Arab J. Nucl. Sci. Appl., Vol. 55, 4, 57-66 (2022)

ISSN 1110-0451

Arab Journal of Nuclear Sciences and Applications

Web site: ajnsa.journals.ekb.eg

(E S N S A)

Evaluation of Natural Radioactivity and Radiological Hazard Indicators in Soil Samples from the Environment of Al-Kasik Oil Refinery in Nineveh Governorate in Iraq

Zainab Mowafaq Marie and Laith A. Najam *

Department of Physics, College of Science, University of Mosul, Mosul, Iraq

ARTICLE INFO

Article history:

Received: 21st Apr. 2022

Accepted: 4th Aug. 2022

Keywords:

Al-Kasik Refinery,
Soil,
Specific Activity,
Radiological hazard,
γ-spectroscopy.

ABSTRACT

The specific activity of ^{226}Ra, ^{232}Th and ^{40}K in the soil samples collected from Al-Kasik Oil Refinery in Nineveh Governorate, Iraq, were assessed by γ-spectroscopy analysis using a NaI(Tl). Results show that the average of the measured specific activities of ^{226}Ra, ^{232}Th and ^{40}K are 19.80±0.948Bq/kg,13.65±1.021Bq/kg and 213.71±8.896Bq/kg, respectively. The average specific activity of these radionuclides was compared with the world average value. The radiological hazard indices were calculated for each of ^{226}Ra, ^{232}Th and ^{40}K and compared with the internationally recommended standard exposure limits, as they were within those limits. The study showed that the soil in the study area may not pose a significant risk to workers and residents close to the area. However, further studies and investigations into the level of exposure of flora and fauna in that area are necessary.

1. INTRODUCTION

Natural radiations from both inside and outside the planet have long been a part of human life. Natural sources of ionizing radiation include naturally occurring radioactive materials (NORM) in the soil and rocks, cosmic rays entering the earth's atmosphere from outer space, and internal radioactive element exposure through food, drink, and air. Natural radioactivity is abundant in the earth's environment, and it can be found in soil, rocks, plants, water, and air in diverse geological formations[1].

The U and Th series, as well as natural K, produce natural radioactivity in soil. Artificial radionuclides, such as ^{137}Cs, can also be found in the environment as a result of weapons testing fallout. NORM are found in the underground formations that may contain radioactive minerals such as uranium and thorium, as well as their daughter products ^{226}Ra and ^{228}Ra. In combination with oil and gas, this can be transported to the surface in the produced water. Furthermore, produced natural gas may contain radon gas, a radium daughter. NORM is usually found in the natural gas stream during gas processing activities as radon gas [2][3].

Various operational procedures, such as remote sensing methods of mapping and explosives related with seismic exploration, drilling equipment and operations, and down-the-hole geophysical logging methods, all contribute to or induce NORM occurrence during exploration and extraction processes. Radioactive marker bullets are sometimes used to assist with relative depth estimations. After the casing has been placed, the gamma ray log is utilized to find the rounds. For the goal of correlation, radioactive tracers are also utilized in measuring the effectiveness of well cementing and underground water and crude oil flow direction [2].

The radiological significance of these radionuclides stems from the body's gamma ray exposure and irradiation of lung tissue caused by inhalation of radon and its daughters. Many countries have conducted significant surveys as a result of the growing global interest in natural radiation exposure. External gamma dose estimation due to terrestrial sources is critical not only because it provides a significant amount (0.46 mSv.y^{-1}) to the aggregate dose, but also because the individual doses associated with this pathway vary significantly. These doses vary based on the amounts of natural radio nuclides ^{238}U, ^{232}Th, their daughter products, and ^{40}K in soils and rocks, which are, in turn, dependent on the geology of each region[2][3].

Corresponding author: prof.lai2014@gmail.com
DOI: 10.21608/ajnsa.2022.135253.1573

Estimating the natural radioactivity level in soils is critical for determining the terrestrial gamma dose rate for outdoor occupation. The ^{226}Ra, ^{232}Th, and ^{40}K concentrations of soil samples are commonly used to determine their natural radioactivity. Because radium and its daughter products account for 98.5 % of the uranium series radiological impacts, the contribution of ^{238}U and other ^{226}Ra precursors is usually overlooked[4].

Radon inhalation, external gamma exposure, ground water ingestion, surface water ingestion, dust inhalation, food ingestion, and skin beta exposure are possible sources of radiation from NORM created by the oil and gas industry [5]. Workers at equipment cleaning facilities, oilfield workers, workers at NORM disposal facilities, and the general public, particularly in coastal communities near shallow water offshore oilfields and land disposal facilities, are all at risk from NORM radiation resulting from the oil industry.

Soil radioactivity measurements are crucial for understanding variations in the natural radiation background as a function of geographical location and time, as well as for creating the foundation for future assessments of the degree of radioactive contamination or pollution in the environment[6][7].

Therefore, the objectives of the present study are to measure the levels of natural radioactivity and to estimate the radiological hazard indicators, radium equivalent, in the soil of Al-Kasik Oil Refinery in Nineveh Governorate. The natural radioactivity in the soil and the corresponding doses of radiation for the population are not available in the oil refinery under study. The data generated in the current study will provide a basic database of radioactivity in the area under study and will be useful to the authorities responsible for implementing radiation protection and protection standards and the general population.

