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Radon Measurements in Egypt Using Passive Etched Track Detectors. A Review

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ABSTRACT

Radon and its progeny may cause serious radiation harm to human health such as lung cancer and other types. Radon measurements based on alpha particles etched track detectors (LR-115, CR-39) are very attractive for assessment of radon exposure. This is due to their high sensitivity, low cost, easy to handle and retain a permanent record of data. Also, these detectors can incorporate the effects of seasonal and diurnal fluctuation of radon activity concentrations due to physical, geological and meteorological factors.

The present review is based mainly on the topic of passive etched track detectors for the measurements of radon in Egypt in the recent years. Published papers include the measurements of radon in dwellings, working places, Cairo METRO stations, ancient Pharaonic places and uranium exploration galleries as well as assessment of radon in drinking water.

Key words: Radon/ Health effect/ Etched track detectors/ Dwellings/ Underground stations/ Pharaonic tombs and temples/ Uranium exploration galleries/ Drinking water/ Egypt.

INTRODUCTION

The presence of naturally occurring radioactive gases radon (222Rn) and thoron (220Rn) and their progeny in indoor environment constitutes a major health hazard for man (1-4). Radon can enter the indoor environment (house, mine, cave, tunnel, etc.) by diffusion from soil and by the emanation from building materials and ground water. In some cases, radon is released from natural gas (5, 6).

According to the assessment made by the UNSCEAR-2000, radon and its progeny average accounts for about half of all human exposure to radiation from natural sources (7). The inhaled radon progeny pass from lungs into the blood and body tissues and may indicate many types of soft tissue cancers such as lung cancer, kidney cancer and prostatic cancer as well as leukemia, melanoma and child cancers (8-9).

It is also noticed that the combination of inhalation of radon gas and smoking increases the risk of lung cancer (9, 10). Ingested radon dissolved in drinking water is a health risk, because it may cause a stomach cancer. The risk caused by drinking water containing dissolved radon is extremely much lower than inhaling radon (11). The health risk due to the presence of thoron in indoor environment is usually neglected because of its short half life. However, in certain not uncommon situations such as when thorium-rich building materials are used, thoron may represent a significant source of radioactive exposure (12, 13). For these reasons, increasing attention has been paid to radon and its associated health risks in both industrialized and developing countries (1, 2, 4, 7).
For developing countries wishing to undertake national survey programs in order to monitor natural alpha radiation, the most appropriate techniques are those making use of nuclear track detectors (CR-39 and LR-115) because they are versatile, simple in handling and processing, low cost and insensitive to beta and gamma radiation \(^{(6,14)}\). Also these detectors incorporate the effects of seasonal and diurnal fluctuation of radon concentrations due to physical and geological factors as well as meteorological conditions \(^{(6)}\). The use of these detectors is today widely spread in several fields of science and technology such as nuclear physics, health physics, nuclear geophysics, environmental science, cosmic rays and space physics \(^{(6, 15-17)}\). These detectors are a convenient useful tool for determining the radon and thoron exhalation rates as well as the 226Ra and 224Ra contents in building materials and geological samples in Egypt \(^{(18-24)}\).

This paper reviews selected radon studies in the recent years in Egypt in dwellings, working places, Cairo METRO stations, ancient pharaonic places and uranium exploration galleries as well as the assessment of radon in drinking water. These studies used the passive etched track detectors.

**ETCHED TRACK DETECTORS**

The technique of nuclear track detection has matured since long as a viable method of charged particle detection. The usage of this method was successfully used in environmental sciences. However, the most frequently applied detectors are cellulose nitrate (LR-115) and allyldiglycol carbonate (CR-39). LR-115 detector has 12 µm thin red layer of cellulose nitrate coated on 100 µm thick transparent supporting sheet of polyester and the chemical formula of the cellulose nitrate layer is C\(_6\)H\(_8\)O\(_7\)N\(_2\).

CR-39 detectors is a thermo set plastic formed as a cross linked polymer form the monomer allyldiglycol carbonate which is extremely transparent and mechanically rigid and its chemical formula is C\(_{12}\)H\(_8\)O\(_7\).

