Measurement of Natural Occurring Radio nuclides

(NORM$_s$) in Soil using Gamma- ray Spectrometry

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Abstract :

The aim of this work is focused on preparation and using gamma- ray spectrometry to investigate and demonstrate a method to determine and evaluate natural radio nuclides which are uranium, thorium and potassium and their activity concentrations, radium equivalent activity , absorbed dose rates in air at one meter above the ground surface and the annual external and internal effective dose rates . The spectrometer consists of NaI (Tl) detector coupled with preamplifier and ADC of 4096 Chanel memory , CASSY type. The suitable gain was determined. The efficiency , energy calibration and resolution had been measured by using some standard source .. In order to evaluate the radiological impact for the population , four soil samples have been Collected from different localities in middle area of Najaf province , and measured in which ^{238}U ,^{232}Th and ^{40}K were noted. The value of activity concentration ranged from 4.84±0.52 to 17.52±0.94, 5.92±0.31 to 7.07±0.344 and 103.39±2.52 to 185.48±2.09 (Bq kg^{-1}) for ^{238}U, ^{232}Th and ^{40}K respectively . The calculated values of radium equivalent activity (Ra_{eq}) ranged from 25.25 to 33.94 (Bq kg^{-1}) whereas absorbed doses varied from 12.35 to 16.09 (Bq kg^{-1}) . Annual effective Doses were found to be in the range (0.061) to (0.079) and (0.015) to (0.020) (mSv) for indoor and Outdoor respectively . The comparison between our results and standard levels recommended by the IAEA and UNSCEAR show low radiation level .

قياس النويدات المشعة المتكونة طبيعياً في التربة باستخدام مطياف اشعة كاما

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الخلاصة :

ان هدف هذا العمل يتركز على استخدام مطياف اشعة كاما لغرض دراسة وتقييم النويدات المشعة وهي اليورانيوم والثوريوم والبوتاسيوم ووليداتها في التربة وقياس مستوى خطورة الاشعاع عن طريق قياس تركيز نشاطها الاشعاعي النوعي وجرعة اليورانيوم المكافئة وكذلك معدلات الجرعة الممتصة على ارتفاع واحد متر من سطح الارض اضافة الى الجرعة السنوية المؤثرة الداخلية والخارجية .يتكون المطياف من كاشف ايوديد الصوديوم المرتبط مباشرة بمضخم ابتدائي والذي يتصل بدوره بوحدة المحول الخطي الى رقمي الذي يحوي على 4096 قناة من نوع كاسي . تم قياس كفاءة الكاشف وقدرته التحليلية للطاقة بأستخدام عدد من المصادر المشعة القياسية . ولغرض تقدير خطورة الاشعاع جمعت اربع نماذج من مواقع مختلفة من وسط محافظة النجف وسجلت الاطياف الكامية لها ولوحظت قمم الطاقة العائدة الى لكل من اليورانيوم 238 والثوريوم 232 وكذلك البوتاسيوم 40 . كما اشارت النتائج بأن قيم النشاط الاشعاعي النوعي لليورانيم والثوريوم والبوتاسيوم تراوحت من 0.52± 84 الى 0.94±17.52 ومن 0.31±5.92 الى 0.34,4±7.07 ومن 2.52±103.39 الى 2.09±185.48 بوحدات بيركل لكل كيلو غرام لكل من اليورانيوم والثوريوم والبوتاسيوم على التوالي . وكانت القيم المحسوبة لجرعة الراديوم المكافئة ضمن المدى من 25.25الى 33.94 بوحدات بيركل لكل كيلو غرام في حين قيم الجرعة الممتصة على ارتفاع واحد متر من سطح الارض تراوحت من 12.35 الى 16.09 بوحدات النانو كري لكل ساعة . اما الجرعة الممتصة السنوية الخارجية والداخلية تراوحت من(0.061) الى (0.079) ومن (0.015) الى (0.020) بوحدات ملي سيفرت على التوالي .من خلال مقارنة النتائج مع المستويات العالمية المسموح بها من قبل الوكالة الدولية للطاقة ومنظمة المجلس العلمي للامم المتحدة (UNSCEAR) كانت النتائج تشير الى ان مستويات الاشعاع تحت الحدود المسموح بها عالميا

