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## ISSUES OF RADON (Rn-222) EXHALATION MEASUREMENTS

### PROBLEMATYKA POMIARÓW EKSHALACJI RADONU (Rn-222)

**Abstract:** The Rn-222 isotope, a naturally occurring radioactive gas, is created in a radioactive decay of Ra-226. Both radionuclides belong to the radium decay chain in which U-238 is the prime parent. Radon is usually in plenty found in the earth crust, rocks, soil, water and air, therefore it is regarded as an indicator of ionizing radiation dose received by a population. Due to radon negative influence on people's health, measurements of its concentration are commonly performed. The presented research concerns assessment of measurements uncertainty of Rn-222 concentration exhaled from soil. The measurements were repeated at the same site. The experiment was carried out in natural conditions, in the city center and lasted about half a year. In Rn-222 concentration measurements the AlphaGUARD radon monitor was used. The device was operating in the 10-minutes flow mode, with the air pump and exhalation-box arranged in the closed cycle. The studies have shown a significant differences between results of radon exhalation measurements, which were carried out sequentially in the same place. Generally, increase in measurements number in a series lowers the result uncertainty. Consequently, the number of measurements in a series can be adjusted to the desired uncertainty of result. What is more, the distribution of the results in series is well described by the Poisson distribution.

**Keywords:** radon, exhalation, concentration, measurements uncertainty, AlphaGUARD

### Introduction

Radon is an only gaseous radioactive element common in the whole world. It constitutes about 40% of an average annual radiation dose to the world population, what means it is a main source of ionizing radiation affecting the human [1-4]. Consequently, the presence of radon in the environment is not neutral for people's health. It can lead to some illnesses like lung cancer in specific conditions [5-8]. Therefore, an effective method of radon measurements interpretation is needed.

From a chemical point of view, radon is situated in the 18<sup>th</sup> column of the periodic table. Its density is 7.5 times bigger than the one of air, so this gas accumulates near the ground. It has no smell, taste or color, that is why people cannot detect radon with their senses. What is more, it is chemically inert and well soluble in water. This element has above 30 isotopes, but the most important is Rn-222, because of the longest half-life, which comes to 3.8 days. It is produced in U-238 decay series, directly from Ra-226. Both elements are common in soil, rocks and crust, therefore these are natural sources of radon [6, 9, 10].

Radon is able to migrate among the atmosphere, lithosphere and hydrosphere. There are three main steps of its migration. Emanation is a process in which radon moves from mineral granules to the intergranular space during radium disintegration in rocks and crust. Transportation consists relocation to the soil, which takes place with other gases or in

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liquids. Exhalation happens when radon is exuded from the soil to the air on the surface of the ground [6, 11-14].

Radon accumulates in closed spaces such as mines, caves, tunnels and even houses. Its migration is caused by diffusion and convection supported by the stack effect. This effect occurs when there is higher pressure outside than inside houses. Lower pressure inside is a result of heating in winter and air condition all over the year [6, 15-17].

Due to radon low concentration in the environment and its chemical inactivity, its activity concentration can be determined using some specialized equipment. This device measures number of alpha-particles emitted from some kind of samples [5, 6, 18-25].

In measurements the radon monitor AlphaGUARD (Saphymo, DE) was used. It determines radon specific activity concentration and, simultaneously, air temperature, pressure and humidity. It has optimal sensitivity coming to 5 cpm at  $100 \text{ Bq/m}^3$  and linear response from 2-2 000 000  $\text{Bq/m}^3$ . This set consists of the radon monitor and an air pump in the basic version [21, 26-28].

The aim of this research was to study distribution of repeated measurement results of radon concentration in the air exhaled from soil and to assess the measurements uncertainty.

## Materials and methods

The study of Rn-222 activity concentration  $a$  was conducted during 7 months, from December 2013 to June 2014, in one testing area located in the Opole University site, near the Kominka Street. It is an ordinary piece of ground situated in the city center. The territories around this area are built-up with residential buildings, so there is no close industry influence. It spanned wide range of temperatures and weather conditions. The place in which the measurements were carried out remain unchanged, so an influence of local factors, like soil type, on results can be omitted.

