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Measurement of Natural Radioactivity in Soil Samples from Bekhma, Kurdistan Region, Iraq

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Abstract- In order to initiate a radiological assessment program and to establish a baseline map of radioactivity background levels in the Kurdistan region environment, this study have been adopted to identify the radionuclide contents in the soil of Bekhma dam region. The activity concentration of natural radionuclide in 12 soil samples, collected from municipal area of Bekhme region, have been studied and evaluated. Gamma ray radioactive standard sources Cesium-137 (^{137}Cs), Potassium Chloride (KCL) and Radium-226 (^{226}Ra) were used to calibrate the gamma-ray spectrometer involving the NaI(TI) scintillation detector. The activity concentration of the natural radioisotopes ^{40}K, ^{226}Ra and ^{232}Th have been estimated to being within the standard acceptable values. Radium equivalent activity, air absorbed dose rate, annual effective dose rate, and the external hazard index were evaluated and found to be within the permissible internationally approved values.

Keywords- Natural Radioactivity, Specific Activity, Gamma-Ray Spectroscopy Nai(TI), Annual Effective Dose Rate.

I. INTRODUCTION

Natural radioactivity arises from the primordial radionuclide, such as ^{40}K, and the radionuclide from ^{238}U and ^{232}Th series and their decay products, which are present at trace levels in all ground formations. The knowledge of specific activities or concentrations and distributions of the radionuclides in these materials are of interest since it provides useful information in the monitoring of environment radioactivity [1].

Mineral and natural resources had been greatly exploited for different uses. Usually, these materials contain natural radionuclides such as from the uranium and thorium series, and K-40, which were known as the Natural Occurring Radioactive Material (NORM). When the NORM is processed, the concentration for these radionuclides became higher in the wastes .Since all these radionuclides have a very long half-life, when concerning about the public safety, it became an urge by regulation under the Atomic Energy Licensing Act (Act 304) to control the limits of discharge [2] therefore, measurements of natural radioactivity in soil are of great interest for many researchers throughout the world, which led to worldwide national surveys in the last two decades [3]. Radium is a radioactive element that occurs naturally in very low concentrations (about one part per trillion) in the earth's crust. Radium in its pure form is a silvery-white heavy metal that oxidizes immediately upon exposure to air. Radium is a major contaminant in mine and milling wastes, such as uranium mill tailings, and is present in various radioactive wastes associated with past uranium processing activities [4].

Potassium is a soft, silver-white metal. An important constituent of soil, it is widely distributed in nature and is present in all plant and animal tissues. Radioactive postassium-40 comprises a very small fraction (about 0.012%) of naturally occurring potassium [4], having a half-life of 1.28×109 years.

The studied area is located in the Kurdistan Region, Iraq, in Duhok Governorate, Beckma Dam District in Fig. 1.