2. MATERIALS AND METHODS

2.1. Description of study area

Al-Kasik Refinery is one of the refineries belonging to the Iraqi North Oil Refineries Company, which was established in the eighties of the last century. The refinery is located in the village of Al-Kasik, which belongs to the district of Tal Afar - northwest of Mosul in Nineveh Governorate, and it is 49 km from the city of Mosul, within coordinates $36°28'9"N$ and $42°40'16"E$. It produces the following oil derivatives: light and heavy naphtha, kerosene, diesel and black oil, and it has two refining units, each unit produces approximately ten thousand barrels per day.

2.2. Sample collection and preparation technique

In the present study, twelve soil samples were selected from the the area aroud Kasik Oil Refinery in Nineveh - Iraqas shown in Table (1) and Figure (1). Samples were collected and prepared according to the well-known protocol, with 15 samples from a depth of 10-١٥ cm, using a pick and a shovel, after dividing each depth horizontally into three sections. A single representative soil sample was prepared, then the samples were placed inside plastic bags each of them was marked to avoid mixing. The samples were then placed on a plastic plate in a suitable place to air dry, after which the samples were placed in an electric oven at a temperature of 100ºC for two hours to rid the samples of moisture, After complete drying, the samples were homogenized by grinding them with an electric mill and then sifted with a mesh sieve with dimensions of 0.75 mm. Each sample was placed in a sealed plastic container weighing 1 kg, and then the samples were stored for at least 4 weeks to achieve a permanent balance between the radionuclides and their daughters [8] .

Table (1): Geographical information on sampling sites in Al-Kasik oil refinery, Iraq

Sample code	Latitude N	Longitude E
K1	36°27'34.01"	42°40'30.53"
K2	36°27'29.32"	42°40'15.72"
K3	36°27'30.83"	42°40'09.73"
K4	36°27'25.97"	42°40'25.54"
K5	36°27'36.39"	42°40'40.19"
K6	36°27'32.19"	42°40'15.37"
K7	36°27'38.94"	42°40'11.9"
K8	36°27'25.88"	42°40'09.94"
K9	36°27'31.91"	42°40'05.78"
K10	36°27'32.21"	42°40'32.66"
K11	36°27'23.23"	42°40'16.08"
K12	36°27'42.38"	42°40'25.38"

Fig. (1): A map of Al-Kasik oil refinery showing the locations of samples

2.3. γ-spectroscopy analysis

In the current study, a system for spectral measurements called (SPECTECH UCS-20) was used. This system consists of a primary amplifier, a main amplifier (contains 4096 channels) equipped with high voltages, and a multi-channel spectral analyzer. The user can choose the number of channels, gamma spectroscopy is coupled with a scintillation detector made of thallium-activated sodium iodide NaI(Tl) with dimensions (3.8cm × 2.5cm), gamma spectroscopy is connected to a computer for the purpose of its operation. The detector is surrounded by lead plates in order to reduce the radiation background, Figure (2) shows the scheme of this system.

In the present study, standard radioactive sources(^{133}Bi, ^{137}Cs and ^{60}Co) of known energy with a radioactive activity of (1 µCi) were used for the purpose of energy calibration. Figure (3) and Table (2) shows the relationship between the energy of the incident photon and the location of the peak. The process of calibrating the efficiency of the scintillation detector NaI(Tl) was also conducted to measure the various energies of the radioactive sources. The standard radioactive source (^{152}Eu) was used, Figure (4) shows the efficiency calibration curve of a gamma spectroscopy system with thallium-activated sodium iodide detector NaI(Tl).

Table (2): Energy and channel number for each radioactive source

Isotopes	Energy (keV)	Channel no.
^{133}Ba	356	178
^{137}Cs	661.6	298
^{60}Co	1332.5	481

