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An Overview of the Concentration of Natural Radionuclides Present in the Iraqi Environment: A Review

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لمحة عامة عن تركيز النويدات المشعة الطبيعية الموجودة في البيئة العراقية

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قسم الفيزياء، كلية العلوم، جامعة بابل، محافظة بابل، العراق

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ABSTRACT

This research conducts a comprehensive literature analysis on the topic of Iraq, specifically examining the evaluation of radioactive activity in seventeen cities and the assessment of the nuclear site environment. A systematic review of the literature and scientific studies on estimating the concentration level of naturally occurring radionuclides in soil and water were carried out using a gamma ray spectrometer system and the RAD-7 device. The results generally indicate that the natural level of radioactivity and radon in soil and water samples from the examined areas fall within the internationally permissible range. However, many areas, such as Basra, Sulaymaniyah, and the area around the thermal Al-Dura station in Baghdad, suffer from high radon levels, indicating potential locations that require attention. The research sites exhibited a comparatively lower average concentration of 238U and 232Th compared to reported calculations in numerous countries and the global average range recommended by the United Nations Scientific Committee on the Effects of Atomic Radiation in 2017. With the increase observed at the average concentration of 40K, it was found that the concentrations of radionuclides in water samples collected from several cities in Iraq were lower than international standards, except in the cities of Sulaymaniyah, Karbala, Mosul, and Najaf. The overall average level of radionuclides in water was discovered to be less than the level stated in other countries.

Keywords: NaI (Tl), CR-39, HPGe, RAD-7, Soil, Water.

INTRODUCTION

The radioactive elements of minerals and natural origin accumulating in the environment are referred to as naturally occurring radioactive material or (NORM). Among these are radiogenic elements which include uranium, thorium, and potassium. NORM is contained in processed materials and some natural resources. This leads the environment, the community and the workers to possible risks[1]. NORM list includes radionuclides with a long half-life that includes uranium-238, thorium-232, and potassium-40 and their different decay chains. This matter is a part of both the Earth's crust and the atmosphere. Among the radionuclides, the most noteworthy ones are known to be the primary source of exposure to the human body[2]. The naturally existing radioactive materials in the air, water, and earth are responsible for the natural background radiation. These two elements are the primary terrestrial radionuclides. The human body is naturally endowed with radioactive substances and individuals are exposed to them through ingestion, inhalation and external exposure[3]. The human body contains radioactive elements which are naturally occurring, and these elements are ingested, inhaled or absorbed through external contact. Nuclear weapons tests, nuclear power plant running, nuclear medicine and industrial compounds containing radioactive elements are typical anthropogenic sources of radioactive elements[4]. The ionizing radiation exposure from radioactive elements, namely radon, thoron and their decay products, is observed in various environmental components like rocks, building materials, and soil[5]. People worldwide get on average 2.4 millisieverts of background radiation from nature annually. Nevertheless, a community wherein people live in different geological structures may vary from 1 mSv/year minimum to 10 mSv/year maximum[6]. It should be borne in mind that a human being's radiation exposure is a dose written, meaning that the entire energy which enters the human body is the measure of radiation[7]. High exposure levels can prevent the body's natural systems from repairing DNA damage produced by radiation, which can have a significant impact on health and may even result in several types of cancer. Thus, it is critical to comprehend how radiation affects DNA damage and repair to create more effective methods and therapies that lessen radiation-related toxicities and stop the onset of cancer. The natural background radiation from primordial radionuclides like ^{226}Ra, ^{232}Th, and ^{40}K, concentrated in sediment, soil, water, and rock, causes variations in radioactivity levels across different regions of the world. The geological and topographical conditions of the area determine the level of radioactivity[8]. Although background radiation is a part of our surroundings, it is typically not considered a severe threat to human health due to its low exposure levels. The type and dose of radiation will indicate the kind of risk to human health. People's radiation dose varies according to the person's location and personal choices. Also, you cannot avoid the negative health ramifications that radiation may bring for a long time[9]. The present review will summarize the measured levels of natural radioactivity gas in the Iraqi governorates. Monitoring and the concentration of radioactive levels in soil and water is done by the use of gamma spectroscopy using a NaI(Tl) detector and a RAD7 detector. Besides that, it underscores the importance of scrupulously obeying all the protection

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regulations for radionuclides, their transmission to consumers, and subsequent contamination that may occur.

