Research Article

An Assessment of Radioactivity Levels of Radionuclides for Surface and Deep Soils Yathrib district, Balad district, Salah al-Din Governorate /Iraq

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Abstract: In this study, the radioactivity levels of the naturally occurring radionuclides represented with uranium ${}^{238}_{92}U$, thorium ${}^{232}_{90}Th$, and isotope of potassium ${}^{40}_{19}K$. As well as calculating the radiation risk indicators of Gamma rays represented by (the activity of the equivalent radium Raeq, the risk index for the gamma rays Iγ and the rate of the absorbed dose in the air (Dγ). Surface and deep soil models (60cm), which were collected from twelve sites in Yathrib sub-district of Balad in Salah al-Din Governorate - Iraq. ${}^{226}_{88}Ra$ ranged between (AD3(2.84) - AD5(105.88) Bq/Kg) and ${}^{228}_{89}AC$ for actinium Bq/Kg) (AD6(6.42) - AD11(43) and for potassium ${}^{40}_{19}k$ (AD6(8.03) -AD5(78.72)) Bq/Kg) for deep soil models (60cm) for radium ${}^{226}_{88}Ra$ ranged between (AD12 (9.96) -AD11 (31.3) Bq / Kg) and for actinium ${}^{228}_{89}AC$ Bq / Kg) (AD10 (0.49) -AD3 (16.31) (and for potassium ${}^{40}_{19}k$ Bq / Kg) (AD9 (8.03) - AD6 (28.12).As for the results of the rate of radiation hazard effects for gamma rays for surface soil models where the equivalent radium activity rate is R_{aeq} (Bq / kg 53.64 AD1 (AD8 (13.25) -), while the risk index ratio for gamma rays is IγBq / kg) (0.36AD1 (AD8)). (0.094) -), and the average absorbed dose in the air Dγ (nGy / h) 20.15 (AD11 (AD8) 5.94) -. For 60cm deep soil models, the equivalent radium activity rate is R_{aeq} Bq / kg (48.33 (AD3)). AD10 (16.81) -, the hazard index for gamma rays Iγ (Bq / kg) 0.333 (AD3 AD10 (0.114) -), and the dose absorbed in air Dγ (nGy / h 21.87) (AD3 (AD10) 7.31) In general, the results showed that the concentration of radionuclides in the surface soil is higher than that of the deep soil.

1. Introduction

Soil is an important element of the environment that provides people with food sources. It is the fragile layer that covers the rocks of the earth's crust. Its thickness is from a few centimeters to several meters, and it is a mixture of mineral and organic materials, water and air, with which the plant can establish its roots and derive the necessary life ingredients. It is A dynamic environment, when becomes polluted leads to a long-term source of environmental pollution that leads to food and air pollution.

Soil pollution takes place when environmental pollutants are added. Thus, an imbalance occurs that changes its natural, chemical or biological properties. It affects directly or indirectly those who live on its surface, whether it is a plant or an animal. The tremendous scientific and technological progress in manufacturing the radioactive materials and their application in many fields were the primary dangers that threaten the elements of the environment. These elements include soil, so it became a necessary to know the nature of these materials, their dangers , how to protect people, how to safely circulate them. Therefore, this study explores the radioactivity, whether natural or industrial and how to treat this kind of radioactivity, especially in soil, because soil is an important environmental element. When it becomes polluted, it becomes the source of plant, water and air pollution [1] that the process of monitoring the level of radioactivity is of great importance in ensuring the safety and security of society. Moreover, it is necessary to know the amount of increase and its negative effects. This unwanted increase is known as radioactive pollution, which is part of environmental pollution, as a type that exists at a concentration higher than the concentrations allowed in local and global environmental measurements [2]. Radiation is generally divided into two types of rays, ionizing radiation and non-ionizing radiation. In this study, ionizing radiation is in turn divided into two types of rays and according to the way they interact with material, which includes direct ionizing radiation. For fast charged particles that give their energy directly to material as a result of a series of coulometric interactions. As for indirect ionizing radiation, it includes X-rays, gamma rays and neutrons, and these radiations give their energy in whole or in part to the charged particles during their passage in material [3].

