Assessment of natural radionuclides and radiological hazards in soil samples of the brick factories in Babylon governorate, Iraq

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Abstract

This study is the first conducted on bricks factories south of Babylon governorate, to determine the natural radionuclides in soil and bricks.

Gamma spectroscopy NaI (Tl) (3"×3") has been applied to determine the radioactivity levels of ^{238}U, ^{232}Th, and ^{40}K in soil samples of raw materials in thirteen brick factories. Average activity values of ^{238}U, ^{232}Th, and ^{40}K for soil samples (23.08± 1.64, 58.69±3.158, and 402.24± 7.05) Bq/kg respectively. The absorbed dose rate (DR), the radium equivalent activity (Ra eq), annual effective dose rate ($AEDE_{out}$, $AEDE_{in}$), and activity concentration index (Iγ), have been calculated. The results are within the permissible limits (UNSCEAR 2008), (^{232}Th), (DR), and (Iɣ) were higher than the internationally permissible limits. This may indicate that the workers receive radiation doses due to radioactivity.

Key Words: Natural radioactivity, Brick factories, NaI (Tl) detector, Radiation hazards.

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Introduction

The spread of nuclear technology and the use of radionuclides in industry, agriculture, medicine, and other nuclear and radiological applications is increasing over the world. This could be accompanied by an increase in accidents, with a large increase in the dangers of external ionizing radiation exposure and radioactive contamination of internal organs (Al-Hamzawi & Kareem, 2022). Soil is the primary source of natural radioactivity, as well as a potential source of radiological risk and radionuclide transmission into the environment. For the radioactive contamination index, natural radioactivity primary soil is considered essential (S. Rahman et al., 2008). Radiation pollution is caused either by spreading radioactive materials in rocks, surface soil, and water. This spreading is either natural or from external pollution [(Zamanian, 2005). Radiation in the environment comes from both natural and industrial sources, with natural radiation posing greater risk than the radiation posed by industrial radioactive sources (Z. Q. Rahman & Al-Hamzawi, 2022; United Nations Scientific Committee on the Effects of Atomic Radiation, 2014). The radionuclide series, such as ^{238}U, ^{232}Th, and ^{40}K, are present naturally throughout the earth's crust. These radionuclides are significant because they provide useful information, but their high solubility and quick transportability make them even more dangerous. Knowing the quantities and distributions in monitoring natural radioactivity pollution in the environment is critical for human health (Bouhila et al., 2017; Boukhenfouf & Boucenna, 2011) .

Radioactivity is common in rivers and oceans in rocks, soil, sand, and sediments, also common in building and home materials, which contain naturally occurring radioactive materials. In general, it includes the remaining primordial radionuclides since the origin of the earth (Yii et al., 2009a). The subject of our study is radionuclides and their effects on the environment. Radionuclides (natural or synthetic) can be transmitted in different media in the short or long term. Humans and the environment are exposed to the natural background radiation of cosmic rays and terrestrial gamma rays. They are also affected by synthetic radionuclides coming from nuclear reactors and explosions, such as reactor accidents, radioactive waste, and weapons tests, all of which contaminate the soil, sediments, and the atmosphere (Al-Hamzawi et al., 2014; Yii et al., 2009a, 2009b). Soil typically provides information on environmental and geochemical contamination and play an important and radioecology (Ravisankar et al., 2015; Wu et al., 2015). Radionuclides travel from the lithosphere to the natural ecosystem through several pathways, such as atmospheric, corrosion of rocks, wind, and water. Soil is also part of the ecosystem and may be affected by contamination over long periods and in large areas. They are also effective and can be detected and followed up easily (Wu et al., 2015). Radioactive decay is the emission of energy in the form of ionizing radiation. The emitted ionizing radiation can include alpha and beta particles or gamma rays. Some of these forms are stable, while others are unstable, which poses health risks to the exposed people (Fallah et al., 2019; Heldal et al., 2021; Pfützner et al., 2012). Since radiation exposure is a major concern, to estimate the amount of radioactivity present in samples Soil used as a raw material for making bricks, was conducted this research. Because the soil contains radionuclides with a long half-life, such as uranium, it forms an external and internal radioactive. due to the frequent use of bricks in building materials, as well as there is also no previous study on soil samples for these factories. It is considered the largest complex in the middle Euphrates region, as it contains a large number of brick factories, the production capacity of the one factory reaches 10 million bricks annually, and these factories supply most of the country’s governorates. The earth was agricultural land before factories were established on it, so it became necessary to know the concentrations of radionuclides and the associated radiological risks. Because of the emission of gamma rays from building materials, humans may be exposed to natural background radiation from primitive radionuclides such as 238U, 232Th, and 40K as well as from decay products (external dosage) and radon exhalation (internal dose), according to this American Nuclear Society. Hence, man should be wary of his natural environment regarding the health effects of radiation. Radiation is carcinogenic and causes many health problems and birth defects (Chhangte et al., 2018a).

