Investigation of natural radioactivity in the soil of Kufa zone , Najaf governorate, Iraq

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Abstract

The natural radioactivity due to presence of ^{238}U, ^{232}Th and ^{40}K radionuclides in soil of Kufa zone , Najaf governorate, Iraq were measured by using gamma-ray spectrometry NaI(Tl) "3× 3". The specific activity of the soil samples ranged from 1.76±2.30 to 77.45±2.35 $Bqkg^{-1}$ with an average of 25.23±2.94 $Bqkg^{-1}$, from 7.92±1.22 to 42.58±1.75 $Bqkg^{-1}$ with an average of 20.09±1.11 $Bqkg^{-1}$ and from 219.58±1176 to 1994.17±16.15 $Bqkg^{-1}$ with an average of 984.30±11.86 $Bqkg^{-1}$ for ^{238}U, ^{232}Th and ^{40}K respectively. The study also examined some radiation hazard indices such as radium equivalent activity (Ra_{eq}), Absorbed Dose rates (D), External Hazard Index (H_{ex}) and Internal Hazard Index (H_{in}). These calculated hazard indices to estimate the potential radiological health risk in soil. The radium equivalent activity (Ra_{eq}) values found to vary from 67.80 to 285.80 $Bqkg^{-1}$, with the average value of 129.74 $Bqkg^{-1}$, which was less than permitted value (370 $Bqkg^{-1}$). The absorbed dose rates, ranged from 32. 1 to 142.08 $nGyh^{-1}$, with a average value of 65.17 $nGyh^{-1}$ that higher than the permissible limit of 55 $nGyh^{-1}$. The external and internal hazard index of soil samples were less than unity.

Keywords: natural radioactivity, gamma ray spectrometry, Soil samples.

الخلاصة:

النشاط الإشعاعي الطبيعي الناتج عن وجود النويدات المشعة ^{238}U ، ^{232}Th و ^{40}K في تربة منطقة الكوفة، محافظة النجف ، العراق، تم قياسها باستخدام مطياف أشعة كاما (Na (Tl "3 × 3" . الفعالية النوعية لنماذج التربة تراوحت من 1.76±2.30 الى 77.45±2.35 $Bqkg^{-1}$ وبمعدل 25.23±2.94 $Bqkg^{-1}$ ، من 7.92±1.22 الى 42.58±1.75 $Bqkg^{-1}$ بمعدل 20.09±1.11 $Bqkg^{-1}$ و من 219.58±1176 الى 1994.17±16.15 $Bqkg^{-1}$ بمعدل 984.30±11.86 $Bqkg^{-1}$ لـ ^{238}U ، ^{232}Th و ^{40}K على التوالي.

بحثت الدراسة بعض عوامل الخطر الإشعاعي مثل الفعالية الإشعاعية لمكافئ الراديوم (Ra_{eq}) ، معدل الجرعة الممتصة (D) ، عامل الخطورة الخارجي (H_{ex}) وعامل الخطورة الداخلي (H_{in}) . هذه العوامل حسبت لتقدير المخاطر الصحية للإشعاع الموجود في التربة. قيم مكافئ النشاط الإشعاعي للراديوم وجدت انها تتغير من 67.80 الى 285.80 $Bqkg^{-1}$ بمعدل 129.74 $Bqkg^{-1}$ وهو اقل من القيمة المسموح بها (370 $Bqkg^{-1}$) . معدل الجرعة الممتصة تتراوح من 32. 1 الى 142.08 $nGyh^{-1}$ بمعدل قيمة 65.17 $nGyh^{-1}$ والتي هي أعلى من الحد المسموح به 55 $nGyh^{-1}$ عامل الخطورة الخارجي والداخلي في نماذج التربة كان اقل من واحد.

الكلمات المفتاحية: النشاط الاشعاعي الطبيعي، مطياف أشعة كاما ، نماذج تربة

1-**Introduction**:

Natural occurring radionuclides (NORM) are known to be present in rocks and soils. These radionuclides such as ^{238}U and ^{232}Th or its progenies and also ^{40}K can be originated from primordial era[1]. The presence of natural occurring radioactive material (NORM) in the terrestrial composition of the natural background is dependent on the geological composition of the soil and rocks. Therefore, systematic and accurate measurements of the radioactivity level in soils are essential for understanding changes in the natural radiation background as a function of geographical location and time [2]. Human exposure to ionizing radiation is inevitable. External exposure to radiation arises from natural and man-made radioactivity [3].The interaction of ionizing radiation with the human body leads to various biological effects which may later show up as clinical symptoms [4]. The nature and severity of the symptoms depend on the absorbed dose as well as the dose rate and many sicknesses and diseases which should have been effectively managed if information about the radiation level of an environment is available are being attributed to other sources. The knowledge of the natural radioactivity concentration of our environment is essential populace and also in forming the basis for the assessment of the degree of radioactive contamination or pollution in the environment in the future.