AREA OF STUDY

Iraq is a country located in the Middle East with the main occupation lying in the southwestern part of Asia. The specific region to be discussed here borders many other countries and it has a coastal area within the northern side of the Persian Gulf. The country's terrain can be categorized into four distinct physiographic zones: alluvial plains, an upland region, deserts, and mountains in the northeast[10]. Iraq spans an area of 437,072 square kilometers and is located in the coordinates 33.00 N and 44.00 E. The total area comprises 4,910 square kilometers of water and 432,162 square kilometers of land. Iraq shares a border with Turkey to the north. Syria is located to the west, Saudi Arabia and Kuwait are situated to the south, and Iran is found to the east[10].
According to recently released data from Iraq's national cancer registry, over 31,500 cancer cases were reported there in 2017–2018[11]. An estimated 11% of all deaths in the region are thought to be caused by cancer, making it one of the leading causes of mortality[12]. In 2018, the age-standardized cancer incidence and death rates in Iraq were 105.5 and 64.7, respectively. Cancers of the breast, leukemia, bronchus and lungs were the most common causes of malignant-associated fatalities in Iraq[13]. Iraq's high cancer incidence rates could be brought on by the country's high radiation exposure from naturally occurring radionuclides. There is a perception that rising cancer rates are directly related to the number of bombs dropped by US forces in specific locations, creating hazardous environments. Furthermore, evaluating naturally occurring radionuclides in various common plant species found in Iraq has demonstrated that environmental geology influences the lifetime cancer risk, with potassium-40 having an exceptionally high soil-to-plant transfer factor compared to other radionuclides[14]. The geographic coordinates and corresponding symbols for these governorates have been identified and represented visually on the map shown in Figure 1.

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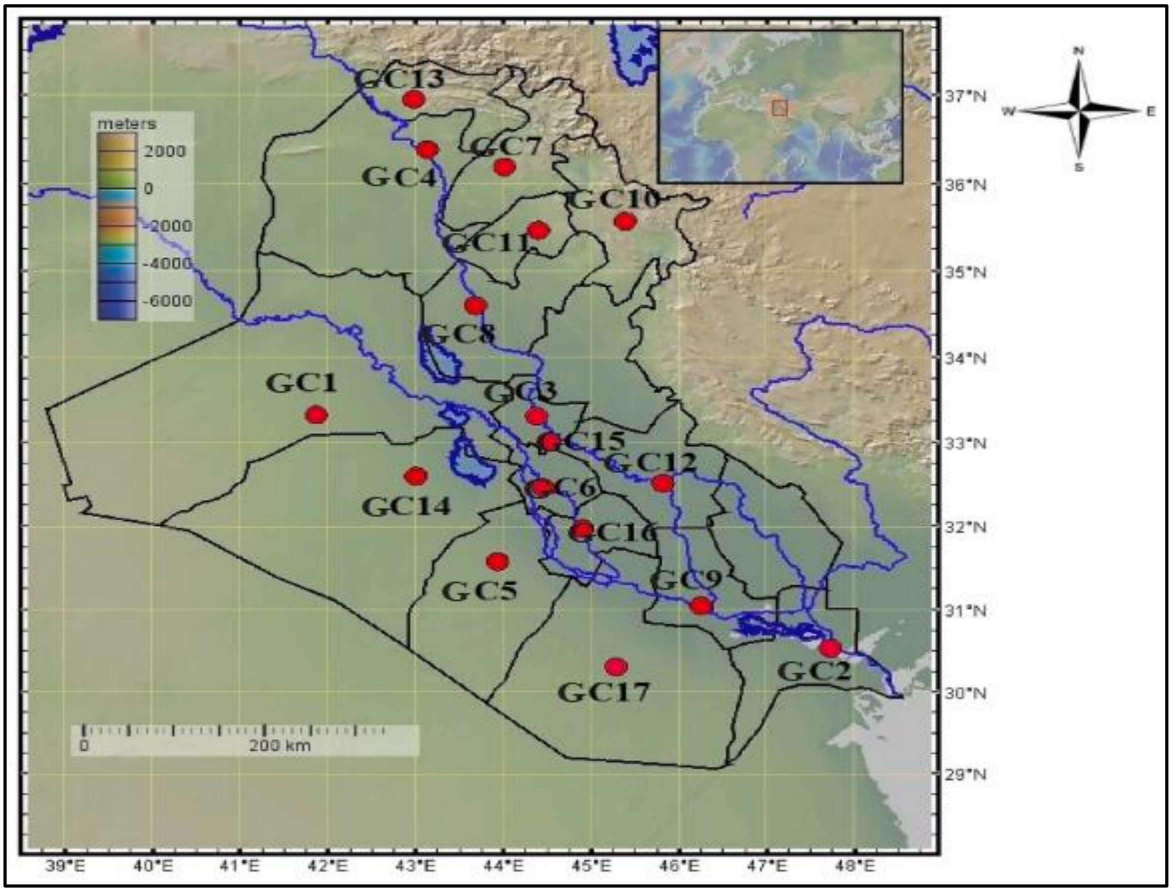

Figure 1 A map of Iraq, including the locations and symbols of the cities from which samples were collected for previous studies (using online GeoMapApp).

NUCLEAR DETECTION SYSTEMS

The detectors used in this study to measure the concentration of radionuclides are thallium-doped sodium iodide, the trace detector (CR-39), high-purity germanium, and the solid-state detector (RAD7). Thallium-doped sodium iodide (NaI(Tl)) detectors are widely used as scintillation detectors in the fields of environmental radiation monitoring and gamma spectroscopy and the areas of nuclear medicine, environmental monitoring, and homeland security applications due to their high efficiency in detecting gamma rays[15]. Solid-state nuclear track detectors called CR-39 detectors find and quantify heavy-charged and alpha particles. Because alpha particle detectors are so good at identifying and measuring radioactive materials that release alpha particles, they are essential for a wide range of scientific and environmental monitoring applications. Alpha particle detection is ideally suited for particular uses because of its unique characteristics. The utilization of high-purity germanium (HPGe) detectors is widely acknowledged as a highly advanced technique in gamma-ray spectroscopy. One of the greatest advantages of HPGe detectors lies in their superior energy resolution. The