The phenomenon of track detection in nuclear etched track detectors is based on the degradation of energy of heavy charged particles as they traverse through a dielectric media such as polymers and have leave evidence of their passage along the particle trajectory as shown in Figure 1. These damage trails are relatively long lived at normal temperature and they are latent. These latent tracks can be etched with the help of a suitable enchant (e.g. NaOH or KOH), whereby not only fixing them but enlarging them sufficiently so that they become visible under an optical microscope. The number of tracks per unit area is proportional to the radon concentration \(^{(6)}\).

The radon measuring device can be a diffusion-cup with internal(filtered) and external(bare)detectors. This device can be used for simultaneous estimation for radon activity concentration \(C\) (Bqm\(^{-3}\)) and the equilibrium factor \(F\).

The track density recorded on the internal detector \(\rho_i\) is related to the radon activity concentration \(C\) (Bqm\(^{-3}\)) by:

\[
C = \frac{\rho_i}{K \eta t} \quad (1)
\]

where \(K\) is the attenuation coefficient of radon, \(\eta\) is radon calibration factor in tracks cm\(^{-2}\) per Bq m\(^{-3}\) per day and \(t\) is the exposure time. The equilibrium factor \(F\) between radon and progeny was calculated using the following empirical formula:

\[
F = a R - b \quad (2)
\]

where \(a\) and \(b\) are fitting parameters, \(R = K \frac{\rho_e}{\rho_i}\) and \(\rho_e\) is the track density recorded on the external detector \(^{(6, 14, 29, 32-36)}\).
The characteristics of these detectors are well documented in several review papers and in the Proceeding International Conferences on Nuclear Tracks in Solids that is held every two years\textsuperscript{(6,14-17)}.

![Creating an Alpha-particle Track](image)

**Figure 1: Creating an Alpha-particle Track**\textsuperscript{(40)}.

**RADON MEASUREMENTS**

- **In Dwellings and Working Places**

  Kenawy et al., 1989\textsuperscript{(25)} determined the radon concentration in the indoor and outdoor air using the can.-technique employing CR-39 detectors. The radon concentration in this survey was 2-11 Bq m\(^{-3}\) in Cairo, 1-6 Bq m\(^{-3}\) in Alexandria and 3-14 Bq m\(^{-3}\) in Assuit. Measurements carried out in Aswan and Sinai ranged between 4-15 Bq m\(^{-3}\). Values of indoors and outdoors radon concentrations were found to vary with time of day, geographic location, season and height above ground.

  Hafez et al., 1990\textsuperscript{(26)} used CR-39 detectors to estimate the activity concentrations of radon and its progeny in indoor air in dwellings and working places in Alexandria. The average exposure time was three months. Results show that the average radon concentration was 33 Bq m\(^{-3}\) and the equilibrium factor between radon and its progeny was 0.3.

  Hassib et al. 1995\textsuperscript{(27)} used kfk passive radon dosimeter with Makerofol PC detector in field application of radon measurements in dwellings in Cairo, Alexandria, Demiette and Rosetta. The indoor radon concentration was between 47 and 3 Bq m\(^{-3}\) with a mean value of 13 Bq m\(^{-3}\) in winter season and 7 Bq m\(^{-3}\) in summer season. The outdoor radon concentrations vary between 23 and 3 Bq m\(^{-3}\) with a mean value of 11 Bq m\(^{-3}\) in winter season and 5 Bq m\(^{-3}\) in summer season.

  Maged and Borham 1997\textsuperscript{(20)} used CR-39 detector to measure indoor and outdoor radon concentrations at two sites in Cairo (Nasr city and Helwan). The indoor radon concentration ranged from 18 to 62 Bq m\(^{-3}\) with a mean value of 39 Bq m\(^{-3}\) and the outdoor radon concentration ranged from 18 to 50 Bq m\(^{-3}\) with a mean value of 30 Bq m\(^{-3}\).

  Maged et al., 1997\textsuperscript{(28)} used open and filtered CR-39 detector to measure indoor radon levels in Sers Ellian city in Delta from March to May 1996. The indoor radon concentration ranged from 15 to 98 Bq m\(^{-3}\) with a mean value of 52 Bq m\(^{-3}\). In this study, the equilibrium factor ranged from 0.2 to 0.8 with a mean value of 0.4.
El-Sersy, 2000 (29) determined radon concentration in clay’s and concrete’s houses in Teta Village, Minoufiya Governorate using bare and filtered CR-39 detectors during spring season from March to May 1999. The average radon concentration was found 133 Bq m$^{-3}$ in clay’s houses and 78 Bq m$^{-3}$ in concrete’s houses. It was noticed that due to uncovered ground in the clay’s houses enhance the radon emanation from soil.