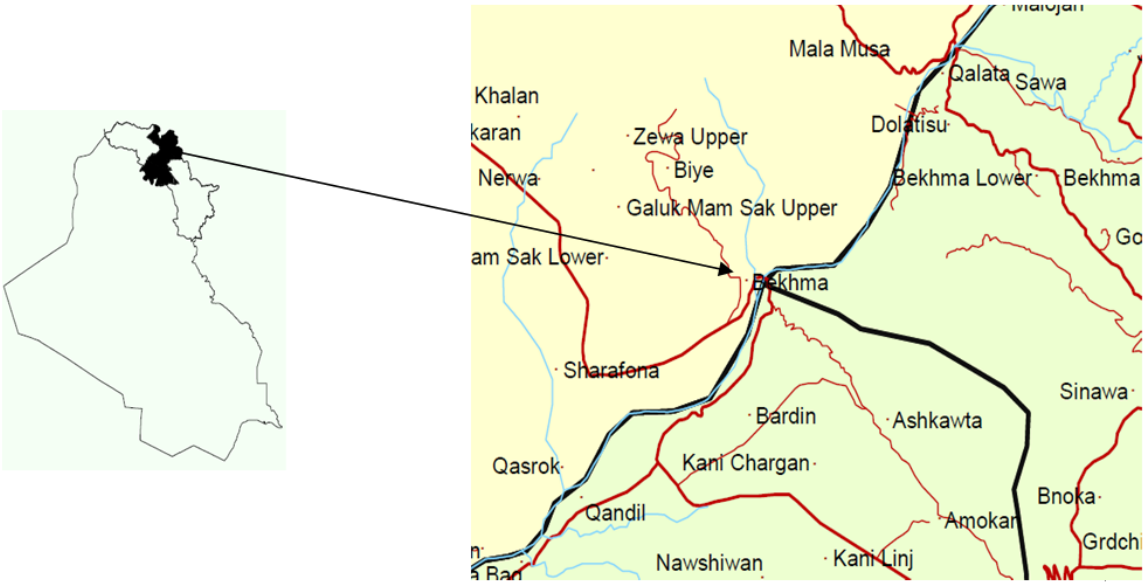

Fig. 1 The Location Map of study area in Beckma Dam, Duhok Governorate, Kurdistan Region, Iraq

II. EXPERIMENTAL METHOD

A) Sample collection and preparation

Twelve Soil samples were collected randomly form the Beckma in the 30 cm depth in the location: N 36^0, E 44^0 and elevation of 377- 401 m. After collection samples were dried at the 100 C^0 for 72 hour to remove moisture and crushed to fine powder, then the homogenized samples were packed in special bottle and sealed tightly with cap kept aside for about month to ensure the equilibrium has been reached between ^{226}Ra and its decay products of short half-life before being taken from gamma spectroscopy analysis.

B) NaI(TI) Gamma Ray Spectroscopy

Gamma ray spectroscopy with scintillation detector NaI (TI) from CASSY has an active area of 2×2 inches, energy resolution 11.3% and Efficiency of 1.2% at the 662 KeV Cs-137 line , was used to determine the activity concentration of U-series, Th-series as well as ^{40}K. The detector was calibrated using ^{226}Ra source form the Nuclear Lab. in Physics department which has eighth ɤ-ray emitters ranged from 186 to 1764 KeV as shown in Fig. 1.

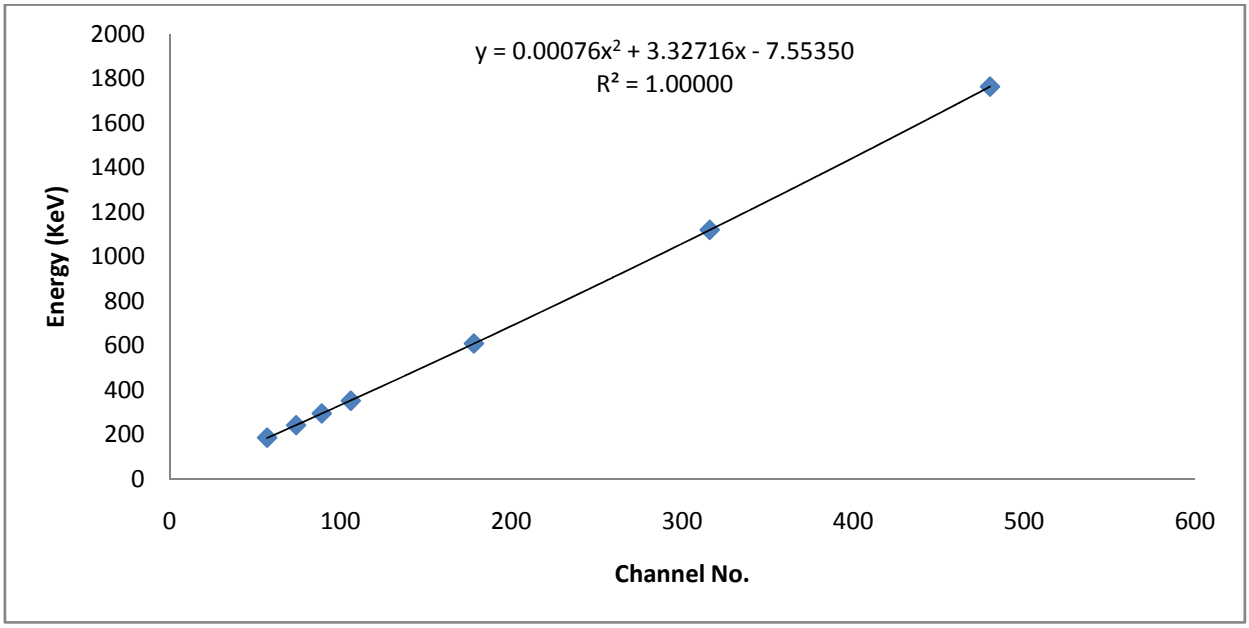

Fig2. Energy Calibration Curve using the ^{226}Ra standard source

The lead castle used in this study to shield the detector had a 10 cm thick as shown in fig. 3. It makes a good shielding material due to its high density and large atomic

