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Estimation of Natural Radioactivity in Soil of Primary Schools at Old City in Najaf

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ABSTRACT

The specific activity levels of Uranium-238, Thorium-232, Potassium-40, and Uranium-235 in soil samples of selected primary schools in the old city of Al-Najaf province, Iraq, were investigated for radiological hazards to determine children's and staff's safety in these schools. Fifteen (15) samples were collected from the soil of schools under study, prepared, and transported to the radiation detection and measurement laboratory for analysis with the use of gamma-ray spectroscopy detector NaI(Tl) with a "3x3" crystal. The average specific activities of Uranium-238, Thorium-232, Potassium-40 and Uranium-235 were (17.18 ±1.63, 24.24±1.96, 318.23 ±21.23 and 0.79±0.07) Bq/kg respectively. The concentrations levels for Uranium-238, Thorium-232, and Potassium-40 were lower than the internationally recommended standard of (33, 45, and 420) Bq/kg. The average values of radium equivalent activity, external hazard index, internal hazard index, gamma index, and alpha index were (76.35±4.97, 0.206 ±0.01, 0.252 ±0.01, 0.569 ±0.03, 0.086 ±0.008) respectively. Furthermore, the average values of absorbed dose rate, annual effective dose equivalent outdoor, annual effective dose equivalent indoor, and excess lifetime cancer risk (ELCR) were (35.85 ±2.31) nGy/h, (0.043 ±0.002) mSv/y, (0.175 ±0.011) mSv/y, and (0.153 ±0.009) respectively. It is observed that all results of the radiological hazard parameters due to a specific activities for Uranium-238, Thorium-232, Potassium-40, and Uranium-235 were within the world of safety limits. Therefore, the children and staff whose schools were assessed are deemed not exposed to any radioactive risks.

INTRODUCTION

Human beings are exposed to radiation in their living situations from both natural and man-made sources. These radionuclides contain primordial natural radioisotopes and may be divided into two categories: natural radioactive decay series (Uranium-235, Uranium-238, and Thourioum-232) and daughters of these nuclides with relatively long half-lives and also daughters of these daughter nuclides, such as (^{210}Pb, ^{226}Ra, ^{210}Po, and ^{210}Bi) [1]. The anthropogenic radiation may have arisen from anthropogenic sources such as nuclear weapons, nuclear accidents, or the nuclear fuel cycle, which might increase naturally occurring radioactive materials [2]. The radioactivity in the air and soil can be transferred to the crops cultivated there. However, it is possible for a small number of radioactive materials to enter human bodies. Food, drink, and other things that come into contact with a mouth can cause ingestion. Natural radionuclides can be found in soil in abundance [3]. It is necessary to examine the radiation levels and the distribution of the radionuclides in the environment to give essential information about radiation. This information is required for understanding human radiation exposure from artificial and natural sources, as well as for developing the production of radiation rules and regulations [4]. Determining the change in natural background activity over time as a result of any radioactive emission requires measuring natural radioactivity in rocks and soils. Environmental protection requires continuous monitoring of any

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radioactive emissions into the environment. Due to their health concerns, environmental contamination, and the management and avoidance of such radiation exposure, the rising interest in monitoring radionuclide concentrations in the environment has substantial radiological effects. [5]. Natural-source radiation makes up most of the human population's overall exposure. Natural radiation levels are too high in several places worldwide, including Brazil, Australia, China, Iran, India, and Japan. The study of natural radioactivity in the soil in all countries has been increasingly important in recent years for estimating the danger of radiation for low levels and long time on human health. The existence of huge amounts of natural radioactivity levels in soils, rocks, sediments, and other materials contributes to the high radiation levels. [6]. Because many people - especially children - spend most of their time at home and school, schools are likely to be the most important source of background radiation exposure after home. The most significant contributor to background radiation for most school children and staff are expected to be exposed to their schools[7]. As a result, those schools must test as well as homes for background radiation levels. It is necessary to study the natural radioactivity for various buildings including schools and universities. The old city of Najaf Province, which contains the holy shrine of AL-Imam Ali and is visited by a huge number of inhabitants throughout the year, is one of the most important religious places in the province. Furthermore, this Area was the site of military activities in 2003 during battles between the USA and the former Iraqi army. The objective of this study is to examine the radioactivity levels due to ^{238}U,^{40}K, and ^{232}Th in soils of primary schools in the old city of Al-Najaf province, Iraq using a gamma-ray spectroscopy detector and to calculate the radiological parameters caused by exposure in these schools. Furthermore, because no other research of this type has been performed in the region, the expected results may be used as a baseline for determining any future variations and developing a database for the area under investigation. There are many experts in Iraq who use NaI(Tl) detector to measure natural radioactivity in soil [8-11].

