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Active and Passive Radon Measurements inside Dendera Ancient Temple, Egypt.

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Abstract: The purpose of this investigation was to measure radon activity concentrations and the equilibrium factors in the air of underground cavities in an ancient temple, namely, Dendera temple, 600 km south of Cairo, Egypt. The measurements were performed monthly for a year using an active technique with an Alpha GUARD detector and the passive technique with the diffusion cups equipped with bare and filtered LR-115 nuclear track detectors. The results from the passive measurements showed a seasonal variation of radon activity concentrations, with summer maxima and winter minima, in the place under investigation and it was found that the concentration strongly correlate with the temperature difference between the inside and outside place under investigation. The yearly mean radon activity concentration and the equilibrium factor were determined inside the crypt of Dendera temple. The estimated annual effective dose to workers, tour guides, and tourists did not exceed the lower bound of the ICRP action levels.

Keywords: Radon, Alpha GUARD, LR115 detectors, Equilibrium factor, Effective doses, Dendera temple, Egypt.

1 Introduction

In Egypt, an avalanche of attention has been noted over the past decade concerning natural radioactivity such as radon in confined places in ancient Egyptian tombs and temples [1-10]. This attention is due to an attempt to explain the occurrence of the phenomenon of the "curse of the Pharaohs" which occurs as a result of the vulnerability of people who open tombs to a massive dose of the radioactive gas radon [10]. Nationwide surveys have been undertaken to determine radon levels in these places and to assess consequent risks of lung cancer and other types of cancers [11-16]. Indoor radon comes from several sources principally the soil and rocks with high concentrations of ^{238}U. Radon can seep through small cracks and fissures and then accumulate in confined places [17].

Many techniques are used for radon measurements. An active technique using the Alpha GUARD detector and the passive integrating plastic nuclear track detectors, such as CR-39 and LR-115, are the most reliable detectors that are widely used in radon dosimetry. This is due to their high sensitivity, low cost, ease to handle, and retaining a permanent record of the data. Also, these detectors incorporate the effects of seasonal and diurnal fluctuation of radioactivity concentrations due to physical and geological factors as well as meteorological factors [17].

In this work, the radon activity concentrations measurements as well as the effective dose estimations were carried out in the air in the underground cavity in an ancient Egyptian temple, namely, Dendera temple. The active Alpha GUARD detector and the sealed cup – technique with bare and filtered LR-115 detectors were used.

The temple of Dendera, on the west bank of the Nile and opposite to Qena city, 600 km south of Cairo (Figure 1), is one of the best preserved and most impressive of the Egyptian temples. This is due to the late date of its construction. This temple as seen today was built from about 116 B.C to 34 A.D. The temple was built from Nubian sandstone. The ceiling and the walls of the temple are 2m thick (Figure 2). Fourteen crypts were built adjacent to the chambers where the priests used the silver and gold vessels in the daily rituals. The scenes on the walls of these crypts represent the king offering sacrifices and slaying hostile gods .Only one of the fourteen is open for tourist visits. The Crypt under investigation is 2.5 in height and 1.8 m in width and 27 m long with 0.8 m entrance wide and it is about 2 m underground (Figure 3)[18].

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Fig.1: Schematic map of Egypt shown Dendera village.

Fig.2: Dendera's Temple of Hather has stood for 2000 years.

Fig.3: The cup locations inside the Crypt in Dendera Temple.

2 Material and Methods

2.1 Active technique: An Alpha GUARD detector.

Alpha GUARD monitor (PQ2000 PRO – GENITRON, Germany) is available in the physics department, faculty of science, South Valley University, Qena, Egypt. Alpha GUARD is a continuous active radon sampling sensor. The radon detector Alpha GUARD is based on the optimized design of the pulse-ionization chamber. In regular operation, this detector measures the radioactivity of the air using the diffusion of gas through the large surface of the glass fiber filter installed inside the ionization chamber. This filter permits the ^{222}Rn gas can pass through and prevents the products of the radon decay from entering to the ionization chamber. It also protects the ionization chamber from contamination by dust particles. The reading inside the crypt of the temple and at its entrance (Figure 3) for every ten minutes cycle for two hours and overall mean radon concentrations were obtained in Bqm^{-3}.

