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Environmental Radioactivity of Radon and its Hazards in Hamash Gold Mine, Egypt

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Radon concentrations have been measured using Sealed Can Technique with CR-39 detector for twenty collected samples from Hamash gold mine area, South Eastern Desert of Egypt. This area is one of the most important areas of gold-bearing granites in Arabian Nubian Shield and is being used as a gold mine. The average values of radon concentrations, the exhalation rates, annual effective doses, and working levels are found to be 27.18 ± 0.13 kBqm^{-3}, 3.27 ± 0.03 Bqm^{-2}h^{-1}, 686.27 ± 5.15 mSvy^{-1} and 2.94 ± 0.02 respectively. The results indicate that the radon concentrations in all samples are higher than the recommended world limit given by ICRP and IAEA. The present study can be used to assess any changes in the radioactive background and any harmful radiation effect on the human in this area. Finally, the obtained data are useful when building a radioactivity atlas of radon for Hamash gold mine and its surrounding region.

Keyword: Radon, CR-39, Gold mine, Can technique, Annual effective dose, Radiation

Introduction

Radon is emitted from the soil, rocks, and water into the air. It comes from the natural decay of radium deposits in the soil, rocks, water and depending on the geographical and the geological features of the region. Radon is an important natural radioactive element that could be harmful to the human population [1]. Radon is a radioactive gas having different isotopes, there a great interest in ^{222}Rn which decays with a half-life of 3.82 days into many short-lived isotopes, but highly alpha emitter daughter progenies such as ^{218}Po and ^{214}Po [2]. Radon and daughter products are the highest contributor to human exposure of the natural background radiation, and hence, it is considered as an environmental health hazard when concentrated in closed areas like underground mines, caves, and cellars or poorly ventilated and badly designed houses. The determination of radon concentration is very important due to the health risk and design the control strategies and to detect the risk of radiation exposure for workers in the studied area. Hamash gold mine area (HGMA) location is in the south Eastern Desert, Egypt. The area is limited by longitudes (34° 04' and 34° 09') and latitudes (24° 38' and 24° 43'). In the current work, radon concentrations were measured for samples of granite stone and metavolcanics, as shown in Fig. (1). From the obtained data, the difference in the radioactivity background level due to geological processes in the studied area can be detected.

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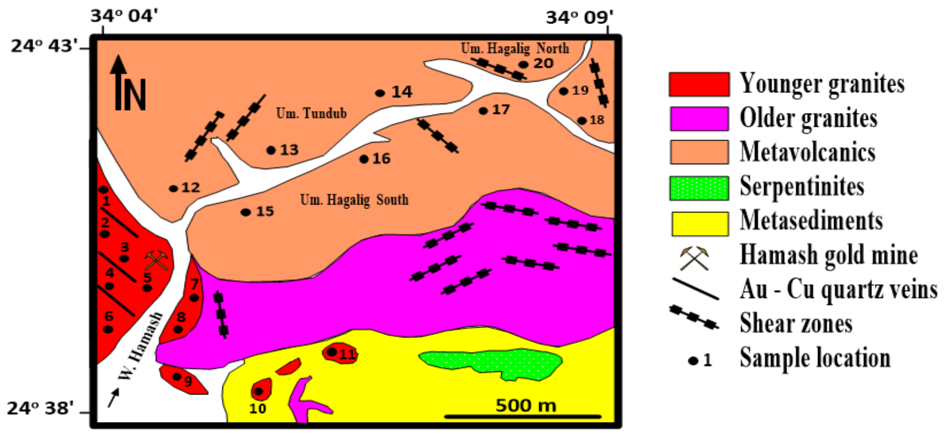

Fig. (1): The location and geological map of the samples [3]

Materials and Methods

Twenty samples have been collected from Hamash gold mine areas. Closed Can technique was used to estimate radon concentrations C_{Rn}, exhalation rates (E_A), Annual effective doses (H_E) and working levels (WL) using CR-39 detectors. The collected samples were dried for 3 hours at 110 °C in the oven, sieved by 1 mm mesh, weighted and saved for 50 days in a closed stainless-steel can (17 cm height & 10.6 cm diameter). All samples were stored within the same volume in the container up to 6 cm height, leaving 11 cm free height to the detector above as shown in Fig. (2). The detectors CR-39 of thickness 500 µm, made by American Technical Plastics, were cut into sheets (1.5 x 1.5) cm^2 and fixed at the internal-side of the can cover and the containers were closed tightly. In the same way, the background radiation has been measured by cans containing no samples. All samples were stored for 50 days in a dry and dark place to reach secular equilibrium. The detectors were removed carefully from the cans and etched in a solution of NaOH with 6.25 N at 70 ± 1°C for 8hrs, then eroded in distilled water and dipped for 5 minutes in a 3% acetic acid solution. Finally, the detectors were washed again with distilled water and dried. The alpha tracks were then counted using an optical microscope at a magnification of 640x, taking into consideration the background [4]. Radon concentrations C_{Rn} were calculated in ($kBqm^{-3}$) by the following equation:

$$C_{Rn} = \frac{\rho}{\eta T} \quad (1)$$

Where ρ is the track density (track cm^{-2}), η is the calibration coefficient of the CR-39 detector and T is the exposure time in days [5].

The exhalation rate E_A of radon was calculated by:

$$E_A = \frac{CV\lambda}{A[T + \frac{1}{\lambda}(e^{-\lambda T} - 1)]} \quad (2)$$

Where λ radon decay constant (h^{-1}), C radon concentration ($Bqm^{-3}h$), V effective volume of the Can (m^3), A is the cross-sectional area (m^2) and T the irradiation time [6, 7].

The annual effective dose H_E was calculated by:

$$H_E\,(mSvy^{-1}) = C_{Rn}\,.\,F.\,H.\,D.\,T \quad (3)$$

Where F = 0.4 the indoor equilibrium factor between radon and its progeny, H is the indoor occupancy factor (0.8), D is the dose conversion factor (9×10^{-6} $mSvh^{-1}$ / Bqm^{-3}) and T is the indoor exposure time equal to 7000 hy^{-1} [2, 4].

The working levels have been given using the following equation:

$$WL = (C_{Rn} \times F)/3700 \quad (4)$$

Where F is the equilibrium factor for radon which equal 0.4 as suggested by [2, 8].

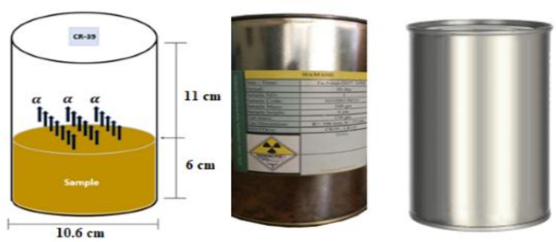

Fig. (2): Closed container Can use for stored samples in passive technique

Results and Discussion

The Locations and description of the investigated 20 samples obtained from (HGMA) are presented in Table (1). The obtained values of radon concentrations (C_{Rn}), exhalation rates (EA), annual effective doses (HE) and Working levels (WL) for all samples using CR-39 detectors are given in Table (2). The average values of C_{Rn}, EA, HE and WL are found to be equal to 27.18 ± 0.13 $kBqm^{-3}$, 3.27 ± 0.03 $Bqm^{-2}h^{-1}$, 686.27 ± 5.15 $mSvy^{-1}$ and 2.94 ± 0.02 respectively.

The differences in radon concentrations from a sample to another are due to the variation in the geological structures and chemical compositions of the samples. From Table (2) it can be noticed that the values of C_{Rn}, E_A, H_E and WL are higher than the reported permissible limit [9, 10, 11, 12]. Most of our results agree with the published data of different countries as shown in Table (3).

Figure (3) shows the radon concentrations of the samples in different locations. Samples No. 7, 8, 9, 10 and 11 have high values of radon concentration. The high values of C_{Rn} in these locations are due to the increase of ^{238}U, since uranium ore deposits are in secular equilibrium with its daughters. The high values of C_{Rn} in these locations can be attributed to increasing of ^{238}U content. Samples No. 15, 16 and 17, which have low values of radon concentration are from the Um. Hagalig area.

Figure (4) shows the correlation between C_{Rn} and E_A, where R^2 = 1. There is a good agreement between C_{Rn} and E_A. The relation is linear because E_A calculation depends on C_{Rn}. E_A is important to understand the relative contribution of the material to the total C_{Rn} found in the samples and is helpful to know radon health hazard.

