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Measurement of Radon Concentrations in Gypsum Stone from Quarries in Northern Iraq Using CR-39 Detector

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Abstract: **A study was conducted to measure radon concentrations in gypsum stone used in construction from three major areas in Northern Iraq. The CR-39 detector was used to measure radon levels in the gypsum samples. This detector allowed for accurate determination of radon concentrations by detecting alpha particle tracks resulting from radon decay.**

The results showed that all recorded levels were within the safety limits set by the International Commission on Radiological Protection (ICRP). This indicates that gypsum extracted from these quarries poses no significant health risk concerning radon emissions in its raw form.

***Keywords*-Radon Gas Concentration, Gypsum Quarries, CR-39.**

I.INTRODUCTION

Radon gas is a naturally occurring radioactive element found in varying amounts in the environment, primarily emitted from the decay of uranium present in rocks and soil. Radon poses a health risk due to its ability to accumulate in enclosed spaces, increasing the likelihood of inhalation and the potential development of lung cancer with prolonged exposure [1]. Gypsum, widely used in construction, is one of the natural materials that may contain radon, raising concerns about its safety when used in buildings [2]. When gypsum is used in construction, radon can slowly seep into the indoor air of buildings, especially in poorly ventilated areas. Therefore, it becomes essential to test radon levels in the materials used in construction, including gypsum, to ensure indoor environmental safety and reduce the long-term health risks associated with radon inhalation [3]. Numerous studies have highlighted the importance of studying radon levels in gypsum used in construction, as some research has shown that radon emitted from building materials like gypsum can contribute to increased concentrations in enclosed spaces. These findings underscore the necessity of monitoring and testing building materials to ensure health safety [4][5]. Studies show that the C39 detector is effective in accurately measuring radon levels in materials such as gypsum, aiding in precise risk assessment and ensuring indoor environmental safety [6]. The importance of this research lies in evaluating radon levels in gypsum rock before processing. The study aims to investigate the impact of gypsum on radon emissions. By measuring radon levels in gypsum samples, a comprehensive understandingof radon concentrations in this widely used construction material can be obtained. This contributes to improving indoor environmental safety and reducing the health risks associated with radon exposure from gypsum used in buildings.

II.STUDY AREA

In this study, samples of gypsum rock were collected from three main quarries located in northern Iraq to measure radon gas concentrations. The first quarry is in the Al-Dibs area, where three samples were collected and labeled as GQ1, GQ2, and GQ3. The second quarry is in the Lilan area, where three additional samples were collected and labeled as GQ4, GQ5, and GQ6. The third quarry is located in the Takya area, with three more samples labeled as GB7, GQ8, and GQ9. These sites were carefully selected to ensure a good representation of the geographical diversity in radonconcentrations in gypsum rock. Fig. 1 shows the locations of the gypsum quarries included in the study.

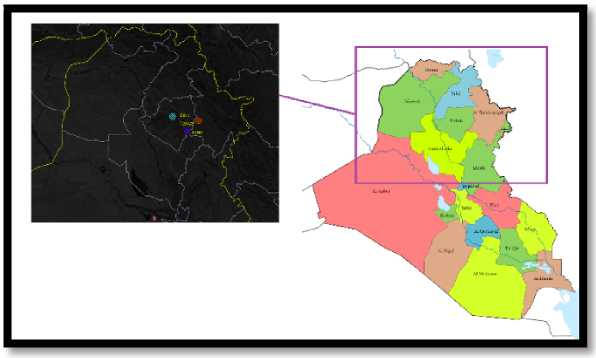

Fig.1 Gypsum quarries in northern Iraq

III. EXPERIMENTALMETHOD

In this study, a CR-39 detector with a thickness of 500µm, sourced from the British company Tasl and measuring 2 × 1 cm, was utilized to record the effects of alpha particles emitted from the selected samples. The samples were placed in irradiation tubes for a duration of 60 days to capture the alpha particle impacts on the detector's surface. These tubes are constructed from plastic with a diameter of 7 cm and a height of 30 cm, featuring a closed bottom and an open top. The prepared samples were positioned within the tubes at a height of 3 cm, with the CR-39 detector placed 25 cm above the sample surface. The setup was sealed tightly to ensure accurate results.Fig.2 illustrates irradiation tube technology diagram.