2.2 Passive technique: A diffusion cup with LR-115 detector.

The measuring device is a diffusion cup of aluminum 3.5 cm in radius and 11 cm in length equipped with two detectors with different sensitivities of LR-115 type II (Kodak Pathé, France), numbered and attached with double adhesive side by side at the top center of the converted cup. The cup is closed by a 50 µm PE filter [19]. Another LR-115 detector is fixed outside the cup (bare detector) as shown in Figure 4. This device was used for simultaneous estimation of radon activity concentration and the equilibrium factor [20-21].

The detection system was calibrated at the National Institute for Measurements and Standards (NIS), Cairo, Egypt [4, 5].

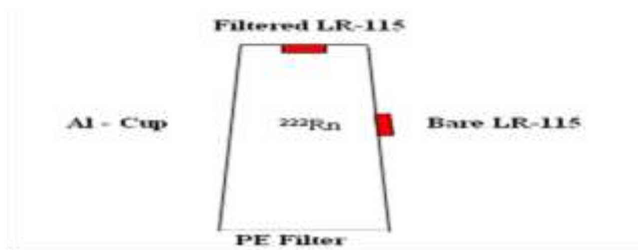

Fig. 4: Schematic diagram of the passive radon device [17].

A total of 5 measuring cups were used per month to measure the indoor radon in the air of the crypt of Dendera temple. The cups were placed about 2 m above the floor. The locations of the cups in the site are illustrated in Figure 3.

The period of the survey was one year from January to December. After the exposure time the detectors were removed and etched in a freshly prepared NaOH solution;

2.5 M at 60Cº for 2 h for LR-115 detectors. The track densities were determined by means of an optical microscope of magnification 600 X. Background track densities were subtracted from the tracks of exposed detectors and the average radon concentration values were determined.

The track density recorded on the internal detector ρi which related to the radon activity concentration C (Bqm^{-3}) in the following way [21-22]:

$$C = \frac{\rho i}{K \eta t} \qquad (1)$$

where K is the attenuation factor of radon transport through the membrane which can be determined by the method reported by Hafez and Somogyi, 1986, η is the calibration coefficient of the measuring system in terms of α-tracks cm^{-2} day^{-1} per Bqm^{-3} radon and t is the exposure time.

The calibration coefficient adopted in the present work of LR-115 was 0.036 tracks cm^{-2} day^{-1} per Bqm^{-3} of radon [4, 5], and they are in good agreement with those reported by other investigators [20 – 22].

The equilibrium factor F between radon and its short-lived daughters can be determined by the following empirical formula [20, 21] :

$$F = a R – b. \qquad (2)$$

where a and b are fitting parameters, $R = K \frac{\rho e}{\rho i}$ and ρ_e is the track density recorded on the external (bare) detector. Recently the values of the above the mentioned fitting parameters were found to be a = 0.5 and b = 0.53 as given by Planinić et al., 1997.

The effective dose (E) of radon and its progeny was calculated using conventions published in ICRP - 65 (1993) and UNSCEAR (1993) using the following equations:

$$E= Ct(\varepsilon_r + \varepsilon_d F), \qquad (3a)$$

where $\varepsilon_r = 0.74 \times 10^{-7}$ $mSvh^{-1}$ per Bqm^{-3} and $\varepsilon_d = 8 \times 10^{-5}$ $mSvh^{-1}$ per Bqm^{-3} [23].

$$E= Ct(\varepsilon`_r + \varepsilon`_d F) \qquad (3b)$$

where $\varepsilon`_r$ = 0.17 $nSvh^{-1}$ per $Bqm^{-3}$ and $\varepsilon`_d$ = 9 nSv h^{-1} per Bqm^{-3} [24].

3 Results and Discussion

Table 1 shows the monthly variation of radon activity concentrations measured in the air of the crypt of Dendera temple (Locations 2-5) and at its entrance (Location 1) using the passive techniques. From passive measurements, it is clear that maximum radon activity concentration values exist in the summer months and the minimum values in the winter months. The highest mean value 616±117 $Bqm^{-3}$was observed inside the crypt in June while the lowest value 43±8 Bqm^{-3} was observed in December. The yearly mean radon activity concentration inside the crypt of Dendera temple was 244 Bqm^{-3} (see Tables 1). These results are in good agreement with the air circular modulation reported by Hakl et al. (1997), Szerbin (1996), Lively and Krafthefer (1995) for caves, Hafez and Hussein (2001) for tombs of the Valley of the Kings and Hafez et al. (1997) in Serapis temple.

