axis	X axis	U-238 (Bq/kg)	Th-232 (Bq/kg)	K-40 (Bq/kg)	CS-137 (Bq/kg)
S_1	Aljmate Hai Al	31.87413	47.12181	18.646±2.418	16.903±1.483	388.323±19.947	3.249±0.338
S_2	Rahma Hai Al	31.89070	47.12746	15.993±1.771	14.047±1.399	345.88±18.912	0.689±0.209
S_3	Al Murtada Hai	31.87733	47.13977	20.984±3.138	17.225±1.480	409.103±20.414	1.546±0.254
S_4	Shuhadaa Hai Al	31.86566	47.13066	25.060±2.757	21.337±1.588	465.544±22.425	B.D.L
S_5	Hai Al-Moualimin Al Jadied	31.86468	47.13868	17.896±0.977	20.760±1.597	471.154±22.871	B.D.L
S_6	Hai Al Zahraa	31.86649	47.14917	16.234±0.940	20.422±1.572	387.255±19.644	0.464±0.182
S_7	Ghadeer Hai Al	31.86276	47.15048	9.659±0.733	13.221±1.425	331.561±18.674	0.750±0.212
S_8	Hai Al Carrama	31.86253	47.16197	34.398±5.743	12.894±1.495	354.665±20.338	B.D.L
S_9	Jihad Hai Al	31.86160	47.17694	14.807±1.986	11.714±1.287	305.246±16.951	0.516±0.160
S_{10}	Hai Al Sadiq	31.86637	47.16637	14.292±0.908	17.457±1.592	398.881±21.126	2.576±0.326
S_{11}	Hai Imam Kadhim	31.86332	47.18597	10.539±0.835	17.183±1.561	316.860±18.091	0.436±0.146
S_{12}	Hai Al Sadir	31.85357	47.21113	34.912±5.611	16.805±1.520	317.908±17.685	3.940±0.393
S_{13}	Hai Al Arouba	31.85521	47.16580	21.576±2.530	15.693±1.352	442.272±21.512	0.757±0.158
S_{14}	Hai Al Hussein Al Jadied	31.83587	47.17289	15.652±0.917	15.211±1.397	387.777±20.052	B.D.L
S_{15}	Hai Al Hussein Al Alkadim	31.84406	47.16401	12.584±0.807	13.829±1.286	212.953±13.071	0.527±0.154
	average			18.882±2.138	16.313±1.468	369.025±19.447	0.896±0.23
	Global limit Cottens[12]			35	30	400	14.8 Tawfiq etal[13]

The highest value of specific activity of (^{232}Th) was found in (Hai Al Shuhadaa) region, which was equal to (21.337±1.588 Bq/kg), while the lowest value of specific activity of (^{232}Th) was found in (Hai Al Jihad) region, which was equal to (11.714±1.287Bq/kg), with an average value of (16.313±1.468 Bq/kg).

The highest value of specific activity of (^{40}K) was found in (Hai Al- Moualimin Al Jadied) region, which was equal to (471.154±22.871Bq/kg), while the lowest specific activity concentration of (^{40}K) was found in (Hai Al Hussein Al Alkadim) regions which was equal to (212.953±13.071Bq/kg), with an average value of (369.025±19.447 Bq/kg).

The highest value of specific activity of (^{137}Cs) was found in (Hai Al sadir) region, which was equal to (3.940±0.393 Bq/kg), while the lowest value of specific activity of (^{137}Cs) was found in (Hai Al Shuhadaa),(Hai Al- Moualimin Al Jadied)and (Hai Al Hussein Al Jadied) regions which were B.D.L, with an average value of (0.896±0.23 Bq/kg).

B.D.L: Below Detection Limit

D.L for (^{137}CS) = 1.368(Bq/kg)

From **Table (2)** it can be noticed that the highest value of radium equivalent activity (Raeq) was found in (Hai Al Shuhadaa) region, which was equal to (91.420 Bq/kg), while the lowest value of radium equivalent activity was found in (Hai Al Hussein Al Alkadim) region which was equal to (48.757 Bq/kg), with an average value of (70.625 Bq/kg).

The highest value of the absorbed gamma dose rate (Dɣ) was found in (Hai Al Shuhadaa) region, which was equal to (43.879 nGy/h), while the lowest value of the absorbed gamma dose rate was found in (Hai Al Hussein Al Alkadim) region which was equal to (23.046 nGy/h), with an average value of (33.965 nGy/h).

The highest value of indoor annual effective dose rate (AED) in was found in (Hai Al Shuhadaa) region, which was equal to (0.215 mSv/y), while the lowest value of indoor annual effective dose rate was found in (Hai Al Hussein Al Alkadim) region which was equal to (0.113 mSv/y), with an average value of (0.166 mSv/y) .