Table (1): Locations of samples obtained from different areas

Sample No.	Area name	Description	Latitude	Longitude
1	Hamash Gold Mine	Younger granite (Au-Cu quartz)	24 ˚ 41' 32"	34 ˚ 04' 31"
2			24 ˚ 41' 12"	34 ˚ 04' 27"
3			24 ˚ 41' 02"	34 ˚ 04' 53"
4			24 ˚ 40' 36"	34 ˚ 04' 49"
5			24 ˚ 40' 36"	34 ˚ 05' 28"
6			24 ˚ 40' 12"	34 ˚ 05' 17"
7	Wadi Hamash		24 ˚ 40' 23"	34 ˚ 05' 57"
8			24 ˚ 40' 05"	34 ˚ 05' 35"
9			24 ˚ 39' 12"	34 ˚ 05' 13"
10			24 ˚ 39' 40"	34 ˚ 05' 39"
11			24 ˚ 40' 05"	34 ˚ 06' 35"
12	Um. Tundub		24 ˚ 42' 40"	34 ˚ 05' 22"
13			24 ˚ 42' 11"	34 ˚ 05' 11"
14			24 ˚ 41' 47"	34 ˚ 05' 33"
15	Um. Hagalig South	Metavolcanics (Shear zones)	24 ˚ 41' 13"	34 ˚ 06' 27"
16			24 ˚ 41' 04"	34 ˚ 05' 57"
17			24 ˚ 40' 49"	34 ˚ 06' 01"
18	Um. Hagalig North		24 ˚ 42' 17"	34 ˚ 07' 58"
19			24 ˚ 42' 53"	34 ˚ 07' 37"
20			24 ˚ 43' 10"	34 ˚ 07' 04"

Table (2): C_{Rn}, E_A, and H_E, of the samples obtained using CR-39 detectors

Sample No.	Area name	C_{Rn} ($kBqm^{-3}$)	E_A ($Bqm^{-2}h^{-1}$)	H_E ($mSvy^{-1}$)	WL
1	Hamash	23.10 ± 0.14	2.78 ± 0.02	583.08 ± 4.16	2.50 ± 0.02
2	Gold	29.88 ± 0.15	3.60 ± 0.03	754.41 ± 5.60	3.23 ± 0.02
3	Mine	26.62 ± 0.15	3.20 ± 0.03	672.06 ± 7.00	2.88 ± 0.03
4	Wadi Hamash	41.29 ± 0.18	4.97 ± 0.04	1042.44 ± 8.71	4.46 ± 0.04
5		34.76 ± 0.17	4.18 ± 0.03	877.45 ± 5.64	3.76 ± 0.02
6		27.28 ± 0.15	3.28 ± 0.04	688.83 ± 8.07	2.95 ± 0.03
7		47.02 ± 0.19	5.66 ± 0.02	1186.99 ± 5.16	5.08 ± 0.02
8		52.00 ± 0.20	6.26 ± 0.03	1312.74 ± 6.43	5.62 ± 0.03
9		54.93 ± 0.21	6.61 ± 0.04	1386.81 ± 7.85	5.94 ± 0.03
10		64.13 ± 0.23	7.72 ± 0.03	1619 ± 5.46	6.93 ± 0.02
11		54.97 ± 0.21	6.61 ± 0.03	1387.90 ± 6.07	5.94 ± 0.03
12	Um. Tundub	3.78 ± 0.06	0.46 ± 0.04	95.53 ± 7.47	0.41 ± 0.03
13		1.47 ± 0.03	0.18 ± 0.03	37.17 ± 5.97	0.16 ± 0.03
14		12.60 ± 0.10	1.52 ± 0.03	318.10 ± 5.44	1.36 ± 0.02
15	Um. Hagalig South	0.03 ± 0.00	0.00 ± 0.04	0.71 ± 8.07	0.00 ± 0.03
16		0.17 ± 0.01	0.02 ± 0.01	4.42 ± 2.22	0.02 ± 0.01
17		0.66 ± 0.02	0.08 ± 0.00	16.74 ± 0.36	0.07 ± 0.00
18	Um. Hagalig North	24.75 ± 0.14	2.98 ± 0.01	624.89 ± 0.73	2.68 ± 0.00
19		22.26 ± 0.13	2.68 ± 0.01	561.98 ± 1.49	2.41 ± 0.01
20		21.95 ± 0.13	2.64 ± 0.01	554.06 ± 1.13	2.37 ± 0.00
Average		**27.18 ± 0.13**	**3.27 ± 0.03**	**686.27 ± 5.15**	**2.94 ± 0.02**

