Evaluation of Radioactivity in Soil Sample from Al-Hadbaa Cement Plant in Nineveh Governorate, Iraq

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Abstract — **The fundamental goal of this study is to measure the level of radioactivity in the soil of the area around Al-Hadbaa cement plant, also to evaluate the radiological hazard of radionuclide, gamma-spectroscopy with an HPGe detector with the crystal diameter of 70.6 mm and length of 70 mm has been used to estimate the specific activity of natural radionuclides ^{226}Ra, ^{232}Th, ^{40}K, and artificial radionuclides ^{137}Cs in the fifteen soil samples collected. The results show that the average concentration of specific activity of ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs was 11.17 ± 1.69, 13.38 ± 0.72, 158.36 ± 5.35 Bq/kg, and 1.52 ± 0.19 Bq/kg, respectively. The average specific activity of these radionuclides is discovered to be lower than the global average which is 33 Bq/kg for ^{226}Ra, 30 Bq/kg for ^{232}Th, and 400 Bq/kg for ^{40}K. Radiological hazard indices are determined according to the activity concentration of the radionuclides in the area under study. The outcome of the radiological hazard index is within the globally recognized limit proposed by UNSCEAR which is 1000 μSv/y for annual effective dose and 290 × 10^{-6} for cancer risk, so it is possible to conclude that there are no radiological hazards as a result of radiation exposure to the workers working in the cement plant as well as the organisms living in the region.**

Index Terms — **Ambient dose, Al-Hadbaa cement plant, ^{137}Cs, Gamma-ray spectroscopy, Nineveh Governorate, Radiological hazard, Soil samples.**

I. Introduction

The emission of radiation from the disintegration of an unstable nucleus by less elementary particles (α or β particles) is known as radioactivity (Abdullah and Ahmed, 2012), or emission of electromagnetic waves (γ ray) (Wais and Najam, 2021).

Life on Earth has developed under constant exposure to radiation, in addition to ionizing radiation from natural sources; a multitude of exposure from artificial sources produced by mankind came into play in the 20th century (Grupen and Rodgers, 2016).

Dating back to the origin of the earth, there has been an abundance of natural radioactivity in the environment and the earth's crust. It may be found in plants, rocks, soil, and water, and since that time, people have been exposed to both internal and external radiation (Marie and Najam, 2022; Kang et al., 2020).

The natural radioactivity in soil produced by the ^{238}U and ^{232}Th decay series, as well as ^{40}K (Isel et al., 2023) and natural radioactivity largely dependent on geological and geographical features of the region (UNSCEAR, 2000). The determination of radionuclides in soil and sand provides a valuable insight into human exposure to background radiation and a potential impact of natural radioactivity on human health (Lee et al., 2023). It is known that a significant part of gamma radiations originates from the surface layer at a depth of 0–25 cm (Küçükönder et al., 2023).

Artificial radioactivity – such as ^{137}Cs (long life 30.2 y) – can be found in the environment and is significant for assessing both internal and external exposure. It has been on increase lately as a result of human activities (Kang et al., 2020) (Taqi and Namq, 2022).

Medical radiation use, nuclear accidents – such as Chernobyl nuclear power plant – and nuclear weapon testing, all make up the majority of artificial radiation sources (Hafizoğlu, 2023).

Many studies were performed to assess the natural and artificial radioactivity in soil, Isel et al., (2023) assessed natural and artificial radioactive pollution in sediment and soil samples of Bosporus, Istanbul.

Another research, made by EL-Taher et al., (2017) measured the effect of cement plant factory exhaust on radiological content of surrounding soil samples in Assuit province, Egypt. In North Iran, Shahroudi and Poukimani, (2023) studied the emission pattern of NORMS and ^{137}Cs in the sediment of Gas River and the Gorgan Bay. Furthermore, Ali et al., (2014) assessed the natural radioactivity of marl as a raw material at Kufa cement quarry in Najaf governorate, Iraq. A researcher Hussein (2019) assessed the levels of natural radioactivity and radiation hazards of soils from Erbil governorate, Iraq Kurdistan. Moreover, the researchers Smail et al.,(2021) measured the natural radioactivity levels in the soil along the Little Zab River, Kurdistan Region in Iraq.

