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Seasonal changeability of indoor radon concentrations in one-family house

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Abstract Indoor radon concentration undergoes 24-hour and seasonal changes. The paper presents first in Poland results of radon concentration changeability in one building during the whole year. We performed 103 measurements of indoor radon concentrations. The following parameters of radon concentration distribution were obtained: arithmetic mean – 224.1 Bq m^{-3}, geometric mean – 194.5 Bq m^{-3}, median – 207 Bq m^{-3}, and geometric standard deviation – 1.84. The minimum observed value was 22 Bq m^{-3} and the maximum – 748 Bq m^{-3}. We determined the monthly and annual values of radon concentrations. The values for particular months are in the range of 0.5 to 1.6 of the annual mean. We observed a correlation between the mean radon concentrations in the examined buildings and the differences in the mean values of indoor ($R = 0.91$, $p < 0.05$) and outdoor temperatures ($R = -0.91$, $p < 0.05$). There was also a connection between the radon concentration inside the buildings and the changes in atmospheric pressure.

Key words radon • seasonal changes

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Introduction

Radon (Rn^{222}) is a naturally occurring radioactive element, a noble gas that is produced in radium disintegration. Radon has the biggest contribution to the effective dose obtained by population. Increased morbidity of lung cancer in uranium miners and an observation that radon exposure in certain houses may be comparable to the exposure in uranium mines have caused the increase of interest in radon. In 1988 International Agency for Research on Cancer considered radon to be the first class carcinogenic.

Indoor radon concentration undergoes 24-hour and seasonal changes. Seasonal changeability of radon concentrations is a well-known phenomenon observed in various parts of the world [1, 2, 6, 7, 16, 17]. Many factors, like geology and climate, may have an influence on the character of this changeability. Knowledge of averaged radon concentrations is required to assess exposure to radon and its possible effects. Corrective coefficients are used to generalize radon concentrations to the annual mean due to seasonal changeability of radon concentrations [8, 14]. It is also possible to recognize that concentrations in certain seasons are closer to the annual mean than in other seasons [4]. In order to determine the character of radon concentration changeability in the northeastern Poland, yearly measurements of radon concentrations were performed. The measurements were accompanied by weather parameter observations. The paper presents first results of radon concentration changeability in one of the buildings.

Methods

The dwelling house, which underwent the observation, was chosen after preliminary examination. A high indoor radon concentration was the most important criterion. Seasonal changes in radon concentrations do not depend on absolute values of its concentration and take similar courses in cases of high and low concentrations [9]. The accuracy of radon concentration measurements increases together with its values increase. A timbered two-storey one-family house with a basement was chosen.

Time changeability of radon concentration in the building was observed using the system of charcoal Pico-Rad detectors. The time of exposure was from 2 to 4 days. The temperature inside was measured using an automatic thermometer, which measured and recorded 4 measurements of temperature per 24 h for one year. Values of pressure and temperature outdoor were obtained from a meteorological station in Białystok. We performed 103 measurements of indoor radon concentrations.

Results and discussion

The distribution of radon concentrations in the building, in consecutive months during one-year observation, is lognormal (Fig. 1). The following parameters of radon concentration distribution were calculated: arithmetic mean – 224.1 Bq m^{-3}, geometric mean – 194.5 Bq m^{-3}, median – 207 Bq m^{-3}, and geometric standard deviation – 1.84. The minimum observed value was 22 Bq m^{-3} and the maximum – 748 Bq m^{-3}.

Arithmetic and geometric mean values of radon concentrations were determined in particular months. We also calculated which portion of the annual mean they made. The values are presented in Table 1. Arithmetic means determined for the particular months are from 0.45 (July) to 1.58 (January) of the arithmetic mean determined for the whole year.

Among arithmetic means of radon concentrations,

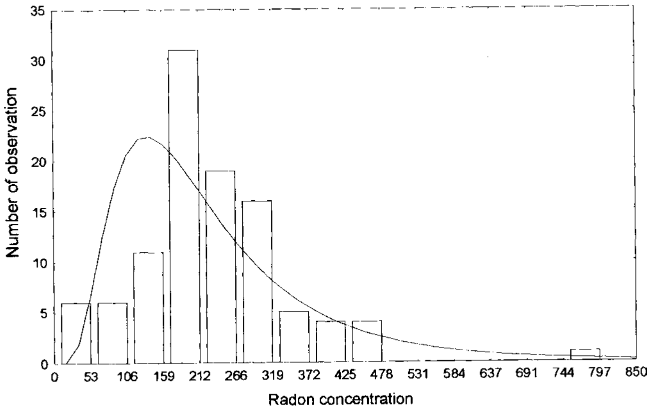

Fig. 1. Lognormal distribution of radon concentration in the examined house obtained during one-year observation.

determined for particular months, values of February, March, and April as well as October and December were closest to the annual mean. January and November showed the highest values of mean radon concentrations. The arithmetic mean values, determined for these months, are approximately 1.5 of the annual mean.

