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Determination of Radon Concentrations in Selected Soil Samples from the City of Mosul Using Nuclear Track Detector CR-39

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Abstract

In this study, concentrations of radioactive radon gas were found in 24 soil samples for selected sites from Mosul (the center of Nineveh governorate) in northern Iraq, using the CR-39 nuclear track detector, to determine the extent of pollution in those sites and the extent of the danger of this gas to the health of individuals in these areas, where samples were collected from the areas under study and placed in irradiation chambers with reagents for 85 days to record the effects of alpha emitted from radon gas with optical microscope after the chemical etching process. The results showed that the highest concentration of radon gas at the study sites was at the Ibn Sina Hospital site (307.18 Bq/m^3), and the lowest value was in the Qulayyat area, by an amount of (16.29 Bq/m^3), and by an average of (99.85 Bq/m^3), noting the recommended value of (200 Bq/m^3) by (ICRP, 1993).

Keywords: Radon, Soil Samples, CR-39 Detector, Mosul City.

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Introduction

Radon ^{222}Rn is one of the main elements in the natural radioactivity of the earth's crust as it is a noble gas with a relatively long life span and enjoys easy movement to reach great distances in different geological environments, radon is found everywhere in rocks, soil, underground and groundwater, in the atmosphere and indoor air.

Radon concentrations in geological environments depend mainly on the diffusion, transition and abundance of the radium parent nucleus ^{226}Ra [1,2].

The presence of radium ^{226}Ra in a region in nature depends on the presence of uranium-^{238}U, which geologists estimate to be present in the earth's crust within (3-4) ppm, which is the main source of radon in nature, and its Half-Life is within (1600 yr). Therefore, radium is expected to be present in all ores containing ^{238}U, which is not distributed homogeneously in different geological regions due to the different geological composition of the earth's components [3].

There are areas that are almost free of this element, while there are other areas that contain high concentrations of ores containing this element, which significantly affects the variation of radon concentrations from one area to another because it seeps and is naturally released from the ground and groundwater to the atmosphere, and consists of three isotopes [4,5].

Radon isotope ^{219}Rn called actinion because it appears in the actinium-^{227}Ac series and has a relatively short half-life estimated at (3.92 sec). Radon isotope ^{220}Rn called Thoron because it appears in the Thorium series ^{232}Th as it has a half-life (55.6 sec). Radon isotope ^{222}Rn called radon. Radon-^{222}Rn appears in the ^{238}U series, its half-life Relatively long (3.825 day).

Since radon has a greater mobility and diffusion capacity than uranium and radium, this enables it to leave the rocks and escape through existing cracks and holes and through the pores between the soil grains, The scientific committee on the effects of atomic radiation of the United Nations (UNSCERAR, 1983) estimates that radon gas, together with the nascent nuclides resulting from its decay, contributes about three quarters of the annual effective dose received by man from natural radioactive sources [6].

Exposure to radon gas leads to serious health problems, and research has shown that the risk of lung cancer increases linearly with long-term exposure to radioactive radon gas by entering radon with air into the lung during breathing, so a large proportion of it is deposited on the walls and membrane lining the respiratory tract and this leads to absorption of doses of this gas by the bronchi [7].

The aim of the study is to determine the concentration of radon gas in selected soil samples taken from different places of the city of Mosul (the center of Nineveh governorate) located in northern Iraq by two samples from each site, and at a depth of 10cm to find the concentration of radon gas in the soil of these areas using the CR-39 solid-state nuclear track detector technology.

The Practical Part

Collection of Soil Samples

The soil samples in this study were collected during the month (September 2023) from the city center of Mosul and along the west bank of the Tigris river(right side), starting from the area of the field near the Iron bridge and ending at the Shifa Medical Area (Mosul medical city), in addition to other samples different from the areas of the eastern side (left side) of the city of Mosul, with 24 samples at a depth of 10 cm from the soil surface, the models were prepared with certain specifications to find the concentration of radon gas.

Sample Preparation

5g of each sample was weighed and then the samples were placed in the irradiation chambers (diffusion cylinder), which is a cylindrical test tube with a length of 6.5 cm and a diameter of 3.5 cm as shown in Figure (1).