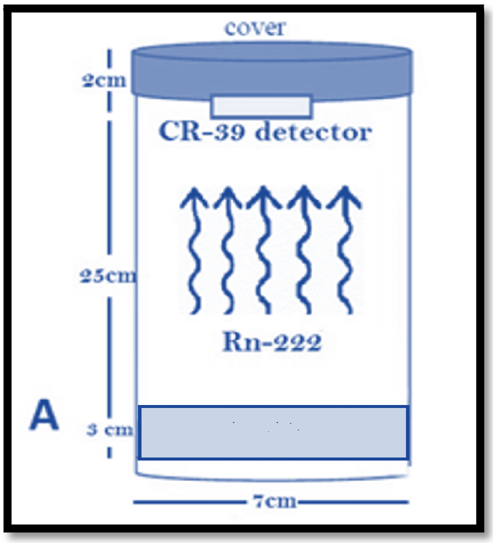

Fig.2 provides a schematic representation of the irradiation tube technology

Sodium hydroxide (NaOH) with a purity of 99% was used as an etchant to investigate the effect of ionizing radiation on the formation of tracks for radon gas concentration calculations. The CR-39 plastic detectors were etched in a NaOH solution (N=6.25) and placed in a water bath at 70°C for three continuous hours. Following etching, the detectors were thoroughly washed with water to remove any residual impurities and etching solution. An optical microscope (10X and 40X magnification) was employed to count the number of tracks formed on the detector.

The diffusion constantK was determined based on the specific design of the irradiation tube. Due to variations in the geometric dimensions, such as diameter and length, the diffusion constant K varies according to the design of the irradiation system. The diffusion constant K was calculated using the following relationship[7]:

$$K = \frac{1}{4} r \left(2\cos\theta c - \frac{r}{R\alpha}\right) \quad (1)$$

r : the radius of the irradiation tube which is(3.5 cm). θ_c: the critical angle for the detector and is about 35□. Rα: range of alpha particles produced from radon in air of (4cm). After substituting the values in the above equation, we notice that the propagation constant K is equal toK0.67=$\mathrm{Tr.cm^{-2}d^{-1}/Bq.m^{-3}}$.

The radon concentration in the air space found by using thefollowing equation [8].

$$C_{Rn} = \frac{\rho}{KT} \qquad (2)$$

$C_{Rn}$is Radon concentration in the air space, measured in $Bq.m^{-3}$. ρ is the density of the resulting effects, measured in $\mathrm{Tr.cm^{-2}}$and T is The irradiation time is about 60 days.

60 days.

Intensity rate of the track (D) measured by the following [7]:

$$D = \frac{\rho}{T} \qquad (3)$$

To measured Radium content in the soil sample for oil fields we must find Radon concentration in soil sample by using the following [9]:

$$C_s = \frac{\lambda_{Rn} C_a h\, t}{L} \qquad (4)$$

C_s : Radon concentration measured by $Bq.m^{-3}$. h: height of the air space (from the surface of the soil sample to the surface of detector) is about 25cm. L: thickness of the soil sample which is about 3cm.

The radioactivity of the Radon element is found in the samples by using the following relationship [10]:

$$A_{Rn} = C_s\, V \qquad (5)$$

A_{Rn}: radioactivity of radon in samples is measured in unit Bq. V: volume of the soil sample measured in m^3, and the volume found by the following:

$$V = \pi\, r^2 L \qquad (6)$$

r: radius of the irradiation tube which is equal to 3.5cm. L: thickness of the sample inside the tube is 3cm.

The Radon emission rate is measured from the sample surface area $E_A$in unit ($\mathrm{Bq.}m^{-2}\mathrm{h^{-1}}$), from this equation [11]:

$$\mathrm{E_A} = \frac{\rho\lambda V}{\mathrm{KAT_e}} \qquad (7)$$

The radon rate emitted in terms of mass E_M in unit ($\mathrm{Bq.}Kg^{-2}\mathrm{h^{-1}}$) and it can be calculated by the following law [11]:

$$\mathrm{E_M} = \frac{\rho\lambda V}{\mathrm{KMT_e}} \qquad (8)$$

V.RESULTS

A. Radon Concentrations of sample of gypsum, raw gypsum stone and soil surrounding quarries

Table I shows the average density of the traces formed on the detector, the concentrations of radon gas in the samples, in units $\mathrm{Bqm^{-3}}$, and the radioactive effectiveness of radon in units mBq.