HPGe detectors are recognized by the extraordinary features that make them a very important contemporary instruments in the science and applications. The applicability of such scanners is especially vibrant in cases when gamma-ray spectroscopy tool is needed for detection of material peculiarities and radiation environment analysis[16]. RAD7 detector is a very specific machine that only detects Radon gas and not list the population who live in that area. Radon, a radioactive gas, itself is a danger to human health and its existence constitutes a potential risk. Therefore, controlling these levels is a crucial measure and the approach that needs to be adopted for minimizing and managing risks. Radon monitoring is a significant issue to assess the problem level and make the corresponding measures. This research explores the outcomes of people being exposed to radon gas in different ecological environment settings. The quality of the natural radioactivity detection on the nuclear detection gear can be improved due to the use of proper reagents, the choice of the detector type and its efficiency which are as well influenced by the energy level of the incident radiation. Knowing those facts is important for handling the measurement procedures of the calibration and standardization, which are required to get trustworthy and accurate measurements in environmental scenarios or radiation protection. In most cases, the sensitivities of HPGe are as high as usually compared to others [18, 19]. Efficiency calibration is a referee to verify the accuracy of energy information elements at a range of energies. The calibration of the energy gain within a gamma spectrometer is done by using standard radioactive sources like ^{60}C0, ^{133}Ba, ^{57}Co, ^{137}Cs, and ^{22}Na or at least three separate energy peaks. This calibration process helps ensure that power measurements are accurate. A comparison will be made between the measured and known energies to identify the emitter energy[20]. Radiation detection and dosimetry frequently use detectors like the CR-39 and RAD7. The fundamental idea is that heavy-charged particles, such as the alpha particles some radionuclides release, interact with the substance of the detector. These particles ionize the material they pass through as they move through it. The next step is to make these pathways observable for analysis after exposure. One method that is frequently used for this is chemical etching. The material surrounding the ionization routes is often selectively dissolved using a potassium hydroxide or sodium hydroxide solution. With this procedure, the tracks become visible via an optical microscope. The more tracks' atoms of nuclear particles etch during their path the higher the etching rate of the whole material is. The analysis of the track is formed by the mass, charge, and energy information leading to the trajectory of the path of a particle. The advantages of SSNTDs, compared to other sensors capable of X-ray detection are numerous. Concerning particles that cover a wide range of interactions, this detector collects comprehensive data sets about individual particles and provides a longer duration of their track persistence. Because measurements can be conducted within long time intervals, this detector is designed simply, cost-effectively and resilient. The primary concept of measurement, quantitative analysis, is achieved by counting the number of tracks of the charged particles as they move through the detector material[23]. The process that detects only specific track phenomena similar to CR-39 or RAD7 also has some influences over rate etch in the bulks, rate etch tracks, ratio

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trench in etching, critical angle, and efficiency among the parameters. They comprise Chemicals. We should look to adjust these parameters to get a more exact quantity and identifiable trajectories which are clear. Applying and characterizing the radiation type and radiation field properties is the guideline for choosing suitable etching conditions. The experimenting and strict fixation of conditions is almost always indicated to attain the desirable results in the given circumstances[24]–[27]. The etching method stands for examining the polymers' thickness and surface chemical behavior but on a day and interval basis. With precise estimation of their mass, charge, energy, and motion orientation, as well as varying their track etching parameters depending on detector material, and its specificity, the closest to the truth information will be provided[25]. Hence, being right with these elements is pertinent for the effective application of solid-state nuclear track detectors under the right conditions.

THE METHODOLOGY USED IN THE REVIEW

The survey as part of the incorporation of the reviews from Iraq includes the measurements of the natural phenomena and the assessment of radionuclide activity in 17 cities as shown in table 1 below. The site environment assessment and analysis are done. The concentration of radionuclides in soil and the measures of transmission to plants hold great importance and the vital areas for study which can affect both human health and the environment. Thus, the obtained findings provide us with profound insights into the complex radionuclide neurotransmission processes and underline the necessity of further investigations in this field that will be of high value in risk assessment and mitigation strategies.

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Table 1: The Iraqi cities in which radioactivity was measured and city codes

Number	City	Sample city	City coordinates
1	Al-Anbar	GC1	33°16′ 06.1″N 41°08′ 50.7″E
2	Basrah	GC2	30°31′ 58.6″N 47°46′ 08.9″E
3	Baghdad	GC3	33°19′ 00.4″N 44°22′ 08.2″E
4	Mosul	GC4	36°21′ 09.9″N 43°09′ 14.7″E
5	Najaf	GC5	32°01′ 24.4″N 44°20′ 03.5″E
6	Babylon	GC6	33°00′ 20.2″N 44°29′ 16.2″E
7	Erbil	GC7	36°11′ 33.2″N 44°00′ 10.0″E
8	Salahadeen	GC8	34°26′ 57.3″N 43°37′ 30.8″E
9	Thi-Qar	GC9	31°06′ 25.7″N 46°14′ 22.1″E
10	Sulaimany	GC10	35°34′ 22.3″N 45°23′ 12.9″E
11	Kirkuk	GC11	35°33′ 41.3″N 44°20′ 59.8″E
12	Al-Kut	GC12	32°31′ 07.3″N 45°49′ 01.3″E
13	Duhok	GC13	36°56′ 18.0″N 43°03′ 51.6″E
14	Karbala	GC14	32°27′ 11.7″N 43°52′ 31.4″E
15	Al-Tuwaitha Nuclear Site	GC15	33°12′ 24.0″N 44°31′ 08.9″E
16	Al-Diwaniyah	GC16	31°58′ 25.0″N 44°53′ 33.4″E
17	Samawah	GC17	31°18′ 39.6″N 45°17′ 01.8″E