2. Theoretical Background

Specific Activity (A)

Specific activity is defined as the radioactivity through the mass unit or volume of the radioactive material and is measured by

1 Bq / kg or Bq / m3, specific activity per unit.[4]

A= $\frac{N}{\varepsilon\gamma I\gamma mt}$ ....(1-1)

As A: the specific activity in units of Bq / kg

N: The net count is below the top

γℇ: represents the counting efficiency of the flash detector

Iγ: the percentage probability of a radionuclide gamma emission

m: the mass of the model in Kg

t: the measurement time

Calculation of Radiological Hazard Indices of Gamma Ray

Radium Equivalent Activity (Raeq)

It is a radiation factor used to estimate the risk of the activity of uranium, thorium and potassium in units of Bq / Kg, and calculated as in the following equation:

Raeq = A_U + 1.43 A_{Th} + 0.077 A_k ………………………. (1-2)

As A_U , A_{Th} , A_k: represents the radioactivity of the uranium nuclides ${}^{238}_{92}U$ thorium ${}^{232}_{90}Th$ and potassium ${}^{40}_{19}K$, respectively, and that the highest value of (Raeq) should be lower. From the globally accepted limit of 370 Bq / kg.[5]

Activity Concentration Index

It is a radiological factor by which the risk levels of gamma rays associated with natural radionuclides and are estimated in the studied samples. It can be calculated from the following equation:[5]

(1-3)........................$\frac{A_k}{1500} + \frac{A_{Th}}{100} + \frac{A_U}{150}$ = Iγ

Absorbed Dose Rate in Air (Dγ)

The rate of absorbed dose in air (Dγ) is calculated as a function of the specific activity of the ground nuclei (uranium ${}^{238}_{92}U$, thorium ${}^{232}_{90}Th$, and potassium ${}^{40}_{19}K$ as in the following equation [8]:

AD = 0.462 A_U + 0.621 A_{Th} + 0.0417 A_k …………………….(1-6)

As (0.462, 0.621, 0.0417): are the conversion factors used to calculate the percentage of absorbed dose in the air for natural radionuclides (uranium ${}^{238}_{92}U$, thorium ${}^{232}_{90}Th$, and potassium${}^{40}_{19}K$). It is measured in (nGy / h).

3. Methodology

Materials and Methods

Collecting and preparing samples

In order to assess the levels of natural radioactivity of the soil in Yathrib sub-district, south of Salah al-Din Governorate, 24 samples were collected, starting from 11/16/2020 to 11/21/2020. The study includes an area about 50 Km distributed in Yathrib district and consists of 12 regions. 12 samples were collected from a (shallow and 60 cm deep) area as shown in Table (1) and Figure (1) which shows the map of the sample collection sites.

The samples were dried by means of an oven for a period of 30 min for each sample and then were exposed to the sun for 3 days to ensure that the samples were completely dry, because humidity affects the net weight of the model. The specimens were ground using an electric grinder to obtain a fine powder. Then, we use a sieve with holes of 75mμ in diameter to obtain homogeneous patterns. Putting each 1Kg of dried soil into a 1Kg plastic bag and closing all the bags and leaving for 30 days to obtain the radioactive balance between the radionuclides and their offspring. At the end of the storage period, each sample was placed in a Marnelli container with a speed of 1Kg which is used in the system Measurement of radioactivity.