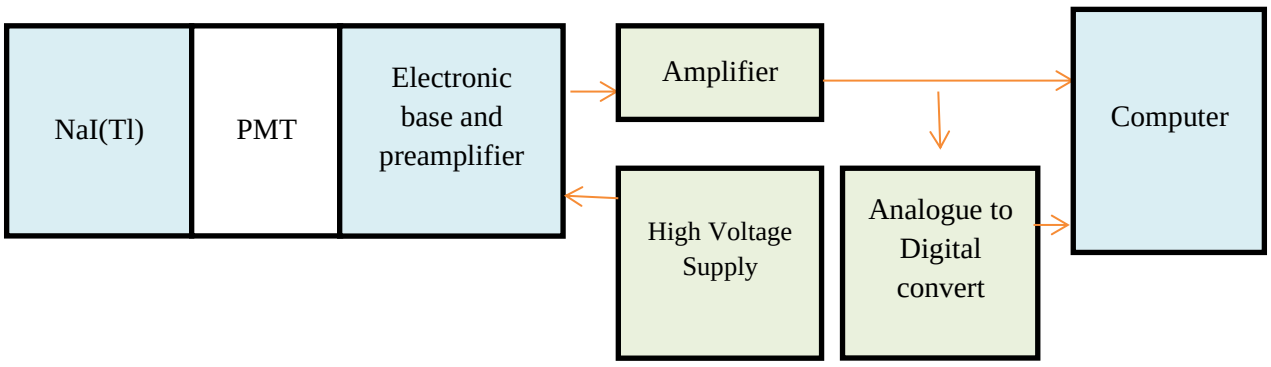

Fig. (2): Electronic circuit of Gamma spectroscopy

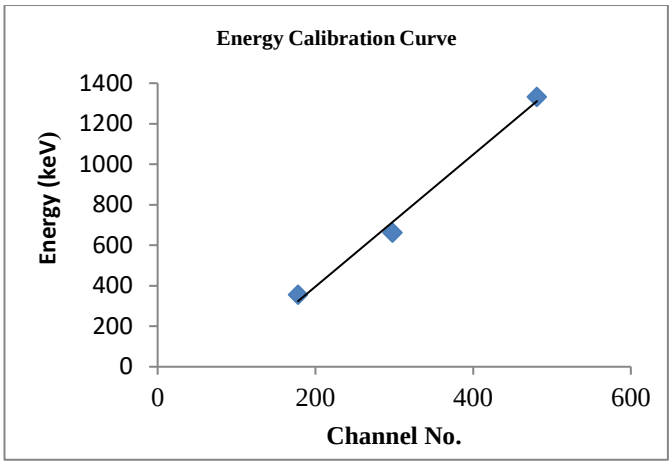

Fig. (3): The relationship between the location of the energy and the amount of energy

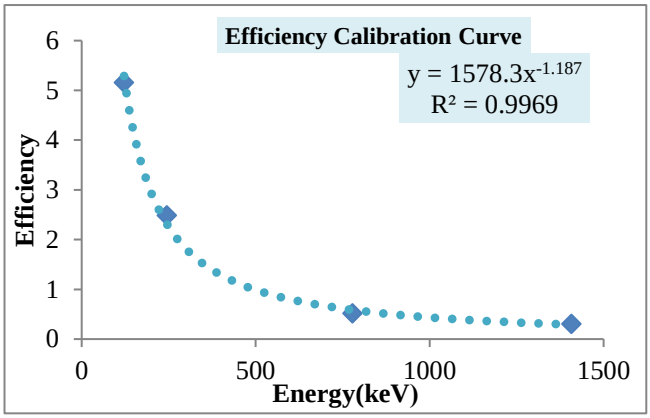

Fig. (4): Efficiency curve as a function of source energies ^{152}Eu

After completing the initialization of the gamma spectrometer and completing the calibration process, the spectrum of each sample in the present study was eamined separately, as the spectrum was collected for a period of time (18000 seconds). In addition, the real area of the optical peak was recorded.

3. CALCULATIONS

3.1. Specific activity

The specific activity of ^{226}Ra, ^{232}Th and ^{40}K for the investigated samples is obtained using the following formula [9][10]:

$$A(Bq/kg) = \frac{N-B}{\varepsilon . I . t . m} \qquad (1)$$

Where A is the specific activity (Bq/kg), N is the net area under the optical peak, B is the background, t is the time collection, m is the weight of the dry sample, ε is the absolute efficiency and I is the probability of the emission of the gamma line corresponding to the peak energy .

The specific activity of ^{226}Ra was determined from the average specific activity c of 295.3 keV of ^{214}Pb and 609.31 keV of ^{214}Bi. The specific activity of ^{232}Th was determined from the average specific activity of ^{228}Ac(338 keV) and ^{228}Ac(911.2 keV), and that of ^{40}K from 1460.0 keV gamma line.

The detection limit, which is defined as the lowest radioactivity of the radionuclides that can be detected at the time of measurement, was calculated using the following equation [11]:

$$D.L = (2.77 + 3.29\sqrt{B}) \times \frac{A\,(Bq/kg)}{N} \qquad (2)$$

Where D.L is the limit of detection.

The minimum detection activity (MDA) is also defined as the smallest value of the radionuclides that can be documented for a specific measurement, and the minimum detection effectiveness can be calculated by taking advantage of the detection limit and using the following equation [12]:

$$MDA = \frac{D.L}{\varepsilon . I . t} \qquad (3)$$

Table (3): The detection limit (D.L) and the minimum detection activity (MDA) of radionuclides in soil samples

Equivalent isotopes	Energy (KeV)	D.L (Bq/kg)	MDA (Bq/kg)
^{214}Pb	295.3	8.240	0.032
^{214}Bi	609.31	8.011	0.054
^{228}Ac	338	11.786	0.297
^{228}Ac	911.2	12.229	0.354
^{40}K	1460.0	13.896	0.988

3.2. Radiological hazard indices

To reach a better and safer conclusion on the health state of population and environment, it is justifiable to use as many of the known radiation health hazard indicators analyses as possible. Seven quantities have

been defined to assess the radiation hazards associated with soil samples.

