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Assessment of Radioactive Risk and Radioactivity Levels in Soil Samples from Al-Samawah City, Iraq

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Abstract

It is important to determine the level of background radiation in order to assess health risks, given the increasing incidence of cancers among people living near old buildings. Therefore, the amount of natural radioactivity in the soil of some old buildings located in different parts of the Iraqi city of Samawah was determined using a NaI(Tl) gamma spectrometer, and it was found that they contain varying amounts of natural radionuclides ^{238}U (uranium-238), ^{232}Th (thorium-232), and ^{40}K (potassium-40), and the reason for the variation is due to environmental factors and climate, agricultural methods, and levels of background radiation. The range values of ^{238}U, ^{232}Th, and ^{40}K (in unit Bq/kg) were 9.2 - 22.9, 2.7 - 11.41, and 119.43 - 174.92, respectively. Additionally, the absorbed dose (Dr) obtained in the study was 31.12 nG/h which is lower than the UNSCEAR 2008 recommended 55 nG/h for the general population, and the values of the external hazard index (H_{ex}) ranged from 0.07-0.142 to 0.095 - 0.204, with an average of 0.102 and 0.148, respectively. However, the estimated annual internal dose from inhalation of the tested radionuclides in the soil was 0.171 mSv/yr. Therefore, all the results of the current study were found to be less than the corresponding permissible limits given by the global average. Thus, the data resulting from the current study can be used as basic radiological data for future investigations.

Keywords: Natural radionuclides; Absorbed dose; Gamma radiation; NaI detector; T1 detector

1. Introduction

The majority of radioactive materials that are exposed to the public come from naturally occurring sources that are present in the environment all the time. Natural Radioactive Materials (NORM) can be classified into two main categories based on where they came from. Terrestrial radionuclides such as ^{238}U (uranium-238) and ^{232}Th (thorium-232) have a natural chain without sequencing, in contrast to ^{40}K (potassium-40), which has a half-life of almost 100 million years (Taskin *et al.,* 2009). There is evidence that when (NORM) is present in the environment, humans are exposed to high doses of radiation. Both beta and alpha particles can produce radionuclides, which the body can absorb by swallowing or inhaling. Thus, there may be a rise in internal exposure. Certain of these nuclear types create gamma radiation, which is the most prevalent form of radiation exposure in humans (Hasan *et al.,* 2011). The natural world's geology and geography largely determine the levels of gamma and alpha radiation. Different sections of the world's soil have them in varying amounts. Agricultural areas have higher soil and plant activity concentrations of naturally radioactive elements (radionuclides) than uncultivated areas do, owing to the impact of

fertilizers on the soil (Kadhim *et al.,* 2020). By contrast, plants can allow radiation effects to enter soil and water. Thus, contaminated plants are eaten by cows and cattle, who subsequently feed humans through the food chain (Ali *et al.,* 2024). Most human bodies have a relatively small amount of uranium, primarily in the bones (Ibrahem, 2024). Even though uranium is a weakly radioactive material, much of the radiation it releases is not able to travel very far from its source. If it's outside the body, as in the soil, the majority of its radiation can find its way through the epidermis and into the body, as Figure 1.

The distribution of radionuclides in the environment and their typical concentration levels in soil are of interest to many international studies to determine the levels of radioactivity in soil samples (Salman *et al.,* 2020; Oleiwi, 2021, Abojassim & Rasheed, 2021; Alasadi & Abojassim, 2022; Dosh & Abojassim, 2023).

This study aims to better understand the relationship between radiation and cancer by measuring the radiation dose of radioactivity concentration of several soil samples in the Iraqi city of Samawah. Due to the increase in cancer cases for all ages, it was necessary to conduct this study to determine the concentrations of radionuclides (^{238}U, ^{232}Th and ^{40}K) in the soil collected from different buildings in Samawah Governorate, which would provide important data on the radiation background of natural radionuclides in Samawah city and to know whether these cancer cases are due to radioactive contamination or another reason.

