Assessment of environmental radioactivity in soil samples of primary schools in North of Al-Najaf governorates

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► ***Original article***

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ABSTRACT

Background: Natural radioactivity in the soil is the main reason behind this research. So, the natural radioactivity (^{40}K, ^{238}U, and ^{232}Th) in soil samples have been measured in ten primary schools at north of Al-Najaf province. ***Materials and Methods***: The specific activities (^{214}Bi belongs to the uranium-238 series; ^{208}Tl belongs to the thorium -232 string and a natural radionuclide ^{40}K) have been indicated by using spectral analysis technique of Gamma-ray of 3"x3" NaI(Tl) scintillation detector has been used. ***Results***: The average value of specified activity for ^{40}K, ^{238}U, and ^{232}Th in all samples is (201.47±24.47) Bq/kg, (10.17±1.78) Bq/kg, and (5.91±0.83) Bq/kg respectively. In this work, the majority of the hazard indices were calculated. The average value of radium Equivalent Activity was (16.673±1.71) Bq/kg, Absorbed Gamma Dose was (16.673±1.71) nGy/h, external hazard index was (0.092±0.009), internal hazard index was (0.120±0.013), representative gamma index was (0.261±0.026), Annual influential dose equivalent indoor was (0.082±0.008), for Annual influential dose equivalent outdoor was (0.020±0.002) mSv/y, and excess lifetime cancer risk was (0.358±0.03) × 10^{-3}. ***Conclusion***: Most of the detected readings are in the recommended values by (UNSCEAR, OECD, and ICRP) When compared with the worldwide average (^{40}K=412 Bq/kg, ^{238}U=35 Bq/kg, and ^{232}Th= 45 Bq/kg). In other words, ten primary schools at Al-Najaf governorates are safe for work and free of radiation hazards to students.

INTRODUCTION

It is well known that Humans are naturally subjected to ionizing and non-ionizing radiation resulted from naturally existed sources. However, some of these sources are ones that exist naturally. Therefore, in order to assess the effects of exposure of the radiation the sources of which are both terrestrial cosmological, a central issue to the study in hand is the distribution of the radionuclide and the levels of radiation in the environment. Those that are considered the main outer sources of radiation of the human body are the terrestrial background radiations. Furthermore, other external sources of radiation also affect human beings such as the emitters of gamma and cosmic rays in the soil, materials used in buildings, liquid H_2O, sustenance and air [(1)]. Considered a major source of radioactive materials, radionuclides emit a type of radiations, although nuclear but can also exist in our daily life.

A well-known and widely utilized manner of projecting radiation to be ionized are the uses of particles radiation (alpha and beta), and electromagnetic radiation (gamma rays). The radiations characteristics have given the rise for wide range of applications such as industry, agriculture, medicine, etc. Being subjected to radiation from various sources, human beings may be disposed to the sources or emitters of radiation from part of or all of the aforementioned sources, contingent to the levels of emissions they do. At any rate, it is highly unlikely that the larger part of any population is vulnerable to these emissions. For example, radiation treatment in medical facilities may cause an elevated rates of exposure in patients and staff than those who do not work in these facilities [(2)]. NORM "Naturally occurring radioactive materials" are part of a radioactivity to which the population is constantly exposed [(3)].

The soil is the important main contributors to natural radioactivity of earth [(4)]. Also, the main natural radioactivity in most schools and homes is the underlying soil. Soil is one of the source that contaminated for building mud houses when containing high levels of natural radioactivity. Because many people - especially children - spend most of their time at home and school, the school is likely to be the most important source of natural radioactivity exposure after homes. The parents are we strongly encourage them to test their homes and school for natural radioactivity and take action to lower the high concentrations of natural radioactivity there. Also, the area of these schools was exposed to bombardments and blasts through war of 1991 and

2003. So it's necessary to look for the radioactivity in the soil, which is in the form of ^{238}U, ^{232}Th chains and ^{40}K when forming the earth.