Measurements of radioactivity concentration in different environments

The main goal of this evaluation will be to carry out a comparison of effectively the intensity of the levels of radioelements originating from various water and land sources in Iraq, including, groundwater, tap water, and running water. The analysis will conform to the principles of the UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) which is internationally accepted. These directions indicate that the maximum concentration of radionuclides is allowed at 32, 30 and 420 Bq/kg average level for ^{238}U, ^{232}Th as well as ^{40}K, respectively[28].

The concentrations of radionuclide activity in water

In this part, the level of concentration of radioactive components in the water collected from different regions of Iraq will be presented. Accurate determination of radioactive concentration in water is essential for knowledge of environmental radioactivity as well as its impact on public health and the ecosystem, which in turn informs the formulation of policies related to the monitoring and regulation of environmental radioactivity.

The radioactivity concentrations of U-238, Th-232, Ra-226, K-40, and Cs-137 were calculated in 12 water samples randomly taken from Dohuk City. NaI(Tl) reagent was used in this study. Levels of U-238, Th-226, Ra-226, and K-40 were measured in the collected water samples. The mean values of radionuclide concentrations were determined as 0.0110, 4.740, 24.30, 102.40, and 0.10 Bq/kg, respectively. Data indicate that the concentration of radioactivity is lower than internationally permissible levels[29].

Al-attiyah and Kadhim conducted a study on the levels of in a study conducted in 2013, Khalid and Inaam employed the RAD7 method to evaluate the radon concentration in a comprehensive set of 88 water samples obtained from 22 specific locations along the Hilla River. The investigators estimated the mean radon concentration, which was found to be 0.103 BqL^{-1}. This suggests that the water in Hilla is devoid of any potential hazards for its residents[30].

Yousef and Abdullah calculated the concentrations of ^{238}U and ^{222}Rn in 40 water samples collected from groundwater and running water in Sulaymaniyah City. A CR-39 detector was employed for this purpose. The water samples were obtained from four different locations; the quantity of radon was 1.1840 to 7.5890 Bq L^{-1}, whereas the content of uranium varied from 0.000958 to 0.006141 Bq/L. The deep wells in the Gapylon and Kanispeka districts had the highest levels of radioactive activity compared to other global locations, mostly attributed to the Geological structure of the soil and rocks around the water sources[31].

Ali conducted a study on uranium concentration in Najaf Governorate. The study included collecting 10 groundwater samples from different neighborhoods within the city. These samples were then analyzed using CR-39 reagent. The measured concentrations of uranium-238 ranged from 1.6180±0.0430 to 5.0790±0.1370 μg^{-1}, the observed uranium concentration was discovered to be less than the mean permissible value set by the UNSCEAR and the level suggested by the WHO (World Health Organization)[32].

In 2014, Abdul Sattar evaluated the Ra-226 and Rn-222 of twenty-five water samples from various sources, including groundwater, wells and tap water, obtained from the Hindiyah area in the city of Karbala. This evaluation was performed using CR-39 reagent. The results were that tap water showed ^{222}Rn and ^{226}Ra activity levels of 6.1200 and 0.2270 Bq L^{-1}, respectively. These values were below the normal limits proposed by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). The concentration of radon and radium in the well water was (17.3480 and 0.5860) Bq L^{-1}, respectively, within the established normal limits[33].

In a study conducted in 2014, Ali, Mahmood, and Nada measured water's ^{222}Rn gas concentration samples obtained from various locations along the stream channel surrounding Salah al-Din City. The researchers employed a CR-39 nuclear path detector for this purpose. The mean radioactivity concentration of Rn-222 was determined to be 0.330 Bq/L. The aforementioned statistics exhibited levels that fall below the recommended thresholds established by the International Commission on Radiological Protection (ICRP)[34].

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In a study conducted in 2015, Jabbar and Abdul R. conducted measurements of radioactive concentration in a total of seventeen samples of surface water that were taken from the Shutt-Alarab region in Basrah. The gas concentration of ^{222}Rn was assessed using solid state detectors, while the concentration of elements ^{238}U, ^{226}Ra, ^{222}Rn, and ^{232}Th was measured using NaI(Tl). The mean concentrations of ^{238}U, ^{226}Ra, ^{222}Rn, and ^{232}Th were determined to be 0.1730, 0.1530, 0.00170, and 0.0440 Bq L^{-1}, respectively. The study's findings indicated that the mean the concentrations of radionuclides were lower than the global average[35].