III. DATA ANALYSIS

A) Activity concentration for K^{40}

The Count rate for each detected photopeak and activity for each of identified nuclides are calculated. After preparing the detector and calculating the area under the peak the activity concentration determined using the formula [5]:

$$K_k = \frac{A^*}{R} \quad (1)$$

Where A* is activity of KCl Source and R is the area under the peak of KCl source sample, so we can calculate the activity of soil samples by

$$A = R^* \times K_k \quad (2)$$

Where R* is area under the peak of soil sample and A is activity of soil sample.

B) Activity concentration for ^{226}Ra, ^{232} Th and ^{40}K

Count rates for each detected photopeak and activity for each of the nuclides are calculated. The activity concentration of each isotope was given by this formula [6]

$$A(Bq) = \frac{A_{net}}{\varepsilon \times I_\gamma \times t} \quad (3)$$

Where, A_{net} is the neat area of the total absorption line, I_γ is the absolute intensity of transition, t is the sample counting time, and ε is the gamma efficiency evaluated in function of the transition energy.

C) Radium equivalent activity (Ra_{eq})

Distribution of Ra-226, Th-232 and K-40 in environment is not uniform, so that with respect to exposure to radiation, the radioactivity has been defined in terms of radium equivalent activity (Raeq) in Bq.Kg^{-1} to compare the specific activity of materials containing different amounts of Ra-226, Th-232 and K-40 [7].

$$Ra_{eq} = A_{Ra} + 1.43\, A_{Th} + 0.077 A_{K..} \quad (4)$$

Where A_{Ra}, A_{Th} and A_K are specific activity

concentration in $Bq.Kg^{-1}$ of ^{226}Ra, ^{232}Th and ^{40}K respectively.

D) Absorbed dose rates

The outdoor air-absorbed dose rates due to terrestrial gamma rays at 1m above the ground are calculated from ^{226}Ra,^{232} Th and ^{40}K concentration values in soil assuming that the other radionuclide, such as ^{137}Cs, ^{90}Sr and the ^{235}U decay series can be neglected as they contribute very little to the total dose from environment [8]. The conversion factors used to calculate the absorbed dose rates is given in this formula

$$D = 0.461A_{Ra} + 0.623\,A_{Th} + 0.0414A_{K..} \quad (5)$$

In the above conversions, it is assumed that all the decay products of ^{226}Ra, ^{232} Th and ^{40}K are radioactivity equilibrium with their precursors.
The effective dose rate (*E*) in units of $mSvy^{-1}$ was calculated by the following formula [9]

Indoor effective dose:

$$E_{ied}\,(mSvy^{-1}) = D\,(nGyh^{-1})\times 8760h\times 0.8\times 0.7SvGy^{-1}\times 10\text{-}6 \quad (6)$$

Outdoor effective dose:

$$E_{oed}\,(mSvy^{-1}) = D\,(nGyh^{-1})\times 8760h\times 0.2\times 0.7SvGy^{-1}\times 10^{-6} \quad (7)$$

E) Effective Dose

To estimate the annual effective dose rate, the conversion coefficient from absorbed dose in air to effective dose (0.7 $Sv\ Gy^{-1}$) and outdoor occupancy factor (0.2) proposed by [11] were used. The effective dose rate in units of $\mu Sv\ yr^{-1}$ was calculated by the following formula [10]

Effective dose rate($\mu Sv\ yr^{-1}$)=

$$Dose\ rate(nGyh^{-1})\times 8760h\times 0.2\times 0.7SvGy^{-1}\times 10^{-3} \quad (8)$$

F) External Hazard Index

A widely used hazard index (reflecting the external exposure) called the external hazard index H_{ex} is defined as follows [11]

$$Hex = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (9)$$

In addition to external hazard index, radon and its short-lived products are also hazardous to the respiratory organs. The internal exposure to radon and its daughter products is quantified by the internal hazard index (H_{in}), which is given by the equation.

$$Hin = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (10)$$

The values of the indices (H_{ex}, H_{in}) must be less than unity for the radiation hazard to be negligible.