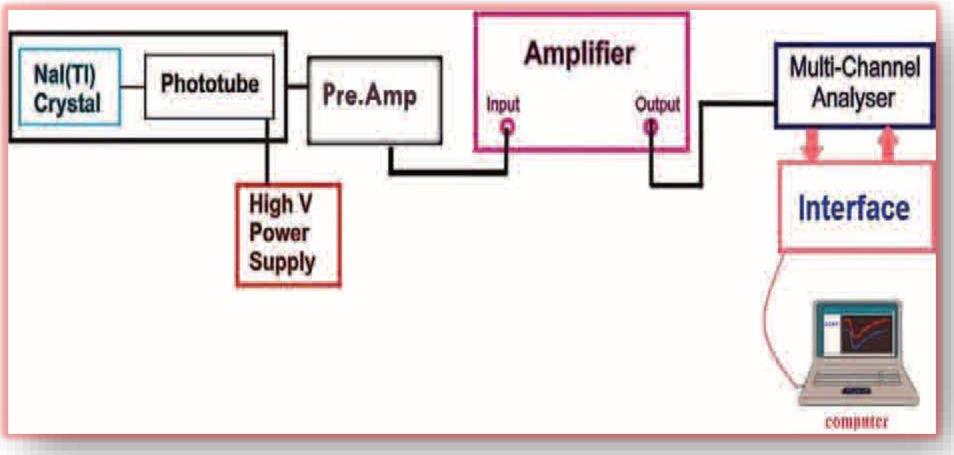
Table (1) symbols and locations of samples in Yathrib sub-district

locations and sequences of the studied soil samples		
Sequence	Sample code	Names of sample regions
1	**AD1**	Al-Saud village before Al-Ishaqi
2	**AD2**	Al-Saud village after Al-Ishaqi
3	**AD3**	Village of Mizarea' Az-Zour
4	**AD4**	Jameat Al-Matn area
5	**AD5**	Ahbab Tal al-Dhahab area
6	**AD6**	Al Ferhatiah area
7	**AD7**	Yathrib sub-district center
8	**AD8**	AlShifa'a Village
9	**AD9**	Al-Buhasan Village
10	**AD10**	Hatimia Area
11	**AD11**	Dour Al-Qaeda area
12	**AD12**	Al-Bomheidi Village

Figure (1) a map of the sample collection sites

4. Procedure

Radionuclide concentrations were measured for soil models using the quantitative and qualitative analysis technique for gamma rays. The measurements were made at the Iraqi Commission for the Control of Radiation Sources in Baghdad, using the NaI (TI) detector (CANBERRA INSPECTOR1000) with a size of 2 in × 2 (mm 50 × 50). As shown in Figure (2), the Marnelle Baker container in which the model is placed around the detector and records the gamma spectrum for a period of (7200sec). The program (Genie 2000) in draws the spectrum and makes a report that includes the channel numbers, the corresponding energies and a net area under the top of the spectrum curve. It is shown in Figure(2)



[9] Figure (2) Diagram of the measurement system for NaI (TI) detector

5. Results and discussion

Table (2) and Fig. (3) show the results obtained for the specific activity levels of radionuclides in the surface soil models of 12 soil models from Yathrib sub-district of Salah al-Din Governorate.

The specific activity levels of U^{238} in (Bq / kg) recorded the highest value of radium Ra^{226} for the models AD5 and AD11 (Ahbab Tal al-Dhahab - Dour al-Qaida areas) and the values were (105.88 - 105.31) respectively. While, the lowest value for the model AD3 (Village of Mizarea' Az-Zour) were Bq / Kg (2.84), and recorded more than the global permissible limit Bq / Kg 25 [10.11]. This may be due to the geological formation of these areas that contain natural radioactivity, as radium is a dangerous radioactive element due to its long half-life. Relatively speaking, we note the dependence of radioactivity in soil on the radioactivity of the rocks that formed it (the origin of soil) and on the total activities that occurred to form the soil [10]. As for the specific activity of thorium ^{232}Th per (Bq / kg), the highest value of actinium Ac^{228} was for the models AD5 and AD11. (Ahbab Tal al-Dhahab - Dour al-Qaida areas) and the values were (43.00 - 42.01) respectively. The lowest value was for the model AD6 (Al- Farhatiah area) and the value was 6.42. For potassium K^{40}, the highest value for models AD5 and AD11 (Ahbab Tal al-Dhahab area – Dour al-Qaeda and was (78.72 - 70.9 8) respectively. While, the lowest value was for the model AD4 (Jameat Al-Matn area) was 8.03.

