Available online at www.scholarsresearchlibrary.com

Scholars Research Library

Archives of Physics Research, 2015, 6 (1):13-19
(http://scholarsresearchlibrary.com/archive.html)

ISSN : 0976-0970
CODEN (USA): APRRC7

Measurement of natural radioactivity in brick samples used in the construction in Iraq

Laith A. Najam[1], Nada F. Tawfiq[2] and Shaher A. Younis[2]

[1]*Physics Dept., College of Science, Mosul Univ., Mosul, Iraq*
[2]*Physics Dept., College of Science, Al-Nahrain Univ.,Baghdad, Iraq*

ABSTRACT

The activity concentrations of the natural radionuclides, namely ^{226}Ra, ^{232}Th and ^{40}K are measured for eleven brick samples collected from some locations of Iraq. An HPGe detector, based on high- resolution gamma spectrometry system is used for the measurement of activity concentrations. The average activity concentration values of ^{226}Ra, ^{232}Th and ^{40}K from the studied are 26.34 Bq/kg , 26.97 Bq/kg and 530.24 Bq/kg respectively. In order to evaluate the radiological hazard of the natural radioactivity , the radium equivalent activity , absorbed dose rate, annual effective dose rate, internal and external hazard indices, gamma index, alpha index, excess lifetime cancer risk and annual gonadal dose equivalent have been calculated.

Keywords: Natural radioactivity, Brick samples, HPGe detector, Radiological hazards, IRAQ

INTRODUCTION

An established fact that all the construction material contains trace amount of the natural radioactivity .This activity in a major source of external and internal radiation exposure to the occupant of the dwelling. The most commonly emountered radionuclide's in the construction material are ^{238}U,^{232}Th their decay products and ^{40}K.Radon isotopes are amongst the members of radioactive series of Uranium and Thorium . The internal exposure due to radon and it's radioactive daughters ,present in the environmental ,result in the largest contribution to the average effective dose received by human beings [1].All building materials such as concrete ,brick, sand, aggregate , marble ,granite, limestone , gypsum , etc., contain mainly natural radionuclide including ^{238}U,^{232}Th their decay products and ^{40}K [2,3].Bricks are used as one of the main building materials, so the knowledge of the basic radiological parameters and radioactive contents in the bricks and others construction materials is important since it allows us to calculate the exposure of the population of the radiation from natural source [4].The aim of this investigation is to estimated the radiological effect to the human being which result from some type of bricks used in Iraq by determine the activity concentration of the ^{226}Ra,^{232}Th and ^{40}K radionuclide's ,and some of the radiological parameters as the radium equivalent activity, gamma absorbed dose rate ,external and internal hazard indices ,and other parameters.

MATERIALS AND METHODS

2.1 Sampling and Sample preparation :

Eleven type of brick samples are collected from different districts of Iraq,(Baghdad factory)(S1),(Al-Taji district)(S2),(Diayla province) (S3), (Erbil factory)(S4),(Kirkuk province)(S5),(Dhululya district)(S6), (Yellow Iranian 1)(S7),(Suylamina province)(S8),(Yellow Iranian 2) (S9),(Karbala province)(S10) and (Red Iranian)(S11). The samples dried by placing it in oven of 110 $^{\circ}$c about 24 h, then crushed to pass through 2 mm sieve to be homogenized in size. The homogenized brick samples were sealed in plastic containers and left for at least one month, before gamma spectrometric analysis, to attain secular equilibrium between radon and its decay products[3] .

2.2 Radioactivity measurement :

The concentration of the natural radioactivity (^{226}Ra, ^{232}Th and ^{40}K) in the brick samples were determined using a high-resolution high purity germanium (HPGe) -spectroscopy system with 40% counting efficiency, and resolution (1.75 keV) , normally based on the measurement of 1.332 MeV gamma ray photo peak of Co-60 source and Cooled with liquid nitrogen **.** A Multichannel analyzer (MCA) with 4096 channel was used. A detector shield had a cavity adequate to accommodate large samples. The Shield had a lead walls with 10 cm thickness lined inside with graded absorber of Cd ~ 1.6 mm Cu ~ 0.4 mm. Calibration and efficiency of the system were carried out using multi – gamma ray standard source (MGS- 5, Canberra) of Marinelli beaker geometry. A library of radionuclide's which contained the energy of the characteristic gamma emissions of each nuclide was analyzed and their corresponding emission probabilities were built from the data supplied in the software.

