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Measurement of radionuclides concentration in soil of selected regions of Kirkuk and Salahuddin

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ABSTRACT

The present research aims to assess the radionuclides concentration in the soil samples by using the spectroscopy technique of high-purity germanium detector. Four samples of soil were collected at depth of 15 cm for selected regions of Kirkuk and Salahuddin governorates with two samples for the two governorates. The study shows that the activity unit for the ^{226}Ra, ^{214}Pb, ^{212}Pb, ^{228}Ac, and ^{40}K in the studied samples ranged between (11.4±0.7-5.6±1.2) in a rate (9.4±0.85) and in a (3.8± 0.4-29±4) and rate (19.3 ± 5.4) (2± 0.1 – 9.4±0.7) in a rate (6.4±0.54) and (1.6±0.2-11.4±1.2) in a rate (7.95 ± 0.775) and (64.2 ± 4.2-226.2 ± 8) in a rate (172.25 ± 7.7) Bq.kg^{-1}, respectively, as well as, calculated EQ Radium (60.7194-12.8314) Bq.kg^{-1}, activity concentration indicator ($\boldsymbol{I_{\gamma}}$) (0.4448-0.096133), internal Risk indicator (0.236988-0.049795), external risk indicator(0.164015-0.03466), values of absorbed dose in air (28.79214-6.23074) nGy.kg^{-1}, the annual effective dose internal factor (0.141243-0.030566) mSv.y^{-1}, the annual effective dose external factor(0.035311-0.007641) mSv.y^{-1}. All these values do not exceed the internationally permissible standards recognized by the World Health Organization (WHO) and have no adverse impact, on the human health or the environment.

1- Introduction

The employment of radiation in science, energy, industrial, medical applications, agriculture and technologies has been brought huge benefits to the humanity [1]. Radioactivity is defined as the spontaneously transformation of an excited nucleus into a stable nucleus after emitting radiation like (α), (β) or electromagnetic radiation known as gamma (γ) rays [2]. The radioactive pollutants represented the contamination which may be a complex problem. The sources of radioactive contamination in the environment vary due to its behavior of newly deposited radioactive pollutants differs from the behavior of the nuclides already existed in the soil [3]. Wind movement is one of the main factors in transferring the pollutants as it moves the soil to different regions carrying these pollutants, leading to pollution of air and nearby soil [4]. Which in turn this study shows the level of radiation background soil models elected province of Kirkuk and Salahuddin for calculating the radioactivity of natural ^{238}U,and ^{234}Th chains and their output ^{228}Ac and ^{226}Ra natural sources of ^{40}K using a the germanium detector ultrapure. and radiological risk effects account for human health (radium equivalent activity (Ra_{eq}) Bq.kg^{-1}, activity concentration indicator (I_{γ}), the internal risk indicator, the external risk indicator, the values of absorbed dose rate in air nGy.kg^{-1}, the values of internal annual effective dose equivalent (mSv.y^{-1}), the values of external annual effective dose equivalent (mSv.y^{-1}).

2 - The theoretical part

2-1 Specific Activity concentration (N)

Specific activity is defined as the radioactivity of per units of mass or volume of the natural radioactive material, which measured in a (Bq/kg or Bq/m^3). It's given by the equation [5].

$$N\left(\frac{Bq}{kg}\right) = \frac{n}{\varepsilon(e_{\gamma}).I_{\gamma}(e_{\gamma}).m.t} \dots\dots\dots\dots (1)$$

n: net count under the peak, $\varepsilon(e_{\gamma})$: γ ray detector efficiency, $I_{\gamma}(e_{\gamma})$: the percentage proloaloity of γ ray emission from the radionuclides under study, m: mass of the sample measured by kg, t: count time in second.