2. .MATERIAL AND METHOD

2.1 Study area

AL-Najaf province is the site of the present study. 15 primary schools were chosen from the old city of AL-Najaf province. Table (1) displays the sample name, code, type, date of establishment, and locations of the selected schools.

2.2 Collection and Preparation of Samples

A total of fifteen soil samples were taken at a depth of 15 cm from primary schools in the old city of A.L-Najaf Governorate. Then, they were coded by special codes (Table 1). The soil samples were collected from schools according to the recommendationof the IAEA by the square of systematic linear. After that, they were sent to the laboratory at the University of Kufa's faculty of science. Each soil sample was dried in an electric oven at $105^{0}C$ for about 2-3hr until all moisture was removed. Then the samples were crushed through the use of a mill and then passed through a 2mm sieve. After this process, the samples were placed in a cylindrical plastic container with screw caps to provide a tight seal and prevent the release of radon gases. All samples were weighed using an electronic weighing balance before filling them out. The mass of each sample was 1kg and stored at least for one month to obtain secular equilibrium [12].

2.3. Gamma-Ray Spectrometer

NaI(Tl system was used, which consists of a scintillation detector NaI(Tl) of (3"×3") crystal dimension, supplied by (Alpha Spectra, Inc.-12I12/3), coupled with a multi-channel analyzer (MCA) (ORTEC –Digi Base) with a range of 4096 channel joined with ADC (Analog to Digital Converter) unit, through the interface. The spectral data was converted directly to the P.C. of the laboratory introduced using (MAESTRO-32) software [12]. MAESTRO is a multi-channel analyzer (MCA) "emulation" software package that is compatible with gamma and alpha spectroscopy systems in a wide variety of industrial, teaching, research, and other scientific applications. To reduce the background radiation, the detector was maintained in a vertical position and shielded by ORTEC cylindrical chamber. NaI(Tl) detector was calibrated for energy and gamma-ray. A ^{137}Cs, ^{54}Mn, ^{60}Co, ^{22}Na, and ^{152}Eu radioactive sources (from the IAEA (Model RSS–8) were employed to serve as sources of calibration and efficiency. The resolution value obtained in the current work was (7.9%) ^{137}Cs standard source that energy 661.66 Kev.

Table (1): Location and coordination of studied samples

No.	Name	Code	type	Date	longitude	latitude
1	Alghaffari	p1	boys	1919	436150.9	3539909
2	Altahdhib	p2	boys	1952	435944.2	3539177
3	Malik Aliashtir	p3	boys	1954	436064.3	3539492
4	Aishab Alkasa	P4	boys	1959	436456.2	3539630
5	Alhaidariya	P5	boys	1933	436900.3	3540156
6	Alsaadiq	P6	boys	1953	437108.5	3539453
7	Eidun	P7	boys	1973	438586.6	3539133
8	Alzainabiya	P8	girls	1937	436100.7	3539435
9	Sikina	P9	girls	1958	435403.2	3540360
10	Ramallah	P10	girls	1958	435289.5	3539809
11	Aleafa	P11	girls	1963	436205.9	3539477
12	Dijula	P12	girls	1964	436003.5	3539253
13	Birdaa	P13	girls	1953	435724.3	3539683
14	Alturath Alearabiu	P14	girls	1981	437178.2	3539517
15	Aliaskandaria	P15	girls	2004	436211	3538606

3. Theoretical Equitation

The specific activity (A) was estimated using the equation [13]:

$$A\left(\frac{Bq}{kg}\right) = \frac{Net\ Area - B.G}{I_\gamma\ \varepsilon\ M\ T} \qquad (1)$$

Net Area = Net Area below energy peak (count). B.G = number of counts in the background spectrum, ε is the absolute detector efficiency, and T is the lifetime for counting the spectrum in seconds. M is the weight of the dried sample in kg.

