Proteção contra radiações na comunidade dos países de língua portuguesa

Luís Neves (coord.)

IMPRENSA DA UNIVERSIDADE DE COIMBRA
2018

High-frequency variability of radon in a stable indoor environment

Variabilidade de alta frequência do radão num ambiente interior estável

S. M. Barbosa – susana.a.barbosa@inesctec.pt (INESC Tecnologia e Ciência)

F. Lopes – (IDL, Universidade de Lisboa, Portugal)

A. C. Pereira – (CEMUC, Department of Earth Sciences, Univ. Coimbra, Portugal)

L. F. Neves – (CEMUC, Department of Earth Sciences, Univ. Coimbra, Portugal)

Keywords: gamma radiation, radon progeny, time series, indoor air quality.

Abstract: Indoor air quality is of paramount importance for the health and well-being of human populations and is a recognized public health concern. In particular Radon (Rn-222) is an ubiquitous indoor air pollutant that seeps into indoor environments by diffusive and mainly advective migration from radon-rich subsoil. Indoor radon measurements are often performed with passive dosimeters measuring the average radon concentration over a given period of time. However, these integrated measurements are not able to provide any information on the temporal variability of indoor radon concentration. This work examines the high-frequency temporal variability of indoor radon concentration from gamma radiation measurements obtained with an NaI(Tl) scintillation sensor. The measurements are taken at the University of Lisbon under stable environmental conditions, in a dedicated closed room at ground level. The measured indoor radon concentration has an average value of 195 Bq.m-3 and displays very small changes, typically inferior to 1%. Albeit small, these changes are characterised by a rich temporal pattern comprising both a periodic diurnal signal, a non-periodic component correlated with the room's temperature, as well as a weekly pattern reflecting the occupation pattern of the building on weekdays.

PALAVRAS-CHAVE: radiação gama, progenia do radão, séries temporais, qualidade do ar interior.

RESUMO: A qualidade do ar interior é de suprema importância para a saúde e bem estar das populações humanas, e um risco de saúde reconhecido. Em particular o Radão (Rn-222) é um poluente atmosférico ubíquo que se infiltra em ambientes interiores por difusão e principalmente advecção a partir de solos enriquecidos em radão. A medição de radão em ambientes interiores é em geral efetuada utilizando dosímetros passivos que medem a concentração média de radão ao longo de um dado período de tempo. No entanto, estas medidas integradas não permitem obter informação sobre a variabilidade temporal da concentração de radão no interior. Neste trabalho é analisada a variabilidade temporal de alta frequência da concentração de radão a partir de medições de radiação gama com um cintilómetro de NaI(Tl). As medições foram efetuadas na Universidade de Lisboa em condições

ambientais estáveis, numa sala fechada num nível térreo. A concentração interior de gás radão tem um valor médio de 195 Bq.m-3 e exibe variações muito pequenas, tipicamente inferiores a 1%. Apesar de pequenas, estas variações são caracterizadas por uma estrutura temporal complexa que inclui um sinal diurno periódico, uma componente não periódica relacionada com a temperatura da sala, assim como um padrão semanal que reflete os padrões de ocupação do edifício nos dias de semana.

1. INTRODUCTION

Radon (Rn-222) is an ubiquitous indoor air pollutant and an established human carcinogen. Indoor radon measurements are often performed with passive dosimeters. However, these integrated measurements are not able to provide any information on the temporal variability of indoor radon concentration. Passive measurements performed for consecutive seasons (Papp et al, 2001) as well as continuous measurements (e.g. Miles, 2001) indicate that indoor radon variability displays a complex temporal pattern, probably reflecting the interplay of multiple factors such as occupancy patterns and meteorological factors. While for health concerns the main interest is on average exposure levels, it is also relevant to examine the temporal changes around mean radon levels. The present study addresses the high-frequency variability of indoor radon concentration in an unoccupied room from the analysis of hourly time series of gamma radiation measurements.

2. METHODS

The study area is located in the center of the city of Lisbon, corresponding from the geological point of view to the lower Tagus Cenozoic sedimentary basin (mainly detritic sediments), locally with alluvium cover. Indoor monitoring is performed in a ground-level dedicated room located in the University of Lisbon. The building is not equipped with air conditioning but has in operation an energy recovery ventilation system. The room selected for the monitoring study was specifically conceived for handling analogical aerial photography, therefore having no windows. Furthermore, the main entrance is preceded by a small antechamber, increasing the isolation of the main room and enhancing the maintenance of stable environmental conditions. The room was not used during the experiment, in order to reduce the influence of occupancy patterns in the results.

