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Research Article

Measurement of radon gas concentrations in soil samples in the research areas located in the Basra City, Southern Iraq: Preliminary research results

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ABSTRACT

In this study, radioactive radon gas (Rn222) measurements were carried out in soil samples in three selected regions of Basra city in Southern Iraq. The study areas were divided into three main regions: north, east and west of Basra city. One of the three selected areas is a natural rural area, the other two are urban-industrial areas. The northern region is called "Al-Qurna"; the second is called "Kutaiban" and is located east of Basra city; the third is called "Al-Shuaiba" and is located west of Basra. Three research points were selected from each study area as a preliminary experiment.
The area, Al-Shuaiba, located approximately 15-20 kilometers west of Basra city center, is characterized by the presence of oil extraction and refining facilities. Five samples were taken from different locations in this region, yielding the highest and lowest concentrations given below: 298.3±4.0 - 352.9±4.7 Bq/m^3. The overall average for the five samples in this area was 315.4±4.18 Bq/m^3.
Al-Qurna is located approximately (70-75 km) north of the center of Basra Governorate. This area where oil production fields are located produces gas, steam and smoke emissions. Five samples were taken from different places and the radon gas concentrations at these places in Al-Qurna were measured as 69.1±9.4 - 126.6±1.7 Bq/m^3. The overall average of these samples is 112.2±3.2 Bq/m^3. The concentrations in this area were found to be within the international system used to measure radon concentrations and therefore safe.
The last area is (Kutaiban) located east of the Basra Governorate center. This area is characterized by a rural area rich in rivers and palm forests and therefore few factories and facilities except the thermal power plant. In these study areas, radon gas concentrations were found in five different locations and yielding the highest and lowest concentrations given below: 36.3±5.3 - 109.1±1.4 Bq/m^3. The overall mean for these samples is 77.8±1.9 Bq/m^3.
As a result, it was found that the radon level measured in natural areas was 2-3 times lower than in industrial areas. It is thought that this situation may be caused by radon gas rising from underground layers to the upper layers as a result of the breaking of these layers during oil extraction.

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INTRODUCTION

The phenomenon of radioactivity was discovered by the French scientist Henri Becquerel in 1896 when he observed that uranium compounds could darken photographic plates without exposure to light. Later, Marie and Pierre Curie named this phenomenon “radioactivity” and discovered the radioactive properties of thorium. In 1908, Ernest Rutherford identified radioactive radon gas through natural decay processes [1].

Radioactivity refers to the spontaneous emission of energy and particles from an unstable nucleus, accompanied by the transformation of radioactive elements into stable isotopes. This phenomenon plays a crucial role in various scientific and practical fields, including energy production, medical diagnostics, and environmental studies [2].

Radioactivity is a natural phenomenon that has existed since the origins of the Earth. It is present everywhere: in the water, the air, the soil and the biota. The human being itself is radioactive.

There are two types of radioactivity: natural radioactivity and artificial radioactivity, also known as induced or man-made radioactivity respectively [3]. The radioactive decay mechanism of Radon-222 is given in Figure 1.

Humans and living organisms are constantly exposed to radiation from natural and industrial sources. Industrial sources include X-ray generators, lasers, nuclear