Also, Table 1 shows the correlation between the seasonal variation of the mean radon activity concentration measured in the air (inside and at the entrance) of the crypt of Dendera temple and the mean external temperature. These observations agree with the previously observed data in Hungarian caves and in the tombs of the Valley of the Kings, Luxor, Egypt and strongly support the air circulation model [4, 17, 25-30]. It was not possible to determine the cause of the seasonal variation of the radon concentrations by active technique

The equilibrium factor F between radon and its daughters in the atmosphere of the crypt and at its entrance was estimated by the method described by Somogyi et al. (1984) and developed by Planinić et al. (1997). Using Eq. (2), the yearly mean equilibrium factor was 0.47±0.01. This value depends on the air, air exchange rate, the aerosol concentration in the air, size, and structure of the temple. According to literature, values of the equilibrium factor within caves or tombs vary between 0.04 and 0.95 [17, 26, and 31] .The mean equilibrium factor measured inside the crypt and at its entrance seems to be higher than that obtained in the tomb of the Valley of the Kings [4]. This may be attributed to the small size of the crypt as well as the large number of visitors resulting in bad ventilation and hence aerosol concentrations are more abundant.

The mean time spent in a temple by the workers, the tour guides, and the tourists was assessed on the personal communication with those persons and the management. The annual residence time in a temple was given as 2400 h and 250 h for the workers and the tour guides, respectively. A mean visiting time of 0.25 h was assessed for the visitors.

Using Eqs. (3.a) and (3.b) and the reported conversion factors, the effective dose values to workers, tour guides, and visitors were calculated based on the yearly mean value of both radon activity concentration and equilibrium factor. As it can be seen from Table 2, all the calculated doses are lower than the 3-10 $mSvy^{-1}$ dose limits recommended by

ICRP-65 (1993). Also, these values are in fair agreement with that reported by Hafez et al. (1997).

Table 1: Annual radon activity concentration C inside the crypt of Dendera temple and at its entrance by active and passive techniques.

Month	°C	C(Bqm^{-3})			
		Active technique		Passive technique	
		Entrance	Inside	Entrance	Inside
January	13	5	33	10	45
February	15	8	54	12	68
March	17	7	62	23	76
April	25	15	120	50	293
May	30	63	108	102	418
June	33	80	176	210	616
July	38	55	166	144	490
Augustus	39	78	218	115	455
September	32	69	104	86	159
October	26	73	115	70	148
November	21	38	46	48	117
December	15	9	35	15	43
Average ±SD		41.3 ±29.9	123.7 ±86.7	73.7 ±58.6	244 ±193.2

Table 2: Yearly mean radon activity concentration C and effective dose E for the worker, tour guide and tourist inside the crypt of Dendera temple by passive technique using LR-115 detectors.

Location	Person	C (Bqm^{-3}) ± S.D	E ($mSvy^{-1}$)		
			UNSCEAR , 1993	ICRP-65, 1993	Average ± S.D
Entrance	Worker	73.75±58.66	0.78	0.66	0.72±0.06
Inside	Worker	244.00±193.19	2.57	2.21	2.39±0.18
	Tour guide		0.26	0.23	0.25±0.02
	Tourist		2.68×10^{-4}	2.30×10^{-4}	$(2.49\pm0.20)\times10^{-4}$

4 Conclusions

The radon levels, the equilibrium factor, and the effective dose have been estimated in the crypt of Dandara temple for a period of one year using the cup techniques with LR115 plastic nuclear track detectors. The radon levels were found to be higher during summer than winter. All the calculated effective doses are lower than the action level (3-10 $mSvy^{-1}$) recommended by ICRP-65 (1993).The results of this work do not represent any significant threat to human health. But the phenomenon of the curse of the Pharaohs due to the radon gas accumulated in the tombs needs further study and analysis. The results reflected the importance of the cup techniques with LR-115 plastic nuclear track detectors in covering seasonal changes in radon gas concentrations in the study place.

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