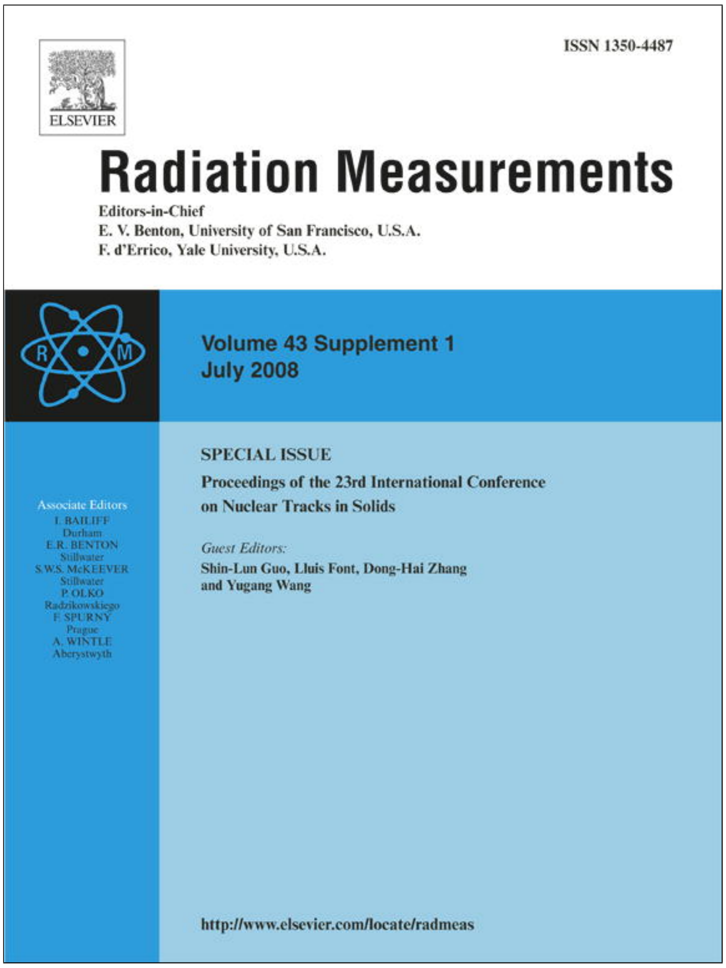
ISSN 1350-4487
ELSEVIER
Radiation Measurements
Editors-in-Chief
E. V. Benton, University of San Francisco, U.S.A.
F. d'Errico, Yale University, U.S.A.
Volume 43 Supplement 1
July 2008
SPECIAL ISSUE
Proceedings of the 23rd International Conference
on Nuclear Tracks in Solids
Guest Editors:
Shin-Lun Guo, Lluis Font, Dong-Hai Zhang
and Yugang Wang
Associate Editors
I. BAILIFF
Durham
E.R. BENTON
Stillwater
S.W.S. McKEEVER
Stillwater
P. OLKO
Radzikowskiego
F. SPURNY
Prague
A. WINTLE
Aberystwyth
http://www.elsevier.com/locate/radmeas

Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Radiation Measurements 43 (2008) S471 – S474
Radiation Measurements
www.elsevier.com/locate/radmeas

Comparative study of short- and long-term indoor radon measurements

M.I. Al-Jarallah*, Fazal-ur-Rehman, Khalid Abdalla

Department of Physics, King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia

Abstract

Short-term indoor radon measurements are used widely. Therefore, it is interesting to find out a correlation between these measurements and long-term measurements which reflect a better average radon concentration of individual measurement. To find the correlation between the two measurements of indoor radon concentrations at low radon levels, a study was carried out at 34 locations of King Fahd University of Petroleum & Minerals (KFUPM), Dhahran, Saudi Arabia using active and passive methods. In the short-term active method, a radon gas analyzer (AlphaGUARD) was used for a duration of 24 h in each measurement. In the long-term passive method, CR-39 based radon dosimeters were utilized for a period of 6 months, from January 2006 to June 2006. The short-term active measurements showed that the average, minimum and maximum radon concentrations were 19, 8 and 58 $\mathrm{Bq\,m^{-3}}$, respectively, with a standard deviation of 8.6 $\mathrm{Bq\,m^{-3}}$. The long-term passive measurements showed that the average, minimum and maximum radon concentrations were 25, 10 and 67 $\mathrm{Bq\,m^{-3}}$, respectively, with a standard deviation of 12 $\mathrm{Bq\,m^{-3}}$. The two measurements showed a poor correlation ($R^2 = 0.38$). The long-term measurements showed on the average higher concentrations by a factor of 1.3.

