Measurement of radioactive nuclides present in soil samples of district Touirij of Karbala province for radiation safety purposes

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Abstract : The study was conducted for the investigation of amount of radioactivity in the different Touirij region in Iraqi town in the province of Karbala, is located just 108 km to the southwest of the Iraqi capital Baghdad. The technique of gamma ray spectrometry was applied using NaI(Tl) gamma ray detector and a PC based Maestro Activity concentration levels due to ^{40}K, ^{238}U and ^{232}Th were measured in. Activity concentrations ranges of the concerned radionuclides for the soils were as follows: ^{40}K was (271.2-170) with the average (245.1), ^{238}U, (30.96-5.86) Bq/Kg with the average (19.45)Bq/Kg, and ^{232}Th, (67.09-2.9) with average(24.47) Bq/Kg respectively. The results have been compared with those of different countries of the world and Iraq. To assess the radiological hazard of the natural radioactivity, the absorbed dose rate, the radium equivalent activity (Raeq), the effective dose rate (Eeff), the annual effective dose equivalent (AEDE), Excess Lifetime Cancer Risk (ELCR), the radioactivity level index (Iγ), and the external (Hex) and internal (Hin) hazard indices were calculated. It can be concluded that no risk may threat the residents around and center of Holy shrines . Hence the probability of occurrence of any of the health effects of radiation is low. Hence, measurements have been taken as representing baseline values of these radionuclides in the soil in studying area.
Keywords: NaI(Tl)detector, natural radioactivity, ^{40}K, ,^{232}Th, ^{238}U ,specific activity, soil.

Introduction:

Gamma ray is electromagnetic radiation produced by nuclear interactions. It is generally characterized as high energy radiation and short wavelengths within the electromagnetic spectrum. This high energy can cause serious damage when absorbed by living cells. Because of its deep penetration property, shielding of gamma ray requires large amounts of mass. Usually materials with a high atomic number and high density are used for better absorption[1]. Gamma-ray spectrometry can be performed using different types of radiation. Ge-detectors combine high resolution with low background to an extent not achievable with thallium activated sodium iodide (NaI) detectors, despite the latter being widely employed for gamma-ray spectrometry. Calculating of the amount of radionuclide present requires knowledge of the efficiency of the detector in the counting geometry. Several methods of determining the efficiency in these unusual geometries have been developed over the years[2] To quantify the efficiency variation as a function of energy, measurements have been made on several coaxial detectors of various crystal types and sizes in different geometries. The full-energy peaks from 60 KeV to 1.3 MeV were used[1]. In the present work, the energy and the range of activity use for

each of these detector types, along with their efficiencies and energy resolutions were measured. Standard analytical gamma-ray peak shape codes were evaluated for both detectors. The goal of this work is to investigate the characterization of NaI(Tl) detectors.

The aim of the present work is study radioactive background in different places in Babylon province , middle of Iraq and determine the type and the concentration for the radioactive nuclides .