G) Gamma radiation representation level index ($I_{\gamma r}$)

An estimate of the gamma radiation hazard levels associated with natural radionuclides in soil samples was calculated based on radiation hazard index $I_{\gamma r}$ from the following [12]

$$I\gamma r = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \quad (11)$$

IV. RESULTS & DISCUSSION

The activity concentration measurements of the ^{226}Ra, ^{232}Th and ^{40}K radionuclides of the studied soil samples are shown in Table I and plotted in fig. 3, the results were ranged between 8.11 – 18.65 for ^{226}Ra and 2.56 – 9.45 for ^{232}Th and 380.64 – 543.05 for ^{40}K. Table II presents the Radium equivalent and Absorbed Dose rate of ^{226}Ra, ^{232}Th and ^{40}K which were found in the ranges 51.44581 - 64.48822 for Radium equivalent and 26.058622 - 32.446618 for Absorbed Dose rate; both of the calculated quantities are plotted in fig. 4. The important human health related quantities, Effective dose and indoor and outdoor effective doses, have been estimated in this study and tabulated in Table III which were observed to range from 31.95829402 to 39.79253232, 0.12783318 to 0.15917013, and 0.12783318 to 0.15917013, respectively. To compare the obtained results with those found in the other previous works, the resulted specific activity and the absorbed dose rate for the studied samples have been presented in Tables IV and V respectively. In these tables different results from different countries have been depended for this comparison in which a good agreement were found and to certify the reliability of the present work results. Furthermore, the external and

internal radiation hazard indices are calculated for each soil sample and presented in Table VI to range from 0.13893466 to 0.173838432 and from 0.169799525 to 0.224243837, respectively; also the representative level index have been estimated to being in the range 0.427273333 - 0.508213333 (< 1 indicating the safe radioactive level of these types of soil) as listed in the last column of Table VI.

Table I

Activity Concentration (Bq.Kg^{-1}) of ^{226}Ra, ^{232}Th and ^{40}K in the Soil Sample

Sample Code	Activity Concentration of Radionuclides in (Bq.Kg^{-1})		
	Ra-226	Th-232	K-40
S.1	12.75±1.82	7.07±1.2	432.08±3.21
S.2	14.73±1.01	5.73±1.0	418.54±2.98
S.3	15.45±2.10	9.45±1.8	461.36±2.74
S.4	16.87±1.9	6.64±1.3	445.53±3.15
S.5	18.65±0.67	5.01±0.8	500.67±2.83
S.6	12.5±1.2	2.56±0.5	543.05±2.93
S.7	13.43±2.3	9.06±1.3	471.47±2.80
S.8	17.87±1.9	6.11±1.5	380.64±2.97
S.9	8.11±0.76	7.85±1.3	512.27±2.92
S.10	11.42±1.3	4.98±0.9	427.33±2.87
S.11	13.43±1.18	8.28±1.1	396.38±3.02
S.12	10.84±2.4	6.59±1.3	433.66±2.98