1-Introduction

The knowledge of radionuclide distribution levels in the environment is important for assessing the effect of radiation exposure due to both terrestrial and cosmogenic sources .Terrestrial radiation is due to radioactive nuclei present in varying amounts in soil , building materials ,water, rocks [1]. The transference of some radio nuclides from these sources to man was happened through food chain or inhalations . The internal exposure is due to irradiation and external exposures occur because of inhalation and ingestion . The particular importance of evaluation of gamma radiation dose from natural sources comes from largest contributor of natural radiation to the external dose of word population [2]. The wide ^{238}U , ^{232}Th, ^{40}K and their daughter product dangers effect to human health is the main motivation behind several studies of measuring radiation in environment including the soil and building materials [3,4,5].For this reason and from the natural risk point of view , it is necessary to obtain a system by which we can observe and measure the natural radiation levels [5,6,7]. Gamma ray spectrometry is a good technique used to measured and analysis of natural and artificial radionuclide [8,9].The result of this study will b used to establish a baseline map for Najaf area which will be use a reference in formation to record any change in the radioactivity background level due to the change in the topography of the location , other developments and settlement around it and any artificial influences on the environment . The aim of this work is to estimate and demonstrate a method based on the use of gamma- ray spectroscopy technique to determine the natural occurring radionuclide (NOR) in soil in middle of Najaf city .

2-Theoretical part

2-1 Specific activity

The calculation of specific activity was based on equation (1):

$$A = C / (\varepsilon I_\gamma t m) \quad \ldots\ldots(1)$$

Where : A : specific activity,

C : area under the photo peak ,

ε : counting efficiency ,

I_γ : probability of gamma transition ,

t : time of measurement ,

m : mass of the sample .

2-2 Ra_{eq} (Radium equivalent activity) :

T o asses the radiological hazard of soil , it is useful to calculate an index called the radium equivalent activity (Ra_{eq}) [10] defined according to estimation that 1Bq kg^{-1} of ^{226}Ra , 0.7Bq kg^{-1} of ^{232}Th and13 Bq kg^{-1} of ^{40}K produce that the same γ-ray dose [10,11] . Ra_{eq} is given as .

$$Ra_{eq} = A_U + B * A_{Th} + C * A_K \quad \ldots.(2)$$

Where : A_U, A_{Th} and A_K : the specific activity of ^{238}U ,^{232}Th and ^{40}K respectively . B , C : are conversion factors .

2-3 Absorbed doses

The gamma dose rate in the outdoor air at one meter above the ground is calculated by using equation (3)[13] .

$$D(nGy/h) = C_1 A_U + C_2 A_{Th} + C_3 A_K \quad \ldots.(3)$$

Where : C1, C2 and C3 : are the absorbed dose rate conversion factors (DRCF) ; AU ,ATh and AK are the activity concentrations of ^{248}U , ^{232}Th and ^{40}K in (Bq kg^{-1}) respectively .

2-4 Effective dose

To convert the absorbed dose rate to human effective dose equivalent with an indoor occupancy of 80 % and 20% for outdoor , a conversion factors (A) and (B) in ($SvGy^{-1}$) were used for indoor and outdoor respectively [1,13] .

The annual effective doses were determined as following [14] .

Indoor (nSv) = (Absorbed Dose) $nGyh^{-1}$ × 8760h × (A) × 0.7 $SvGy^{-1}$ …… (4)

Outdoor (nSv) = (Absorbed Dose) $nGyh^{-1}$ × 8760h × (B) × 0.7 $SvGy^{-1}$ …… (5)

Where : A and B are conversion factors .

3- Experimental Part :

3-1 Sample preparation

Four surface soil samples were collected from different locations in the middle area of Najaf province . from each location , one sample was collected by digging a hole at a depth of 10 cm before the ground surface . the samples were , crushed , sieved through 0.2 mm mesh and dried in an oven at a temperature of 100 C^0 for 24 h . One kg of each sample was packed in polyethylene marginally beaker of 1.4 L volume . The samples were counted for a period of 10000 second .

3-2 Shielding

The block diagram of gamma ray spectrometry was shown in fig (1) .The detector is shielded by a chamber of 2 layer starting from inside with copper (2 mm thick), followed by lead 10 cm thick from out side .