Material and Methods

Samples collection

Thirteen factories brick has been chosen to collect the raw material soil samples from Al Shomali city, Iraq, a map of the brick factories in Babylon governorate indicating field sampling points and the studied areas (sample sites) is given in Fig 1. The coordinates of the soil samples are illustrated in table 1. Babylon is located in the center of Iraq, with an area of 5,119 Km2 and a population of 2,065,042 million people, bordered by Baghdad Governorate to the north, Al- Diwaniyah governorate to the south, Karbala governorate to the west, and Wasit governorate to the east.

Figure 1: Iraq's map and study region are included

Table 1: Demographic information for the studied factories.

Factory Code	Names of brick factories	Location	
		Latitude (N)	Longitude (E)
F1	AL-Etimad	32° 28’ 17 .39 ”	45° 03 ’ 58 .47 ”
F2	AL Rawasi	32° 24 ’ 15 .63 ”	45° 04 ’ 52 .8 ”
F3	AL Masra	32° 21 ’ 55 .58 ”	45° 04 ’ 11.1 ”
F4	AL Rafidain	32° 24 ’ 11 .21 ”	45° 05 ’ 00 .23 ”
F5	AL Saleam	32° 23 ’ 51 .53 ”	45° 05 ’ 24 .66 ”
F6	Gibran	32° 23 ’ 55 .86 ”	45° 05 ’ 24 .67 ”
F7	AL Hazem	32° 23 ’ 40 . 45”	45° 05 ’ 32 .37 ”
F8	AL-Muna	32° 24 ’ 07 .30 ”	45° 05 ’ 59 .87 ”
F9	Hatem Tariq	32° 24 ’ 18 .13 ”	45° 05 ’ 47 .3 ”
F10	Abu Tariq	32° 24 ’ 39 .22 ”	45° 05 ’ 21 .44 ”
F11	AL –Yaqin	32° 23 ’ 58 .03 ”	45° 06 ’ 10 .88 ”
F12	Wissam Tariq	32° 24 ’ 26 .36 ”	45° 05 ’ 36 .37 ”
F13	AL Bahja	32° 41 ’ 31 .81 ”	45° 08 ’ 58 .66 ”

Experimental Method

Soil samples were collected and cleaned from large impurities and placed inside polyethylene bags with the sample code installed for each factory. Samples coordinates have been located using the GPS as shown in Table (1). Then it was transferred to the laboratory. Using an electric oven, the samples were dried at a temperature of (110 c°) for 24 hours in a row to remove moisture. The mixture was then ground using an electric grinder and sifted through a sieve with holes (300μm) to create a homogeneous sample. Then, a digital scale was utilized to weigh each sample by (1Kg) and placed within a handcrafted Marinelli container created specifically for this purpose and a tight-fitting lid, which is retained until the time of the experiment to ensure that the natural radionuclides and their daughter achieve a radioactive equilibrium. The electronic counting and analysis system is used in the detection of nuclear rays, (Spectra Alpha3/12I12.-Inc) with a multi-channel analyzer (MCA Base Digi-ORTEC) 4096 channels (Hamid et al., 2002).

A computer program called (MAESTRO 32) performs nuclear measurements and analyses as shown in figure (1). The spectra for each sample were analyzed for (5400 Sec), Spectroscopic measurements were carried out for the period from 20/12/2021 to 10/2/2022. Before the measurement, the system must be calibrated, the purpose of the energy calibration process is to find out where the energy of the falling photon is on each channel. This was done by using radioactive sources 60Co, 137Cs, and 22Na to find the relationship between gamma energy and channel number, which showed a straight line with a good correlation (0.99) (Kadem et al., 2017). The concentration of 238U was measured by the daughter of Bismuth (214 Bi) with an energy of 1764 KeV, the concentration 232Th was measured by the daughter of thallium (208TI) with an energy of 2614 KeV. The concentration of radioactive 40K nuclide with energy 1460 keV (Salim, 2017).