In Iraq, using various methods and technologies, researches have been made in order to study and determine the levels of radioactivity and the radioactive elements in the collected soil samples [5-8]. Similarly, the study at hand is made for the same purpose as the above studies in soil samples taken from ten primary schools at north of Al-Najaf governorates using NaI(Tl) detector. Also, the study aims at inspecting the values of the radiological hazard index.

Moreover, the rate of activity by gamma dose in the mentioned samples of this study are to be thoroughly analyzed and assessed. Because of the absence or no study about the natural radioactivity survey in previous studies covering these schools. So, the novelty for this action is the first study to measure natural radioactivity levels in these schools, and using Geographic information system" GIS (GIS version 10.2) technical for drawing natural radiation maps.

MATERIALS AND METHODS

Samples collection

Soil samples are collected at depth 15 cm in order to be applicable to this research. The samples have been collected in ten primary schools at north of Al-Najaf province that determined using "Global Positioning System" GPS and draw using “Geographic information system" GIS, as shown in figure 1 that shown area of study. Table 1 shown the sample code and name of schools.

Table 1. The name of samples in present study.

No.	Sample code	Name of school	Coordinates	
			North	East
1	P1	Saba	32.04799643906463	44.313891711189534
2	P2	Al-Tathamon	32.04207504490679	44.30844101539583
3	P3	Al-Tharayt	32.06790000000001	44.309475000000006
4	P4	Al-Yacoubi	32.05367761628112	44.31120681994562
5	P5	Al- Tanseem	32.07197499999999	44.303675000000005
6	P6	Al-Sahel ala-kadhar	32.04050283846967	44.30880445472005
7	P7	Moussa Bin Al-Natheer	32.05343323516523	44.31214782828202
8	P8	Al-Mozamel	32.071203333333344	44.306018333333334
9	P9	Fadak	32.046604318767656	44.30973786346419
10	P10	Al-Mustagar	32.05826579792359	44.311490240033656

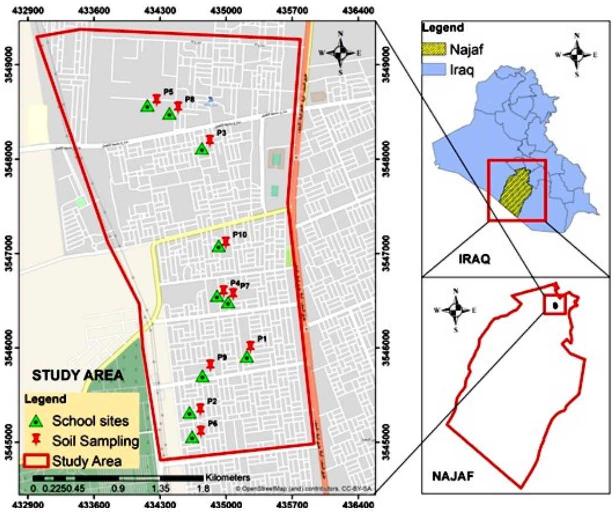

Figure 1. Area of study.

Sampling preparation

In order to prepare the sample for their final phase of labs measurement, these samples were extensively dried in a specialized oven. The mentioned oven temperature was set at (60°C) for 24 hours to get rid of any residual humidity from the samples, after they were powered by (650) µm diameter sieve for obtaining uniform particle size and weighted in 1 kg in marinelli beaker. Then, samples were weighed by digital balance. The samples were stored for 1 month for obtaining permanent radioactive of secular equilibrium [8,9]. The distribution of radioactivity of ^{238}U, ^{232}Th and ^{40}K in the soil samples were next analyzed.