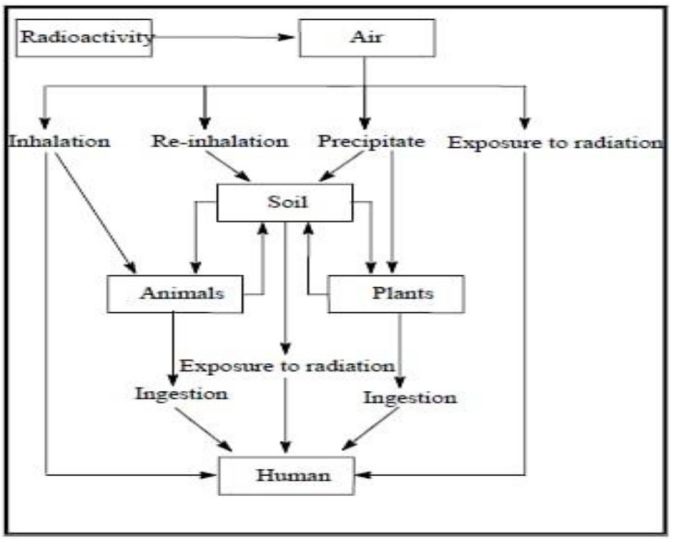
2. Methodology

2.1 Study area

Samawah City, which is situated on the Euphrates River 280 kilometers (174 km) southeast of Baghdad, is the capital of the Al Muthanna Governorate today. It is situated between 31.3188° North latitude and 45.2806° East longitude, as seen in Figure (2) (Ministry of Water Resources, 2020). The city serves as the community's agricultural market hub, where orchards and vineyards are grown (Kadhim *et al.,* 2020).

2.2 Collection and preparation samples

In order to determine the natural radiation levels, eighteen soil samples are taken in the autumn of 2023 from old buildings in the Iraqi city of Samawa. These samples were split up into nine zones, with two samples in each zone. Additionally, as Table 1 illustrates, it is found that the type of soil differed depending



Source: Duarte *et al*., 2023

Figure 1. Design of translation of radiation from air to the human body

on the area where the sample was taken. The soil samples utilized in this study were collected and then brought to the detection and analysis lab in the physics department of the University of Babylon's Faculty of Education for Pure Science. There, foreign items like gravel and broken stones were removed by crushing and cleaning them. To make sure that any moisture that could be observed was gone, these samples were dried for an hour at 100 °C. Afterward, a 300 μm-diameter sieve was employed to produce a uniform powder, which was subsequently weighed 1 kg. After that, the samples were tightly packed into a single cubic decimeter Marinelli beaker made of polyethylene plastic with a fixed volume to ensure geometric homogeneity around the detector. These plastic Marinelli beakers were placed in storage for a month after being taped shut to allow secular equilibrium to be attained between ^{222}Rn (radon) and its parent ^{226}Ra (radium) in the uranium chain (Abojassim & Rasheed, 2021).

2.3 Gamma spectrometer

The components of a gamma-ray spectrometer are an ORTEC (3" × 3") crystal NaI(Tl) detector supplied by Alpha Spectra, Inc., combined with an ORTEC-Digi Base

