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Long-term vs. short-term measurements in indoor Rn concentration monitoring: Establishing a procedure for assessing exposure potential (RnEP)

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ABSTRACT

Radon (Rn-222 or Rn) is a naturally occurring chemical element that belongs to the progeny of U-238 released from soil and rocks into the atmosphere, whose impact on organisms is not negligible when it occurs inside confined spaces, such as mine shafts or low-ventilated buildings. The current methodologies for indoor radon assessment are based on passive and active detection. If passive detectors are mainly designed for long-term assessment, active detectors are electronic equipment that can allow on-time visualization of results and, therefore, faster decision-making on risk mitigation measures implementation. However, despite offering a prompt and informed decision, the uncertainty associated with active detector results may cast doubt on the quality of the measurements, which especially arises from the duration of the monitoring campaign. Since radon emanation from soils and rocks depends on a set of variables related to meteorological parameters and soil structure, the seasonal variation of these parameters impacts indoor radon concentration assessment, both on short-term and long-term measurements. Therefore, short-term monitoring campaigns lasting a month, a week, or a day may not produce a statistically representative description of indoor radon exposure for the monitored building. Accordingly, the study compares the reliability of short-term and long-term indoor radon measurements. It proposes a procedure for assessing the indoor Radon Exposure Potential (RnEP) based on in situ measurements through the analysis of the frequency of occurrence of results divided into three classes of potential exposure (low, moderate and high) to reduce occupants' radon risk exposure.

1. Introduction

Radon (Rn-222 or Rn) is a naturally occurring chemical element that belongs to the progeny of U-238 [1,2]. It is the only element in this sequence of radioactive decay that occurs in the gaseous state under the conditions of pressure and temperature found on the planet's surface [3,4]. Rn is released from soil and rocks into the atmosphere, whose impact on organisms is negligible since its concentration is very low and quickly dispersed [5]. However, when this release occurs inside confined spaces, such as mine shafts or inside buildings, its concentration can reach high values, which constitutes an exposure risk for users of these spaces [6,7]. Rn has a half-life of 3.8 days, which means that at the end of that period, it also decays, giving rise to a Pb-218 atom, with the simultaneous release of radiation in the form of α particles [8]. It is precisely this exposure to α particles that makes Rn pose a risk to confined space users [9]. As it is a gas, Rn can be inhaled, and its decay will occur inside the pulmonary alveoli [10]. When the α particles are released, they will bombard the surface layer of the pulmonary alveoli, so the risk of degeneration of these cells will be greater the higher the concentration of indoor Rn, as well as the longer the exposure time [11–15]. That is, the risk associated with exposure to Rn is higher as the level of contact, and the duration of that contact is more significant [16–20]. The World Health Organization (WHO) classifies Rn as the second cause responsible for the occurrence of lung cancer [21–26]. The evaluation and monitoring of indoor Rn concentration are increasingly crucial as more and more studies reinforce the causal link between exposure to indoor Rn and certain types of oncological problems [27–29].

The methodologies currently available for indoor Rn concentration

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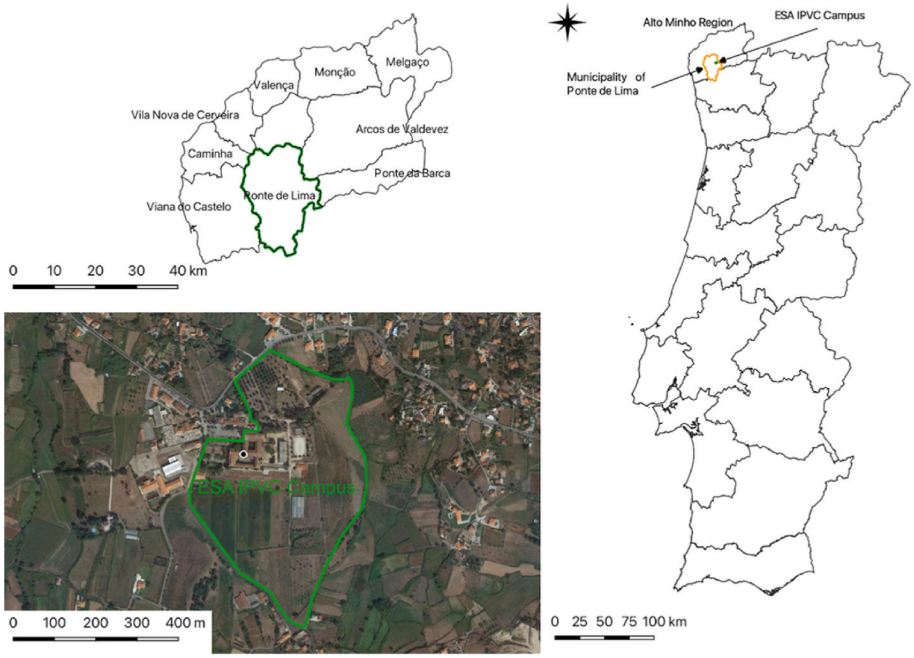

Fig. 1. Location of the building where the indoor Rn concentration was monitored.

Table 1
Technical specifications of the AirThings Corentium Plus Radon Monitor probes, model QRI, used in the monitoring of indoor Rn concentration.

