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The Dependence of Volumetric Radon Activity in Indoor Air on Environmental Conditions

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Abstract: *The radon isotope, ^{222}Rn, has a significant impact on human beings due to the irradiation caused illnesses. The article deals with the process of radon entering into residential buildings and its residential exposure level related to changes in environmental parameters such as temperature, pressure and moisture content. Dependence of the indoor radon activity on environmental factors has been studied at three sites: two multi-storey and one low-rise buildings in autumn (September – November 2014) period. During the study period radon activity values in low-rise house constructed in 2009, in Lithuania at Ukmergė district, Jogvilų village, ranged from 73 ± 13 to 747 ± 134 Bq m^{-3} and the average value was 382 ± 76 Bq m^{-3}. This value is higher than the allowed average activity value of 300 Bq m^{-3} and could present a radiological risk for inhabitants if the above mentioned parameters are not taken into account.*

Keywords: *^{222}Rn activity, environmental parameter, ionizing radiation*

1. Introduction

Radon is inert, colorless, odorless gas 7.5 times heavier than air. It is hazardous due to the ionizing radiation generated by its disintegration in time, being a radioactive gaseous element which has a significant impact on human's health. Radioactive decay in indoor air, containing radon gas, results in air-borne radon decay products (^{218}Po, ^{214}Pb, ^{214}Bi, ^{214}Po - short-lived radon decay products). A person gets maximum radiation via emission of radon isotope which has atomic weight of 222, i.e. ^{222}Rn [1]. Inhaled radon or its short-lived decay products deposit and split up inside the respiratory tract of a human, spreading ionizing radiation. As a result, the person experiences internal irradiance. During the decomposition of radon, radioactive alpha particles which are characterized by high ionizing capability are emitted [2, 3] leading to lung cancer. Radon activity is usually higher in indoor air in comparison with outdoor air, due to the presence of natural radioisotopes in building materials and soil beneath the foundation at the site of construction [4]. The concentration builds-up indoor due to the low air ventilation. Indoor radon levels can vary from one to multiple orders of magnitude over time and space, as it depends on several natural and anthropogenic factors, such us the radon concentration in soil under the construction and the weather conditions.

Radon sources are different including construction materials, soil, water and natural gases. The main source of radon in Lithuania is the soil, 62% [5]. There are different radon levels in the soil depending on the soil type. For example, the content of these gases in clay can be between 10 and 120 kBq m^{-3} and in gravel between 4 and 20 kBq m^{-3} [1, 6, 7]. Volumetric radon (^{222}Rn) activity in soil air

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varies depending on the atmospheric pressure, moisture content of soil, permafrost, natural (ice, snow) and artificial (concrete, asphalt) coatings [8]. Volumetric radon activity in soil air also depends on the seasonality. Volumetric radon activity in soil air during the summer season is lower and higher in winter season. This is due to the difference in ambient and soil temperatures [9]. Changes in radon content in the soil depend on physical soil properties for example, on permeability. This change is the highest in the soils composed of large and the small particles. Thickness of soil layer, where the influence of the wind can be observed, depends on the soil permeability, while the wind influence in depths greater than 1 m is scarce, except in cases where the soil is highly permeable [2].

Gas permeability from the soil and rock is one of several important factors that determine the potential sources of radon at any place and therefore it is one of the most important parameters of radon risk classifying the building sites [10]. ^{222}Rn movement in the soil is described by the main differential carry Equation. (1) derived from the mass conservation law:

$$C(z) = C_{\infty} \cdot \left(1 - exp^{-\left[\left(\sqrt{\frac{v}{2 \cdot D_{\varepsilon}}} \right)^{2} + \frac{\lambda}{D_{\varepsilon}} + \frac{v}{D_{\varepsilon}} \right] \cdot z} \right) \tag{1}$$

where: C(z) - measured volumetric (^{222}Rn) radon activity at depth *z*, Bq m^{-3}; C_{∞} - volumetric radon (^{222}Rn) activity at the deepest bore site, Bq m^{-3}; λ - radon decay constant, $2.0974 \cdot 10^{-6}$ s^{-1}; ε - soil porosity by depth, %; ν - convective radon carry velocity, m/s; D_e – diffusion coefficient

This equation is used for the determination of radon molecular diffusion, evaluating convective transport of radon, emission and recession due to radioactive decay. The main objective of this equation is to determine the rate of radon convection, which cannot be measured under natural conditions. This theoretical model can be applied to low-moisture soil [11].