The average radon concentration in the room was previously measured during a 2 months period using passive CR39 sensors yielding an average radon concentration of 195 Bq.m-3. Continuous monitoring is performed using an NaI(Tl) scintillation sensor of 3" x 3" (Scionix, Holland) measuring gamma radiation in the range 475 KeV to 3000 KeV. The sensor measures the gamma radiation from the radioactive decay of the radon progeny Pb-214 and Bi-214, as well as the background contribution from U-238, Th-232 and K-40. The temporal variability of the gamma radiation reflects directly the temporal variability of radon above a constant background, since only radon, as a gas, is able to be transported and change in time. Therefore, and because of their high sensitivity, gamma sensors are particularly advantageous for continuous radon monitoring, the results being directly comparable with direct measurements of the alpha particles emitted by Rn-222, Po-218 and Po-214 (Barbosa et al, 2010; Zafrir et al, 2011; 2013).

Gamma radiation is measured every minute during a 21-days period, from 13 June to 3 July 2013. Furthermore, air temperature is simultaneously measured, both inside the room (near the gamma sensor) and outside (in the room's antechamber). Ancillary observations of hourly atmospheric pressure values are obtained from the Politécnica meteorological station in Lisbon. The 1-minute time series are aggregated into hourly values by computing the median of the measurements over every hour. The resulting hourly time series are considered hereafter.

3. RESULTS

The hourly time series of gamma counts, air temperature and atmospheric pressure are displayed in Figure 1. The radon progeny variations are small (typically< 2%), but with a clear diurnal cycle. The two temperature series are very similar but not identical, and the difference, defined as the interior minus the exterior temperature series, exhibits a clear weekly pattern, with a strong 24h cycle on week days. The atmospheric pressure series from Lisbon shows the expectedly weak 12h and 24h cycles superimposed on a well defined multi-day pattern.

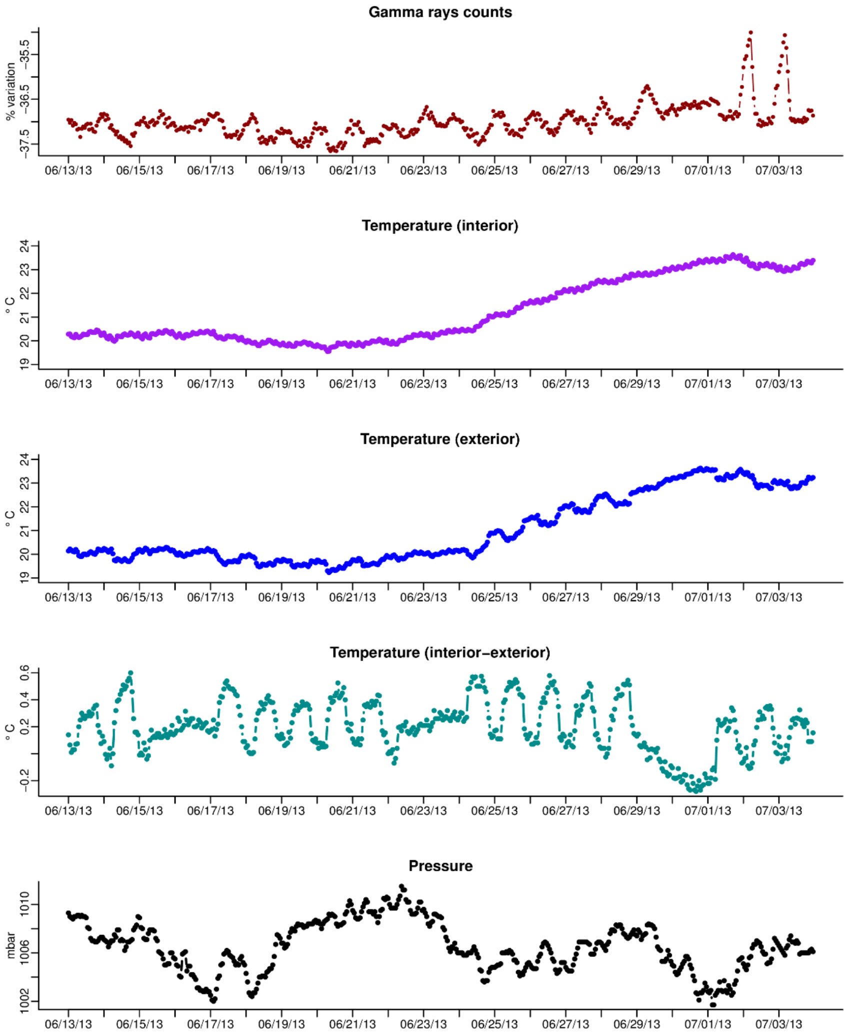

Figure 1. Time series of gamma ray counts variations, temperature, and atmospheric pressure.