Gamma-ray spectrometer

The spectrometer used to measure gamma-ray contains a detector of scintillation Nal (TI) that has a dimension of crystal and the company system provider (3” × 3”) (Alpha spectra, Inc.-12112/3) accompanied by an analyzer that has multiple channels (MCA) (ORTEC – Digi Base) which includes a 4096 channel which, through an interface, connects the ADC "Analog to Digital Convertor" unit. The experimental measurements that are taken by the spectroscope (described as spectroscopic) are analyzed with a unique software (MAESTRO-32) and are then inserted into a lab PC, which provides tremendous assistance as this PC is part of a network that is connected to the system of measurements and analysis. The spectrometer was calibrated for energy by acquiring a spectrum from radioactive standard sources of known energies and gamma-ray 1µCi. The standard sources that used in present study were ^{137}Cs, ^{60}Co, ^{22}Na and ^{152}Eu.

Calculations
Specific activity

The specific activity (A) in soil samples of the present study using equation (1) [10-12].

$$A(Bq/kg) = \frac{N}{t(sec) \times I_\gamma \times \mathcal{E} \times M(kg)} \quad (1)$$

where, N is net area of photo peak, t_c is counting time(18000 sec), $I\gamma$ is gamma probability, ε is the efficiency of NaI(Tl) detector that used in the present study, and M is mass of the soil sample.

Radiation hazard index calculation

There are seven radiation hazard index quantities of the soil sample in present study were found as follow:

Radium Equivalent Activity (Ra_{eq}), the quantity value of Ra_{eq} was determined according to specific activity of A_{Ra} for ^{226}Ra (^{238}U), A_{Th} for ^{232}Th and A_K for ^{40}K using equation (2) [14]:

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

Gamma Rate of Dose Absorption ($D\gamma$), D_γ can be calculated by equation (3) [14,15].

$$D_r\left(\frac{nGy}{hr}\right) = 0.462\,A_{Ra} + 0.621A_{Th} + 0.0417A_K \quad (3)$$

External Hazard Index (H_{ext}), H_{ext} is provided as illustrated in the equation (4) [16].

$$H_{ext} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \quad (4)$$

Internal Hazard Index (H_{int}), H_{ext} is provided as illustrated in the equation (5) that follows [17].

$$H_{int} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \quad (5)$$

Index of Gamma Representative (I_γ), I_γ can be calculated by equation (6) [15, 18].

$$I_\gamma = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_k}{1500} \leq 1 \quad (7)$$

Annual Effective Dose Equivalent (AEDE), AEDE in indoor, outdoor, and total are calculated by applying the equations (7, 8 and 9), respectively, as following [19, 20]:

$$AEDE_{indoor}\left(\frac{mSv}{y}\right) = D_r\left(\frac{nGy}{hr}\right) \times 8760\left(\frac{hr}{y}\right) \times 0.7\left(\frac{Sv}{Gy}\right) \times 0.8 \times 10^{-6} \quad (8)$$

$$AEDE_{outdoor}\left(\frac{mSv}{y}\right) = D_r\left(\frac{nGy}{hr}\right) \times 8760\left(\frac{hr}{y}\right) \times 0.7\left(\frac{Sv}{Gy}\right) \times 0.2 \times 10^{-6} \quad (9)$$

$$AEDE_{total}\left(\frac{mSv}{y}\right) = AEDE_{indoor}\left(\frac{mSv}{y}\right) + AEDE_{outdoor}\left(\frac{mSv}{y}\right) \quad (10)$$

Excess Life Time Cancer Rate (ELCR), ELCR is represented by the following mathematical equation (10) [21, 22].

$$ELCR = AEDR \times DL \times RF \quad (11)$$

where, DL is average period of life time (estimated to be 70 years) and RF is conversion factor, the RF value used by ICRP for the public is 0.05 Sv^{-1} .

Statistical analysis

The results of mean, stander error, and stander divisions for ^{40}K, ^{238}U, and ^{232}Th in present study were analyzed by using by using; a statistical package of the social sciences (SPSS20) program. T-test has been used to calculate the significance of the probability level (P).