2-2 Radium Equivalent Activity (Ra_{eq})

Radium equivalent activity Ra_{eq} stand for a factor used to ensure the uniform distribution of natural radionuclide's, ^{226}Ra, ^{232}Th, and ^{40}K measured by($Bg.kg^{-1}$), Which calculated by using the following equation [6-7].

$$R_{eq}\left(\frac{Bq}{kg}\right) = N_{Ra} + 143\times10^{-2}N_{Th} + 7.7\times10^{-2}N_K \dots\dots (2)$$

N_{Ra} N_{Th} and N_K are the radioactivity of ^{226}Ra, ^{232}Th and ^{40}K respectively. The maximum acceptable value for the equivalent radium efficiency is (370) $Bg.kg^{-1}$[7,8].

2-3 Activity Concentration Indicator (I_γ)

The gamma γ radiation risk indicator is a radiometric factor in which the risk levels γ rays associated with natural radionuclide's are estimated, and can be calculated using the following equation.

$$I_\gamma\left(\frac{Bq}{kg}\right) = \frac{N_{Ra}}{150} + \frac{N_{Th}}{100} + \frac{N_K}{1500} \dots\dots\dots\dots\dots\dots (3)$$

The risk indication for γ rays is less than unity [5,9].

2-4 Risk Indicators

Risk indicator defined as a radiological factor used to measuring internal and external radiation risks. The internal Risk indicator (R_{in}) and the external risk indicator (R_{ex}) calculated by using the following equation [6,11].

$$R_{in}\left(\frac{Bq}{kg}\right) = \frac{N_{Ra}}{185} + \frac{N_{Th}}{259} + \frac{N_K}{4810} \le 1 \dots\dots (4)$$

$$R_{ex}\left(\frac{Bq}{kg}\right) = \frac{N_{Ra}}{370} + \frac{N_{Th}}{259} + \frac{N_K}{4810} \le 1 \dots\dots (5)$$

The internal Risk indicator (R_{in}) and the external Risk indicator (R_{ex}) should be less than unity [10-11].

2-5 Absorbed Dose Rate in Air(D_γ)

The average absorbed dose of γ rays in air D_γ at 1m above ground level can be calculated using the following equation.

$$D_\gamma(nGy.h^{-1}) = 46.2\times10^{-2}\,N_{Ra} + 60.4\times10^{-2}\,N_{Th} + 4.17\times10^{-2}\,N_K \dots\dots\dots\dots (6)$$

The conversion factors used for calculating the gamma-absorbed dose in the air correspond to (46.2×10^{-2} nGy/h) for ^{226}Ra, (60.4×10^{-2} nGy/h) for ^{232}Th and (4.17×10^{-2}nGy/h)for ^{40}K [5, 6].

2-6 Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent is represent a radiation parameter used to determine the health effects of the absorbed dose measured by ($mSv.y^{-1}$). The annual effective dose estimates using the conversion factor ($0.7Sv.Gy^{-1}$) which converts the absorbed dose in air to the effective dose, as well as using the internal occupancy factor (80%) and the external occupancy factor (20%) can be calculated using the following equation [12-13].

$$AEDE_{in}(mSv.y^{-1}) = D_\gamma(nGy.h^{-1})\times10^{-6}\times 8760h.y^{-1}\times0.7Sv.Gy^{-1}\times80\% \dots (7)$$

$$AEDE_{out}(mSv.y^{-1}) = D_\gamma(nGy.h^{-1})\times10^{-6}\times 8760h.y^{-1}\times0.7Sv.Gy^{-1}\times20\% \dots (8)$$

3 - Experimental part

All the radioactivity parameter has been measured by using quality and quality analysis for gamma rays using high-purity germanium detector. In Radiation protection center: RPC Ministry of Environment.

