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Estimation of Natural Radioactivity and corresponding doses in Al-Najaf Teaching Hospital, Iraq

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ABSTRACT

Measuring natural radioactivity levels within residential buildings is of great public health importance. The primary objective of the study is to investigate radionuclides concentrations in Al Najaf Teaching Hospital building in Najaf Governorate. It also aims to assess the potential risk of cancer due to radioactivity exposure. To achieve this goal, a comprehensive radioactivity survey was conducted across 29 different locations in the hospital using NaI gamma ray spectroscopy. The objective of this survey was to thoroughly evaluate the health risks that the hospital workers are exposed to and implement measures to mitigate these risks. The specific radioactivity values for the radioisotopes ^{238}U, ^{232}Th, and ^{40}K for soil samples were ranged from 1.07 Bq/kg to 39.31 Bq/kg, from 1.23 to 18.55 Bq/kg and 56.81 to 428.86 Bq/kg respectively. In addition, both the annual effective dose, the number of lung cancer cases and other hazard indices were seen to be less than the permissible limit adopted by international organizations.

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تقدير النشاط الإشعاعي الطبيعي والجرعات المقابلة في مستشفى النجف التعليمي، العراق

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الكلمات المفتاحية:

الـــخُـــلاصـــة

يُعدّ قياس مستويات النشاط الإشعاعي الطبيعي داخل المباني السكنية ذا أهمية بالغة للصحة العامة. يهدف هذا البحث بشكل أساسي إلى دراسة تركيز النويدات المشعة في مبنى مستشفى النجف التعليمي بمحافظة النجف، وتقييم المخاطر المحتملة للإصابة بالسرطان نتيجة التعرض للإشعاع. ولتحقيق هذا الهدف، أُجري مسح شامل للنشاط الإشعاعي في 29 موقعًا مختلفًا داخل المستشفى باستخدام مطيافية أشعة غاما (NaI). وكان الهدف من هذا المسح هو التقييم الدقيق للمخاطر الصحية التي يتعرض لها العاملون في المستشفى، واتخاذ التدابير اللازمة للحدّ من هذه المخاطر. تراوحت قيم النشاط الإشعاعي للنظائر المشعة (^{238}U, ^{232}Th, ^{40}K) في عينات التربة بين 1.07 و39.31 بيكريل/كغ، وبين 1.23 و18.55 بيكريل/كغ، وبين 56.81 و428.86 بيكريل/كغ على التوالي. بالإضافة إلى ذلك، تبين أن كلاً من الجرعة الفعالة السنوية وعدد حالات سرطان الرئة ومؤشرات الخطر الأخرى أقل من الحد المسموح به الذي اعتمدته المنظمات الدولية.

النشاط الإشعاعي، مطيافية يوديد الصوديوم، التعرض الخارجي، مستشفى، النجف، العراق.

1. INTRODUCTION

Terrestrial gamma radionuclides constitute a significant portion of the overall radioactivity originating from naturalistic sources. Only those nuclides possessing half-lives that are commensurate with the geological age of the Earth, such as ^{232}Th, ^{238}U, and ^{40}K, are of paramount interest due to their potential to induce both internal and external radiation hazards attributable to gamma radiation [1]. Presently, it is known that people are living in an environment that include radionuclides, where the inhalation and ingestion of these radioactive entities occur routinely through the consumption of food, water, and air, as no location on the Earth's surface is free of radioactivity [2].

Soil represents one of the most critical reservoirs of radioactivity. It serves as a fundamental raw matter in the construction of infrastructure, including roads, buildings, landfills, and recreational areas. A significant number of studies conducted on a global scale has demonstrated that ^{238}U, alongside its decay products in soils and rocks, as well as ^{232}Th found in specific types of sand such as monazite sands, are predominant contributors to regions characterized by elevated natural background radiation levels [3].

All organisms are exposed to a baseline level of natural background radiation, which serves as a reference point for evaluating human exposure to anthropogenic radioactive sources [4, 5]. According to the World Health Organization (WHO), up to 7.3 × 10^6 deaths occur annually due to indoor and outdoor air pollution, with 4.3 × 10^6 of these fatalities attributed specifically to poor indoor air quality. Human populations are continuously exposed to natural radioactivity present in the ambient environment. Terrestrial radioactive elements and cosmic rays account for the largest proportion of natural radioactivity both on Earth and within the human body [6, 7].

Monitoring of the background radiation, which changes with increasing human activity, is crucial for establishing baseline data on radioactivity. This data is vital for assessing the impact of pollution on humans and the environment, as well as for obtaining environmental quality records for future use. Interest in radionuclides, both naturally occurring and man-made, has increased since the Chernobyl nuclear accident. Due to increased public awareness, policymakers and scientists are focused on estimating the validity of ecosystems, and many researchers have conducted studies on water of oceans and naval sediments [8,9].