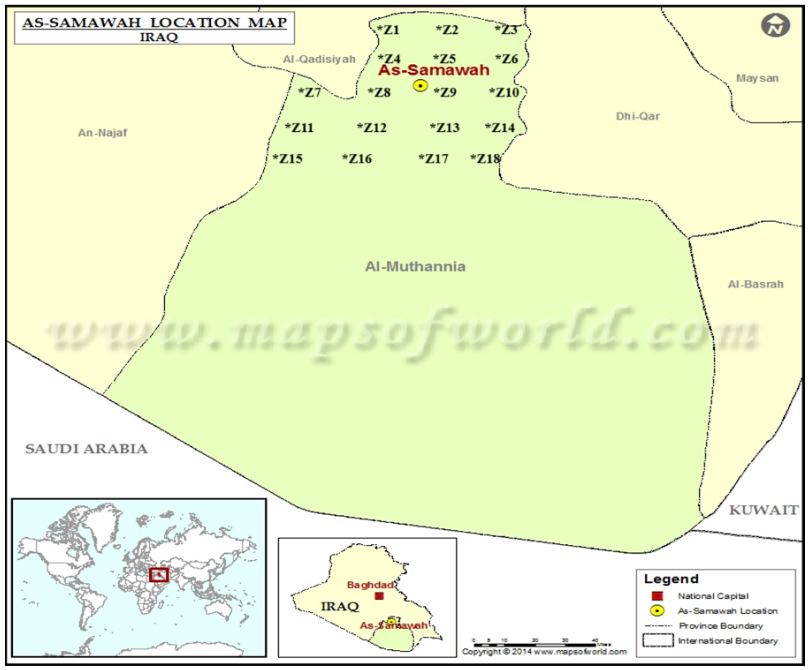


Figure 2. Study area's location on a map

Figure 3. NaI(Tl) detection system

multi-channel analyzer (MCA) with 1024 channel capacity connected for (Analog to Digital Converter) ADC (Hamed and Qadar 2018). The (MAESTRO-32) software on the PC performs the spectroscope observations and analysis, as shown in Figure 3. Compared with the typical results found in the range of (5 – 10) % for this energy in commercial NaI(Tl) detectors (Puputti, 2022), the energy resolution at the 0.662 MeV gamma of ^{137}Cs source is 8%.

2.4 Measurement of radioactivity

For the determination of radioactivity, the samples were created by setting them on the detector within the lead shielding, after which the spectrum was gathered. Every sample was measured over a five-hour accumulation period. In contrast, ^{40}K's gamma line of 1460.8 keV provided a direct approximation. Since the progenies of ^{238}U and ^{232}Th were in secular equilibrium with them, the γ-rays they released can be used to determine the specific activity at high energies and honestly separated photopeak, as found in our data. It was thus possible to determine the exact activity of ^{238}U using the gamma lines at 1765 keV (^{214}Bi). We computed the corresponding results of ^{232}Th using the γ-ray lines 2614 keV (^{208}Tl) (Dosh & Abojassim, 2023). The equation can be used to determine the radionuclide's specific activity in Bq/kg (Dosh *et al.,* 2023).

$$A\left(\frac{Bq}{kg}\right) = \frac{N}{I_{\gamma}.\varepsilon.m.t.} \pm \frac{\sqrt{N}}{I_{\gamma}.\varepsilon.m.t.} \qquad (1)$$

where m is the sample mass 1 kg, t is the counting period (18000 sec), I_{γ} refers to the radionuclide under study's percentage of gamma emission probability, N refers to net photopeak count (C/sec), and ε is the gamma efficiency.

3. Results and Discussion

3.1 Activity concentration of natural radionuclides

Table 1 displays the specific activity for the eighteen soil samples that were taken from various zones in Smawah City, and the relationship between the specific activity of ^{238}U, ^{232}Th, and ^{40}K radionuclides and the sample is depicted in Figures 4, 5, and 6, respectively.

Table 1. Specific activity concentration of the studied radionuclides (^{238}U, ^{232}Th, and ^{40}K) for different samples of soil

Sample No.	Specific Activity (Bq/kg)		
	^{238}U	^{232}Th	^{40}K
Z1	25 ± 0.8	22 ± 0.8	380 ± 3.9
Z2	23 ± 0.8	19 ± 0.7	332 ± 3.6
Z3	28 ± 0.9	20 ± 0.8	336 ± 3.7
Z4	24 ± 0.8	10 ± 0.4	285 ± 3.4
Z5	21 ± 0.8	12 ± 0.5	353 ± 3.8
Z6	10 ± 0.5	14 ± 0.6	244 ± 3.1
Z7	27 ± 0.9	15 ± 0.6	339 ± 3.7
Z8	13 ± 0.6	5 ± 3.0	212 ± 2.9
Z9	16 ± 0.7	13 ± 0.5	304 ± 3.5
Z10	24 ± 0.8	11 ± 0.5	285 ± 3.4
Z11	19 ± 0.8	10 ± 0.4	237 ± 3.1
Z12	26 ± 0.9	19 ± 0.7	253 ± 3.2
Z13	22 ± 0.8	22 ± 0.8	313 ± 3.6
Z14	25 ± 0.8	18 ± 0.7	304 ± 3.5
Z15	25 ± 0.8	9 ± 0.4	253 ± 3.2
Z16	18 ± 0.7	18 ± 0.7	342 ± 3.7
Z17	15 ± 0.7	14 ± 0.6	258 ± 3.2
Z18	21 ± 0.8	6 ± 0.3	249 ± 3.1
Ave ± SD	21 ± 0.8	14 ± 0.5	293 ± 3.4
Max ± SD	28 ± 0.9	22 ± 0.7	380 ± 3.9
Min ± SD	10 ± 0.5	5 ± 0.3	212 ± 2.9
Global limit	35	30	420