Kufa area , Najaf governorate, which is located on the Euphrates west side, and about 170 km south of Baghdad and 10 km northeast of Najaf. The area of study was agricultural, sandy nature and using agricultural chemical fertilizers continuously, agricultural chemical fertilizers are an essential component of the agricultural activities that help to increase crop production and improve the properties of the nutrient-deficient lands. However, a possible negative effect of chemical fertilizers is the contamination of cultivated lands by trace elements and some naturally occurring radioactive materials (NORM) [5].

This research aims to make a continues monitoring of soil contamination due to using of agricultural fertilizers an order to keep health and safety of people from the radiation due to radioactivity of (NORMs) in soil.

2-Material and methods

A total of 36 soil samples have been collected from four locations of Kufa area and each chosen location has (3) zones, the distance between zones is (10m). Each zone was taken from (3) depths (0-10,10-20, 20-30). The samples were crushed and dried in an oven at 100 ˚C for 24 h to ensure that any significant moisture was removed from the samples, Later, they were grinded into fine powder to pass through a 100-mesh screen and the homogenized samples were sealed in 1L marinelli beakers and dry weighed. The samples were then stored and kept sealed for about 1 month to maintain a radioactive equilibrium between ^{226}Ra and its daughters, each sample was counted using a gamma spectroscopy device for 18000s. The samples were analyzed by using NaI(TI) detector with crystal of 3"×3" dimensions (Alpha Spectra, Inc.-12I12/3) coupled with a multi-channel analyzer 4096 channel (ORTEC-Digi Base) joined with computer software (MAESTRO-32). The detector is surrounded by a 5 cm thick lead shield to reduce the gamma radiation background. The detector has an energy resolution of about 7.2 keV at 662 keV of ^{137}Cs. The photopeak at 1460 keV was used for the measurement of ^{40}K while those at 1764.5 keV peak from ^{214}Bi and 2614 keV from ^{208}Tl were used for the measurement of ^{238}U and ^{232}Th, respectively. The minimum detectable activity (MDA) of the system was calculated as follows [6].

$$MDA(Bqkg^{-1}) = \frac{4.66\sqrt{C}}{\varepsilon \cdot I_{\gamma} \cdot m \cdot t} \qquad (1)$$

where the factor 4.66 corresponds to one level of confidence of 95% , C is the background counts, t is the counting time (s), I_{γ} is the gamma emission probability, ε is the absolute efficiency of the detector at particular gamma energy and m is the sample weight (kg).

The specific activity of each radionuclide was calculated by the following equation [7, 8].

$$A_s(Bqkg^{-1}) = \frac{C}{\varepsilon \times p_{\gamma} \times M_s} \qquad (2)$$

where, C is the count rate of gamma rays (counts per second), ε is the counting detector efficiency, p_{γ} is the absolute transition probability of γ-decay and Ms is the mass of the sample (kg).

3-Results and discussion:

The specific activity of the radionuclide ^{238}U, ^{232}Th and ^{40}K in the soil samples collected from the study area are listed in Table 1. The values ranged from 1.76±2.30 to 77.45±2.35 Bqkg^{-1} with an average of 25.23±2.94 Bqkg^{-1}, from 7.92±1.22 to 42.58±1.75 Bqkg^{-1} with an average of 20.08±1.11 Bqkg^{-1} and from 219.58±1176 to 1994.17±16.15 Bqkg^{-1} with an average of 983.58±11.86 Bqkg^{-1} for ^{238}U, ^{232}Th and ^{40}K respectively. generally figure (1-a,1-b) shows the specific activity due to ^{238}U, ^{232}Th and ^{40}K increases with depth. These increments may be attributed to use agricultural chemical fertilizers for the long time . The minimum values of the specific activity of ^{238}U noted in location S3, as well as for ^{232}Th and ^{40}K noted in location S4 and the maximum values of the specific activity of ^{238}U, ^{232}Th recorded in location S2, and for ^{40}K recorded in location S1. This difference may be ascribed to the different types of phosphate fertilizer used in the soil of different places and in different amounts. The average values of specific activity of soil were found below action value recommended by UNSCER 2000 [9] which are 35 and 30 Bqkg^{-1} for ^{238}U and ^{232}Th, respectively, except for ^{40}K (the corresponding typical world value is 400 Bqkg^{-1} [9].