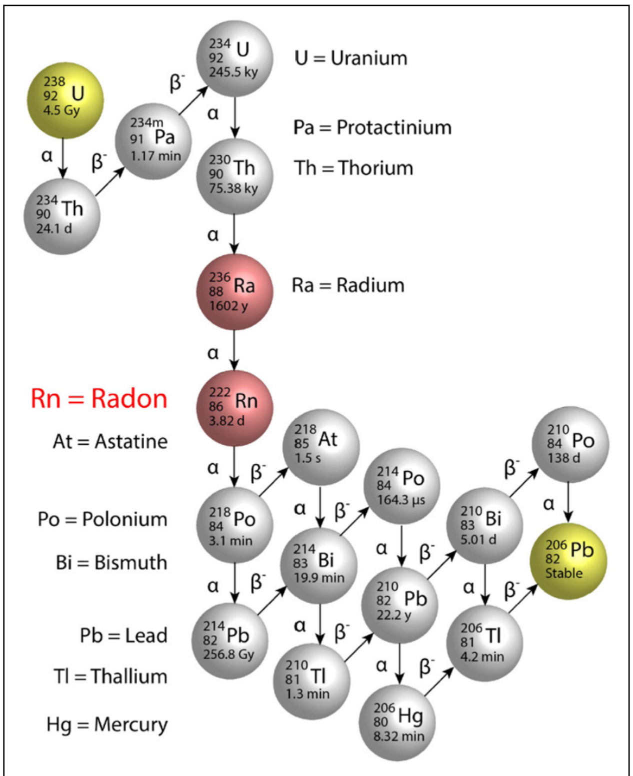

Figure 1. Radioactive decay series of radon from uranium [4]

reactors, and devices used in medical, industrial, agricultural, and scientific applications. Natural radiation, on the other hand, originates from sources present in our daily lives, such as cosmic rays from outer space, as well as materials in the Earth’s crust, food, water, air, and building materials [5-8].

Natural radioactivity is produced from external atmospheric sources, from isotopes sensed in the ground, and is represented by the amount of series of natural radioactivity. Natural radioactivity is the radioactivity found in nature as uranium, thorium ores, and natural nuclear fuels. Radioactive waste is produced during mining and ore milling, and the waste mostly contains natural radioactive substances such as uranium, thorium, radium, radon, etc. The water pumped out from mines to keep them dry contains traces of radioisotopes; mill waste contains radium. In the case of the fabrication of fuel, radium, thorium, and several radioactive decay products are removed in the initial steps as liquid waste. Although this liquid waste contains a low level of radioactivity, still the contaminated scrap produced in the fabrication plant is dangerous. [6-10]

The origin of the primordial natural radionuclides of the earth is associated with the phenomenon of nucleosynthesis in stars [8-14]. The fact that the uranium, thorium, and actinium decay chains are found in nature is directly related to the very long half-lives of the parents of these chains. The absence of the neptunium decay chain is due to the lack of sufficiently long-lived members of this chain; complete decay of the parent radionuclides and their progeny has already occurred. Naturally occurring radionuclides with long half-lives that are not members of decay chains also exist in relatively high isotopic abundance [6, 15-18].

Radon gas is a colorless, odorless, tasteless, non-flammable, radioactive gas that occurs naturally from the decay of uranium and thorium found in soil, rocks, and water. Radon is a radioactive element and is heavier than air. Radon gas can leak into homes from the soil beneath them, and when it accumulates in closed spaces, its concentration can reach dangerous levels. Prolonged exposure to high concentrations of radon can increase the risk of lung cancer, which is why it is recommended to measure gas levels in homes, especially in areas where it is known to be present. Radon gas is dangerous to health because when inhaled, the respiratory system is exposed to radioactive particles that lead to tissue damage and an increased risk of lung cancer [8, 18- 21].

In this study, radioactive radon gas (Rn222) measurements were carried out in soil samples in three selected regions of Basra city in Southern Iraq. The measured natural radon concentrations were evaluated and interpreted according to international standards.

MATERIALS AND METHODS

Study Area

The study areas was chosen for several reasons, as the Basra region represents urban and rural areas, as well as oil extraction and refining areas, in addition to desert areas, which are determined by the coordinates (30.5085° N) and (47.7804° E). Research areas are given in Figure 2.

The choice fell on an area in the north of Basra, defined by the geodesy (30.6557° N) and (47.7275° E). This area includes several agricultural and industrial areas and is bordered by cities such as Al-Qurna and Al-Madinah. This is because they were previously submerged lands in recent years, where they were marshes. After the marshes were drained, they became dry lands, and urban areas were built there, and the infrastructure was expanded, in addition to the establishment of factories, as well as the start of oil extraction operations from several sites.

The area located in the east of Shatt al-Arab and represented by the coordinates (30.5° N) and (48.5° E) because this area is closer to the border areas and witnessed military operations in the previous decades. After urban expansion in it, it became connected areas and there are some industries near it, such as the power generation station in addition to some construction industries.

This region was and still is considered the food basket of Basra city, as it contains palm forests and fresh water, and produces some food crops that supply the labor market, and it produces dairy products and their derivatives.

