International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 15s,2025
https://theaspd.com/index.php

Using A Nuclear Trace Detector (CR-39) To Determine The Percentage Of Radon Gas In The City Of Shatrah

Ibtihaj Kadhim
Department of Biology Science, College of Education for Girls, Shatrah University, Iraq, Ibthhaj-ahmad80@shu.edu.iq& Ibtihajkahdim@gmail.com, 0000-0002-2289-7643

Abstract
Background: *Rn^{222} is the second most common Cause of lung cancer. Radon is produced from uranium-bearing rocks and can seep through the ground and into buildings through passages created by faults, fractures and permeable sediments.*
Methodology: *Building stones containing uranium are an important source of radon gas in the environment, (CR-39) was used to study the activities of charged particles and fragments resulting from fission.* ***Results:*** *The highest concentration recorded in the industrial area was (1614.087±18.56069) Bq/m^3, while the lowest concentration recorded in the doctors' area was (1037.417±9.395634) Bq/m^3 .*
Conclusion: *While the overall average was (1327.953) Bq/m^3The results were recorded higher than the limit of normal values specified by the World Health Organization (800)Bq/m^3 (World Health Organization). This indicates contamination of all samples.*
Keywords: *Radon Rn^{222} ,isotopes , radioactive activity , Radon properties*

Background: Radiation spreads in nature as a result of the contribution of radioactive isotopes to the structure of the matter surrounding us. The phenomenon of radioactivity and the resulting radiation existed in nature long before the existence of life on Earth. It is believed that radiation was one of the products of the big bang, and the phenomenon of radioactivity was discovered by the French scientist. Henri Becquerel, from whom I derived the expression to indicate the ability of the nuclei of some atoms to spontaneously transform into other nuclei, and radioactivity is accompanied by the emission of rays that were later known and identified (1). The majority of the elements found in nature that make up the periodic table (oxygen, hydrogen, copper, iron, sulfur, and uranium) are believed to constitute the basic building blocks in building material existence. To indicate the capacity of the nuclei of some atoms

Radioactivity is accompanied by the spontaneous transformation into other nuclei, and that each element has one state in which it appears that determines its chemical and physical properties and qualifies it to occupy a specific place in the table and not another in the table. The phenomenon of the presence of more than one physical (nuclear) state for each element was discovered, which is called (isotopes), and the isotopes of the element differ. Their nuclear properties are the same, although their chemical properties are identical.((2)Chemical reactions, and thus the chemical properties of the elements, are linked to their electrons, while nuclear properties depend on the composition of the nucleus (1). Humans are exposed to natural radiation resulting from the elements available in rocks. In addition, they are exposed to radiation from industrial sources as a result of previous nuclear tests, radiation accidents, or industrial technological activities (3).

Radon gas is considered one of the most important natural sources of radiation. It is a colorless, odorless radioactive gas produced by the decomposition of uranium. It weighs seven and a half times the weight of air, and the radiation generated from it constitutes half the radiation dose to which humans are exposed from all natural sources combined, which is much greater than the radiation dose resulting from various industrial activities. In fact, this gas is considered in many countries to be the greatest continuous source of radiation, and it has sometimes reached the point where people are exposed to it up to eight times the maximum limit allowed for miners, without them realizing this danger.Exposure to this radiation is usually from inhaling air laden with radioactive radon gas and what is generated from it. The danger intensifies as a person inhales radon gas while bathing in water rich in it (4) .

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 15s,2025
https://theaspd.com/index.php

The dangers of the presence of radon gas

The presence of radon gas in homes constitutes a type of environmental risk that should be alerted to, as inhaling it for long periods of time causes lung cancer. It also contributes, when disintegrated with its nuclides, about 14% of the radiation emitted from natural sources, and most of this dose results from inhaling radionuclides, especially in places Closed areas where radon gas tends to accumulate

The negative effect of this gas has been observed for a long time, but the extent of its danger and its role in causing lung cancer were not confirmed until recently. To be more precise, radon nuclides are the main cause of infection, as they are more active than radon, as the energy resulting from their decomposition reaches the same amount as the energy resulting from the decomposition of radon gas itself (5).