Radium Equivalent Activity (Ra_{eq}): Ra_{eq} is a widely assessed hazard index that is calculated using Eq (2) [14]:

$$Ra_{eq}\left(\frac{Bq}{kg}\right) = A_U + 1.43\ A_{Th} + 0.077 A_K \qquad (2)$$

Where A_{Th}, A_U, and A_k are the specific activity of ^{232}Th, ^{238}U, and ^{40}K, respectively

Absorbed Dose Rate in Air (D_r): The following formula (Eq.3) is used to compute D_r [15].

$$D_r\left(\frac{nGy}{h}\right) = 0.462\ A_U + 0.604\ A_{Th} + 0.0417 A_K \qquad (3)$$

External hazard index (H_{ex}): The following equation gives the external hazard index for the investigated samples [16]:

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (4)$$

Internal hazard index (H_{in}): The internal hazard index controls the internal exposure to ^{222}Rn and its radioactive daughters. The following equation can be used to compute it. [17]

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (5)$$

Representative Level Index (Iγ): Another index, named the representative level index (I_r), was used to estimate the radiation hazards of the specific radionuclides of ^{238}U(^{226}Ra), ^{232}Th, and ^{40}K.To compute $I_{\gamma r}$ for the soil samples under investigation, applying the equation below [18].

$$I_\gamma = \left(\frac{1}{150}\right) A_U + \left(\frac{1}{100}\right) A_{Th} + \left(\frac{1}{1500}\right) A_K \qquad (6)$$

Alpha index (Iα): The alpha index was performed to evaluate the excess of the alpha radiation caused by radon inhalation from building materials. Equation (7) was used to calculate the alpha- index [19]:

$$I_\alpha = \frac{A_U}{200\ (\frac{Bq}{kg})} \qquad (7)$$

Exposure rate ($\dot{X}$): Due to the uniformly distributed of the ^{238}U, ^{232}Th decay series, and ^{40}K in the material, the value of $\dot{X}$ is given by [20, 21]:

$$\dot{X}\left(\frac{\mu R}{h}\right) = 1.90\ A_U + 2.82\ A_{Th} + 0.197 A_K \qquad (8)$$

Annual gonadal equivalent dose (AGED): AGED for inhabitants in the studied schools related to the specific activities of ^{238}U, ^{232}Th, and ^{40}K was computed using equation (9) as [22-24]:

$$AGED\left(\frac{\mu Sv}{y}\right) = 3.09\ A_U + 4.18\ A_{Th} + 0.314 A_K \qquad (\mathbf{9})$$

Annual Effective Dose Equivalent (AEDE): The equations (10) and (11) are used to compute annual effective dose indoor and outdoor, respectively, which depend on D_r and occupation factor (indoor=0.2, outdoor = 0.8), as follows [22, 25]:

$$AEDE_{outdoor}\left(\frac{mSv}{y}\right) = [D_r(mGy/hr) \times 8760\ hr \times 0.2 \times 0.7 Sv/Gy] \times 10^{-6} \qquad (\mathbf{10})$$

$$AEDE_{indoor}\left(\frac{mSv}{y}\right) = [\mathrm{D_r(mGy/hr)} \times 8760\ \mathrm{hr} \times 0.8 \times 0.7\mathrm{Sv/Gy}] \times 10^{-6} \qquad (\mathbf{11})$$

Excess Lifetime Cancer Risk (ELCR): This shows the probability of having cancer throughout a lifetime at a particular exposure level, assuming a human life expectancy of 70 years. It is written as [26, 16].

$$ELCR = AEDE\ \times DL\ \times RF \qquad (\mathbf{12})$$

Where DL is life expectancy (70 y), while R.F. is a fatal risk factor in (Sievert), and it is pegged at 0.05 per Sievert.