In order to determine the background distribution due to naturally occurring radionuclide's in the environment around the detector, an empty Marinelli beaker container was counted in the same manner as the samples. After measurement and subtraction of the background, the activity concentrations were calculated.

The activity concentrations for the natural radionuclide's in the samples were computed using the following relation [5,6].

$$A = (CPS)\ net / I \times \varepsilon \times M \qquad (1)$$

where A is the activity concentration in Bq/kg, (cps) net is the (count per second) and equal {(cps)sample - (cps) background}, I is the intensity of the γ-line in a radionuclide, ε is the measured efficiency for each γ-line observed and M is the mass of the sample in gram.

Estimation of ^{226}Ra and ^{232}Th and ^{40}K :

^{226}Ra concentration was determined from γ-peak of 1765keV from ^{214}Bi, ^{232}Th concentration was determined from γ-peak of 911keV from ^{228}Ac and ^{40}K concentration was measured from 1460 keV γ –line.

RESULTS AND DISCUSSION

3.1 Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K :

The activity concentration of ^{226}Ra, ^{232}Th and ^{40}K measured in brick samples are shown in table 1. As seen from table 1, the activity concentration of ^{226}Ra ranged from 15.02Bq/kg (S4) to 41.29 Bq/kg (S5),with an average value of 26.34Bq/kg, while the activity concentration of ^{232}Th ranged from 15.63Bq/kg (S4) to 37.62Bq/kg (S11) with an average value of 26.97Bq/kg and finally the activity concentration of ^{40}K ranged from 293.03Bq/kg (S2) to 786.71Bq/kg (S11) ,with an average value of 530.24Bq/kg. The activity concentration of ^{226}Ra, ^{232}Th and ^{40}K are illustrated in figs.(1) and (2).

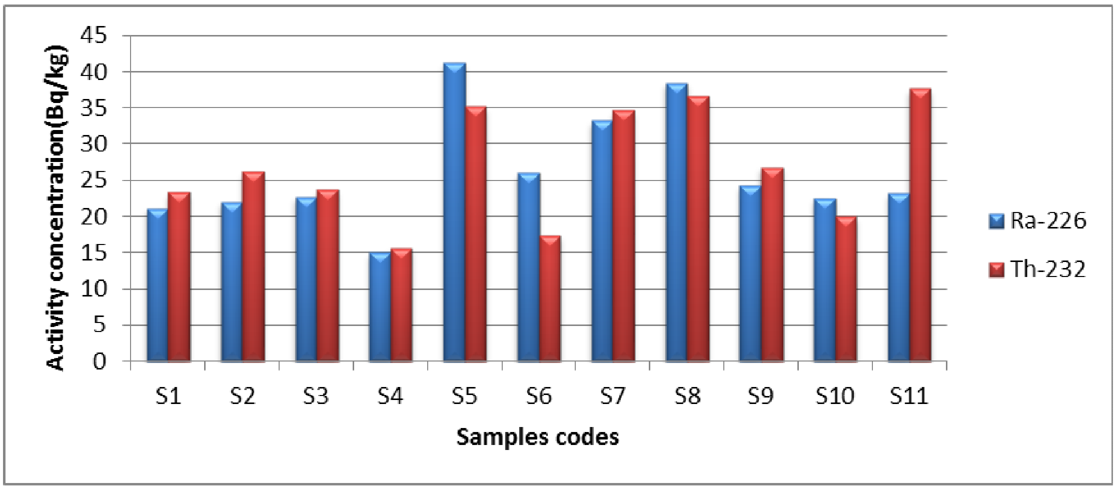

Fig.1 : The activity concentration of ^{226}Ra and ^{232}Th in brick samples in different locations of Iraq