The time series of gamma counts is dominated by two large diurnal peaks at the end of the monitoring period, on the 2nd and 3rd July. A possible explanation would be the occurrence of precipitation, and consequent increase of radon progeny in the soil due to wash-out, but the meteorological records show that these were dry summer days.

The visual inspection of Figure 1 shows that the diurnal variability is reduced on weekend days for both gamma and the temperature difference. This is confirmed by the scatterplot of the daily IQR (interquartile range) of the two variables displayed in Figure 2. The solid circles denote the weekend days, for which the diurnal cycle is absent (very low daily IQR) in both temperature difference and gamma radiation counts.

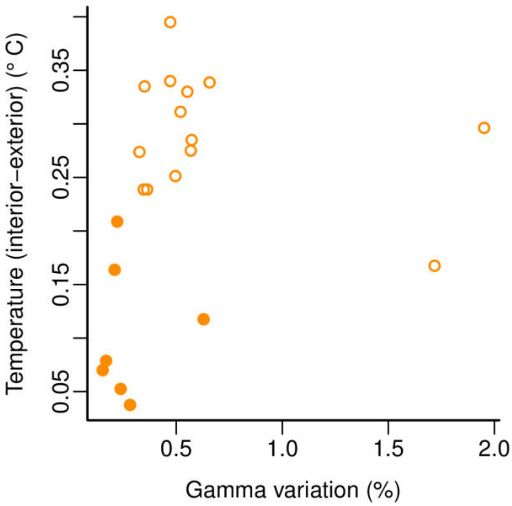

Figure 2. Scatterplot of daily IQR (interquartile range) values of gamma variations and temperature difference (interior-exterior). Solid circles denote weekend days.

Figure 3 shows the average diurnal cycle for each variable, computed as the average value for each hour of the day over the whole period. The gamma radiation is highest in the early morning (- 06:00), decreases fast in the next 6 hours, stabilizing around mid-day and increasing again fast after the minimum in the late afternoon (~18:00).

The temperature difference exhibits an inverted behavior with minimum around 05:00, a fast increase in the next 6 hours followed by a stable level and a fast decrease after the maximum at ~17:00. The diurnal cycle of the temperature difference is mainly determined by the exterior temperature, since the air temperature inside the room displays a much weaker cycle (amplitude of 0.16 °C) with minimum in the morning (~08:00) and maximum in the early evening (~21:00). The diurnal cycle of the exterior temperature, with an amplitude of about 0.3 °C, reflects the artificial ventilation of the building. The temperature decreases fast after 06:00, reaching a minimum level at about 10:00 and decreasing slowly afterwards. In the late afternoon the temperature increases until ~21:00, stabilizing afterwards.

The shape of the diurnal cycle of the gamma radiation and meteorological variables suggests that the daily variation in gamma counts is associated with the temperature difference between the interior and exterior of the room rather than with the interior temperature and the atmospheric pressure. This is confirmed by the corresponding correlation coefficients, displayed in Table 1.

Table 1. Correlation coefficient between diurnal time series components. The symbol * denotes correlations which are not significant for a 95% confidence level.

	Temperature (interior)	Temperature (exterior)	Temperature (difference)	Pressure
Gamma	-0.32	0.79	-0.97	*