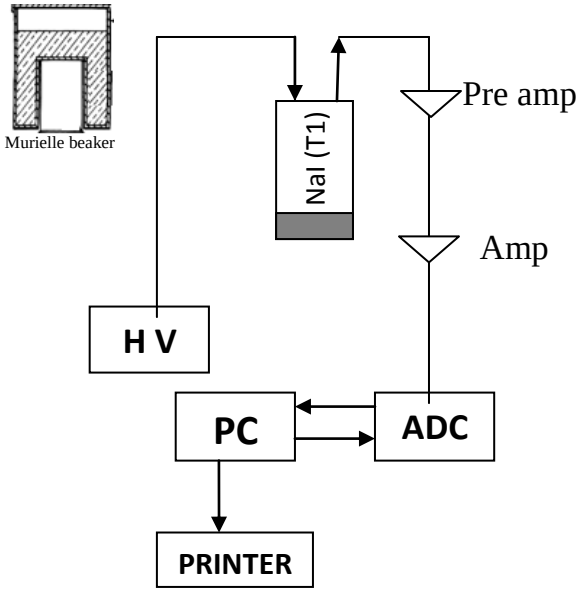


Figure (1) : Block diagram of spectrometer

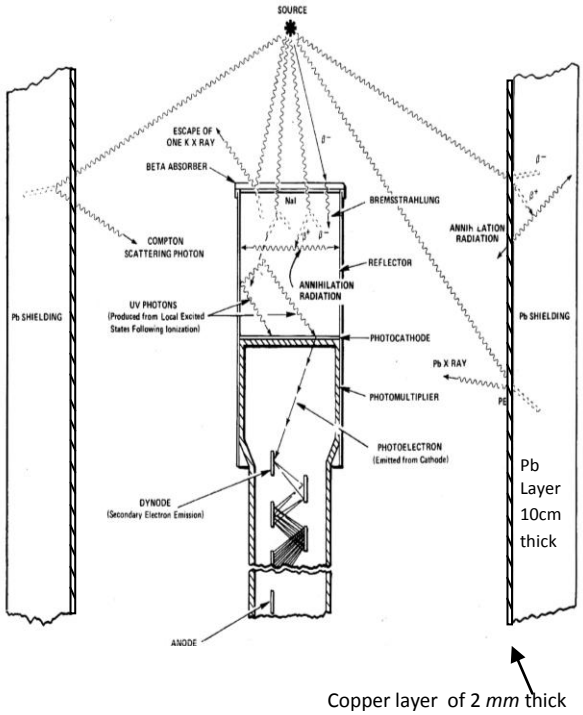
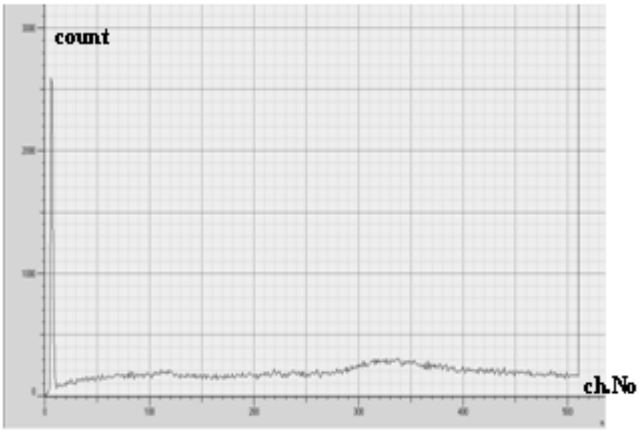


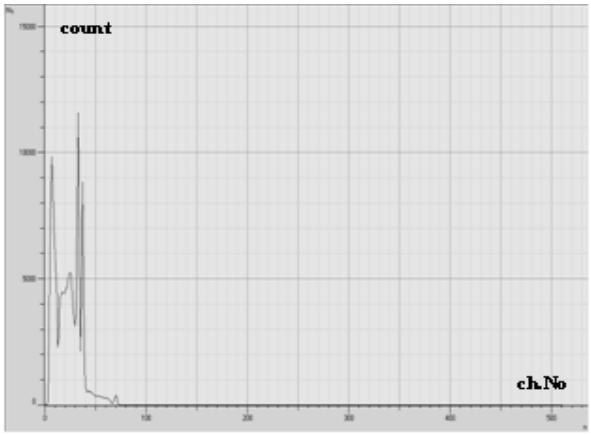
Figure (2): Different processes in the NaI(Tℓ) crystal