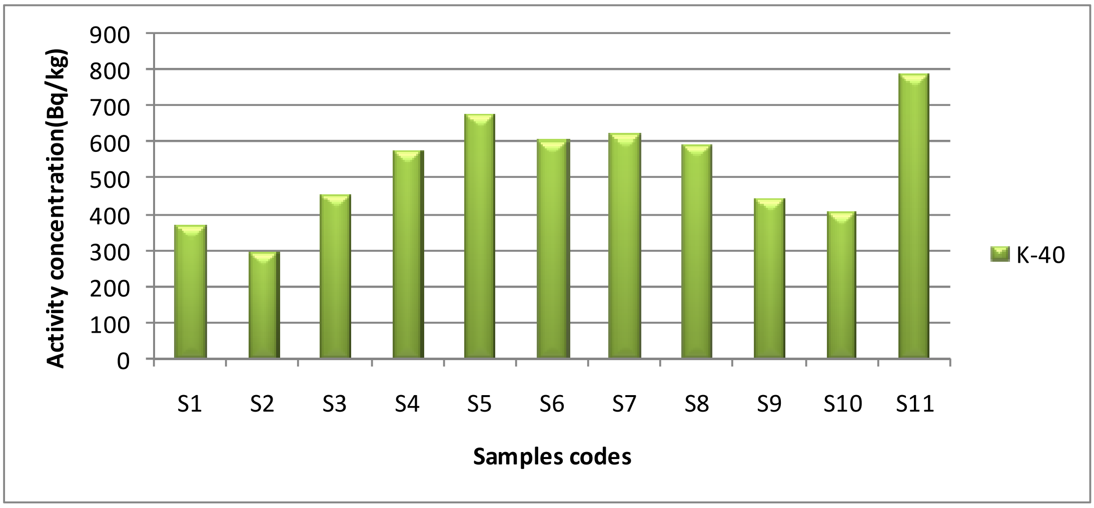

Fig. 2 : The activity concentration of ^{40}K in brick samples in different locations of IRAQ

Table(1) : The activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in Brick samples in different locations of Iraq

Samples codes	Samples weight (gm)	Activity concentration (Bq/kg)		
		^{226}Ra	^{232}Th	^{40}K
S1	350	21.14	23.28	366.01
S2	300	21.95	26.14	293.03
S3	315	22.72	23.66	455.65
S4	375	15.02	15.63	578.97
S5	280	41.29	35.13	678.71
S6	320	25.94	17.41	604.74
S7	170	33.21	34.61	620.50
S8	275	38.46	36.56	597.17
S9	145	24.28	26.78	446.97
S10	150	22.53	19.94	404.25
S11	205	23.20	37.62	786.71
Average± S.D.		26.34± 7.96	26.97± 7.90	530.24± 148.31

3.2 Radiological parameters :

3.2.1 Radium equivalent activities(Ra_{eq})

To represent the activity concentrations of ^{226}Ra, ^{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 ^{226}Ra, ^{232}Th and ^{40}K and is given by the expression [7]:

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

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

As we seen from table(2), the calculated value of (Ra_{eq}) varied from 81.89 Bq/kg (S2) to 143.78 Bq/kg (S5),with an average value of 105.74 Bq/kg . These values are less than 370 Bq/kg, which are acceptable for safe use [8].

3.2.2 External hazard index (H_{ex})

To limit the external gamma-radiation dose from building materials, an extensively used hazard index, the external hazard index (H_{ex}) was calculated from the equation [9].

$$H_{ex} = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \quad \leq 1 \qquad (3)$$

The calculated values of H_{ex} are ranged from 0.221 (S2) to 0.388 (S5) with an average of 0.285 as in table 2, where all values of H_{ex} are less than the critical values of unity [8].

3.2.3 Internal hazard index (H_{in})

Radon and its short-lived products are also hazardous to the respiratory organs. So internal exposure to radon and its short-lived products is quantified by internal hazard index and is expressed mathematically [10].

$$H_{in} = A_{Ra}/185 + A_{Th}/259 + A_K/4810 \leq 1 \quad (4)$$

The calculated values of H_{in} are ranged from 0.261 (S4) to 0.499 (S5), with an average of 0.356 as in table 2,which is less than the critical values of unity [8].

3.2.4 Gamma Index (I_γ)

The gamma index (I_γ) for soil samples was calculated by using the following equation [11].

$$I_\gamma = A_{Ra}/150 + A_{Th}/100 + A_K/1500 \leq 1 \quad (5)$$

I_γ varies from 0.603 (S2) to 1.079 (S5) with an average of 0.798 . The types of bricks which the I_γ values was higher than the critical values of unity are (S5,S8 and S11), as listed in table 2.