The Diffusion chambers were closed for 30 days to reach the ideal equilibrium state between Radium and its precursors, and after the completion of the radiation balance process, the covers of the irradiation chambers were replaced with others in which the CR-39 nuclear track detector was installed with an area of (1.5*1.5 cm^2) it was hermetically sealed and left for 85 days, to ensure the recording of the effects of alpha particles on the detector and emitted from radioactive radon gas emitted from the soil, as in Figure(1), The emission from the soil sample to the detector takes more time than the half-life of Thoron gas, depending on the length of the chamber used.

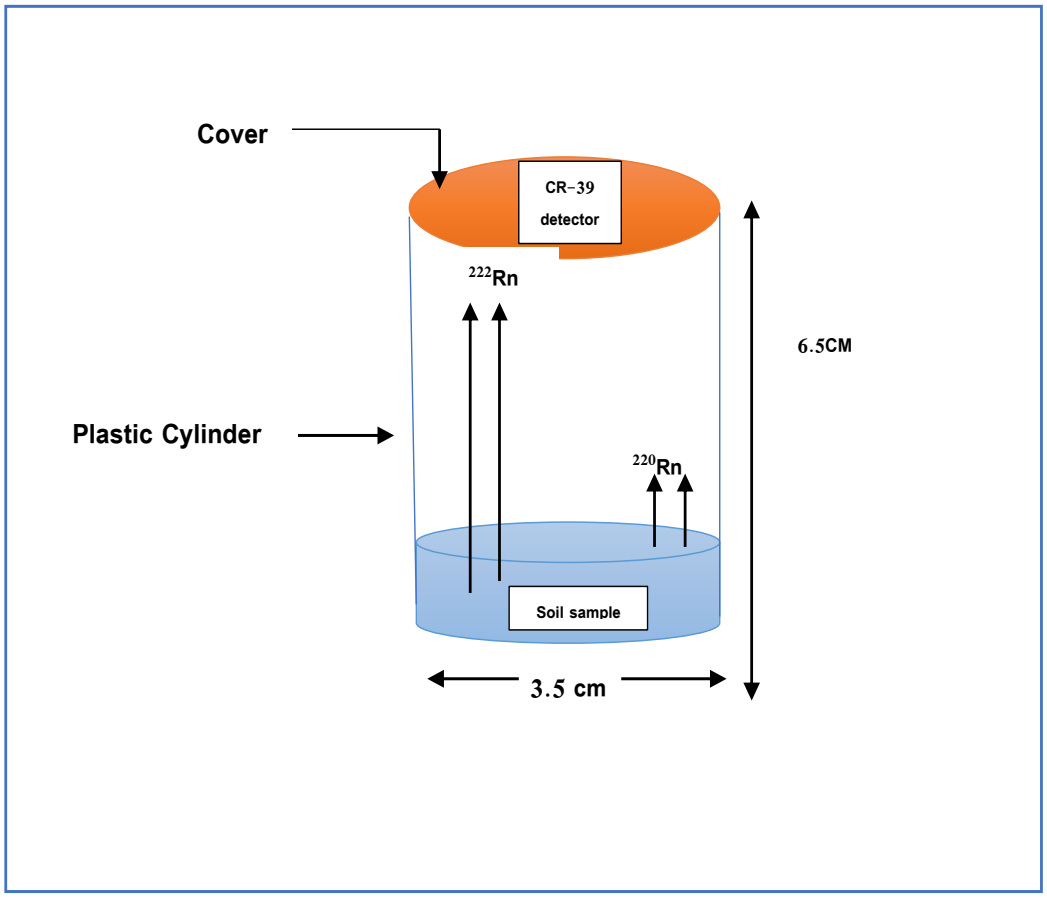


Figure 1: Cylindrical Diffusion System for Measuring Radon Concentration in Soil Samples

Then the detectors were lifted after the end of the exposure period, and showing the effects of the alpha particle emitted by radon gas, the detectors were treated chemically by chemical etching by placing them in an aqueous solution of sodium hydroxide with a normality of 6.25 N for 6 hours at a temperature of 60°C, after that, the detectors was washed with distilled water and dried, to calculate the effects recorded in the CR-39 detector by microscopic inspection with a power of 400x.