Keywords: Indoor radon; Short and long terms; CR-39 based passive radon dosimeter; Saudi Arabia

1. Introduction

Natural radiations are the biggest sources of radiation exposure to the world population. The sources of natural radiation include cosmic radiation and terrestrial radiation which cause external and internal exposures. The annual average dose to the world population from natural radiation sources has been estimated to be 2.4 mSv of which one-third is the external exposure and two-third the internal exposure (Wang, 2002). The highest component of the annual equivalent dose comes from the inhalation of radon (^{222}Rn) and its short-lived alpha-emitting decay products ^{218}Po and ^{214}Po. Alpha particles emitted from ^{222}Rn, ^{218}Po and ^{214}Po deposit their energies to the tissues of the lungs, as a result, lung cancer might be produced (William Field et al., 2000; Lubin and Boice, 1997). Soil and rocks under houses plus building materials are ordinarily the principal contributors to indoor radon which is typically four or five times more concentrated than the radon outdoors, where greater air dilution occurs (Turner, 1995). There has been more measurement of radon and its short-lived decay products than of any other radioactivity except weapons test fall-out (Harley, 1992). International conferences were held recently to present and review the work on radon in different parts of the world (Fernandez et al., 2005; Sugahara et al., 2004). A variety of methods were developed to measure radon and its decay products which included active and passive methods, short- and long-term measurements. Different ionization chambers and scintillation counters were used in the active measurements of radon while thermoluminescent detectors, charcoal adsorption and nuclear track detectors (NTDs) were applied in the passive measurements of radon. In recent years, some research work has been carried out in the field of radon dosimetry in Saudi Arabia (Al-Jarallah and Fazal-ur-Rehman, 2005, 2006; Al-Mustafa et al., 2005; Abu-Jarad et al., 2003; Fazal-ur-Rehman et al., 2003). Because radon levels tend to vary from day to day and season to season, a short- term test is less likely than a long-term test to represent the home's average radon level (National Safety Council, USA, 2004; Arizona Radiation Regulatory Agency USA, 2007). Seasonal correction factors for short-term radon measurements are generally derived from consideration of the

* Corresponding author. Tel.: +966 3 860 2281; fax: +966 3 860 2293.
E-mail address: mibrahim@kfupm.edu.sa (M.I. Al-Jarallah).

1350-4487/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.radmeas.2008.04.053

average variation of radon concentration in a large number of houses in many countries. However, these factors might not be appropriate in areas which are geologically very different (The University of Northampton, 2007).

A comparative study of short- and long-term measurements of indoor radon concentrations at low radon levels was carried out at 34 locations of King Fahd University of Petroleum & Minerals (KFUPM), Dhahran, Saudi Arabia using active and passive methods, respectively. These locations include offices (16), student dormitories (11) and faculty houses (7). In the short-term measurement, radon gas analyzer was used (Al-Jarallah, 2001), whereas in the long-term measurement, CR-39 NTDs based radon dosimeters were used (Al-Jarallah and Fazal-ur-Rehman, 2005). The results of this comparative study are presented in this paper.