3.2.5 Alpha index (I_α)

Also several indexes dealing with the assessment of the excess alpha radiation due to the radon inhalation originating from building materials(brick) "called alpha indexes or internal-indexes" have been developed [5]. In the present work ,alpha indexes were determined through the following formula [12] :

$$I_\alpha = A_{Ra}/200 \text{Bq/kg} \leq 1 \quad (6)$$

$I\alpha$ varies from 0.075 (S4) to 0.206 (S5) with an average of 0.131 ,(table 2), which is less than the critical values of unity [8].

The values of H_{ex}, H_{in}, I_γ and $I\alpha$ are shown in fig.3.

3.2.6 Absorbed Gamma Dose Rate (D)

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

$$D \text{ (nGy/h)} = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_K \quad (7)$$

The absorbed dose in the brick samples ranges from 38.14 nGy/h (S2) to 68.59 nGy/h (S5) with an average of 50.75 nGy/h ,as presented in table 3.

Table (2): Radium equivalent activity, external and internal hazard Indices, gamma index and alpha index for brick samples in different locations of Iraq

Samples codes	R_{aeq} (Bq/kg)	H_{ex}	H_{in}	I_γ	I_α
S1	82.61	0.223	0.280	0.617	0.105
S2	81.89	0.221	0.280	0.603	0.109
S3	91.63	0.247	0.308	0.691	0.113
S4	81.95	0.221	0.261	0.642	0.075
S5	143.78	0.388	0.499	1.079	0.206
S6	97.40	0.263	0.333	0.750	0.129
S7	130.48	0.352	0.442	0.981	0.166
S8	136.72	0.369	0.473	1.020	0.192
S9	96.99	0.261	0.327	0.727	0.121
S10	82.17	0.221	0.282	0.619	0.112
S11	137.57	0.371	0.434	1.055	0.116
Average± S.D	105.74 ±25.69	0.285 ±0.069	0.356± 0.087	0.798± 0.193	0.131 ±0.039

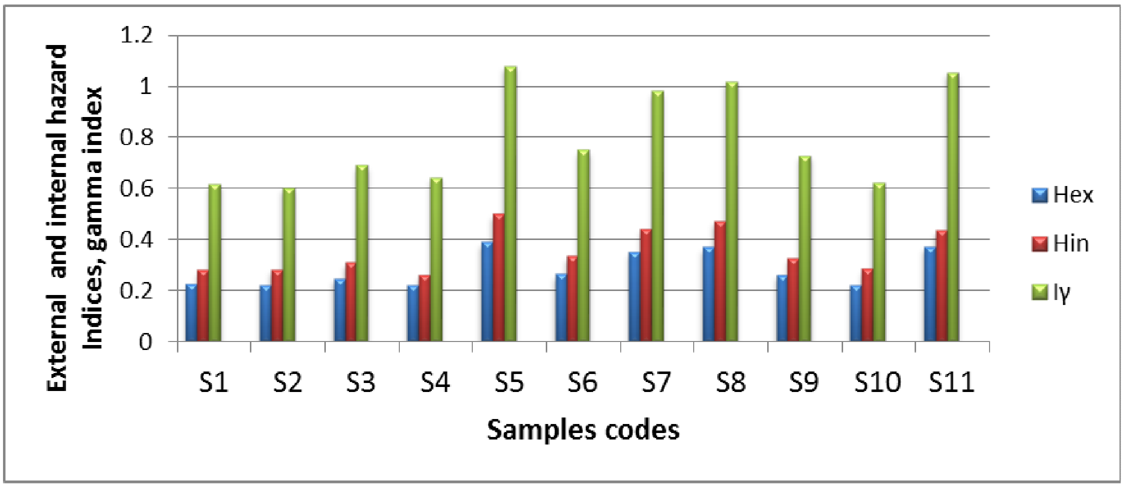

Fig. 3 : Shows external and internal hazard Indices, gamma index in brick samples in different locations of Iraq .

3.2.7 Annual Effective Dose Equivalent (AEDE)

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]:

$$(AEDE)_{out}\ (\mu Sv/y)= D_{\gamma}\ (nGy/h)\times 10^{-3}\times 8760\ h/y\times 0.20\times 0.7 Sv/Gy \qquad (8)$$

$$(AEDE)_{in}\ (\mu Sv/y)= D_{\gamma}\ (nGy/h)\times 10^{-3}\times 8760\ h/y\times 0.80\times 0.7 Sv/Gy \qquad (9)$$

$(AEDE)_{out}$ varies from 46.78µSv/y (S2) to 84.12µSv/y(S5) ,with an average of 62.02µSv/y , the present results are given in table 3 the values of $(AEDE)_{out}$ were lower than the value of the outdoor annual effective dose equivalent global limit which is equal to460µSv/y [8].