3-1 Preparation Soil Samples

Some precaution must take into consideration in collecting and preparing the samples under study is that keep these samples clean and preventing them from contamination. Four sample where collected for the period between (10-16) November 2017, at a depth of 15cm from Earth's surface. Table (1) shows the soil samples information which are dried to remove the moisture and left it for a period of 22 days to ensure the equilibrium and homogeneity situation and then grind the samples into fine powder, and sifted with 0.2 mm pores clamp to remove the gravel and plant roots sticking, the samples were weighed using a sensitive scale of 0.0001/gm. and 500g were taken from dried soil, the samples is placed in the pot Marinelli Beaker and the design of this vessel is identical to the detector neck.

Table (1): shows the symbol and the number of samples with their locations and dates study

Sample code	**S1**	**S2**	**S3**	**S4**
Zone name	Kotrgah- Tuzkhurmto	Qadsiya	AL-asarya region	**AL-zawraa**
Province	Salahuddin	Kirkuk	Salahuddin	**Kirkuk**
Sampling date	10 November	12 November	15 November	**16 November**
Time	8:44AM	10:40PM	7:40AM	**3:20PM**
Year	2017	2017	2017	**2017**

3-2 Description of the study area

Both AL-Qadsiya and Al-Zawraa districts belonging to the Kirkuk province which containing high population density, kotrgah region and the Al-asarya region belonging to Salahuddin province ,Kotrgah region is of a great importance because It's contain a water spring, that used for skin diseases remedy. The sample was taken at a distance of 15m from the water, The sample was taken from Al-asarya region semi open area within 5m of the water project which feeds Tuzkhurmto with water. These coordinates were fixed locations using GPS, figure (1) shows the locations of the provinces to Kirkuk and Salahalddin, they studied regions indicator coordinates using Google Earth programme.

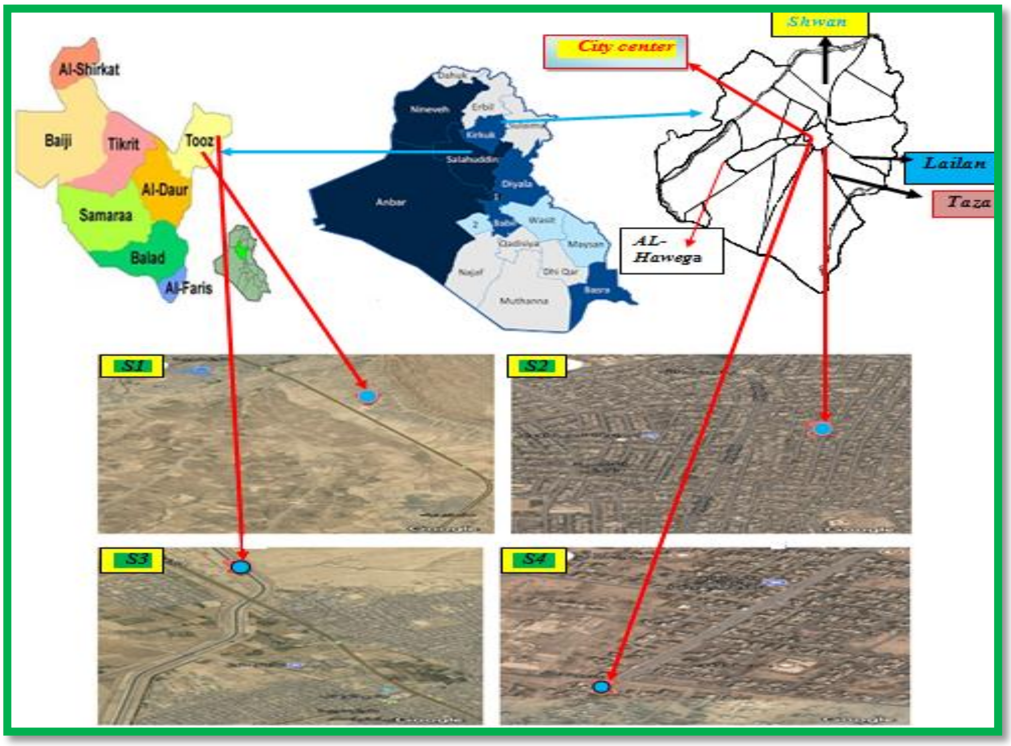

Fig (1) shows the locations regions under study in both Kirkuk and Salahalddin provinces.