Table 1: Specific activity of ^{238}U ^{232}Th and ^{40}K in soil samples.

locations	Zone	Depth(cm)	Specific Activity ($Bqkg^{-1}$)		
			^{238}U	^{232}Th	^{40}K
S1	Z1	0 -10	18.92±2.64	14.13±1.06	672.15±10.82
		10 -20	19.71±3.08	14.61±1.22	833.30±10.50
		20 -30	39.26±4.35	19.44±1.15	834.95±12.62
	Z2	0 -10	32.96±2.97	20.85±0.90	1002.93±10.57
		10 -20	35.70±2.74	13.85±1.15	564.63±13.101
		20 -30	42.39±2.59	32.86±1.04	1352.21±10.82
	Z3	0 -10	11.00±3.28	15.59±1.31	637.64±1239
		10 -20	33.74±3.81	26.05±1.13	1215.10±10.98
		20 -30	37.85±2.69	36.37±1.71	1994.17±16.15
S2	Z1	0 -10	37.80±2.40	25.52±0.95	1089.03±11.06
		10 -20	42.49±2.10	33.64±1.80	1855.05±16.31
		20 -30	77.45±2.35	42.58±1.75	1915.04±15.68
	Z2	0 -10	8.51±3.37	11.59±0.88	595.14±14.27
		10 -20	13.54±1.96	9.83±0.99	907.57±10.12
		20 -30	18.97±3.18	21.38±0.92	1014.69±10.35
	Z3	0 -10	22.10±2.69	10.07±1.29	850.24±12.94
		10 -20	15.84±2.25	26.58±0.95	1173.88±11.37
		20 -30	30.76±2.69	27.80±1.01	1024.33±10.98
S3	Z1	0 -10	14.52±3.67	16.88±0.99	897.96±10.89
		10 -20	33.00±3.18	26.14±1.04	1007.76±10.78
		20 -30	34.28±3.37	22.91±1.11	1095.54±11.29
	Z2	0 -10	32.81±3.57	16.67±1.09	756.76±1098
		10 -20	10.80±2.84	15.40±1.11	851.42±10.82
		20 -30	39.26±4.06	17.73±1.06	788.21±11.21
	Z3	0 -10	1.76±2.30	23.67±1.04	638.35±11.60
		10 -20	15.45±3.08	11.73±1.22	954.13±10.19
		20 -30	11.49±2.40	21.13±0.95	1039.23±10.82
S4	Z1	0 -10	11.98±2.93	18.61±1.06	936.19±10.19
		10 -20	22.49±3.77	18.56±1.02	813.85±10.27
		20 -30	25.18±2.40	24.29±0.92	738.65±11.29
	Z2	0 -10	14.77±2.84	7.92±1.22	1347.43±11.10
		10 -20	7.33±2.74	15.93±0.95	838.79±14.12
		20 -30	22.40±2.84	14.39±1.20	869.92±13.88
	Z3	0 -10	8.46±2.77	15.26±0.97	1075.07±11.60
		10 -20	30.46±3.03	14.29±0.85	219.58±1176
		20 -30	32.71±3.91	18.9±0.90	1033.82±11.84