We note that the potassium component in soil depends on the nature of the soil and increases in some agricultural areas as a result of the use of phosphate fertilizers. It results from the continuous use of phosphate fertilizers, uranium in soil is concentrated. Industrial radioactive materials such as pesticides and chemical fertilizers with radioactivity are among the important sources of soil pollution [10]. As for the radium equivalent R_{aeq} unit (Bq / kg), the highest value was for the model AD1 (Sa'ud before Ishaqi village) and was 53.64, and the lowest value was for the model AD8 (Al-Shifaa village) was 13.25. The effective rate of the equivalent of radium is less than the global average for the equivalent effectiveness of radium, which is 370 [13,12]. As for the severity index for gamma rays ($I\gamma$) in (Bq / Kg), the highest value was for the model AD1 (Sa'ud before Ishaqi village) and was 0.368, and the lowest value was for the model AD8 (Al-Shifa village) and was 0.094. The risk index for gamma rays is less than the global average value of Bq / Kg 1 [13,12]. As for the rate of the absorbed dose in the air ($D\gamma$) in units (nGy / h), the highest value for the model AD1 (Saud before Ishaqi village) was 24.39 . The lowest value of the model AD8 (Al-Shifa village) was 5.94, and the rate of absorbed dose in air is less than the global average of 84 nGy / h [13,12].

Table (2): Specific activity levels of different nuclides, radium equivalent Raeq, risk index for gamma rays ($I\gamma$) and absorbed dose rate in air ($D\gamma$) in surface soil models in Yathrib district.

Simples code	Ra-226	Ac-228	K-40	Raeq(Bq/Kg)	Iγ	Dγ
AD1	**15.36**	**6.42**	**17.41**	**53.64**	**0.368**	**24.39**
AD2	**13.09**	**14.33**	**29.46**	**29.13**	**0.199**	**13.40**
AD3	**2.84**	**12.35**	**13.39**	**39.32**	**0.273**	**17.93**
AD4	**23.9**	**7.41**	**8.03**	**36.49**	**0.248**	**16.70**
AD5	**105.88**	**42.01**	**78.72**	**31.50**	**0.213**	**14.38**
AD6	**23.9**	**6.42**	**8.03**	**35.75**	**0.246**	**16.27**
AD7	**27.89**	**13.34**	**20.09**	**23.46**	**0.164**	**10.72**
AD8	**13.66**	**12.35**	**22.76**	**13.25**	**0.094**	**5.94**
AD9	**17.07**	**12.35**	**33.48**	**38.41**	**0.260**	**17.68**
AD10	**18.21**	**11.36**	**30.8**	**37.95**	**0.259**	**17.63**
AD11	**105.31**	**43**	**70.98**	**44.29**	**0.303**	**20.15**

