Evaluation the level of Natural Radio nuclides in Al- Kufa River Sediments

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Abstract :

In this work, the level of natural radioactivity has been evaluate in the Euphrates river sediments soils. Twenty samples were collected at different positions along the river inside Al-Kufa city. The specific activity of Naturally Occurring Radioactive Materials (NORMs) of the ^{238}U and ^{232}Th decay chains and ^{40}K were measured by gamma-ray spectrometry system consist of NaI(Tl) (3"x3") detector. It was found that the ranges of the specific activity in units of (Bq/kg) for ^{238}U, ^{232}Th and ^{40}K is from 19.22 to 101.13, 15.93 to 69.89 and from 424.93 to 1429.00, respectively. The results obtained have been compared with the worldwide average values of 35, 30 and 400 Bq/kg , respectively, reported by the UNSCEAR (2000). To assess the radiological hazard of river sediments, the radium equivalent activity (Ra_{eq}) ,the absorbed dose rate (AD) (in nGy/h), the outdoor annual effective dose equivalent (AEDE) and external hazard index (H_{ex}) have been calculated. It was observed that the (Ra_{eq}) values for all samples are lower than the accepted safety limit average value of 370 Bq/kg , and the (AD) ,(AEDE) for most samples are greater than the permissible limits and the external hazard index (H_{ex}) are lower than the limit of unity.

Key words : Specific activity, Euphrates river, NORMs.

الخلاصة :

في هذه الدراسة تم تقدير مستوى النشاط الإشعاعي الطبيعي في رسوبيات نهر الكوفة، حيث جمع عشرون نموذج في مواقع مختلفة على امتداد نهر الفرات داخل مدينة الكوفة . تم تحديد النشاط الاشعاعي للمواد المشعة في النماذج والمتكونة من انحلال سلاسل الاشعاع الطبيعي, يورانيوم-238 و ثوريوم-232 بالاضافة الى النظير المشع البوتاسيوم-40 باستخدام مطياف كامي يتكون من كاشف (3"x3") NaI(Tl). لقد وجد ان قيم النشاط الاشعاعي الطبيعي لليورانيوم-238, الثوريوم-232 والبوتاسيوم-40 تتراوح من 19.22 إلى101.13 , ومن 15.93 الى 69.89 ومن 424.93 الى 1429.00 (بيكرل /كغم), على التوالي. تم مقارنة نتائج هذه الدراسة مع المعدل العالمي والحدود المسموح بها من قبل منظمة [UNSCEAR] . تم حساب كل من النشاط الاشعاعي المكافئ للراديوم (Ra_{eq}), معدل الجرعة الممتصة (AD), الجرعة الفعالة السنوية الخارجية (AEDE) ومعامل الخطورة الخارجي (H_{ex}) لتقييم مخاطر الاشعاع . اظهرت النتائج ان النشاط الاشعاعي المكافئ للراديوم (Ra_{eq}) لجميع النماذج هو ادنى من الحد المسموح 370 (بيكرل /كغم), اما بالنسبة لمعدل الجرعة الممتصة (AD) والجرعة الفعالة السنوية (AEDE) فقد كانت لاغلب النماذج هي اعلى من الحد المسموح , اما معامل الخطورة الخارجي (H_{ex}) لجميع النماذج هو اقل من الواحد.

1-Introduction

The primordial radionuclides have radioactive decay half-lives that are approximately earth's age. These radionuclides and their radioactive decay products are an important source of earth's radioactivity [1]. Natural radionuclides are present in varying amounts in air , water, plants, animals, soil and rocks . Naturally occurring radionuclides and particularly their decay products are transported in ground and surface water [2]. River sediments are mineral depositions formed through weathering and erosion of either igneous or metamorphic rocks. River sediment depositions on the bottom of rivers most frequently consist of sand and gravel particles with different sizes. When rocks are disintegrated through natural processes radionuclides are carried to river sediments by rain and flows [3]. Many nutrients, contaminants and natural radionuclides are attached to river sediment particles and are, thus, transported and deposited with sediments posing risk to society, environment and humans when it is used [4] . Natural radionuclides in river sediment generate a significant component of the background radiation exposure of the population [5]. Therefore, the knowledge of the concentrations and distributions of the natural radionuclides in the river sediments are of great interest since it provides useful information in monitoring of environmental contamination and associated human health by natural radioactivity [6].