The last area is the area located near the city of Basra and is similar to the previous areas and is considered part of the center of Basra Governorate and has a huge and dense population and is close to the Shatt al-Basra River, which feeds from the Shatt al-Arab and connects with Khor al-Zubair from the south, where it is considered a navigable river with bridges and gates that close and open when needed. More importantly, it is located in an area with oil operations in addition to oil extraction operations, as it is close to oil well fields and extraction, as well as the presence of oil refineries such as the Shuaiba refinery. It is closer to desert areas because its land is sandy and this area witnesses the continuous saturation of the air with gases from oil production, extraction and refining. People live in an area polluted by chimney smoke.

The reason for choosing the study area in these places is to study the concentration of radon gas as an indicator of the presence of radioactive isotopes and the extent of their potential impact on human, animal and plant health in the environment.

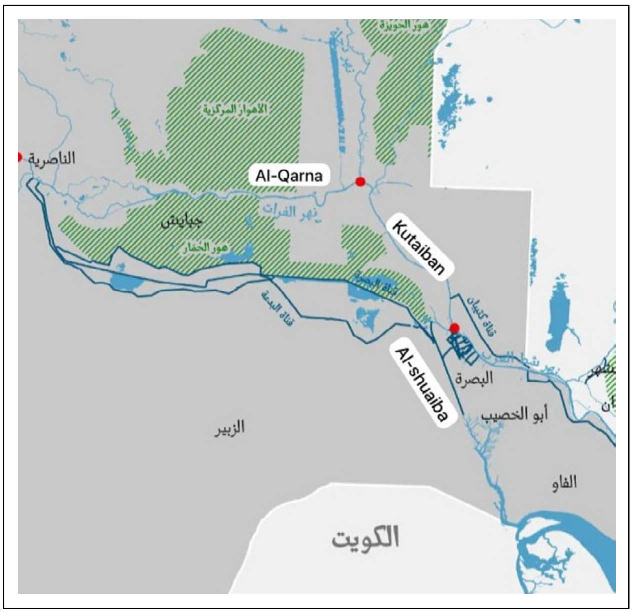

Figure 2. The study areas

Measurement of Radioactivity in the Soil Samples

Measuring radioactivity in the soil is an essential process for understanding environmental radiation levels and assessing potential risks to human health and ecosystems. Various techniques and instruments are employed to determine the concentration of radioactive isotopes in the soil, providing critical data for environmental studies and safety assessments [8].

In this research, "Solid State Nuclear Track Detectors (SSNTDs)" were used. Solid State Nuclear Track Detectors (SSNTDs) are insulating materials that record the trajectory of charged particles, such as alpha particles, protons, and heavy ions, by creating damage tracks in the material's structure. The operation of SSNTDs is based on the interaction between the charged particles and the detector material. When a charged particle passes through the material, it creates a trail of damage along its path, resulting in a latent track. The latent track can then be revealed through a chemical etching process, which enlarges the track to a size that can be observed using an optical microscope. The characteristics of the track, such as its length, width, and shape, provide information about the type and energy of the particle that created it. In this study, CR-39 lens was used for radon measurements (Fig. 3). CR-39 (allyl diglycol carbonate): a widely used plastic material that is sensitive to alpha particles and other charged particles. [10]. Calcu-

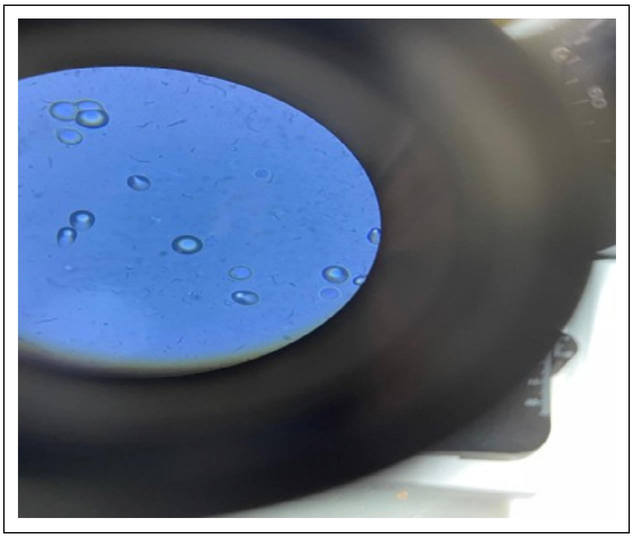

Figure 3. CR-39 lens when viewed under the microscope

lations were made by counting the tracks created by radon molecules as they passed through the detector using a LEICA DM500 optical microscope.

