

Natural Radioactivity Measurement in Soil Samples of District Al-Hindiya of Karbala Governorate-Iraq

قياس النشاط الإشعاعي في عينات تربة منطقة الهندية في محافظة كربلاء-العراق

Mohsin Kadhim Muttaleb

Department of Physics, College of Science ,University of Babylon

E-mail: ama50_24 @ yahoo.com

Abstract

The research was conducted for the investigation of amount of radioactivity in the different Al-Hindiya region in the Governorate 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 (R_{eq}), the effective dose rate (E_{eff}), the annual effective dose equivalent (AEDE), Excess Lifetime Cancer Risk (ELCR), the radioactivity level index (I_{γ}), and the external (H_{ex}) and internal (H_{in}) 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.

Keywords: Natural radioactivity, ^{40}K , ^{232}Th , ^{238}U , specific activity, soil, NaI(Tl) detector.

الخلاصة:

تم إجراء البحث للتحقق من كمية النشاط الإشعاعي في منطقة الهندية محافظة كربلاء، والتي تقع 108 كم إلى الجنوب الغربي من العاصمة العراقية بغداد. تم تطبيق تقنية مطياف أشعة كاما باستخدام كاشف ايوديوم الصوديوم المطعم بالثاليوم للكشف عن الأشعة وجهاز كمبيوتر فوجدت مستويات التركيز إلى ^{40}K ، ^{238}U و ^{232}Th وكانت على النحو التالي: ^{40}K (170 إلى 271.2) بمتوسط (245.1)، ^{238}U (5.86 - 30.96) بيكريل / كغم بمتوسط (19.45) بيكريل / كغم، و ^{232}Th (2.9 - 67.09) مع متوسط (24.47) بيكريل / كغم على التوالي. وقد تم مقارنة النتائج مع نتائج من مختلف دول العالم والعراق، لتقييم المخاطر الإشعاعية من النشاط الإشعاعي الطبيعي، ومعدل الجرعة الممتصة، والراديويم (R_{eq})، ومعدل الجرعة الفعالة (E_{eff})، والمستوى الفعلي للجرعة (AEDE)، ومدى احتمالية الإصابة بالسرطان (ELCR)، أما النشاط الإشعاعي تم حساب مؤشر مستوى (I_{γ}) الخارجي ومؤشرات المخاطر الداخلية. ويمكن أن نخلص إلى أن أي تهديد على السكان حول مركز المزارات المقدسة لا يوجد وبالتالي احتمال وقوع أي آثار صحية للإشعاع منخفض.

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 Al-Hindiya region in the Governorate of Karbala, middle of Iraq and determine the type and the concentration for the radioactive nuclides .

practical part

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(Tl) (3"× 3") and the supplier of the company (Alpha Spectra, Inc.-12112 / 3) [3] provider is a multi-channel analyzer (MCA) (ORTEC -Digi Base) that contains a 4096 channel connecting unit called ADC (Analog to digital Converter) 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):