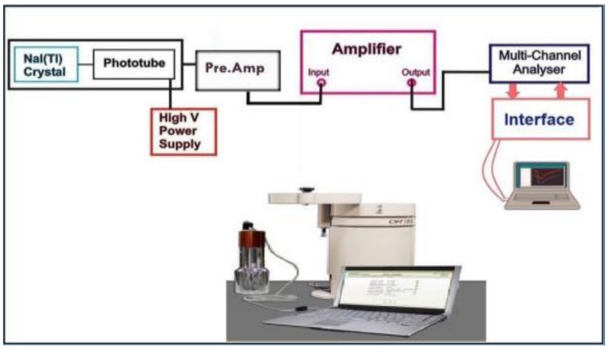

Figure (1) thallium doped sodium iodide detector system NaI (Tl) (3"×3").

Equation (1) was used to calculate of Activity of radioactive nuclides (A) (Majeed et al., 2014; Okeyode, 2010).

$$A(Bq.kg^{-1}) = \frac{N_{net}}{\varepsilon.I_\gamma.M.t} + \frac{\sqrt{N_{net}}}{\varepsilon.I_\gamma.M.t} \qquad (1)$$

Where N_{net}: is the net count under the corresponding photo peak Subtracting the background spectrum. Ɛ: is the efficiencies of the detector at particular energy gamma. I_γ: is absolute gamma intensity the corresponding gamma energy. M: mass of measured sample (kg). t: is counting time in second (Cottingham & Greenwood, 2001).

The radium equivalent activity (Ra_{eq}) were calculated using equation (2) (Beretka & Matthew, 1985; F et al., 2003):

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

Where: $A_U.A_{Th}$and $A_K$are the activity concentrations of the 238U ,232Th and 40 K respectively.

Equation (3) to calculate absorption of a gamma dose (DR) in the air (Radenkovic et al., 2009).

$$DR = 0462A_U + 0.604A_{Th} + 0.0417A_K \qquad (3)$$

Where DR is the absorbed dose rate (nGy/h) and AU, A Th, and A k are activity concentrations (Bq/kg), 238U, 232Th, and 40k. An annual effective dosage can be calculated using equation (DR), and the conversion factor (0.7Sv/Gy) from (Radenkovic et al., 2009; Santos Júnior et al., 2005)

$$AEDE_{outdoor}(mSv/y) = DR(nGy/h) \times 8760h/y \times 0.2 \times 0.7Sv/Gy \times 10^{-6} \quad (4)$$

$$AEDE_{indoor}(mSv/y) = DR(nG/h) \times 8760h/y \times 0.8 \times 0.7Sv/Gy \times 10^{-6} \quad (5)$$

Equation (8) used to calculate the Activity concentration index (I_{γ}) of the soil [25].

$$I_{\gamma} = \frac{A_U}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \quad (6)$$

Results

The activity concentrations of the naturally occurring radionuclides (238U, 232Th, 40K) are shown in table 2. From this table, the values of specific activity for the (238U, 232Th, and 40K) radionuclides ranged between the high value to the low value as followed (39.21–13.19, 85.21 – 39.60, and 585.50 – 273.28 Bq.kg-1). The highest concentrations of 238U occurred in soil sample code (S2) for in the factory (F2) (39.215 ± 2.178) Bq.kg-1 and for 232Th the sample (S3) has the highest value in (F3) (85.219±3.822) Bq.kg- 1 also for the highest concentration of 40K for sample (S4) in the factory (F4) (585.50 4± 8.547) Bq.kg- 1. The mean values of 238U, 232Th, and 40K levels were (23.08, 58.69, and 402.24 Bq.kg-1), respectively.

It was found that all (Raeq) values in the studied samples are lower than the standard limit of 370 Bq/kg, average of these soil samples (137.98 ± 6.63) Bq/kg. Absorbed gamma dose rate (DR) ranged from 46.92 nGy/h in the (S8) sample in the factory (F8) to 78.88 nGy/h (S3) in the factory (F3) with an average value of 62.6 nGy/h. It is evident that the mean value of the rate of absorbed dose in the studied factories is higher than the global limit of 55 nGy/h [14]. The annual effective dosage (AEDE in) ranged from 0.23 mSv/y in a soil sample (S8) in the (F8) to 0.383 mSv/y in a soil sample (S3) in the (F3) the average of these samples was 0.307 mSv/y, The annual effective dosage (AEDE out) ranged from 0.05 mSv/y in a soil sample (S8) in the (F8) to 0.093 mSv/y in a soil sample (S3) in the (F3) the average of these samples 0.074 mSv/y. The Activity concentration index (I_{γ}) of the soil ranged from 0.76 in a soil sample (S8) in the (F8) to 1.27 in a soil sample (S3) in the (F3) the average of these samples was 1.00.