Table I: Shows the concentrations of radon gas, the radioactivity of radon, and the average density of traces for the selected samples in the study area

Sample code	D Tr/cm2.d	Bqm^{-3}	Bqm^{-3}	mBq
GQ1	67.99	103.01	8333.06	961.55
GQ2	60.64	91.88	7322.99	845.00
GQ3	64.31	97.44	7828.03	903.28
GQ4	73.50	111.36	9090.61	1048.97
GQ5	64.31	97.44	7828.03	903.28
GQ6	18.38	27.84	1515.10	174.83
GQ7	12.86	19.49	757.55	87.41
GQ8	58.80	89.09	7070.48	815.86
GQ9	40.43	61.25	4545.31	524.48
Mean	51.25	77.64	6032.35	696.07
range	12.86-73.50	19.49-111.36	757.55-9090.61	87.41-1048.97

Fig. 3 shows the linear relationship between the average intensity of traces formed in units Tr/cm2.d and the concentrations of samples using CR-39 detector measured in units Bqm^{-3} . The highest density of traces formed on the detector was recorded in sample GQ4 was73.50 Tr/cm2.d , while the lowest average density of traces formed on the detector in sample GQ7 raw gypsum stone was12.86 Tr/cm2.d.

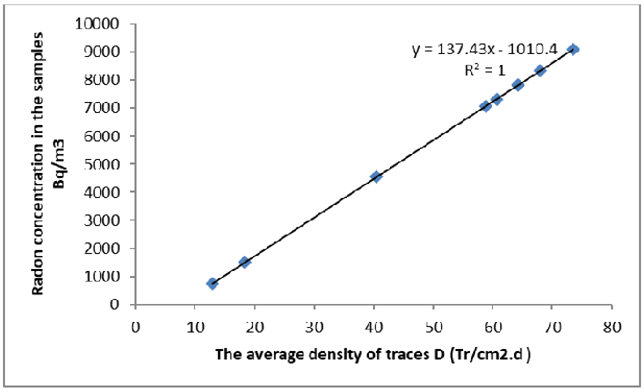

Fig. 3 linear relationship between the average intensity of traces formed in units Tr/cm2.d and the concentrations of samples using CR-39 detector measured in units Bqm^{-3}.

The highest value of the radioactivity of radon gas for samples from the study area was recorded in sample GQ4 was1048.97 mBq , while the lowest value of the radioactivity of radon was recorded in sample raw gypsum stone GQ7 was 87.41 mBq.As shown in the Fig.4.

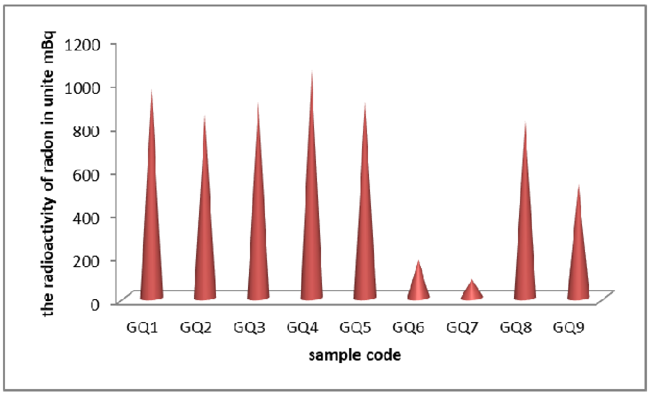

Fig. 4 shows the radioactive activity of radon gas in selected samples in the study area using .

The concentration of radioactive radon gas in sample GQ1 103.01 Bqm^{-3}, and the highest concentration of radon was in sample GQ4, where it reached about111.36 Bqm^{-3}, while the lowest concentration of radon was recorded for the raw gypsum stone for sample GQ7 19.49 Bqm^{-3} as shown in Fig 5.

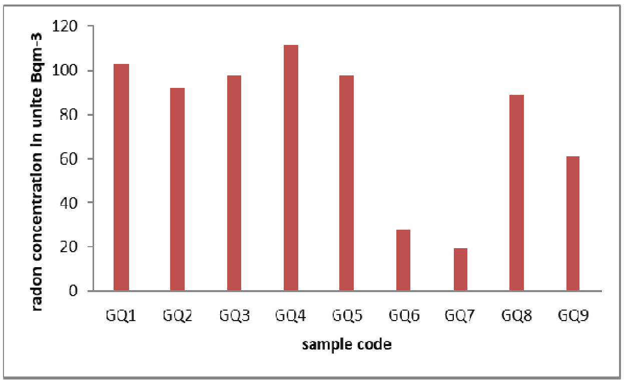

Fig5. Radon gas concentrations measured using CR-39 detector for samples from the study area