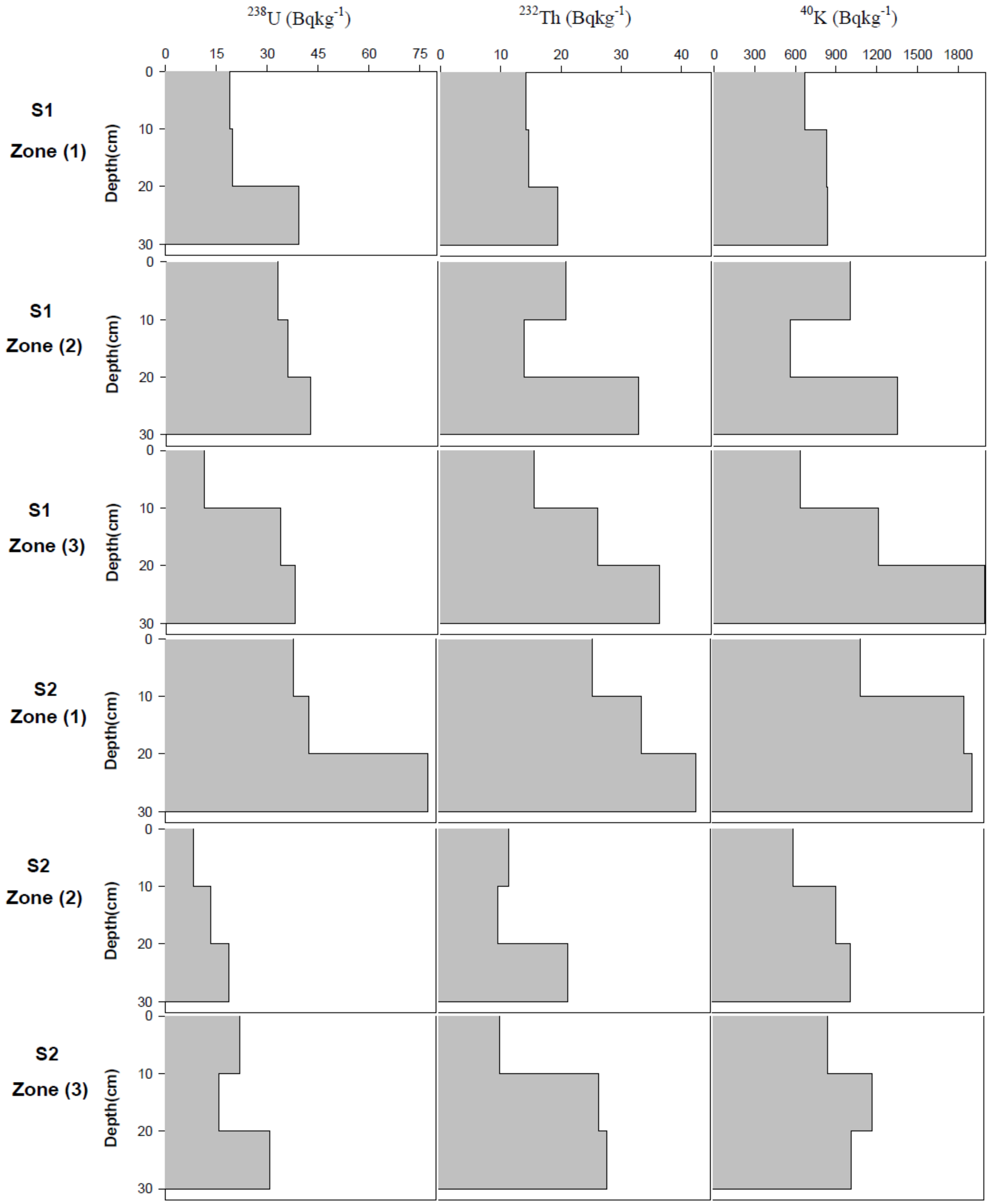

Fig. 1-a Specific activity of soil samples

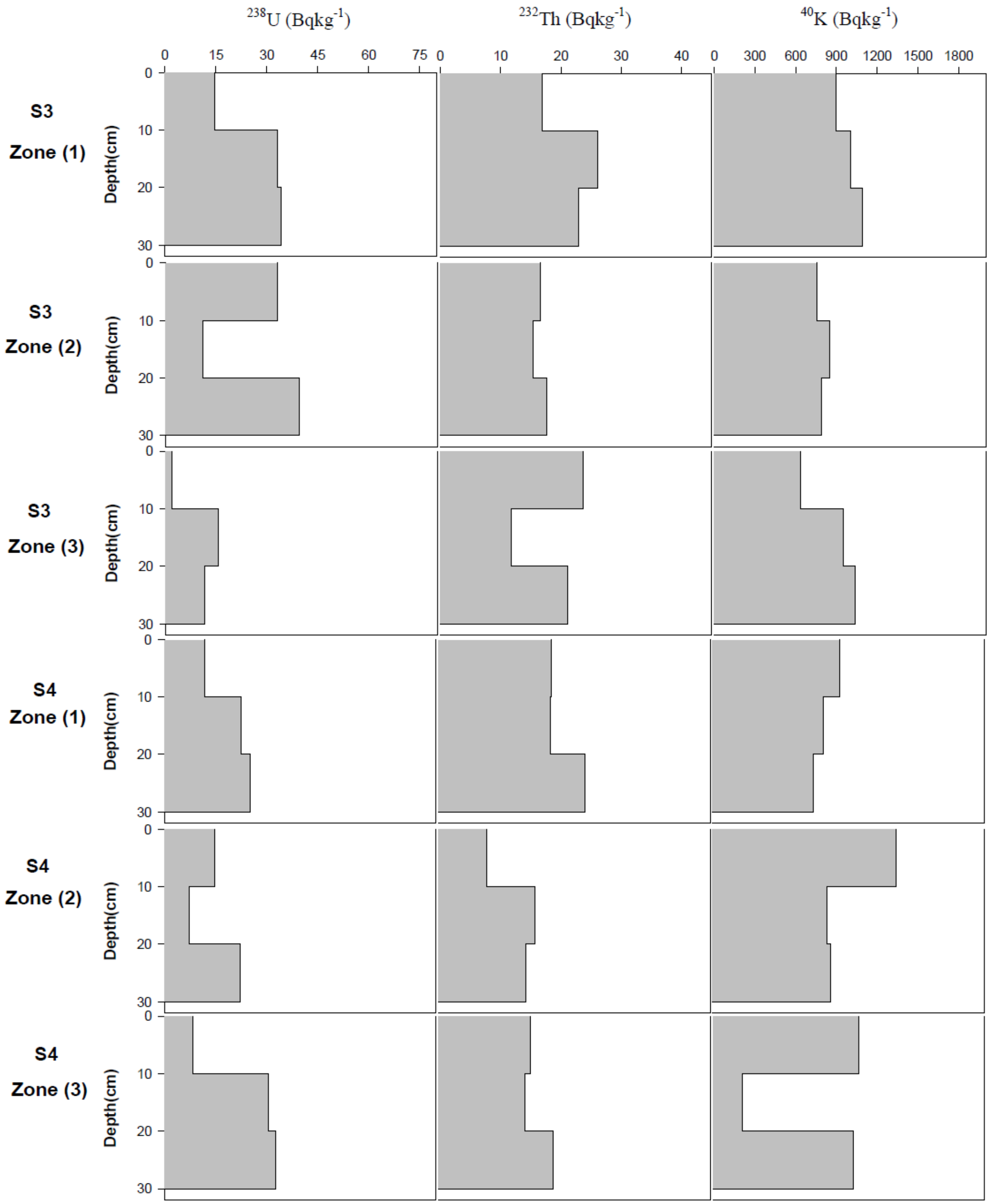

Fig. 1-b Specific activity of soil samples

Radium equivalent activity (Ra_{eq})

To represent the activities due to ^{238}U, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazard with them, a common index called the radium equivalent (Ra_{eq}) in Bq kg^{-1} has been introduced. This activity index provides a useful guideline in regulating the safety standards on radiation protection for the general public residing in common dwellings.

The radium equivalent activity (Ra_{eq}) is a weighed sum of activities of the above-said three natural radionuclides and is based on the assumption that 370 Bq kg^{-1} of ^{238}U, 259 Bq kg^{-1} of ^{232}Th and 4810 Bq kg^{-1} of ^{40}K produce the same gamma-radiation dose rate. The material whose Ra_{eq} exceeds 370 Bq kg^{-1} is discouraged in order to avoid radiation hazards . The radium equivalent activity was calculated by using the following relation [10,11]:`

$$Ra_{eq} = A_U + 1.43A_{Th} + 0.077A_K \qquad (3)$$

where A_U, A_{Th} and A_K the specific activity of ^{238}U, ^{232}Th and ^{40}K respectively. expressed in Bq kg^{-1}. The values of the radium equivalent activity listed in Table 2. and shows in figure (2-a, 2-b). The maximum value of Ra_{eq} must be < 370 Bq kg^{-1} in order to keep the external dose < 1.5 mSv y^{-1} [12]. The Ra_{eq} values varied from 67.80 to 285.80 $Bqkg^{-1}$, with the average of 129.74 Bq kg^{-1}, which is less than the allowable level of 370 Bq kg^{-1} .