Radon occurs naturally in three ways: The first way; 219Rn, identified in 1903 by Debierne and Giesel through the decay of 235U. The second way; 220Rn, commonly referred to as thoron, discovered in 1889 by Owens and Rutherford via the decay of thorium (232Th); and the third way; 222Rn, a decay product of 238U, first detected in 1901 by Dorn [22]. The half-life of 222Rn is comparatively long, approximately 3.82 days, enabling the migration of 222Rn gas into the air and water present in soils and rocks. Radon mixed into the atmosphere in this way can have harmful effects on living things, including humans. Although various studies have proven that exposure to radon gas causes lung cancer among underground miners, there is no definitive information yet about diseases caused by indoor radon. Various studies are being conducted on the existence of Radon-222 in nature due to its possible effects on human health. Research and evaluations on this subject continue [22-24].

RESULTS AND DISCUSSION

In this study, soil samples were taken from three different areas (Al-Shuaiba, Al-Qarna and Kutaiban) within the borders of the city of Basra in Iraq and radon analyses were performed.

Al-Shuaiba Region

In the Al-Shuaiba region, the highest radon concentration was found in sampling point 2nd research number. This high concentration of radon gas is thought to be caused by oil seeps near the research area. We notice that there is something like a small lake or a small swamp with oil spills on this soil, and we also notice that its color tends to be dark due to the amount of spills present, and this indicates that there is a high concentration of radon gas because the components of oil contain high concentrations of radioactive activity, and thus radon is one of the offspring resulting from these isotopes, and certainly the sample that has a low concentration was taken from an area far from the oil spills and is a somewhat clean and urban area, as well as clean land with no human activity or activity of any other kind, which changed the features of the soil and affected the concentration of radon gas. Radon concentrations measured in this research area are given in Table 1. The radon and radium measurements in the research points are given visually in Figures 4-6.

While the remaining samples are either close to the sample with a high concentration and thus take a percentage of the radon gas concentration or are far from the oil spills, where the concentration in both cases ranges between the highest and lowest amount, the lowest concentration of radon gas due to its proximity or distance from these areas that contain oil pollutants or the like.

Table 1. Radon concentration, surface and mass radon emission rate, and effective radium for soil samples taken from the Shuaiba area

S.N	CRn (Bq/m^3)	EX A (mBq/m^2.h)	EX M (mBq/Kg.h)	Ra eff (Bq/Kg)
1	298.3±4.0	5.41	0.095	6.98
2	352.9±4.7	6.40	0.131	7.13
3	312.8±4.1	5.68	0.118	6.19
4	308.5±4.1	5.60	0.124	5.74
5	304.1±4.0	5.52	0.080	8.65
Max	352.9±4.7	6.40	0.131	8.65
Min	298.3±4.0	5.41	0.080	5.74
Avr	315.4±4.18	572	0.109	6.94

Max: Maximum; Min: Minimum; Avr: Average.

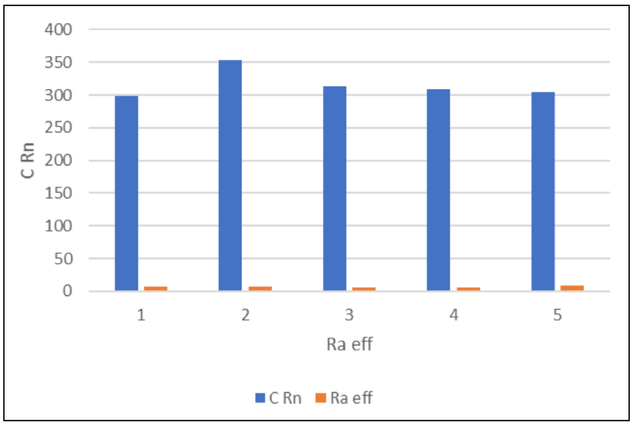

Figure 4. Correlation factor between the values of radium-226 concentration and radon gas concentration measured by nuclear trace detectors in the Shuaiba area