Study area

Euphrates River has got two branches in AL- Najaf governorate : the eastern branch called Al-Abbasia River and the western branch called Al -Kufa River. We have started in collecting the samples from Al- Kufa River (at position 32° 08′ 77.4″ N , 44° 21′ 55.8″ E) and ended at the position (31° 58′ 29.3″ N , 44° 27′ 74.3″ E) at southern borders of AL-Kufa city. Therefore the total distance studied of the river is about 22.8 km. We have studied Euphrates river because it has a significant role in the local irrigation and it supports agricultural activities which widely spread along it’s sides and the local vicinity.

2-Theoretical part

2-1 Specific Activity

The specific activity, in terms of the activity concentration, is defined as the activity per unit mass of the sample (i.e Bq/kg or Ci/gm). The specific activity of individual radionuclides in soil samples can be calculated from the following equation [7]:

$$A(\mathrm{Bq/kg}) = \frac{\mathbf{C}}{\boldsymbol{\varepsilon}\,.\,\mathbf{I}_{\boldsymbol{\gamma}}\,.\,\mathbf{m.\ t}} \qquad \text{........(1)}$$

where A: specific activity, C: net area of gamma peaks (background subtracted), ε: the efficiency at photopeak energy, I_γ : the absolute intensity of gamma transition, t: time of measurement (sec) and m: mass of the sample in kg .

2-2 Radium equivalent activity (Ra_{eq})

To evaluate the real activity level of ^{238}U,^{232}Th and ^{40}K in the soil samples and the radiation hazards associated with their radionuclides. Radium equivalent activity can be calculated from the following equation [8]:

$$Ra_{eq}\ (\mathrm{Bq\ kg^{-1}}) = A_U + 1.43\ A_{Th} + 0.077\ A_K \qquad \text{.........(2)}$$

where, A_U, A_{Th} and A_K are the specific activities of ^{238}U, ^{232}Th and ^{40}K, respectively.

2-3 Absorbed Dose Rates in Air (AD*)*

The absorbed dose rates in air at one meter above the ground surface, is the received dose in the open air from the radiation emitted from radionuclides in environmental materials. This dose have been calculated using the following equation [7]:

$$AD = 0.462\ A_U + 0.621A_{Th} + 0.0417\ A_K \qquad \text{......(3)}$$

where 0.462, 0.621 and 0.0417 (nGy h^{-1}/ Bq kg^{-1}) are the conversion factors of ^{238}U, ^{232}Th and ^{40}K, respectively.

2-4 Annual Effective Doses Equivalent (AEDE)

To estimate the annual effective dose rate, account must be taken of the conversion coefficient from absorbed dose in air to effective dose and the outdoor occupancy factor. The annual effective dose equivalent can be estimated using the following equation [9]:

$$AEDE(m\,Sv\,y^{-1}) = AD(nGy\,h^{-1}) * 8760(h) * 0.2 * 0.7(Sv\,Gy^{-1}) * 10^{-6} \quad \ldots..(4)$$

The values of the parameters used in the last equation according to UNSCEAR report (2000) are 0.7 $Sv.Gy^{-1}$ for the conversion coefficient from absorbed dose in air to effective dose received by adults and 0.2 for the outdoor occupancy factor [10].