Rn sampling	Passive diffusion chamber
Detection method	Alpha spectrometry
Detector	1 silicon photodiode
Diffusion time constant	25 min
Measurement range	0-50,000 Bq·m^{-3}
Sampling rate	1 h
Operation environment	4 °C to 40 °C
	5% RH to 85% RH non-condensing
	50 kPa–110 kPa
Temperature	0.336 °C resolution, ±1 °C accuracy
Humidity	0.5% RH resolution, ±4.5% accuracy
Barometric pressure	0.01 kPa resolution, ±1 kPa accuracy

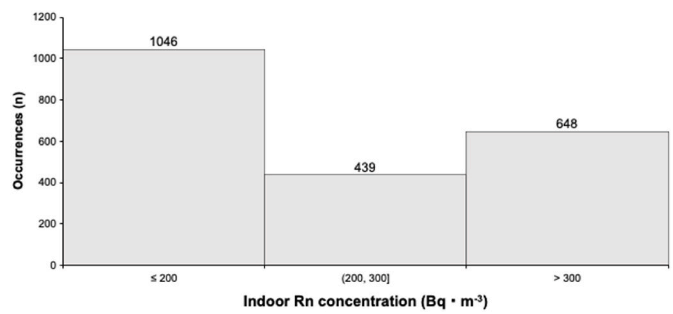

Fig. 3. Frequency diagram representing the distribution of results obtained in long-term monitoring of the indoor Rn concentration.

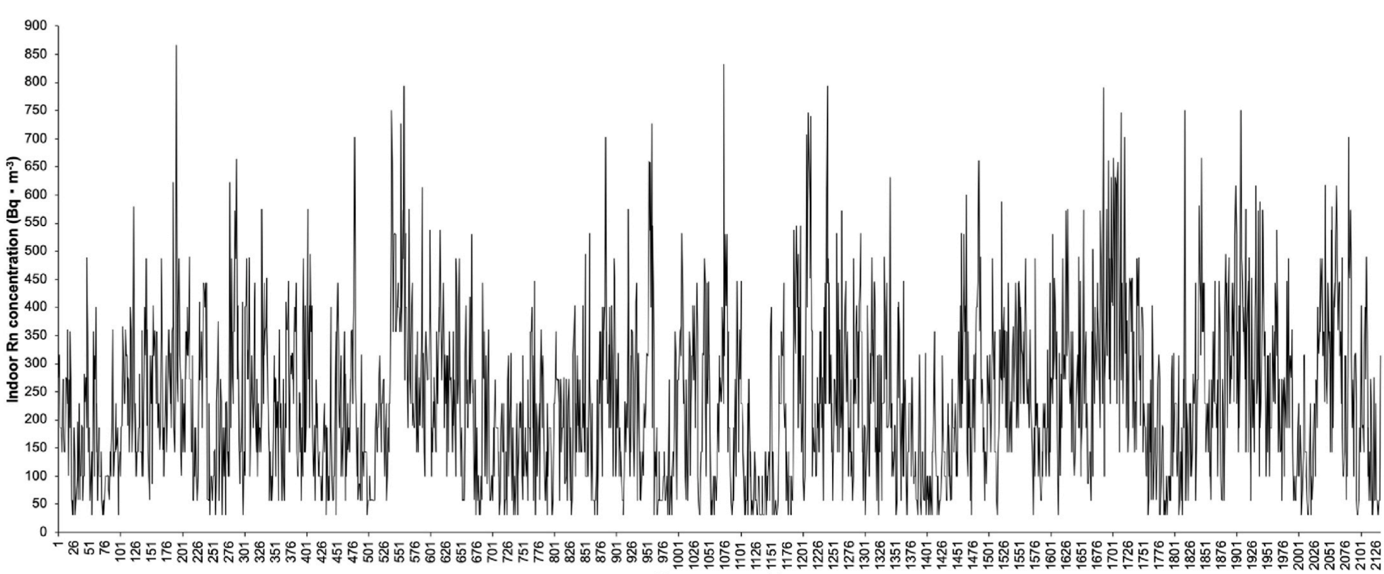

Fig. 2. Distribution of the indoor Rn concentration results over the monitoring period.

Table 2
Statistical descriptors of the monitoring periods in short-term mode extracted from the long-term sequence.

Reference	Measurements (n)	Average (Bq·m^{-3})	Standard deviation (Bq·m^{-3})	Uncertainty (Bq·m^{-3})	Minimum Value (Bq·m^{-3})	Maximum value (Bq·m^{-3})	Variance
1 Month (I)	744	216.4	144.0	5.3	31.9	831.5	20737.0
1 Month (II)	720	252.2	149.9	5.6	31.9	789.8	22457.5
1 Week (I)	168	219.6	126.7	9.8	31.9	866.7	16062.9
1 Week (II)	168	196.7	170.9	13.2	31.9	831.5	29211.1
1 Week (III)	168	271.6	133.3	10.3	31.9	789.8	17781.2
1 Week (IV)	168	282.0	152.0	11.7	31.9	750.5	23113.6
1 Day (I)	24	307.9	177.1	36.1	31.9	664.6	31362.4
1 Day (II)	24	118.3	108.5	22.1	31.9	400.8	11779.6
1 Day (III)	24	286.7	149.4	30.5	31.9	599.3	22330.2
1 Day (IV)	24	218.2	139.8	28.5	31.9	489.1	19533.5

Table 3
Comparison of the variances of the data series in short-term mode with the original data series obtained in long-term mode through the F-Snedecor test.

1 Month (I)	1 Month (II)	1 Week (I)	1 Week (II)	1 Week (III)	1 Week (IV)	1 Day (I)	1 Day (II)	1 Day (III)	1 Day (IV)
0.54	0.49	0.01	0.005	0.11	0.51	0.15	0.08	0.83	0.82

Table 4
Comparison of the means of the data series in short-term mode with the original data series in long-term mode using the *t*-Student test.

1 Month (I)	1 Month (II)	1 Week (I)	1 Week (II)	1 Week (III)	1 Week (IV)	1 Day (I)	1 Day (II)	1 Day (III)	1 Day (IV)
0.0006	0.002	0.09	0.004	0.0006	0.00002	0.007	0.00006	0.04	0.30

assessment are essentially based on passive or active detectors [30]. Passive detectors can be placed where the Rn concentration is to be evaluated and remain for three months (long-term measurement) [31, 32] Active detectors are electronic equipment that, unlike passive detectors, need a source of energy (which can be batteries or even a connection by electrical wire) and are placed in the spaces to be monitored [33]. However, this equipment records the instantaneous indoor Rn concentration in previously established time intervals (which may vary depending on the equipment used or can even be adjusted to adapt to the monitoring objective), allowing know the variation of the concentration over time [34]. In the same way, many of these devices already allow on-time visualization of results [35]. For example, active detectors can present average values for short-term monitoring periods, one or seven days, of indoor Rn concentration [36]. However, as previously mentioned, the risk of exposure does not depend solely on the instantaneous concentration of the indoor Rn but also on the exposure time.