In a study done in 2018 that was led by AL-Alawy, Mohammed, Fadhil, and Hasan, the levels of natural radioactivity in twenty water samples collected from river water that flows in the Al-Husseiniya area were investigated. In the course of the analysis, the radiological measurement of the natural radionuclides ^{235}U, ^{232}Th, and ^{40}K was done using the HPGe counter. Along with those, the researchers also consist data presenting Rn-222 activity recorded using the CR-39 detector. The study showed that the average activity concentrations of ^{235}U, ^{232}Th, ^{40}K, and ^{222}Rn are 1.90, 1.230, 10.10, and 2.400 BqL^{-1}, respectively. The research results show that the radioactive content was in the normal range[36].

Ali, Hassan, Laith, and Atef (2019) investigated the behavior of ^{238}U, ^{235}U, and ^{234}U in surface water sampling taken from the Al-Heera and Al-Manathira regions and located in the middle of Najaf. With CR-39 detector the neutron event rate may be recorded and monitored. The Investigated Area presented the occurrence of nuclide activity concentrations below recommended concentrations by (ICRP)[37] and the adoption of an exposure pathway[38].

An Alaboodi, Kadhim, Abojassim, and Baqir produced the study in 2020, which involved sampling and testing of ^{226}Ra, ^{232}Th, ^{40}K, ^{222}Rn, and underground water from the Najaf province, of which Al-Hurrah district was the primary sampling location. These instruments involved the scientists – RAD7 and NaI(Tl) detectors. The outcome establishes that the conveyed median values for the concentration of ^{226}Ra were found to be 1.840, 2.310, and 7.150 Bq L^{-1}, correspondingly. Firstly, the number of ^{232}Th was observed to be 1.310, 0.980, and 2.190 Bq L^{-1}, while perhaps, the number of ^{40}K was observed to be 9.07, 22.29, and 40.89 Bq L^{-1} in those water sources. Secondly, the concentrations of ^{222}Rn were observed to be 35.50, 355.500, and 712.00 mBq L^{-1} when the distances were 0.0 cm, 0.1 cm, and 0.2 cm, respectively. According to the study, the calculated annual effective dose from both drinking and river water is below the ICRP[37] 1 mSv/year limit level. Nonetheless, the yearly average effective dose in deep groundwater outweighs the ICRP reference values and thereby shows to be in a potentially unsafe zone[39].

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The concentrations of radionuclide activity in soil

In a research work that was done by Nidal, Riyadh, and Shorouk in 2011, the researchers measured uranium concentration levels in together 25 soil samples that had been taken from 5 specific sites within the city of Kut. CR-39 was utilized as the main tool for analysis in this investigation. The results indicate that the average concentration of ^{238}U was determined to be 1.2550ppm. First, the researchers found that the uranium concentration in the top layers of soil was much higher than the levels detected at other depths[40].

A 2013 study by Dashty and Ali explored the levels of radionuclides ^{226}Ra and ^{222}Rn in soil samples collected from Erbil Governorate. The detection system used was NaI(Tl).The concentrations of ^{226}Ra and ^{222}Rn in soil were seen to vary between 8.11 and 22.420 Bq/kg, and between 1459.80 and 4035.6 Bq/m^3, correspondingly. The acquired data were subjected to analysis and subsequently as opposed to those of other nations, revealing that they were lower than the global average[41].

In the year 2013, Kamal and Rasheed conducted a study whereby they assessed the amounts of ^{238}U, ^{232}Th, and ^{40}K in soil at five distinct depths, namely 10, 20, 30, 40, and 50 cm. The research was carried out in Suleimani city, located in the northern region of Iraq, encompassing a total of nine distinct settlements. The detection technique employed in this study involved the utilization of sodium iodide activated with thallium NaI(Tl). The results indicate that the mean concentrations of ^{238}U, ^{232}Th, and ^{40}K were determined to be 83.3370, 19.1470, and 284.860 Bq/kg, correspondingly. The results revealed that the levels of fall within the global range, with the exception of SaidSadiq, Penjween, and Garmek towns, where increased amounts were seen[42].

In a study conducted in 2014, Adel, Asia, and Murtdha utilized a High Purity Germanium (HPGe) detector to investigate the levels of ^{226}Ra, ^{232}Th, and ^{40}K concentrations in soil samples collected from Baghdad, specifically Al-Sader City. The concentration of radioisotopes varied from 4.1200 to 44.860, 6.110 to 11.950, and 2.8200 to 709.520 Bq/kg, respectively. The finding was that they went below the world average norms[43].

In 2014, the measurement was done by using the digital radon soil detectors at Salaheddin. Analysis of the samples collected by the region with Takreat showed that the soil from this region has the highest radon level, with a value of 100.750 Bq/m^3. On the other hand, though, Al-Faris had the lowest spectrum, which was 45.250 Bq.m^{-3} with an average of 77.070 Bq.m^{-3}. The resulting data demonstrates that the readings of radon gas in the soil were under the tolerable levels that are set by the International Commission on Radiological Protection (ICRP) being 200 Bq/m^3[37].