AD12	27.89	13.34	20.09	32.94	0.226	14.91
MAX	105.88	43	78.72	53.64	0.368	24.39
MIN	2.84	6.42	8.03	13.25	0.094	5.94

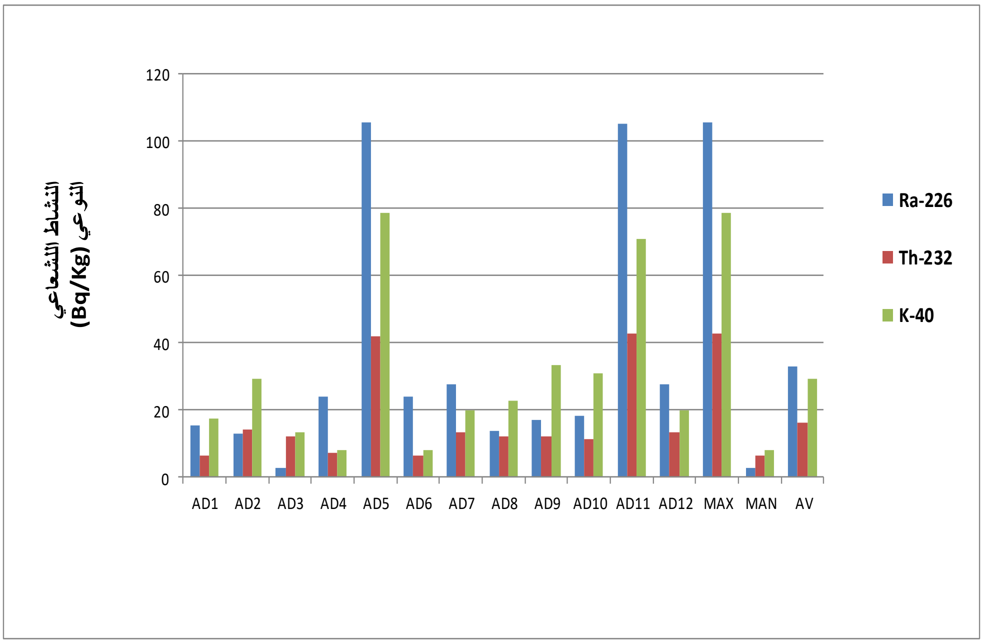


Figure (3) the specific activity levels of the different nuclides in the topsoil models of Yathrib district

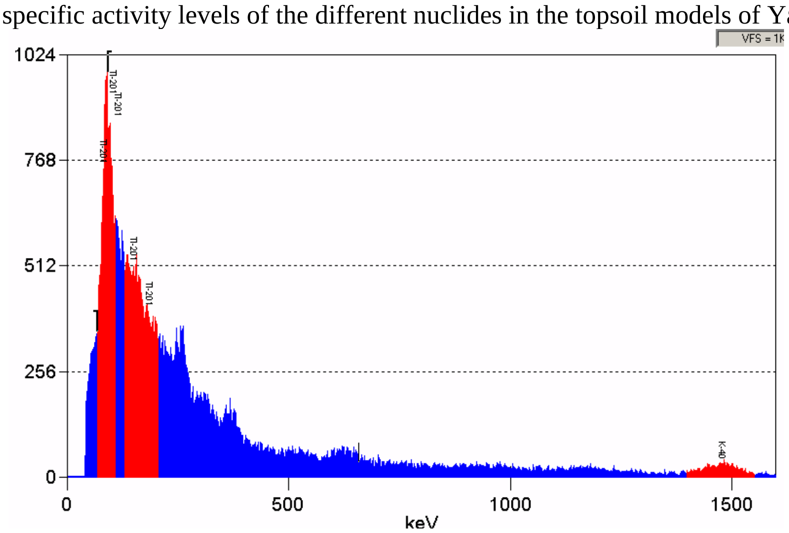


Figure 4: Gamma-ray spectrum of the surface soil model for the NaI (TI) detector.