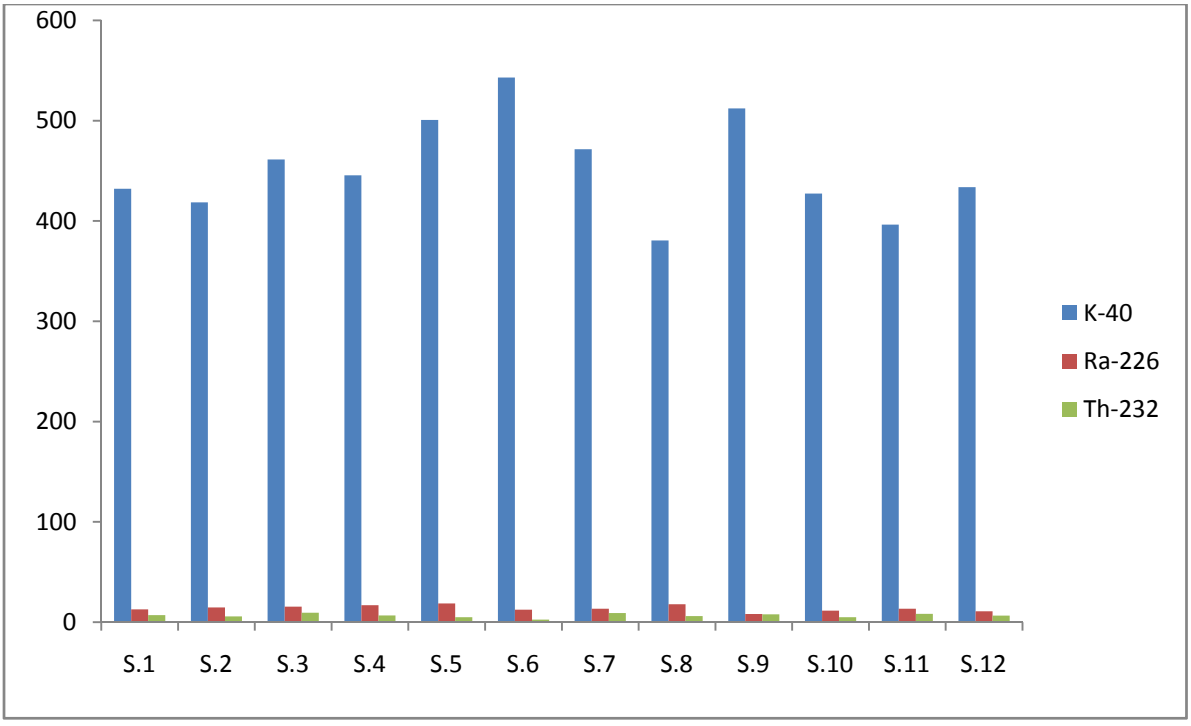

Fig. 3. Activity Concentration (Bq.Kg^{-1}) of ^{226}Ra, ^{232}Th and ^{40}K in the Soil Sample

Table II

Radium equivalent and Absorbed Dose rate of ^{226}Ra, ^{232}Th and ^{40}K in the Soil Sample

Sample Code	***Radium equivalent activity***	***Absorbed dose rates***
S.1	56.13026	28.170472
S.2	55.15148	27.687876
S.3	64.48822	32.110104
S.4	60.67101	30.358732
S.5	64.36589	32.446618
S.6	57.97565	29.83965
S.7	62.68899	31.354468
S.8	55.91658	27.803096
S.9	58.78029	29.837238
S.10	51.44581	26.058622
S.11	55.79166	27.759802
S.12	53.65552	27.056334

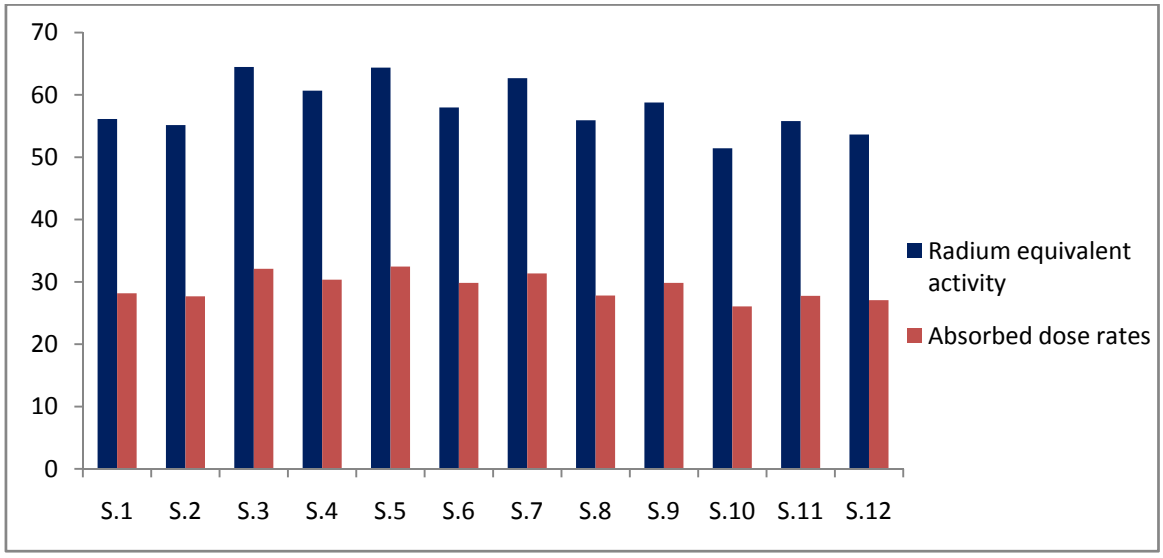

Fig. 4. Radium equivalent and Absorbed Dose rate of ^{226}Ra, ^{232}Th and ^{40}K in the Soil Sample