3-3 Radioactivity Measurement System: The gamma-rays were detected by using a germanium detector system which , shown in fig (2).

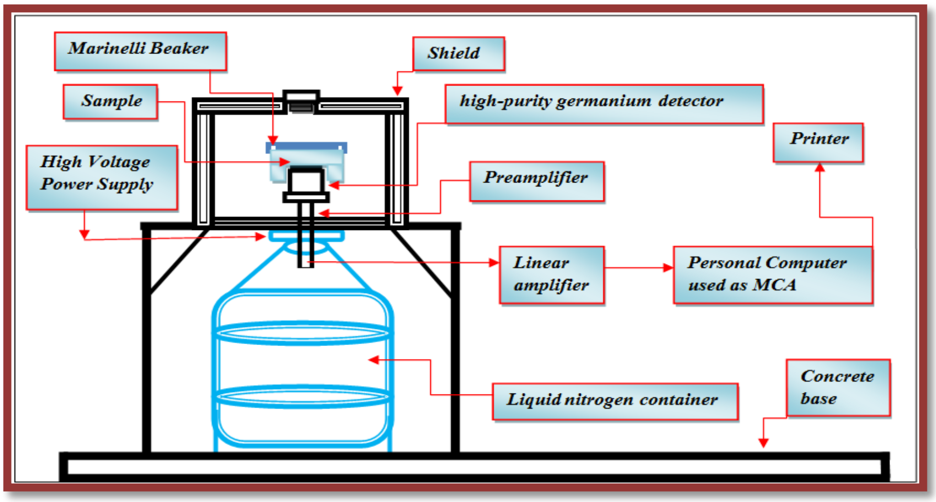

Fig (2) sketch of detecting set-up.

3-4 High- purity germanium detector (HPGe)
At present time modern techniques were able to fabrication a high purity germanium crystals with least quantity amount of impurities and reagent used is the production company (Canberra). voltage of the detector $(4 \times 10^3 \text{V})$ supplied by (TENNELEC). ultrapure germanium detector needs for-196.15℃ temperature cooled by liquid nitrogen during operation to reduce the noise pulses of current leakage that is generated in degree Room temperature [14]. Detector is surrounded by bulletproof armor thickness (0.1m) to reduce the impact of natural radiation background on the work of the detector to detector interface enclosed layers of aluminum, iron, copper and cadmium, respectively [15].

3-5 Activity Specific
The qualitative activity of the soil sample is measured by putting the samples in template soil in Marinelli pot as it installed on germanium detector with a time $(3600\ sec)$. and then measuring the sample efficiency by using equation (1) as shown in the laboratory table (2).

Table: (2) Weather Parameters of the laboratory shows qualitative activity for each sample.

Sample no.	*Radon Concentration in lab.*	*Temperature*
S_1	9 Bq/m^3	20 ℃
S_2	7 Bq/m^3	20℃
S_3	4 Bq/m^3	20℃
S_4	6.6 Bq/m^3	20 ℃

4 - Measurement of Specific Activity for Soil Sample

Table (3) illustrates the measurement of the specific activity to four soil samples in Kirkuk and Salahuddin governances , the highest results for specific gravity of radium was$(11.4 \mp 0.7\ \mathrm{Bg.kg^{-1}})$ for sample S_3 which is lower than the standard value of $(35\ \mathrm{Bg.kg^{-1}})$ [16,17] while the lowest value is $(5.6 \mp 1.2\mathrm{Bg.kg^{-1}})$ in the sample (S_1) with average value$(9.4 \mp 0.85\mathrm{Bg.kg^{-1}})$ as show in Fig (3), the lead specific activity in (S_1) was the lowest which is$(3.8 \mp 0.4\mathrm{Bg.kg^{-1}})$ and the highest value was for the S_3 was $(29 \mp 4\ \mathrm{Bg.kg^{-1}})$ with average$(19.3 \mp 5.4\mathrm{Bg.kg^{-1}})$ which by Comparison with standard value show the result of present study is lower .The highest and lowest of the specific gravity for Thorium series of (^{228}Ac, ^{212}Pb) ranged $(9.4 \mp 0.7\mathrm{Bg.kg^{-1}}), (1.9 \mp 20\mathrm{Bg.kg^{-1}})$ for S1 and S4 samples which is lower than the standard value of $(30\ \mathrm{Bg.kg^{-1}})$ [16,17].

