Radioprotection 49(3), 201-203 (2014)

DOI: 10.1051/radiopro/2014007

Available online at:
www.radioprotection.org

BRIEF NOTE

Indoor radon concentration measurements at the site of the first nuclear power plant in Egypt

A.S. Hussein[a]

Naif Arab University for Security Sciences, Riyadh, KSA.
Nuclear Power Plants Authority, Cairo, Egypt.

Received 8 December 2013 – Accepted 24 March 2014

Abstract – Radon (^{222}Rn) is a radioactive gas that occurs naturally when uranium in soil and rock breaks down. Long-term exposure to ^{222}Rn increases the risk of lung cancer. The principal objective of this work was to determine the ^{222}Rn activity concentration in an indoor air environment at the El-Dabaa site proposed for a nuclear power plant project in Egypt using the track etch technique with LR115 detectors. The annual average indoor ^{222}Rn activity concentration in apartment buildings varies from 24 to 77 Bq.m^{-3}, with a mean value of 54 Bq.m^{-3}. The annual effective dose received by residents of the studied area was estimated to be 0.41 mSv. The annual estimated effective dose is less than the recommended action level by ICRP (3–10 mSv.y^{-1}). The results from this work provide a radiological assessment program and update the background of the natural radioactivity map at the El-Dabaa site.

Keywords: Radon / environmental samples / El-Dabaa / LR115 detectors / nuclear power

1 Introduction

The first Egyptian nuclear power plant was proposed to be built at the El-Dabaa site. The El-Dabaa site is located on the Mediterranean sea coast of the western desert and is about 400 km from Cairo and about 150 km west of Alexandria. The site is about 15 km long and 3–4 km wide, as shown in Figure 1.

The Nuclear Power Plants Authority (NPPA) has set up an environmental laboratory at this site to conduct the pre-operational environmental radiological monitoring program for the El-Dabaa area. This program provides a baseline map of natural and man-made radioactivity background levels in all exposure pathways in the El-Dabaa area. This map will be used as reference information to assess any changes in radioactivity background levels due to the operation of the future nuclear power plant on this site (EL-Daly and Hussein, 2008). The current measurements deal with the ambient gamma dose rate, gross low alpha and low beta emitters, gamma ray spectroscopy with NaI(Tl) and HPGe detectors, alpha spectrometry, and water chemical analysis (EL-Daly and Hussein, 2008; IAEA, 2000). As part of this program, radon activity concentration measurements are carried out in indoor air using LR115 alpha track detectors with the cup technique. LR115 detectors have high sensitivity, low cost, are easy to handle and retain a permanent record of the data. Also, these detectors incorporate the effects of seasonal and diurnal fluctuation of radon activity concentrations due to physical and geological factors as well as meteorological factors (Durrani and Ilic, 1997). Radon and its decay products, called radon daughters or radon progeny, emit highly ionizing alpha radiation. Radon has been classified as a human carcinogen. Since environmental radon on average accounts for about a half of all human exposure to radiation from natural sources, as shown in Figure 2 (UNSCEAR, 2000). Increasing attention has been paid to exposure to radon and its associated health risks in both industrialized and developing countries (WHO, 2009).

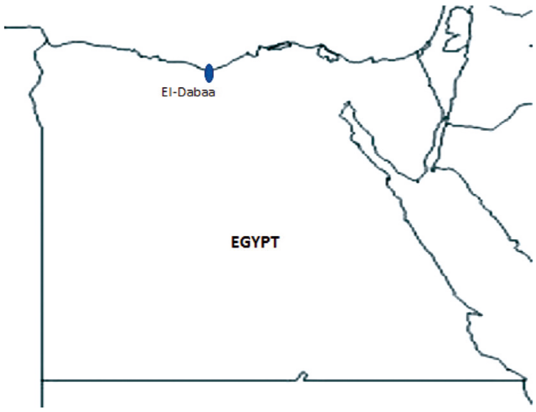

Fig. 1. Location of the El-Dabaa site.