Experimental

The nuclear Detector system

The radioactivity of radionuclide's emitting gamma rays to measure by reference to the power of the high penetration of gamma rays in the material using counting and electronic analysis used in the detection consisting of an array of detectors of nuclear radiation sodium iodide system Restaurant thallium NaI(TI) (3"× 3") and the supplier of the company (Alpha Spectra, Inc.-12I12 / 3) [3] provider is a multi-channel analyzer (MCA) (ORTEC -Digi Base) that contains a 4096 channel connecting unit called ADC (Analog to digital Convertor) helps the analyst to convert the next pulse into digital numbers, though nuclear measurements and analysis done by a computer program called (MAESTRO-32) in the laboratory as it is linked to parts of the system ,as Figure (1).
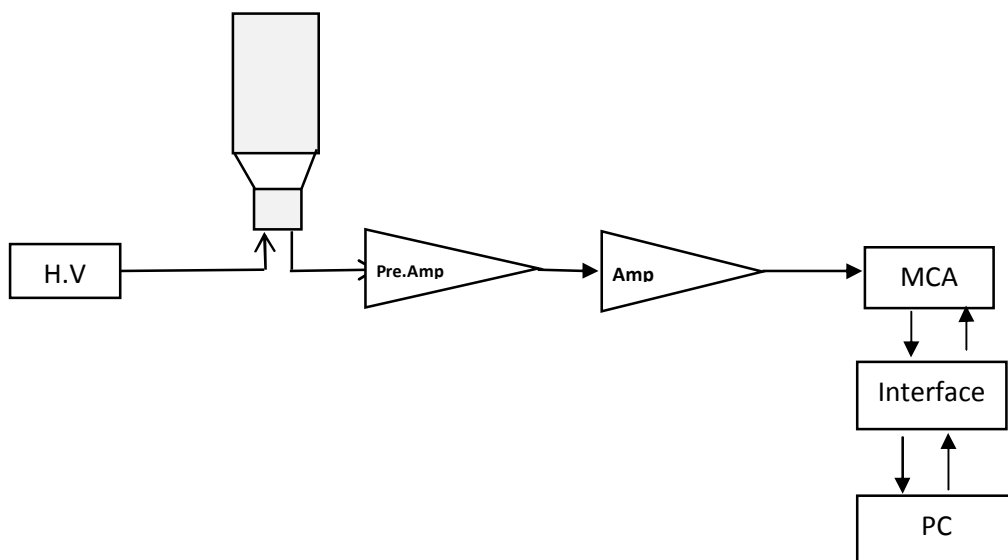

Fig. (1) NaI(Tl) detector(3"x3")[3]

The soil samples preparation

Nine selected places from different *Touirij* region in Iraqi town in the province of Karbala. Located about 25 km east of the city of Karbal (32 ° 32'50 "N 44 ° 14'40" E) is located on the banks of the Shatt al-Hindi a branch of the Euphrates River, which connects the Shatt al-Hilla. The city has palm groves and its neighboring citrus, and a population of about 320,000 people, according to census in 2012 .
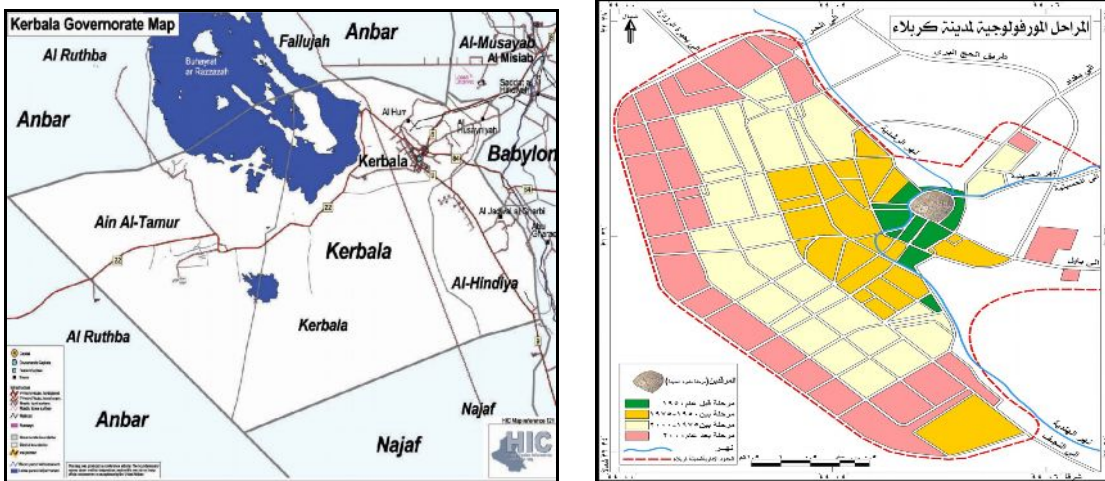
Figure (2) the region selected in the studied[4]

Sample counting

Each prepared soil container was placed on a shielded, NaI(Tl) Scintillator, detector 3″×3″ , and by 1.8 *keV* energy resolution (FWHM) at the 1.33 *MeV* reference transition of ^{60}Co. The samples were measured for a counting time of 18000 *seconds*, and samples were mass (1kg), to obtain a statistically small error (3-5%) for the γ−ray peaks of interest. Further details of the high-resolution spectrometry system, as well as of the data analysis technique are presented elsewhere[5].