The aim of this study is to determine the specific activities of (^{226}Ra, ^{232}Th, ^{40}K) and (^{137}Cs) in soil samples from the environment of Al-Hadbaa cement plant in Hamam Al-Alil, a sub-district in Nineveh government.

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II. Materials And Methods

A. Study Area

Al-Hadbaa cement plant is in Hamam Al-Alil sub-district which is at a distance of 20 km to the south of the city of Mosul, Nineveh governorate, as shown in Fig. 1, at coordinates of 36°09′29″ N and 43015′34″ E. This plant was established by FCB (French Company) in 1963 and it produces Portland cement.

B. Samples Collection

In this study, on October 6, 2022, 15 samples were taken using a shovel from the soil near the Al-Hadbaa cement plant. The samples were taken at a depth of 10–15 cm within an area of (1 m × 1 m) for each sample. Then, the sample has been divided into three sections, all mixed to prepare homogenized samples. These samples were placed inside polyethylene bags with a mass of 2 kg.

Table I and Fig. 2. show the coordinates of the location of each sample located using the global position system.

C. Samples Preparing

All samples were air-dried before being placed in an electric oven set at 100°C for 2 h to completely remove the moisture. To create homogeneous samples, the samples were then sieved through a mesh size of 2 mm. To achieve the radioactive equilibrium between radionuclides and their daughters, the sieved soil was placed in (1 kg) Marinelli beakers and totally sealed for at least 1 month (Isel et al., 2023), (Cherie and Deressu, 2023).

D. γ-Spectroscopy Analysis

γ-spectroscopy with high purity Germanium detector (HPGe) and p-type vertical closed-end coaxial from PGT (Princeton Gamma Tec-PGT Company-USA) in Koya university's nuclear radioactivity laboratory has been used to measure the specific activity of radionuclide in soil samples. The crystal of the detector has a diameter of 70.6 mm and a length of 70 mm, as shown in Fig. 3.

The gamma-ray spectrometry system was calibrated for energy using standard point gamma-ray sources such as ^{60}Co (peaks of 1173.2 and 1322.5 keV), ^{137}Cs (peak 661.7 keV), and ^{226}Ra (peaks of 186,351,609, 1120, 1764) keV. The efficiency calibration was measured using three standard point gamma-ray sources ^{226}Ra, ^{60}Co, and ^{137}Cs. These samples were left for at least 4 h (PGT Company, 2002).

The resolution (FWHM) at 122 keV for ^{57}Co is 1.1 keV, and 1332 keV for ^{60}Co is 1.97 keV, with an efficiency of 73.8%. The specific activity of (^{226}Ra, ^{232}Th, and ^{40}K) and (^{137}Cs) in soil samples was measured by (HPGe) detector. The spectrum was collected for (36,000 s) and the background has been measured by putting an empty beaker on the detector for the same period of time.

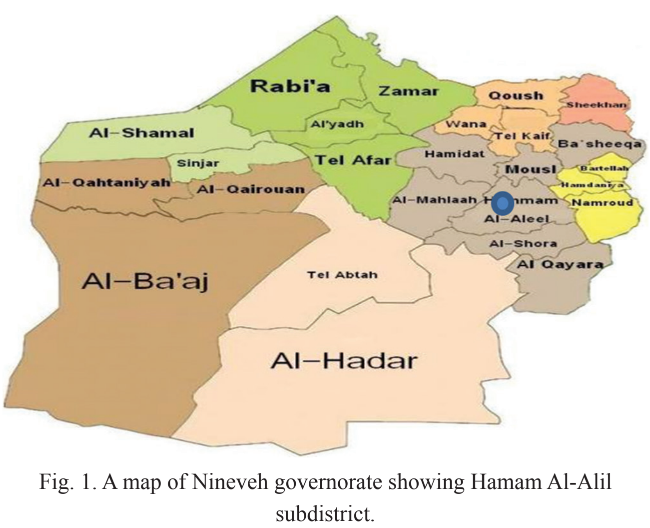

Fig. 1. A map of Nineveh governorate showing Hamam Al-Alil subdistrict.