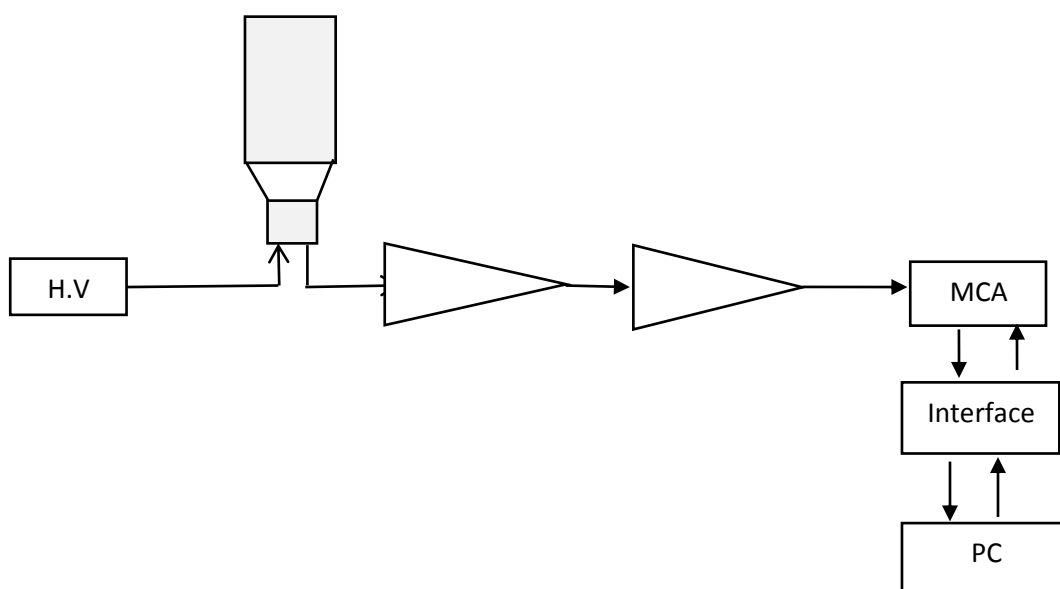


Fig. (1) NaI(Tl) detector(3"x3")[3]

Material and methods

Nine selected places from different Al-Hindiya region in the Governorate 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 .

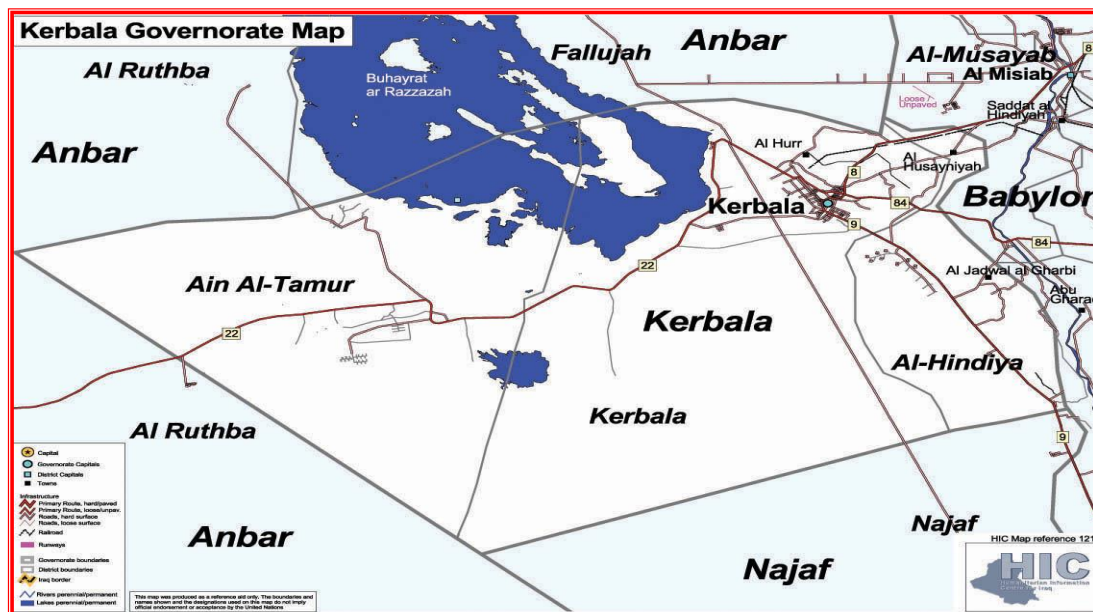


Figure (2) the region selected in the studied [4]

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 ⁶⁰Co. 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 ²³²Th and ²³⁸U, and 4.0×10⁻² Bq.kg⁻¹ for ⁴⁰K, for the counting time of 18000 second .

The Detector 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 standard radioactive sources putted in a container of 0.25 L volume .

