EKOLOGIJA. 2012. Vol. 58. No. 4. P. 405–412

Variation of activity concentration of radon decay products in the Curonian Spit

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Variation of radon decay products activity concentration on the ground level of the atmosphere has been researched in the Curonian Spit. The influence of meteorological parameters on variation in these pollutants has been estimated. During the measurement period, activities concentration of radon short-lived decay products varied from 2 to 16 Bq/m^3 and values of activity concentration measured during day and night varied from 5 to 7 times. The investigation data showed that meteorological parameters as temperature, relative humidity, wind speed and direction had great influence on radon decay products activity concentration. Negative corelation (–0.77) between radon decay products activity concentration and the temperature and positive correlation (0.8) with the relative humidity was determined. It has been observed that variations of activity concentration of radon decay products were influenced by the periodically varying wind direction – breeze, a phenomenon which rarely occurs in the region of the Baltic Sea.

Key words: radon decay products, activity concentration, meteorological parameters, the Curonian Spit

INTRODUCTION

Radon (^{222}Rn) is radioactive scentless and colorless inert gas. It is formed in the result of decay of ^{226}Ra, which is a member of decaying chain of ^{238}U isotope.

Radon and its decay products compose most of ionizing radiation (Girgždys, Ulevičius, 1985; Gesell, 1983). 55% of background radiation is composed of radon (^{222}Rn) and its decay products. The average annual exposure of Lithuanian inhabitants caused by natural sources is about 2.2 mSv, about 1 mSv is conditioned by radon and its decay products ionizing radiation (UNSCEAR, 2000). Radon is one of the main sources of radiation in the environment. Many other natural and artificial sources of radiation are many times lesser (Nedveckaitė, 2004).

The half-life of radon is 3.8 days, therefore its decay range is sufficient for gas to get to the atmosphere from the upper layers of soil. Generally, internal exposure is influenced by short-term products of radon decay – ^{218}Po (half-life 3 min), ^{214}Pb (27 min), ^{214}Bi (20 min), ^{214}Po (164 µs) and others. While evaluating the impact of radon short-term decay products on human health, it is important to know what amount of the decay products atoms is attached to the aerosol particles. The inhalation of radon decay products depends not only on their concentration in the air but also on the amount of the decay products attached to the aerosol particles (Clavensjo et al., 1999).

Most of radon radiation and its decay products are easily absorbed by human skin surface, therefore human internal exposure becomes most important, i. e. the internal exposure due to inhaled radon decay products in the organism (Hess et al., 1983; Mohammed, 1999). Being inhaled with the air filled with radon short-lived decay products, they settle and decay on breathing organs. Then the emitted alpha particles penetrate and damage the tissue. Due to that cancer of lungs or breathing organs can develop (Lubin, 2003; Ishikawa et al., 2003).

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Likewise to many other countries, in Lithuania the largest source of radon is soil (Clavensjo et al., 1999; Mastauskas, Morkūnas, 1996). There are two stages in studying radon diffusion: its emanation through pores of a solid material and its carrying by air outwards (Ackers, 1984).

When radon gets into air, gas diffuses in the atmosphere. Activity concentration of the radon decay products in the upper layer of the atmosphere mostly depends on the radon emanation rate from the soil and the intensity of the air mixing (Girgždys, Ulevičius, 1985).

The radon concentration undergoes a typical diurnal variation over the land in case of anticyclone with a maximum during the night and a minimum in the afternoon ascribed to the formation of thermal inversions during the night. The trend in radon concentration distinguishes clearly between days on which there is a nocturnal accumulation of radon and days on which there is an air mixing; during these days the level of radon remains nearly constant night and day and the pollutants disperse high during the day and at night (Desideri et al., 2007).

Radon concentration is dominant on the ground level at night due to the decrease of vertical air mixing. However, it is effective only over the land, since radon gas emanates from soil where it is formed in the result of the decaying of ^{226}Ra. Radon emanation and concentration over the water surface is very low. Therefore higher radon concentrations over the sea are found only in case of advection from the land. Typically, the concentration in soils is 10^5 Bq · m^3 (Ghita, Vasilescu, 2011), whereas in the oceans it is only about 2 Bq · m^3 (Burnet et al., 1998). Radon emanation is therefore much greater, usually by a factor 100, over the land than over the sea. The vertical mixing of air generally results in an additional loss of radon at sea level. However, if the upper air has come from over the land, and the lower air is purely maritime, vertical mixing may cause an increase in radon concentration (Whittlestone, 1985).

The aim of the experiment was to establish activity concentration of radon progeny in the atmosphere in the Curonian Spit.