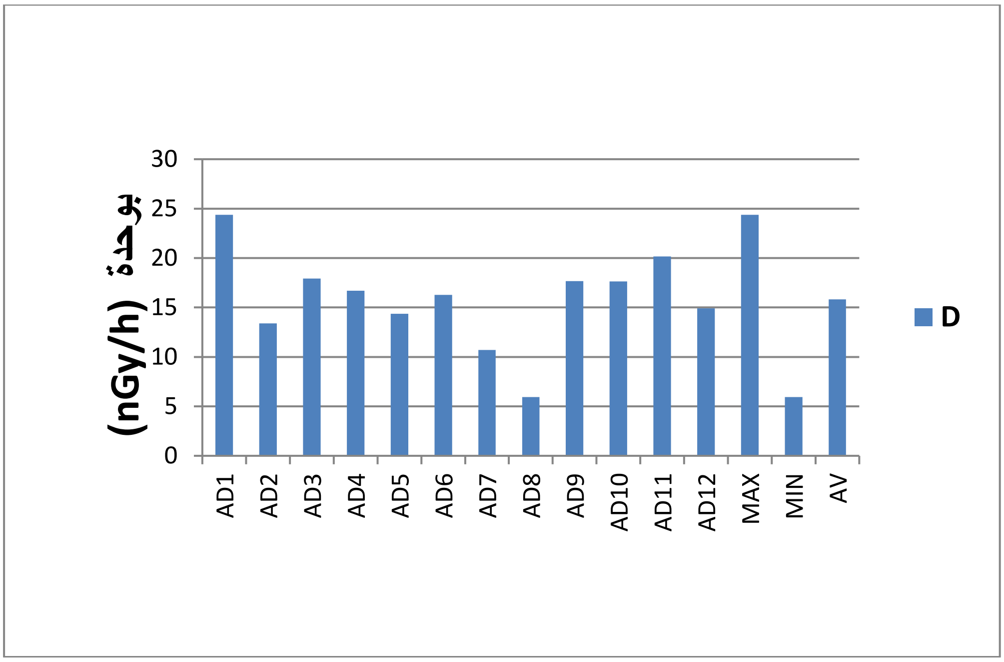


Figure 5: Air-absorbed dose rate levels in topsoil models

6. Specific activity of radionuclides in deep soils (60cm)

Table (4) and Figure (5) show the results obtained for the specific activity levels of radionuclides in deep soil models (60cm) of 12 soil models from Yathrib district of Salah al-Din Governorate.

The specific activity levels of U^{238} in units (Bq / kg) recorded the highest value of radium Ra^{226} for the models AD11 and AD1 (Dour al-Qaeda area - Al-Saud before Ishaqi village) and the values were (31.30 - 27.03) respectively. The lowest value for the model AD12 (Al-Bumhidi village) were (Bq / Kg 9.96). Moreover, it recorded more than the global permissible limit Bq / Kg25 [10.11]. This may be due to the geological formation of these areas that contain natural radioactivity. Radium is one of the most dangerous radioactive elements due to its relatively long half-life. We note the dependence of radioactivity in the soil on activity. The radioactivity of the rocks that formed the soil (the origin of soil) and the total activities that occurred to form soil [10]. As for the specific activity of thorium ^{232}Th in (Bq / kg), the highest value for actinium Ac^{228} was for the model AD6 (Al-Ferhathia area) and the value was 16.31, and the lowest value was for the model AD10 (the Hatimia area) and the value was 0.49. For potassium K^{40}, the highest value for the model AD6 (Ferhatiah area) was 28.12, and the lowest value was for the model AD9 (Al-Buhasan village) and was 8.03. We note that the potassium component in soil depends on the nature of soil and increases in some agricultural areas as a result of the use of phosphate fertilizers and results from the continuous use of phosphate fertilizers. The concentration of uranium in soil, as for industrial radioactive materials such as pesticides. Chemical fertilizers with radioactivity are one of the important sources of soil pollution [10]. As for the radium equivalent R_{aeq} unit (Bq / Kg), the highest value was for the model AD3 (the village of Mazari'a Az-Zour) and was 48.33, and the lowest value was for the model AD10 (the Hatimiyah area) which was 16.81.

The activity rate of the equivalent radium is less than the global average of the equivalent efficacy of radium, which is 370 [13,12]. As for the risk index for gamma rays ($I\gamma$) in units (Bq / Kg), the highest value was For the model AD3 (Mazari'a Az-Zour), was 0.333, and the lowest value for the model AD10 (Al-Hatmiah area) was 0.114, and the risk index of gamma rays was less than the global average value of 1 Bq / kg [13,12]. As for the rate of absorbed dose in the air ($D\gamma$) in units (nGy / h), the highest was for the model AD3 (the village of Mazariyat Al-Zour) and it was 21.87, and the lowest value was for the model AD10 (Al Hatamia area) and it was 7.31, and the rate of the absorbed dose in the air is less than the global average The adult is 84 [13,12.[

Table (3) shows the specific activity levels of the different nuclides, the radium equivalent R_{aeq}, the risk index for gamma rays (Iγ) and the average absorbed dose in the air (Dγ) in the deep soil models (60cm) for Yathrib district.