Calculation of Radon Concentration

To calculate the radon concentration in the sample (soil), by calculating the number of alpha tracks and then calculating the density of the tracks in the samples by the equation [8]:

$$\rho Rn = N/A \qquad (1)$$

Where the: N: the number of Alpha tracks on the detector., A : the area of the included lens.

The concentration of radon gas in air space (cylindrical chamber) was then determined by the relationship [9]:

$$CRn = \rho_{Rn} / Kt \qquad (2)$$

Where the: C_{Rn}: radon concentration in the air tube by unit (Bq/m^3)., ρ_{RN}: the density of tracks in soil samples (Tr./cm^2)., t: is the exposure time (day85)., K: calibration factor or sensitivity factor. (Tr/cm^2.d per Bq/m^3) can be found by the equation [10] :

$$K = \frac{1}{4} r(2cos\theta_c - r/R\alpha) \qquad (3)$$

Where the: r: the radius of the storage tube (1.75 cm)., θ: is the critical angle of the CR-39 detector (35°)., Rα: represents the range of alpha particles in the air (4.14 cm).

According to the equation (above), the calibration factor is K 0.0443 (Tr/cm^2.d per Bq/m^3). Thus, the concentration of radon in the air space of soil samples can be calculated by equation (2) [9]:

$$C_{SRn} = \frac{ht\lambda C_{Rn}}{\ell} \qquad (4)$$

Where the: C_{Rn}: concentration of radon in the air space in units (Bq/m^3)., h : the distance between the sample and the detector (5.3cm).,λ: decay constant 0.1814 d^{-1}., t: exposure time (85day)., ℓ: The thickness of the sample was about (1cm).

Table (1) and Figure (2) show the sample locations and radon concentrations.

Table 1: Radon Concentrations in Soil Samples in the Areas Under Study

Sample No	Sample Code	Sites	ρ_{Rn} (tracks/mm^2)	C_{Rn} (Bq/m^3)	C_{SRn} (Bq/m^3)
1	M1	Al-Medan 1	760.355	16.82201327	1374.7067
2	M2	Al-Medan 2	2511.834	55.57154867	4541.345858
3	M3	Al-Medan 3	1301.775	28.80033186	2353.58328
4	M4	Al-Medan 4	2.95E+03	65.25893805	5333.006099
5	Q5	Qulayyat 1	1032.544	22.84389381	1866.818992
6	Q6	Qulayyat2	736.686	16.29836283	1331.913619
7	SH7	Al-Shahwan	2662.721	58.90975664	4814.146549
8	SHB8	Sheikh Al-Shatt 1	3002.958	66.43712389	5429.288271
9	SHB9	Sheikh Al-Shatt 2	4192.307	92.75015487	7579.607581
10	N.G.SH10	The Prophet Gargis	2807.692	62.11707965	5076.251231
11	T.11	Toaleb	10559.171	233.6099779	19090.77092
12	K.S.12	Qara Saray	4677.514	103.484823	8456.852176
13	N.H.13	Nineveh health directorate	4985.207	110.2921903	9013.154993
14	B.14	Bashtabya Castle	9304.733	205.8569248	16822.77199
15	M.M15	Mosul Medical City / Emergency building	3671.597	81.23002212	6638.174269
16	M.M16	Mosul Medical City / Al-Batool hospital	6772.189	149.8271903	12243.98287
17	M.M17	Mosul Medical City / blood bank	6488.165	143.5434735	11730.47313
18	M.M18	Mosul Medical City / Consulting Center	8334.319	184.3875885	15068.2828
19	M.M19	Mosul Medical City / Ibn-Sina hospital	13884.615	307.1817478	25103.10746
20	M.M20	Mosul Medical City / dialysis center	6784.023	150.0890044	12265.3785
21	L.S1	Rashidiyya	2168.639	47.97873894	3920.856131
22	L.S2	Sumer	2073.964	45.88415929	3749.685616
23	L.S3	AL- Gufran	1505.917	33.31674779	2722.667951
24	L.S4	Nabi Yunus	5150.887	113.957677	9312.701134
AVERAGE					99.85206121