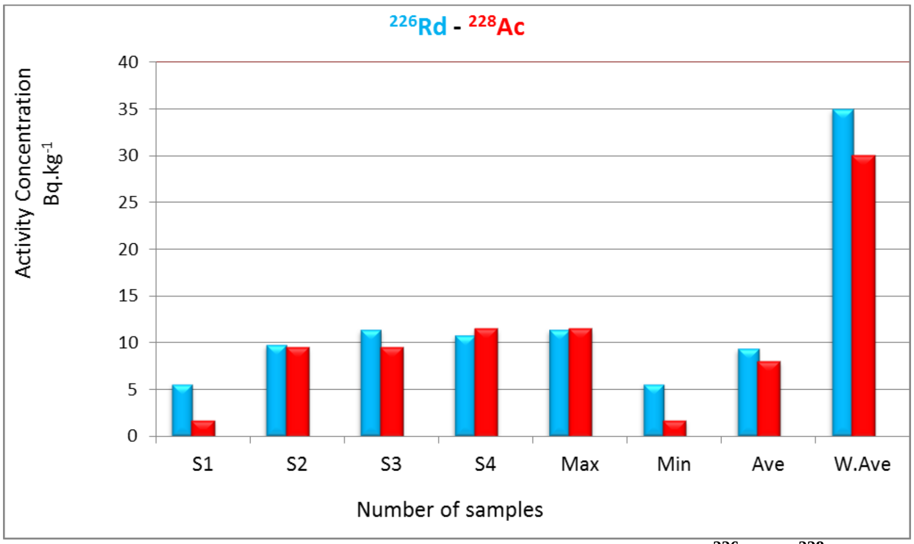

Fig (3): concentration of radionuclide qualitative activity (^{226}Ra – ^{228}Ac)

The specific activity ^{40}K between minimum and maximum value $(S_4 = 226.2 \pm 8, S_1 = 64.2 \pm 4.2)$ Bg.kg^{-1}, and the overall rate (172.25 ± 7.7) Bg.kg^{-1}. The results of the current study show that the activity rate of potassium is less than the international accepted value (420) Bg.kg^{-1} as shown in figure (4) [16, 17].

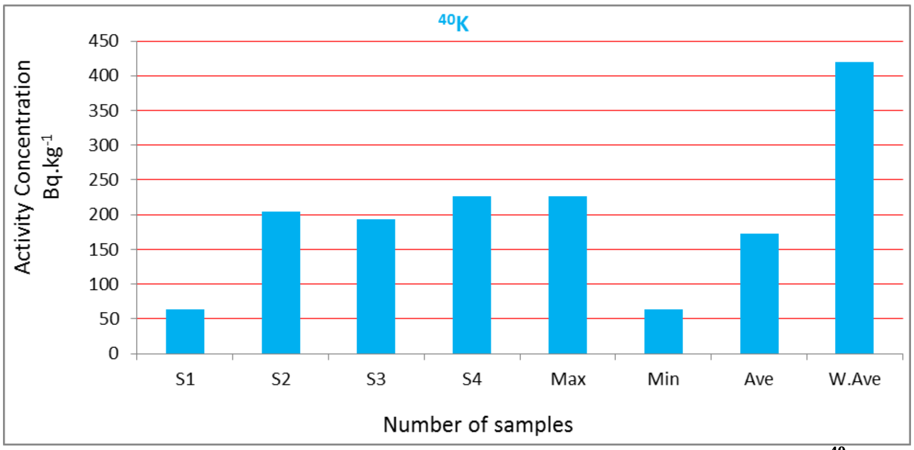

Fig (4): The Concentration of the specific activity of the radionuclide (^{40}K).