In this perspective, active detectors may present advantages over passive detectors, as they allow a faster measurement of results and, therefore, faster decision-making on risk mitigation measures implementation. However, despite the advantages that active detectors present, namely the possibility of obtaining immediate results and how the indoor Rn concentration evolves, the uncertainty associated with the results obtained may cast doubt on the quality of these results. For this reason, the discussion about the duration of the monitoring campaigns is crucial for the correct collection of data since several factors influence the emanation of Rn from soils and rocks. Here can be identified meteorological parameters, such as temperature, atmospheric pressure, or relative humidity, but also parameters related to soil structure, such as permeability and water content [37]. Thus, since many of these parameters show seasonal (and even daily) cyclical variations, Rn emanation (and its consequent concentration) likely follows correlation patterns with some of these parameters [38]. For this reason, carrying out short-term monitoring campaigns lasting a month, a week, or a day may not be statistically representative of the reality of the intended space [39]. Since fluctuations in the indoor Rn concentration can be significant (in the case of datasets with a large variance), presenting the mean as a reference value may not represent reality in the best way [40]. For example, it can be composed of a large set of measurements showing low values and a less extensive set of very high ones. Still, their average will be influenced by default by the group of lower values, which occur in much greater numbers. However, it may be the case that the sequence of results with very high values occurs precisely during the space occupation period. As the average value does not indicate this trend, mitigation measures are not taken to reduce the exposure risk for space users. For all these reasons, the main objectives of this study are, firstly, to comparatively analyze the quality of the results obtained in the long-term and short-term modes. Secondly, to contribute to the establishment of an expeditious procedure for assessing the potential of exposure to indoor Rn concentration (RnEP), from a perspective of prevention and anticipation of the problem, through the analysis of the frequency of occurrence of results divided into three classes of potential exposure (low, moderate and high).

2. Materials and methods

For the monitoring, a professor cabinet in a school building with a preponderance of high indoor Rn concentrations was selected. It is a listed building with a high heritage value, consisting of several building blocks, whose construction began in the 12th century, went through the overlapping of different historical periods, and was reconstructed in the last decades of the 20th century. The building has been the subject of several studies reporting high indoor Rn concentrations. As listed as a heritage building, interventions involving architectural changes are prohibited, so mitigation efforts have been dedicated to evaluating constructive measures, such as the use of barrier membranes and interior coating mortars. Measures related to natural ventilation procedures and the relationships between other parameters, namely air temperature, atmospheric pressure, and relative humidity, have also been the subject of interest and study. The building, which is currently occupied by one of the higher education schools of the Polytechnic Institute of Viana do Castelo (IPVC), the Escola Superior Agrária (ESA IPVC), is located in the parish of Refóios do Lima, in the municipality of Ponte de Lima (North of Portugal). The region is characterized by abundant granitic rocks, with frequent high indoor Rn concentrations [41]. Fig. 1 shows the location of the building where the monitoring campaign took