A study by Ali in 2014 aimed at determining the contamination of soil with uranium in ten localities of Najaf province covering all of the possible soil types in the selected area. CR-39 was per se the main parameter used in conducting the assessment. According to the level uranium had

values ranging from 0.093 to 0.184 (ppm). Indicator informs that the result report of this survey's submission is significantly below the given international expectations[32].
In a study which was carried out in 2014 Nahlah, Shaymaa, Alasadi and Almayahi found out the level of radioactivity in soils across the Najaf governorate. The field study looked at seven separate locations. The experimenters used NaI(Tl) as the solution for measuring radioactivity. The mean assessed values for ^{232}Th, ^{238}U, and ^{40}K were 17, 58, and 250 Bq/kg, correspondingly. The study revealed that the average radioactive results were observed to be below the established international limits[44].
In a study conducted in 2014, Shafik, Asia, and Muna conducted an assessment of ^{238}U concentration in soil models obtained from different depths in the city of Al-Anbar. The CR-39 detector was employed for this purpose. The quantities of uranium varied between 8.970 and 45.520, 10.620 and 37.290, and 27.220 and 4.440 Bq kg^{-1} at depths of 15, 30, and 45 cm, respectively. The data analysis statistically conducted on the data reveals that the three depths' average value was 23.270 Bq/kg, which is observed to be lower than the global mean value recommended by (UNSCEAR)[45].

In 2015, a study conducted by Laith and Shaher aimed to ascertain the radiation levels that naturally occur in soil models. A total of 19 soil models were taken from various places throughout Nineveh Province. The method employed for this estimation was NaI(Tl) analysis. The arithmetic means of U-238 (33.550 Bq kg^{-1}), Th-232 (41.240 Bq kg^{-1}), and K-40 (21.520 Bq kg^{-1}) were published, as well as the mean concentration of 326.740 Bq kg^{-1} for the last radionuclide. The amounts of radiation that it was endured were more than the average on the world but not 238U which was found to have the level higher than the average[46].

The investigation conducted by Laith, Hazim, Nada and Mahmood with 2016 published study revealed that they detect the pollution level of gamma rays using HPGe in the soils of Thi-Qar Governorate. The obtained data demonstrate the average activity of the radionuclides elements U-238, Th-232, K-40, and Cs-137: Bqkg^{-1} are in the range of 29.20, 22.70, 304.60, and 3.150, respectively. However, the data was processed, and afterwards the result was compared to the global average[47].

In a study conducted in 2016, where the NaI(Tl) detector was used, Mahmoud, Hassan and Al-Taghreed revealed that naturally occurring radionuclides (U-238, Th-232, and K-40) are concentrated in soil samples extracted from the Babylon region. He stated that the average samples are represented by the average activity numbers, which will be 15.4850, 15.5050, and 232.5400 Bq kg^{-1}. Radioactivity occurred, as claimed by Karim and Daroysh Hameed (2016). It was not high enough for any hazardous health effects to occur, at least not at the international standards[48].

Research conducted in 2016 by Leena has examined the soil models taken from the Al-Dura electrical station that is located in the southern region of Baghdad. These models represent the 13

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sites where the breach of the border of U-238, Th-232, and K-40 radionuclides has been detected. The detection was fulfilled by using NaI(Tl) as a method for the analysis. The diagnosis was made by measuring the radio activity average values of medical radionuclides and determining them to be of the normal type of values at 40.470, 15.730, and 2094 Bq/kg, respectively. Results of radio isotopic dating established a nuclides abundance less than commonly seen in the world, but there was an increased level of ^{40}K[49].

In a mid-2017 research article, Taqi, Ali, Abbas, and Laith just focused on the retained quantities of natural radionuclides in 23 collected soil samples (as it was investigated in four different areas within the city of Kirkuk). The samples were analyzed using a high-purity germanium (HPGe) detector. The study determined that the activity concentrations of ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs ranged from 7.310 to 63.330, 3.540 to 42.950, 103.210 to 798.520, and 0.70 to 9.530 Bq/kg, correspondingly. The results indicate that there are no negative effects of radiation in the research area, and all study results were within internationally permissible limits[50].

In the year 2017, Mohsen and Saif conducted a study whereby they assessed the levels of radioactivity in 10 soil models obtained from the Babil Governorate. The measurements were taken at two different depths, specifically 5 cm and 25 cm, utilizing a gamma spectrometer system. The findings indicated that the mean concentration the radioactivity measurements for ^{40}K, ^{238}U, and ^{232}Th are as follows: at a depth of 5 cm, the radioactivity values are (68.2510, 2.4330, and 2.7880) Bq/kg, respectively; at a depth of 25 cm, the radioactivity values are (66.2240, 1.9180, and 4.2250) Bq/kg, respectively; average radon gas level in the soil was (612.20) Bq/m^3 at a depth of 50 cm and (150.7430) Bq.m^{-3} at a deepness of one hundred cm. The findings fall within the prescribed thresholds, as advised by the United Nations Scientific Committee[51].

The quantities of ^{226}Ra, ^{238}U, ^{232}Th, and ^{40}K were reported by Rasha, Raghad, and Rana in 2018. The measurements were conducted on eighteen soil models in Basra using an HPGe system. The level of radioactivity was estimated within the geographical areas of the study area. The calculated mean values for Abu Al Khasib were 58.440, 43.560, 19.380, and 321.760 Bq kg^{-1}, whereas for Ad Dayr they were 45.710, 35.530, 20.330, and 337.020 Bq kg^{-1}, respectively[52].