Kenawy et al., 2002 (30) evaluated radon concentrations in different locations in Cairo city using CR-39 detector. The average ± S.D radon concentrations were 9.32 ± 0.47, 22.95 ± 5.43, 41.64 ± 5.77 and 10.83 ± 1.29 Bq m$^{-3}$ in autumn, winter, spring and summer, respectively. The environmental radon concentration was found to vary substantially with time (season). The indoor radon concentration was found to be strongly depending on the constructing materials.

Abdel-Naby and Morsy, 2002 (31) measured radon levels in several cities in Egypt namely Cairo, Alexandria, Ismailia, Sohag and Aswan. The measurements were carried out over three months in each case starting in January 1997 and continued to December 2000 using TASTRAK CR-39 detectors. The radon level during summer varied from 11.8 to 46.8 Bq m$^{-3}$ with an arithmetic mean of 27.4 Bq m$^{-3}$. The highest radon level was observed in Aswan and lowest in Alexandria. The radon level in autumn varied from 30.8 to 79 Bq m$^{-3}$ with a mean value of 44.8 Bq m$^{-3}$. The indoor radon level in the environment of Egypt from this study was 23 Bq m$^{-3}$.

- **In Cairo Underground Stations**

Hafez et al., 2000 (32) and Hussein, 2002 (33) measured radon activity concentration in air of two different underground METRO stations in Cairo city, namely Mubarak and El-Sadat. The measurements were performed monthly from Feb. 1998 to Jan. 1999 using bare and filtered LR-115 detectors. The yearly mean radon activity concentration was found to be 23 Bq m$^{-3}$, ranging from 14 to 40 Bq m$^{-3}$. The yearly mean equilibrium factor's" between radon and its progeny was 0.1 inside the two stations. The small value of F can be explained by the fact that the two stations are very well ventilated.

- **In Ancient Pharaonic Sites:**

Kenawy and Morsy, 1991 (18) measured radon concentration in the interior of the great pyramid of “Cheopes” at Giza. Measurements were carried out for a period of 10 weeks using bare CR-39 detectors. The radon level inside the pyramid was about 185 Bq m$^{-3}$ which is relatively high compared with the level outside the pyramid in open air which reaches 4 Bq m$^{-3}$.

Hafez et al., 1997 (34) measured radon activity concentration and equilibrium factor in two archaeological sites namely Kom El-Shukafa catacombs and Serapis temple in Alexandria, Egypt. The radon activity concentration and equilibrium factors were measured by open and filtered LR-115 nuclear track detectors. The average value of radon activity concentrations ranged from 34-267 Bq m$^{-3}$ in Kom El-Shukafa catacombs and from 22.1234 Bq m$^{-3}$ in Serapis temples. Seasonal variation of radon levels, with summer maximums and winter minimums were observed in the two places. The average equilibrium factor per month varied between 0.11 to 0.27 given an arithmetic mean 0.2 ± 0.04 in Kom El-Shukafa catacombs. Whereas in Serapis temple the average equilibrium factors ranged from 0.1 to 0.28 with arithmetic mean of 0.19 ± 0.06.

Measurements of radon activity concentration and equilibrium factor were carried out for the first time in the air of some ancient Egyptian places such as tombs of the Valley of the Kings in Luxor, the crypt of Dandara temple and in the great pyramid at Giza by Hafez and Hussein, 2001 (33, 35), Hussein, 2002 (33) and Hafez et al., 2003 (36). In this study the same measurements were repeated in Kom El-Shukafa catacombs and Serapis temples in pomby’s pillar area in Alexandria (34). These measurements were carried out monthly during the year 1998 using the sealed can- technique with bare and filtered
LR-115 detectors. The yearly mean values of radon activity concentrations ($C$) and equilibrium factors ($F$) in the studied places are summarized in Table 1.