The process of radon gas access from the soil air into the building is quite complicated. It gets easy into the room through cracks of the building and accumulates in the building. Radon enters the building from the soil together with the soil air [12]. Due to the difference in the pressure inside the building and the atmospheric pressure, a particular thrust is formed, where the building pressure is lower than atmospheric, convection processes occur [3]. Where the soil under the building is permeable to the air, a large amount of soil air, as well as radon, can get into the building due to the difference in resulting temperatures (indoor and outdoor) [13]. This difference in temperatures causes natural thrust, also called in literature “chimney effect” [2, 14]. Especially high values of volumetric radon activity may accumulate in the building if it is tight and there is no sufficient ventilation [15]. Volumetric radon activity also depends on the atmospheric pressure, temperature, wind speed, humidity, season, ventilation intensity of premises, radon exhalation from the soil, change in atmospheric stability, etc. [3, 9].

The highest volumetric radon activity is in the basement or on the first floor of premises: the higher it is the lower is volumetric radon activity. On average, volumetric radon activity in individual houses in Lithuania reaches 70-75 Bq m^{-3}, and in multi-storey buildings it does not usually exceed 30-40 Bq m^{-3} [16]. Average volumetric radon activity value in residential places in European countries is up to 100 Bq m^{-3} [17]. According to Clavensjo et al. [2], the global average volumetric radon activity value in premises is 39 Bq m^{-3}, and in Lithuania is 54 Bq m^{-3}. According to the Lithuanian Hygiene Norms [18] the new residential buildings must be designed and constructed such a way, that the average radon concentration in residential premises would not exceed 200 Bq m^{-3}. In residential buildings, which were issued before the date of entry into force of the hygiene norms (i.e. until 2011), the average volumetric radon activity must not exceed 300 Bq m^{-3} [19].

Indoor radon in the buildings is also observed in some European countries [20]. The indoor radon distribution in Transylvania, Romania, together with the measurements of radon in soil and water, were recently studied in Transylvania, Romania [21]. A complete map was plotted, based on 3,300 indoor radon measurements, covering an area of about 42 % of the Romanian territory [22]. The indoor radon concentrations ranged from 5 to 3,287 Bq.m^{-3}, with an updated preliminary arithmetic mean of 179 Bq.m^{-3} and a geometric mean of 122 Bq.m^{-3}. In about 11 % of the investigated grid cells the indoor radon concentrations exceeded the threshold limit of 300 Bq.m^{-3}. In soil the radon concentration varied from 0.8 to 169 kBq.m^{-3}, with a geometric mean of 26 kBq.m^{-3}. For water samples, the results showed radon concentrations within the range of 0.3 – 352.2 kBq m^{-3}, with a geometric mean of 7.7 Bq.m^{-3}. A weak correlation between the three sets of values (residential, soil, water) was observed. The highest concentrations of indoor radon were found in Bihor, Mures, Brasov, and Cluj counties [22]. In these regions further investigations are needed on the factors influencing the radon accumulation in indoor air. Factors like soil type and geology, ventilation, building materials and architectural features should be taken into consideration during the investigations [23, 24].

The aim of the work was to determine experimentally the amount of radon gas entering into the premises of low-rise and multi-storey buildings and to analyze the impacts of environmental parameters including temperature, pressure, and humidity on changes in volumetric radon activity in the premises.

2. Materials and methods

2.1. Area of monitoring sites

The radon level map of Lithuania with indication of monitoring sites is shown in Figure 1.