Simples code	Ra-226	Ac-228	K-40	Raeq(Bq/Kg)	Iγ	Dγ
AD1	**27.03**	**8.4**	**17.41**	**40.38**	**0.275**	**18.44**
AD2	**12.23**	**12.35**	**17.41**	**31.23**	**0.216**	**14.07**
AD3	**23.05**	**16.31**	**25.44**	**48.33**	**0.333**	**21.87**
AD4	**17.07**	**15.32**	**22.76**	**40.37**	**0.282**	**18.37**
AD5	**15.65**	**2.47**	**26.78**	**21.24**	**0.146**	**9.88**
AD6	**20.2**	**16.31**	**28.12**	**45.68**	**0.316**	**20.67**
AD7	**23.09**	**6.42**	**21.42**	**33.91**	**0.232**	**15.56**
AD8	**22.76**	**8.4**	**22.76**	**36.52**	**0.250**	**16.69**
AD9	**23.33**	**7.41**	**8.03**	**34.54**	**0.234**	**15.72**
AD10	**15.08**	**0.49**	**13.39**	**16.81**	**0.114**	**7.31**
AD11	**31.3**	**8.4**	**14.73**	**44.44**	**0.302**	**20.30**
AD12	**9.96**	**13.44**	**20.09**	**30.72**	**0.214**	**13.81**
MAX	**31.3**	**16.31**	**28.12**	**48.33**	**0.333**	**21.87**
MIN	**9.96**	**0.49**	**8.03**	**16.81**	**0.114**	**7.31**

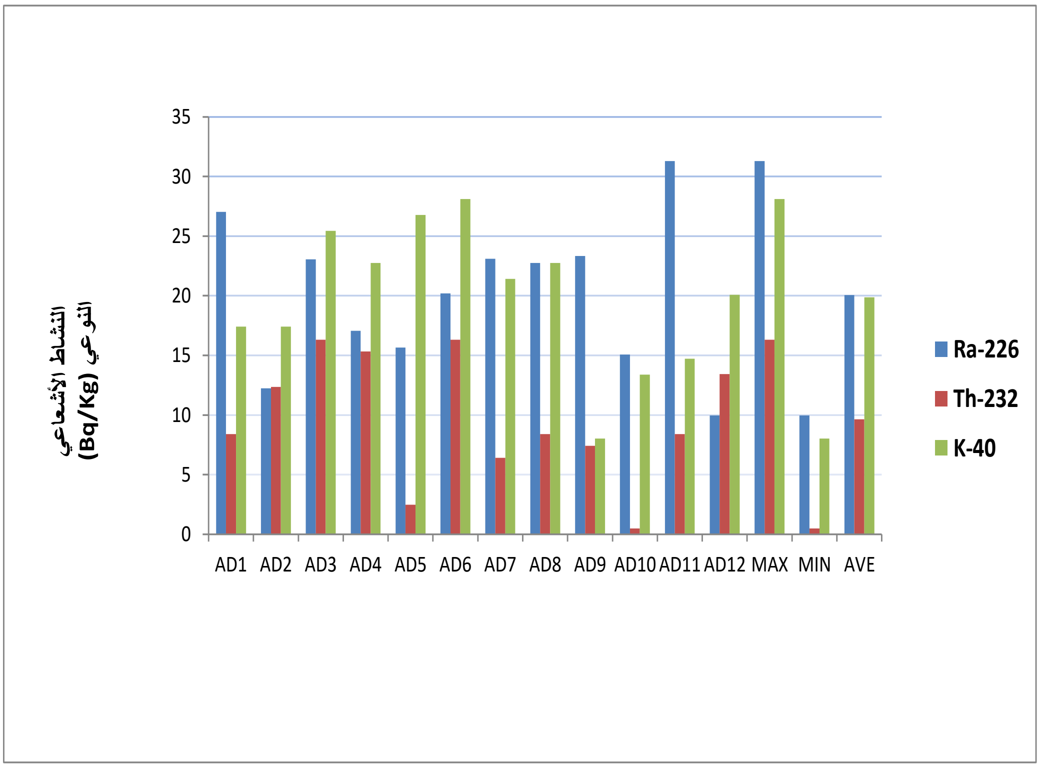


Figure (6) Specific activity levels of radium, thorium and potassium in deep soil models (60cm)