$(AEDE)_{in}$ varies from 187.14µSv/y(S2) to 324.97µSv/y (S11) with an average value of 248.10µSv/y, as mentioned in table 3, which is lower than the value of the indoor annual effective dose equivalent global limit which is equal to460µSv/y [8].

3.2.8 Excess Lifetime Cancer Risk (ELCR)

This gives the probability of developing cancer over a lifetime at a given exposure level, It is presented as a value representing the number of extra cancers expected in a given number of people on exposure to a carcinogen at a given dose, and we can calculate (ELCR) by eq. (10) if considering 70 years as the average duration of life for human being.[15].

$$ELCR = AEDE \times DL \times RF \qquad (10)$$

Where AEDE is the Annual Effective Dose Equivalent, DL is the average Duration of Life (estimated to be 70 years) and RF is the risk factor (Sv^{-1}), fatal cancer risk per Sievert. For low dose background radiations which are considered to produce stochastic effects, ICRP 60 uses values of 0.05 for the public exposure [15]. This value-free units because it represents the probability of cancer incidence through this we can deduce the equation above.

From table 3, the (ELCR) values varied from 133.52 $\times 10^{-6}$ (S2) to 240.08x10^{-6} (S5) ,with an average of 177.01$\times 10^{-6}$, for all samples is less than the world average of 290$\times 10^{-6}$ [15].

3.2.9 Annual Gonadal Dose Equivalent (AGDE)

The annual gonadal dose equivalent (AGDE) in mSv /y due to the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K was calculated using the following formula [16] :

$$AGDE(\ mSv/\ y) = (3.09A_{Ra} + 4.19A_{Th} + 0.314A_{K})/1000 \qquad (11)$$

As seen in table 3, the AGDE values of brick samples varied between 0.269 mSv/y (S2) and 0.487 mSv/y with an average value of 0.360mSv/y.This result is slightly higher than the permissible safety limit of 0.3 mSv/y.[17].

The values of (Iα &AGDE) , {$(AEDE)_{out}$ &$(AEDE)_{in}$ } and(Ra_{eq},D ELCR) are shown in figs.4,5 and 6 respectively.

Table (3) : Absorbed Gamma Dose Rate ,Annual Effective dose equivalent (outdoor &indoor) ,Excess Lifetime Cancer Risk and Annual Gonadal Dose Equivalent for brick samples in different regions of Iraq

Samples codes	D nGy/h	AEDE(out) µSv/y	AEDE(in) µSv/y	ELCR×10^{-6}	AGDE mSv/y
S1	39.09	47.94	191.76	136.81	0.277
S2	38.14	46.78	187.14	133.52	0.269
S3	43.78	53.70	214.80	153.25	0.312
S4	40.52	49.69	198.78	141.82	0.293
S5	68.59	84.12	236.50	240.08	0.487
S6	47.71	58.52	234.08	167.01	0.343
S7	62.12	76.18	304.74	217.42	0.442
S8	64.75	79.41	317.65	226.63	0.459
S9	46.03	56.45	225.81	161.10	0.327
S10	39.30	48.20	192.83	137.58	0.280
S11	66.24	81.24	324.97	231.86	0.476
Average ± S.D	50.75 ± 12.22	62.02 ± 14.98	248.10 ± 59.95	177.01 ± 42.77	0.360 ± 0.087