Figure 1 Radon level map of Lithuania where the monitoring sites are pointed out (•) [25]

Indoor radon monitoring sites were selected in the regions where the average volumetric radon activity is higher than the average level in Lithuania, as follows:

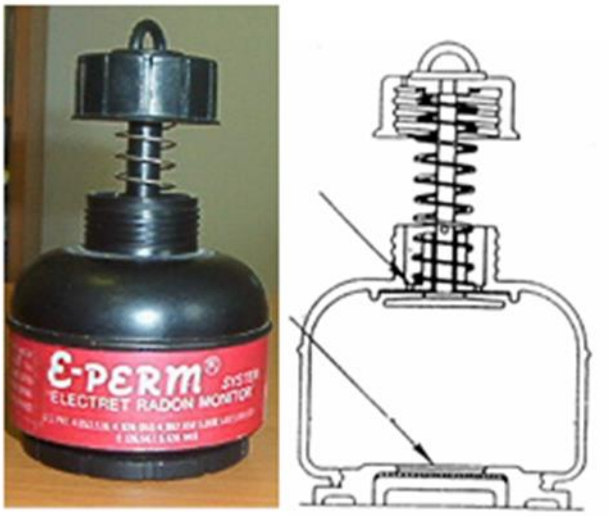
- A semi-detached individual house (two-floor building) in Lyduokiai ward of Ukmergė district with a construction permit issued in 2009. With regard to the year of construction permit issuance, according to Hygiene norm HN 85:2011 [18], an average radon concentration in this house should not be higher than 300 Bq m^{-3}. This site was selected because Ukmergė district is characterized by higher value (60-80 Bq m^{-3}) of volumetric radon activity than the average value (54 Bq m^{-3}) in Lithuania. The typical of soil prevalent in this area is gravel and coarse sand, i.e. breathable soils.
- A multi-storey building (eleven-floor building) in the city of Vilnius with a construction permit issued in 2007, the average volumetric radon activity value should not exceed 300 Bq m^{-3}. An average volumetric radon activity in the city of Vilnius is 70 Bq m^{-3}, i.e. the value is higher than the average value of Lithuania (54 Bq m^{-3}). Variation range of the volumetric radon gas activity in the buildings of

Vilnius region is the same as in Ukmergė district, i.e. it is between 60 and 80 Bq m^{-3}. In this area, sandy loam at 0.2 m, light loam at 0.4 m and medium loam from 0.6 to 10 m of depths are prevalent.

- A multi-storey building at Utena University of Applied Sciences, Utena was investigated as well. Considering the construction year of the building, the average volumetric radon activity value in this building should not exceed 300 Bq m^{-3}. The value of volumetric radon activity in Utena district varies from 40 to 60 Bq m^{-3}, i.e. is higher than the average value of Lithuania (54 Bq m^{-3}). In this area, the predominant type of soil is sandy loam.

2.2. Equipment for volumetric radon activity monitoring

In order to determine the average value of volumetric radon activity E-PERM (Electret Passive Environmental Radon Monitor) electrets having measuring range from 30 to 600 Bq m^{-3} were used (Figure 2).



2a 2b

Figure 2 The electret with Teflon disc (a) and its scheme (b) was used for the test with opened camera input. The upper arrow indicates the filter, and the lower one shows the Teflon disc [26]

The electrets were left at study sites for 21 days. The test was carried out during the heating season, when radon enters easier to the premises due to higher difference in indoor and outdoor temperatures. Volumetric radon activity (A, Bq m^{-3}) is calculated by the following Eq. (2) [27]:

$$A = \frac{\mathrm{I - F}}{\mathrm{kT}} - B \tag{2}$$

where: *I* - initial potential of radon meter; *F* - rear potential of radon meter; *k* - calibration factor, B – correction factor introduced considering the γ radiation influence on variation of electret potential; *T* - measurement time in days.

The systematic error (EO) of the determination method of the average volumetric radon activity value can be determined in the following Equation (3) [27]:

$$EO = \sqrt{\left(\frac{I - F}{kT}\right)^2 \cdot \left(0.0025 + \frac{2}{(I - F)^2}\right) + \left(0.10 \cdot K_f\right)^2} \tag{3}$$

where: K_f - background γ ray absorbed dose rate.

AlphaGUARD PQ2000 (Figure3a) and RTM 2200 (Figure 3b) were used for the determination of the volumetric radon activity variation in the premises.