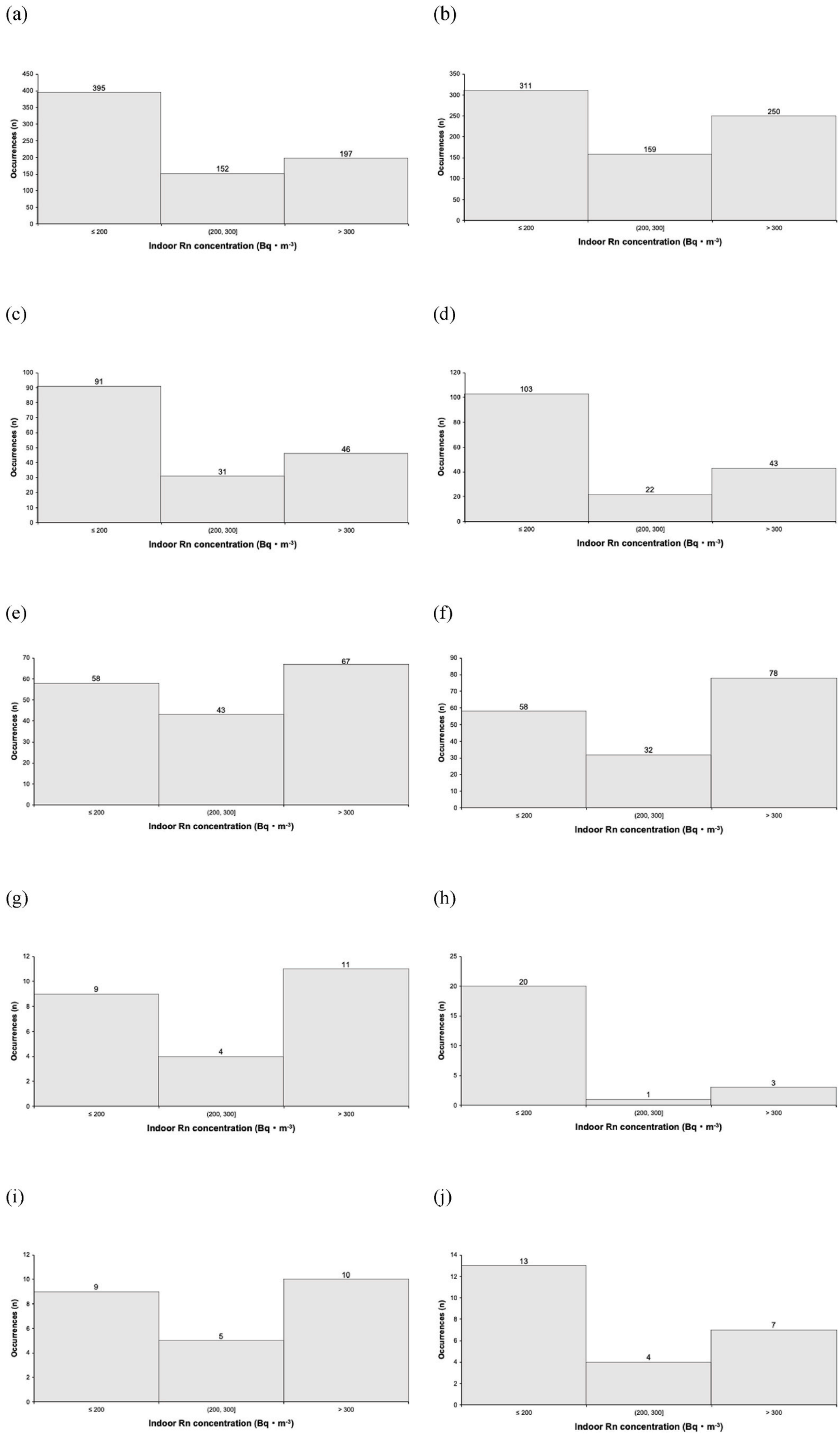

Fig. 4. Frequency diagrams of each of the time series in short-term mode extracted from the original series obtained in long-term mode. (a) 1 Month (I); (b) 1 Month (II); (c) 1 Week (I); (d) 1 Week (II); (e) 1 Week (III); (f) 1 Week (IV); (g) 1 Day (I); (h) 1 Day (II); (i) 1 Day (III); (j) 1 Day (IV).

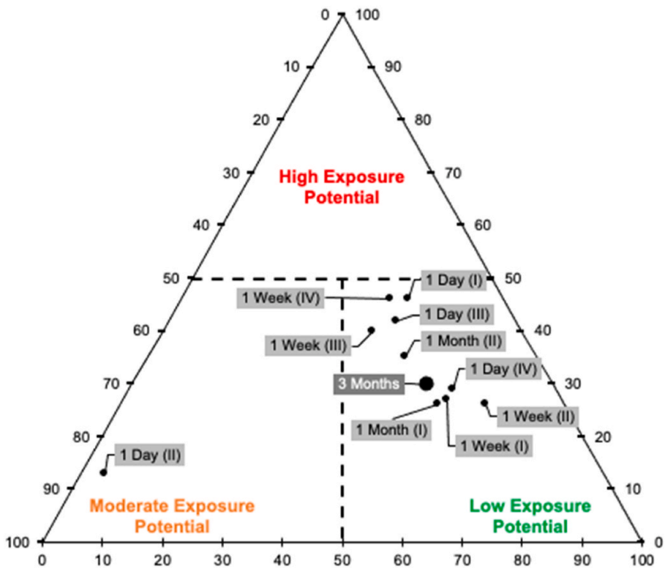

Fig. 5. Ternary diagram with the projection of the exposure potential (RnEP) of each of the analyzed time series.

place.

For the monitoring campaign, a cabinet was selected where previous monitoring campaigns had already been carried out and which measured values are considered reasonable but with some variability, represented by peaks of high momentary concentrations followed by sharp drops. The selected cabinet has an approximate volume of 84 m^3, with an access door from a corridor limited at one end by a meeting room with several windows to the outside and at the other end with a connection to the central nave of the floor (3rd floor) of the building. The cabinet has a window to the outside, which is usually opened when weather conditions permit. The office typically has its door open or at least ajar when occupied. The window, as it is a heritage building, is made of wood with single glazing, opening by raising the lower part in the traditional style.

This choice aimed to analyze the variability of the extracted short-term series concerning the original long-term series. The monitoring campaign took place between April 4, 2022, and May 4, 2022, by using two AirThings Corentium Plus Radon Monitor probes, model QRI, which were placed over the desk (80 cm from the floor and 30 cm from the wall). Table 1 presents the technical specifications of the probes used in the monitoring campaigns.

Two probes were used to verify the probable occurrence of errors associated with the operation of the equipment. After the long-term monitoring campaign, the two data groups were analyzed by comparing the means and variances of the two sets of data to validate the data merger into a single group. For this purpose, the t-Student and F-Snedecor statistical tests were used, followed by the transformation of the two sets into a single one by the arithmetic mean of each corresponding pair. Then, a random selection of data series was carried out in a short-term mode, lasting one month, one week, and one day, with the selection of two, four, and four data sets, respectively. Comparison of the statistical descriptors of each of these sets with the data set. Comparing the statistical descriptors of each of these sets with the initial data set was performed again using the t-Student and F-Snedecor statistical tests. Frequency analysis was also used in the study of the groups, which served as the basis for obtaining the data used in constructing the triangular diagram to assess the potential for exposure to indoor Rn. The Fast Fourier Transform (FFT) was used to study the indoor Rn concentration evolution.