B. Radon Exhalation Rate

Radon gas is partly formed in the soil and released to reach the surface, thus being released into the Earth's atmosphere. The exhalation rate of radioactive radon gas depends mainly on the permeability of the soil and weather conditions such as temperature, humidity, air pressure, and soil permeability.[12]. Table II shows the surface and mass emission rate of radon gas for samples from the study area. we note the highest surface emission was 25.06 m Bq/m2.h for sample GQ4, and its lowest value was 4.38 m Bq/m2.h for sample GQ7 of gypsum stone, and the surface emission rate was 17.47 m Bq/m2.h. with a range of 4.38-25.06 m Bq/m2.h in the study area and for selected samples as shown in Fig. 6.

Table II IV Surface emission EA(mBq/m2.h) and mass emission EM (mBq/h.Kg) rates of radon gas for samples from the study area

Sample code	EA mBq/m2.h	EM mBq/h.Kg
GQ1	23.18	0.81
GQ2	20.67	0.74
GQ3	21.92	0.67
GQ4	25.06	0.76
GQ5	21.92	0.69
GQ6	6.26	0.18
GQ7	4.38	0.14
GQ8	20.05	0.64
GQ9	13.78	0.39
mean	17.47	0.56
range	4.38-25.06	0.14-0.81

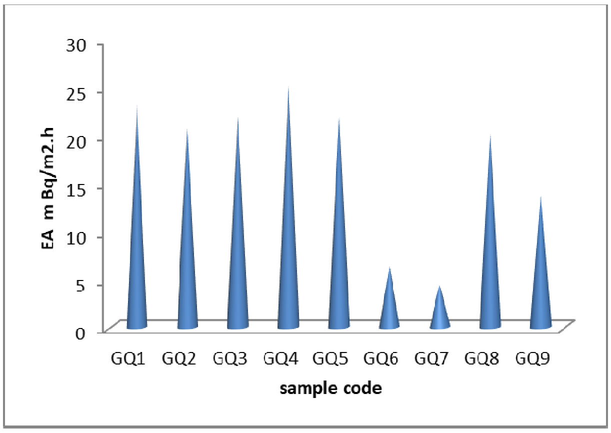

Fig6 Surface emissionEA of samples from the study area

Fig. 7 shows the mass emission rate of radon gas for samples from the study area. It was found that the highest mass emission value recorded in sample GQ1 was 0.81, and its lowest value was in sample 0.14 for sample GQ7. Fig. 8 show the linear relationship between radon gas concentrations in unit $Bq.m^{-3}$ and the surface emission EA in unit $mBq.m^{-2}.\mathrm{h}^{-1}$and the mass emission EM in unit $mBq.Kg^{-1}.\mathrm{h}^{-1}$.

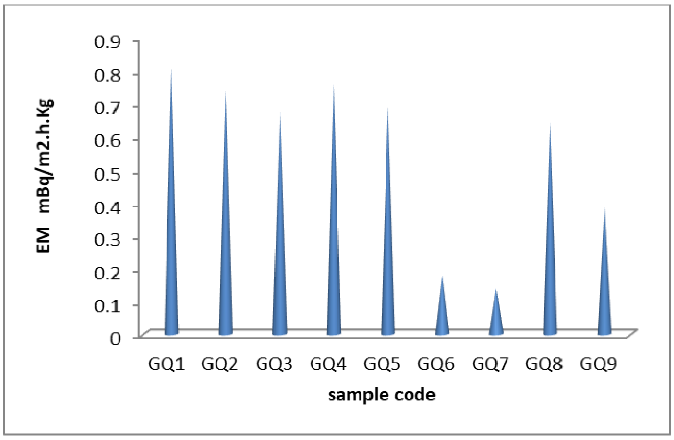

Fig. 7 Mass emissionEM of samples from the study area.