The highest value of outdoor annual effective dose rate (AED)out was found in (Hai Al Shuhadaa) region, which was equal to (0.053 mSv/y), while the lowest value of outdoor annual effective dose rate was found in (Hai Al Hussein Al Alkadim) region which was equal to (0.028 mSv/y), with an average value of (0.041 mSv/y).

The highest value of internal hazard index (Hin) was found in (Hai Al sadir) region, which was equal to (0.319), while the lowest value of internal hazard index was found in (Hai Al Hussein Al Alkadim) region which was equal to (0.165), with an average value of (0.241).

The highest value of external hazard index (Hex) was found in (Hai Al Shuhadaa) region which was equal to (0.246) ,while the lowest value of external hazard index was found in (Hai Al Hussein Al Alkadim) region which was equal to (0.131), with an average value of (0.190).

The highest value of the gamma Index (Iɣ) was found in (Hai Al Shuhadaa) region which was equal to (0.690) , while the lowest value of activity concentration index was found in (Hai Al Hussein Al Alkadim) region which was equal to (0.364), with an average value of (0.534).

Table 2: Radium equivalent activity (Raeq), absorbed gamma dose rate (Dɣ), annual effective dose rate (AED) in and (AED) out annual effective doses, hazard indices (Hin) and (Hex), and the gamma Index (Iɣ) for soil samples in selected regions in AL-Amara city.

				AEDE (m Sv/y)		Hazard	Index	Iɣ
Number of samples	**Location**	Ra_{eq} (Bq/Kg)	$D_ɣ$ (nGy/h)	IN	OUT	H_{in}	H_{ex}	
S_1	Aljmate Hai Al	72.719	35.017	0.171	0.042	0.246	0.196	0.552
S_2	Rahma Hai Al	62.713	30.296	0.148	0.037	0.212	0.169	0.477
S_3	Al Murtada Hai	77.117	37.158	0.182	0.045	0.264	0.208	0.584
S_4	Shuhadaa Hai Al	91.420	43.879	0.215	0.053	0.314	0.246	0.690
S_5	Hai Al- Moualimin Al Jadied	83.862	40.454	0.198	0.049	0.274	0.226	0.641
S_6	Hai Al Zahraa	75.256	35.983	0.176	0.044	0.247	0.203	0.570
S_7	Ghadeer Hai Al	54.096	26.274	0.128	0.032	0.172	0.146	0.417
S_8	Hai Al Carrama	80.146	38.469	0.188	0.047	0.309	0.216	0.594
S_9	Jihad Hai Al	55.062	26.644	0.130	0.032	0.188	0.148	0.419
S_{10}	Hai Al Sadiq	69.970	33.780	0.165	0.041	0.227	0.188	0.535
S_{11}	Hai Imam Kadhim	59.509	28.461	0.139	0.034	0.189	0.160	0.453
S_{12}	Hai Al Sadir	83.422	39.536	0.193	0.048	0.319	0.225	0.612
S_{13}	Hai Al arouba	78.072	37.889	0.185	0.046	0.269	0.210	0.595
S_{14}	Hai Al Hussein Al Jadied	67.263	32.589	0.159	0.039	0.223	0.181	0.514
S_{15}	Hai Al Hussein Al Alkadim	48.757	23.046	0.113	0.028	0.165	0.131	0.364
	average	70.625	33.965	0.166	0.041	0.241	0.190	0.534
	Global limit Cottens[12]	370	55	1	1	1	1	1 Tawfiq etal[13]

CONCLUSIONS

The present results show that the specific activity of (^{238}U), (^{232}Th) ,(^{40}k) and(^{137}CS) for soil samples in the studied regions in AL-Amara city were lower than the value of the global limit which is equal to (35 Bq/kg), (30 Bq/kg), (400 Bq/kg) and (14.8 Bq/kg)), respectively Cottens[12].

The present results have shown that values of Radium equivalent activity, absorbed gamma dose rate, annual effective dose rate (AED) in and annual effective doses(AED) out, hazard indices(H_{in}) and (H_{ex}) , and the gamma Index for the soil samples in the studied regions in AL-Amara city were lower than the value of the global limit which is equal to (370 Bq/kg)**,** (55 nGy/h), (1 mSv/y), (1 mSv/y), (1),(1)and (1)**,** respectively Cottens[12].

The present results have shown that values of Radium equivalent activity, absorbed gamma dose rate, annual effective dose rate (AED) $_{in}$ and annual effective doses(AED) $_{out}$, hazard indices(H_{in}) and (H_{ex}) , and the gamma Index for sediment samples in the studied regions in AL-Amara city were lower than the value of the global limit which is equal to (370 Bq/kg), (84 nGy/h), (0.5 mSv/y), (0.07mSv/y),(1),(1),(1), respectively Cottens[12].

These levels confirm the absence of any unusual nuclear activities within the region during the last period doubled from those levels.

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