2. Measurements and methods

2.1. Short-term measurements by active system

A radon gas analyzer type Alpha Guard 2000 PRQ from Genitron Instruments (Germany) was used to measure radon concentration (Al-Jarallah, 2001; Al-Jarallah et al., 2001). The measuring gas gets in diffusion mode via a large surface glass filter into an ionization chamber. Only the gaseous radon-222 may pass, while the radon progeny products are prevented to enter the ionization chamber. At the same time the filter protects the interior of the chamber from contamination of aerosol particles. This radon measuring system can be operated either on battery or online. The system also registers air temperature, parametric pressure and relative humidity. A PC Software support allows a graphic presentation and calculation of the average concentration in the measured period. The measurements were carried out in a total of 34 locations of King Fahd University of Petroleum & Minerals (KFUPM), Dhahran, Saudi Arabia. The radon concentration was measured in 1-h cycles for an average time of 24 h in each room and the average radon concentration was calculated by the system.

2.2. Long-term measurements by passive radon dosimeter

Time integrated passive radon dosimeters containing CR-39 NTD ($1.5 \times 1.5\,cm^2$) at its bottom center, fixed with a double sided solo tape, were used for long-term measurement of radon concentration. The CR-39 NTD is manufactured by Page Moulding Ltd., UK. The schematic diagram showing the geometry of the dosimeter is shown in Fig. 1. It is made from plastic cup with a hole in the top cover which is covered with a 5 mm thickness of soft sponge. The design of the chamber ensures that the aerosol particles and radon decay products are deposited on the soft sponge from outside and that only radon, among other gases, diffuses through it to the sensitive volume of the chamber. The soft sponge is preferred to filter paper because it is more durable in handling. During disintegration of the ^{222}Rn in the chamber into its products, three alpha particles will be emitted. Some of these alpha particles will hit the track

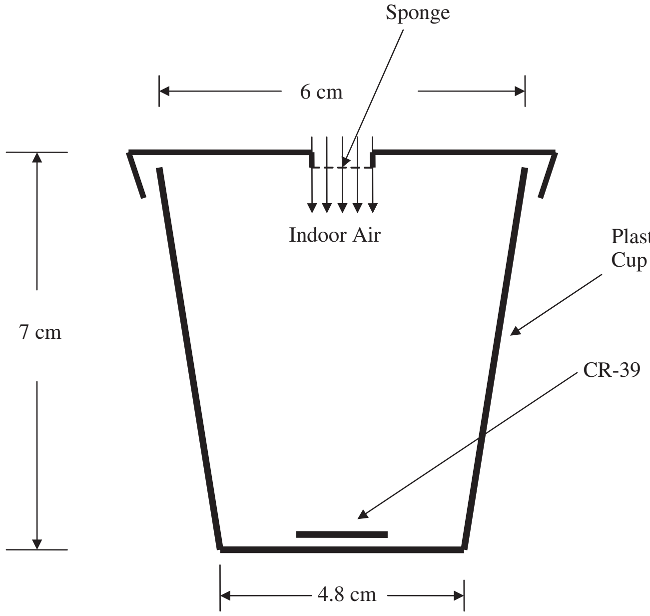

Fig. 1. Schematic diagram showing the geometry of the CR-39 NTD based passive radon dosimeter.

detector (CR-39) if it falls within their range. The detector will thus accumulate a number of tracks proportional to the concentration of radon gas in the room since radon concentration in the room and the chamber will be the same. The dosimeters were calibrated at standard source facility of the National Radiological Protection Board (NRPB), UK. A total of 34 passive radon dosimeters were placed in KFUPM Buildings for a period of 6 months to measure average indoor radon concentration.

The dosimeters were collected back after the exposure period. The CR-39 detectors were detached from the dosimeters and were etched in 30% KOH solution at 70 °C for 9 h. The detectors were then washed with water and were dried. The alpha tracks were counted manually under an optical microscope.

3. Results and discussion

In the short-term measurement method, radon concentration was measured in each room every 1 h for a total period of 24 h. Fig. 2 shows one of these measurements, where the x-axis indicates the measurement time while the y-axis indicates radon concentration. The error bars in individual measurements are also shown in the figure. The uncertainty in individual measurement is better than 20% which is relatively high because of low radon concentrations. The short-term active measurements showed that the average, minimum and maximum radon concentrations were 19, 8 and 58 $Bq\,m^{-3}$, respectively, with a standard deviation of 8.6 $Bq\,m^{-3}$.