During recent years, numerous papers have appeared in the literature demonstrating the interest in monitoring radon in indoor environments in Egypt (Hafez *et al.*, 2000a, 2000b; Hafez and Husein, 2001; Hussein, 2002, 2006; Hafez *et al.*, 2003; Abu El-Ela *et al.*, 2004; El-Bahi, 2004; Gomma *et al.*, 2004; Abdel-Ghany, 2005; Abo-Elmagd *et al.*, 2007; Abd El-Zaher, 2011).

[a] drahmedsaad860@gmail.com

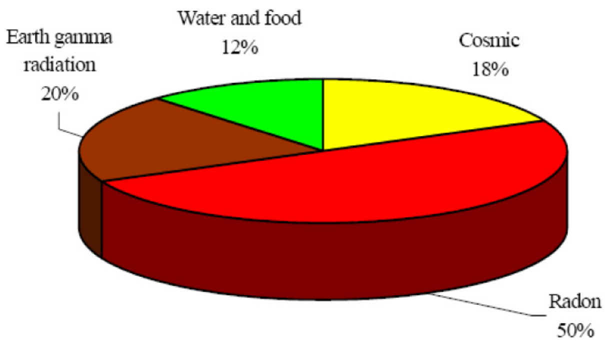

Fig. 2. Sources and average distribution of natural background radiation for the world's population (UNSCEAR, 2000).

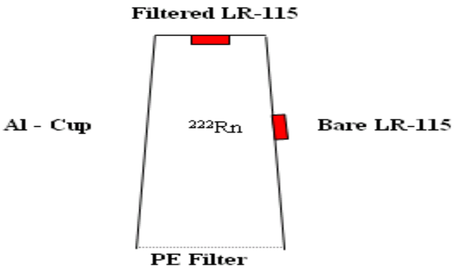

Fig. 3. Schematic diagram of the passive radon device (Durrani and Ilic, 1997).

The aim of the present work is to determine the radon activity concentrations in indoor air in the El-Dabaa area, as well as radon health effects.

2 Materials and methods

The radon measuring device was a diffusion cup with internal (filtered) and external (bare) LR115 detectors as shown in Figure 3 (Durrani and Ilic, 1997).

This device can be used for simultaneous estimation of the radon activity concentration (C) and the equilibrium factor (F) between radon and its progeny. Four measuring devices were deployed inside each measured building. Most of the buildings in the surveyed area are concrete buildings and built using cement, sand, bricks, marble and concrete as the construction materials, and are all one-floor buildings. In every measuring location, the devices were hung about 2.5 m from the ground in bedrooms and living rooms (two cups in each). The period of the survey was during 2007−2010, covering all seasons. The exposed LR115 detectors were chemically etched in NaOH solution under standard conditions (2.5 M at 60 °C for 2 h) and the track density measurements were made using an optical microscope of magnification of 100× (Durrani and Ilic, 1997).

The track density recorded on the internal (filtered) detector ρ_i is related to the radon activity concentration C (Bq.m^{-3}) by (Somogy, 1990; Planinić *et al.*, 1997):

$$C = \frac{\rho_i}{K\eta t}, \tag{1}$$

where K is the attenuation coefficient of radon, η is the 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 its progeny was calculated using the following empirical formula (Frank and Benton, 1997; Somogy, 1990):

$$F = aR - b \tag{2}$$

where a and b are fitting parameters, $R = K\frac{\rho_e}{\rho_i}$, $1.2 < R \leqslant 3$ and ρ_e is the track density recorded on the external (bare) detector. Recently the values of the above-mentioned fitting parameters were found to be $a = 0.5$ and $b = 0.53$ as given by Planinić *et al.* (1997). Substituting the value of the slope of the regression line between the track densities of LR115 detectors (ρ_e and ρ_i) in equation (2), the equilibrium factor F could be calculated.

The effective dose (E) was calculated using conventions published in ICRP Publication 65 (1993) by the following equation:

$$E = CT\,(\varepsilon_r + \varepsilon_d\, KF), \tag{3}$$

where $K = 1.6 \times 10^{-6}$ WLM per Bq.h.m^{-3}, T is the occupancy time in hours, m and $\varepsilon_r = 0.74 \times 10^{-7}$ mSv.h^{-1} per Bq.m^{-3} and $\varepsilon_d = 5$ mSv per WLM for work are the conversion factors for radon free progeny and radon daughters, respectively.