3-3 The gain

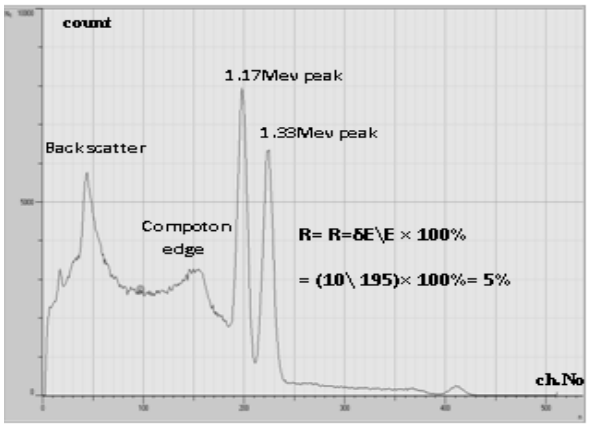
To obtain a suitable value of gain , we recorded several spectra of ^{60}Co standard source for different values of gain as shown in figures (3,4,5) .



Figure(3) : Measured spectrum of ^{60}Co , gain = (-8) .



Figure(4) : measured spectrum of ^{60}Co , gain = (+3) .



Figure(5) : measured spectrum of ^{60}Co , gain = (-0.98) .

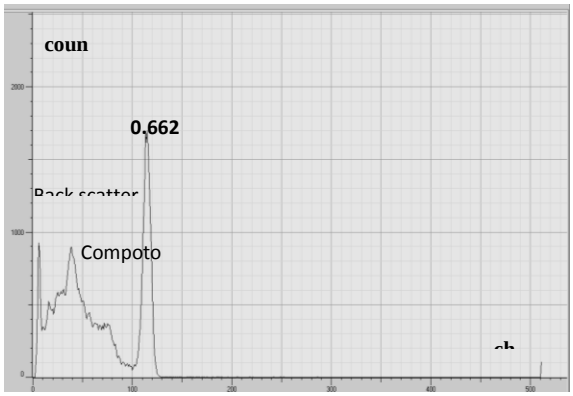


Figure. (6) Spectrum of ^{137}Cs

From the three figures (3,4,5) , the best value of the gain was of -0.98 .For energy calibration we requiring a spectrum from radioactive standard sources of known energies like (^{137}Cs , E_γ = 662 KeV) and (^{60}Co ,$E_{\gamma 1}$= 1173 KeV and, $E_{\gamma 2}$=1332 KeV) as shown in figures (5,6).

3-4 Counting efficiency

To calculate the counting efficiency of the detector we use equation (6) [1,4].

$$\varepsilon = A_{re} / A_t \,.\, t \times 100\ \% \qquad \ldots.(6)$$

Where :

A_{re} : recorded area under the photo peak ,

A_t : Activity of standard source ,

We used equation (7) to correct equation (1)[1].

$$A_t = A_O\, e^{-\lambda t_d} \qquad \ldots\ldots\ldots\ldots\ldots(7)$$

Where:

$\mathbf{A_o}$: The primary activity at manufactured date.

$\mathbf{t_d}$: The period of time between the date of manufacturing and the date of measuring in second.

3-5 Energy resolution:

The resolution of spectrometer is defined as the ability to separate two peaks that closed together in energy

The resolution of photo peach is found by solving the followin

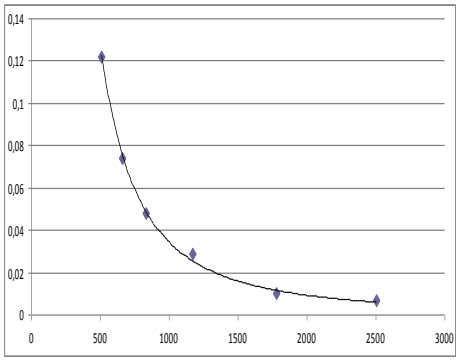
$$\mathbf{R = \frac{\Delta ch}{P.P} \times 100\% \ldots\ldots (8)}$$

Where :**R**: The resolution **; Δch** = The Full width of photo peak at half of the maximam count level (FWHM) measured in number of channels; **P.P** : The channel number at the centre of the photo peak.

4- Result and Discussion:

The counting efficiency of the system was calculated by using ^{137}Cs , ^{60}Co and ^{22}Na ,standard sources. The efficiency curve was plotted in figure (7)

ε



E(KeV)

Figure (7) : Counting efficiency of the detector

From these spectra , three gamma-ray lines of ^{214}Bi (1760 KeV) , ^{208}Tℓ (2615 KeV) and ^{40}K (1460 KeV) were used to determine the activity concentration of ^{238}U, ^{232}Th and ^{40}K respectively .