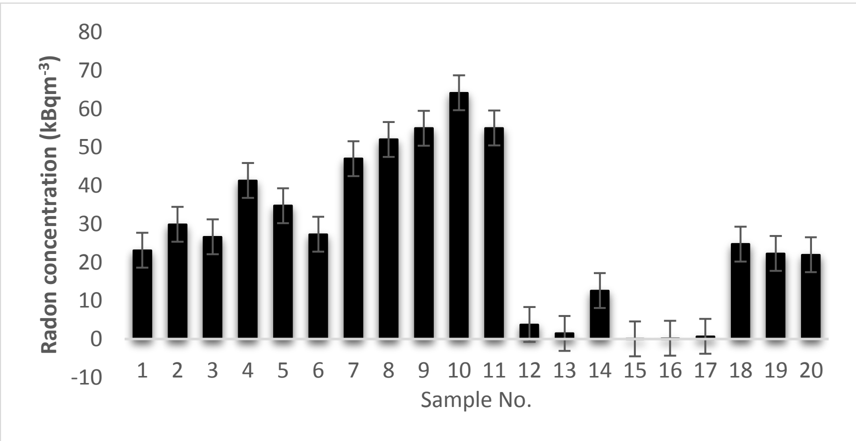

Fig. (3): Comparison of the results of radon concentrations of the samples

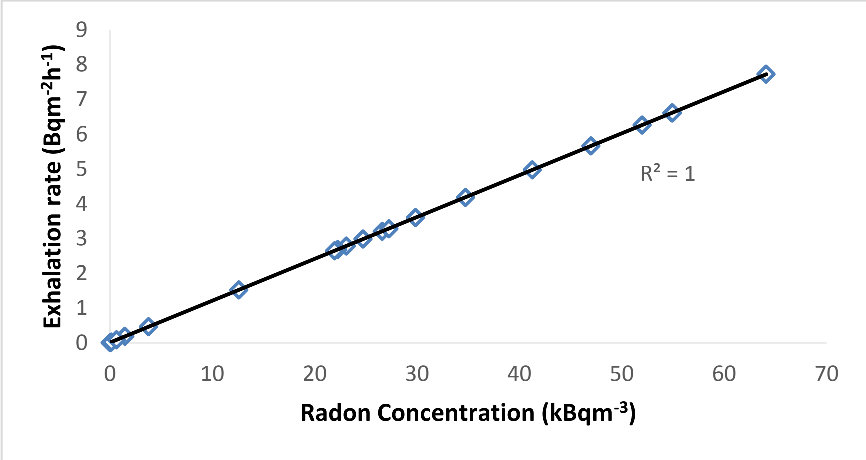

Fig. (4): Correlation relation between C_{Rn} and E_A of the samples

Table (3): Comparison between present and previous publication in different countries

Region	C_{Rn} ($kBqm^{-3}$)	E_A ($Bqm^{-2}h^{-1}$)	Reference
Poland	8.90		[13]
France	598		[14]
South Africa	226.50		[15]
Hungary	1.7		[16]
Germany		1.89	[17]
India	30.45		[18]
East Asia		1.75	[19]
China		2.97	[20]
Australia		2.60	[21]
India	1.74		[22]
Spain		1.85	[23]
Brazil	1.80	1.02	[24]
South Africa		1.20	[25]
Egypt	27.18	3.27	Present study

Conclusion

The present study clearly demonstrates that Hamash gold mines area (HGMA) is highly contaminated with radon due to its geological structure and chemical composition of different rocks from the surrounding areas. The average values of $\mathbf{C_{Rn}}$, $\mathbf{E_A}$, $\mathbf{H_E}$ and **WL** are found to be equal to 27.18 ± 0.13 $kBqm^{-3}$, 3.27 ± 0.03 $Bqm^{-2}h^{-1}$, 686.27 ± 5.15 $mSvy^{-1}$ and 2.94 ± 0.02 respectively. Obtained results agree with published data from different countries [14, 15, 18]. The results indicate that the radon concentrations $\mathbf{C_{Rn}}$ of all samples are higher than the permissible recommended world limit [9, 10, 11]. It is generally higher than the reference level (0.50-1.50 $kBqm^{-3}$) recommended in workplaces. The obtained data help in detecting any change in the radioactive background level due to geological processes, and it can be used as reference information in Hamash gold mine to detect any harmful radiation that would affect the workers in this area.

For the above reasons, strong safety considerations are recommended for protecting the working personnel in Hamash gold mine and its surrounding areas.

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