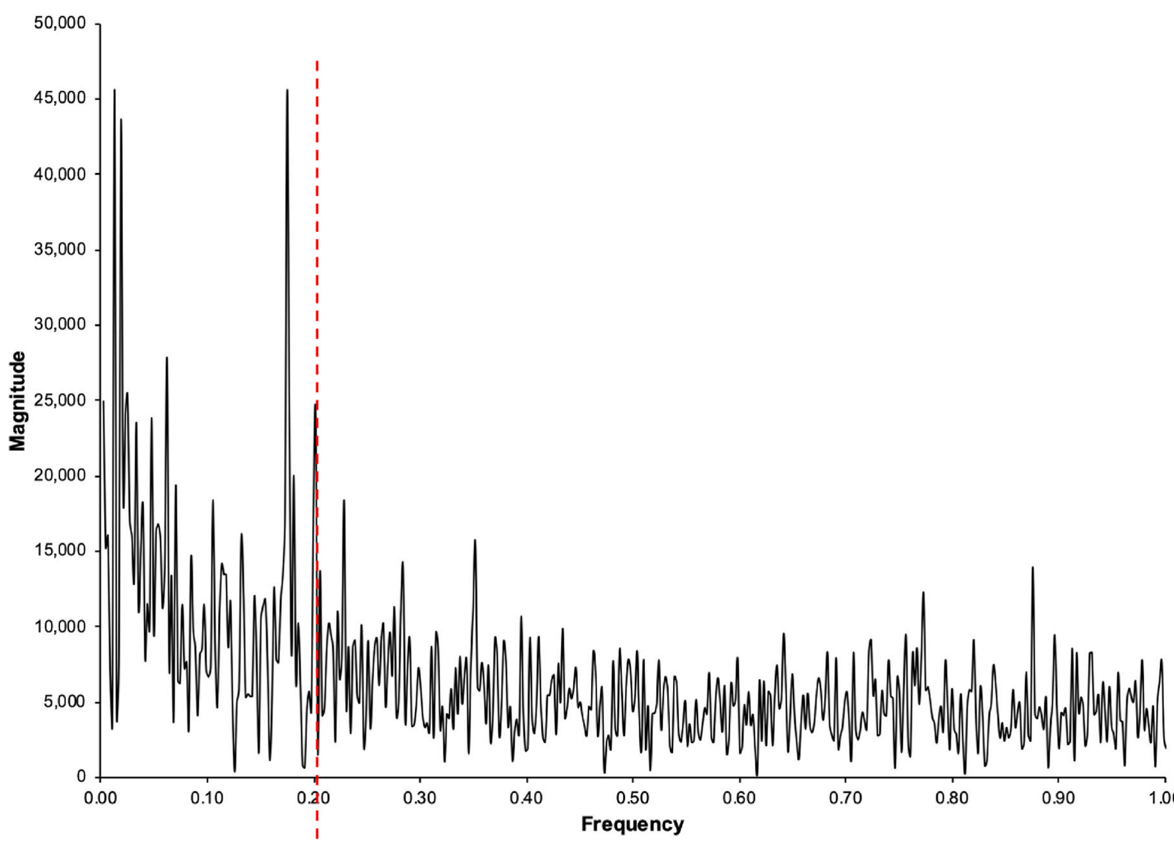

Fig. 6. Schematic representation of the application of the Fast Fourier Transform (FFT) to the data series obtained from monitoring in a long-term mode in the compartment under analysis in this study.

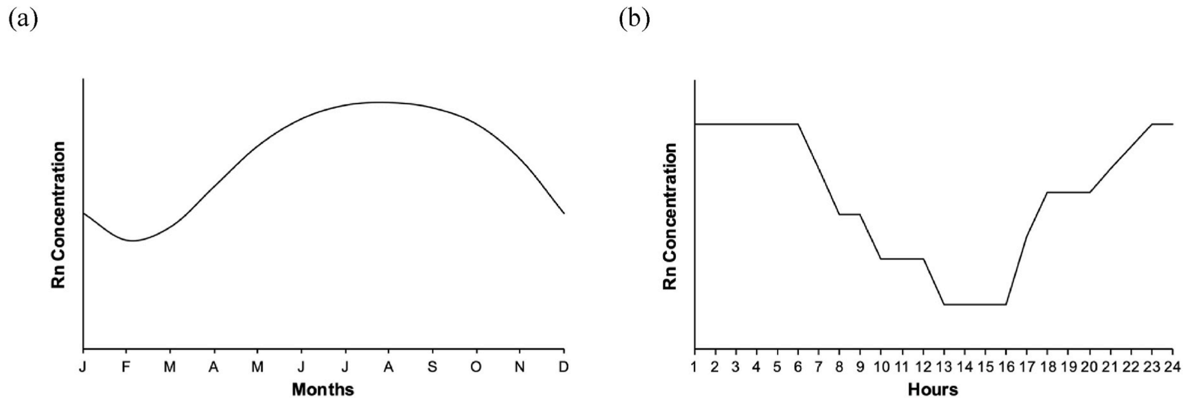

Fig. 7. Seasonal (a) and daily (b) variation of Rn concentration in the atmosphere, closely related to meteorological factors (temperature, atmospheric pressure and relative humidity) [49–52].

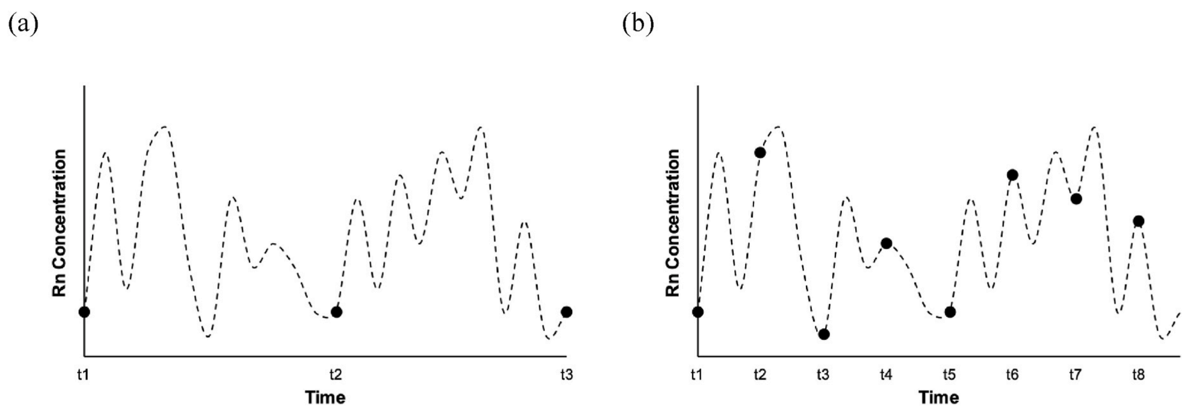

Fig. 8. Example of a situation where the difference between the same situation is visible with (a) the monitoring is done with a very long time spacing, and (b) in the same situation is monitored on the same period but with a smaller spacing between measurements.