Table (3) illustrates the various specific activity for radionuclides in soil samples.

Sample no.	Specific Activity Concentrations (Bq.kg $^{-1}$)				
	^{238}U		^{232}Th		^{40}K
	^{214}Pb	^{226}Ra	^{212}Pb	^{228}Ac	
S_1	3.8±0.4	5.6±1.2	2±0.1	1.6±0.2	64.2±4.2
S_2	17.4±4	9.8±0.8	6.8±0.4	9.4±0.8	204.8±11.6
S_3	29±4	11.4±0.7	7.4±0.6	9.4±0.9	194±7
S_4	27±13.2	10.8±0.7	9.4±0.7	11.4±1.2	226.2±8
Max	29±4	11.4±0.7	9.4±0.7	11.4±1.2	226.2±8
Min	3.8±0.4	5.6±1.2	2±0.1	1.6±0.2	64.2±4.2
Ave	19.3±5.4	9.4±0.85	6.4±0.54	7.95±0.775	172.25±7.7
International standards [17,18]	35		30		420

Through the table (3) by using the equation (2) the results shows that the value of (Ra_{eq}) in soil samples ranging ($S_1 = 12.8314$ *to* $S_4 = 60.7194$) Bq.kg^{-1} and overall activity of Radium was (44.3856) Bq.kg^{-1}. The present data show that activity rate of Radium equivalent to the elected regions is less than the international standards of activity equivalent of Radium (370) Bq.kg^{-1} [16, 17]. In which samples of the soil($S_1 = 0.096133$ *to* $S_4 = 0.4448$) and the overall rate (0.326033). using the equation (3). The obtained results showed that the activity concentration parameter in region to be less than the world average (0.8) [16, 17] and using the equation (4). We note that the lower and higher value for internal risk indicator (R_{in}) in soil samples ($S_1 = 0.236988$ *to* $S_4 = 0.049795$) and the general rate (0.173273). The rate of internal risk indicator in the regions thought to be less than the international standards of (1) [16,17] using the equation (5) We note that the lower and higher value for external risk indicator (R_{ex}) in soil samples ($S_1 = 0.03466$ *to* $S_4 = 0.164015$) and the overall rate (0.119895). The obtained results clarifying that the rate of external risk indicator in regions considered less than the international standards acceptable value (1) [16, 17].