The effective dose could also be calculated by using the formula given in UNSCEAR (1993):

$$E = CT\,(\varepsilon_r + \varepsilon_d\, F), \tag{4}$$

where $\varepsilon_r = 0.17$ nSv.h^{-1} per Bq.m^{-3} and $\varepsilon_d = 9$ nSv.h^{-1} per Bq.m^{-3}.

3 Results and discussion

The calibration coefficient η for the LR-115 detectors obtained from the calibration experiment was 0.036 ± 0.006 α-tracks cm^{-2}.d^{-1} per Bq.m^{-3} of radon (Hussein, 2002). This value was used to estimate the radon activity concentration C with the help of equation (1). From the measured track densities ρ_i and ρ_e and using equation (2), the equilibrium factor F was calculated. Using equations (3) and (4) the effective dose values were calculated based on the yearly mean value of both the radon activity concentration and equilibrium factor inside the studied buildings. In this study it was assumed that the occupancy factors were 0.62 for houses and 0.2 for workplaces.

The results for the annual indoor radon concentration C, the annual equilibrium factor F and the annual effective dose E are shown in Table 1.

It is clear that ^{222}Rn activity concentrations in the indoor air of the studied areas are below the action levels stipulated by ICRP Publication 65 (1993): 200−600 Bq.m^{-3} for dwellings and 200−1000 Bq.m^{-3} for workplaces, except in the simulator room which was found to be within this level. It is a closed room with a bad ventilation system. All estimated doses were found to be less than the lower bound of the action levels (3−10 mSv.y^{-1}) recommended by ICRP Publication 65 (1993). It is observed that the site area is safe as far the health hazard effects are concerned.

Table 2 shows the comparison of results obtained from this study with other Egyptian studies of radon activity concentrations in indoor air using the same technique. It is clear from Table 2 that ^{222}Rn activity concentrations in indoor air of the

Table 1. Yearly average radon activity concentration (*C*), equilibrium factor (*F*) and effective dose (*E*) in indoor air at the El-Dabaa site.

Location	*C* (Bq.m^{-3})		*F*		*E* (mSv.y^{-1})	
	Ave.	Range	Ave.	Range	ICRP (1993)	UNSCEAR (1993)
Apartment Buildings	54	24–77	0.20	0.12–0.32	0.41	0.47
Environmental Lab.	80	53–137	0.23	0.10–0.43	0.23	0.27
Training Center:						
– Simulator room	480	156–570	0.12	0.1–0.15	0.69	0.90
– Lecture rooms	42	32–70	0.20	0.15–0.29	0.11	0.11

Table 2. Comparison of radon activity concentrations in indoor air with other studies in Egypt.

The studied area	*C* (Bq.m^{-3})	Reference
El-Dabaa site	54 (24–77)	This study
Alexandria City	65 ± 10	Abd El-Zaher, 2011
Qena City	40 (19–59)	Hussein, 2006
Mansura City	170 (43–423)	Abu El-Ela *et al.*, 2004
Cairo City	47.94–84.32	Abdel-Ghany, 2005

studied area were found to be consistent with data obtained by other authors, and it is in a low background radiation area in Egypt.

4 Conclusion

In this study, an attempt was made to obtain an overview of the ^{222}Rn activity concentrations in indoor air environments in the El-Dabaa area. These measurements were made using LR115 etched track detectors with the cup technique. The measured values of ^{222}Rn activity concentrations in indoor air reflect a low background radiation area in Egypt. In the near future it is planned to expand our study to different environmental samples (air, water, soil) at the El-Dabaa site as well as the new proposed sites for nuclear power plants in Egypt.

References

Abd El-Zaher M. (2011) Seasonal variation of Indoor Radon concentration in dwellings of Alexandria City, Egypt, *Radiat. Prot. Dosim.* **143** (1), 56-62.