3.2.1 Radium equivalent

A common radiological index has been introduced to represent the activity levels of ^{226}Ra, ^{232}Th, and ^{40}K by a single quantity that takes into account the radiation hazards associated with them[13]. The Radium Equivalent Index (Ra_{eq}) is mathematically defined as follows [13]:

$$Ra_{eq}(Bq/kg) = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad (4)$$

The specific activity levels of ^{226}Ra, ^{232}Th, and ^{40}K are represented by A_{Ra}, A_{Th}, and A_K, respectively. In the above equation, 10 Bq/kg of ^{226}Ra, 7 Bq/kg of ^{232}Th, and 130 Bq/kg of ^{40}K are assumed to produce the same gamma dose. Ra_{eq} in the soil must have a maximum value of less than 370 Bq/kg [14].

3.2.2. Absorbed dose rate

The absorbed dose rate is caused by gamma radiation in the air at "one meter" above the earth's surface. It is used to characterize the terrestrial radiation because of the regular distribution of naturally occurring radionuclides (^{226}Ra, ^{232}Th, ^{40}K). It is commonly measured in nGy/h. As a result, equation 3 can be used to compute the absorbed dosage rate, as shown below[15]:

$$D_\gamma(nGy/h) = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_K \quad (5)$$

3.2.3. External and Internal hazard indices

The hazard index is widely used, as it reflects exposure to natural radiation, while the internal hazard index represents the internal exposure to radon and its daughters, and the external hazard index (H_{ex}) and the internal hazard index (H_{in}) are calculated through the following relationships [16]:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (6)$$

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (7)$$

The values of the external hazard index and the values of the internal hazard index must be less than or equal to one [14].

3.2.4. Gamma representative level index

This indicator is used to estimate the gamma radiation associated with the natural radionuclides in the soil and is calculated as follows [17]:

$$I_\gamma = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \leq 1 \quad (8)$$

This index has a safety value of 1 [14].

3.2.5. Annual effective dose equivalent

It is defined as a radiometric coefficient used to judge the extent of health effects resulting from the absorbed dose, and it is measured in mS/y. The annual effective dose is estimated using the conversion factor (0.7 Sv/Gy), if this factor converts the absorbed dose in the air into the effective dose, alsousing the external occupancy factor (0.2) and the internal occupancy factor (0.8). The annual effective equivalent dose is calculated by the equations [18]:

$$AEDE_{out}(mSv/y) = D(nGy/h) \times 10^{-6} \times 8760\ (h/y) \times 0.7(Sv/Gy) \times 0.8 \quad (9)$$

$$AEDE_{in}(mSv/y) = D(nGy/h) \times 10^{-6} \times 8760(h/y) \times 0.7(Sv/Gy) \times 0.2 \quad (10)$$

3.2.6. Excess lifetime cancer risk (ELCR)

ELCR can be used to calculate the lifetime risk of acquiring cancer as a result of human exposure to ionizing radiation, as shown in equation 9 [19].

$$ELCR_{out} = AEDE_{out} \times L \times F_R \quad (11)$$

Where $AEDE_{out}$, L and F_R are outdoor annual effective dose, time of life (70 year), and a lethal risk factor per Sievert (0.05 Sv^{-1}), respectively.

3.2.7. Annual gonadal dose equivalent

The gonads are one of the most sensitive parts of the body to radiation. The annual equivalent dose received by the gonads of the exposed population is represented by AGDE. The existence of particular activity levels of ^{226}Ra, ^{232}Th, and ^{40}K in the soil samples was used to calculate the AGDE [20]:

$$AGDE_{out}(\mu Sv/y) = 3.09A_{Ra} + 4.18A_{Th} + 0.314A_K \quad (12)$$

4. RESULTS AND DISCUSSION

4.1. Specific activity

The results of the specific activity of ^{226}Ra, ^{232}Th and ^{40}K radionuclides in the soil samples from a refinery in the Iraq North Oil Company is Al-Kasik Refinery are presented in Fig. (3) and Table (2). The range of the measured specific activity of ^{226}Ra 14.53±0.845-33.60±1.297 Bq/kg in the soil of Al-Kasik Refinery site was with an average of 19.80±0.948 Bq/kg. The

minimum value obtained in the soil samples was of code K4 and the maximum for the soil sample was of code K12. The variations are due to the geochemical composition and origin of the soil types in a given area. The range of the measured specific activity of ^{232}Th for the soil samples was 8.75±0.773-16.86±0.996Bq/kg with an average of 13.65±1.021 Bq/kg. The minimum value obtained in the soil samples was of code K6 and the maximum for the soil sample was of code K3. The differences are significant in all the samples. The specific activity of ^{40}K was 115.10±6.650-411.15±12.570Bq/kg in the soil samples with an average value of 213.71±8.896 Bq/kg. The minimum value obtained in the soil samples was of code K6 and the maximum for the samples was of code K12. These differences are attributed to the different types of soils in the area under study, as well as to industrial oils waste.

Furthermore, the average values obtained are within the range of the corresponding worldwide values and other published results listed in Table (4). The worldwide average specific activity levels of ^{226}Ra, ^{232}Th and ^{40}K are 35 Bq/kg, 30 Bq/kg , 400 Bq/kg respectively [14].

From Fig.(3), the specific activity of ^{226}Ra is higher than that of ^{232}Th in all samples. It is also observed that the measured specific activity of ^{40}K exceeds markedly the values of both radium and Thorium, as it is the most abundant radioactive element under consideration.