Physical and chemical properties of radon

Radon belongs to the noble or inert gases. The radon atom, like other rare gases, rarely reacts, so it can spread freely. Across all gas-permeable materials, because they are chemically inert and not electrically charged, they are radioactive, meaning they decompose automatically, producing dust particles of other radioactive elements. These elements are electrically charged and can stick to the wall of the lungs and in turn decompose into other elements. During this Decomposition It emits a type of radiation called alpha rays. The nucleus of the helium atom is a type of ionizing ray, meaning that it causes ionization of living cells. It is what leads to their damage as a result of destroying the DNA of these cells, which is the first step to lung cancer, and because alpha rays are relatively heavy particles and therefore they can cross short distances in the human body, meaning they cannot reach the cells of other organs to destroy them (6)

Radon sources

Radon comes from soil, water, and building materials. . Approximately 80% of the gas to the external environment is produced from the upper surfaces of the Earth. The availability of radium 226 and uranium 238 is the main element in the release of radon gas into the soil. The difference in the proportion of radium and uranium from one place to another is due to the geological structure, as is clear in Figure (1). Rocks in the Earth's crust are formed at about 1 millicurie per gram (5). Every disintegration of a radium atom present in soil or rock grains can escape into the external environment. Studies indicate that about 10% of radon gas generated per meter closer to the soil surface is released into the external environment (5)

Building materials made from soil and rock, such as cement, blocks and ceramics, contain radioactive materials of natural origin, such as uranium and radium, which generate radon gas. These materials have sufficient permeability to release the radon gas generated within them into the external environment. Figure (2) shows the main places from which radon gas enters buildings. In general, the concentration of radon gas inside buildings depends on the habits and behaviors of residents and ventilation methods.. Humidity and temperature are also affected, as temperature plays an important role because the temperature inside buildings is usually higher than outside. It generates a pressure difference, which leads to the air being sucked into the soil under the house, which in turn can raise the concentration of radon inside. It has been found that the concentration changes from time to time, even between night and day.

Figure (1) Figure (1) shows the release of radon gas from the decomposition of uranium in soil.

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 15s,2025
https://theaspd.com/index.php

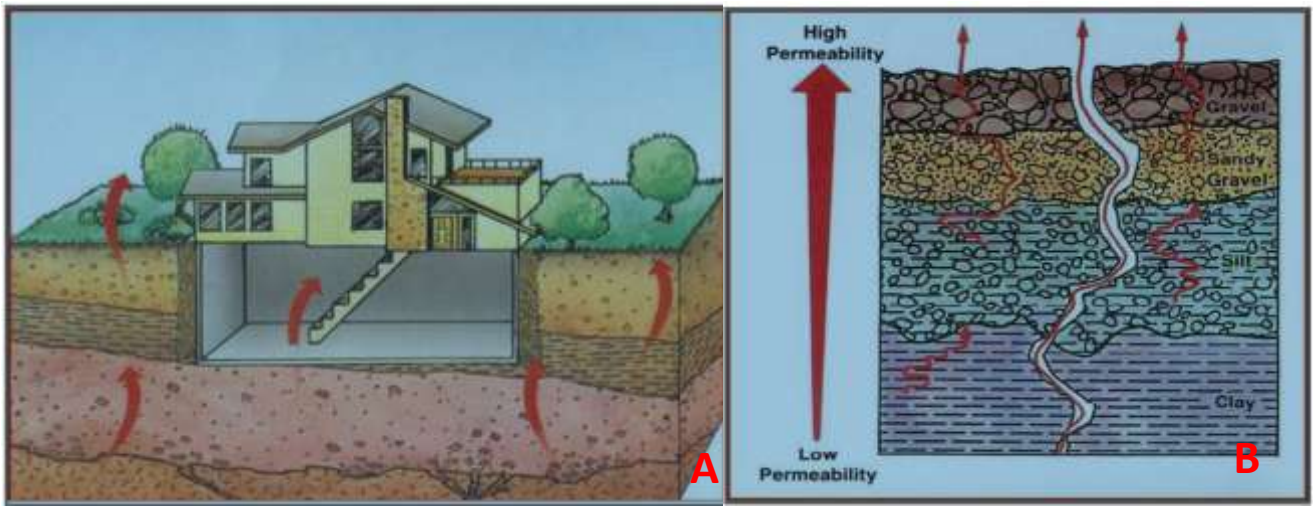


Figure (2) (A)Places from which radon enters buildings,(B) mechanism of external radon transmission

Aim:

The study measures background radiation spectra, due to its role in studies to protect the environment from pollution, monitor natural and artificial radioactivity, and explore the possibility of the presence of radioactive materials. The gas results from the natural radioactive decay of uranium, which is found in all rocks and soil. It can also be found in water, and easily seeps from the soil into the air, where it decays and produces more radioactive particles. During breathing, particles collect on cells lining the airways, can damage DNA and possibly cause lung cancer. Radon is moderately soluble in water and some other liquids.