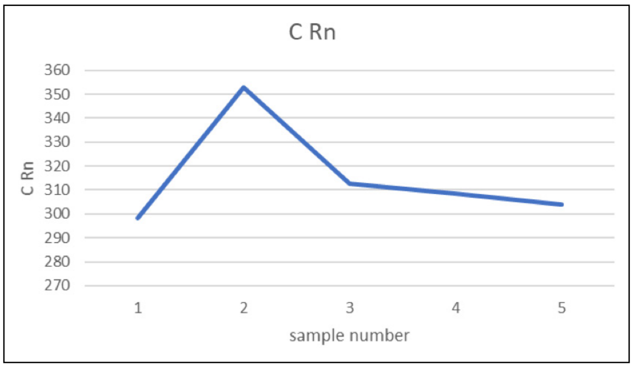

Figure 5. Radon-222 concentration levels in soil samples in the Shuaiba area

Also, some samples are close to human activity, which is clear and obvious. It is possible that the concentration of sample No 3 is the closest to the concentration of the sample that is the highest possible, not because there are oil spills, but because of human activity and in addition to the geological nature of the land, which causes an increase in some concentrations.

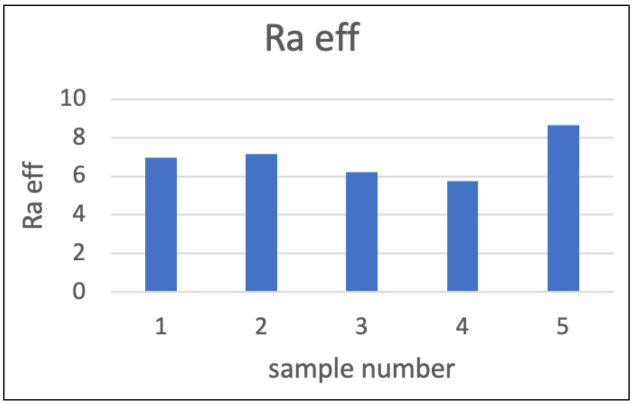

Figure 6. Levels of effective radium content in soil samples in the Shuaiba area

Since this area is an extraction and refining area, it has many chimneys or flues that contain a lot of black smoke loaded with carbon and its derivatives. In the end, when these fumes fall to the ground, they cover a large area as a result of weather factors, whether the winds are north or south, covering this area, as the concentration is found according to these conditions and has a large and direct effect on surface samples when collected from the soil.

Al-Qurna region

The second part of the study is the Qurna area where samples were taken from the distance between Qurna and the city called (Al-Khas). This area in previous years was mostly a rural area and there are many marshes in it and the street from which we took the samples was almost the edges of the marshes, but due to recent years as a result of modernity and development in the stages of life, it has almost turned into a residential area and as a result of that, many local and craft industries began, but now it has turned into an industrial area and thus this has affected the nature of the area.

Also, this area has become mostly oil companies that were taken over by international and foreign companies, as these companies extract fossil oil and drill wells. These chimneys began to spread dust and exhaust from the chimneys and spread in the atmosphere of the area, as well as what falls from them to the ground due to acid rain.

Therefore, the nature of this land and this region has changed as a result of the changes mentioned previously, as well as the increase in the number of residents due to the abundance of crafts and internal and external transportation lines. All of this will be reflected in the lives of the residents and the nature of the region.

The results we obtained for the concentration of radon gas in the samples along the path connecting Al-Qurna and the city, which lies within the coordinates 31.0000°N: 47.3500°E) and are distributed according to Table 2. The radon and radium measurements in the research points are given visually in Figures 7-9.