Abdel-Ghany H.A. (2005) Variability of radon concentrations in different compartments of dwellings in Egypt, *Medical Journal of Islamic World Academy of Sciences* **15**, 153-156.

Abo-Elmagd M., Metwally S.M., El-Fiki S.A., Eissa H.M., Salama E. (2007) Passive and active measurements of radon-related parameters inside ancient Egyptian tombs in Luxer, *Radiat. Meas.* **42**, 116-120.

Abu El-Ela A., Hafez A.F., Othman M., El-Farrash A.H. (2004) Study of radon levels in some closed area in Mansoura City, Egypt. In: *Proceedings of the Environmental Physics Conference,* 24–28 Feb. 2004, Minya, Egypt.

Durrani S.A., Ilic R. (1997) *Radon Measurements by Etched Track Detectors*. World Scientific, Singapore.

El-Bahi S.M. (2004) Assessment of radioactivity and radon exhalation rate in Egyptian cement, *Health Phys.* **86** (5), 517-522.

EL-Daly T.A., Hussein A.S. (2008) Natural radioactivity levels in environmental samples in north western desert of Egypt. In: *3rd Environmental Physics Conference*, 19–23 Feb. 2008, Aswan, Egypt.

Frank A.L., Benton E.V. (1997) Radon dosimetry using plastic nuclear track detectors, *Nucl. Track Detection* **1**, 149-179.

Gomaa M.A., Hussein A.S., El-Arabi A.M. (2004) Radon measurements in Egypt using passive etched track detectors: a review. In: *Seventh Conference of Radiation Physics and Protection*, 27–30 Nov. 2004, Ismaelia, Egypt.

Hafez A.F., Hussein A.S., Rasheed N.M. (2000a) Radon measurements in underground metro stations in Cairo city, Egypt. In: *Seventh Conference of Nuclear Sciences and Applications*, Cairo, Egypt, 6–10 February, 2000.

Hafez A.F., Hussein A.S., Rasheed N.M. (2000b) A study of radon and thoron release from Egyptian building materials using polymeric nuclear track detectors, *Appl. Radiat. Isotopes* **54**, 291-298.

Hafez A.F., Hussein A.S. (2001) Radon activity concentrations and effective doses in ancient Egyptian tombs of the Valley of the Kings, *Appl. Radiat. Isotopes* **54**, 355-362.

Hafez A.F., Bishara A.A., Kotb M.A., Hussein A.S. (2003) Regular radon activity concentration and effective dose measurements inside the Great Pyramid with passive nuclear track detectors, *Health Phys.* **85** (2), 210-216.

Hussein A.S. (2002) Measurements of environmental alpha – activity using CR-39 and LR-115 plastic nuclear track detectors, PhD thesis, Alexandria University.

Hussein A.S. (2006) Radon concentrations in some Egyptian dwellings using LR115 detectors. In: *Eighth Conference of Radiation Physics and Protection,* 12–17 Nov. 2006, Bani Sueif, Egypt.

IAEA (2000) *Environmental and source monitoring for purpose of radiation protection*, IAEA Safety Guide N° Rs-G-1.8.

ICRP Publication 65 (1993) International Commission on Radiological Protection, *Protection Against Radon-222 at Home and at Work*. Pergamon Press, Oxford.

Planinić J., Radolic V., Faj B., Varga Z. (1997) Radon equilibrium factor and aerosol, *Nucl. Instrum. Meth. A*, **396**, 414-417.

Somogy G. (1990) *The environmental behavior of radium*, Technical Report Series No. 310, Vol. 1 Chaps. 3–8, International Atomic Energy Agency.

UNSCEAR (1993) United Nations Scientific Committee on the Effects of Atomic Radiation, *Sources and effects of ionizing radiation*, United Nations, New York.

UNSCEAR (2000) *Sources and Effects of Ionizing Radiation*, Report to the general Assembly, United Nations, New York.

WHO (2009) *Handbook on Indoor Radon: A public Health Perspective*. World Health Organization Press.

Cite this article as: A.S. Hussein. Indoor radon concentration measurements at the site of the first nuclear power plant in Egypt. Radioprotection 49(3), 201-203 (2014).