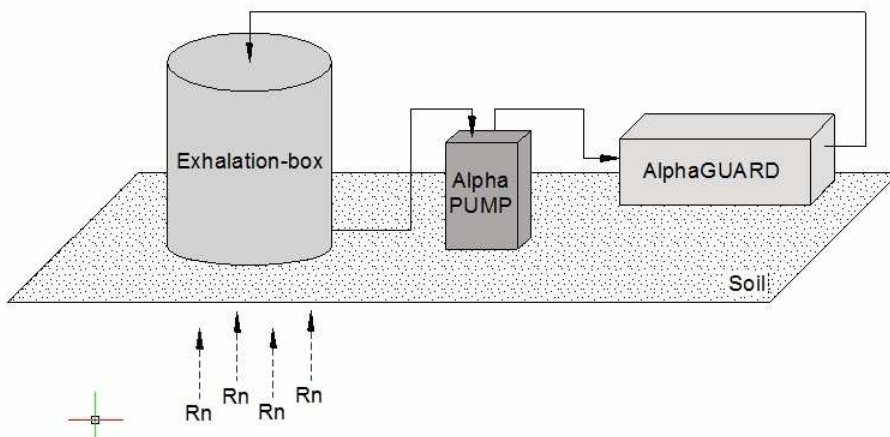


Fig. 1. Scheme of the radon exhalation measurements stand

The main device used in the research was the radon monitor AlphaGUARD. It was operating in 10-minute flow mode with the air pump AlphaPUMP, which enabled air transport from a radon-box to AlphaGUARD. Air flow rate was 1 dm<sup>3</sup> per minute. The exhalation-box was a specially prepared container partially hammered into the ground surface. It limited the volume of analyzed air. After the air sample analysis, it was transported back to the exhalation-box, so all the components remain in the closed volume. The AlphaGUARD was calibrated during its production and it has guaranteed 5 years stability, so recalibration was not needed. In Figure 1 scheme of the stand used in measurement is shown.

The measurements were carried out in different dates, but always in the same place. Each series of measurements lasted 2 hours and 10 minutes and included 13 measurements. Every measurement result was an arithmetic mean from 10-minute continuous examination.

## Results and discussion

A chart in Figure 2 shows four exemplary measurement series from different days. The analysis indicates large variation of radon concentration during each series. There is not also any common trend between radon concentration and measuring time among other series. It suggests the influence of many factors as weather conditions and soil parameters on radon exhalation process. They can lead either to the increase or to decrease in number of radon particles, exhaled in the tested area.

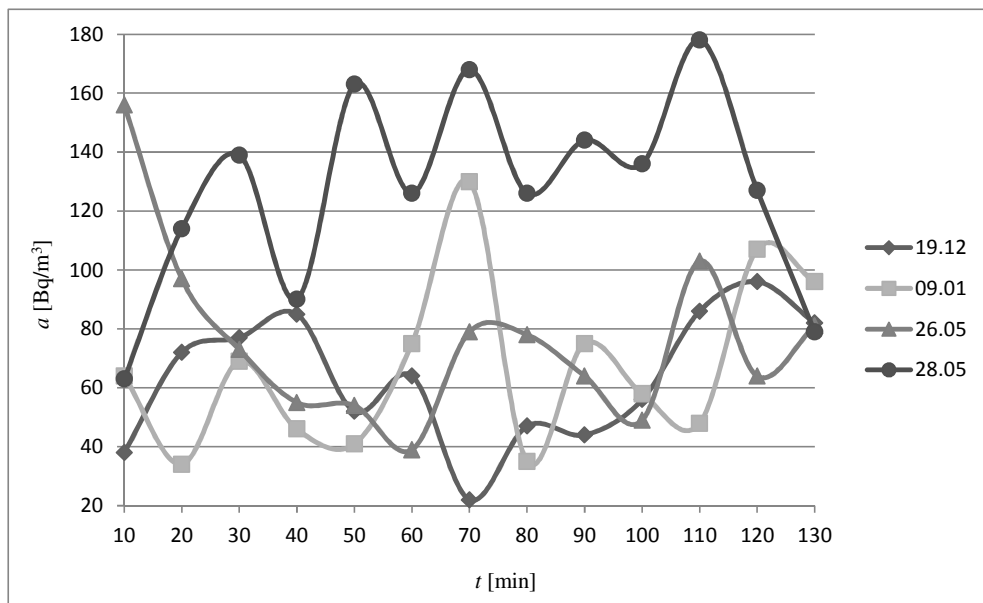


Fig. 2. Four examples of radon concentration variability over measurement series

In Figure 3 basic statistic parameters of all measurement series are presented. These are minimum and maximum values depicted as narrow vertical lines, first and third

quartiles forming an upper and lower edge of the box and also the median forming horizontal cut of the box. As it can be seen from the comparison of 20 measurement series, interquartile ranges (middle fifties) are not the same. It might be very small as in the 5<sup>th</sup> one or big as in the 8<sup>th</sup> one. Interquartile range containing large range of radon concentration values, as for example on day 10.03.2014, is probably caused by a change of the temperature and low air humidity during measurements time. Then low range of radon concentration values containing in the middle fifty might be induced by stable and optimal weather conditions. Furthermore, it is worth noting, that radon concentration values were relatively stable during winter months (until the beginning of March), when the temperature did not exceed 10°C. Both in spring and early summer it was variable.