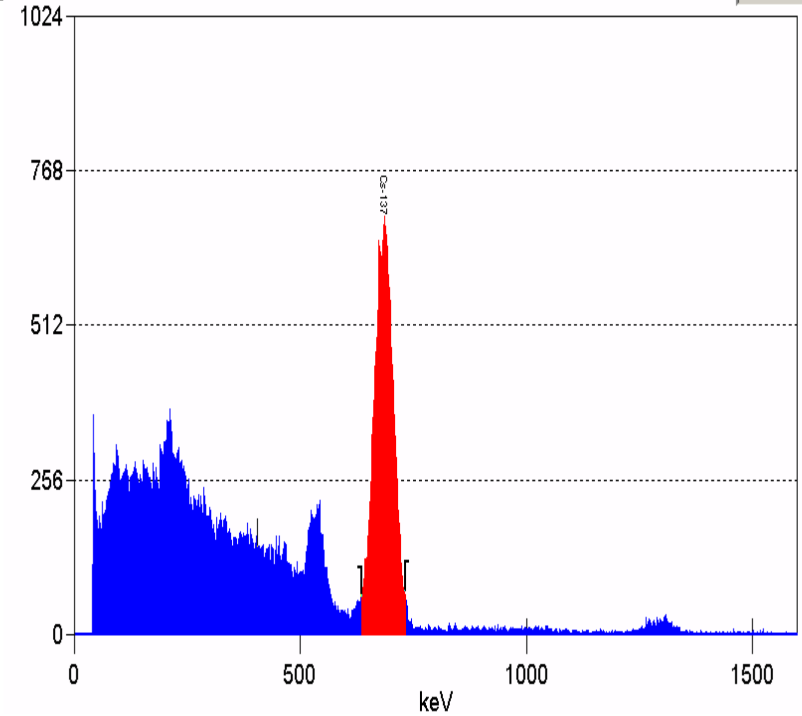


Figure (7) a gamma ray spectrum of a soil model with a depth of (60cm) for NaI (TI) detector.

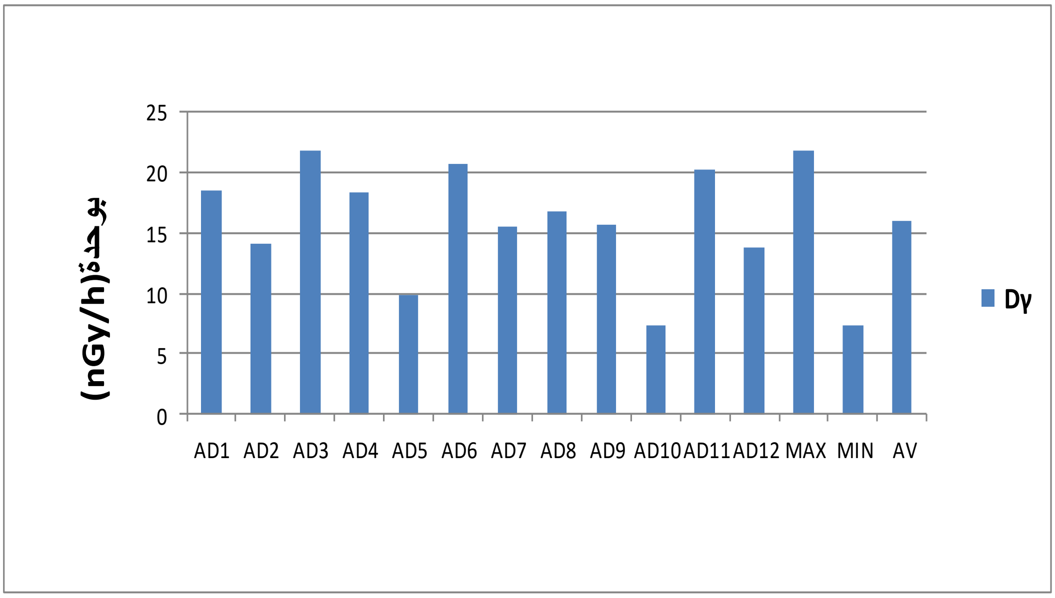


Figure (8) Absorbed dose rate levels in soil models, depth (60cm)

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