In the long-term measurement, track density (tracks cm^{-2}) was calculated from the alpha tracks counted manually under an optical microscope. The track densities found on the analyzed NTDs were converted into radon concentrations ($Bq\,m^{-3}$) using the calibration factor of 8.0 tracks $cm^{-2}\,kBq^{-1}\,m^3\,h^{-1}$ for

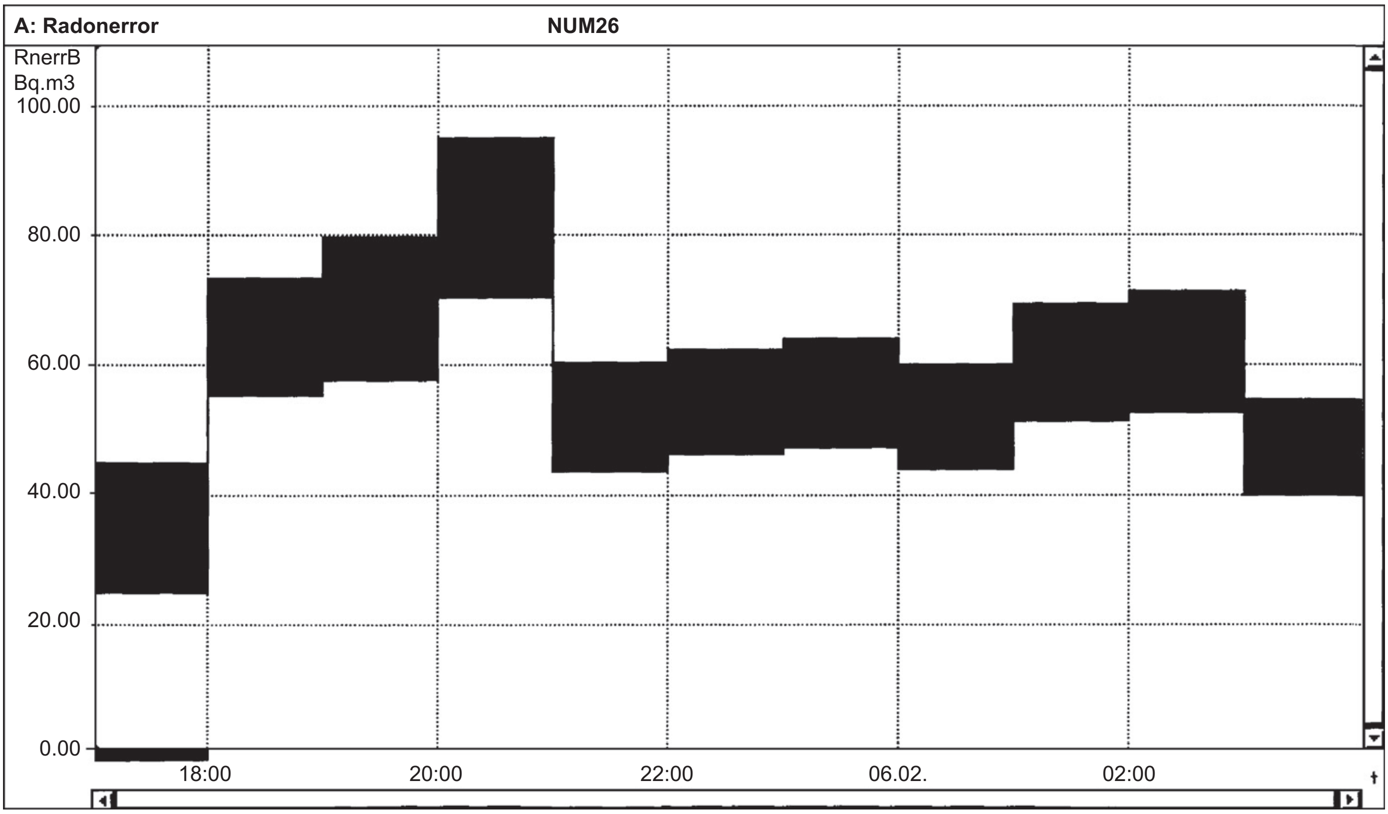

Fig. 2. Short-term radon concentration along with error bars in one of the rooms by the active system. The x-axis indicates the measurement time while the y-axis indicates radon concentration.