4-RESULTS AND DISCUSSION

The data of the specific activities in soil samples of primary schools in the old city for radionuclides ^{238}U, ^{232}Th, ^{40}K, and ^{235}U are presented in Table (2) and depicted in Figure (1). The specific activity of ^{238}U was found to range between 6.8 ± 0.5 and 30.8 ±1.0Bq/kg, with an average value of 17.18 ±1.63 Bq/kg. The minimum value was found in sample (P4), and the maximum value was found in sample (P3). The present work's average value is lower than the average world value (33 Bq/kg) [27]. ^{232}Th activity concentrations in the soil samples ranged from 9.4±0.6 Bq/kg in the sample (P9) to 38.2±1.2 Bq/kg in the sample (P14) with an average value of 24.24 ±1.96 Bq/kg. The current work's average value is lower than those reported in the literature (45 Bq/kg) [27]. Furthermore, the concentrations of ^{40}K measured samples ranged from 168.6±2.4 to 454.4±4.0Bq/kg for the sample(P10) to sample (P14), with an average value of 318.23 ±21.23 Bq/kg, which is lower than the average world concentration (412 Bq/kg) [27]. At the same time, the specific activity of ^{235}U varies from 0.31 Bq/kg to 1.42 Bq/kg, and an average value of 0.79 ±0.07 Bq/kg. Because ^{40}K is the most ubiquitous radioactive isotope under concentration, its activity concentration was found to be greater than ^{238}U and ^{232}Th in all analyzed samples.

Table (2): Specific activity for gamma emitters (^{238}U, ^{232}Th, ^{40}K, and ^{235}U) in the Soil samples

No.	Sample Code	Specific activity Bq/kg			
		^{238}U	^{232}Th	^{40}K	^{235}U
1	p1	15.6 ±0.7	32.2±1.1	378.1±3.6	0.72
2	p2	12.3 ±0.7	24.6±0.9	279.7±3.1	0.57
3	p3	30.8 ±1.0	23.9±0.9	296.0±3.2	1.42
4	P4	6.8 ± 0.5	21.2±0.9	203.5±2.7	0.31
5	P5	25.4±0.9	32.5±1.1	363.1±3.6	1.17
6	P6	8.4 ±0.5	18.4±0.8	312.2±3.3	0.39
7	P7	26.7±1.0	29.0±1.0	421.0±3.8	1.23
8	P8	14.1±0.7	20.5±0.8	308.7±3.3	0.65
9	P9	15.3±0.7	9.4±0.6	186.4±2.6	0.71
10	P10	16.2±0.8	13.9±0.7	168.6±2.4	0.75
11	P11	20.5±0.8	30.5±1.0	354.6±3.5	0.94
12	P12	16.7±0.8	28.9±1.0	358.0±3.5	0.77
13	P13	19.8±0.8	15.9±0.7	283.8±3.2	0.91
14	P14	14.1±0.7	38.2±1.2	454.4±4.0	0.65
15	P15	15.0±0.7	24.6±0.9	405.4±3.8	0.69
Average±S.E		17.18 ±1.63	24.24 ±1.96	318.23 ±21.23	0.79 ±0.07
Worldwide average [27]		33	45	420	.....

Table (3) shows the results of the radium equivalent activity. Ra_{eq} values varied from 43.095 to 100.587 Bq/kg, with an average value of 76.35 ±4.97Bq/kg, which is below the permissible limit of 370 [28]. As a result, the maximum value in this investigation is within the acceptable limits. Equations (4), (5), (6), and (7) in Table (3) were used to compute the values of the Hazard index (external and internal index), representative level index, and alpha index for the samples collected. In all the studied samples, the average values of H_{ex}, H_{in}, $I_{\gamma r,}$ and I_{α} were (0.206 ±0.01, 0.252 ±0.01, 0.569 ±0.03, and 0.086 ±0.008), respectively. All values for all samples analyzed in this study's hazard indexes (external and internal), representative level index, and alpha index are lower than unity which is the maximum value of the acceptable safety level recommended by the UNSCEAR[19].