The subsoil is the main source of radon in dwelling rooms [3, 5, 12, 13, 15]. Radon, occurring in soil gas, is transported to the building through all, even microscopic, leaks of construction due to diffusion and thermal convection, frequently strengthened by the chimney effect [11]. The participation of particular mechanisms responsible for radon inflow depends on weather parameters and their dynamics. The amount of inflowing radon depends on atmospheric pressure fluctuations [7]. The chimney effect is a factor, which may increase significantly radon concentration in the air inside the building. Difference in pressures occurs between the building and subsoil, which leads to soil air induction. It is dependent on the difference in temperatures between the inside and the surrounding.

The changes of radon mean concentration in the building were analyzed depending on the temperature

Table 1. Arithmetic and geometric means of radon concentration determined for consecutive months and the fraction they make in relation to the annual mean.

Month	Arithmetic mean (Bq m^{-3})	Geometric mean (Bq m^{-3})	Ratio of monthly arithmetic mean to the annual mean	Ratio of monthly geometric mean to the annual mean
January (8)	354	327	1.58	1.68
February (8)	235	233	1.05	1.20
March (8)	242	236	1.08	1.21
April (9)	224	209	1.00	1.07
May (9)	186	163	0.83	0.84
June (8)	165	164	0.73	0.84
July (9)	100	80	0.45	0.41
August (8)	151	115	0.67	0.59
September (9)	194	168	0.87	0.86
October (9)	251	242	1.12	1.24
November (10)	331	319	1.48	1.64
December (8)	250	245	1.11	1.26

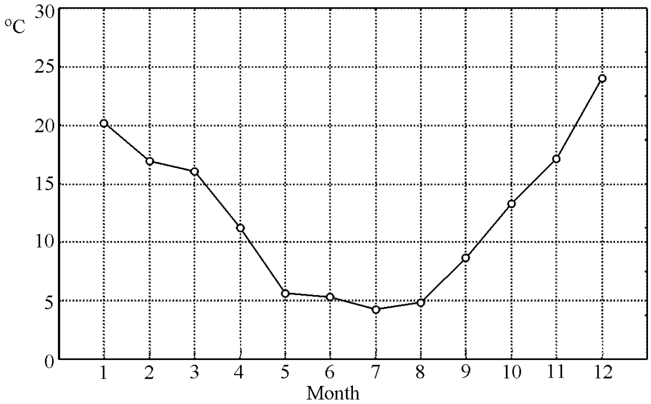

Fig. 2. The differences between mean monthly temperatures inside and outside the building *vs.* number of month.

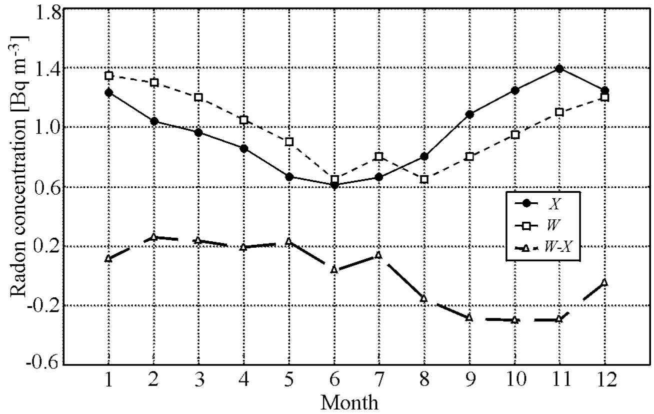

Fig. 4. Seasonal corrective coefficients *vs.* number of month: *W* – determined by Wrixon; *X* – determined for the examined building; *W–X* – the difference between *w* and *x* values.

arithmetic means recorded indoor and outdoor. As the radon concentration distribution is lognormal in the examined building, a non-parametrical correlation was used. A statistically significant coefficient of the Sperman's correlation of $R = -0.91$, $p < 0.05$ between the radon concentration and the outside temperature was obtained. The Sperman's correlation coefficient, statistically significant, of $R = 0.91$, $p < 0.05$ between radon monthly concentrations inside and the differences in the monthly mean values of temperatures measured inside and outside were also obtained. Figure 2 presents the differences between the mean temperatures inside and outside the building in particular months.