The quantification of soil radioactivity and the construction of risk distribution maps constitute a robust approach to ascertain the levels of natural background radiation [10, 11]. The data pertaining to natural background radiation can be employed for a multitude of applications, such as mineral exploration, risk evaluation, the detection of anthropogenic contamination attributed to uranium, and the monitoring of various environmental phenomena [12, 13]. Al Najaf, acknowledged as one of the cities in Iraq that has experienced significant economic growth, exhibits a significant inhabitance density. This is largely attributable to the pervasive chemical weathering of sandy formations prevalent throughout the region [14, 15]. Numerous studies have been conducted in recent years in Najaf Governorate to measure radioactivity [16-20].

Notwithstanding numerous prior investigations conducted to evaluate exposure severity, the majority of these studies concentrate on specific urban locales.

The aim of the current study is to ascertain the activity concentrations of isotopes ^{238}U, ^{232}Th, and ^{40}K within the surface soil obtained from the Najaf Teaching Hospital site in Najaf Governorate, which will serve as a reference for forthcoming investigations regarding natural radiation levels in the region.

In addition, the calculations of "radium equivalent activity (Ra_{eq}), external hazard index (Hex), gamma absorbed dose rates (D), and annual effective dose rates (AEDR)" will be performed to delineate the distribution profile for the assessment of radiological hazards throughout the area.

2.Materials and methods

2.1. Studied area and sample collecting

Najaf is 161 km away from the capital, Baghdad. It is one of the southern cities of Iraq. Its coordinates are 32°0′0″ north latitudes, and 44°20′0″ east longitudes (Figure 1). About 1,200,000 people live on its 28,824 km² area, and its plateau rises 70 meters above sea level [21].

Najaf featured with a desert climate, that is characterized by hot, arid summers and cold winters with minimal precipitation. The Euphrates River flows through its flat lands, and the southern parts of its desert are higher. Humidity is about 18% in June and July and 50% in December and January. The average maximum temperature is 42 ºC July and minimum temperature nearly 8 ºC in February [22]. Al-Najaf Teaching Hospital began in July 2024, The hospital is managed by a staff of 3,000 medical and administrative personnel. The total number of hospital beds is 536, including 44 intensive care beds. It also contains 16 fully equipped operating rooms for various operations.

Fig.1: Location of Al-Najaf city in Iraq and site of Al-Najaf Teaching Hospital

Soil samples were taken to quantify radiation levels at 29 distinct measurement locations. In conducting the survey, soil samples were obtained from sites situated at considerable distances from structures and thoroughfares to reduce the influence of anthropogenic disturbance on the findings. Each of the samples consisted of approximately 1.5 kg of soil sample, collected at depth with range between 5 to 30 cm.

2.2. Sample preparation for measurement

Soil specimens were extracted from the designated site at depths varying from 5 to 30 centimetres. All specimens underwent drying in an oven set to 100°C for a duration of 24 hours to ensure the elimination of moisture. Subsequently, the specimens were mechanically pulverized and subjected to sieving through a mesh with a pore size of 0.8 mm to achieve homogeneity; approximately 1 kg of the uniform soil specimen was then placed in a Marinelli (polyethylene) beaker, meticulously sealed, and stored for a minimum of 5 weeks prior to the counting phase to attain secular equilibrium. Prior to utilization, the containers were cleansed with a dilute hydrochloric (HCl) acid solution, rinsed with deionized water, and labelled with a specific code to facilitate differentiation among the samples [23, 24].

The specific activity of NORMs (Naturally Occurring Radioactive Materials) within the samples were quantified utilizing the Gamma-ray spectroscopy technique, employing a NaI(Tl) crystal of dimensions (3"×3") provided by ("Alpha Spectra, Inc."), in conjunction with MCA (Multi-Channel Analyzer) model (ORTEC-Digi Base) encompassing a spectrum of 4096 channels linked to an Analog to Digital Converter (ADC) unit via an interface. The measurements and subsequent analysis were conducted using the MAESTRO-32 software executed on the laboratory's personal computer [25]. The resolution of the system was of 6.73 keV for the 0.662 MeV ^{137}Cs photo-peak. The counting efficiency of the system was measured by using standard sources (^{22}Na, ^{57}Co, ^{60}Co, ^{109}Cd, ^{133}Ba, ^{137}Cs and ^{152}Eu Model RSS–8), where was 3.5% for 1.332 MeV of ^{60}Co. In order to subtract the background from each measurement, an empty marinelli beaker (with the same geometry) was measured. The accumulation time for each sample was 18000s just to obtain gamma spectrum with appropriate to the detector statistics.