Table 2: concentrations of radionuclides (238U, 232Th, 40K) in the (soil) basic material for the brick industry.

Names of brick factories	Factory Code	No. Sample	Specific Activity concentrations (Bq/kg)		
			^{238}U	^{232}Th	^{40}K
AL-Etimad	F1	S1	28.20 ± 1.84	73.73 ±3.55	344.41 ±6.55
AL Rawasi	F2	S2	39.21 ± 2.17	62.24±3.26	465.95 ±7.6
AL Masra	F3	S3	25.05 ± 1.74	85.21±3.82	386.21 ± 6.94
AL Rafidain	F4	S4	29.65 ± 1.89	57.27 ± 3.13	585.50 ± 8.54
AL Saleam	F5	S5	13.55 ± 1.28	65.15 ± 3.34	452.35 ±7.513
Gibran	F6	S6	16.70 ± 1.42	61.55 ± 3.24	424.90 ± 7.28
AL Hazem	F7	S7	14.64 ±1.33	39.60 ± 2.60	423.52 ± 7.26
AL-Muna	F8	S8	13.19± 1.26	49.03 ± 2.89	273.28 ± 5.83
Hatem Tariq	F9	S9	30.01± 1.90	59.49 ± 3.19	345.41 ± 6.56
Abu Tariq	F10	S10	14.64 ±1.33	39.60 ± 2.60	423.52 ± 7.26
AL –Yaqin	F11	S11	27.95 ± 1.83	55.04± 3.07	358.76 ± 6.69
WissamTariq	F12	S12	22.39 ± 1.64	49.89± 2.92	386.71 ± 6.94
AL Bahja	F13	S13	24.81 ± 1.73	51.61± 2.97	406.93 ± 7.12
	Max		39.21 ±2.17	85.21±3.822	585.50 ± 8.54
	Min		13.19 ± 1.33	39.60 ± 2.60	273.28 ± 5.83
	Avg		23.08± 1.64	58.69±3.158	402.24 ± 7.05
	W.Ave		33	45	420

concentrations of Au, Ag and NPS against the enzyme activity. The findings revealed that a rise in nanoparticles of Ag had a negative impact on CK

Table 3: shows the results of radiological hazards in a soil of brick factories (Ra_{eq}, DR, AEDE $_{in}$, AEDE $_{out}$,I_γ).

Factor Code	No.Sample	Ra_{eq} $Bq/kg)$	DR nGy/h	AED_{ind} oor mSv/y	$AEDE_{out}$ door mSv/y	I_γ
F1	S1	160.15 ±7.43	71.64	0.356	0.089	1.15±0.05
F2	S2	164.09 ±7.42	74.81	0.36	0.091	1.19±0.05
F3	S3	176.64 ±7.73	78.88	0.383	0.090	1.27±0.05
F4	S4	156.63 ±7.03	72.29	0.354	0.085	1.16±0.04
F5	S5	141.56 ±6.63	64.165	0.3148	0.079	1.04±0.04
F6	S6	137.44 ±6.62	62.318	0.305	0.076	1.01±0.04
F7	S7	137.44 ±6.62	62.318	0.305	0.076	0.87±0.04
F8	S8	104.35 ±4.98	46.92	0.23	0.056	0.76±0.04
F9	S9	141.69 ±6.98	63.96	0.31	0.077	1.02±0.04
F10	S10	103.89 ±5.61	48.05	0.236	0.059	0.77±0.03
F11	S11	134.29 ±6.74	60.87	0.296	0.076	0.97±0.04
F12	S12	123.52 ±6.36	56.33	0.273	0.06	0.90±0.04
F13	S13	129.94 ±6.53	59.32	0.295	0.07	0.95±0.04
Max		176.64 ±7.73	78.88	0.383	0.093	1.27±0.05
Min		103.89 ±5.61	46.92	0.23	0.056	0.76±0.04
Avg		137.98 ± 6.6	62.6	0.307	0.074	1.00±0.04
W.Ave [26]	370	55	≤1	≤1	≤ 1	

Discussion

The outcomes of natural radionuclides for samples of raw materials from soil used for making bricks in the brick factories southern of Babylon governorate, Iraq has shown in Table 2. The results varied from one factory to another due to the presence of radionuclides in the earth depending on their physical, chemical, and geochemical properties.