Table 2. Radon concentration, surface and mass radon emission rate, and effective radium for soil samples taken from the Qurna area

S.N	CRn (Bq/m^3)	EX A (mBq/m^2.h)	EX M (mBq/Kg.h)	Ra eff (Bq/Kg)
1	126.6±1.7	2.30	0.053	2.28
2	122.2±1.6	2.22	0.032	3.48
3	117.8±1.5	2.14	0.059	1.75
4	125.1±1.7	2.27	0.063	1.87
5	69.1±9.4	1.25	0.028	1.29
Max	126.6±1.7	2.30	0.063	3.48
Min	69.1±9.4	1.25	0.028	1.29
Avr	112.2±3.2	2.04	0.047	2.13

Max: Maximum; Min: Minimum; Avr: Average.

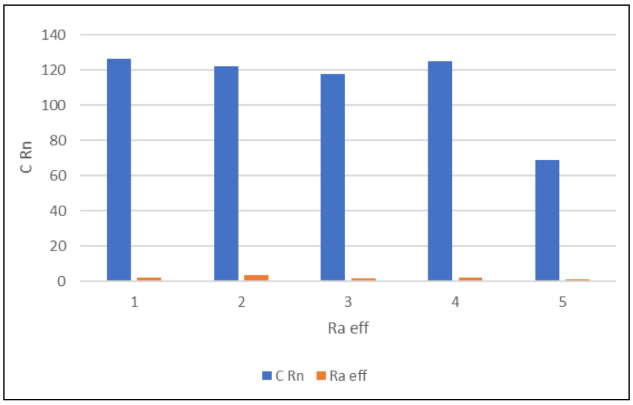

Figure 7. Correlation factor between the values of radium-226 concentration and radon gas concentration measured by nuclear trace detectors in the Qurna area

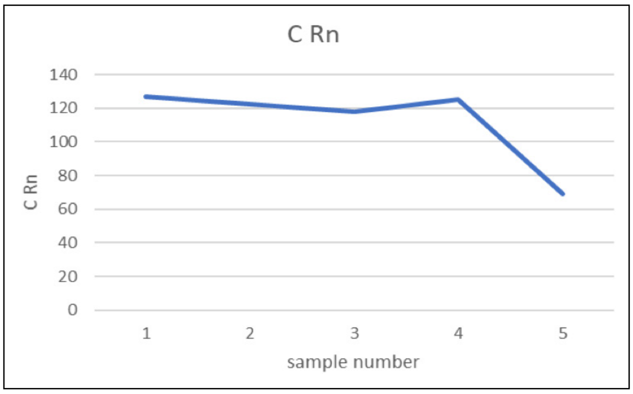

Figure 8. Radon-222 concentration levels in soil samples in the Qurna area

Through the special table for measuring the concentrations of radon 222 for the samples found in this area, it was shown that the highest concentration of radon 222 gas was in sample No. 1 as 126.6±1.7 Bq/m^3.

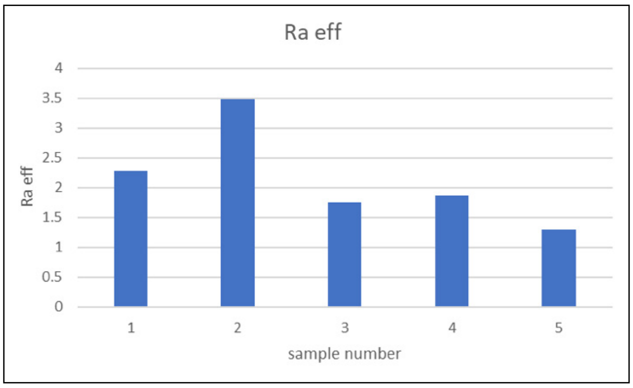

Figure 9. Levels of effective radium content in soil samples in the Qurna area.

The lowest concentration appeared in sample No. 5 as 69.1±9.4 Bq/m^3. The general average of samples in this area is 112.2±3.2 Bq/m^3.

The reasons for the high concentration in this sample (1) could be due in any case to the geographical nature, in addition to what was observed, as it appeared that the soil of the sample is fragile and the voids in the soil allow the release of the largest amount of radon-222 gas.

As for the sample with the low concentration, it was taken from an area close to the residence, and thus this land is considered to have been transferred from a place unknown to us as a result of the urban movement in this area, and thus the concentration depends on the source of the sample from which it was transferred.