Methodology:

Calculating radon concentration: The long-term measurement method is used using solid nuclear impact detectors and is considered more efficient in measuring radon gas concentrations. **(CR-39)**detector was used. The detector is placed in closed rooms in a cylindrical or semi-conical shape to measure the concentration of gas released from the soil. Radon emits alpha particles and its offspring, which balance between it and them. The sample is exposed to the rate of radon gas leakage on the walls of the room, depending on the dimensions. The best distance for the irradiation system is when the distance between the threshold surface and the detector is greater than (7 cm) [9]. It is worth noting that its effect is about (55-60%), while the effect of radon is about (40-45%). Since radon and $\mathbf{Th}^{234}$ come from the same element (they belong to two different decay series). They can only be separated on the basis of the large difference in decomposition rates. The presence of $\mathbf{Th}^{234}$ can be neglected by inhibiting diffusion through the use of a polymer membrane or a thin layer of sand, or on the basis of the distance between the detector and the threshold. **Radon** and $\mathbf{Th}^{234}$ can be distinguished by the effects formed by the molecules from The alpha emitted because the radon diameters are larger than the effects of $\mathbf{Th}^{234}$.

Impact mechanics: Damage areas formed after being treated with a chemical can be observed to show them using an electron or optical microscope. The shape and type of damage areas depend on the mass, energy and charge of the falling particles and the type of solid [10]. The ion explosion theory explains how polymers are composed of large, repeating and interconnected molecules. They are called monomers, Because they are often interconnected plastic materials by a covalent bond dominated by hydrogen and carbon (HC). When exposed to radiation, they produce small polymer chains with ends called active radicals Ionic radicals have the ability to interact with each other or with other atoms. [11] Irradiation melts the polymer or fuses its molecules. Incident radiation causes irritation and ionization of molecules, Destroying the links between them and damaging the polymer under normal conditions.[12] The damaged areas have greater energy. Areas affected by ionizing radiation It has the ability to react with alkaline solutions such as sodium hydroxide compared to healthy areas. The chemical solution quickly reacts to the areas affected by radiation, causing an increase in depth and diameter. By increasing the skimming time, the latent effect of ionizing radiation can be observed. Under the microscope.[13]

3- Diffusion Constant Calculation: The diffusion constant (K) is used to measure gas concentration, represented by the mathematical relationship [14].

P= KCT .....(1)

P: The intensity of the effect represents Tr. cm^{-2}

K: constant propagation

C: Radon gas levels in airspace of unit Bq. cm^{-3}

T: Irradiation time in seconds

D: represents the intensity of impacts in Tr. cm^{-2} h^{-1} according to the equation

D =P/T = K.C ..... (2)

Depending on the dimensions K it is possible to find the diffusion constant geometry of the experimental chamber represented by the relation:

$K = 1/4\ r(2\cos \theta_c - r/R_\alpha)$ .....(3)

Where r: the current diameter of the tube is 1.19 cm and θ_c is the critical angle of the detector

CR-39, 35 C°, and Rα The range of alpha particles in the air emitted from Rn^{222} and the value of 4.15 cm appears in equation[10] .

$= (0.005\ E_\alpha + 0.285)\ E_\alpha^{3/2}$ .....(4) R_α

E α The energy of alpha particles is measured in Mev units whose value (K) The geometry of the irradiation chamber affects the results. Therefore, when k is calculated from equation (3), its propagation constant value of length units is K = 0.402 cm.

4- Calculating the radon concentration in the samples: The radon percentage is calculated

$C_X = \lambda R_n C_\alpha\ ht / L$ .....(5)

C_X :Concentration of radon inside the sample in unit Bq. cm^{-3}

.C_α: Concentration of radon in the air space of Bq. cm^{-3}

λR_n: The radon decay constant equals 0.1814 day.

h :The height of the airspace is equal to 9.5 cm .

L: The sample thickness is determined to be approximately 5% cm. The irradiation duration is estimated at 60 days.t

practical part:

1. Sample collection and preparation stage: I collected the forms in June - **2023** for five different areas of the city of Shatrah in Thi Qar Governorate (Hay Al-Amin area, Al-Hussein neighborhood area, Al-Hay industrial area, Al-Atebaa area, and Baghdad neighborhood area). The most populated and oldest area is in the city of Shatra, and it was the area most exposed to bombing during the war.