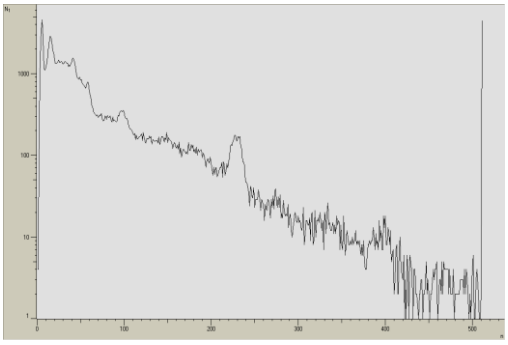


Figure (8) Spectrum of soil sample s_1

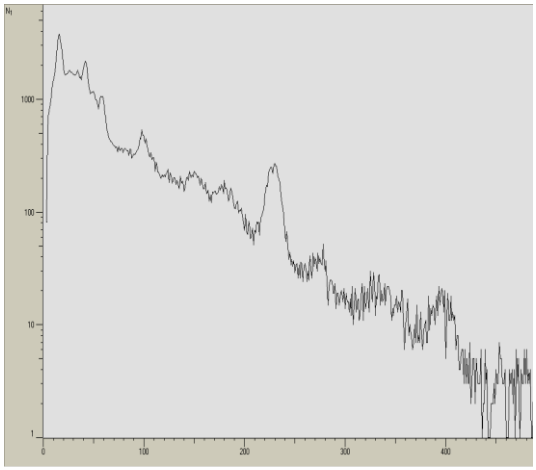


Figure (9) Spectrum of soil sample s_2

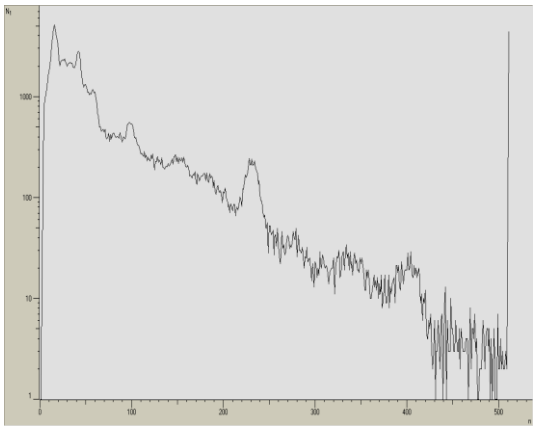


Figure (10) Spectrum of soil sample s_3

Table (1) represents the activity concentrations of soil sample obtained by direct gamma-ray spectrometry . the activity concentrations of ^{40}K was found to be in the range 103.39±2.52 to 185.48±2.09 (Bq kg^{-1}) while for ^{238}U it was in the range 4.84±0.52 Bq kg^{-1} to 17.52±0.94 Bq kg^{-1}. On the other hand

Table (1) : Activity concentrations of the sample

Sample Code	Activity concentration Bq kg^{-1}		
	^{238}U	^{232}Th	^{40}K
S_1	9.18±0.67	6.38±0.32	163.2±2.86
S_2	17.52±0.94	5.92±0.31	103.39±2.32
S_3	4.84±0.52	6.21±0.33	149.69±2.9
S_4	9.85±0.70	7.07±0.34	185.48±2.09

the activity concentrations of ^{232}Th was found to be in the range5.92±0.31 to 7.07±0.344 Bq kg^{-1}. The results are comparable to the world average activity concentration . which are 40.35 and 420 Bq kg^{-1}. For ^{238}U , ^{232}Th and ^{40}K . respectivity [13]. Table 1 indicates also that the activity concentrations of ^{238}U , ^{232}Th and ^{40}K are under the worldwide average .