the utilized radon dosimeter. The concentration of radon was calculated using the following equation:

$$C_{\mathrm{Rn}} = \frac{\rho}{ft} \times 1000 \quad (1)$$

where C_{Rn} is the radon concentration in $\mathrm{Bq\,m^{-3}}$, ρ is the track density in tracks $\mathrm{cm^{-2}}$, f is the calibration factor for the dosimeter used in the survey in the units of tracks $\mathrm{cm^{-2}\,kBq^{-1}\,m^3\,h^{-1}}$ and t is the exposure time in h. The long-term passive measurements showed that the average, minimum and maximum radon concentrations were 25, 10 and $67\,\mathrm{Bq\,m^{-3}}$, respectively, with a standard deviation of $12\,\mathrm{Bq\,m^{-3}}$. The average uncertainty in the measurements was 14%. The radon concentration obtained in long-term passive method was plotted versus radon concentration measured by the short-term technique as shown in Fig. 3. The figure shows a poor correlation between the two measurements. The linear correlation coefficient between the measurements of the two techniques was found to be 0.38. The difference in the two measurement methods is mainly due to air ventilation. For example the long-term measurements include week ends when the ventilation in the offices is low because they are closed. This could explain why the long-term radon concentration is higher on the average compared to short-term measurements.

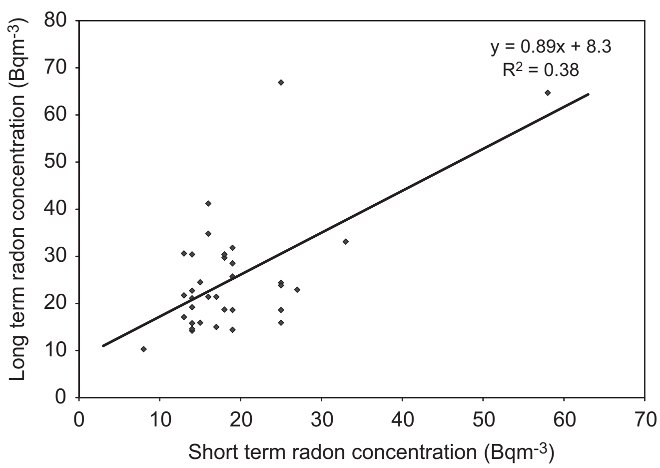

Fig. 3. Correlation between long-term and short-term measurements of indoor radon concentration.

The ratio of the long-term passive to the short-term active measurements was also plotted versus measurement number as shown in Fig. 4. The long-term measurements showed on the average higher concentrations by a factor of 1.3. Fig. 4 also shows that the ratio of the long-term to the short-term measurements varies from 0.6 to 2.7. It was reported that radon levels may fluctuate by as much as a factor of two or three (National Safety Council, USA, 2004).

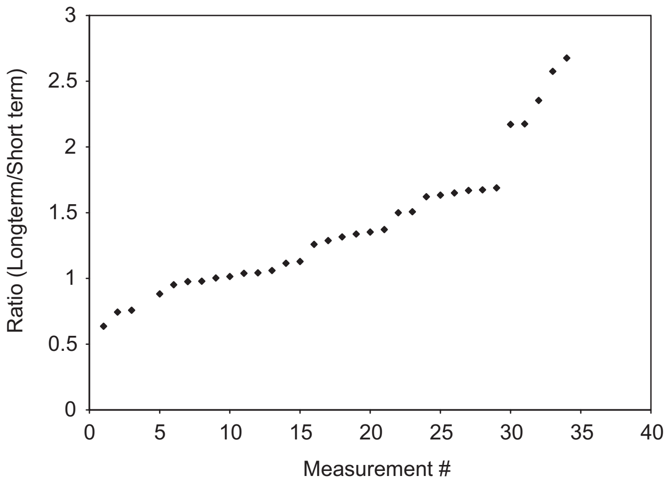

Fig. 4. Ratio of the long-term and short-term radon concentration measurements at different locations.