Following the spectrum analysis, count rates for each detected photopeak and activity concentration in units of *Bq.kg−¹* for each of the detected nuclides are calculated[6]. The total uncertainty of the radioactivity measurements, which is also applicable to the calculated gamma dose and effective dose rates, was typically in the range 3−10%. It has been calculated by taking into consideration the counting statistical error (3%) and other weighted systematic errors that mainly include the uncertainty in the efficiency calibration (0.5−8%)[7]. Depending on the peak background of the measured spectra, the Minimum Detectable Activity (MDA) was calculated to be 1.0×10−2 *Bq.kg−¹* for both ^{232}Th and ^{238}U, and 4.0×10−2 *Bq.kg−¹* for ^{40}K, for the counting time of 18000 *second* .

The Detection system calibration

Two calibration were done for the gamma ray nuclear detection system , the first for the detection efficiency and the second is the energy , by using a standrad radioactive sources putted in a container of 0.25 L volume .

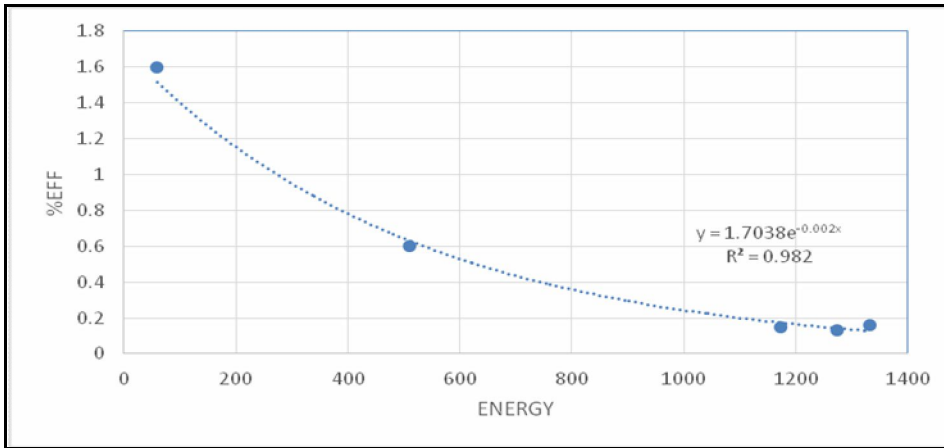The calculate efficiency (ξ) is given by[6]

$$\xi = = \frac{N/T}{A .I\gamma} \qquad \text{……………} (1)$$

N: count rate under photo peak position.

T : time measurement .

A : activity of radioactive sources using of calibration .

I_γ : relative intensity of each energy source of the energies of the radioactive

Fig. (3) The relationship between efficiency and energy

Energy resolution (E.R) shows the ability of a detector to distinguish gamma sources with slightly different energies. The E.R of the detector is defined as the full width at half maximum (FWHM) divided by the location of the peak centroid (n) [7].

A formal definition of FWHM and peak centroid (n) are shown in Fig. (4), where E.R is expressed as percentage [8]

$$\text{E.R} = \frac{FWHM}{Ch} \times 100\% \qquad \ldots\ldots (2)$$

F.W.H.M : Full width at high maximum .

Ch .no : photo peak position

In the present work, the resolution of the detector is found about 8.7% measured by   using Cs-137[9].