2. Measurement method: Long-range radiation sensing technology was chosen to obtain the effects of alpha particles emitted associated with radon gas. I used **CR-39** with a thickness of **(100 micrometers)** and equal dimensions **(1 x 1 cm^2)**. **(12 g)** for the sample. The sample is weighed using a sensitive balance **(0.5×10^{-2}).** The samples were placed in conical irradiation chambers**.** The dimensions of the room are **(8.5 cm x 5 cm)** and it is closed with a rubber cover while maintaining the distance between the two surfaces. bottom of the batch containing the detector piece [15]. Then each sample is given a period **(22 days)** to obtain an ideal balance **(98%)** between radium and its radon isotopes. Without radon escaping from the compartments, the charge was quickly removed and replaced with another charge with a lower piece on the detector. tightly and maintain a constant distance between the detector and the sample face before raising the pressure. The reagents remain in the irradiation chamber for **(60 days)** after the reagents are removed and prepared for the chemical sizing process using NaoH solution with purity **(98%).** It becomes clear here how dangerous the effect of radon gas is on the detector. The temperature for this process is **(70°C).** Solution concentration used was **(6.25 N)** and **(25 g)** of **NaoH** in 100 ml of distilled water to take into account the low level of water in the bottle evaporation due to the high temperature resulting from the dissolution process when adding water. To the bottle after thermal balancing with the surroundings and calculating the equation criterion:

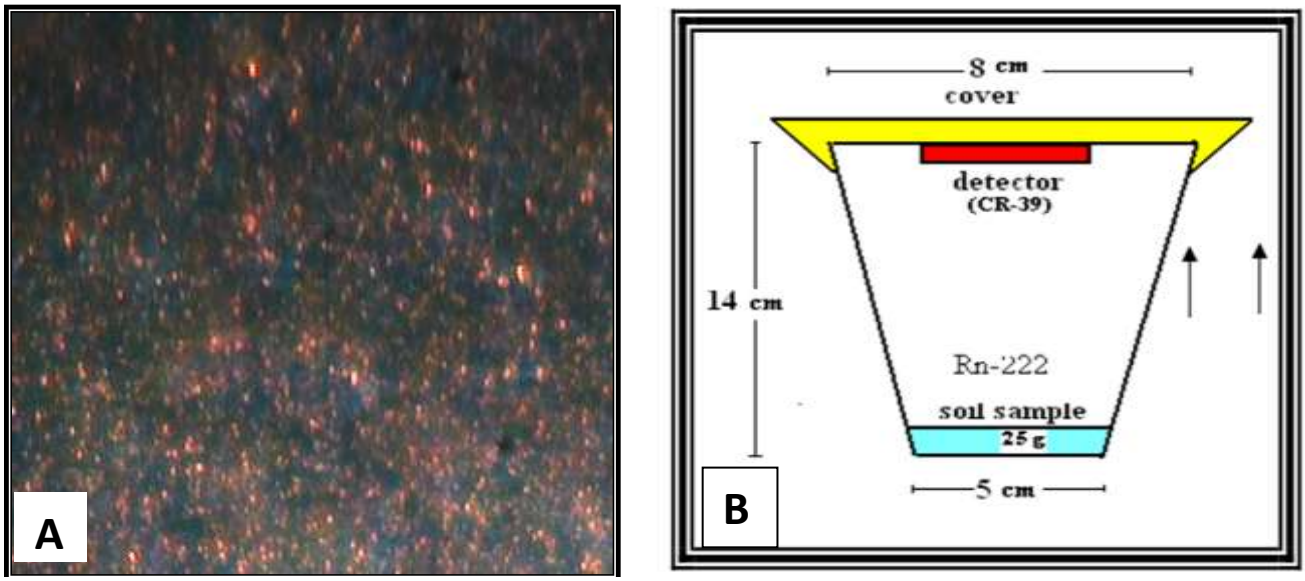
$W\ (g) = N \times V \times W_{eq}$ .....(6)

W (g): represents the weight of sodium hydroxide granules

N: represents the required standard (6.25 N)

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 15s,2025
https://theaspd.com/index.php

V:Volume of distilled water
W_{eq} : molecular weight of NaoH is 40
To perform the scraping process in a water bath heated to (60°C), the reagent is kept inside the scraping solution for (17 hours) at a rate of (3-4 hours) daily by washing the reagent after each time with plain water, then with distilled water and drying [16] Microscopic examination appears visually and is detected by counting the number of visible impacts on the detector resulting from the interaction between the emitted alpha particles accompanying the gas. The radiation rate is measured by installing the detector in a sealed cylinder As in Figure (3,4)