2-5 External Hazard Index (H_{ex})

The external hazard index is an assessment of the hazard of the natural gamma radiation. It have been calculated from the following equation [11]:

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \leq 1 \quad \ldots\ldots(5)$$

3- Experimental Part

3-1 Sampling and sample preparation

Twenty samples were collected from sediment in the bottom of the river. These samples were taken from a different positions along the Euphrates River within the boundaries of the administrative governorate of Al-Najaf in Al-Kufa city. We have collected the samples from 20 positions with the distance between each two positions is of 1200 meter as shown in Figure 1. These positions were recorded in terms of degree-minute-second (Latitudinal and longitudinal position) using hand-held Global Positioning System (GPS) (Model:GARMIN GPS-12). The samples were packed in plastic bags and then transported to the laboratory for radiation measurement in physics Department, College of science, University of Kufa. Sample preparation was carried out by placing each soil sample in an oven for drying process at a temperature of 100°C until a constant weight was reached to ensuring complete removal of any residual moisture. The dried samples were pulverized into a fine powder and passed through a standard 0.5 mm mesh size. The homogenized samples were weighed and filled into 1L Marinelli beakers which were then hermetically sealed with the aid of plastic tape to prevent the escape of airborne ^{222}Rn and ^{220}Rn from the samples and stored for thirty days to reach secular equilibrium [12,13].