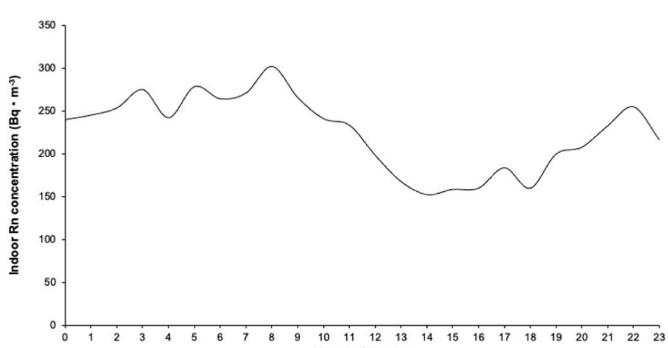

Fig. 9. Hourly average values of the evolution of the indoor Rn concentration over the 24 h of the day.

3. Results

The results obtained with the two probes were compared to validate their fusion. This evaluation was carried out by comparing the means and variances of the two data sets by applying the t-Student statistical test, which compares the means, and the F-Snedecor, which compares the variances. Both in the *t*-Student test and in the F-Snedecor test, $p > 0.05$ were obtained. In comparing the means by the *t*-Student test, the value obtained does not reject the H0 hypothesis, which means that there are no significant differences between the means of the two groups. In the case of comparing the variances using the F-Snedecor test, the result obtained does not reject the H0 hypothesis, which means that they are supposedly equal. The results were merged into a single group through the arithmetic mean of each pair of data obtained with each probe, with the final result shown in Fig. 2.

This set of results, obtained with long-term monitoring, which took place from April 02, 2022 to April 05, 2022 (three months), totaling 2133 measurements, with an interval of 1 h between measurements. This sequence has an average of 233.8 Bq·m^{-3}, with a standard deviation of 146.8 Bq·m^{-3}, ranging from a minimum value of 31.9 Bq·m^{-3} to a maximum value of 866.7 Bq·m^{-3}. The uncertainty associated with these results is $\pm$3.2 Bq·m^{-3}.

Next, the distribution of the results obtained by three classes previously defined corresponding to low, moderate, or high potential exposure to indoor Rn was carried out. For this purpose, the classes defined for the indoor Rn concentration were $\leq$200 Bq·m^{-3}, 200–300 Bq·m^{-3} and $>$300 Bq·m^{-3}, corresponding, respectively, to low exposure potential, moderate exposure potential and high exposure potential, with the distribution shown in Fig. 3.

As seen in the previous frequency diagram, the results are distributed distinctly across the three classes, with approximately half of the results of the indoor Rn concentration, 49%, presenting values $\leq$ 200 Bq·m^{-3}. In about half of the monitoring time, the indoor Rn concentration showed low exposure potential values. To this low potential exposure, one can also add the fraction corresponding to the results classified as belonging to a moderate exposure potential, with 21% of occurrences, which means that 70% of the time, the indoor Rn concentration in the monitored compartment was below the recommended limit of 300 Bq·m^{-3}. In the remaining 30% of the time, the 648 occurrences recorded point to indoor Rn concentration values greater than 300 Bq·m^{-3}.

For the comparative analysis between monitoring in long-term and

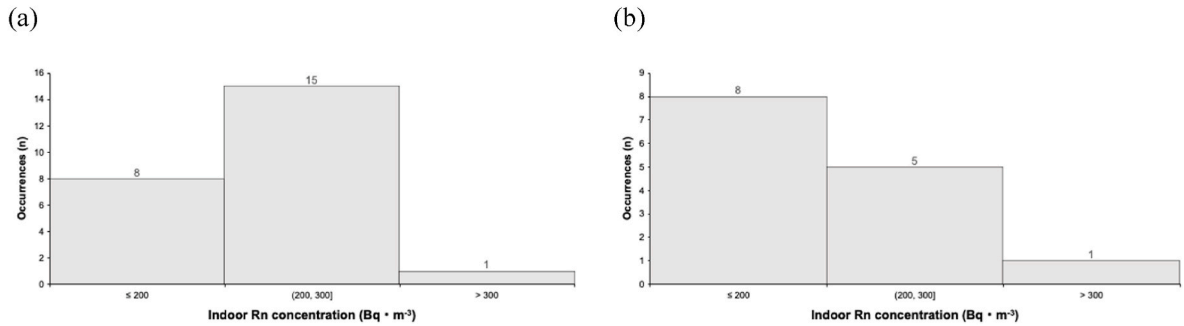

Fig. 10. Frequency analysis (a) of the hourly average of the entire sequence, and (b) only of the period of occupancy of the building, from 07:00 to 20:00 (14 h).

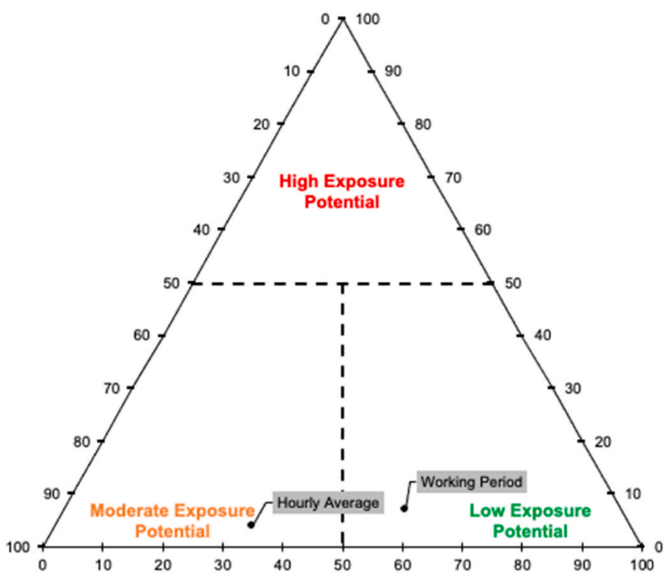

Fig. 11. Ternary diagram with the projection of the exposure potential of the hourly average for the entire period and the hourly average restricted to working hours.

short-term modes, different periods were separated and randomly selected from the data obtained in the long term to analyze each of the short-term time sequences. For this purpose, shorter temporal sequences were selected, lasting one month, one week, and one day.