The gamma-ray radiation risks due to the particular radionuclides ^{226}Ra, ^{232}Th, and ^{40}K were estimated through various points. The activity concentrations of the samples have been calculated using the net area below photo-peaks as below, Uranium-238 was detected by the 1.76 MeV energy that corresponded to the absorption of ^{214}Bi of ^{238}U series and used to identify and quantify the natural uranium. Natural thorium-232 was identified by the ^{208}Tl peak which corresponded to the 2.62 MeV absorption energy. Potassium-40 was identified and quantified by means of the absorption of the 1.46 MeV energy which corresponded to a sole natural isotope ^{40}K [26].

$$A_s\ (Bq/kg) = C_a/\varepsilon P_\tau\ M_s \quad \text{.....(1)}$$

Where A_s is the specific activity of the soil sample, C_a is the net area of total count rate under the corresponding peak, P_τ is the probability of absolute transition of the certain gamma line, M_s is the quantity of the soil sample in (kg), and ε is the absolute efficiency of system detector of the certain gamma line energy.

2.3. Evaluation indicators.

2.3.1. Ra_{eq} - (Radium equivalent activity)

To assess the uniformity of radiation exposure in the soil samples, the radium equivalent activity (Ra_{eq}), as a standard radiological index, was calculated as follows [27, 28].

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

In which A_K, A_{Th} and A_U refer to the activity concentrations of ^{40}K, ^{232}Th, and ^{238}U, respectively. Based on the 259 Bq/kg of ^{232}Th, 370 Bq/kg of ^{238}U and 4810 Bq/kg of ^{40}K that generate the same rate of dose from gamma, Raeq was calculated [27].

2.3.2. Hex – (External hazard index)

External exposure, expressed as the external hazard index, can be estimated via the following [27]:

$$H_{ex} = A_U/370 + A_{Th}/259 + A_K/4810 \quad \text{...(3)}$$

A_K, A_{Th} and A_U indicate the similar as in Eq. (2). An upper limit of Ra_{eq} has to be less than 370 Bq/kg.

2.3.3. D- (Rate of Gamma dose)

The concentration of radionuclides within the soil play a man rule in effective impact on the gamma dose rate (D), from this fact one can derived the rate of absorbed dose utilizing the following formula [28].

$$D\left(\frac{nGy}{h}\right) = 0.462\ A_U + 0.604\ A_{Th} + 0.0417 A_K \quad \text{...(4)}$$

D: represent the rate of dose at 1 m higher land level, and A_K, A_{Th}, and A_U are the specific activity of ^{238}U, ^{232}Th, and ^{40}K (Bq/kg), respectively.

2.3.4. AEDR - (Rate of Annual effective dose)

The rate of "annual effective dose (AEDR)" was computed depending on the following equation [28]:

$$(AEDR) = D \times T \times O_{if} \times C_F \quad \dots(5)$$

D: is representing the rate of absorbed dose in (nGy/h) unit, T refers to the residency period (T= 8760 in h/y unit), O_{if} is the residency parameter, which equivalent to (0.2), and C_F is the transformation parameter of dose with value (0.7 Sv/Gy).

2.3.5. Excess Life Time Cancer Risk

This metric can be accessed via the following formula [28]:

$$ELCR = AEBR \times DL \times RF \quad \dots(6)$$

Where: AEDR: Annual Effective Dose Rate. DL: Life expectancy, RF: fatal risk factor per Sv (0.05) for people.

Results and discussion 3.

The specific radioactivity values for the radioisotopes ^{238}U, ^{232}Th, and ^{40}K for 29 soil samples are presented in Table 1. The values ranged from 1.07 Bq/kg to 39.31 Bq/kg, with mean of 14.47 ± 8.98 Bq/kg, from 1.23 to 18.55 Bq/kg with mean value of 12.46 ± 5.46 Bq/kg and 56.81 to 428.86 Bq/kg with an average value of 252.33 ± 120.30 Bq/kg for each of ^{238}U, ^{232}Th and ^{40}K respectively.

The fluctuations in the specific activity of radionuclides, namely ^{238}U, ^{232}Th, and ^{40}K, may be attributed to the types of fertilizers employed or to alternative factors such as pH levels.

Table 1: Descriptive statistics for calculated Specific activity, Ra_{eq}, H_{ex}, D, AEDR and SD.