RESULTS

Natural radioactivity of specific activities for ^{238}U (^{214}Bi at 1765 keV), ^{232}Th (^{208}Tl at energy 2614 keV), and ^{40}K (1460 keV directly) were used in present study [8]. These specific activities are below listed each with its radionuclide in table 2. Form table 2, it is found that, the lowest specific activity of ^{40}K was (107.08±2.11 Bq/kg) for the samples (P9),while the highest specific activity was (332.50±3.98) Bq/kg with sample (P2), the mean of ^{40}K with the total number of samples was (201.47±24.47) Bq/kg. The lowest specific activity of ^{238}U was (3.71±0.38) Bq/kg for the sample (P10), while the highest specific activity was (19.80±0.94) Bq/kg for sample (P8), the mean with the total number of samples was (10.176±1.78) Bq/kg see table 2. In table 2, also the lowest specify activities of ^{232}Th was (1.90±0.17) Bq/kg for the sample (P9), while the highest specific activity was (9.30±0.41) Bq/kg for sample (p1), the average for all samples was (5.91±0.83) Bq/kg.

The results of Ra_{eq}, D_γ, H_{ex}, H_{in}, I_γ, AEDE and ELCR in all samples were be listed in the table 3. At finish, it is drawn to natural radioactivity maps to 40K, 238U, and 232Th using GIS technical, as shown in figures 2, 3 and 4, respectively. The parallel activity of the radium (Ra_{eq}) can be attained as shown in equation (2). The Radium equivalent that is of the largest activity value was equal to (44.988) Bq/kg, while the lowest value of radium equivalent activity was equal to (15.512) Bq/kg with an average rate of (34.143±3.54) Bq/kg. The rate at which Gamma absorption dose is taken (D_γ) is acquired by applying equation (3), the largest amount of the ratio for the gamma dose absorption was equivalent to (22.498 nGy/h, while the lowest rate of the absorbed gamma dose rate was (7.715) nGy/h, with an average rate of (16.673±1.71) nGy/h.

The external hazard index (H_{ex}) acquired through the application of equation (4), the highest value of external hazard index was (0.121), while the lowest value of external hazard index was (0.042) ,with an average value of (0.092±0.009. The internal hazard index (H_{in}) obtained by using the equation (5), the highest value of internal hazard index was (0.152),while the lowest value of internal hazard index was (0.045) ,with an average value of (0.120±0.013). The Gamma Index Representative (I_γ)

that is acquired through the application of equation (6), that largest rate it was (0.354).

On the other hand, the lowest rate point of Gamma Index Representative was (0.121), with an average value of (0.261±0.026). The indoor annual effective dose equivalent $(AEDE)_{in}$ received through the application of equation (7), the largest indoor yearly dynamic dose equivalent was (0.110) mSv/y, while the lowest rate of indoor annual effective dose equivalent was (0.038) mSv/y, with an average ratio of (0.082±0.008) mSv/y. The outdoor annual effective dose equal $(AEDE)_{out}$ obtained by using the equation (8), the highest rate of outdoor annual effective dose equal was (0.028) mSv/y, while the lowest rate of outdoor annual effective dose equivalent was (0.009) mSv/y, with an average value of (0.020±0.002) mSv/y. The values of ELCR×10^{-3} were ranged from 0.166 to 0.483, with an average value of 0.358±0.03.

Table 2. Results values of ^{40}K, ^{238}U, ^{232}Th in present study.

Sample code	Specific Activity in Bq/kg		
	^{40}K	^{238}U	^{232}Th
P1	189.94±3.02	18.80±0.92	9.30±0.41
P2	332.50±3.98	11.22±0.71	5.71±0.32
P3	291.54±3.42	4.29±0.40	6.22±0.31
P4	141.07±2.39	8.59±0.57	2.06±0.18
P5	151.45±2.76	10.82±0.71	9.26±0.42
P6	276.89±3.08	11.90±0.62	8.13±0.33
P7	205.25±3.13	8.08±0.60	4.13±0.28
P8	205.57±3.12	19.80±0.94	5.65±0.32
P9	107.08±2.11	4.55±0.42	1.90±0.17
P10	113.49±2.18	3.71±0.38	6.79±0.33
Average ±S.D	201.47±24.47	10.17±1.78	5.91±0.83

Table 3. Results value of radiation hazard index in present study.