Table (4): Specific activity of ^{226}Ra, ^{232}Th and ^{40}K in soil samples collected from Al-Kasik oil refinery

Sample ID	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)
K1	18.16±0.972	14.51±0.980	168.46±8.049
K2	15.05±0.668	10.37±0.842	116.53±6.694
K3	20.47±1.033	16.86±0.996	137.69±7.277
K4	14.53±0.845	13.31±0.938	178.46±8.284
K5	17.25±0.659	15.52±1.025	228.84±9.381
K6	16.50±0.926	8.75±0.773	115.10±6.650
K7	17.06±0.943	12.23±0.861	305.11±10.830
K8	19.5±0.990	13.34±1.873	295.76±10.661
K9	21.78±1.055	16.24±1.053	214.23±9.077
K10	24.85±1.102	13.92±0.970	145.76±7.487
K11	18.86±0.887	12.31±0.906	251.92±9.843
K12	33.60±1.297	16.54±1.044	411.15±12.570
Min.	14.53±0.845	8.75±0.773	115.10±6.650
Max.	33.60±1.297	16.86±0.996	411.15±12.570
Ave.	19.80±0.948	13.65±1.021	213.71±8.896

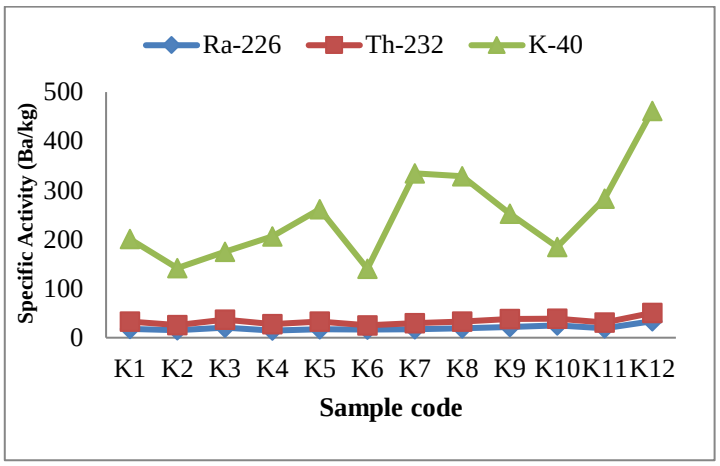

Fig. (5): Variation of specific activity of radionuclides in Al-Kasik oil refinery

Table (5) introduces a comparison of the measured value with the specific activity levels of some facilities present in literature from some parts of the world. It was found that the specific activity levels of the three radionuclides that were examined in the current study is lower than some values in similar facilities for countries such as Spain and Bangladesh. It was found that the average values of ^{226}Ra, ^{232}Th and ^{40}K were lower than the worldwide average.

Table (5): A comparison of the specific activity levels (Bq/kg) of ^{226}Ra, ^{232}Th and ^{40}K measured in the current study with those in other countries of the world and for facilities similar to the studied one

Country	^{226}Ra	^{232}Th	^{40}K	Reference
Egypt	16.7±2.7	19.4±5.0	262±82	[21]
Saudi Arabia	14.5±3.9	11.2±3.9	225±63	[22]
Iraq	24.7	13.6	538.9	[23]
Bangladesh	48.32	53.34	481.35	[24]
Pakistan	21.7±4.4	31±6.6	393.2±83.2	[25]
Sudan	28.31	20.21	280.29	[26]
Nigeria	41±5	29.7±4	412.54±20	[27]
Spain	46	49	650	[28]
Iraq (Kirkuk)	26.02	13.75	288.89	[29]
Iraq	19.80	13.65		Present Study
Worldwide average	35	30	400	[14]

4.2. Radiological parameters

The effects of the radiological hazards are of great importance, because they are often used to find out the amount of radiation hazard to the individuals of a particular studied area. Radiation protection organizations have set fixed values for all limits of radioactive pollution indicators, and they vary from one indicator to another, and if those values exceed that limit in a particular area, that area is considered one of the radiologically dangerous areas. Table (4) shows the radiological parameters of the soil samples collected from Al-Kasik Oil Refinery.

The radium equivalent Ra_{eq} for the soil samples was between 37.87 to 89.36Bq/kg with an average of 55.81Bq/kg. as shown in Fig.(4). The radium equivalent activity value for all of the soil samples studied is well within and less than the allowed limits of 370 Bq/kg [14]

The absorbed dose rate Dɣ ranged from 17.70 to 42.65nGy/h with an average value of 26.31nGy/h. as shown in Fig.(4). It could be noted that the total values of this indicator for all samples are within the safety level, i.e. less than 55 nGy/h [14].

The external hazard index H_{ex} was calculated and was found to range from 0.102 to 0.204 in the soil samples, with an average value of 0.150. As shown in Fig.(5), the average is less than unity and within the world average.

The internal hazard index H_{in}. values (Figure 5) in the samples ranged from 0.146 to 0.331, with an average of 0.203. All the values of the internal hazard index were less than those of the world average, which is equal to one [14].

The calculated values of I_γ for all samples in Al-Kasik Refinery ranged from 0.274 to 0.474 with an average of 0.395. as shown in Fig.(5) . The calculated values for all samples were lower than the worldwide values ($I_\gamma < 1$) [14].