Figure(3) A\ Explains the process of chemical skimming of the reagent
B/Explains the effects of alpha particles accompanying the gas in the trace detector (CR-39)

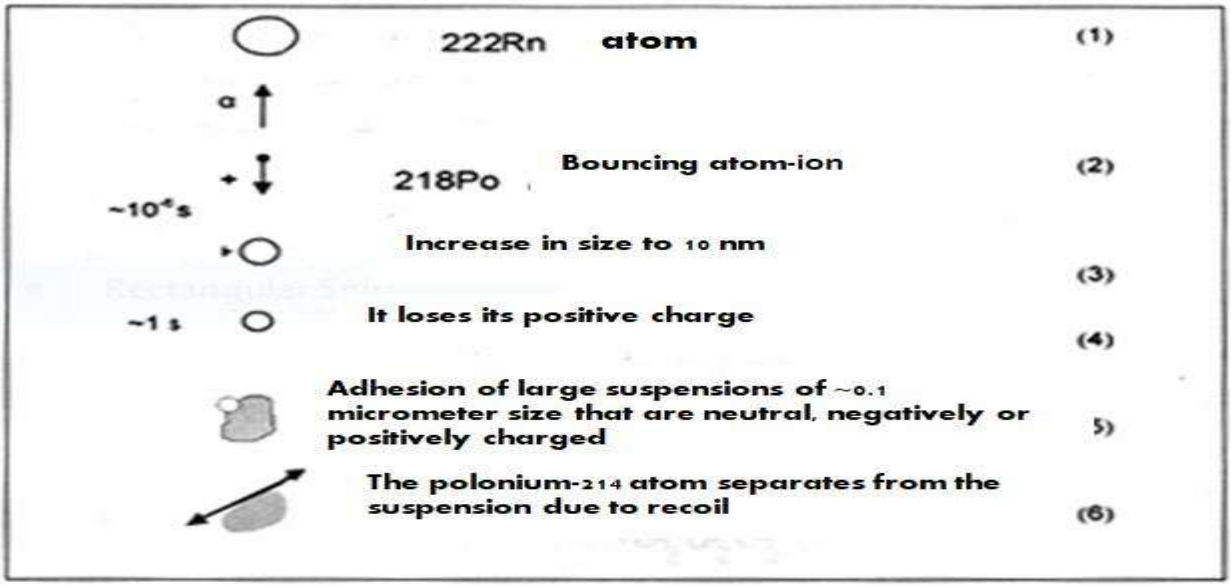


Figure (4) Explains the mechanism of connection between radon emissions

Results and discussion

Table(1) It shows the effect of alpha particles and the percentage of radon gas in the samples. The highest value was in Al-Hay industrial area where (1614.087±18.56069) Bq / m^3 was recorded and the lowest concentration was Al-Atebaa area t with a value of (1037.417±9.395634) Bq / m^3 Higher than the natural exposure limit set recorded by WHO (800) Bq / m^3 [17].Radon is the natural gas production of uranium decomposition and soil is the source Most of the construction material of the building materials is contained in a certain amount of uranium, thorium and radium emitting radon, and is more radioactive than gypsum and calcite, which is saturated with alum, flint, and stones fluorescent. The gas comes from under houses, especially when there are cracks in building foundations and indoor places have a higher concentration of radon gas compared to the outdoor air in winter than in summer. Gases collect in closed spaces with no or little ventilation because it leads to the accumulation of gases in closed spaces because the radon gas produced in the air varies depending on the ventilation rate [16] The values show that radon gas increased during the Gulf War (1991-2003), which resulted in the city being polluted with depleted uranium and its decomposition products. Radon gas is present in the Earth's atmosphere[18] and (10%) of radon seeps From rock fractures and soil pores to reach the soil surface. [19] Figure (4) shows radon concentrations in samples from the study area

Table (1) Concentration of radon gas in the soil models under dorsal

The name of the area	The intensity of the effect ± standard deviation (Track / mm^2)	Concentration ± error ratio Bq / m^3
Al-Hay industrial area	94827.59±1090.441	1614.087±18.56069
Al-Hussein neighborhood area	86206.9± 1442.517	1467.351± 24.55349
Baghdad neighborhood area	78362.9±1866.932	1333.822±31.77756
Hay Al-Amin area	69741.38± 603.4483	1187.087± 10.27146
Al-Atebaa area	69948.28 ± 551.9935	1037.417±9.395634
The overall rate	±18. 91177	1327.953
Universal Limiter		800 [18]

The results of the current study can be compared with previous studies according to Table (2). There are variations between the radon concentration with radon concentrations in previous global and local studies using nuclear impact detectors.