Parameter	^{238}U	^{232}Th	^{40}K	Ra_{eq} (Bq/kg)	D (nGy/h)	H_{ex}	AEDR (mSv/y)	ELCR (10^-3)
Min	1.07	1.23	56.81	25.64	11.55	0.07	0.01	0.05
Max	39.31	18.55	428.86	93.65	44.58	0.25	0.05	0.19
Average	14.47	12.46	252.33	51.71	24.73	0.14	0.03	0.11
SD	8.98	5.46	120.30	14.25	6.93	0.04	0.01	0.03

Additionally, the radium equivalent activity levels were computed and are presented in Table 1. The Ra_{eq} values exhibit variability ranging from 25.64 to 93.65 Bq/kg, with a mean of 41.71±14.25 Bq/kg. The values of the absorbed dose ranged between 11.55 - 4458 nGy/h and an average of 24.73±6.93 nGy/h.

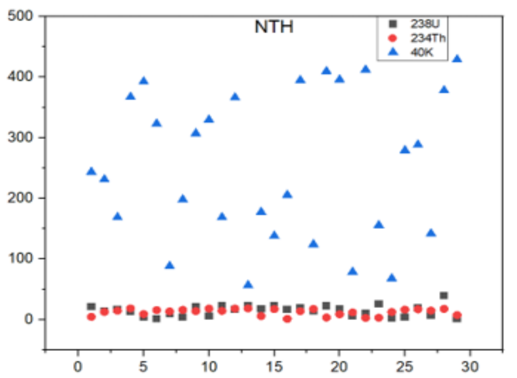

Fig.2: Specific activity of ^{238}U, ^{232}Th and ^{40}K in a soil sample at Najaf Teaching Hospital.

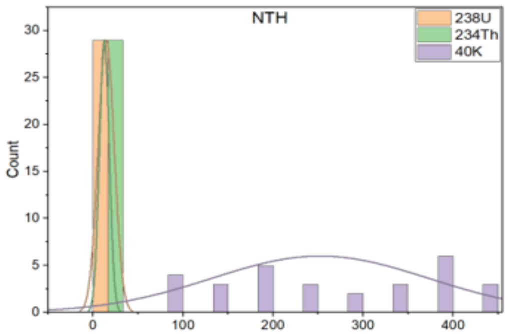

Fig.3: Statistical distribution of the specific activity values of ^{238}U, ^{232}Th and ^{40}K in a soil sample at Najaf Teaching Hospital.

Figures 2 and 3 show the specific activity values and statistical distribution of ^{238}U, ^{232}Th and ^{40}K, and Figures 4 and 5 show the radium equivalent, absorbed dose and statistical distribution of the values respectively.

From the figures above, it can be observed that the values of uranium-238, thorium-232, and potassium-40, the radioactivity equivalent to radium, and the absorbed dose were lower than the global average, which is equal to 35 Bq/kg for Uranium-238, 45 Bq/kg for Thorium-232 and 420 Bq/kg for Potassium-40, respectively [4].

It can be noted from Table 1 that the values of the External Hazard Index (H_{ex}) were (0.07-0.25) with an average of (0.14±0.04), while the values of the

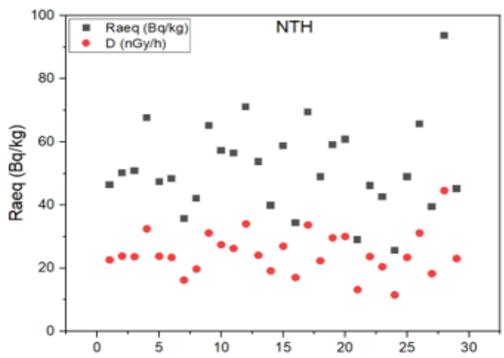

Fig.4: Values of radium equivalent dose and absorbed dose in a soil sample at Najaf Teaching Hospital.

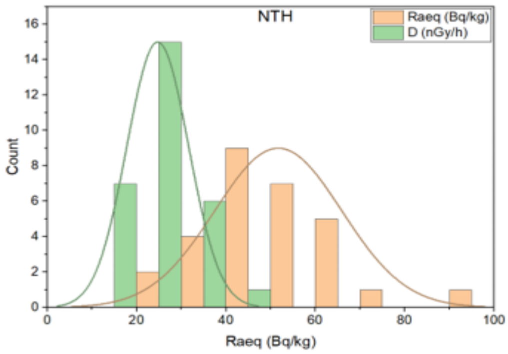

Fig.5: Statistical distribution of radium equivalent dose values and absorbed dose in a soil sample at Najaf Teaching Hospital.