Table III

Effective dose rate in the Soil Sample

Sample Code	Effective dose rate		
	E_f	E_{in}	E_{ou}
S.1	34.54826686	0.13819307	0.034548267
S.2	33.95641113	0.13582564	0.033956411
S.3	39.37983155	0.15751933	0.039379832
S.4	37.23194892	0.1489278	0.037231949
S.5	39.79253232	0.15917013	0.039792532
S.6	36.59534676	0.14638139	0.036595347
S.7	38.45311956	0.15381248	0.03845312
S.8	34.09771693	0.13639087	0.034097717
S.9	36.59238868	0.14636955	0.036592389
S.10	31.95829402	0.12783318	0.031958294
S.11	34.04462117	0.13617848	0.034044621
S.12	33.18188802	0.13272755	0.033181888

Table IV

Comparison of Specific Activity of ($Bq.Kg^{-1}$) of in the Soil Sample in Soil samples in Bekhma region in other countries[13]

Countries	Activity Concentration of Radionuclides in ($Bq.Kg^{-1}$)					
	Ra-226		Th-232		K-40	
	Mean	Range	Mean	Range	Mean	Range
India	29	7 - 81	64	14 - 160	400	38 - 760
Japan	33	6 - 98	28	2 - 88	310	15 - 990
Spain	32	6 - 250	33	2 - 210	470	25 - 1650
United Sates	40	8 - 160	35	4 - 130	370	100 - 700
Egypt	17	5 - 64	18	2 - 96	320	29 - 650
Iran	28	8 - 55	22	5 - 42	640	250 - 980
Denmark	17	9 - 29	19	8 - 30	460	240 - 610
Belgium	26	5 - 50	27	5 - 50	380	70 - 900
Bulgaria	45	12 - 210	30	7 - 160	400	40 - 800
Poland	26	5 - 120	21	4 - 77	410	110 - 970
Medium	35	17 - 60	30	11 - 64	400	140 - 850
Present Study	14	-	7	-	452	-

Table V
Comparison of Absorbed dose rate in the Soil samples in Bekhma region in other countries

Countries	Absorbed Dase Rate in air ($nGyh^{-1}$)	
	Mean	Range
India	56	20 – 1100
Japan	53	21 - 77
Spain	76	40 - 120
United Sates	47	14 - 118
Egypt	32	8 - 93
Iran	71	36 - 130
Denmark	52	35 – 70
Belgium	43	13 – 80
Bulgaria	70	48 – 96
Poland	45	18 – 97
Medium	57	-
Present Study	29	18 - 93

Table VI
Radiation Hazard index in the Soil Sample

Sample Code	Radiation Hazard Index		
	H_{ex}	H_{in}	$I_{\gamma r}$
S.1	0.151586279	0.186045738	0.443753333
S.2	0.148948916	0.188759727	0.434526667
S.3	0.174160083	0.21591684	0.505073333
S.4	0.16385744	0.209452034	0.475886667
S.5	0.173838432	0.224243837	0.508213333
S.6	0.156568162	0.190351945	0.470966667
S.7	0.169296703	0.205594001	0.494446667
S.8	0.151023166	0.199320463	0.433993333
S.9	0.158728839	0.180647758	0.47408
S.10	0.13893466	0.169799525	0.41082
S.11	0.150673894	0.186971191	0.436586667
S.12	0.144899317	0.174196614	0.427273333

V. CONCLUSION

The measurement level of natural radioactivity of the studied soil sample in the present study shows normal levels of radioactivity concentration. All the obtained K^{40} values show levels within the natural permissible values. Preliminary values for Radium equivalent (Ra_{eq}), Radiation hazard index (H_{ex}) and Annual Effective dose equivalent indicate that the areas monitored can be regarded as having normal levels of natural radioactivity

and can be regarded as a risk free area.

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