The annual effective indoor dose rate ranged from 86.82µSv/y (K6) to 209.22µSv/y (K12), with an average value of 129.10µSv/y. The annual outdoor effective dose rate ranged from 21.70 (K6) to 52.30 (K12), with an average of 32.27 µSv/y as revealed in Fig.(6). Furthermore, the annual effective dose rate for both indoor and outdoor should be less than 1mSv/y [14]. The average indoor and outdoor effective dose rate values obtained are within the permissible limit, according to the results. As a result, the soil samples are fine, and there are no radiation risks owing to the presence of ^{226}Ra, ^{232}Th, or ^{40}K.

The ELCR was calculated by applying equation (9) as shown in Table (4) and Figure (5). The highest value for the excess lifetime cancer risk index was 183.05×10^{-6} and the lowest value was 75.95×10^{-6} and with an average value 106.58×10^{-6}, as all the values of this index for all samples were less than the worldwide average which equals 290×10^{-6} [14]

The AGED was calculated by applying equation (10), AGED in sample (K12) equals 302.06µSv/y, which is the highest value, while the AGED was 123.70µSv/y in sample (K6), and with an average of 185.49µSv/y. The annual gonadal dose equivalent AGED for all the studies sites are less than the value 300µSv/y recommended by UNSCER[14].

Table (6): Shows radiological hazard indices of soil samples in Al-Kasik Oil Refinery

Sample code	Ra_{eq} Bq/kg	D_γ nGy/h	H_{ex}	H_{in}	I_γ	$AEDE_{out}$ µSv/y	$AEDE_{in}$ µSv/y	$ELCR_{out}$ $\times10^{-6}$	AGDE µSv/y
K1	51.88	24.17	0.140	0.189	0.378	29.64	118.56	103.74	169.66
K2	38.85	18.07	0.104	0.145	0.281	22.16	88.64	77.56	126.44
K3	55.18	25.38	0.149	0.204	0.396	31.12	124.50	108.92	176.96
K4	47.30	22.19	0.127	0.167	0.348	27.21	108.85	95.23	156.57
K5	57.06	26.88	0.154	0.200	0.422	32.96	131.86	115.36	190.03
K6	37.87	17.70	0.102	0.146	0.274	21.70	86.82	75.95	123.70
K7	58.04	27.99	0.156	0.202	0.439	34.32	137.31	120.12	199.64
K8	61.35	29.39	0.165	0.218	0.460	36.04	144.17	126.14	208.88
K9	61.49	28.80	0.166	0.224	0.450	35.32	141.28	123.62	202.45
K10	55.97	25.96	0.151	0.218	0.402	31.83	127.35	111.40	180.74
K11	55.86	26.65	0.150	0.201	0.416	32.68	130.73	114.38	188.83
K12	88.91	42.65	0.240	0.331	0.474	52.30	209.22	183.05	302.06
Min.	37.87	17.70	0.102	0.146	0.274	21.70	86.82	75.95	123.70
Max.	89.36	42.65	0.240	0.331	0.474	52.30	209.22	183.05	302.06
Ave.	55.81	26.31	0.150	0.203	0.395	32.27	129.10	106.58	185.49