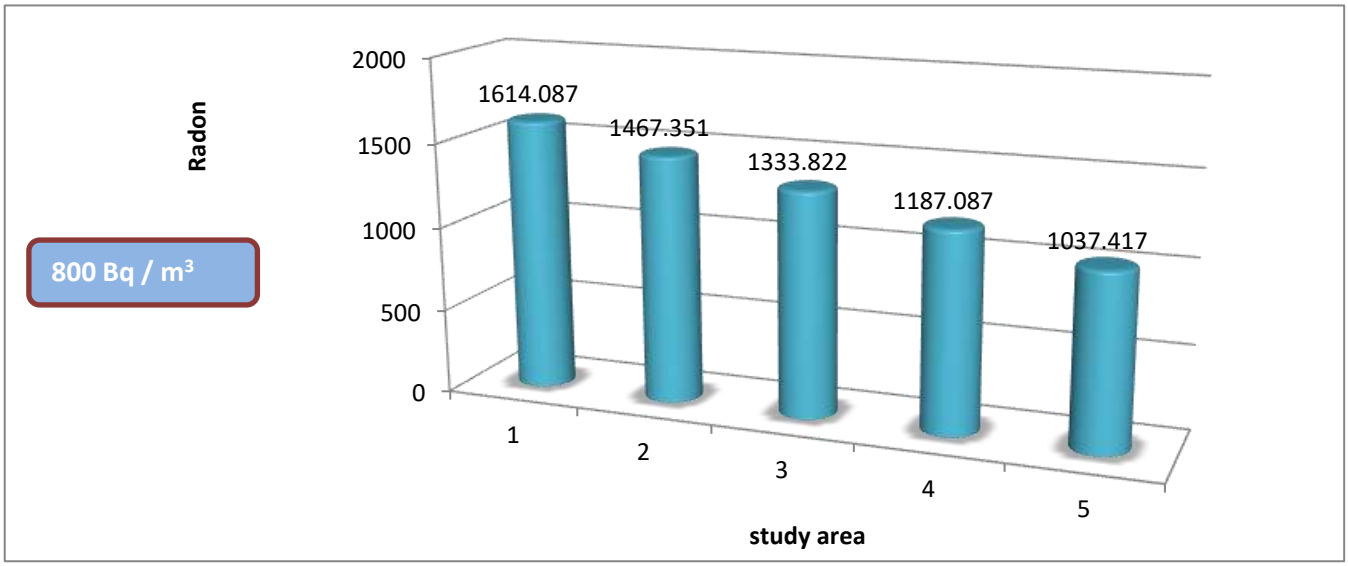


Table (2) Radon levels are shown in our current study of the records of Jabbar (2011) [20] and Mahasr (2009)[19] and the record of AL-Baidhani (2006),[21] Muhammad (2008)[22] and Karim (2004)[23] From Dunia (2000) [24]and Munazza et al (2008)[25] and Muslim et al (2011) [26] recorded the lowest recorded concentrations in the south of Iraq - Al-Darwishi station (Kobeissi et al 2008)[27] and the record for the Kadhim (2014)[28]. The proportion of the gas is mainly recorded in the city of Shatrah due to missile bombing during the Second Gulf War (2003). Radon gas is considered the primary nucleus of the decomposition products of uranium and thorium, as well as the radioactivity resulting inside buildings. These buildings are composed of components containing different proportions of natural radioactive elements such as K^{40}, Ra^{226} and U^{238}. Buildings can be a significant source of radon, especially when there are holes or cracks in the building base [30].