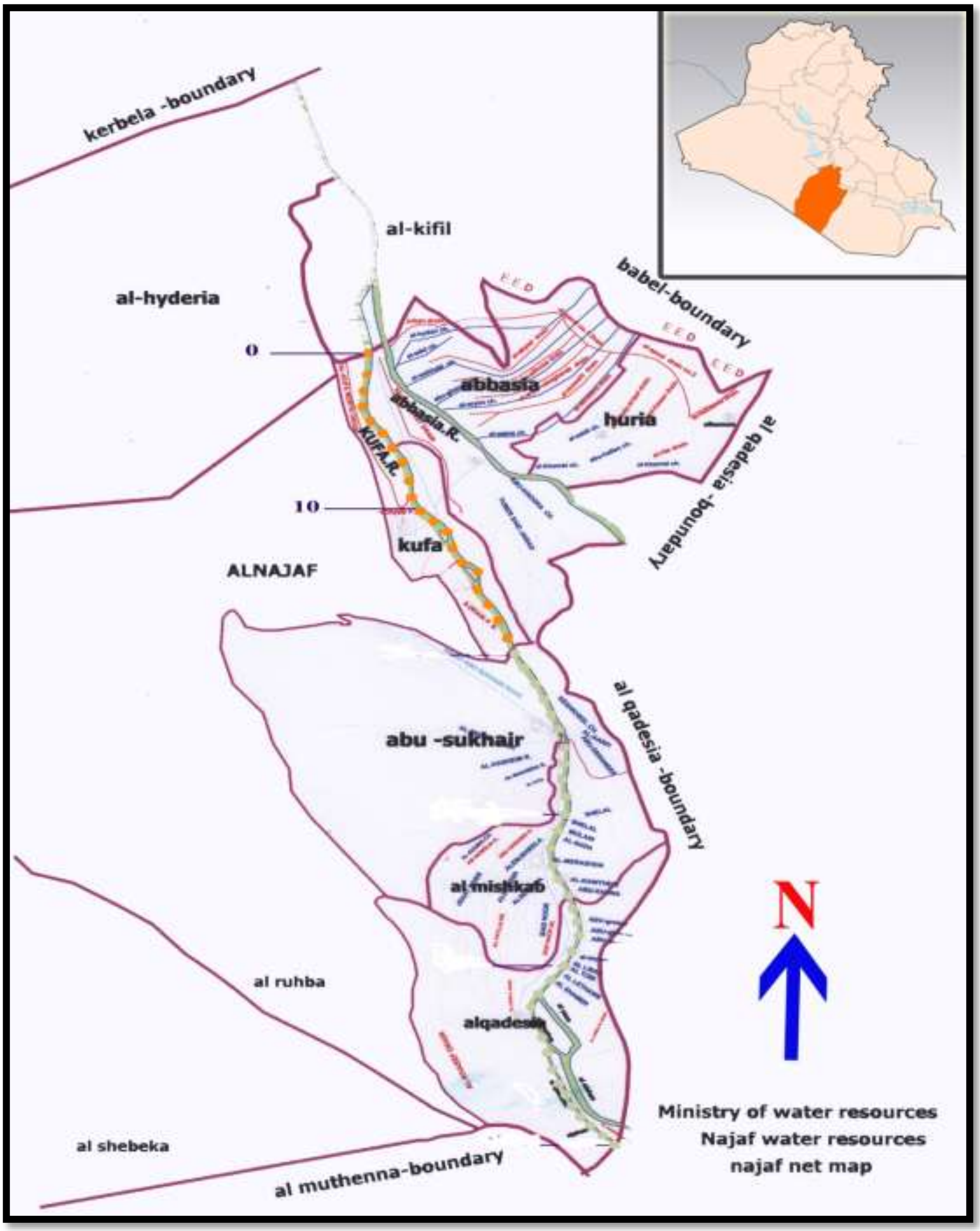

Figure 1: Map of Euphrates river inside Al-Najaf governorate .

3-2 Gamma-spectrometric analysis

To measured the specific activity of the samples, we used gamma-ray spectrometr which consist of a NaI(Tl) scintillation detector of (3"×3") crystal dimension, supplied by (Alpha Spectra,Inc.-12I12/3), coupled with a multi-channel analyzer (MCA) (ORTEC –Digi Base) of 4096 channels joined with ADC (Analog to Digital Convertor) unit, through interface. Finally, the spectral data was converted directly to the PC of the laboratory introduced by using (MAESTRO-32) software. The detector was enclosed in a graded lead shield. The gamma ray spectra of the collected samples were measured and the activities of ^{238}U series,^{232}Th series and ^{40}K in each sample were obtained by measuring the intensity of gamma-peaks of their daughters. The gamma line at 1764 keV of ^{214}Bi was used to determine ^{238}U series activity, and the line at 2614 keV of ^{208}Tl for ^{232}Th series. Also the peak at 1460 keV was used for ^{40}K activity [14].

4-Results and Discussion

4-1 Detector Characterisation

The counting efficiency of the system as a function of energy was calculated using ^{137}Cs, ^{60}Co and ^{22}Na, standard sources. The efficiency curve was shown in Figure 2.

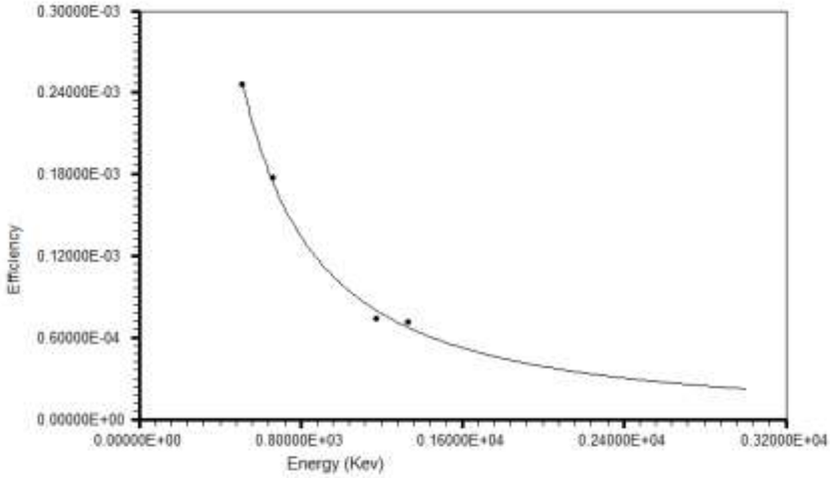

Figure 2: The efficiency calibration curve of gamma spectrometer

Same standard sources were used for energy calibration of the gamma spectrometer. The energy calibration curve is presented in Figure 3. Finally the energy resolution of the detector was calculated and found to be about 7.09 % for 662 keV gamma line of ^{137}Cs.