A study conducted by Amin, Al-Khateeb, and Abd (2018) examined the presence of natural radionuclides, specifically Uranium-238, thorium-232, and potassium-40 in soil models collected from Bu'Aitha, located in the southern region of Baghdad. The researchers employed NaI(Tl) as the detection method for their analysis. The average radioactivity level of natural nuclei (^{238}U, ^{232}Th, and ^{40}K) was calculated as 7.350, 2.890, and 204.540 Bq/kg, correspondingly. Radioactivity concentrations fall within internationally permissible limits[53].

In their study conducted in 2019, Malik, Hanaa, Muna, and Thoalfiqar conducted an assessment of the level of U-238 in soil samples of the study area obtained from twenty distinct locations inside the AL-Hamdaniya region, situated to the east of Mosul. The researchers employed the

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trace detector as a means of measurement; the uranium-238 concentration in the city exhibited a range of values, with measurements ranging from 0.313 to 0.784 ppm. The average concentration was determined to be 0.488 ppm. It is worth noting that these values were found to be below the global range[58].

Salama, El-kameesy, and Rawaa (2019) conducted a study in which they analyzed the amounts of ^{235}U, ^{238}U, ^{232}Th, ^{226}Ra, ^{40}K, and ^{210}Pb in soil models using NaI(Tl) at Al-Anbar city. The activity levels of U-235, U-238, Th-232, ^{226}Ra, K-40, and Pb-210 were determined to vary from 1.28 to 1.34, 25.4 to 26.1, 11.51 to 11.75, 20.09 to 21.94, 96.53 to 112.130, and 19.980 to 20.760 Bq/kg, correspondingly. The results fall below the global average range[54].

In a study conducted in 2019, Majied and Anees investigated the levels of the level of radon in soil models obtained from 20 different regions within the southern Iraqi city of Al-Diwaniyah. Samples were obtained from various depths (0, 0.1, 0.2, 0.3, and 0.4 m) in each region, and the CR-39 detector was used to measure the level of radon present. The findings indicate a negative correlation between radon gas level and soil depth, with values ranging from 163.60 to 689.90 Bq/m ^{3} and an average of 350.60 Bq/m ^{3}. In light of the results, it was determined that the levels of radon gas in each model were under the recommended threshold of 600 Bq/m^3 as proposed by the International Commission on Radiological Protection (ICRP)[55].

In a study conducted in 2023, researchers Esraa and Khalid examined the amounts of naturally occurring radioactivity in soil models taken in Babylon Governorate, by utilizing NaI(Tl) as a detection method which is the results of the study showed that average levels ^{238}U ranged from 0.36598 Bq/kg to 2.2188 Bq/kg, with an overall average value of 0.9590013 Bq/kg. Similarly, the specific activity of ^{232}Th varied between 0.58962 Bq/kg and 21.79410 Bq/kg, with an average value of 6.019551 Bq/kg. Furthermore, the concentration of ^{40}K ranged from 145.79660 Bq/kg to 291.52570 Bq/kg, with an average value of 205.711170 Bq/kg. The collected samples from the Babylon city had values that were found to be below the allowed thresholds[56].

DISCUSSIONS

This review includes an assessment of levels of natural radioactivity found in water and soil within the time frame from 2011 to 2023 in Iraq. Evaluations of the concentration of radionuclides within the human body are of utmost importance to the well-being of Iraqi citizens, as high levels of these radioactive elements that can contribute to the development of many forms of cancer. Measurement of radon activity and natural radionuclides was performed using various detectors. The review results revealed differences in radioactive concentration levels observed in soil and water samples that were taken at different levels and from the surface. The reasons behind the rate of presence of radioactive elements in the samples analyzed can be due to a myriad of factors such as geographic conditions, physical concentration of the research area, wind speed, humidity, temperature, and the particular substance being studied. Finally, research shows some lower and upper concentrations of uranium-238 with soil model values ranging from 0.093 to 83.337 per kilogram. The revealed results documented the fact that the ^{232}Th threshold in soil samples coming from different areas across the governorates of Iraq spread in a range ranging from minimum and maximum values of 2,890 Bq/kg to 42,950 Bq/kg. The study tabulated data on 40,000 printed works from a range of cities, varying in scale from one end to the other. The minimum concentration was 2,8200 Bqkg^{-1} in Baghdad, which is the lowest concentration recorded in the southern part of the country, while the highest concentration of 2,094 Bq/kg was recorded at the Doura power facility that uses coal as fuel. Fuel type. Soil samples were taken from different areas, and it was found that ^{222}Rn concentrations ranged from a minimum of 77,070 Bq/m^3 in Saladin residents to a maximum of 4035.60 Bq/m^3 in Erbil. The level of the radioactive isotope ^{226}Ra in the soil was evaluated, and it was found that the lowest value was 4.12 Bq kg^{-1} in Baghdad and the highest value was estimated at 63.33 Bq/kg in Kirkuk.