According to Table 1, the ^{238}U, the specific activity range at this location was 10 to 28 Bq/kg, with an average of 21 ± 0.8 Bq/kg. A mean value of 293 ± 3.4 Bq/kg was found for the specific activity in ^{40}K, ranging from 212 to 380 Bq/kg, while the average value for ^{232}Th was 5 to 22 Bq/kg, with an average of 14 ± 0.5 Bq/kg. The geochemical makeup and origin of the clay and sandy soil types in this region generate noticeable variations in the same nuclide activities in different samples for these values of specific activities in Smawah City. Additionally, Table 1 shows that in all samples, uranium activity is higher than thorium activity. Additionally, as ^{40}K is the most prevalent radioactive element, it is seen that its activity much outperforms that of ^{238}U and ^{232}Th. Moreover, it was observed that samples Z1, Z2, Z3, Z5, Z13, and Z14 had higher radioactive concentrations than the other samples because they were collected from regions with sandy and clayey soil, which is nutrient-rich and maintains moisture reasonably well. Because of its high level of fertility, the sandy clay soil requires sufficient fertilizing to make it appropriate for agricultural use. This explains the rise in radioactive concentrations, specifically ^{40}K. The study's soil samples had a specific activity in natural radioactivity below the global average (35, 30, and 420) Bq/kg for ^{238}U, ^{232}Th, and ^{40}K, respectively, as reported by (UNSCEAR, 2008).

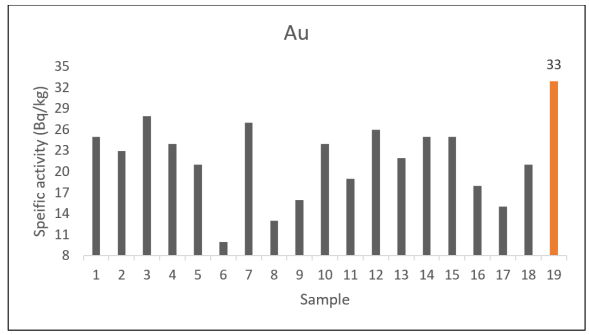


Figure 4. Specific activity of the samples ^{238}U

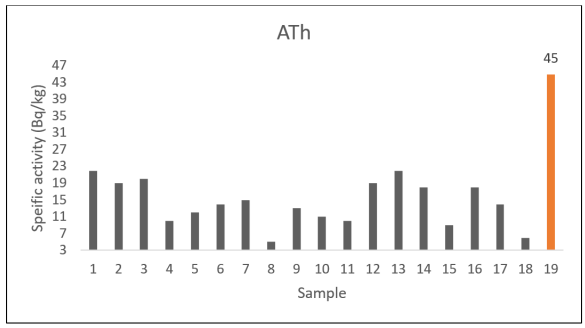


Figure 5. Specific activity of samples ^{232}Th

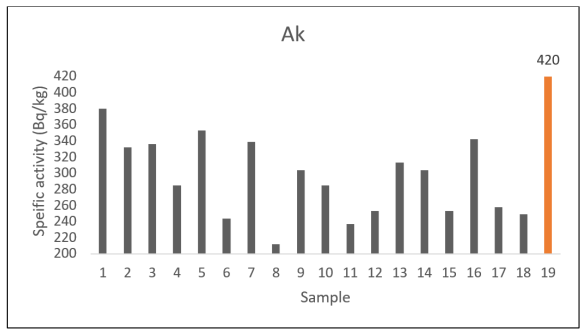


Figure 6. Specific activity of samples ^{40}K

Figures 4, 5, and 6 show the specific activity of ^{238}U, ^{232}Th, and ^{40}K, respectively, where it is clear that the specific activity of ^{232}Th was less concentrated while ^{40}K had the highest specific radioactivity concentration.