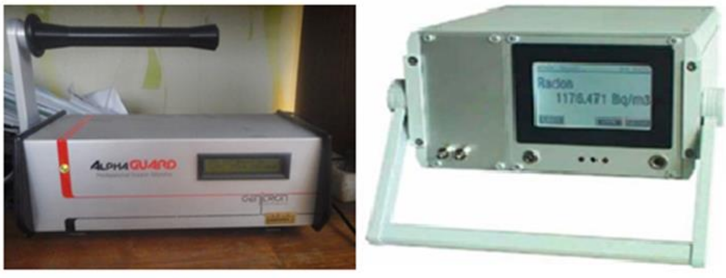

3a 3b

Figure 3 (a) Alpha GUARD PQ2000 and (b) RTM 2200 equipment
for measuring the variation of volumetric radon activity

The volumetric radon activity measuring instruments are placed in places that are the most representative in respect of volumetric radon activity and climatic conditions in premises. The detector may not be placed on the floor. The distances from the wall should not be less than 0.25 m, and from heating devices and ventilation ducts 1.5 m [28].

Radon distribution in soil can be described by the equation used to determine the molecular radon diffusion, considering the convective transport of the gas, emission and recession as a result of radioactive decay. This is a theoretical model applied to low-moisture soils according to Equation (4) [10, 29]:

$$C(z) = C_\infty \cdot \left\{1 - exp\left[-\left(\sqrt{\frac{v}{2\cdot\varepsilon\cdot D_e}}\right)^2 + \frac{\lambda_{Rn}}{D_e} + \frac{v}{2\cdot\varepsilon\cdot D_e}\right]\cdot z\right\} \tag{4}$$

where meaning of symbols and letters are similar to Equation (1).

Volumetric radon activity in the soils near study buildings was determined using the devices Markus 10 (Figure 4) and RTM 2200 (Figure 3b).

Figure 4 Markus 10 type instrument
for measuring radon level

When determining volumetric radon activity in the soil air with the device Markus 10, the probe at a depth from 0.7 to 1.0 m is hammered into the soil by which the soil air is pulled into the measuring chamber [30]. Depending on the soil, soil air suck time may be from 30 s to 3 min. Radon decay products in the measuring chamber of the device deposit on the detector being exposed to an electric field (area – 100 cm^2, resolution <16 keV). The detector registers the decay particles □□emitted during the decay process [28]. During the test of volumetric radon activity in the soil air with device RTM 2200, a vertical bore is drilled in the soil at a depth of 0.2 m using a drill into which a measuring probe is inserted. Soil air gets to the sampling bag along the probe, which is then sealed to prevent the passage of outside air. During the sampling of soil air, the radon monitor RTM 2200 is connected to the probe by a special tube. Air from the soil is pumped for a 30 min, and then volumetric radon activity in the soil air is measured. During the measurement with the device TESTO - 400, atmospheric pressure, humidity, air temperature and wind speed are determined, and air temperature in the bore is measured using a thermocouple [1, 29].

The relationship between the environmental factors (temperature, pressure, humidity) and the indoor volumetric radon activity is determined by estimating the linear correlation coefficient, *r*, by Equation (5) [31]:

$$r = \frac{\sum_{i=1}^{n} \mathbf{x}_i \cdot y_i - \frac{\mathbf{1}}{n}\sum_{i=\mathbf{1}}^{n} \mathbf{x}_i \sum_{i=\mathbf{1}}^{n} y_i}{\sqrt{\left(\sum_{i=\mathbf{1}}^{n} \mathbf{x}_i{}^{2} - \frac{\mathbf{1}}{n}\left(\sum_{i=\mathbf{1}}^{n} \mathbf{x}_i\right)^{\mathbf{2}}\right) \cdot \left(\sum_{i=\mathbf{1}}^{n} y_i{}^{2} - \frac{\mathbf{1}}{n}\left(\sum_{i=\mathbf{1}}^{n} \mathbf{y}_i\right)^{\mathbf{2}}\right)}} \tag{5}$$

where: x_i and y_i are the measurement data: x_i is indoor volumetric radon (^{222}Rn) activity, y_i is value of environmental parameter (temperature, pressure, humidity).

3. Results and discussions

During the test of volumetric radon activity in the soil air, in the 1 m deep soil layer in the areas of study sites (individual semi-detached individual building in Lyduokiai ward of Ukmergės district and a multi-level building in the city of Vilnius), it was found that volumetric radon activity in the soil near the building is as follows:

- at semi-detached individual house in Lyduokiai ward of Ukmergė district: near the building the value was 8.9 ± 0.9 kBq m^{-3} and in the soil under the building the value was 49.0 ± 4.3) kBq m^{-3};
- at multi-storey building in the city of Vilnius the value was 26.6 ± 5.2 kBq m^{-3}.