Sample code	Ra_{eq} (Bq/kg)	D_γ (nGy/h)	Hazard index		I_γ	Annual effective dose Equivalent (mSv/y)			ELCR×10^{-3}
			H_{ex}	H_{in}		$(AEDE)_{in}$	$(AEDE)_{out}$	$(AEDE)_{Total}$	
P1	46.667	22.199	0.126	0.177	0.345	0.109	0.027	0.136	0.477
P2	44.988	22.498	0.121	0.152	0.354	0.110	0.028	0.138	0.483
P3	35.633	17.896	0.096	0.108	0.285	0.088	0.022	0.110	0.384
P4	22.398	11.095	0.060	0.084	0.172	0.054	0.014	0.068	0.238
P5	35.723	16.907	0.096	0.126	0.266	0.083	0.021	0.104	0.363
P6	44.846	21.955	0.120	0.150	0.345	0.108	0.027	0.135	0.472
P7	29.790	14.786	0.080	0.102	0.232	0.073	0.018	0.091	0.318
P8	43.708	21.132	0.118	0.172	0.326	0.104	0.026	0.130	0.454
P9	15.512	7.715	0.042	0.054	0.121	0.038	0.009	0.047	0.166
P10	22.158	10.548	0.060	0.070	0.168	0.052	0.013	0.065	0.227
Average ±S.D	34.143±3.54	16.673±1.71	0.092±0.009	0.120±0.013	0.261±0.026	0.082±0.008	0.020±0.002	0.102±0.01	0.358±0.03

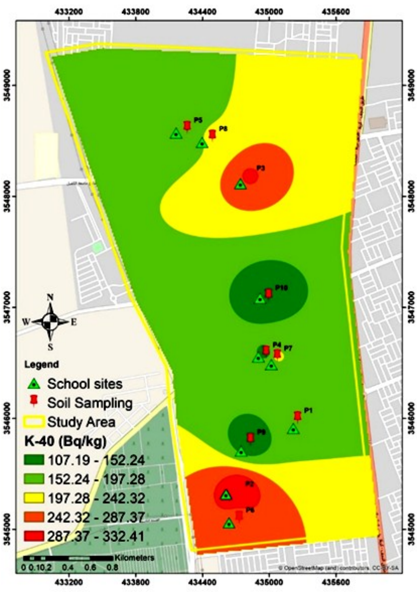

Figure 2. Map of the specific activity for ^{40}K in present study.

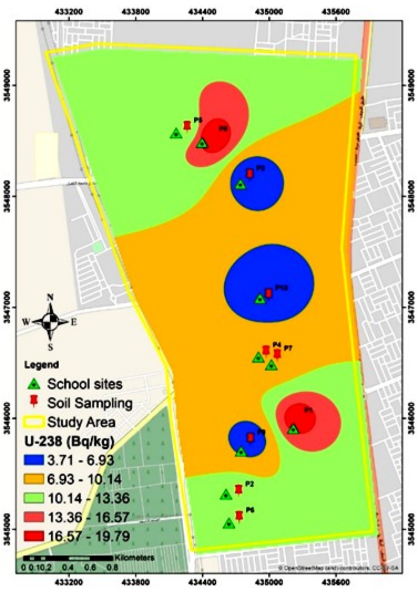

Figure 3. Map of the specific activity for ^{238}U in present study.

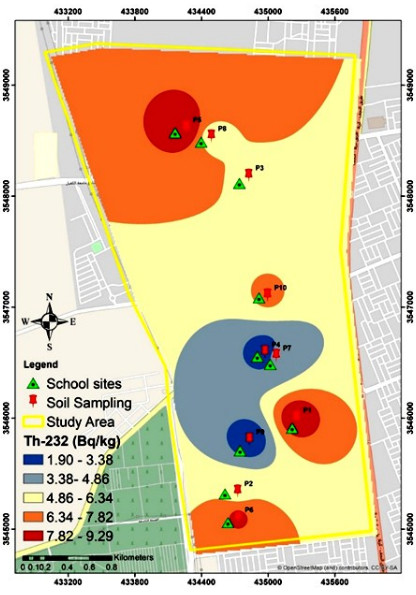

Figure 4. Map of the specific activity for ^{232}Th in present study.