III. Theoretical Equations

A. Specific Activity

Using the equation below, the specific activity of (^{226}Ra, ^{232}Th, and ^{40}K) and (^{137}Cs) in soil samples is determined (Xinwei and Xiaolan, 2006).

$$A_s\ (Bq/kg) = C_a/\varepsilon P^{\tau} M_s \quad (1)$$

Where (A_s) is the radio nucleus activity concentration of the sample, (C_a) is the net count rate below the corresponding peak, (ε) is the efficiency of detecting at the specific γ ray energy, (P^{τ}) is the absolute transition probability of the specific γ ray, and (M_s) is the mass of the sample in kg.

The activity concentration of ^{226}Ra has been measured as the average of the activity found using the gamma-ray line at 351.9 keV from ^{214}Pb and at 609.31 keV, 1120 keV, and 1764.5 keV from ^{214}Bi. The activity concentration of ^{232}Th has been measured as the average of the activity found in gamma-ray lines at 238.36 keV from ^{212}Pb decay, 583.19 keV, and 2614.5 keV from ^{208}Tl. The gamma-ray line at 1460.8 keV has been used to directly measure the activity level of ^{40}K, the gamma-ray line at 661.7 keV has been used to directly measure the activity level of ^{137}Cs.

B. Radiological Hazard Indices

TABLE I
Coordinates of samples taken from the area near Al-Hadbaa cement plant.

Sample no	Sample code	Longitude E	Latitude N
1	H1	43°21′22.74″	36°20′8.58″
2	H2	43°21′26.5″	36°20′19.13″
3	H3	43°21′28.87″	36°20′14.3″
4	H4	43°21′15.69″	36°20′21.43″
5	H5	43°21′19.09″	36°20′24.68″
6	H6	43°21′21.41″	36°20′32.204″
7	H7	43°21′27.37″	36°20′35.52″
8	H8	43°21′28.96″	36°20′38.46″
9	H9	43°21′31.15″	36°20′41.97″
10	H10	43°21′31.02″	36°20′44.67″
11	H11	43°21′30.82″	36°20′48.31″
12	H12	43°21′33.02″	36°20′48.57″
13	H13	43°21′33.46″	36°20′53.37″
14	H14	43°21′34.34″	36°20′55.69″
15	H15	43°21′31.61″	36°20′56.56″

Fig. 2. A map of Al – Hadbaa cement plant showing the locations of samples.

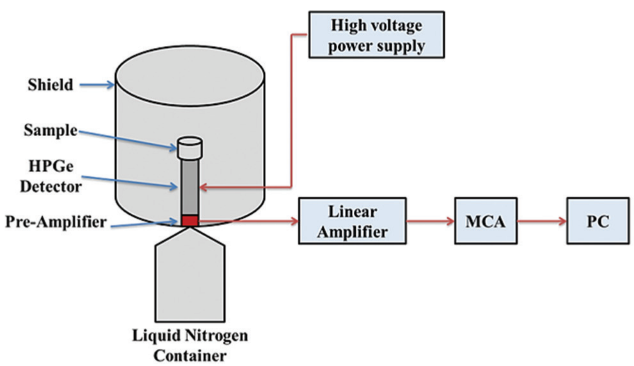

Fig. 3. Schematic layout of gamma-ray spectrometry system.

Radium equivalent activity (Ra_{eq})

The presence of (^{226}Ra, ^{232}Th, and ^{40}K) in soil samples is typically used to estimate their normal radioactivity. Radium equivalent index is used to describe the total amount of radiation exposure from these radionuclides, Ra_{eq} measured in (Bq/kg), and the following equation is used to calculate it (Qureshi et al., 2014).

$$Ra_{eq} = A_{Ra} + 1.43 A_{Th} + 0.077 A_K \quad (2)$$

Where (A_{Ra}, A_{Th}, and A_K) are the specific activities of (^{226}Ra, ^{232}Th, and ^{40}K) in Bq/kg, respectively.