Comparing the results of volumetric radon activity in the soil air, it was found that volumetric radon activity determined in Ukmerge district is 1.8 times higher than in Vilnius. In the work of Morkūnas et al. [32] it is stated that the radon content determined in the soil air in Lithuania changed from 1 kBq m^{-3} to 130 kBq.m^{-3}. Analyzing the value of the volumetric radon activity in different soil types it can be concluded that radon mainly occurs in moraine loam with granite (40-200 kBq m^{-3}) and higher in soil with shale (50-1000 kBq m^{-3}). The volumetric radon activity in gravel and bulky sand in the air varies from 10 kBq m^{-3} to 150 kBq m^{-3} [32]. Estimating the results of volumetric radon activity in soil air, it is to be noted that these results in studied areas are in the same order of magnitude as in the work of Morkūnaset al. [32]. However, considering the risk related to the accumulation of radon gas in buildings, the predominant soil type and its properties are to be taken into account during the planning of the construction. Table 1 provides information on the risk of radon occurrence in premises, considering the soil permeability and volumetric radon activity in soil air [32].

Table 1 Classification of radon risk [32]

Risk level	Volumetric radon activity in soil air, kBq m^{-3}		
	Low soil conductivity	Medium soil conductivity	High soil conductivity
Low	< 30	< 20	< 10
Medium	30 – 100	20 – 70	10 – 30
High	> 100	> 70	> 30

According to study results and considering the predominant type of soil, it can be seen that radon risk in Ukmerge district is classified as high, and in Vilnius it is at the medium risk level. The study of volumetric radon activity in the individual house in Ukmerge district with E-PERM electrets showed a medium value of volumetric radon activity was 540 ± 60 Bq m^{-3}, i.e. 1.8 times higher than stipulated by Lithuanian Hygiene Norms [18] (HN 2011). During the autumn period, the volumetric radon activity values studied in multi-storey buildings were as follows:

- Multi-storey building in Vilnius varied from 11 ± 3 to 45 ± 7 Bq m^{-3};
- Multi-storey building in Utena town varied from 43 ± 3 to 99 ± 3 Bq.m^{-3}.

During the analysis of fluctuation in volumetric radon activity at different floors of the building, it was established that in all three tested sites the highest volumetric activity is in the basement and on the first floor (Table 2).

Table 2 Fluctuation of volumetric radon activity at different floors of the building in autumn period

Study object	Building floor	Medium volumetric ^{222}Rn activity, Bq m^{-3}
Multi-storey building in the city of Vilnius	Basement	43 ± 6
	1st	45 ± 7
	11th	15 ± 4
Multi-storey building in Utena town	Basement	94 ± 6
	1st	48 ± 3
	9th	43 ± 3
Two-storey house in Ukmergė district	Basement	780 ± 80
	1st	540 ± 57
	2nd	120 ± 22

According to the collected data:

- The volumetric activity value of this radioactive gas decreases on higher floors of the buildings in comparison with the basement level figures: in Ukmerge district its average content on the 1st floor of the building of Utena University of Applied Sciences is 48 ± 3 Bq m^{-3}, while on the 9th floor of the building it is 43 ± 3 Bq m^{-3};
- On the 1st floor of a multi-storey building in Vilnius it is 45 ± 7 Bq m^{-3}, and on the 11th floor of the building it is 15 ± 4 Bq m^{-3};
- On the first floor of low-rise building in Ukmergė district it is 540 ± 60 Bq m^{-3}, and on the 2nd floor of the building it is 120 ± 20 Bq m^{-3}.

Alpha GUARD PQ2000 device was used for the more detailed analysis of fluctuations in volumetric radon activity, which in addition to volumetric radon activity, the instrument also registered the internal temperature, pressure and humidity. A study site exhibiting the maximum average volumetric activity value was selected for the analysis of fluctuations in the volumetric activity at two-storey building in Ukmergė district. The study on changes in volumetric radon activity at the study site located in Ukmergė district took place from 24 September 2014 to 31 October 2014. Studies were carried out on the first floor of the building, in the room above the basement. Figure 5 shows an average daily changes in volumetric radon activity.