Through table 2, the results showed a decrease in the concentration levels of 238U in the brick factories for soil sample, except the factory (F3), which exceeded the internationally permissible limits due to the geological nature of the soil(Radiation U, 2008). The concentrations of thorium have exceeded the permissible limit in most brick factories for soil samples due to the exposure of the area to military bombardment (1991, and 2003). The highest amount of 40K dominates in the studied samples over the other isotopes because it is the earth was agricultural fields before the establishment of the brick factories on it. So the soil is rich in phosphate fertilizers. the mean natural activity concentrations of the soil sample following the order of 238U < 232Th < 40K. These elements have different behaviors in soil 238U, 40K dissolves in water while 232Th is a particularly insoluble element and is usually found bound with a solid material

Table 3 showed the results of radiation risks in soil samples; from this table, the figures of radium equivalent, and annual effective dose rate (AEDE in, AEDE out) were lower than permissible limits, except for absorption dose rate gamma (DR) in air and activity concentration index (Iɣ) which exceeded the internationally permissible limits due to of the closeness of the brick factories to each other, the activity concentration index (Iɣ) levels are found to be high in samples in which 232Th or 40K concentrations are elevated. Because it is used to compute the gamma radiation associated with natural radionuclides and this indicates that Since workers receive radiation doses and workers must take all possible precautions to protect against high radioactivity.

Table (3): the radioactivity of the radionuclides for the international and local study is compared with the current study of brick samples, which is the building material.

Table 4 shows the comparison of a particular activity in soil samples between this investigation and other studies and global values. The average of 238U in the present study is less than that in China and Lebanon (Baydoun et al., 2020; Chhangte et al., 2018b; Yang & Sun, 2022), and higher than in other studies. While 232Th contents are low relative to the other researchers (Chhangte et al., 2018b; Yang & Sun, 2022) and higher than the other studies. On other hand, the average of 40K in the current study is lower than the results in China and India, (Chhangte et al., 2018b; Yang & Sun, 2022) and higher than the other studies. Also in this study.

From the results, it is clear that the average values of 238U, and 40K concentrations are less when compared with the worldwide average value except for the average value 232Th (Santos Júnior et al., 2005).

Table 4 the radioactivity of the radionuclides for the international and local study is compared with the current study of soil samples.

C	Countries	Specific Activity centration			References
		(Bq/Kg)			
		238U	232Th	40K	
1	China	79.3	101	535.8	(Yang & Sun, 2022)
2	India	33.47	67	942.25	(Chhangte et al., 2018b)
3	Lebanon	35	34	385	(Baydoun et al., 2020)
4	Kuwait	18	15	385	(Alazemi et al., 2016)
5	Iraq (Baghdad)	16.5	9.7	368	(Abojassim & Rasheed, 2021)
6	Iraq(Najaf-Kufa)	25.73	3.72	165.16	(Hasan & Hamad, 2018)
7	Iraq(Najaf)	23.59	12.1	60.68	(Najy Hady et al., 2014)
8	Worldwide	33	45	420	(Santos Júnior et al., 2005)
9	Iraq(Babylon-Shomali)	23.08	58.69	402.24	Present Study

Conclusion

It was found that the radioactivity values for ^{238}U were within the recommended global natural limits, which were provided by (UNSCEAR 2008), except for samples from the factory (F2) that exceeded the permissible limit. For most of the ^{232}Th radioactivity values exceeded the permissible limit due to the exposure of the area to the military bombardment in two years (1991,2003), the low solubility of thorium, the geological nature of the soil. Also, concentrations ^{40}K were high in most samples because the earth was agricultural fields before the establishment of the brick factories on it. So the soil is rich in phosphate fertilizers. The radiological hazard values for (Ra_{eq} , $AEDE_{out}$ and $AEDE_{in}$) were within the recommended limits (UNSCEA 2008), values of (DR and I_{γ}) exceeded the recommended limit in most of the samples and their reason is the increase in the concentration of (^{238}U,^{232}Th,^{40}K) and because of the closeness of the brick factories to each other, and this indicates that Since workers receive radiation doses and workers must take all possible precautions to protect against high radioactivity. Using of these soil in brick industry not pose any significant radiological hazards, except for (F1, F2, and F5) factories, therefore the material can be considered safe for residents.

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