The radioactive samples test

The radiation background (B.G) were calculated to sub it from the energy spectrum for the studied sample as in following equation[9].

$$B.G \ (Bq) \quad = \frac{Area}{I_\gamma\%\xi\%T} \qquad \ldots\ldots(3)$$

The specials radioactivity was calculated for each sample with (18000) s time and it calculated from[10] :

$$= \frac{Area\,/\,T - B.G}{I_\gamma\%\xi\% \quad m} \qquad \ldots\ldots(4) \ \textit{Specific Activity (}\text{Bq.Kg}^{-1}\textit{)}$$

Where :

Area : net area under the photo peak position .

m : mass of sample unit (Kg) .

Calculation of Radiation Hazard Indices

You can measure the radium equivalent (Req) of the following equation[10] :

$$Ra_{eq}(Bq/kg) = A_U + 1.43\,A_{Th} + 0.077\,A_K \ldots\ldots\ldots\ldots(5)$$

where A_k, A_{Th}, A_U is the qualitative effectiveness of a series of uranium and thorium series and potassium, respectively. Where the highest value of Raeq must be less than the allowable limit internationally (370 Bq.Kg^{-1}).

The Absorbed Dose Rate in Air

The absorbed dose rate in air express the received dose in the open air from the radiation emitted from radionuclides concentrations in water. The absorbed dose rate can be determined by using Eq. (6).

$$AD\,(nGy\,/\,h) = 0.462\,A_U + 0.621\,A_{Th} + 0.0417\,A_K \ldots\ldots(\,6\,)$$

where 0.461, 0.623 and 0.0414 nGy h^{-1}/Bq kg^{-1} are the conversion factors of ^{226}Ra, ^{232}Th and ^{40}K, respectively [9].

Determination of Radiation Hazard Indices

Many of the radioactive materials decay naturally and when these materials decay produces external radiation field which exposed humans. In terms of dose, the principal primordial radionuclides are ^{232}Th, ^{238}U and ^{40}K. Thorium and uranium head series of radionuclides that produce significant human exposure.

The external hazard index (Hex)

The external risk guide is to assess the risk of natural gamma radiation, is calculated by Eq.(9).

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \ldots\ldots(9)$$

where A_U, A_{Th} and A_K, are the radioactivity concentrations in Bq.Kg^{-1} of ^{238}U, ^{232}Th and ^{40}K .respectively. The value of this index must be less than one for the radiation hazard to be negligible if equal to or greater than one indicates the presence of radiation risk[10] .

The internal hazard index (Hin)

Internal exposure is due to inhalation of radon and his counterpart ,can be calculated by Eq.(10)

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \ldots\ldots(\,10\,)$$

The value of this index must be less than one for the radiation hazard to be negligible [11].

Activity Concentration Index (Iγ)

Coefficient is used to measure the risk arising from gamma radiation associated with natural radionuclides (^{238}U , ^{232}Th and ^{40}K) in the studied material is calculated by Eq.(11)

$$I_\gamma = \frac{A_U}{150} + \frac{A_{Th}}{100} + \frac{A_k}{1500} \ldots\ldots(\,11\,)$$

The value of *Iγ* must be less than unity in order to keep the radiation hazard insignificant[9].

Results and Discussion

Table (1): Specific activities of radionuclides, absorbed dose, Rate of annual effective dose , hazard indices and Activity concentration index of soil samples taken from the surface