- For the sequences with 1 month, 2 time periods were chosen: from 1 to March 31, 2022 and 1 to April 30, 2022.
- For the sequences with 1 week, 4 time periods were selected: from 6 to February 12, 2022, 20 to March 26, 2022, 9 to April 15, 2022, and 24 to April 30, 2022.
- For the sequences with 1 day, 4 dates were selected: February 16, 2022, March 23, 2022, April 6, 2022, and May 3, 2022.

Table 2 presents the statistical descriptors of the data sets corresponding to each of the selected sequences.

As can be seen from the results presented in the previous table, with the decrease in the number of measurements, the uncertainty associated with the result grows progressively. The uncertainty associated with long-term monitoring (3 months) is ±3.2 Bq·m^{-3}, but this changes to ± 5.3 Bq·m^{-3} and ±5.6 Bq·m^{-3} when the time series is reduced to one month, in which 744 measurements are performed, in the case of a month with 31 days, or 720 measurements, in the case of a month with only 30 days. In the situation of the weekly series, with 168 measurements, the uncertainty can vary between ±9.8 Bq·m^{-3} and ±13.2 Bq·m^{-3}, already indicating greater variability in the distribution of results. In the case of daily time series, the uncertainty varies between ±22.1 Bq·m^{-3} and ±36.1 Bq·m^{-3}. This variability in the results is also evident by analyzing the minimum and maximum values found in the different time series. If, on the one hand, the minimum value recorded is the same in all situations (31.9 Bq·m^{-3}), most likely associated with the indoor Rn background concentration in the compartment monitored in this study, in the case of the maximum value, this oscillates between 400.8 Bq·m^{-3} and the 866.7 Bq·m^{-3}. It appears that, since apparently, these higher peak values are relatively infrequent, the probability of being detected in shorter short-term monitoring is lower and may not characterize in a way that is representative of the real evolution of the indoor Rn concentration in that compartment.

As a way to compare if there is any relationship between the means and variances of all short-term sequences and the initial long-term sequence, the F-Snedecor test was first applied for the analysis of variances since the *t*-Student test presents different behaviors in case the samples have equal variance (homoscedastic), or samples having unequal variance (heteroscedastic). The results obtained are shown in Table 3.

Of all the results obtained, only the comparison between 1 Week (I) and 1 Week (II) with the 3 Months series presents $p < 0.05$, rejecting hypothesis H0. That is, there are differences between the variances, which are not equal. In all other situations, $p > 0.05$, not rejecting H0. That is, there are no differences between the variances, which are assumed to be equal.

The comparison of means was carried out considering the previous result, with series 1 Week (I) and 1 Week (II) being treated as samples with unequal variance (heteroscedastic) and with all the remaining series being processed as samples with equal variance (homoscedastic) for the 3 Months series. The results obtained are shown in Table 4.

As can be seen in the results obtained, except for series 1 Week (II), 1 Day (I), and 1 Day (IV), the all-time series show $p < 0.05$, rejecting hypothesis H0. That is, there are significant differences between the averages of these groups compared to the group of the 3 Months series. In the case of series in which this premise is not verified, since they present $p > 0.05$, not rejecting H0, and which, therefore, do not have significant differences concerning the average of the 3 Months series. This situation seems to be more related to mere chance than with some probability of being representative of the evolution of the indoor Rn concentration. This situation is confirmed through the frequency analysis for each time series by the distribution of occurrences verified by each exposure potential class, as shown in Fig. 4.

As seen previously, the main series (long-term) shows a tendency for the occurrence of measurements in the class <300 Bq·m^{-3} of 70%. This situation indicates that the probability of registering a higher number of occurrences in this class is higher for time series of shorter duration. Thus, the probability that monitoring in a short-term mode can be representative of reality is very low. Fig. 5 presents the projection of each of the series used in a ternary diagram, constructed from the results obtained by the frequency analysis, in which the position of the representative point of each of the series in the graph represents its tendency towards a more or less high exposure potential to indoor Rn.

As can be seen, there is a great dispersion of the results obtained around the representative point of the monitoring series in long-term mode. This distribution indicates that the short-term series do not represent the reality of the evolution of the indoor Rn concentration in the monitored compartment. When a closer approximation occurs, it is caused by a particular pattern in the evolution of the indoor Rn concentration over time. This situation can, in some way, be verified through the analysis of the Fast Fourier Transform (FFT) applied to the data set obtained in the monitoring sequence in long-term mode, as shown in Fig. 6.

When applying the FFT to the long-term series dataset, consisting of 2133 measurements, only 2048 of these data were used since, in the FFT analysis, the number of input values must be a power of 2. As seen in the evolution of the indoor Rn concentration over time, it is possible to divide the graph into two parts, in which a certain homogeneity in the behavior of the sequence is verified (to the right of the dashed line in Fig. 6). From this moment on, roughly from August 02, 2022, the oscillation of the indoor Rn concentration seems to follow a more predictable, cyclical trend. However, since on the left of the dashed dividing line, it is not possible to identify another type of trend, it is not possible to say whether it is a broader cycle or whether it is a transition between different behaviors, which follow a (or several) seasonal trend(s) over a longer period. For example, it could be related to the relationship between the emanation of Rn from the soil and the oscillation of atmospheric pressure, air temperature or relative humidity, as already described in several previous works [42–48].