The absorbed does rate in air (D)

The absorbed dose rate in air at 1 m height from the ground in each sampling location were calculated from the estimated soil activities of ^{238}U, ^{232}Th and ^{40}K. The conversion factors used to compute absorbed gamma dose rate (D) in air per unit activity concentration corresponds to 0.462 nGy h^{-1} per Bq kg^{-1} for ^{238}U, 0.621 nGy h^{-1} per Bq kg^{-1} for ^{232}Th and 0.0417 nGy h^{-1} per Bq kg^{-1} for ^{40}K. The absorbed dose rate was calculated from the following expression [13].

$$D(nGh^{-1}) = 0.462A_U + 0.621A_{Th} + 0.0417A_K \qquad (4)$$

where A_U, A_{Th} and A_K are the specific activity of ^{238}U, ^{232}Th and ^{40}K respectively. The calculated values of absorbed dose rate was listed in Table 2. and displayed in figure (2-a, 2-b).The value of absorbed dose rate due to the presence of ^{238}U, ^{232}Th and ^{40}K in soil ranges between 32.1 and 142.08 nGy h^{-1} with average of 65.17 nGy h^{-1} which is higher than the estimate of average global primordial radiation of 55 $nGyh^{-1}$[14].

Table 2 : radiation hazard indices of soil samples

locations	Zone	Depth	Ra_{eq} ($BqKg^{-1}$)	D ($nGyh^{-1}$)	H_{ex}	H_{in}
S1	Z1	0 -10	90.88	45.54	0.25	0.30
		10 -20	104.77	52.93	0.28	0.34
		20 -30	131.35	65.03	0.35	0.46
		0 -10	140.00	70.00	0.38	0.47
	Z2	10 -20	98.98	48.64	0.27	0.36
		20 -30	193.50	96.38	0.52	0.64
		0 -10	82.39	41.35	0.22	0.25
	Z3	10 -20	164.55	82.43	0.44	0.54
		20 -30	243.41	123.23	0.66	0.76
S2		0 -10	158.15	78.72	0.43	0.53
	Z1	10 -20	233.43	117.88	0.63	0.75
		20 -30	285.80	142.08	0.77	0.98
		0 -10	70.91	35.95	0.19	0.21
	Z2	10 -20	97.48	50.21	0.26	0.30
		20 -30	127.67	64.35	0.34	0.40
		0 -10	101.97	51.92	0.28	0.34
	Z3	10 -20	144.24	72.78	0.39	0.43
		20 -30	149.39	74.19	0.40	0.49
S3		0 -10	107.80	54.64	0.29	0.33
	Z1	10 -20	147.98	73.50	0.40	0.49
		20 -30	151.40	75.75	0.41	0.50
		0 -10	114.92	57.07	0.31	0.40
	Z2	10 -20	98.38	50.06	0.27	0.29
		20 -30	125.31	62.02	0.34	0.44
		0 -10	84.76	42.13	0.23	0.23
	Z3	10 -20	105.69	54.21	0.29	0.33
		20 -30	121.73	61.77	0.33	0.36
S4		0 -10	110.68	56.13	0.30	0.33
	Z1	10 -20	111.70	55.85	0.30	0.36
		20 -30	116.79	57.52	0.32	0.38
		0 -10	129.85	67.93	0.35	0.39
	Z2	10 -20	94.70	48.26	0.26	0.28
		20 -30	109.96	55.56	0.30	0.36
		0 -10	113.06	58.22	0.31	0.33
	Z3	10 -20	67.80	32.10	0.18	0.27
		20 -30	139.34	69.96	0.38	0.46

External hazard index (H_{ex})

The external hazard index (H_{ex}) is a radiation hazard index defined to evaluate the indoor radiation dose rate due to the external exposure to γ-radiation from the natural radionuclides in soil. In order to evaluate this index, a model proposed by Beretka and Mathew in 1985 [15] was used in the current study.

$$H_{ex} = A_U/370 + A_{Th}/259 + A_K/4810 \qquad (5)$$

where A_U, A_{Th} and A_K are the specific activity of ^{238}U, ^{232}Th and ^{40}K, respectively. The maximum value of H_{ex} equal to unity corresponds to the upper limit of Ra_{eq} (370 $Bqkg^{-1}$), the external hazard index should be below unity [15]. The H_{ex} values were given in Table 2. and displayed in figure (2-a, 2-b). From this figure we noted that all values of this index for all depth of selected soil sample were found to be less than the safety limit.