The results of another radiological hazard, such $\dot{X}$, AGED, D_r, $AEDE_{indoor}$, $AEDE_{outdoor}$, and ELCR are recorded in Table (4). The maximum values of Exposure rate ($\dot{X}$) in sample P14 was found to be 224.031 μR h^{-1} , while the minimum values were in sample P9 with the value 92.299 μR h^{-1}, and average value of 163.70 ±10.60 μR h^{-1}. The results of the absorbed dose rate D_r ranged from 20.519 nGy h^{-1} to 48.535 nGy h^{-1} with an average value of 35.85 ±2.31 nGy h^{-1}. According to the UNSCEAR publication 2000 [19], the results of the absorbed dose rate were lower than the world average, which would be equivalent to 55 nGy/h. The values of annual gonadal equivalent dose AGED as shown in Table (4) are from 145.099 μSv y^{-1} to 345.927 μSv y^{-1} with an average of 254.36 ±16.39 μSv y^{-1}. The results of AGED were lower than the world average allowed level of ≤ 300 μSv y^{-1} (expect samples p1, P7, P11, P14) [29]. The calculated values of the annual effective doses equivalent for outdoor, indoor and for total ($AEDE_{outdoor}$, $AEDE_{indoor}$ and $AEDE_{total}$) for this research varied from 0.025 mSv y^{-1} to 0.060 mSv y^{-1} with an average of 0.043 ±0.002 mSv y^{-1}, from 0.101 mSv y^{-1} to 0.238 mSv y^{-1}) with an average of 0.175 ±0.011 mSv y^{-1}, and from 0.126 mSv y^{-1} to 0.298 mSv y^{-1} with an average of 0.219 ±0.014 mSv y^{-1} respectively. The values of ($AEDE_{outdoor}$, $AEDE_{indoor}$ and $AEDE_{total}$) were less than the worldwide results (0.08, 0.42 and 0.50 mSv y^{-1} respectively) [30]. Table (4) also displays the results of the computed Excess lifetime cancer risk (ELCR) of the selected schools. The range of the values was 0.088×10^{-3} to 0.208×10^{-3}, with an average of $0.153 \pm0.009\times10^{-3}$. Because the ELCR values are low based on these results, it is possible to conclude that the risk of cancer is negligible.

Table (3): Radiological parameters of the radionuclides (^{238}U, ^{232}Th, and ^{40}K) for samples in studied schools

No.	Sample code	Ra_{eq} (Bq/kg)	H_{ex}	H_{in}	I_{γ}	I_{α}
1	p1	90.760	0.245	0.287	0.678	0.078
2	p2	69.015	0.186	0.220	0.514	0.062
3	p3	87.769	0.237	0.320	0.642	0.154
4	P4	52.786	0.143	0.161	0.393	0.034
5	P5	99.834	0.270	0.338	0.736	0.127
6	P6	58.751	0.159	0.181	0.448	0.042
7	P7	100.587	0.272	0.344	0.749	0.134
8	P8	67.185	0.181	0.220	0.505	0.071
9	P9	43.095	0.116	0.158	0.320	0.077
10	P10	49.059	0.133	0.176	0.359	0.081
11	P11	91.419	0.247	0.302	0.678	0.103
12	P12	85.593	0.231	0.276	0.639	0.084
13	P13	64.390	0.174	0.227	0.480	0.099
14	P14	103.715	0.280	0.318	0.779	0.071
15	P15	81.394	0.220	0.260	0.616	0.075
Average ± S.E.		76.35 ±4.97	0.206 ±0.01	0.252 ±0.01	0.569 ±0.03	0.086 ±0.008

Table (4): Results of $\dot{X}$, D_r, AGED, $AEDE_{indoor}$, $AEDE_{outdoor}$, $AEDE_{total}$ and ELCR