4. Discussion

The concentration of Rn in the atmosphere shows seasonal variations, with a tendency towards a pattern that indicates a correlation between air temperature and a variation in the daily concentration, shown in Fig. 7.

This double variability raises some questions regarding the representativeness at the time of collection and recording of the indoor Rn concentration since the assumption of a value as representative of the concentration in a given location can induce a decision-making contrary to that would be necessary. For example, short-term monitoring (hours) performed within the time interval between 12:00 and 18:00, in Fig. 7(b), would show a low result for the indoor Rn concentration. However, this time interval only corresponds to the period where the indoor Rn concentration is lowest and cannot be extended to the day's remaining hours. For example, if the measurement corresponds to an industrial unit that works in shifts, workers who work the day shift would be subject to a lower potential exposure than workers working night shifts. However, as the value measured refers to the daytime period, the situation would not consider mitigating this concentration, increasing the risk of exposure.

The adoption of frequency analysis as a methodology for assessing exposure potential has some advantages. This assessment is always based on monitoring carried out in continuous mode or data collection mode with a previously defined sampling rate, which will be more reliable the shorter the interval between measurements. For example, a sequence with long-spaced measurements does not allow the detection of errors in the measurement, which contributes to the error introduced in the calculation of the statistical descriptors to be significant, as can be easily understood by the example shown in Fig. 8.

The statistical descriptors corresponding to the monitoring schematized in Fig. 8(a), such as the mean and the standard deviation, will always present a lower value than the calculated descriptors for the situation described in Fig. 8(b). By systematically carrying out a monitoring campaign in long-term mode, with measurements 1 h apart, 2133 results are obtained, representing the evolution over the entire monitoring period. However, when analyzing the mean of the set (233.8 Bq·m^{-3}) and the respective standard deviation (145.8 Bq·m^{-3}), it is verified that the maximum value resulting from the sum between both values can be very high (380.6 Bq·m^{-3}), which would expose space users to an indoor Rn concentration substantially above the recommended limit value (300 Bq·m^{-3}) by European and national legislation (Directive 2013/59/Euratom and Decree-Law No. 108/2018, which transposes the European directive to Portugal). In this way, the frequency analysis of the entire data set allows a more efficient weighting since the weight of each class is given by the number of occurrences recorded for a given set of values. As seen in Fig. 5, this approach allows a weighted assessment of the potential exposure to Rn (RnEP), which is more effective the longer the time series analyzed are.

As already mentioned, the seasonal and daily variation caused by the correlation between the indoor Rn concentration and other parameters (of a meteorological type or related to soil characteristics) can be identified through the application of the FFT. This application results in a harmonic line, where it is possible to identify the magnitude and frequency of the series as a function of time. However, as can also be seen in the case presented here, even with a series obtained in the long-term mode, consisting of the sequence of data collected over three months, doubts persist about the true representativeness of this time series for the entire year, a since, as shown in Fig. 8(a), there is a difference in the performance of the indoor Rn concentration between the summer and winter months. In the case of daily variation, assuming for this purpose the average of all records made in the long-term measurement, we obtain the average daily evolution shown in Fig. 9, which confirms the theoretical evolution shown in Fig. 7.

If frequency analysis is applied to the data set generated by calculating the averages for each of the hours of the day, the graph shown in Fig. 10(a) is obtained. In contrast, Fig. 10(b) shows the same data set but now dealing only with the group of hours that are usually considered to correspond to the period of the day when there is a probability of occupation of the building and which was considered to be from 07:00 to 20:00, in a total of 14 h.

In this scenario, there is an immediate decrease in the average amplitude values, contributing to the decrease in the average (which may not reduce the standard deviation). This frequency analysis on the triangular diagram (Fig. 11) shows that the entire day can be considered a moderate exposure potential. However, when projecting data only for the working period, it appears that the level of exposure drops significantly, moving to the sector of low exposure potential.

5. Conclusions

A cabinet in a high heritage value school building was subject to a long-term experimental monitoring campaign to assess indoor radon concentration for three consecutive months, by using two radon monitors to check the occurrence of the errors associated with the operation of the equipment. After the long-term monitoring campaign, the two data groups were analyzed by comparing the means and variances of the two sets of data to validate the data merger into a single group, and then a random selection of two, four, and eight data series with one month, one week and one-day duration (short-term series) were picked for statistical analysis by using the t-Student and F-Snedecor tests. Additionally, the frequency analysis was used to extract data for the construction of the triangular diagram designed to assess the potential for exposure to indoor Radon. The Fast Fourier Transform (FFT) was applied to study the indoor Rn concentration evolution. The research allows concluding that the short-term series do not represent the real scenario for indoor Rn concentration description in the monitored room during the long-term experimental measurement. When a closer approximation occurs, it is caused by a particular pattern in the evolution of the indoor Rn concentration over time. This situation occurs since the concentration of Rn both in the atmosphere shows not only daily but also seasonal variation, and therefore a short-term series cannot be representative of long-term measurement. Based on this, a weighted assessment of the potential exposure to Rn allows calculating the parameter RnEP, through the analysis of the frequency of occurrence of results divided into three classes of potential exposure (low, moderate, and high).

Credit author statement

Conceptualization, L.J.R.N., and A.C.; methodology, L.J.R.N. and A. C.; validation, L.J.R.N. and A.C.; formal analysis, L.J.R.N., and A.C.; investigation, L.J.R.N., and A.C.; resources, L.J.R.N. and A.C.; data curation, L.J.R.N., and A.C.; writing—original draft preparation, L.J.R. N., and A.C.; writing—review and editing, L.J.R.N. and A.C.; visualization, L.J.R.N., and A.C.; supervision, L.J.R.N., and A.C. All authors have read and agreed to the published version of the manuscript.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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