Seasonal variation of radon activity concentrations with summer maxima and winter minima were observed in the tombs of the Valley of the Kings, in the crypt of Dandara temple, in Kom El-Shukafa catacombs and in Serapis temple. On the other hand, seasonal variation of radon activity concentrations with winter maxima and summer minima were observed inside the great pyramid as shown in figure 2. These finding could be explained similarly to the model of air circulation in caves (6, 33-38).

Table 1: Annual mean radon activity concentration ($C$) Bq m$^{-3}$ and annual mean equilibrium factor ($F$) inside and near the entrance of the sites studied (33).

<table>
<thead>
<tr>
<th>Site</th>
<th>Location</th>
<th>$C$ ± S.D</th>
<th>$F$ ± S.D</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Tutankhamon tomb.</td>
<td>Entrance</td>
<td>86 ± 50</td>
<td>0.29 ± 0.05</td>
</tr>
<tr>
<td></td>
<td>Inside</td>
<td>540 ± 420</td>
<td>0.11 ± 0.04</td>
</tr>
<tr>
<td>- Merenptah tomb.</td>
<td>Entrance</td>
<td>76 ± 60</td>
<td>0.11 ± 0.05</td>
</tr>
<tr>
<td></td>
<td>Inside</td>
<td>670 ± 790</td>
<td>0.17 ± 0.04</td>
</tr>
<tr>
<td>- Thutmos III tomb.</td>
<td>Entrance</td>
<td>2166 ± 2302</td>
<td>0.48 ± 0.01</td>
</tr>
<tr>
<td></td>
<td>Inside</td>
<td>3155 ± 3500</td>
<td>0.25 ± 0.08</td>
</tr>
<tr>
<td>Crypt of Dandara Temple.</td>
<td>Entrance</td>
<td>71 ± 57</td>
<td>0.47 ± 0.01</td>
</tr>
<tr>
<td></td>
<td>Inside</td>
<td>240 ± 200</td>
<td>0.47 ± 0.01</td>
</tr>
<tr>
<td>Kom El-Shukafa Catacombs.</td>
<td>Inside</td>
<td>76 ± 60</td>
<td>0.30</td>
</tr>
<tr>
<td>Serapis Temple.</td>
<td>Inside</td>
<td>278 ± 344</td>
<td>0.18</td>
</tr>
<tr>
<td>The great pyramid.</td>
<td>Entrance</td>
<td>25 ± 7</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>Inside</td>
<td>100 ± 43</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Figure 2: The correlation between the monthly variation of the mean radon activity in the air of the great pyramid and the mean outside temperature (36).
• **In Uranium Exploration Galleries:**

Abdel – Hafez et al., 1996 (37) measured radon concentrations and the working levels using CR-39, LR-115 and CN-85 detectors in three uranium exploration galleries at Qattar, El-Missikat and El-Eredya areas; Eastern Desert, Egypt. The measurements were done at 10 monitoring for 50 days in winter (Jan. – Mar., 1995) and for 27 days in summer (Jun – Jul., 1996). The obtained average radon concentration ranged from 2900 – 5900 Bq m\(^{-3}\) in winter and from 4700 – 11000 Bq m\(^{-3}\) in summer.

Abdel – Monem et al., 2000 (38) measured radon concentration in air of uranium exploration tunnels in Allouga, West Central Sinai by LR-115 and CN-85 detectors. The radon concentrations were varied from 700-2550 Bq m\(^{-3}\) under dry conditions and from 8550 – 50000 Bq m\(^{-3}\) under wet and non-ventilated conditions.

• **In Drinking Water**

Kenway et. al., 2000 (39) measured radon levels in different natural water samples from various resources in Egypt such as spring, tap water, Nile river and some commercially available water using the sealed can technique with CR-39 detectors. Radon concentrations were found to be in the range from 1 to 10 Bq m\(^{-3}\).

**CONCLUSION**

Radon contents in indoor air in Egypt may increase in the future due to the use of new building materials, energy conserving measures and the change of living conditions. Thus, measurements of indoor radon are important for the evaluation of its impact on public health and to build a country wide map of radon levels.

So that, research in this area should be coordinated between agencies active in this field and the educational programs can be used to inform health officials and the public about the health threat from radon and about associated risk factors such as smoking.

Radon monitory devices based on alpha – particle etched track detectors, on account of their excellent performance and unique characteristics can be considered to be the main radon dosimeters nowadays and in the future.

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