Table (2) Global and local studies on measurement of radon concentrations in soil models using nuclear impact detectors

Sampel NO.	Soil source	Concentration of radon Bq / m^3	Researcher and Year
1	Pakistan	376	Munazza et al,(2008) [25]
2	Turkey	3.4 - 138	Muslim et al,(2011) [26]
3	South Lebanon	291- 1774	Kobeissi et al,(2008) [27]
4	Iraq (Central and Northern Region)	33-100	Dunia(2000) [24]
5	Baghdad-Al-Wardia	697.18	Karim(2004)[23]
	Baghdad - Riyadh district	163.45	
	Baghdad – Tuwaitha	119.17	
6	Baghdad – Taji	229.27-665.56	AL-Baidhani(2006)[21]
	Karbala	229.27-478.94	
	Sight (public)	388.96-607.21	
7	Sulaymaniyah	22.3	Muhammad(2008)[22]
	Erbil	26.17	
8	Southern Iraq - Karma Bani Saeed	1146.227	H.R Mahasr.(2009)[19]
	Southern Iraq - Darwishi Station	18329.47	
9	Kut	583.594	Jabbar (2011)[20]
10	Nasiriyah	1386.236	Kadhim (2014)[28]
11	Shatrah	1375.7876	I.A.Kadhim(2018)[29]
12	Shatrah	1327.953	Current knowledge(2023)

	e limit	800	WHO(1993)[18]

CONCLUSIONS

1-We notice high concentrations of radon gas in the selected soil samples, as they exceeded the global limit for background radiation

2- High radon gas concentration indicates the presence of uranium. This indicates continued Exposure to this gas, especially the half-life of uranium, is known to be long. It is the main source of radon.

Recommendations

1. Explaining the danger of radon gas and the diseases that can result from exceeding the natural limit of radon, as increased exposure causes cancer

2. Trying to find new scientific methods and methods to measure the Rates of uranium and radon in the same areas and compare them with the current results, for example using gamma ray spectroscopy technology using a germanium counter.

3- Spreading environmental and health awareness among the population through posters, seminars, radio, and scientific programs

4-Reduce the concentration of radon in existing homes through the following:(Increase new bottom area. Installing a special system for collecting radon gas in the floor or underground. Prevents radon leakage From the lower deck of the living rooms. Sealing floors and walls. Safe for home ventilation).I set procedures that mitigate the ineffective effects of reducing the effect of radon gas by 50%. If products are used that reduce radon to less than this.

REFERENCES

[1] S. Darby, D. Hill, A. Auvinen, J. M. Barros-Dios, H. Baysson, F. Bochicchio, H. Deo, R. Falk, F. Forastiere, and M. Hakama, "Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies," *Bmj*, vol. 330, no. 7485, p. 223, 2005.

[2] Barros-Dios, J.M., Ruano-Ravina, A., Gastelu-Iturri, J. and Figueiras, A.,2007.Factors underlying residential radon concentration: Results from Galicia, Spain, Environmental Research, Vol. 103, Issue 2, pp 185-190.

[3] R. L. Fleischer and P. B. Price, "Tracks of charged particles in high polymers," *Science (80.).*, vol. 140, no. 3572, pp. 1221–1222, 1963.

[4] R. L. Fleischer, P. B. Price, and R. M. Walker, "Ion explosion spike mechanism for formation of charged-particle tracks in solids," *J. Appl. Phys.*, vol. 36, no. 11, pp. 3645–3652, 1965.

[5] C. POLICY and C. JUSTICE, "Examining Possible Causes of Gulf War Illness," 2005.

[6] R. L. Fleischer, P. B. Price, and R. M. Walker, "Solid-state track detectors: applications to nuclear science and geophysics," *Annu. Rev. Nucl. Sci.*, vol. 15, no. 1, pp. 1–28, 1965.

[7] B. G. Cartwright, E. K. Shirk, and P. B. Price, "A nuclear-track-recording polymer of unique sensitivity and resolution," *Nucl. Instruments Methods*, vol. 153, no. 2–3, pp. 457–460, 1978.

[8] K. N. Yu, F. M. F. Ng, J. P. Y. Ho, C. W. Y. Yip, D. Nikezic, T. C. Avenue, K. Tong, H. Kong, and L. Bluff, "MEASUREMENT OF PARAMETERS OF TRACKS IN CR-39 DETECTOR FROM REPLICAS," vol. 111, no. 1, pp. 93–96, 2004.

[9] A. Detectors, S. Decay, and P. Nucleus, ".SENSITIVITY AND SENSING OF SOIL GAS RADON POLLUTION IN CERTAIN AREAS OF THE PROVINCE OF SALAHIDIN USING CR-39 DETECTOR.

[10] Asmaa Ahmad Aziz. "Evaluation of radioactivity of cereals and legumes using a nuclear impact detector CN-85", Iraqi Journal of Physics, 2018

[11] Ridha A A Karim M S and Kadhim N F 2014 Civil and Environmental Research 6 24.