No.	Sample code	$\dot{X}$ (μR/h)	D_r (nGy/h)	AGED (μSv/y)	$AEDE_{outdoor}$ (mSv/y)	$AEDE_{indoor}$ (mSv/y)	$AEDE_{total}$ (mSv/y)	ELCR×10^{-3}
1	p1	194.93	42.42	301.52	0.052	0.208	0.260	0.182
2	p2	147.84	32.20	228.66	0.039	0.158	0.197	0.138
3	p3	184.23	41.00	288.01	0.050	0.201	0.251	0.176
4	P4	112.79	24.43	173.52	0.030	0.120	0.150	0.105
5	P5	211.44	46.50	328.34	0.057	0.228	0.285	0.200
6	P6	129.35	28.01	200.89	0.034	0.137	0.172	0.120
7	P7	215.44	47.40	335.91	0.058	0.233	0.291	0.203
8	P8	145.41	31.76	226.19	0.039	0.156	0.195	0.136
9	P9	92.29	20.51	145.09	0.025	0.101	0.126	0.088
10	P10	103.19	22.91	161.10	0.028	0.112	0.140	0.098
11	P11	194.81	42.68	302.17	0.052	0.209	0.262	0.183
12	P12	183.75	40.10	284.81	0.049	0.197	0.246	0.172
13	P13	138.36	30.58	216.75	0.038	0.150	0.188	0.131
14	P14	224.03	48.53	345.92	0.060	0.238	0.298	0.208
15	P15	177.73	38.69	276.47	0.047	0.190	0.237	0.166
Average ± S.E.		163.70±10.60	35.85±2.31	254.36±16.39	0.043 ±0.002	0.175 ±0.011	0.219 ±0.014	0.153 ±0.009
Worldwide average		…….	55[19]	≤ 300 [29]	0.08 [30]	0.42 [30]	0.50 [30]	………