| Sample	specific activity (Bq/Kg)			Ra_{eq} (Bq/Kg)	absorbed dose rate AD((nGy.h^{-1})	The Annual Effective Dose (mSv.y^{-1})		Hazard Index		Activity concentration index (I_γ)
	^{238}U	^{232}Th	^{40}K			Indoor	Outdoor	External $(H_{ex} \leq 1)$	Internal $(H_{in} \leq 1)$	
1	7.79	7.56	271.2	39.49	19.61	0.09	0.024	0.1	0.127	0.3
2	5.86	17.2	170.07	43.57	20.48	0.1	0.025	0.11	0.13	0.32
3	14.74	7.56	269.9	46.35	22.76	0.11	0.027	0.12	0.16	0.35
4	12.81	2.9	222.1	34.08	16.99	0.08	0.02	0.09	0.126	0.26
5	26.29	27.67	255.1	85.64	40.03	0.19	0.049	0.23	0.3	0.62
6	30.40	22.11	256.27	81.76	38.46	0.18	0.047	0.22	0.3	0.59
7	19.50	21.19	230.83	67.59	31.8	0.15	0.039	0.18	0.23	0.49
8	27.16	67.09	265.28	143.52	65.27	0.32	0.08	0.38	0.46	1.02
9	30.96	47.22	265.45	118.92	54.69	0.26	0.067	0.32	0.4	0.85

To explain the disparity in the values of specific activity radionuclide in the study area for surface models, has been drawing the relationship between the values of quality activity unit (Bq/Kg) as in Figures(4),(5),(6).
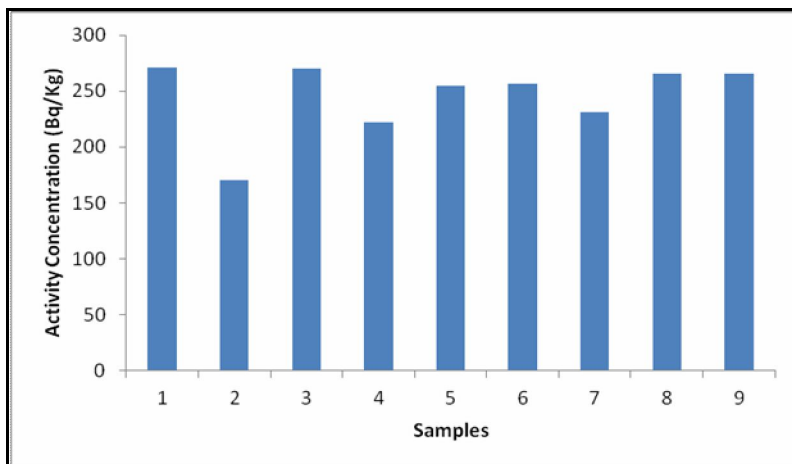
Fig.4. Specific activities of ^{40}K in the surface soil
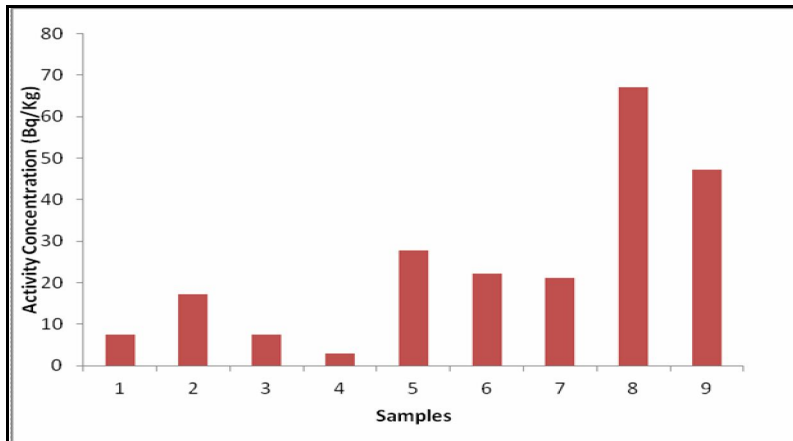
Fig.5. Specific activities of ^{232}Th in the surface soil
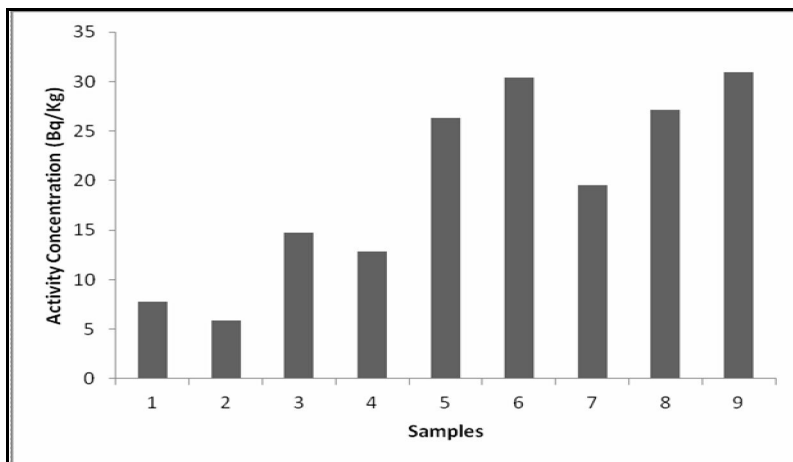
Fig.6. Specific activities of ^{238}U in the surface soil