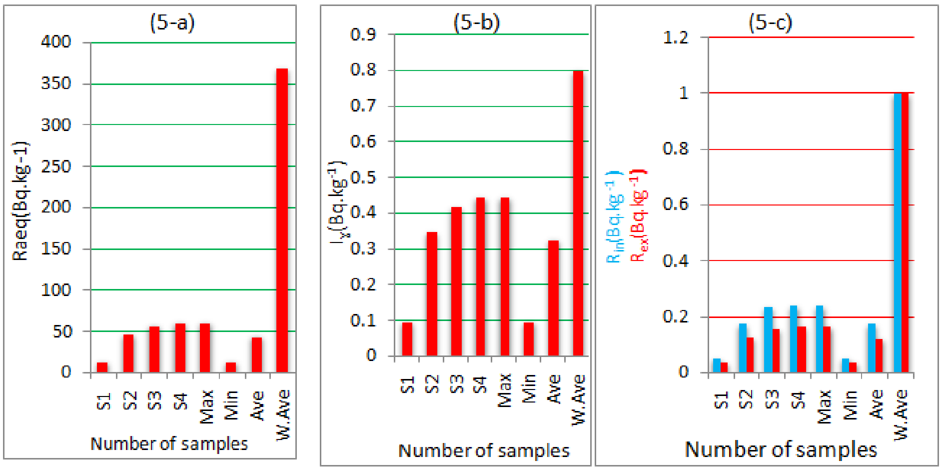

Figure (5-a):Show that the radium equivalent activity Ra_{eq}(Bq.kg^{-1}) in the soil samples.
Figure (5-b): Show that the activity concentration indicator I_γ(Bq.kg^{-1}) in the soil samples.
Figure (5-c): Show that the internal(R_{in}) and external (R_{ex}) risk indicator in the soil samples

Using equation (6) for measuring absorbed dose rate in air of the soil samples were between ($S_1 = 6.23074$ *to* $S_4 = 28.79214$) nGy.h^{-1} and the overall rate (21.11121) nGy.h^{-1}. The results of present show that the average absorbed dose to air in region to be less than the world average (55) nGy.h^{-1}[16,17]. Using equation (7) which shows that the annual effective dose rate values for internal exposure is measured in (nGy.h^{-1}) soil samples ranging for ($S_1 = 0.030566 S_4 = 0.141243$) and the overall rate is (0.103563), The results of the present study show that the average annual effective dose internal exposure in region thought to be less than the international standards of (0.45) [16,17].and using the last equation (8) found that the annual effective dose rate of external exposure in soil sample ranging for ($S_1 = 0.007641$ *to* $S_4 = 0.035311$) mSv.y^{-1} and in the rate (0.025891) mSv.y^{-1}. The results of the current study that the annual effective dose rate outdoor is less than the international standards of (0.07) mSv.y^{-1}.

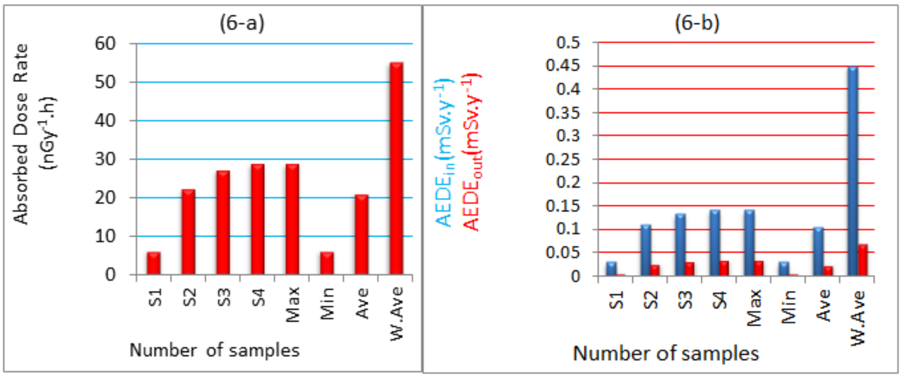

Fig (6-a): Show that the values of absorbed dose in air nGy.kg^{-1} in the soil sample.
Fig (6-b): Show that Internal annual effective dose equivalent (mSv.y^{-1}), external annual effective dose equivalent (mSv.y^{-1}) $AEDE_{out}$ in the soil sample.

Table (4): The risk parameter values for each of the radium equivalent activity (Ra_{eq}) Bq.kg^{-1}, activity concentration indicator (I_γ), internal risk indicator, external risk indicator, the values of absorbed dose in air nGy.kg^{-1}, internal annual effective dose equivalent (mSv.y^{-1}) $AEDE_{in}$, external annual effective dose equivalent (mSv.y^{-1}) $AEDE_{out}$.