Kutaiban region

This area is considered a rural area with many trees (palm trees) and an urban area with a small population, especially in the years before 2003. However, now the social character has begun to change as a result of the displacement of many people and the movement of many people to it due to the congestion The Kutaiban area is located in the eastern part of Basra Governorate, in the northeastern part of it. This area is located along the Shatt al-Arab River, which starts from Khalid Bridge in the south to the Al-Deir area in the north. in the city center.

After reviewing the results of the concentrations of radon-222 gas, it became clear that there is a low concentration rate in the Kutaiban area and less than the previous areas, namely Al-Qurna and Al-Shuaiba. It is possible to explain this reason for the low concentrations to the fact that this area, as we mentioned previously, is a sparsely populated area with little human activity. Therefore, most of the lands from which samples were taken are pure lands that were not transported to it or taken from it.

Also, there are not many heavy industries in this region, such as refining or oil production or similar heavy industries, production and extraction. Therefore, this region has preserved its prevailing nature, most of which is agricultural land, as it is considered the food basket of the city of Basra in terms of vegetables and some fruit trees such as palm trees and others that supply the local market.

It is worth mentioning that in the eighties this area was a military area as a result of the war that took place between Iraq and Iran in those years, but it was not affected by the increase in some of the concentrations of radioactive isotopes due to the absence of anything that affects the increase in concentration or activity of concentration in it, thus this area maintained its nature and its current situation without an increase in concentration.

There is also another reason, which is the direct reason for all increases or decreases in concentration, which is the geological nature of the land, which is considered the basis for the level of concentration. It appears that this region, according to its geological nature of the sedimentary plain, as a result of its presence in the east of Basra, may be responsible for the decrease in the concentration of radon-222 gas from the samples taken from that region.

The concentrations of radon-222 gas are distributed in the Kutaiban area according to Table 3 and the number of samples is 4, where the highest concentration appeared in sample No. (4) (109.1±1.4 Bq/m^3) and the lowest value of radon concentration in this area is in sample No. (5) (36.3±5.3Bq/m^3) and the general average of radon concentration in the soil for this area is (77.8±1.9 Bq/m^3). The radon and radium measurements in the research points are given visually in Figures 10-12.

As a result of the research, much higher radon-222 concentrations were measured in the test areas fractured by oil wells. In addition, industrial areas were also found to be effective on radon-222 concentrations. Much lower concentrations of radon-222 have been measured in areas close to nature, such as agricultural fields and palm groves.

Table 3. Radon concentration, surface and mass radon emission rate, and effective radium for soil samples taken from the Kutaiban area

S.N	CRn (Bq/m^3)	EX A (mBq/m^2.h)	EX M (mBq/Kg.h)	Ra eff (Bq/Kg)
1	83.6±1.1	1.52	0.027	1.96
2	77.1±1.0	1.40	0.029	1.56
3	82.9±1.1	1.50	0.031	1.64
4	109.1±1.4	1.98	0.032	2.75
5	36.3±5.3	0.66	0.011	8.80
Max	109.1±1.4	1.98	0.032	8.80
Min	36.3±5.3	0.66	1.011	1.56
Avr	77.8±1.9	1.41	0.026	3.34

Max: Maximum; Min: Minimum; Avr: Average.

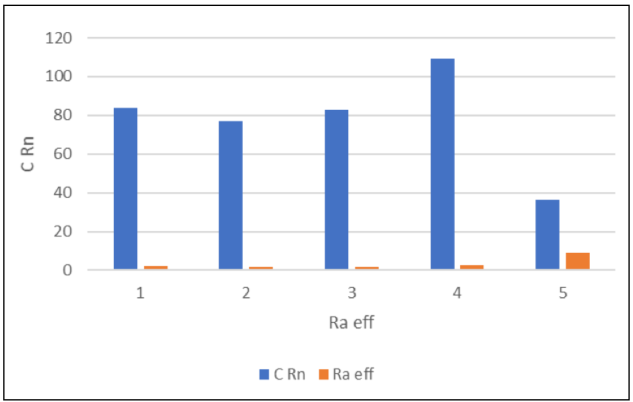

Figure 10. Correlation factor between the values of radium-226 concentration and radon-222 concentration measured by nuclear trace detectors in the Kutaiban area.