4. Conclusion

A comparative study of short- and long-term indoor radon measurements in KFUPM Buildings was carried out using active and passive techniques, respectively. The correlation between the two measurements was poor showing a linear correlation coefficient of 0.38. The long-term measurements showed on the average higher concentrations by a factor of 1.3.

Acknowledgment

The authors would like to thank Physics Department, King Fahd University of Petroleum & Minerals (KFUPM), Dhahran, Saudi Arabia for the research support.

References

Abu-Jarad, F., Fazal-ur-Rehman, Al-Jarallah, M.I., Al-Shukri, A., 2003. Indoor radon survey in dwellings of nine cities of the Eastern and the Western provinces of Saudi Arabia. Radiat. Prot. Dosim. 106 (3), 227–232.

Al-Jarallah, M.I., Fazal-ur-Rehman, 2006. Indoor radon concentration measurement in the dwellings of Al-Jauf region of Saudi Arabia. Radiat. Prot. Dosim. 121 (3), 293–296.

Al-Jarallah, M.I., Fazal-ur-Rehman, 2005. Anomalous indoor radon concentration in a dwelling in Qatif city of Saudi Arabia. Radiat. Prot. Dosim. 117 (4), 408–413.

Al-Jarallah, M.I., 2001. Radon exhalation from granites used in Saudi Arabia. J. Environ Radioact. 5, 391–398.

Al-Jarallah, M.I., Abu-Jarad, F., Fazal-ur-Rehman, 2001. Determination of radon exhalation rates from tiles using active and passive techniques. Radiat. Meas. 34, 491–495.

Al-Mustafa, H., Al-Jarallah, M.I., Fazal-ur-Rehman, Abu-Jarad, F., 2005. Radon concentration measurements in the desert caves of Saudi Arabia. Radiat. Meas. 40 (2–6), 707–710.

Arizona Radiation RegulatoryAgency, USA ⟨http://www.arra.state.az.us/RadonWeb/testing.htm⟩, 2007.

Fazal-ur-Rehman, Al-Jarallah, M.I., Musazay, M.S., Abu-Jarad, F., 2003. Application of can technique and radon gas analyzer for radon exhalation measurements. Appl. Radiat. Isot. 59 (5–6), 353–358.

Fernandez, F., Ilic, R., Font, L.I., Domingo, C., 2005. Radiat. Meas. 40 (2–6),

Harley, J.H., 1992. Measurements of ^{222}Rn: a brief history. Radiat. Prot. Dosim. 45 (1–4), 13–18.

Lubin, J.H., Boice, J.D., 1997. Lung cancer risk from residential radon: meta-analysis of eight epidemiologic studies. J. Natl. Cancer Inst. 89 (1), 49–57.

National Safety Council, USA ⟨http://www.nsc.org/ehc/radon/rad_faqs.htm⟩, 2004.

The University of Northampton, Radon and seasonal variation ⟨http://www2.northampton.ac.uk/portal/page/portal/aps/appliedscience/envsci/research⟩, 2007.

Sugahara, T., Sasaki, Y., Morishima, H., Hayata, I., Sohrabi, M., Akiba, S. (Eds.), 2004. High levels of natural radiation and radon areas: radiation dose and health effects. In: International Congress Series, vol. 1276.

Turner, J.E., 1995. Atoms, Radiation and Radiation Protection. Willy, New York.

Wang, Z., 2002. Natural radiation environment in China. In: International Congress Series, vol. 1225, pp. 39–46.

William Field, R., Steck, D.J., Smith, J., Brus, C.P., Fisher, L., Neuberser, J.S., Platz, C.P., Robinson, R.A., Woolson, R.F., Lynch, C.F., 2000. Residential radon gas exposure and lung cancer. Am. J. Epidemiol. 151 (11), 1091–1102.