Absorbed gamma dose rate (D^{γ})

The absorbed gamma dose rate in the air at (1 m) above the ground level can be calculated using the specific activity of natural radionuclide (^{226}Ra, ^{232}Th, and ^{40}K) (Örgün et al., 2007).

$$D_{\gamma}\,(nGy/h) = 0.462 A_{Ra} + 0.604 A_{Th} + 0.0417 A_K \quad (3)$$

Where D^{γ} is the absorbed dose rate in nGy/h.

Annual effective dose equivalent (AEDE)

The AEDE is calculated using the absorbed gamma dose rate which is measured in (µSv/y) to evaluate the level of health effects brought on by D^{γ}, the conversion factor (0.7 Sv/Gy) has been used to estimate the annual effective dose along with the indoor occupancy factor (0.8), and with the outdoor occupancy factor (0.2), the annual effective dose can be calculated by using the equations (Fisher et al, 1983, Kolo et al, 2017).

$$AEDE_{indoor}(\mu Sv/y) = D(nGy/h) \times 0.7 \times 0.8 \times 8760 \times 10^{-3} \quad (4)$$

$$AEDE_{outdoor}(\mu Sv/y) = D(nGy/h) \times 0.7 \times 0.2 \times 8760 \times 10^{-3} \quad (5)$$

Annual gonadal dose equivalent (AGDE)

The most sensitive organs of human body to radiation exposure are the gonads. Their calculation is based on the specific activity of natural radionuclides in soil samples through the following equation (Kolo et al., 2017).

$$AGDE(\mu Sv/y) = 3.09 A_{Ra} + 4.18 A_{Th} + 0.314 A_K \quad (6)$$

Excess lifetime cancer risk (ELCR)

ELCR can be used to determine the amount of extra cancer risk caused by exposure to ionizing radiation. ELCR measurement is based on AEDE by the equation (Taskin et al., 2009).

$$ELCR = (AEDE) \times D_L \times D_F \quad (7)$$

Where (D_L) is the mean of human time of life (70 year), (D_F) is the lethal risk factor per Sievert (0.05 Sv^{-1}).

External and internal hazard indices

The external hazard index (H_{ex}) represents the exposure to natural radiation, while the internal hazard index (H_{in}) represents the exposure to radon nuclide and its daughters. The (H_{ex}) and the (H_{in}) have been calculated by the equations (Najam et al., 2011, Mahur et al., 2008).

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \le 1 \quad (8)$$

$$H_{in} = \frac{A_{Ra}}{180} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \le 1 \quad (9)$$

Gamma radiation level index (I^{γ})

The gamma radiation level index can be used to determine the extent of gamma radiation risk associated with the natural radionuclides in soil. (I^{γ}) is calculated using the following equation (Kafala and Macmahon, 2007)

$$I_{\gamma} = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \le 1 \quad (10)$$

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The ambient dose equivalent rate H*(10)

It is a quantifiable quantity that offers a conservation estimation of the effective dose and evaluates the risk to human health caused by radiation exposure. The ambient dose equivalent rate of (^{226}Ra,^{232}Th, and ^{40}K) and (^{137}Cs) in the air at (1 m) above the ground was calculated as follows (Lee et al., 2023).

$$H^*(10)\ (nSv/h) = 0.674\ A_{Ra} + 0.749\ A_{Th} + 0.0512\ A_K + 0.192\ A_{Cs} \quad (11)$$