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

$$\xi = \frac{N/T}{A \cdot I_{\gamma}} \quad \dots \dots \dots (1)$$

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

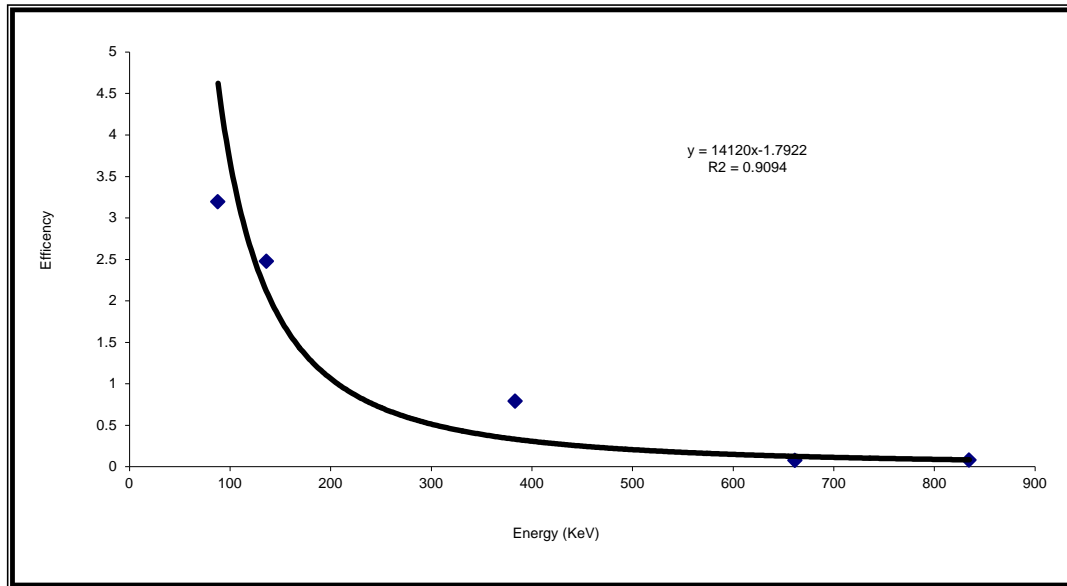


Fig. (3) The relationship between efficiency and energy.

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]

$$E.R = \frac{FWHM}{Ch} \times 100\% \quad \dots\dots\dots (2)$$

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 ¹³⁷Cs [9].

Results and Discussion

The radiation background (B.G) were calculated to sub it from the energy spectrum for the studied sample as in following equation [10] .

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

The specials radioactivity was calculated for each sample with (18000) s time and it calculated from [11]:

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

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 [11]:

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

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 Ra_{eq} 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).

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

where 0.461, 0.623 and 0.0414 nGy $\text{h}^{-1}/\text{Bq kg}^{-1}$ 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).

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

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 [11].

The internal hazard index (Hin)

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

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

The value of this index must be less than one for the radiation hazard to be negligible [12] .

Activity Concentration Index (I γ)

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)

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

The value of I_{γ} must be less than unity in order to keep the radiation hazard insignificant [9].

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.

Sa.	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 _v)
	²³⁸ U	²³² Th	⁴⁰ K			Indoor	Outdoor	External (H _{ex} ≤1)	Internal (H _{in} ≤ 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).