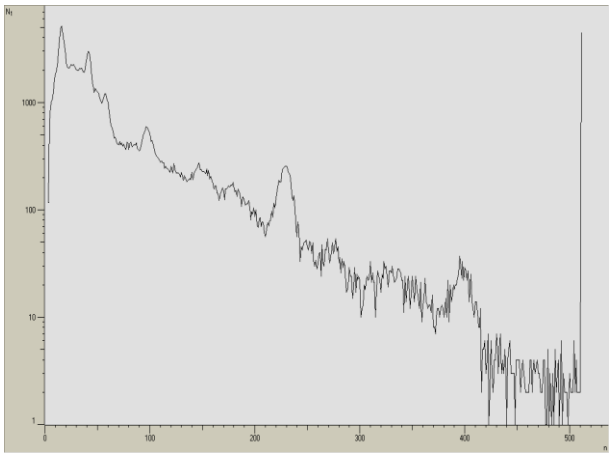


Figure (11) Spectrum of soil sample s_4

The air-absorbed dose rate due to the gamma-ray emission from the samples ranged from 12.35 to 16.09 $nGyh^{-1}$ which is also in the permissible limit [13] . the obtained results showed that the effective doses were lower than world average which is 1.0 Svy^{-1} .

Ra_{eq} ($Bq\ kg^{-1}$)	AD ($nGyh^{-1}$)	Indoor (AED^{*})(mSv)	Outdoor (AED^{*})(mSv)
30.87	15.02	0.074	0.018
33.94	16.09	0.079	0.020
25.25	12.35	0.061	0.015
26.54	12.52	0.061	0.015

5- Conclusions

gamma ray spectrometry has some advantages which are , it is a good technique extensively used in determination of radio nuclides , the wide range of natural and artificial radio nuclides that can be determined and its applicability in a variety of sample matrices . the value of activity concertinos , radium equivalent activity and absorbed dose rate of ^{238}U, ^{232}Th and ^{40}K were found to be lower than the world average . the activity concentration of ^{40}K was higher than that of ^{238}U and ^{232}Th . in general the obtained results showed that indoor and outdoor effective dose due to natural radioactivity of soil samples were less than permissible limit which is 1.0 Svy^{-1}

References

[1] Joga sigh, Harmanjit Singh, Surinder Singh, B.S. Baj wa, R.G.Sonkow comparative study of natural radioactivity levels in soil samples from the upper siwaliks and punjap India using gamma spectrometry .(jornal of environmental radioactivity 100(2009)94.98.

[2] ((Sources Effects and Ricks of Ianizing Radiation)) United Nation Scientific Committee on the Effects of Atomic Radiation . United Nations , New York USA.

[3] Salama, T.A.; Seddik, U.; Dosoky. , T. M. and Ahmed, A. M. (2006)." Determinant of thorium and uranium contents in soil samples using ssNTD`s passive method . paramana journal of physics , vol. 67. No.2. pp: 269-276.

[4] Maher, O.E.L.-G Hossain, Read M. Abu saleh .(2007)." Radiation measurement of Gaza – Strip using different type of detectors. The Islamic university journal , vol.15 , no.1,pp 23-37

[5] E. Vosniakos, K.zavlaris, (2002)."Measurement of natural radioactivity concentration of building materials in Greece , Journal of nvironmental protection and ecology 3,No.1,24-29.

[6] J. Beretka, P.J. Mathew.(1985). Natural radioactivity of Australian building materials". Health physics.,48, 87-95.

[7] D. M. Hamby, A.K. Tynkbekov.(2000)."Uranium , Thorium and Potassium in soil along the shore lake . Issyk kyol in the kyrghy2 republic . Environ .Monitoring assessment,73,101-108.

[8] M.F. Maduar, P.M. Junior." Gamma spectrometry in the determination of radionuclide's comprised in radioactive series" . International nuclear atomic conference-INAC-2007.,Santos SP, Brazil, September 30 to October 5, 2007. ISPAN.

[9] K. Debertin, R.Jianping (1989)." Measurement of the activity of radioactive samples in Marinelli beakers. Nuclear Instruments and methods in physics research . A. 278,541-549.

[10] A.Malanca ,V.passina, G.Dallara, Radiul .Prot. Dosim , 24(1991) 27 .

[11] N.K. Ahmed .(2004)."Natural radioactivity of ground driniking water in some areas of upper Egypt. Turkish, J.Eng. Env. Sci, 28, 345-354.

[12] A. Aziz.(1981)."Method of low-level counting and spectrometry symposium, Berlin, 221.

[13] UNSCEAR "sources ,effects and ricks of ionization radiation " ,United Nation Scientific committee on the Effects of Atomic Radiation Report to the General assembly , with Annexes , New York (2000).

[14]United Nation Committee On the effect of Atomic Radiation (UNSCEAR), (1993),