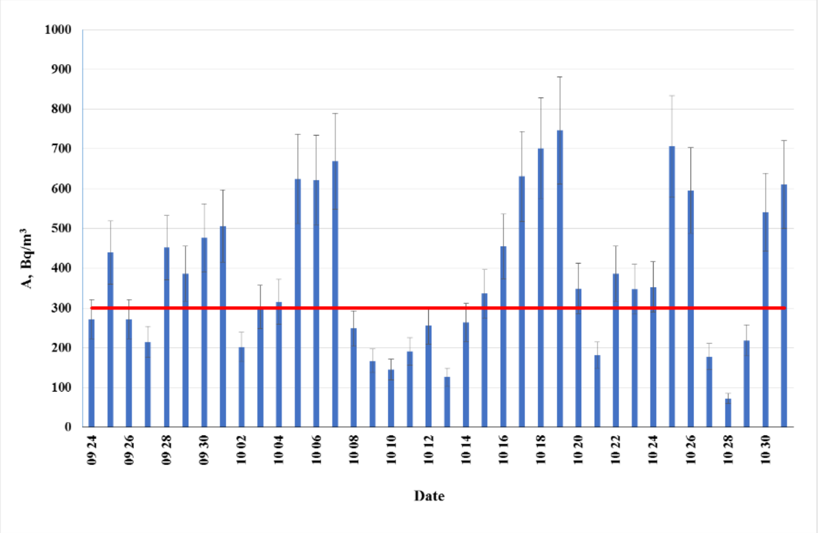
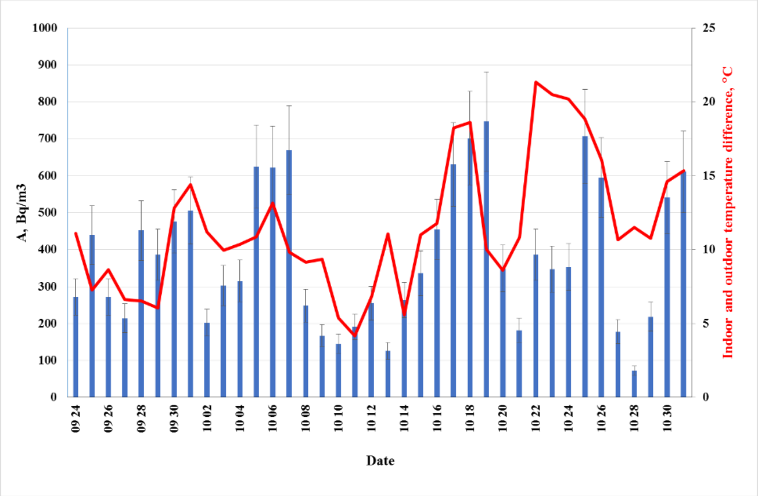


Figure 5 Change in volumetric radon (^{222}Rn) activity, A, Bq m^{-3} at two-storey building located in Ukmergė district for period of 24 September 2014 to 31 October 2014. The red horizontal line represents the limit value

During the study period, the highest limit of the average daily volumetric radon activity in low-rise building on the ground floor was 746.6 ± 130 Bq m^{-3}, i.e. it exceeded by 2.5 times the allowable norm of Lithuanian Hygiene Norms [18] in individual residential houses (300 Bq m^{-3}). The lowest average volumetric radon activity value was 72.7 ± 13 Bq m^{-3} and the average volumetric activity of study site was 380 ± 70 Bq m^{-3}.

Volumetric radon activity depends on several factors. Meteorological parameters such as temperature, pressure, humidity are to be mentioned. In this paper the relationship between the atmospheric parameters and volumetric activity of radon gas as well as the relationship between the indoor gas volumetric activity and the difference of ambient (outdoor and indoor) parameters was analyzed. Figures.6a, 6b and 6c show the differences of change in indoor volumetric radon activity and outdoor and indoor ambient parameters (temperature, pressure, humidity).