[12] M. Milovanovic, "Water quality assessment and determination of pollution sources along the Axios/Vardar River, Southeastern Europe," *Desalination*, vol. 213, no. 1–3, pp. 159–173, 2007.

[13] A. Azam, A. H. Naqvi, and D. S. Srivastava, "Radium concentration and radon exhalation measurements using LR-115 type II plastic track detectors," *Nucl. Geophys.*, vol. 6, no. 9, pp. 653–657, 1995.

[14] R. Barillon, D. Klein, A. Chambaudet, and C. Devillard, "Comparison of effectiveness of three radon detectors (LR115, CR39 and silicon diode pin) placed in a cylindrical device-theory and experimental techniques," *Nucl. Tracks Radiat. Meas.*, vol. 22, no. 1–4, pp. 281–282, 1993.

[15] M. K. M. Al-jnaby, "Radon Concentration in Drinking Water Sources of the University of Babylon / Iraq vol. 14, no. 4, 2016.

[16] U. N. S. C. on the E. of A. Radiation, "United Nations Scientific Committee on the Effects of Atomic Radiation report to the General Assembly New York (United Nations) Google Scholar," 1982.

[17] T. E. Liolios, "Assessing the risk from the depleted uranium weapons used in Operation Allied Force," *Sci. Glob. Secur.*, vol. 8, no. 2, pp. 163–181, 2000.

[18] W. H. Organization, "Guidelines for drinking-water quality. Vol. 2, Health criteria and other supporting information: addendum," Geneva: World Health Organization, 1998.
[19] A. A. Kareem, H. N. Hady, and A. A. Abojassim, "Measurement of natural radioactivity in selected samples of medical plants in Iraq," vol. 11, no. 14, pp. 178–182, 2016.
[20] "Determination of 222 Rn activity in the sediments of Basrah Governorate marshes (Iraq) using Solid State Nuclear Track Detectors (SSNTDs)," pp. 1613–1620, 2007.
[21] N. H. Kadhim, R. Y. Kassim, and S. J. Jabbar, "Estimation the Radioactive Pollution by Uranium in the Soil of Al-Kut City / Iraq Abstract : Introduction : Materials and Methods :," vol. 8, no. 2, pp. 532–537, 2011.
[22] M. A. Al-Baidhani, "Determination of the radioactivity in soil and water in Baghdad, Karbala and Basrah samples." M. Sc. Thesis, College of Science, Al-Nahrain University, 2006.
[23] M. M. Ali, "Uranium and radon concentrations in soil of some northern Iraqi regions using nuclear track detector (CR-39)." M. Sc. Thesis, Baghdad University, College of Science for women, 2008.
[24] N. F. Kadhum, L. A. Jebur, and A. A. Ridha, "Studying Different Etching Methods Using CR-39 Nuclear Track Detector," no. July, pp. 45–53, 2016.
[25] A. Ridha, "Determination of Radionuclides Concentrations in Construction Materials Used in Iraq," 2013.
[26] M. Faheem, "Radon exhalation and its dependence on moisture content from samples of soil and building materials," vol. 43, pp. 1458–1462, 2008.
[27] M. M. Sac, C. Harmansah, B. Camgoz, and H. Sozbilir, "Radon Monitoring as the Earthquake Precursor in Fault Line in Western Turkey.," *Ekoloji Derg.*, vol. 20, no. 79, 2011.
[28] M. A. Kobeissi, O. El Samad, K. Zahraman, S. Milky, F. Bahsoun, and K. M. Abumurad, "Natural radioactivity measurements in building materials in Southern Lebanon," *J. Environ. Radioact.*, vol. 99, no. 8, pp. 1279–1288, 2008.
[29] I. A. Kadhim, "The use of the nuclear detector effect (CR-39) in determining the concentration of radon in samples of the Nasiriya City soil, South of Iraq," *Int. J. Res. Applied, Nat. Soc. Sci.*, vol. 2, no. 11, pp. 103–110, 2014.
[30] I. A. Kadhim,Measurement of Radon Concentration in the Soil of Some Areas of the City of Shatrah Using the Nuclear Impact Detector (Cr-39).March 2017.Indian Journal of Public Health Research and Development 10(3):326-331
[31] Shafi-ur-Rehman, Matiullah, Shakeel-ur-Rehman and Said Rahman,2006.Studying 222Rn exhalation rate from soil and sand samples using CR-39 detector, Radiation Measurements, Vol. 41, Issue 6, , pp 708-713.