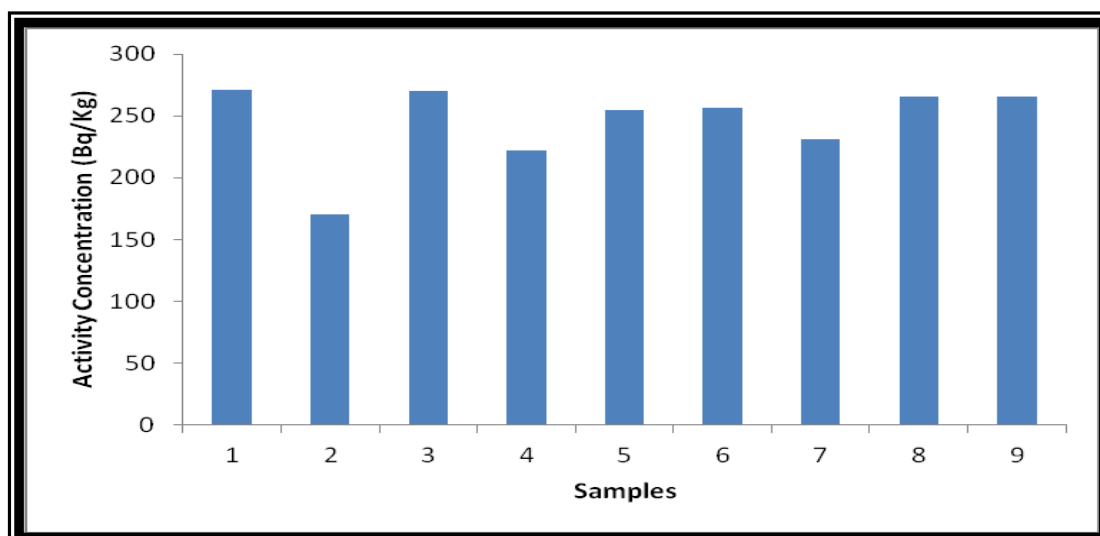


Fig.4: Specific activities of ⁴⁰K in the surface soil

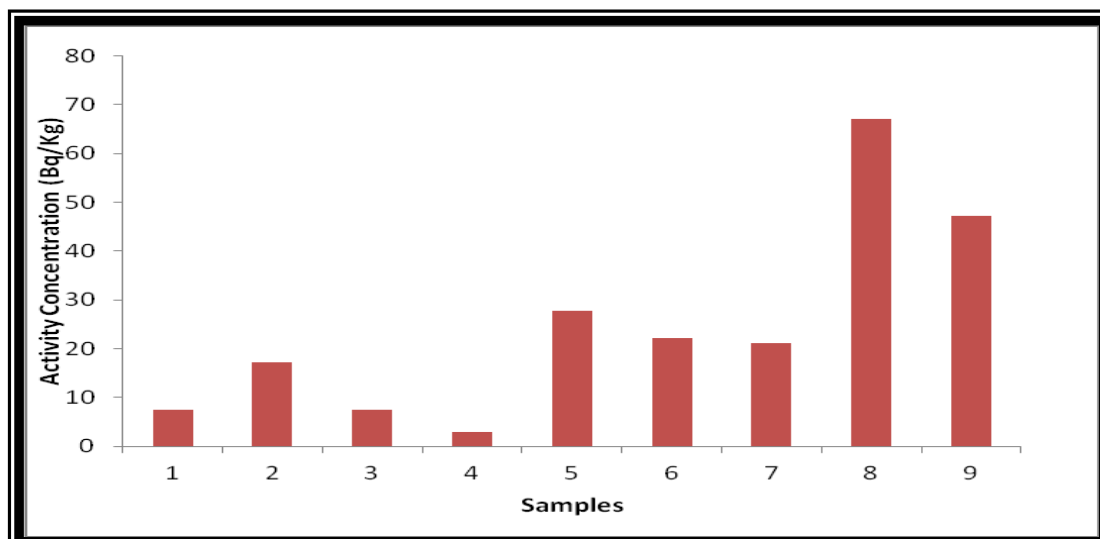


Fig.5: Specific activities of ^{232}Th in the surface soil

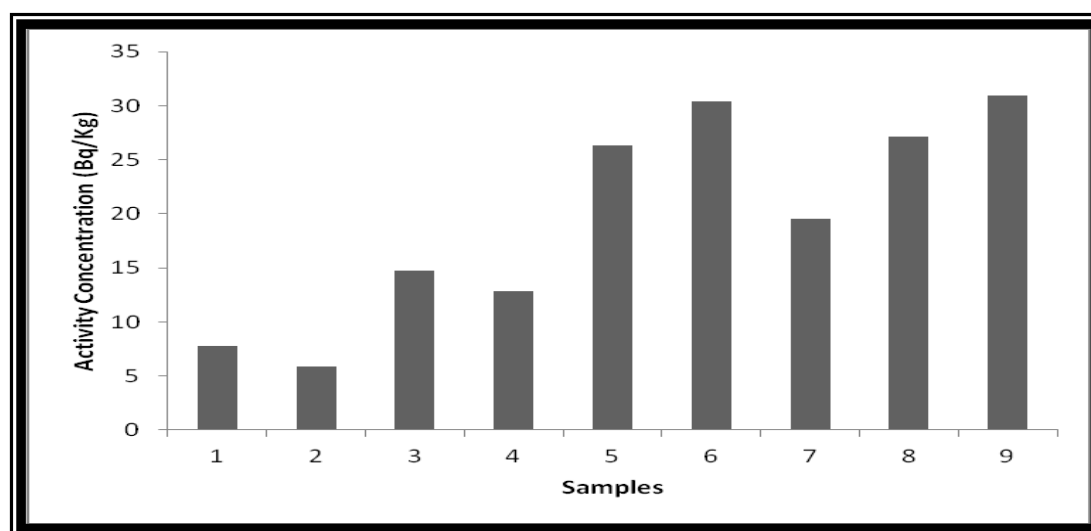


Fig.6: Specific activities of ^{238}U in the surface soil

Conclusion

The activity concentration of terrestrial radionuclide (^{238}U , ^{232}Th , ^{40}K) in soil were measured in nine located in Al-Hindiya region . 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 Al-Hindiya region /Karbala Governorate were lower than the world averages. In summary, all studies in Al-Hindiya region /Karbala Governorate 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 Governorate.

References

- [1] G.,Knoll," Radiation Detection and Measurement " , John Willey & Sons , New York , Third edition ,2000.
- [2] Joel Kindem, Chuanyong Bai, and Richard Conwell, "CsI(Tl)/PIN Solid state Detectors for Combined High Resolution SPECT and CT Imaging", IEEE Journal, PP.1987-1990 ,2010.
- [3] C.M,Salgado,L.E.B, Brandao , C.M.N.A, Pereira, and C.C, Conti, "Validation of a NaI(Tl) detector's model developed with MCNP-X code" ,Elsevier Journal, Vol.59, PP. 19-25, 2012.
- [4] Tsoufanidis, N., "*Measurement and Detection of Radiation*", Hemisphere Publishing Corporation, Washington, 1983.
- [5] Feroz A.Mir, Sajad A.Rather," Measurement of radioactive nuclides present in soil samples of district Ganderbal of Kashmir province for radiation safety purposes ",Journal of Radiation Research and Applied Sciences , Vol. 8 ,pp. 155-159, (2015) .