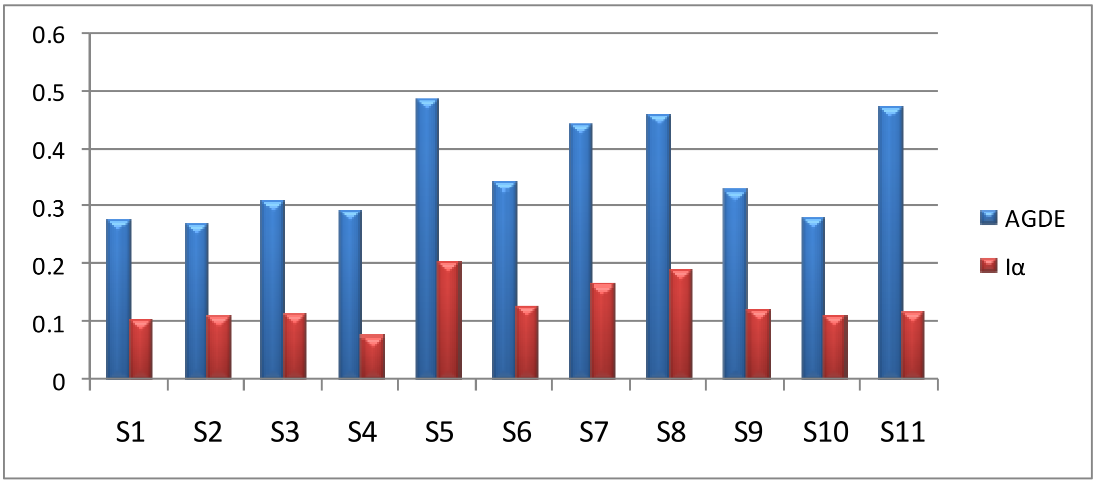

Fig. 4 : Annual Gonadal Dose Equivalent and alpha index for brick samples in different locations of Iraq

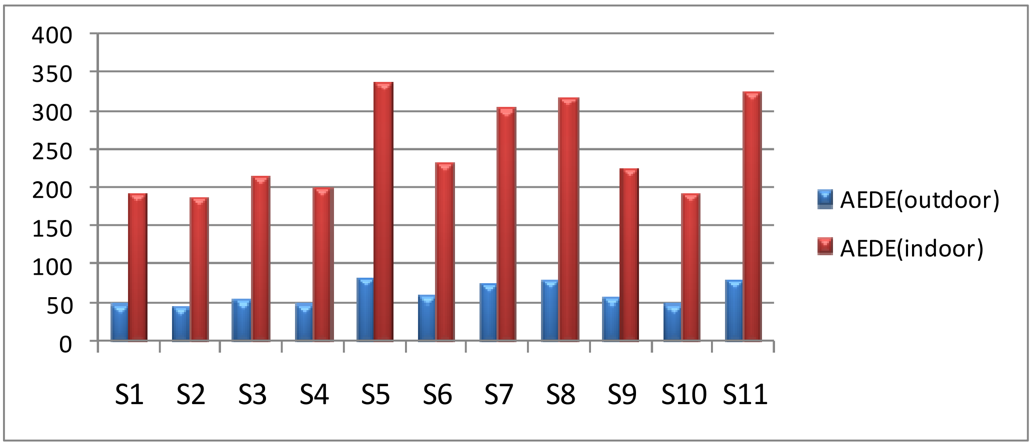

Fig. 5 : Annual Effective dose equivalent (outdoor &indoor) for brick samples in different locations of Iraq

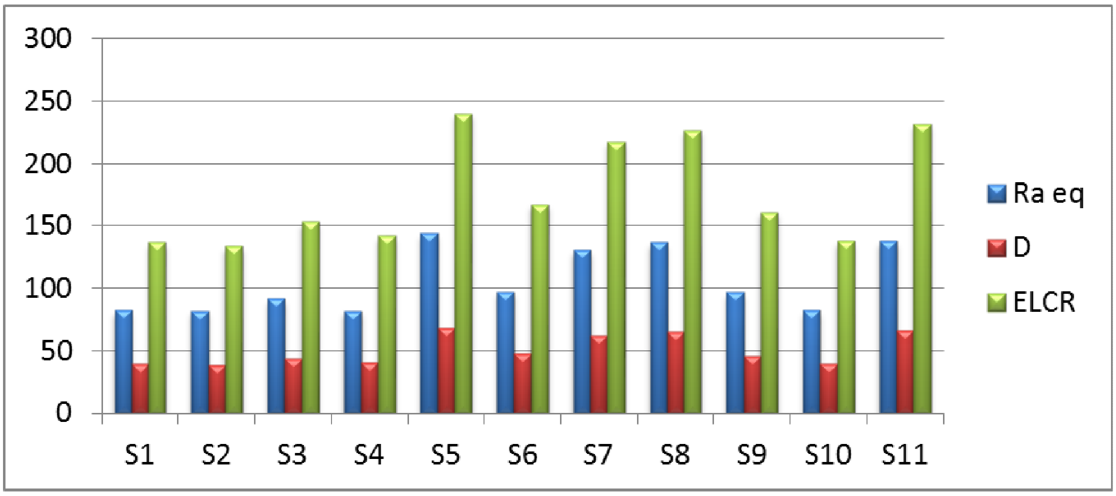

Fig. 6 : Radium equivalent activities, Absorbed Gamma Dose Rate and Excess Lifetime Cancer Risk for brick samples in different locations of Iraq