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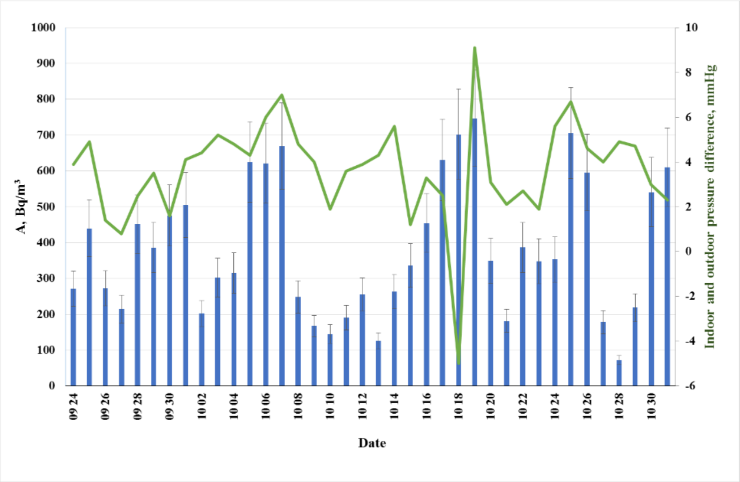

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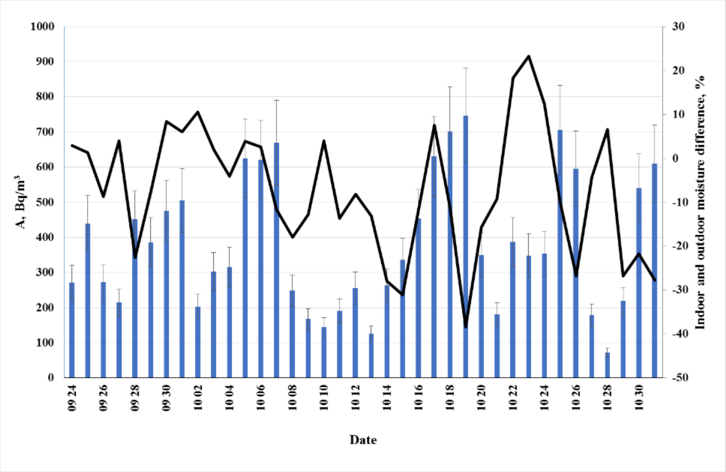

6c

Figure 6 Change in volumetric radon ^{222}Rn activity and ambient parameters at two-storey building located in Ukmergė district during autumn period:
a) is change in volumetric radon activity and the difference between the indoor and outdoor temperature; b) is change in volumetric radon activity and the difference between the indoor
b) and outdoor pressure; c) is change in volumetric radon activity and the difference
c) between indoor and outdoor humidity

Volumetric radon activity depends on the difference of indoor and outdoor temperatures. The analysis of the data (Figure 6c) shows that in case of maximum temperature differences ($\Delta T = T_{indoor} - T_{outdoor} \geq 7.5$ °C) at the study site (Ukmergė district), the volumetric radon activity was higher than the average (380 ± 70 Bq m^{-3}) value determined during the investigation period or close to it.

With higher difference in air pressures, the air convection process is faster, so it is likely that ^{222}Rn access to the premises will be more intensive. The analysis of data in Figure 6b leads to the conclusion that those periods can be identified, when the difference between the indoor and outdoor pressure values has a tendency to increase, for example: from 28/09 to 30/09 and from 22/10 to 25/10. If the change in volumetric radon activity is considered during these periods, it could be noticed that the latter one is close to the maximum set volumetric activity, e.g.: from 390 ± 70 to 480 ± 90 Bq m^{-3}; and from 340 ± 60 to 750 ± 130 Bq m^{-3}, respectively. During the periods when the difference between pressures decreases, the values of volumetric radon activity are lower or close to the average determined during the study period.

The previous work [1] states that the volumetric radon activity depends on changes in the ambient temperature and humidity. With increasing difference between the indoor and outdoor air temperatures, the volumetric radon activity increases, and the volumetric radon activity decreases with increasing indoor moisture level. Similar tendency in volumetric radon activity and humidity was also observed in this study (Figure 6c) except for a period from October 5 to 7. During this period, volumetric radon activity is higher than the average determined value but the difference in humidity change can be characterized by a downtrend.

During the period from October 15 to 19, the volumetric radon activity is also higher than the average determined value during the study period. This period is interesting because the differences of humidity, indoor and outdoor temperature parameters were at the maximum, while the pressure difference showed a tendency to decrease; moreover, the outdoor pressure on October 19 was higher than indoors. The analysis of this situation leads to the conclusion that the change in volumetric radon activity indoors is influenced by all environmental parameters and their influence should be analyzed holistically. In order to evaluate the influence of each of ambient parameters under consideration on volumetric radon activity indoors, linear correlation analysis was carried out. Table 3 shows correlation coefficients between indoor and outdoor environmental factor (temperature, pressure, humidity) differences and volumetric radon activity.