3.2 Radiological Impacts

3.2.1 Radium equivalent activity (Ra_{eq})

Radium equivalent activity in Bq/kg, which is determined by equation, was employed to determine the significance of the ^{214}Bi, ^{208}Tl, and ^{40}K activities (Alasadi & Abojassim, 2022).

$$(Ra_{eq}\ Bq/kg) = A_{Bi} + 1.43A_{Th} + 0.077A_K \quad (2)$$

where the specific activities of ^{214}Bi, ^{208}Tl, and ^{40}K in (Bq/kg) are represented by the variables A_{Bi}, A_{Tl}, and A_K.

3.2.2 Hazard Index

A hazard index is used to reflect external exposure. Equation (3) may be utilized for calculating this risk, which is represented by H_{ex} and specified in terms of the external radiation hazard index (El-Taher & Uosif, 2006)

$$H_{ex} = \frac{Au}{370} + \frac{ATh}{259} + \frac{Ak}{4810} \quad (3)$$

$$H_{in} = \frac{Au}{185} + \frac{ATh}{259} + \frac{Ak}{4810} \quad (4)$$

3.2.3 Gamma Absorbed Dose Rate (D_r)

It is possible to find the absorbed dose rate by (Abojassim & Rasheed, 2019).

$$D_r\left(\frac{nGy}{h}\right) = DCF_U.A_U + DCF_{Th}.A_{Th} + DCF_K.A_K \quad (5)$$

where DCFU (0.427), DCFTh (0.662), and DCFK (0.043) are dose conversion factors for, ^{238}U, ^{232}Th, and ^{40}K in nSv/h per Bq/kg (Pekşen *et al.,* 2021).

3.2.4 Annual Effective Dose (AED)

Utilizing a conversion factor of Annual Effective Dose of 0.7sv/Gy for a single person, the projected value was calculated. The corresponding effective dosage for an 80% interior occupancy and a 20% outdoor occupancy was then calculated using (Abojassim, 2021).

$$(AED)_{in}\ (mSv.y^{-1}) = Dr\left(\frac{nGy}{h}\right) \times 10^{-6} \times 8760\ h \times 0.8 \times 0.7\left(\frac{sv}{Gy}\right) \quad (6)$$

$$(AED)_{out}(mSv.y^{-1}) = Dr\left(\frac{nGy}{h}\right) \times 10^{-6} \times 8760\ h \times 0.2 \times 0.7\left(\frac{sv}{Gy}\right) \quad (7)$$

3.2.5 Excess Lifetime Cancer Risk (ELCR)

The value of excess lifetime cancer risk can be calculated by (Alasadi & Abojassim, 2022; Abojassim, 2021).

$$ELCR = AEDE\ .\ DL\ .\ RF \quad (8)$$

where RF denotes the fatal cancer risk factor per Sievert (ICRP uses RF as 0.05 Sv^{-1} for stochastic impacts) (ICRP, 2007); DL represents for average lifespan (estimated to be 70 years); and ELCR stands for excess lifetime cancer risk.

Table 2 shows the radiation influences (Ra_{eq}, D_r, and H_{ex}) on soil samples collected from the Smawah in Iraq. The computed Raeq for the soil samples is 64.22 ± 0.6 Bq/kg on average, with a range of 36.47 to 58.72 Bq/kg. Every soil sample that was analyzed had radium equivalent activity values that were found to be substantially lower than the 370 Bq/kg permissible limits (OECD, 1979). The estimated absorbed dose rate varied from 17.97 to 41.57 nGy/h depending on (UNSCEAR, 2008), with an average of 31.12 ± 0.5 nGy/h. This is the same as the average annual exposure to terrestrial gamma rays worldwide outside (55 nGy/h) (UNSCEAR, 2008). The bulk of the samples' recorded values in the research area are significant for health, meaning that the local population is not at risk. In the end, the specific activity detected in the soil samples determines the amount of radiation administered externally as a gamma dose. The computed average values of the external danger index ranged from 0.098 to 0.231, with an average value of 0.173 ± 0.003, as per the radiation protection report) (EC-European Commission, 1999).