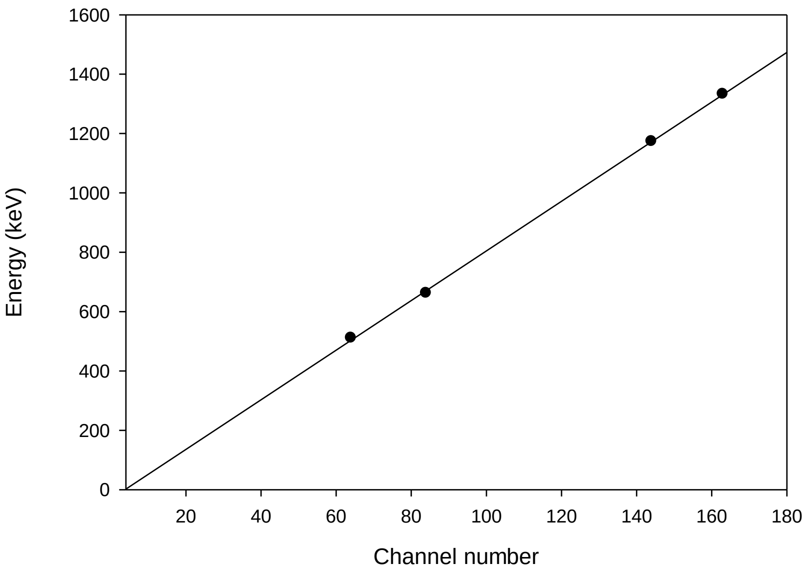

Figure 3: Energy calibration curve of gamma spectrometer.

4-2 Specific Activity

The results of specific activity calculation in (Bq/kg) for ^{238}U, ^{232}Th and ^{40}K are presented in Table (1). From the table it can be observed that the specific activity are values varied from 19.22 ±2.62 at sample (S5) to 101.13±5.53 at sample (S16), 15.93±1.61 at sample (S5) to 69.89 ±4.17at sample (S19) and 424.93±9.85 at sample (S5) to 1429.0±23.93 at sample (S19) for ^{238}U, ^{232}Th and ^{40}K respectively. The average value for ^{238}U, ^{232}Th and ^{40}K is 60.1±5.04 Bq/kg, 40.48±2.54 Bq/kg and 941.69±13.4 Bq/kg, respectively. As demonstrated in Table 1 it can be seen that all values except only one value in sample (S5) of ^{238}U specific activity are high than the world wide average, which is 35 Bq/kg [10]. For ^{232}Th, there are 16 samples have values upper than the world wide average , whereas the 4 samples have lower values than the world wide average, which is 30 Bq/kg. On the other hand, for the ^{40}K radionuclide all the values was found to exceed the world wide average, which is 400 Bq/kg [10].

Table 1: Specific Activity of ^{238}U, ^{232}Th and ^{40}K in sediment samples.

Sample code	Specific activity (Bq/kg)		
	^{238}U	**^{232}Th**	**^{40}K**
S0	51.08 ± 5.16	51.56 ± 2.42	937.64 ± 12.67
S1	53.94 ± 4.13	61.66 ± 2.65	993.81 ± 13.29
S2	95.26 ± 5.48	36.32 ± 2.36	921.88 ± 12.67
S3	73.93 ± 7.81	62.73 ± 4.20	1381.82 ± 18.8
S4	55.61 ± 4.84	38.22 ± 2.25	807.00 ± 11.62
S5	19.22 ± 2.62	15.93 ± 1.61	424.93 ± 9.85
S6	58.00 ± 5.24	49.31 ± 2.59	956.48 ± 13.55
S7	44.81 ± 5.32	47.98 ± 2.59	1050.94±13.29
S8	57.36 ± 4.52	38.22 ± 2.48	1082.54±12.14
S9	51.88 ± 4.37	36.14 ± 2.65	856.21 ± 12.41
S10	44.49 ± 4.21	48.79 ± 2.42	986.68 ± 12.32
S11	68.96 ± 5.4	39.20 ± 2.07	960.35 ± 12.5
S12	68.80 ± 4.44	39.49 ± 2.77	884.56 ± 13.02
S13	54.98 ± 4.37	36.26 ± 2.3	974.53 ± 11.97
S14	67.61 ± 5.08	34.93 ± 2.25	725.39 ± 1.26
S15	35.03 ± 4.44	21.30 ± 1.96	677.33 ± 10.91
S16	101.13 ± 5.53	22.55 ± 2.22	942.23 ± 14.7
S17	52.21 ± 4.69	26.89 ± 2.25	918.00 ± 13.52
S18	53.00 ± 4.78	32.27 ± 2.62	922.51 ± 13.51
S19	94.78 ± 8.36	69.89 ± 4.17	1429.00±23.93
Min	**19.22 ±2.62**	**15.93±1.61**	**424.94±9.85**
Max	**101.13±5.53**	**69.89±4.17**	**1429.0±23.93**
Average	**60.1±5.04**	**40.48±2.54**	**941.69±13.4**