Internal hazard index (H_{in})

There is another hazard index called internal hazard index (H_{in}), which is defined as following[15]:

$$H_{in} = A_U/185 + A_{Th}/259 + A_K/4810 \qquad (6)$$

The maximum value of H_{in} equal to unity corresponds to the upper limit of Ra_{eq} (370 $Bqkg^{-1}$), the external hazard index should be below unity [15]. The values of the internal hazard index was tabulated in Table 2. and shown in figure (2-a, 2-b). These values ranged from 0.21 to 0.98 with an average of 0.42 which is less than unity.

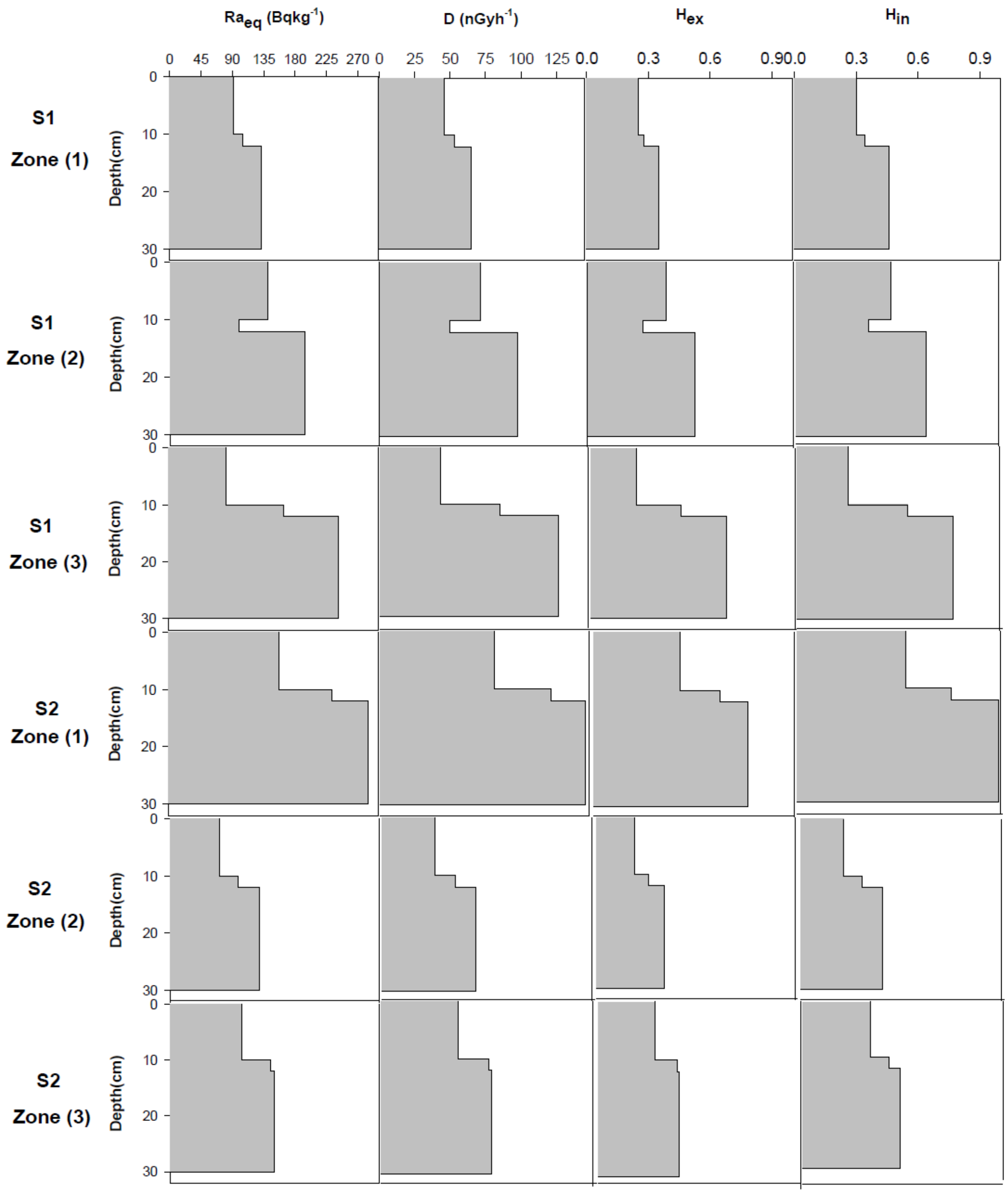

Fig. 2-a hazard index of soil sample

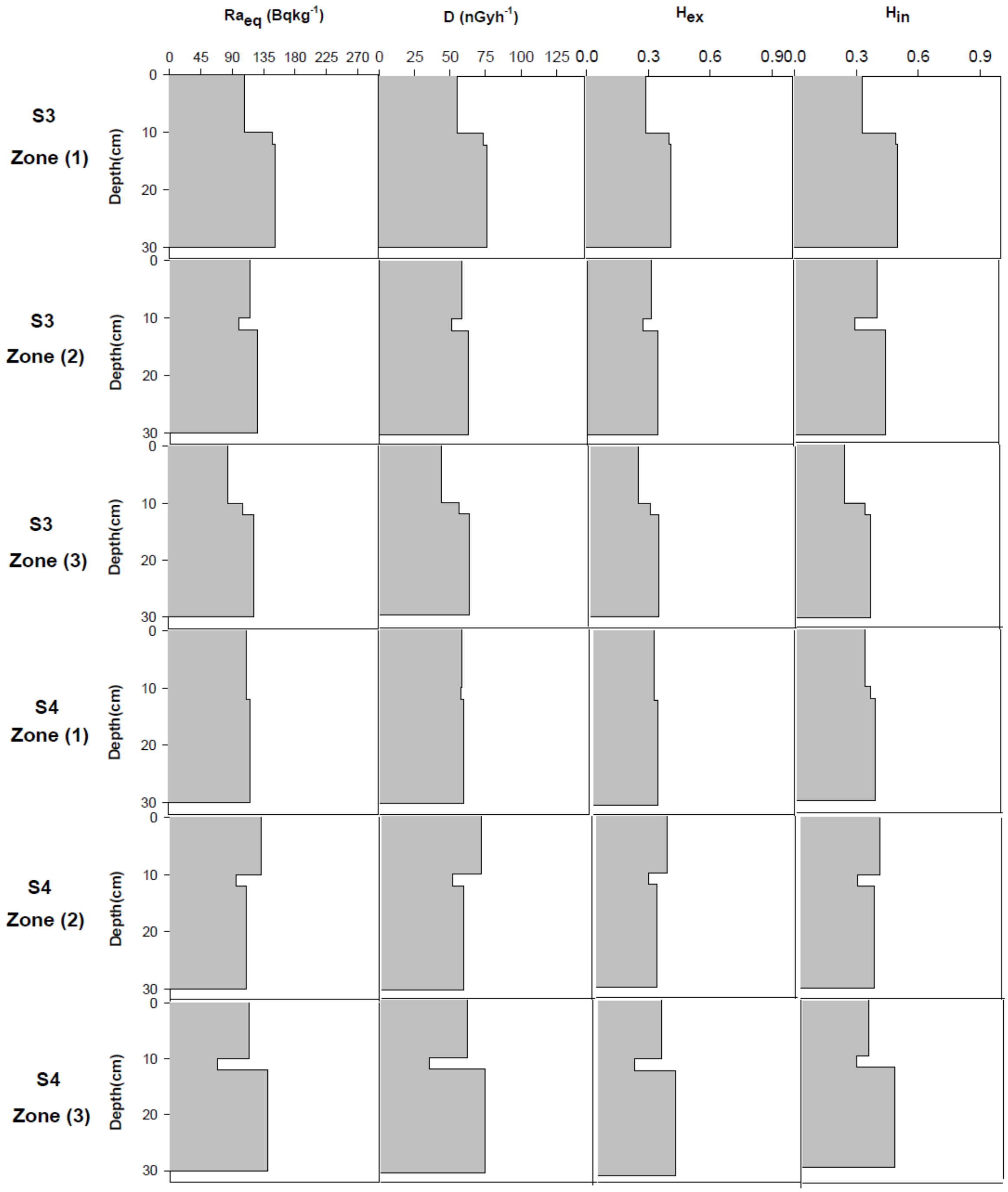

Fig. 2-b hazard index of soil sample

4-Conclusions

The natural radioactivity and related radiation hazards in soil samples in the Kufa area , Najaf governorate, Iraq were assessed by using γ-ray spectrometry. The average specific activity of ^{238}U , ^{232}Th and ^{40}K were 25.23±2.94, 20.08±1.11 and 983.58±11.86 $Bqkg^{-1}$. The average Ra_{eq} value of the studied samples was below the internationally accepted values. Almost the calculated absorbed dose rate were higher than the estimate of average global primordial radiation of 55 nGy/h). The external and internal hazard indices were found to be less than 1.

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