IV. Results and Discussion

A. Specific Activity

The results of the concentration of specific activity of (^{226}Ra, ^{232}Th, and ^{40}K) and (^{137}Cs) radionuclides in soil samples from Al-Hadbaa cement plant are presented in Table II and Fig. 4 below. The specific activity of (^{226}Ra) ranges from (7.861 ± 0.948 Bq/kg) for sample (H2) to (14.492 ± 1.066 Bq/kg) for sample (H4) with a mean value (11.172 ± 1.085 Bq/kg). The specific activity of (^{232}Th) ranges from (7.687 ± 0.434 Bq/kg) for sample (H2) to (16.945 ± 0.641 Bq/kg) for sample (H13) with mean value (13.383 ± 0.727 Bq/kg). For (^{40}K), the specific activity ranges from (93.12 ± 3.929 Bq/kg) for sample (H1) to (208.8 ± 5.945 Bq/kg) for sample (H15) with a mean value (158.368 ± 5.356 Bq/kg). The specific activity of (^{137}Cs) ranges from (0.224 ± 0.107 Bq/kg) for sample (H1) to (7.285 ± 0.497 Bq/kg) for sample (H8) with a mean value (1.529 ± 0.192 Bq/kg).

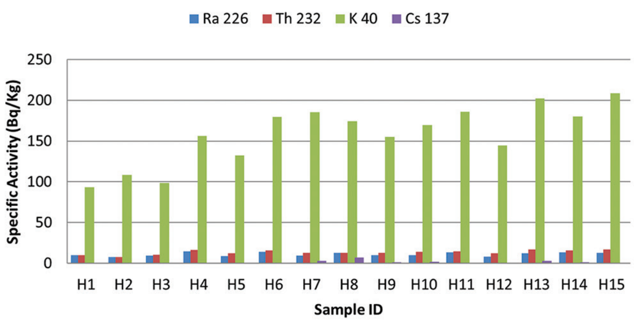

Fig. 4. Variations of specific activity of (^{226}Ra, ^{232}Th, and ^{40}K) and (^{137}Cs) in the soil samples.

TABLE II

Specific activity of (^{226}Ra, ^{232}Th, and ^{40}K) and (^{137}Cs) in the soil samples collected from Al-Hadbaa cement plant

	Specific Activity (Bq/kg)			
Sample ID	^{226}Ra	^{232}Th	^{40}K	^{137}Cs
H1	10.179±0.9876	9.979±0.54	93.12±3.929	0.224±0.107
H2	7.861±0.948	7.687±0.434	108.7±4.018	0.433±0.102
H3	9.376±1.0666	10.424±0.65	98.7±3.966	ND
H4	14.492±1.0661	16.595±0.806	156.3±5.459	0.277±0.151
H5	9.053±1.0263	12.349±0.564	132.3±4.694	0.546±0.131
H6	13.978±1.1714	15.62±0.809	179.8±7.073	0.569±0.123
H7	9.619±1.0921	13.033±0.73	185.6±5.231	2.862±0.267
H8	12.619±1.0095	12.633±1.192	174.6±6.864	7.285±0.497
H9	9.968±0.9612	12.553±0.721	154.9±4.983	1.028±0.177
H10	9.922±1.0922	13.72±0.779	169.7±5.515	1.94±0.201
H11	13.563±1.0534	14.811±0.914	186.2±5.046	0.698±0.15
H12	8.454±1.0534	12.021±0.732	144.4±5.275	0.667±0.142
H13	12.181±1.6899	16.945±0.641	202.5±6.949	2.817±0.306
H14	13.524±0.9349	15.566±0.666	179.9±5.387	1.468±0.186
H15	12.799±1.132	16.82±0.728	208.8±5.945	0.604±0.148
Min	7.861±0.948	7.687±0.434	93.12±3.929	0.224±0.107
Max	14.492±1.0661	16.945±0.641	208.8±5.945	7.285±0.497
Ave.	11.172±1.085	13.383±0.727	158.368±5.356	1.529±0.192

The average specific activity values determined for the radionuclides (^{226}Ra,^{232}Th, and ^{40}K) are below the global average recommended by the (UNSCEAR, 2000) which are: (33 Bq/kg) for ^{226}Ra, (30 Bq/kg) for ^{232}Th, and (400 Bq/kg) for ^{40}K, as shown in Table III.