CONCLUSION

The activity concentration of ^{226}Ra, ^{232} Th and ^{40} K measured in commonly used building materials(brick samples) used for construction purpose in Iraq have been determined by high purity germanium detector. For each sample in this study , the activity concentration ,radium equivalent activity, external and internal hazard indices, gamma index, alpha index, Annual effective dose equivalent (outdoor and indoor), Excess lifetime cancer risk and Annual gonadal dose equivalent have been determined to assess the radiological hazards from brick samples.

The values obtained in the study are within the recommended safety limit, showing that the brick samples do not pose any significant radiation hazard and hence the use of these brick samples in the construction of dwelling is considered to be safe for the inhabitants. This study can be used as a reference for more extensive studies of the same subject in future

REFERENCES

[1] UNSCEAR(**1982**) Sources effects and risks of ionization radiation. United Nation Scientific committee on the Effects of Atomic Radiation. Report to general assembly ,with annexes united Nation. New York.

[2]Ravisankar R.,Vanasundari K.,Chandrasekarran A., Rajalakshmi A., Suganya M., Vijayagopal P.,&Meenakshisundaram V.(**2012**) *Applied Radiation and Isotopes* ,70 ,699-704.

[3]Ravisankar R.,Vanasundari K.,Chandrasekarran A., Rajalakshmi A., Suganya M., Vijayagopal P.,& Meenakshisundaram V.(**2011**) Measurement of natural radioactivity in brick samples of Namakkal, Tamil Nadu, India using gamma- ray spectrometry,2(2) ,95-99

[4] Mehra R., Sonkawade R.G, Badhan K., and Singh S.(**2009**) *Asian Journal of Chemistry*, 21(10), 212-215.

[5] Hayumbu, P., M.B. Zaman, N.C.H. Lubaba, S.S. Munsanje, D. Nuleya, (**1995**) *J. Radional. Nucl. Chem*., 199, 229-238.

[6] Ibrahim, N., (**1999**) *Journal of Environmental Radioactivity*,43, 255-258.

[7] Jose A., Jorge J., Cleomacio M., Sueldo V. and Romilton S.. (**2005**) *Brazilian Archives of Biology and Technology Journal*, 221-228.

[8] UNSCEAR (**2000**) United Nations Scientific Committee on the Effects of Atomic Radiation, Report to the general assembly. Annex B: Exposures from Natural Radiation Sources, New York.

[9] Xinwei L (**2005**) *Radiat .Meas*., 40, 94–97.

[10] Berekta, J., & Mathew, P. J. (**1985**) *Health Physics*, 48, 87-95.

[11] Kafala S. I.& Macmahon T. D**.** (**2007**) *Radiation physics and chemistry*,71,507-516.

[12] Khan, M.S.; Srivastava, D.S.; Azam, A. (**2012**) *Env. Earth Sci*., DOI 10.1007/s12665-012-1581-7.

[13] Vosniakos F., Zavalaris K. and Papaligas T.,(**2003**) *Indoor Journal of Environ. Protect. Ecol*., 4(3),733-737.

[14] Laith A., Nada F., and Fouzey H.(**2013**) *Australian Journal of Basic and Applied Sciences*, 7(1),56-66.

[15]Taskin, H.M, Karavus, P., Ay, A., Touzogh, S., Hindiroglu and Karaham, G., (**2009**) *Journal of environmental radioactivity,* 100,49-53.

[16] Mamont-Ciesla K, Gwiazdowski B, Biernacka M, Zak A. (**1982**) Radioactivity of building materials in Poland. In: Vohra G, Pillai KC, Sadavisan S (eds) Natural radiation environment. Halsted, New York.

[17] Zaidi JH, Arif M, Ahmad S, Fatima I, Qureshi IH (**1999**) *Applied Radiation and Isotopes* ,5,559–564.