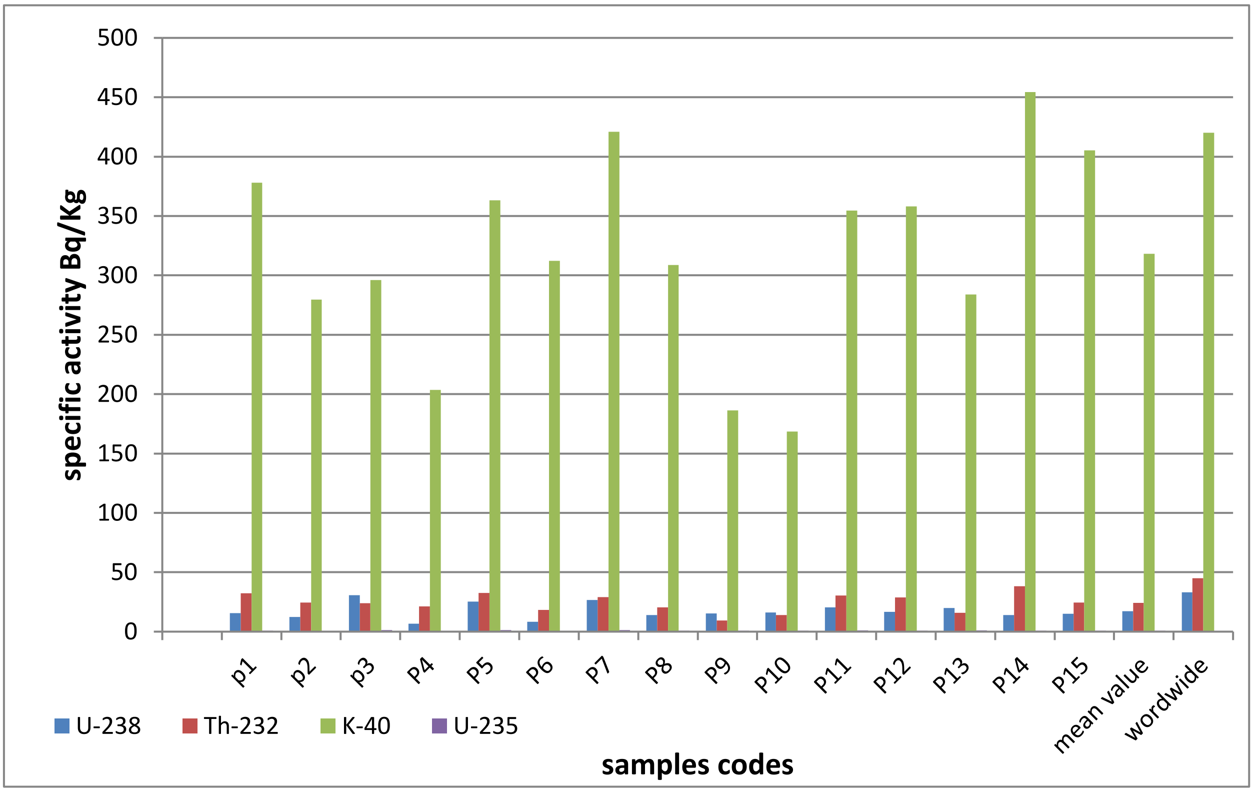

Fig. (1): Specific activity of radionuclides ^{238}U, ^{232}Th, ^{40}K, and ^{235}U in soil samples collected from the schools under study

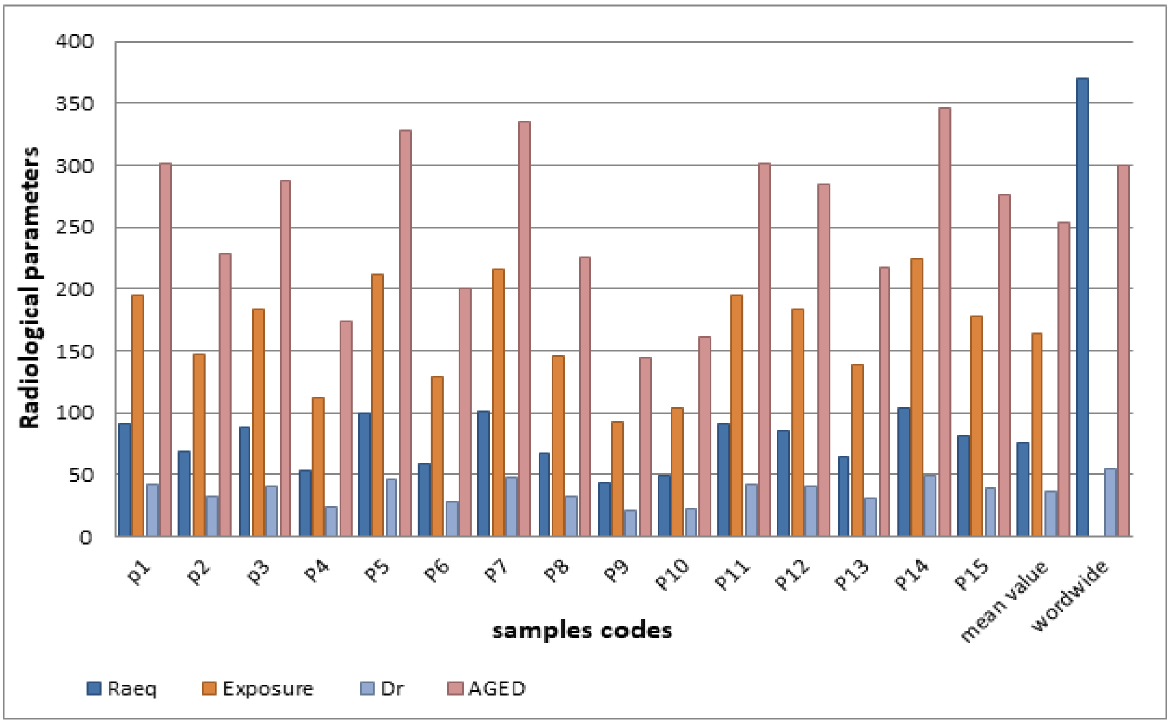

Fig. (2): Radiological parameters Ra_{eq}, Exposure, D_r, and AGED due to gamma-ray emitters for samples in the studied schools