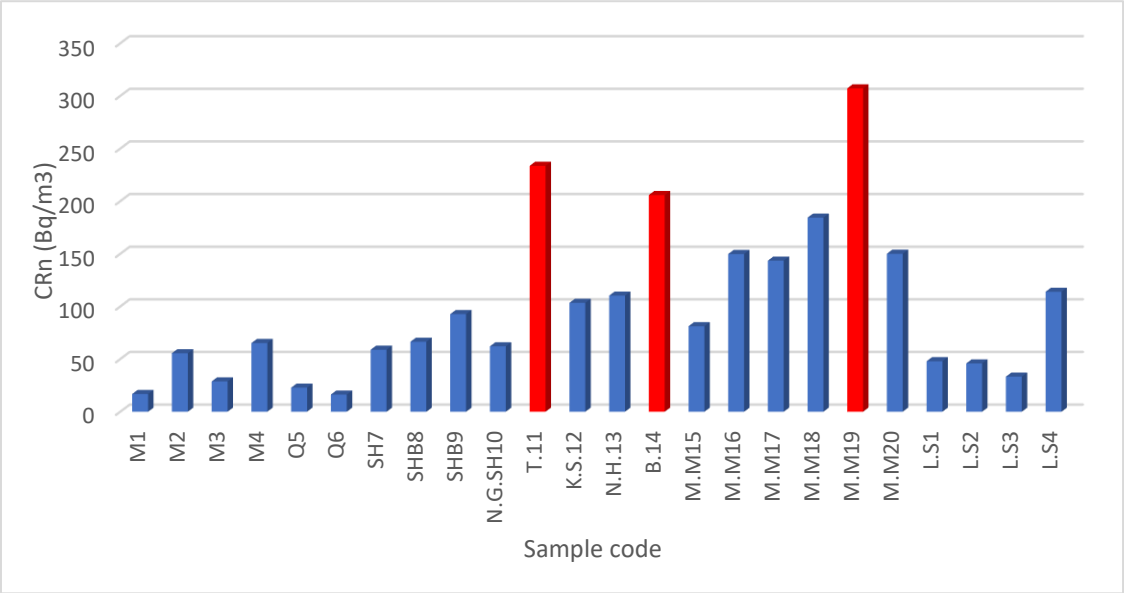


Figure 2: Radon Concentration in Soil Samples from Different Regions as a Function of Geographical Locations

Results and Discussion

We note from table (1) and figure (2) a relative variation in radon concentrations in the studied samples, through which it can be noted that the highest concentration of radon gas in the soil was in the Shifa Medical Complex (Mosul medicine city) at the site of Ibn-Sina hospital with a concentration of (307.18 Bq/m^3), which is considered a high value, this may be due to the presence of linear accelerators of atomic medicine or radioisotopes used in the treatment of cancerous tumors at the Institute of Radiology and medical materials for radiotherapy, as well as a result of aerial bombardment during the years 2014-2017, While the lowest concentration of radon gas for the study area was in the Qulayyat area, where it reached (16.29 Bq/m^3), although these areas were bombed and destroyed during that period.

The average concentration of radon in the studied areas was (99.85 Bq/m^3), this value is within the permissible, which was determined by (ICRP, 1993), which determined the maximum permissible concentration of radon is (200 Bq/m^3) [11].

Conclusions

- There are areas where the radon concentration was high and exceeded the internationally permissible limit.
- Radon concentrations for other study sites, although their level is below the permissible limit, there are sites with relatively high concentrations, and there are also areas of low radon concentration.
- The average concentration of radon gas in all areas under study was (99.85 Bq/m^3), so it is within the internationally permissible limit.

Recommendations

- Conducting further studies to identify radon gas in other areas of Mosul, especially those exposed to shelling to find out the concentrations of radon in them.
- The relevant authorities should work to address this pollution, especially since the highest concentration of radon gas was in the Medical City, where patients, employees and visitors are located.

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