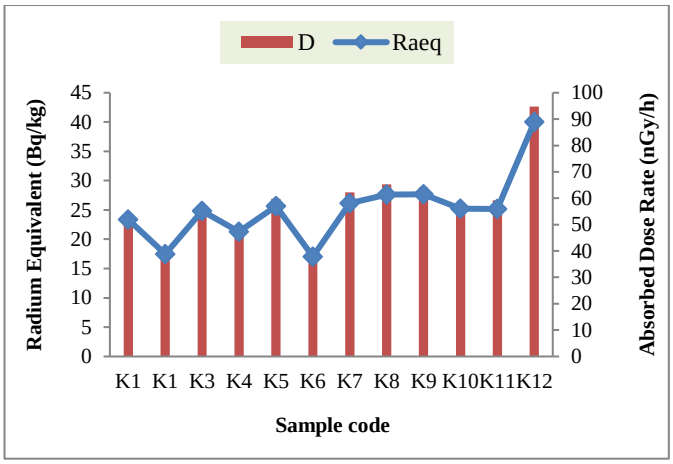

Fig. (6): Ra_{eq} and D_γ for all Al-Kasik Oil Refinery soil samples

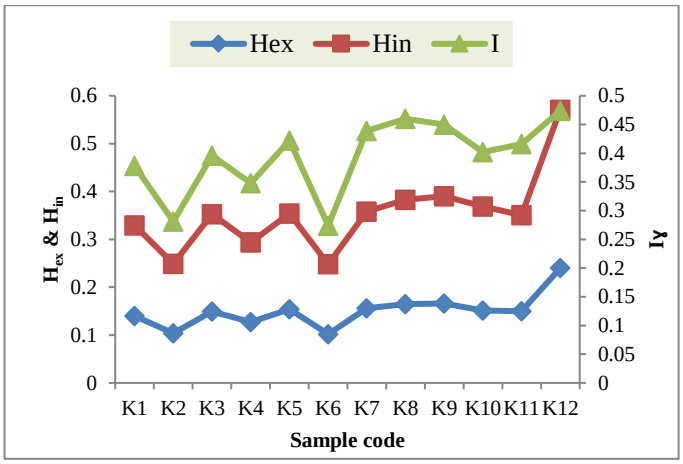

Fig. (7): H_{ex}, H_{in} and I_γ for all Al-Kasik Oil Refinery soil samples

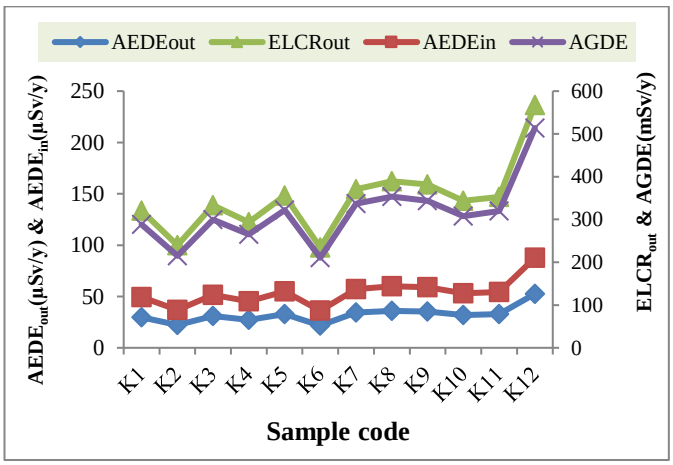

Fig. (8): AEDE(outdoor), AEDE(indoor), ELCR(out) and AGDE for all Al-Kasik Oil Refinery soil samples

5. CONCLUSION

γ -ray spectroscopy was exploited to determine specific activity due to naturally occurring nuclides ^{226}Ra, ^{232}Th and ^{40}K and the associated radiological hazard levels in 12 oil samples from some areas in the Al-Kasik Refinery- Nineveh . The average specific activity for ^{226}Ra, ^{232}Th and ^{40}K were 19.80±0.948 Bq/kg,13.65±1.021 Bq/kg and 213.71±8.896 Bq/kg, respectively. These average specific activity levels were lower than the worldwide average values. The averages of the obtained radiological hazard indices such as: the Radium equivalent, the Absorbed dose rate, the Outdoor and the indoor annual effective dose, the Excess lifetime cancer risk, the Annual gonadal dose equivalent, the Gamma representative level index and the External and Internal hazard indices were within the permissible range worldwide. The study concluded that there are no radioactive effects on the population located in the areas near the oil refinery under study at the present time, but it may lead to health effects in the future due to the accumulation of radionuclides, which requires continuous follow-up due to the increase in the accumulated works. .

ACKNOWLEDGEMENT

The authors extend their thanks to everyone who contributed to the completion of the present work.

REFERENCES

[1] Avwiri, G. O., & Ononugbo, C. P. (2012). Natural radioactivity levels in surface soil of Ogba/Egbema/Ndoni oil and gas fields. *Energy Science and Technology*, *4*(2), 92-101.

[2] Ajayi, T. R., Torto, N., Tchokossa, P., & Akinlua, A. (2009). Natural radioactivity and trace metals in crude oils: implication for health. *Environmental geochemistry and health*, *31*(1), 61-69.

[3] Mokobia, C. E., Adebiyi, F. M., Akpan, I., Olise, F. S., & Tchokossa, P. (2006). Radioassay of prominent Nigerian fossil fuels using gamma and TXRF spectroscopy. *Fuel*, *85*(12-13), 1811-1814.

[4] Zastawny, A., Kwasniewicz, E., & Rabsztyn, B. (1979). Measurements of the thorium, uranium and potassium concentration in some samples of ashes from power-stations in Poland. *Nukleonika*, *24*(5), 535-540.

[5] Smith, K. P., Blunt, D. L., & Arnish, J. J. (1998). *Potential radiological doses associated with the disposal of petroleum industry NORM via landspreading. Final report, September 1998* (No. DOE/BC/W-31-109-ENG-38-5). Argonne National Lab., Lakewood, CO (United States).

[6] Aswood, M. S., Jaafar, M. S., & Salih, N. (2017). Estimation of annual effective dose due to natural radioactivity in ingestion of vegetables from Cameron Highlands, Malaysia. *Environmental Technology & Innovation*, *8*, 96-102.

[7] Al-kubaisi, A. M. A., & Farhan, A. O. (2018). Measurement of the radioactivity in raw materials used in the ceramic industry in AL-Ramadi ceramic factory using (HPGe) detector. *Iraqi Journal of Science*, 307-313.

[8] Najam, L. A., & Wais, T. Y. (2022). Radiological Hazard Assessment of Radionuclides in Sediment Samples of Tigris River in Mosul city, Iraq. *Arab Journal of Nuclear Sciences and Applications*, *55*(1), 45-52.

[9] Tome, F. V., Rodríguez, M. B., & Lozano, J. C. (2003). Soil-to-plant transfer factors for natural radionuclides and stable elements in a Mediterranean area. *Journal of Environmental Radioactivity*, *65*(2), 161-175.