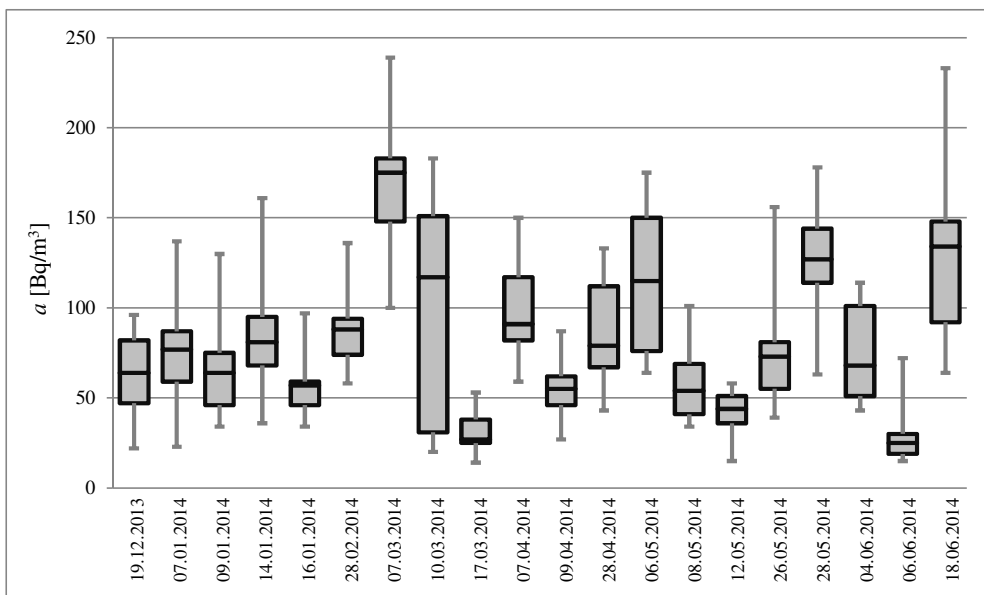


Fig. 3. Box-plot of radon concentration for all measurement series

Statistical analysis revealed a significant correlation between amount of measurements in one place and the size of measurement uncertainty. Figure 4 shows how the probability of obtaining a result similar to the average and dispersion of these results changes when there is less measurements in one place done, for example only: 3, 4, 5, 6, 7, 8, 9 or 10. The results showed that the more measurements are made, the lower measurement uncertainty is. This dependence is generally known, but the analysis confirms legitimacy of multiple measurements performing.

The charts (Figs. 4, 5) below show an analysis of one randomly selected measurements series. Rectangles present a histogram of radon concentration density distribution. It was created basing on the results obtained during experiment (centers of horizontal lines). The full lines are the centers extended on both sides about half the value of measurement uncertainty, so they demonstrate values representing real values with the biggest

probability. Narrow vertical lines shows Poisson distribution for this measurements series. It is a discrete probability distribution, which can be used to describe nucleuses decay, because it expresses the probability of series of events occurring in determined time, when the average of events occurring frequency is known and this events occur independently of the time since the last event [29, 30]. It should be noticed that radon concentration density distribution is described well by Poisson distribution.