These values were less than unity. One modest source of radioactive radon and its byproducts is these radionuclides. The results of the radiological impacts (indoor, outdoor, and total of AEDE and ELCR) of the soil samples collected from the city of Al-Samawah are shown in Table 3.

Table 3 displays the computed AEDE values for the outdoor, indoor, and total. The mean values were 0.04 ± 0.001, 0.15 ± 0.003, and 0.19 ± 0.003 mSv/y, in that order. The fact that these values are less than the corresponding worldwide values which are, respectively, 0.08, 0.42, and 0.50 mSv/y (ICRP, 1994). The estimated extra lifetime cancer risk for this area is shown in Table 3. The average is 0.667 ± 0.006 $x10^{-3}$, and the range of values is 0.385 $x10^{-3}$ to 0.892 $x10^{-3}$. These findings indicate that there is very little chance of developing cancer. The results of the present study concerning values of radium equivalent activity, annual effective dose rates, external hazard indices, all were found to be lower than their corresponding allowed limits given by world average.

Table 2. Radium equivalent activity, the absorbed dose rate, and external hazard index in soil samples

Sample No.	Ra_{eq} Bq/kg	D_r (nG/h)	H_{ex}
Z1	85.72	41.57	0.231
Z2	75.73	36.67	0.204
Z3	82.47	39.64	0.222
Z4	60.24	29.12	0.162
Z5	65.34	32.09	0.176
Z6	48.81	24.03	0.131
Z7	74.55	36.04	0.201
Z8	36.47	17.97	0.098
Z9	57.99	28.51	0.156
Z10	61.67	29.78	0.166
Z11	51.54	24.92	0.139
Z12	72.65	34.56	0.196
Z13	77.56	37.42	0.209
Z14	74.14	35.66	0.200
Z15	57.35	27.51	0.154
Z16	70.07	34.31	0.189
Z17	54.88	26.76	0.148
Z18	48.75	23.64	0.131
Ave±SD	64.22 ± 0. 6	31.12 ± 0. 5	0.173 ± 0.003
Max	85.72	41.57	0.231
Min	36.47	17.97	0.098
Global limit.	370	55	≤ 1

Table 3. Soil samples' outdoor, indoor, and total annual effective dose equivalent (AEDE), excess lifetime cancer risk (ELCR)

No.	AEDE $_{outdoor}$,mSv/y	AEDE $_{indoor}$,mSv/y	AEDE $_{total}$,mSv/y	ELCR*10^{-3}
Z1	0.051	0.203	0.254	0.892
Z2	0.045	0.179	0.224	0.787
Z3	0.049	0.194	0.243	0.850
Z4	0.036	0.142	0.178	0.625
Z5	0.039	0.157	0.196	0.688
Z6	0.029	0.117	0.147	0.515
Z7	0.044	0.176	0.221	0.773
Z8	0.022	0.088	0.110	0.385
Z9	0.034	0.139	0.174	0.611
Z10	0.037	0.146	0.182	0.639
Z11	0.031	0.122	0.152	0.534
Z12	0.042	0.169	0.211	0.741
Z13	0.046	0.183	0.229	0.803
Z14	0.044	0.174	0.218	0.765
Z15	0.033	0.134	0.168	0.590
Z16	0.042	0.168	0.210	0.736
Z17	0.032	0.131	0.164	0.574
Z18	0.028	0.115	0.144	0.507
Ave ± SD	0.04 ± 0.001	0.15 ± 0.003	0.19 ± 0.003	0.667 ± 0.006
Max	0.051	0.203	0.254	0.892
Min	0.022	0.115	0.110	0.385
Global limit.	0.08	0.42	0.50	-

4. Conclusion

Iraq's Smawah has less specific activity for ^{238}U, ^{232}Th, and ^{40}K than the global average values, per UNSCEAR 2000. The bulk of radiological effects, including Ra_{eq}, D_r, H_{ex}, AEDE, and ELCR, are found to be less than the global average, according to radiation protection publications. Thus, there is no danger of radioactive damage to the people living in the study area. Finally, it may contribute to this study by making a base of natural radioactivity levels in the soil of Al-Samawah city in preparation for creating a radiation map for all regions of Iraq.

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