Changes in meteorological parameters lead to changes in soil air radon concentration [10]. One of the important factors influencing radon concentration in soil and thus in the building is the variable atmospheric pressure [3]. There was a statistically significant correlation between the difference in the maximum and minimum pressure, measured during one month and the mean monthly radon concentration; the Sperman's correlation coefficient was $R = 0.77$, $p < 0.003$. Figure 3 presents the dependence of radon concentration in buildings on atmospheric pressure differences in a given month (maximum *vs*. minimum).

Seasonal corrective coefficients are used to assess annual mean concentrations on the basis of values obtained during shorter exposures. Wrixon [18] published corrective coefficients whose values were determined as the ratio of radon concentrations for quarterly exposure and the values for the all-year observation. The values were determined on the basis of a large number of observed houses. Similar ratios of values obtained in the period of 3 months and annual values for the examined building were determined. Figure 4 presents a comparison of coefficients determined by Wrixon and the values determined for the examined building in this paper.

In the Polish climate conditions, coefficient values for the examined building are lower in the first half of the year and higher from August to December than values determined for Great Britain by Wrixon.

In some countries, radon concentrations measured in a 2-month exposure in the house-heating period were considered to be representative for annually averaged radon concentration.

Arithmetic means of radon concentrations for two subsequent months in the house-heating period were determined and the obtained values ranged from 233 Bq m^{-3} (March–April) to 295 Bq m^{-3} (January–February). All the values were higher than the annual mean. Hubbard *et al.* [4] presented similar results, and their studies revealed that the mean determined during a 2-month exposure in the house-heating period is overestimated.

The arithmetic mean values of 2 consecutive months were presented in Fig. 5.

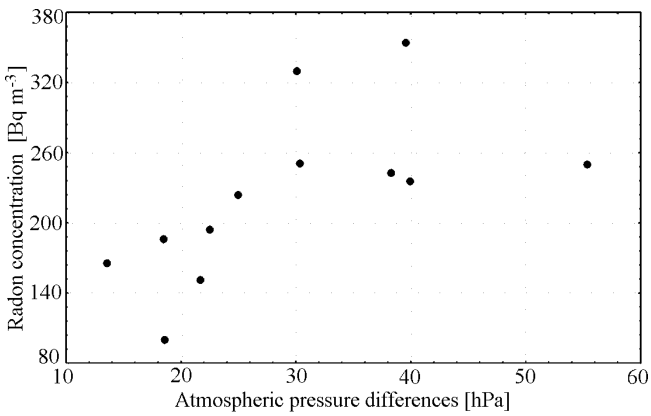

Fig. 3. Radon concentration *vs.* atmospheric pressure differences.

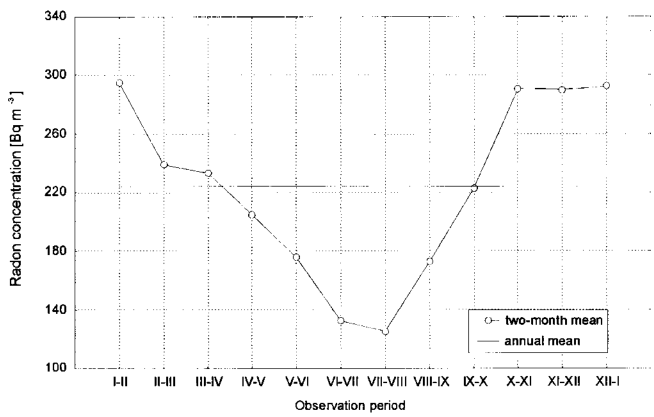

Fig. 5. The arithmetic mean values of 2 consecutive months *vs.* number of month.

Conclusion

The monthly values of radon concentrations, from 0.5 to 1.6 of the annual mean concentration, were observed in the examined building. The averaged values of radon concentrations for 2 months made from 0.6 to 1.3 of the annual mean. A statistically significant negative correlation was obtained between radon concentration and outdoor temperature. We also observed a correlation between the radon concentration in the examined building and the difference between the maximum and minimum atmospheric pressure noted in the month.

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