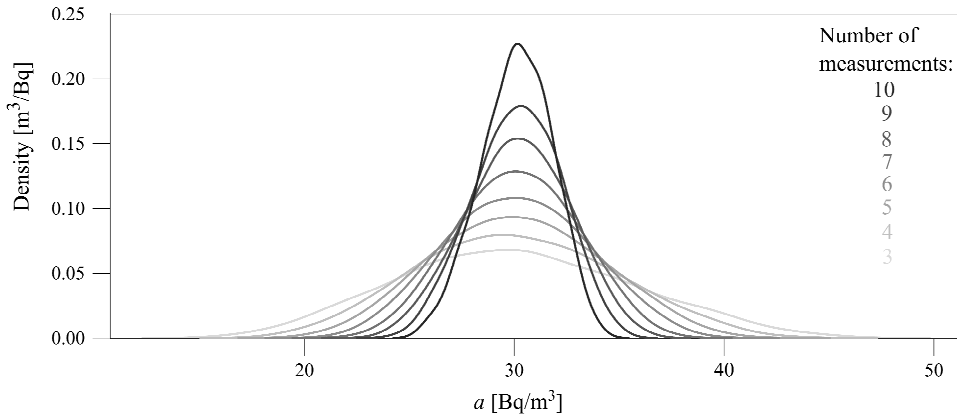


Fig. 4. Distribution of the means from several measurements

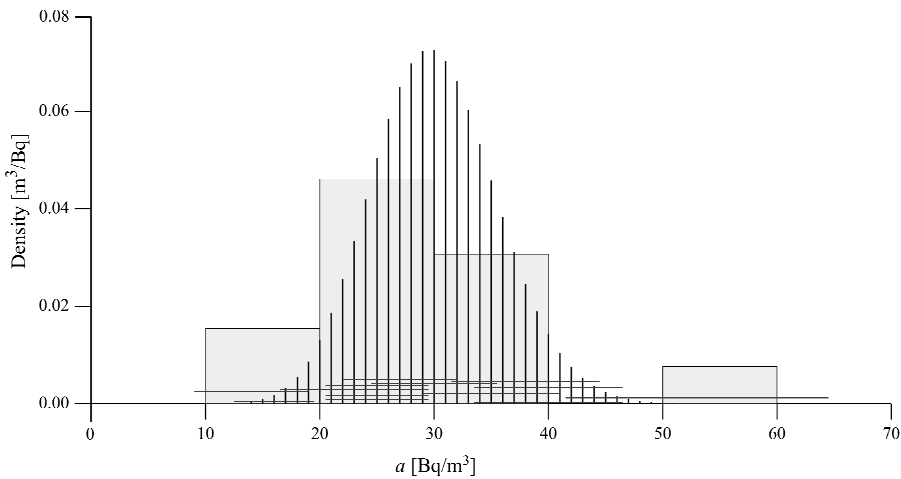


Fig. 5. Histogram of the measurements results distribution with their uncertainties and Poisson distribution

## Conclusions

The study of radon (Rn-222) exhalation measurements allowed to enunciate the following conclusions:

1. There is a large variation between radon concentration results in one series.
2. There is not any common trend between different radon concentration measurements series.
3. Decrease in the result uncertainty might be gained by an increase in measurements number in a series.
4. The number of measurements in a series can be adjusted to the desired uncertainty of result.
5. Poisson distribution well describes distribution of radon activity concentration in series.
6. It is possible to optimize the Rn-222 concentrations measurement procedures to reduce consumed time (and costs) of the works.

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## PROBLEMATYKA POMIARÓW EKSHALACJI RADONU (Rn-222)

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**Abstrakt:** Izotop Rn-222, naturalnie występujący radioaktywny gaz, powstaje na skutek rozpadu promieniotwórczego Ra-226. Oba radionuklidy należą do szeregu uranowo-radowego, który rozpoczyna U-238. Radon występuje w dużych ilościach w skorupie ziemskiej, skałach, glebie, wodzie i powietrzu, dlatego jest on traktowany jako wskaźnik dawki promieniowania jonizującego otrzymywanego przez ludzi. Ze względu na negatywny wpływ radonu na zdrowie ludzi pomiary stężenia tego gazu są często wykonywane. Zaprezentowano wyniki badań niepewności pomiarowej stężenia Rn-222 w powietrzu ekshalowanym z gleby. Pomiary powtarzano wielokrotnie w tym samym miejscu. Eksperyment przeprowadzony został w warunkach naturalnych, w centrum miasta i obejmował okres około pół roku. Do pomiarów stężenia radonu wykorzystano monitor radonowy AlphaGUARD. Pracował on w 10-minutowym trybie przepływowym, z pompą oraz komorą ekshalacyjną w obiegu zamkniętym. Badania wykazały znaczne różnice pomiędzy wynikami pomiarów, wykonywanych w całym okresie badawczym. W pojedynczej serii większa liczba pomiarów zmniejsza niepewność pomiarową. Dzięki temu ilość pomiarów w serii może być dostosowana do oczekiwanej niepewności pomiarowej wyniku. Stwierdzono, że rozkład wyników aktywności radonu w serii jest dobrze opisywany przez rozkład Poissona.

**Słowa kluczowe:** radon, ekshalacja, stężenie, niepewność pomiarowa, AlphaGUARD