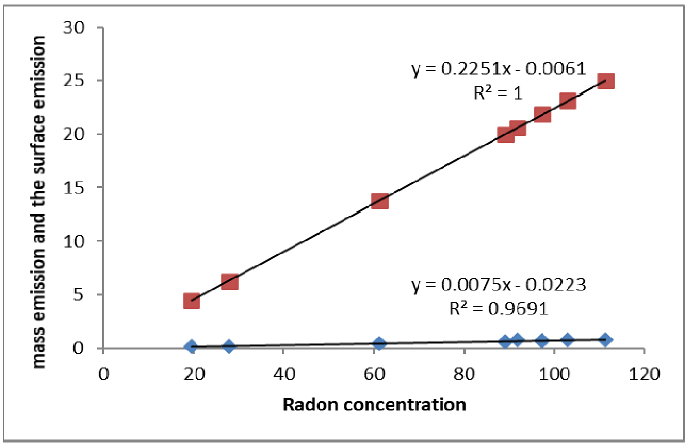

Fig.8 The linear relationship between radon gas concentrations in unit $Bq.m^{-3}$ and the surface emission EA in unit $mBq.m^{-2}.\mathrm{h}^{-1}$and the mass emission EM in unit $mBq.Kg^{-1}.\mathrm{h}^{-1}$.

III COUCLUSION

The mean of radon concentration is about 77.64 Bqm^{-3} mesured by use CR-39 detector for the different samples of raw gypsum stonewith range about (19.49-111.36 Bqm^{-3}) and all the radon concentrations are below the action level (200-600 Bqm^{-3}) as recommended by ICRP [13]. The range of mass emission 0.14-0.81 m Bq/kg.h and the mean is about 0.56 m Bq/kg.h , while the range of surface emission is 4.38-25.06 m Bq/m2.h and it is mean about 17.47 m Bq/m2.h , UNSCEAR determined that the highest permissible limit for surface emission reached 1250 m Bq/m2.h [14]. Therefore, it was found that all measured results are within the safe range.

IV REFRENCES

[1] Sukanya S.andSabu Joseph “Environmental Radon: A Tracer for Hydrological Studies” Springer Nature Singapore,2023.

[2]WouterSchroeyer s “Naturally Occurring Radioactive Materials inConstruction” Elsevier Science ,2017.

[3] E.S. Simopoulos ‹F. Steinhäusler and J.P. McLaughlin “The Natural Radiation Environment VII” Elsevier Science, 2005.

[4] . Lysandrou [a b], A. Charalambides [a], I. Pashalidis “Radon emanation from phosphogypsum and related mineral samples in Cyprus” Radiation Measurements, Vol. 42, pp.1583-1585, 2007.

[5] O'Riordan M.C., Duggan M.J., Rose W.B. and Bradford G.F. “The radiological implications of using by-product Gypsum as a building material” 1972.

[6] Bećo Pehlivanović “Measurement of the Indoor Radon Concentration from Different Building Materials Using CR-39 Nuclear Track Detectors and the Associated Annual Effective Dose Determination” Post Scriptum journal, 2022.

[7] Azam, A., Naqvi, A. H., and Srivastava, D. S.,“ Radium concentration and radon exhalation measurements using LR-115 type II plastic track detectors“ Nuclear geophysics, 9(6), pp. 653-657,1995.

[8] Omar Abdul Aziz Ahmad and Anmar DhrarKusag "Measuring of Radon Concentration in Soil and Plant by Using CR39 Detector in Anbar, Iraq" International Journal of Emerging Technology and Advanced Engineering, vol. 2, 2013.

[9] Malik H. Kheder, "Measurement of RadonConcentration Using SSNTD in Bartella Region "Al-Mustansiriyah Journal of Science, vol. 29, 2018.

[10] G. Somogyi, "The environmental behavior ofradium " Technical Reports Series., IAEA, Vienna,vol. 1, no. 310, pp. 229-256, 1990.

[11] P S Miklyaev, T B Petrova and P A Sidyakin "Abnormal High Radon Exhalation Levels on the Mount Beshtau, North Caucasus" International science and technology conference "Earth science" ,No.2,vol.272,2019.

[12] Hasan A. K.,.Subber A. R. H., Shaltakh A. R. " The Measurements of Radon Concentration and Thoron to Radon Ratio in Soil Gas in the Environs of Al-Kufa City-Iraq " Caspian Journal of Applied Sciences Research,2(1) , pp. 23-30 (2012).

[13] ICRP, International Commission on Radiological Protection, “ International Commission on Radiological Protection for Protection against Radon at home and at work ICRP“ publication 65, Pergamon Press, oxford, UK., Nov. 1993.

[14] United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR) ,Sources, Effects and Risk of Ionizing Radiation, U.N, New York (1993).