- [6] Masashi Takada a, So Kamada, Kazuaki Yajima, Kazuki Iwaoka, Hiroko Enomoto, Hiroyuki Tabe, Hidenori Yonehara and Nobuyuki Sugiura,"Measurement of radiation environment inside residential houses in radioactive contaminated areas due to the Fukushima nuclear accident",Journal of Progress in Nuclear Science and Technology, Vol. 4 ,pp. 43-46, (2014) .
- [7] Mirela Angela Saizu and Gheorghe Cata-danll,"Lanthanum Bromide Scintillation Detector for Gamma Spectrometry Applied in Internal Radioactive Contamination Measurements" ,U.P.B.Sci.Bull., Series A,Vol.73, Iss.4, 2011.
- [8] H.M.Diab, S.A.Nouh, A.Hamdy and S.A.EL-Fiki, "Evaluation of Natural Radioactivity in a Cultivated Area Around A Fertilizer Factory",J.Nuclear and Radiation Physics, Vol.(3),No.(1), P:53-62, (2008).
- [9] United Nations Scientific Committee on the Effects of Atomic Radiation, (UNSCEAR),"Sources, Effects and Risks of Ionizing Radiation", New York, United Nations, (2000).
- [10]A.EL-Taher and S.Makhluf," Natural radioactivity levels in phosphate fertilizer and its environmental implication in Assuit governorate ,Upper Egypt",Indian Journal of Pure & Applied Physics, Vol.(48),P:697-702, (2010) .
- [11] J.Singh, H. Singh, S.Singh , B.S. Bajwa and R.G.Sonkawade, " Comparative study of natural radioactivity levels in soil samples from the Upper Siwaliks and Punjab, India using gamma-ray spectrometry", Journal of Environmental Radioactivity,Vol.(100), P:94-94 , (2009).
- [12] A.K.Mahur, K.Rajesh,M.Mishra,S.A.Ali,R.G.Sonkawade,B.P.Singh, V.N.Bhardwaj and R. Prasad,"Study of radon exhalation rate and natural radioactivity in soil samples collected from East Singhbhum Shear Zone in Jaduguda U - Mines Area, I harkhand, India and its radiological implications", Indian Journal of Pure & Applied Physics, Vol.(48),P:486-492, (2010).