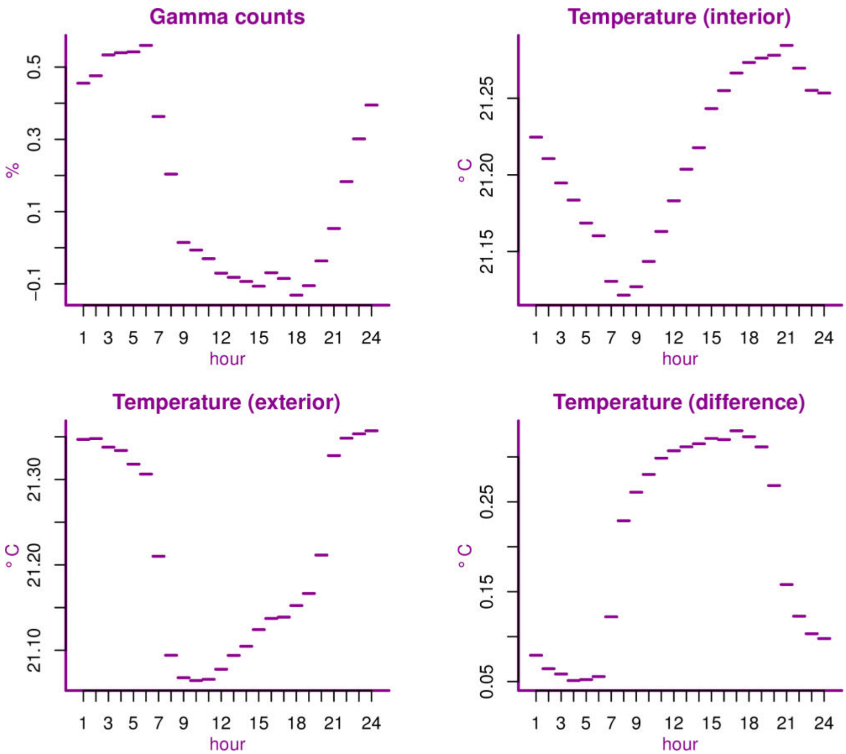

Figure 3. Average diurnal cycle.

In order to discard sub-daily signals and focus on long-term variability, the hourly time series are aggregated into daily sequences by computing the median value over each day. Table 2 shows the statistically significant (95% confidence level) correlation coefficients between daily gamma counts and daily averaged ancillary variables both for the whole period and a subset of daily values excluding the 1st day of the record (13/06/2013) and the weekend days (15/06, 16/06, 22/06, 23/06, 29/06, 30/06). The results show that the long-term variability of gamma counts is associated with the long-term variability of temperature (which is the same inside and outside the room in terms of daily-averaged values) but not with the temperature difference nor atmospheric pressure.

Table 2. Correlation coefficient between daily-averaged gamma counts and meteorological variables. The symbol * denotes correlations which are not significant for a 95% confidence level.

	Temperature (interior)	Temperature (exterior)	Temperature (difference)	Pressure
Gamma (whole period)	0.87	0.89	-0.67	*
Gamma (excluding weekends)	0.97	0.97	*	*

4. CONCLUSIONS

Variations in gamma counts over the monitoring period are small (typically below 2%), but are characterized by a rich temporal pattern comprising both periodic (diurnal) and non-perioc variability, as well as a weekly pattern. The analysis of ancillary temperature and atmospheric pressure data suggests distinct influences on the observed periodic and non-periodic signals:

i) the periodic diurnal signal is of non-tidal origin, being correlated with the temperature difference between the room's interior and exterior compartments;

ii) the long-term, non-periodic signal is not associated with the temperature difference but with the non-periodic variability of the room's temperature itself;

iii) the weekly pattern reflects the occupation of the building (and not of the room itself).

Both periodic and non-periodic features don't seem to be influenced by atmospheric pressure.

Agradecimentos

The measurements were performed in the framework of the project PTDC/CTE-GIX/110325/2009, funded by FCT. Technical support was kindly provided by Ivo Bernardo and António Soares. Antónia Valente provided the atmospheric pressure data. This work is financed by ERDF – European Regional Development Fund through the Operational Programme for Competitiveness and Internationalisation - COMPETE 2020 Programme within project «POCI-01-0145-FEDER-006961», and by National Funds through the FCT – Fundação para a Ciência e a Tecnologia (Portuguese Foundation for Science and Technology) as part of project UID/EEA/50014/2013 and programme IF2013.

Referências

Barbosa S.M., Zafrir H., Malik U., Piatibratova O. (2010) Multi-year to daily Radon variability from continuous monitoring at the Amram tunnel, southern Israel, Geophysical Journal International Vol. 182, 829-842.

Miles, J.C.H. (2001) Temporal variation of radon levels in houses and implications for radon measurement strategies, Radiat. Prot. Dosim. Vol. 93, 369-375.

Papp, G., Marx, G., Szalai, S., Tóth, E. (2001) Year by year changes of indoor radon levels, Journal of Radioanalytical and Nuclear Chemistry Vol. 250, 541-545.

Zafrir H, Barbosa SM, Malik U (2013) Differentiation between the Effect of Temperature and Pressure on Radon within the Subsurface Geological Media, Radiation Measurements Vol. 49, 39-56.

Zafrir H., Haquin G., Malik U., Barbosa S.M., Piatibratova O., Steinitz G. (2011) Gamma versus Alpha Sensors for Rn-222 Long-Term Monitoring in Geological Environments, Radiation Measurements Vol. 46, 611-620.