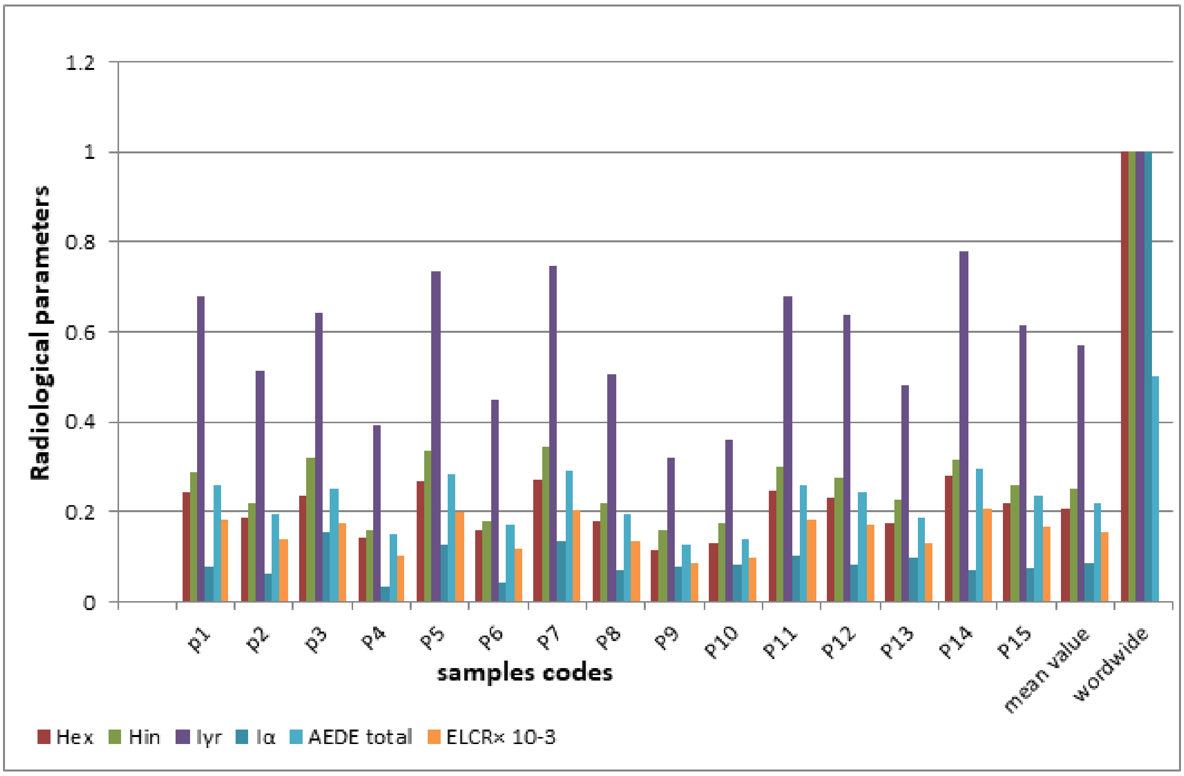

Fig. (3): Radiological parameters H_{ex}, H_{in}, I_{γ}, Iα, $AEDE_{total}$, and ELCR for soil samples in the selected schools

5-CONCLUSION

To investigate the effects of the natural radioactivity in soil samples on the students and staff from 15 primary schools in the old city of AL- Najaf province, a gamma-ray spectrometry (NaI(Tl)) detector has been used to examine the soil samples from the selected schools. ^{238}U, ^{232}Th, and ^{40}K activity concentrations were lower than the acceptable world values. Additionally, all the radiological parameters studied in the current research were found to be within the recommended safe limits. Furthermore, ^{40}K was shown to be the main contributor to environmental radionuclides in the studied region. As a result, the occupants of these schools (children and staff) are not at risk of radiological exposure from their immediate surroundings. In order to protect the air and public health from exposure to radiation, there are many recommendations such as forming a specialized work team to conduct a radiological survey of other schools in Al-Najaf Governorate, planning an integrated radiological principles, increasing the number of the samples studied and providing a study in all governorates of the country to draw a rediological map.

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