By comparing the results of this study with the studies described, we find that the specific radioactivity for a selected soil samples lower as compared with these studies . where, In 2010 studied the researcher[12] background radiation in selected areas of the provinces of Iraq using detector sodium activated iodide thallium NaI(Tl) (1"×1.5") It was found that the highest amount of radioactivity specific radioactivity nuclide ^{212}Bi in Dohuk province and was (12.797 Bq / Kg) and nuclide ^{214}Pb in Dhi Qar province, amounting to (4.897 Bq/Kg) and nuclide ^{226}Ra, ^{234}Th concentrations in Basra province reached Bq/Kg (37.844, 38.604) respectively, The nuclide potassium individual (^{40}K) the highest value reached in Tamim province, as well as isotope cesium (^{137}Cs industrial) It was found that the highest value was in Salahuddin province has reached (4.706 Bq/Kg) The lowest value was in the region Latifiyah of Baghdad province has been reached (1.457 Bq/Kg), Has also conducted a researcher (Dawood) in 2011[13] a study to measure the radioactivity of the isotope of radium ^{226}Ra in some soil samples for different areas in the city of Karbala in Iraq, as was noted that between Bq/Kg (11.41 to 99.6) Bq/Kg .In 2011, the researcher[14] measuring and studying natural radioactivity levels of the soil in the Madhlom region in the province of Najaf in Iraq and measured concentrations activities of each of ^{226}Ra, ^{232}Th and ^{40}K, concentration range of activity of radium ^{226}Ra from (11.30 to 25.98 Bq/Kg) , and the concentration range of activity of thorium from ^{232}Th (2.30 to 11.91) Bq/Kg , the concentration of activity for potassium ranged from ^{40}K (66.53 to (25.32 Bq/Kg). the researcher (Aboudi) in 2013[15] measured the concentrations of radioactivity in the eighty-five model for the soil surrounding areas lab Cement Kufa in Najaf province and the results were for ^{238}U vary between (15.90 -102.92) Bq/Kg and ^{232}Th vary between (9.51 -74.55) Bq /Kg and ^{40}K change between (70.15 -4358.83) Bq /Kg by gamma rays Technology using the system detector sodium iodide NaI (Tl) dimensions (3 "× 3").

Conclusion

The activity concentration of terrestrial radionuclide (^{238}U, ^{232}Th, ^{40}K) in soil were measured in nine located in Region *Touirij* . Based on ^{238}U, ^{232}Th, measurements, it can be said that the average activity concentration of these radionuclides are lower than world averages, expect ^{40}K. However, this value of ^{40}K concentration can be accepted to be normal because of the high usage of fertilizers those have potassium. The results of the present work indicate that the radionuclide activity concentrations of the soil samples varied within the study area due to the differences of geological structures. The mean absorbed dose rate and the average annual effective dose equivalent due to naturally occurring radionuclides in Region *Touirij* /Karbala city were lower than the world averages. In summary, all studies in Region *Touirij* / Karbala city are radiology safe; none of them exceeds the recommended action level. This study would be useful for establishing base line data on the natural radioactivity levels in different areas of Karbala province.

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