4-3 Hazard Index

The calculated values of ; Radium equivalent activity (Ra_{eq}), The Absorbed dose rate (AD), Outdoor annual effective dose equivalent (AEDE) and External hazard index (H_{ex}) of sediment samples from the current work are summarized in Table (2). From this Table the Ra_{eq} values ranged from 74.73 to 304.77 Bq/kg with an average value of 190.51 Bq/kg. All values are under the permissible limt (370 Bq/kg) . The estimated absorbed dose rate based on soil radioactivity ranged from 36.72 to 147.32 nGy/h with a average value 92.35 nGy/h which is greater than the world wide average of 57 nGy/h. The outdoor annual effective dose above one meter for the soil samples varied from 0.04 to 0.18 mSv/y ,with the average value 0.11 mSv/y which is also greater than the world wide average value of 0.07 mSv/y. The calculated values of the external hazard index for all soil samples studied vary from 0.20 to 0.82 with an average value of 0.56 which are within the permissible limit [10]

Table 2: Radium equivalent activity, Absorbed dose rate, Outdoor annual effective dose and External hazard index of sediment samples.

Sample code	Ra_{eq}(Bq/kg)	AD(nGy/h)	AEDE(mSv/y)	H_{ex}
S0	197.02	95.68	0.11	0.53
S1	218.66	106.00	0.13	0.59
S2	218.18	103.86	0.127	0.58
S3	270.04	131.60	0.16	0.72
S4	172.42	83.26	0.10	0.46
S5	74.73	36.72	0.04	0.20
S6	202.16	97.94	0.12	0.54
S7	194.35	95.36	0.11	0.52
S8	195.38	95.58	0.11	0.52
S9	169.50	82.33	0.10	0.45
S10	190.24	93.06	0.11	0.51
S11	198.98	96.09	0.11	0.53
S12	193.39	93.03	0.11	0.52
S13	181.87	88.71	0.10	0.49
S14	173.42	82.80	0.10	0.46
S15	117.66	57.70	0.07	0.31
S16	205.93	98.07	0.12	0.55
S17	161.36	78.91	0.09	0.43
S18	170.19	83.02	0.10	0.45
S19	304.77	147.32	0.18	0.82
Min	**74.73**	**36.72**	**0.04**	**0.20**
Max	**304.77**	**147.32**	**0.18**	**0.82**
Average	**190.51**	**92.35**	**0.11**	**0.51**

Conclusions

The average value of specific activity measurments for ^{238}U ^{232}Th and ^{40}K in the sediment samples are greater than the world wide average as reported by the UNSCEAR (2000). The value of the radium equivalent activity (Ra_{eq}) for all samples are lower than the acceptable safety limit value. The average values of absorbed dose rate (AD) and the outdoor annual effective does equivalent (AEDE) of the sediment samples are found to be higher when compared with the world wide average values. The average value of the external hazard index (H_{ex}) for sediment samples are lower than the permissible limit value. Gamma ray spectrometry is a good technique extensively used in determination of activity concentration of radionuclides.

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