Table 3 Analysis of relationship between volumetric radon activity, A, Bq m^{-3} and environmental factors (temperature, pressure, humidity)

Values analyzed	Correlation coefficient, r
A+ difference between indoor and outdoor temperatures	0.455
A+ difference between indoor and outdoor pressures	0.074
A+ difference between indoor and outdoor humidity	-0.179
A+ indoor temperature	0.058
A+ indoor pressure	0.238
A+ indoor humidity	-0.178
A+ outdoor temperature	-0.426
A+ outdoor pressure	0.229
A+ outdoor humidity	0.096

According to the correlation analysis data presented in Table 3, it can be concluded that the difference between the indoor and outdoor temperatures (r = 0.455) has the greatest influence on volumetric radon activity indoors typical of the average linear correlation. The work by Streckytė and Butkus [1] also states that the volumetric radon activity in indoor air depends on the difference in ambient and indoor air temperatures: volumetric radon activity in the air increases with increasing difference in temperatures. However, the difference in pressures and volumetric activity (r = 0.074) is characterized by a very weak correlation.

The relationship between volumetric radon activity in the room and difference of indoor and outdoor humidity is slightly negative. Assessing the impact of radon gas on volumetric activity in the room separately for each parameter it is to be noted that the most important environmental factors are: temperature (r = 0.43) and pressure (outdoor r = 0.23, indoor r = 0.24).

A similar conclusion, based on the correlation analysis, was obtained by the Romanian scientists [33] pointing out the primordial importance of the temperature (among others weather conditions) toward natural radioactivity, even if their investigation was related to the outdoor radioactivity (atmospheric natural radioactivity), where other parameters as wind speed and precipitations were taking into consideration, as well.

4. Conclusions

It was concluded that volumetric radon (^{222}Rn) activity in the soil air under two-storey building in Ukmergė district 49.0 ± 4.3 kBq m^{-3} is 1.8 times higher than under eleven-storey building in the city of Vilnius (26.6 ± 5.1 kBq m^{-3}). Considering the predominant soil type and determined volumetric activity of radon gas in the soil air, it can be assumed that the possibility of radon access from the soil into the building in Ukmergė district is likely to increase and in Vilnius it shows the average value.

The volumetric radon activity in multi-storey buildings studied in autumn period changed as follows: in multi-storey building in Vilnius changed from 11 ± 3 to 45 ± 7 Bq m^{-3}; in multi-storey building in Utena town changed from 43 to 99 ± 3 Bq m^{-3}. It was found that the highest volumetric activity in all three studied objects can be experienced in the basement and on the first floor.

When the temperature differences (inside – outside temperatures) in the studied two-storey building at Ukmergė district were at the maximum, the volumetric radon activity was higher than the average (381.8 ± 68.7 Bq m^{-3}) determined value during the study period, or close to it. The periods when the difference between the indoor and outdoor pressure has a tendency to increase were distinguished in a study site in Ukmergė district, for example from 28/9 to 30/9, and from 22/10 to 25/10, when the volumetric radon activity values were close to the maximum volumetric activities determined: from 386 ± 69 to 476 ± 86 Bq m^{-3} and 336 ± 61 to 746 ± 134 Bq m^{-3} respectively. During the periods when the difference in pressures decreases, while it is higher than average, the volumetric radon activity values are lower than or close to the average determined value during the study period. Volumetric radon activity increases with increasing difference between indoor and outdoor air temperatures, and the radon concentration decreases when the moisture level in the room is increasing. Change in volumetric radon activity in the room is influenced by all ambient parameters and their influence should be analyzed holistically.

According to the data of correlation analysis, the difference between the indoor and outdoor temperatures has the greatest influence on volumetric radon activity in the room, having linear correlation in average (r = 0.455), and the lowest influence on the differential pressure which is characterized by a very weak correlation (r = 0.074).

Considering the impact assessment of volumetric radon activity in the room, in the presence of each environmental parameter (the indoor and outdoor temperatures, humidity and pressure respectively), only the temperature has significant influence.

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