Samples no.	(Bq.kg^{-1})				(D_γ) (nGy.h^{-1})	Annual Effective Dose (mSv.y^{-1})	
	(Ra_{eq})	(I_γ)	Risk Indicator			AEDE	
			In	Ex		In	Out
S_1	12.8314	0.096133	0.049795	0.03466	6.23074	0.030566	0.007641
S_2	46.6116	0.346533	0.172925	0.125898	22.25656	0.109182	0.027295
S_3	57.38	0.416667	0.233383	0.155004	27.1654	0.133263	0.033316
S_4	60.7194	0.4448	0.236988	0.164015	28.79214	0.141243	0.035311
Max=S_4	60.7194	0.4448	0.236988	0.164015	28.79214	0.141243	0.035311
Min=S_1	12.8314	0.096133	0.049795	0.03466	6.23074	0.030566	0.007641
Ave	44.3856	0.326033	0.173273	0.119895	21.11121	0.103563	0.025891
International standards[16,17]	370	0.8	1	1	55	0.45	0.07

Conclusions

The activity of naturally occurring radioactivity elements in the collected soil samples within current study, has founded to have normal concentrations of elements (^{40}K, ^{228}Ac, ^{226}Ra), in range $(172.25 \pm 7.7, 7.95, \pm 0.775, 9.4 \pm 0.85, 19.3 \pm 5.4, 3.8 \pm 0.4 - 29 \pm 4)$ Bq.Kg^{-1}respectively, and no anomalies existing. The reason for low levels of radioactivity in the regions under study is may be accounted to climatic and geographical conditions. The results obtained in current study showed that the rates of radiological risk factors, the radium equivalent activity (44.3856) Bq.Kg^{-1}, activity concentration indicator (0.326033) Bq.Kg^{-1}, internal (R_{in}) and external (R_{ex}) risk indicator (0.173273)(0.11895) respectively, absorbed dose in air (21.11121)n Gy.h^{-1} ,the annual effective does internal and external exposure is equal to (0.03563) (0.025891)mSy.y^{-1} respectively, and all these results is less than the international standards. Which these areas can be said radiologically scanned are suitable for dwelling, as well as the industrial and agriculture investments.

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قياس تراكيز النويدات المشعة في ترب لمناطق منتخبة من محافظتي كركوك وصلاح الدين

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الملخص

تهدف الدراسة الحالية الى قياس تراكيز النويات الطبيعية المشعة في عينات التربة باستخدام مطياف الجرمانيوم عالي النقاوة. حيث جمعت أربعة عينات من ترب مناطق منتخبة لمدينتي كركوك وصلاح الدين بعمق 15 سنتمتر. هذه الدراسة أظهرت ان الفعالية الإشعاعية المقاسة بوحدة $Bq.kg^{-1}$ لعنصر الراديوم ^{226}Ra ونظيري الرصاص ^{214}Pb , ^{212}Pb والاكتينيوم ^{228}Ac و البوتاسيوم ^{40}K في هذه العينات تتراوح (11.4±0.7- 5.6±1.2) وبمعدل (9.4±0.85) و (3.8±0.4-29±4) بمعدل (2±0.1-9.4±0.7) (19.3±5.4) و (6.4±0.54) و (1.6±0.211.4±1.2) بمعدل (7.95±0.775) و(64.2±4.2226.2±8) بمعدل (172.25±7.7)، على التوالي. وقد تم حساب العامل EQ لعنصر الراديوم (60.7194-12.8314) بيكرل/كغم ومعامل تركيز الفعالية الإشعاعية I_γ يبلغ (0.4448-0.096133)، معاملات الخطورة الداخلية والخارجية بلغت (0.236988−0.049795), (0.164015-0.03466) على التوالي, قيم الجرعة الممتصة بواسطة الهواء (28.79214-6.23074) بيكرل/كغم، الجرعة الفعالة الداخلية والخارجية السنوية بلغت (0.141243-0.030566) ملي سيفرت/ سنة و (0.035311-0.007641) ملي سيفرت/ سنة على التوالي. جميع القيم المدروسة ضمن هذا البحث لم تتجاوز قيم المنظمة الدولية للصحة المسموحة (WHO) ولا توجد تأثيرات سلبية لهذه المعاملات على الصحة والبيئة.