DISCUSSION

Table 2 shows the three radionuclides had been detected (^{40}K, ^{238}U and ^{232}Th), the results appearance of the specific activity of the existence of ^{238}U and ^{232}Th radionuclides belong to the natural radioactivity decay series with the worldwide average which it is equal to (35 and 45) Bq/kg respectively [23]. Also, natural radionuclide (^{40}K) appeared in all samples were less than the worldwide average (412) Bq/kg [23]. The results here revealed that equivalent activity of radium values were lower than those the proposed of (370) Bq/kg, as the worldwide equivalent activity of Radium [24]. The values of D_r have been lower than what is proposed which is (55 nGy/h) to the ratio of gamma dose that is absorbed as indicated by worldwide average [22]. The results at hand is indicative that the recommended value of (<1) is higher than external hazard index values as well as internal hazard, as given by UNSCEAR for both internal and external values of hazard indices [14].

The results of our present study reveal that the recommended rate of (<1) of the Representative Gamma Index values as given by UNSCEAR were higher than the results at hand [14]. The present results show that the indoor yearly dynamic dose equal were lesser than the recommended rate of (20mSv/y) for the indoor yearly dynamic dose equivalent given by ICRP [25]. In addition to the outdoor yearly dynamic dose equal were lesser than the recommended rate of (1mSv/y) for the outdoor yearly dynamic dose equal given by ICRP [25]. At last the values of ELCR in all samples under study are little. Thus, the risk of cancer is almost nonexistent.

The variability seen in the soil samples measured radioactivity among different locations of the world raised from variable geological and geographical conditions of studies areas; together the existed level of fertilizers distributed in agricultural lands. In addition to, it is found that the rise in the potassium nuclide concentration on uranium-238 and thourium -232 is referred to agricultural lands being existing widely and these areas containing phosphate. The specific activity of each of Uranium-238, Thorium-232 and potsium-40 in the samples of the studied areas was compared with corresponding values of other governorates can be seen in table 4. The latter comparison revealed that the current study values of radioactivity are lower than those published literature.

Referring to the report of European Commission in Radiation Protection and as along as the values distributed randomly in the above table are within the specified area around the small hole, therefore, the area study is not safe as a result, and thus will pose significant radiological threat to the population according to the European Commission for 1999 [31]. Finally, there are statistical significant differences found between specific activity for ^{40}K, ^{238}U, and ^{232}Th, as well as radiological hazard indexes of the present study at (level 0.01).

Table 4. Comparison of activity concentration levels in different area of the world.

No.	Country	Average of specific Activity (Bq/kg)			Ref.
		^{40}K	^{238}U	^{232}Th	
1	Kurdistan (Iraq)	284.86	83.337	19.147	R. M. Yousuf [26]
2	Najaf (Iraq)	426.31	77.33	9.36	H.H.Al. Gazaly [27]
4	Babylon (Iraq)	308.24	16.07	9.60	A.A.Abojassim [28]
5	Missan (Iraq)	453.91	21.19	9.72	A.Z. Jassim [29]
6	Wassit (Iraq)	204.26	19.42	18.48	L.A.Najam [30]
7	Present study	201.47	10.17	5.91	---------

CONCLUSION

The results of natural radioactivity (^{40}K, ^{238}U, and ^{232}Th) as well as radiation hazard indices have been detected in the selected soil samples were lesser than the recommended rate by worldwide average. Our gamma spectroscopic investigations allow us to almost certainty say that the soil samples in ten primary schools at north of Al-Najaf governorates were safe.

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Conflict of interests: The author declares that there are no conflicts of interests.

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Authors' contributions: The author(s) read and approved the final manuscript.

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