Table III shows a comparison of the average value of the specific activity level for radionuclides (^{226}Ra,^{232}Th, and ^{40}K) and (^{137}Cs) that results in this study with another local and global studies that are similar to this study, the result of the average specific activity of (^{226}Ra) is comparable to the value of ^{226}Ra in Turkey and Rabia region in Nineveh governorate, on the other side, the average value of (^{232}Th) is comparable to the value in Egypt and South Korea, and the value of specific activity of (^{40}K) is comparable to the value in Egypt. Finally, the average of specific activity for (^{137}Cs) is comparable to the average in South Korea and Duhok governorate.

B. Radiological Hazard Indices

Radiological hazard indices have been determined according to the activity concentration of the radionuclides in the area under study. Table IV shows the radiological hazard indices of the soil samples collected from Al-hadbaa cement plant.

The values of radium equivalent Ra_{eq} range from (27.223 Bq/kg) to (52.929 Bq/kg), with a mean value of (42.506 Bq/kg), all values of Ra_{eq} are below the allowed limit (370 Bq/kg) suggested by (UNSCEAR, 2000).

While the values of absorbed dose (D^{γ}) range between (12.808 nGy/h) and (24.779 nGy/h) with a mean value

TABLE III

A comparison of the average specific activity in unite (Bq/kq) of (^{226}Ra, ^{232}Th, and ^{40}K) and (^{137}Cs) in this study with similar study in another local and global region

Country	Specific activity (Bq/kg)				References
	^{226}Ra	^{232}Th	^{40}K	^{137}Cs	
South Korea	21.9	11.1	661	0.9	Lee et al., 2023
Turkey	60.2	50.1	631	5.5	Turhan, 2023
Turkey	11.65	9.55	369.43	4.57	Isel et al., 2023
Bangladesh	27	64	762	-	Dina et al., 2022
Iran	17.61	35.91	398.65	4.01	Shahroudi and Pouriman, 2023
Egypt	20.35	10.52	158.16	0.13	Mansour et al., 2022
Saudi Arabia	21.16	18.80	202.15	0.16	Mansour et al., 2022
Iraq, Kirkuk	57.8	25.4	479.9	4.2	Taqi and Nomp, 2022
Iraq, Duhok	21.6	35.4	438	1.0	Abdullah and Ahmed, 2012
Iraq, Kurdistan	14.1	6.8	281	7.1	Smail et al., 2021
Iraq, Rabia	12.85	19.66	214.52	-	Wais et al., 2023
Iraq, Hamam AL-Alil	11.17	13.38	158.36	1.52	Present study
Worldwide Ave.	33	30	400	-	UNSCEAR, 2000

TABLE IV

The Radiological Hazard Indices of soil sample in this study	Ra_{eq} (Bq/kg)	D_γ (nGy/h)	AEDE (μSv/y)		ELCRout×10^{-6}	Hazard indices		I_γ	AGDE (μSv/y)	H*(10) nSv/h
			$AEDE_{in}$	$AEDE_{out}$		H_{ex}	H_{in}			
H1	31.619	14.613	71.686	17.922	62.725	0.085	0.114	0.230	102.405	19.145
H2	27.223	12.808	62.829	15.707	54.975	0.074	0.096	0.202	90.554	16.704
H3	31.882	14.744	72.326	18.082	63.285	0.086	0.113	0.233	103.536	19.180
H4	50.258	23.236	113.988	28.497	99.740	0.136	0.177	0.367	163.226	30.253
H5	36.899	17.158	84.171	21.043	73.650	0.100	0.125	0.272	121.135	22.229
H6	50.159	23.390	114.742	28.685	100.399	0.135	0.175	0.369	164.941	30.435
H7	42.547	20.055	98.384	24.596	86.086	0.115	0.142	0.318	142.479	26.297
H8	44.128	20.741	101.748	25.437	89.029	0.119	0.155	0.327	146.623	28.305
H9	39.846	18.647	91.473	22.868	80.038	0.108	0.136	0.295	131.911	24.248
H10	42.609	19.947	97.854	24.463	85.622	0.115	0.143	0.316	141.294	26.024
H11	49.080	22.976	112.713	28.178	98.624	0.133	0.171	0.363	162.286	29.902
H12	36.763	17.188	84.317	21.079	73.777	0.099	0.123	0.273	121.712	22.223
H13	52.005	24.307	119.239	29.810	104.334	0.140	0.175	0.386	172.054	31.810
H14	49.636	23.152	113.573	28.393	99.377	0.134	0.173	0.366	163.344	30.266
H15	52.929	24.779	121.558	30.389	106.363	0.143	0.179	0.393	175.420	32.031
Min	27.223	12.808	62.829	15.707	54.975	0.074	0.096	0.202	90.554	16.704
Max	52.929	24.779	121.558	30.389	106.363	0.143	0.179	0.393	175.420	32.031
Ave.	42.506	19.849	97.373	24.343	85.202	0.115	0.147	0.314	140.195	25.937