The reported results indicate that samples of ^{238}U water that were found in different locations in Iraq displayed the range of levels from a minimum of 0.011 Bq/L to the maximum of 3.50 ppm in the water. The conclusions of the research confirm that the level of concentration of ^{232}Th differs much in samples collected from urban areas. The city of Basra was the town that registered the lowest reading level of 0.0440 Bq/L, while Dohuk was the city that showed the highest reading level of 24.30 Bq/L. The results of the study provide evidence that this water contains different components of ^{40}K. From the locations measured in this study, Najaf showed the least containment of 9.070 Bq/L, while Dohuk was found to have the highest level of 102.40 Bq/L. It is worth to mention that the investigators established multiple levels of the ^{222}Rn concentrations in the inspected water samples going from the minimum detected value of 0.0620 Bq/L in Basra up to 712 Bq/L in Najaf. The removed study revealed the major difference in the level of ^{226}Ra going through water models, as the minimum value registered was 0.1530 becquerels per liter in Basra, while the maximum value hit 7.150 becquerels per liter in Najaf.

The study offers observations on the concentrations of some isotopes namely ^{238}U, ^{232}Th, and ^{40}K recorded in soil samples collected in Iraq. While comparing and measuring changes according to worldwide benchmarks and practical data, it has its own unique feature. This study underlines the need to do collective research on empirical data and areas from different geographical settings in order better to comprehend uneven distribution of radionuclide concentrations in the region. The provided material has significant value in the process of enhancing global models and establishing standardized practices. The data indicates that the average percentage of uranium-238 in the surveyed research sites is somewhat lower when compared to the global average. There is notable diversity observed in the average concentration of thorium-232 when compared to worldwide standards and empirical data that has been collected. The concentration of ^{40}K displays considerable fluctuation when compared to both global levels and empirical data.

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The main reasons for the fluctuations in the results of previous studies described above are:

- This can be attributed to the geographical environment of the research area, the geological nature of the study area, wind speed, humidity, temperature, and the nature of the materials being analyzed.
- Previous studies have shown that ^{238}U, ^{232}Th, and ^{40}K radioactivity concentrations are generally acceptable. The values are below the limit recommended by the United Nations Scientific Committee on the Effects of Atomic Radiation.
- The specific activity of potassium is higher than that of uranium and thorium due to the geological nature of the sites of previous studies.
- In some studies, the specific activity of thorium was higher than that of uranium because the study areas may be muddy and do not contain sedimentary or igneous rocks.
- The results showed that the concentrations of radon and thoron, on average, were lower than the permissible standard values issued by the United Nations Scientific Committee on the Effects of Atomic Radiation. This is because the specific activity of uranium is lacking in the sites of previous studies, or the reason for the decrease in the concentration of radon gas may be because the area covered by the study is agricultural land rich in water.
- The radon concentration in most samples is low due to the high humidity in the study area. The measurement may have been carried out in the winter.

CONCLUSIONS

This review comprehensively examines research conducted to assess levels of radioactive materials in soil and water within Iraq during previous decades based on available information. We note that examining the levels of natural radioactivity in Iraqi cities produced a wealth of data proving that the measured concentrations of natural radionuclides fall within acceptable limits except in Suleimani, Al-Dura thermal power plant, and Basra and represent typical levels of radioactivity. This research advances knowledge of the radiation environment in Iraq and provides important information for making informed decisions on urban planning and public health activities.

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Conflict of interests

There are non-conflicts of interest.

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الخلاصة

يقوم هذا البحث بإجراء تحليل شامل للأدبيات المتعلقة بدراسة تقييم النشاط الإشعاعي في سبعة عشر مدينة وتقييم بيئة الموقع النووي في العراق. تم إجراء مراجعة منهجية للأدبيات والدراسات العلمية حول تقدير مستوى تركيز النويدات المشعة الطبيعية في التربة والمياه باستخدام مطياف اشعة كاما وجهاز الراد-7. وتشير النتائج بشكل عام إلى أن المستوى الطبيعي للنشاط الإشعاعي وغاز الرادون في عينات التربة والمياه من المناطق المدروسة يقع ضمن النطاق المسموح به دوليا. إلا أن البصرة والسليمانية والمنطقة المحيطة بمحطة الدورة الحرارية في بغداد، تعاني من ارتفاع مستويات غاز الرادون، مما يشير إلى مواقع محتملة تتطلب الاهتمام. أظهرت مواقع البحث متوسطًا أقل نسبيًا لتركيز اليورانيوم والثوريوم مقارنة بالقيم المبلغ عنها في العديد من البلدان ومتوسط القيمة العالمية التي أوصت بها لجنة الأمم المتحدة العلمية المعنية بآثار الإشعاع الذري في عام 2017. مع الزيادة الملحوظة في متوسط تركيز البوتاسيوم وتبين أن تركيزات النويدات المشعة في عينات المياه التي تم جمعها من عدة مدن في العراق كانت أقل من المعايير الدولية، باستثناء مدن السليمانية وكربلاء والموصل والنجف. وقد تم اكتشاف أن المتوسط العام لمستوى النويدات المشعة في المياه أقل من المستوى المذكور في بلدان أخرى.

الكلمات المفتاحية: كاشف يوديد الصوديوم، كاشف الأثر، كاشف الجرمانيوم، جهاز الراد-7، التربة، الماء.