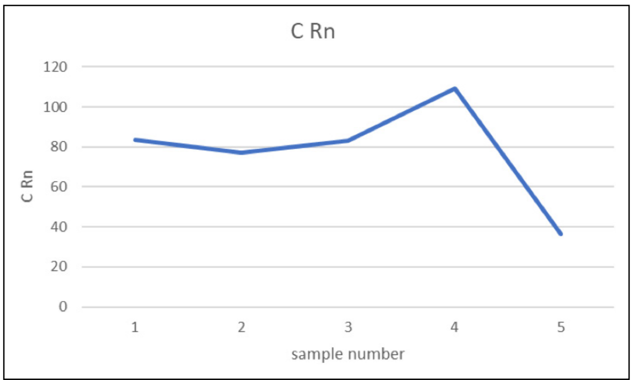

Figure 11. Radon-222 concentration levels in soil samples in the Kutaiban area.

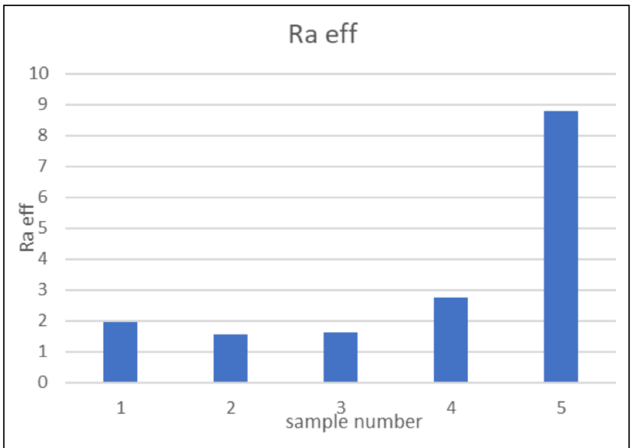

Figure 12. Levels of effective radium content in soil samples in the Kutaiban area.

CONCLUSION

As a result of the research, much higher radon-222 concentrations were measured in the test areas fractured by oil wells. The reason for this is considered to be that during the drilling of oil wells, the soil and/or rock layers underground are broken, causing the radon gas in these layers to come to the surface layer.

In addition, industrial areas were also found to be effective on radon-222 concentrations. Although this area is an industrial area, there are a few oil wells. The presence of a few oil wells next to the industrial facilities in this area is considered to be the result of the soil and/or rock layers being broken during drilling, causing the radon gas in these layers to come to the surface. There is moderate radon pollution in this area.

Much lower concentrations of radon-222 have been measured in areas close to nature, such as agricultural fields and palm groves. Since there are no underground fractures in these natural areas, radon gas is prevented from reaching the surface.

The World Health Organization (WHO) has recommended that the permissible radon concentration in the atmosphere be normally 100 and at most 300 Bq/m^3. However, this recommended value varies considerably in the international community, and in some countries, values four times higher than the 100 Bq/m^3 recommended by WHO (2007) may be accepted, and a maximum of 300 Bq/m^3 is allowed. However, this recommended value varies considerably in the international community, and in some countries, values four times higher than the 100 Bq/m^3 recommended by WHO (2007) may be accepted. US EPA sets maximum limit of 150 Bq/m^3, half the value established by EUROCON and WHO. These last two organizations agree with maximum limit of 300 Bq/m^3; however, they disagree by 200% regarding recommended values [24]. In this context; if the permissible limit value is accepted as 300 Bq/m^3, it is seen that the radon concentrations in regions of the Kutaiban and Al-Qurna are below the limit value and around the limit value in the Al-Shuaiba as a dense oil well region.

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AUTHORSHIP CONTRIBUTIONS

Concept: Mehmet Karabulut Design: Mehmet Karabulut, Supervision: Bora Isildak, Data: Mehmet Karabulut, Analysis: Mehmet Karabulut, Literature Search: Mehmet Karabulut, Writing: Bora Isildak, Mehmet Karabulut.

DATA AVAILABILITY STATEMENT

The published publication includes all graphics and data collected or developed during the study.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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