AGDE: Annual gonadal dose equivalent

(19.849 nGy/h), it could be noted that all values of D^γ were below the world average value (55 nGy/h) (UNSCEAR, 2000).

The indoor equivalent annual effective dose ($AEDE_{in}$) and outdoor equivalent annual effective dose ($AEDE_{out}$) were calculated. The value of ($AEDE_{in}$) ranges between (62.829 – 121.558) μSv/y with a mean value (97.373 μSv/y). The value of ($AEDE_{out}$) ranges between (15.707 – 30.389) μSv/y with a mean value (24.343 μSv/y). The values of ($AEDE_{in}$) and ($AEDE_{out}$) are within the world average which is equal to (1 mSv/y) (UNSCEAR, 2000).

The value of the ELCR ranged between (54.707 × 10^{-6}– 106.363 × 10^{-6}) with a mean value of (85.202 × 10^{-6}). The average value is less than the world average value (290 × 10^{-6}) (UNSCEAR, 2000).

For the values of external (H_{ex}) and internal (H_{in}) radiological indices, they range between (0.074–0.143) a mean value of (0.115) for (H_{ex}), and between (0.096 – 0.179) with a mean of (0.147) for (H_{in}).

The resulting values of the gamma radiation level index (I^γ) for all soil samples range between (0.202) and (0.393), with an average value of (0.314). All the obtained values of (H_{in}), (H_{ex}) and (I^γ) are below one (worldwide value), which is suggested by (UNSCEAR, 2000), and the values of these indices for all samples were with the safety standard values.

For the value of AGDE, it ranges between (90.554 and 175.420) μSv/y, with a mean value of (140.195 μSv/y). The values of (AGDE) are less than the global permissible value, which is less than (300 μSv/y) (UNSCEAR, 2000).

The values of the ambient dose equivalent rate H*(10), it is ranging between (16.704 nSv/h) to (32.031 nSv/h) with a mean value of (25.937 nSv/h).

V. Conclusion

In this study, a 15 soil samples near Al-Hadbaa cement plant have been collected to evaluate the natural and artificial radioactivity. Gamma-ray spectrometry with (HPGe) detector has been used to determine the activity concentration level for radionuclides (^{226}Ra, ^{232}Th, and ^{40}K) and (^{137}Cs). The radiological hazard indices and the activity concentration of ^{40}K were the dominating natural radioactivity in soil, which confirmed the abundance of ^{40}K in the Earth's crust. The radioactivity level of ^{137}Cs is found to be insignificant. Some variations of the activity concentration measured in soil samples are observed because of the physical, chemical, and geological structure.

The values of the specific activity obtained in the study are lower than the worldwide average values, and ^{40}K is the main contribution of the radioactivity in this study. The result of all radiological hazard indices such as: Ra_{eq}, D^γ, AEDE, ELCR, H_{ex}, H_{in}, AGDE, and H*(10) is within the internationally accepted limits, thus it can be concluded that there are no radiological hazards due to the directed and continuous exposure of ionizing radiation from radionuclides to the working workers in this cement plant and organisms that live in this region. This study establishes a significant information base about the radioactivity in the studied region.

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