[10] Najam, L. A., & Younis, S. A. (2015). Assessment of natural radioactivity level in soil samples for selected regions in Nineveh Province (Iraq). *International Journal of Novel Research in Physics Chemistry & Mathematics*, *2*(2), 1-9.

[11] Santos Júnior, J. A. D., Cardoso, J. J. R. F., Silva, C. M. D., Silveira, S. V., & Amaral, R. D. S. (2005). Analysis of the 40K levels in soil using gamma spectrometry. *Brazilian Archives of Biology and technology*, 48(SPE2), 221-228.

[12] Al-Ubaidi A. M. (2014)." Environmental Radioactivity of Al-Rashidiyah Site Baghdad", Ph.D.Thesis, University of Baghdad, College of Science for Women.

[13] Diab, H. M., Nouh, S. A., Hamdy, A., & El-Fiki, S. A. (2008). Evaluation of natural radioactivity in a cultivated area around a fertilizer factory. *Nuclear and Radiation Physics*, *3*(1), 53-62.

[14] United Nations Scientific Committee on the Effects of Atomic Radiation. (2000). Sources and effects of ionizing radiation, ANNEX B, Exposures from natural radiation sources. *UNSCEAR 2000 REPORT, New York*, *1*, 97-99.

[15] Beretka, J., & Matthew, P. J. (1985). Natural radioactivity of Australian building materials, industrial wastes and by-products. *Health physics*, *48*(1), 87-95.

[16] Mahur, A. K., Kumar, R., Sonkawade, R. G., Sengupta, D., & Prasad, R. (2008). Measurement of natural radioactivity and radon exhalation rate from rock samples of Jaduguda uranium mines and its radiological implications. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, *266*(8), 1591-1597.

[17] OECD e Organization for Economic Cooperation and Development. (1979). Exposure to radiation from the natural radioactivity in building materials (Report by a group of experts). Paris, France: Nuclear Energy Agency.

[18] Veiga, R., Sanches, N., Anjos, R. M., Macario, K., Bastos, J., Iguatemy, M., ... & Umisedo, N. K. (2006). Measurement of natural radioactivity in Brazilian beach sands. *Radiation measurements*, *41*(2), 189-196.

[19] Taskin, H., Karavus, M. E. L. D. A., Ay, P., Topuzoglu, A. H. M. E. T., Hidiroglu, S. E. Y. H. A. N., & Karahan, G. (2009). Radionuclide concentrations in soil and lifetime cancer risk due to gamma radioactivity in Kirklareli, Turkey. *Journal of environmental radioactivity*, *100*(1), 49-53.

[20] Mamont-Ciesla, K. B. M. A. G., Gwiazdowski, B., Biernacka, M., & Zak, A. (1982). Radioactivity of building materials in Poland. In *Natural radiation environment*, 16(10), 551-557

[21] Saleh, I. H., Hafez, A. F., Elanany, N. H., Motaweh, H. A., & Naim, M. A. (2007). Radiological study on soils, foodstuff and fertilizers in the Alexandria region, Egypt. *Turkish Journal of Engineering and Environmental Sciences*, *31*(1), 9-17.

[22] Alaamer, A. S. (2008). Assessment of human exposures to natural sources of radiation in soil of Riyadh, Saudi Arabia. *Turkish Journal of Engineering and Environmental Sciences*, *32*(4), 229-234.

[23] Yousif, S. A. R., Abojassim, A. A., & Hayder, A. (2019). Mapping of natural radioactivity in soil

samples of Badra oil field project using GIS program. *Ядерна фізика та енергетика*, (20,№ 1), 60-69.

[24] Kabir, K. A., Islam, S. M. A., & Rahman, M. M. (2009). Distribution of radionuclides in surface soil and bottom sediment in the district of Jessore, Bangladesh and evaluation of radiation hazard. *Journal of Bangladesh Academy of Sciences*, *33*(1), 117-130.

[25] Fatima, I., Zaidi, J. H., Arif, M., Daud, M., Ahmad, S. A., & Tahir, S. N. A. (2008). Measurement of natural radioactivity and dose rate assessment of terrestrial gamma radiation in the soil of southern Punjab, Pakistan. *Radiation protection dosimetry*, *128*(2), 206-212.

[26] Sam, A. K., Ahmed, M. M. O., El Khangi, F. A., El Nigumi, Y. O., & Holm, E. (1997). Assessment of terrestrial gamma radiation in Sudan. *Radiation protection dosimetry*, *71*(2), 141-145.

[27] Agbalagba, E. O., Avwiri, G. O., & Chad-Umoreh, Y. E. (2012). γ-Spectroscopy measurement of natural radioactivity and assessment of radiation hazard indices in soil samples from oil fields environment of Delta State, Nigeria. *Journal of environmental radioactivity*, *109*, 64-70.

[28] Sam, A. K., Ahmed, M. M. O., El Khangi, F. A., El Nigumi, Y. O., & Holm, E. (1997). Assessment of terrestrial gamma radiation in Sudan. *Radiation protection dosimetry*, *71*(2), 141-145.

[29] Taqi, A. H., Al-Ani, L. A. A., & Ali, A. M. (2016). Assessment of the natural radioactivity levels in Kirkuk oil field. *Journal of Radiation Research and Applied Sciences*, *9*(3), 337-344.