Annual Effective Dose Rate (AEDR) were (0.01-0.05 mSv/y) and its average value was (0.03±0.001mSv/y), and the values of the Excess Lifetime Cancer Risk (ELCR) were (0.05-0.19) with an average of (0.11±0.03). Figures 6 and 7 represent the values of (H_{ex}, AEDR and ELCR) and the statistical distribution of the values in Najaf Teaching Hospital, respectively.

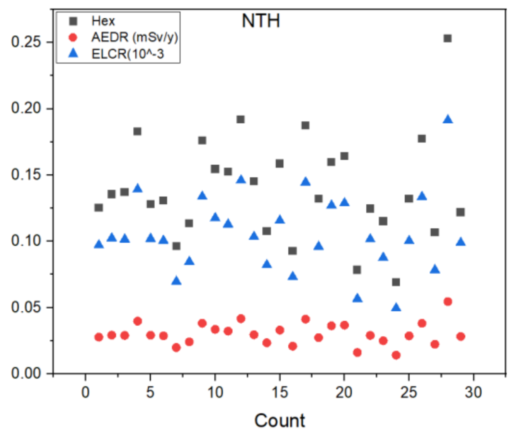

Fig.6: The values of (Hex, AEDR and ELCR) at Najaf Teaching Hospital.

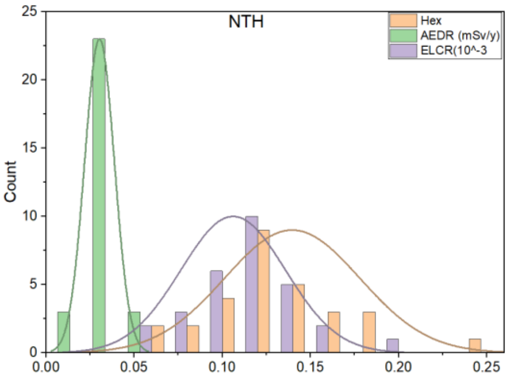

Fig.7: The statistical distribution of the values of (Hex, AEDR and ELCR) at Najaf Teaching Hospital.

The specific activity of Uranium-238, Thourium-232 and Potassium-40 in soil samples from the Study areas were compared with those from resembling Studies conducted in other countries and summary results were shown in Table 2. The comparison indicates that the Values of soils under consideration are extremely low in accordance with others. It has been reached that meaning. The values of Thourium-232 and Uranium-238 in the current study was lower than for all countries except Kuwait and Saudi Arabia. Among the value of Potassium-40 concentration, the value is high comparison with Oman but it is lower than other counters as shown in Table 2. The disparities in the radioactivity concentrations that are present in the soil of many locations all over the world Depends upon the geological and geographical conditions of that area and the extent of fertilizer applied to the agriculture lands.

Table 2: Comparison of the average specific activity of ^{238}U, ^{232}Th, ^{40}K in this study with previous studies.

No.	Country	The average of the specific activity Bq/kg			Reference
		^{238}U	^{232}Th	^{40}K	
1	Iraq (Baghdad)	16.5	9.7	368	[29]
2	Iraq (Dhi Qar)	10.85	5.81	354.11	[30]
3	Iran	28	22	640	[28]
4	Saudi Arabia	14.22	14	968.19	[31]
5	Oman	29.7	15.9	225	[32]
6	Kuwait	13.3	10	370	[33]
7	Jordan	49	27	291	[34]
8	Egypt	37	18	320	[35]
9	**Present study**	**14.47**	**12.46**	**252.33**	
10	Worldwide average	35	45	420	[4]

From the results above such as specific activity and radiological parameters, it can be concluded. According to the report of European Commission in Radiation Protection that the area of the current study is safe and harmless and posing no significant radiological threat to the population or workers in this hospital [36].

4. Conclusion

This study represents the first measurement process of natural radioactivity concentration at Al-Najaf Teaching Hospital in Najaf city, Iraq. The findings acquired indicated that the specific radioactivity of isotopes ^{238}U and ^{232}Th remained within the acceptable thresholds in this medical facility, whereas certain measurements of ^{40}K surpassed the global mean. It was also noted that there is a clear variation in the measured values between the locations. In addition, both the annual effective dose, the number of lung cancer cases and other hazard indices were less than the permissible limit adopted by international organizations. The importance of this study lies in providing information and data on natural radioactivity concentration in hospital environments, where very few studied were conducted in Iraq. It would be very useful to conduct extensive and systematic measurement campaigns to estimate radioactivity concentrations in all Iraqi hospitals, taking into account the type of workplace and using a standardized measurement methodology. This will enable comparison of estimated results in similar workplaces. These campaigns will contribute to the adoption of efficient alleviation techniques supported by trustworthy data, in addition to educating people about the possible health dangers of radiation exposure.

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