MATERIALS AND METHODS

The experiment was carried out at Juodkrantė (55°32'N and 21°06'E) surroundings (the Curonian Spit) on 11–17 July, 2010. The investigations were performed in Juodkrantė location which is ~100 m from the Baltic Sea and ~1.5 km from the Curonian Lagoon (Fig. 1). The location is surrounded by sand dunes from the side of the Baltic Sea and by pinewoods from the side of the Curonian Spit.

Radon activity concentration and meteorological parameters in the ambient air were measured continuously by averaging the data of 5 minutes (Fig. 2).

Measurements were carried out applying equipment and method for constant measurements of radon decay products activities concentration in the air (Jasaitis, Girgždys, 2007). The measuring equipment consists of filtration device with a radiometer and air volume meter with a pump.

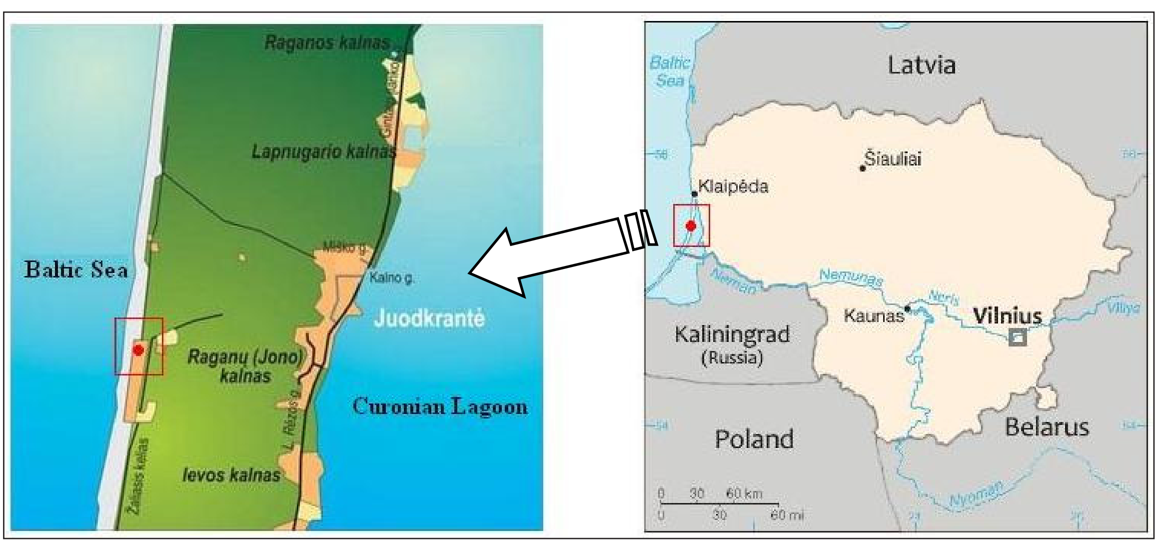

Fig. 1. Measurement location

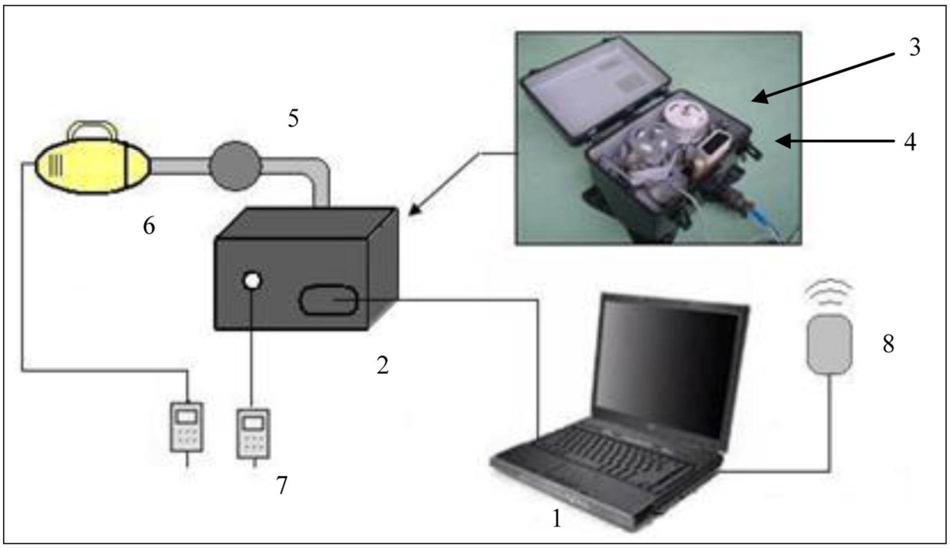

Fig. 2. Measurement scheme: *1* – computer, *2* – filtration device, *3* – filter band, *4* – radiometer, *5* – air volume meter, *6* – air pump, *7* – stopwatches, *8* – weather station

The metal frame of filtration device (340 × 230 × 220 mm) has an inlet and outlet. The diameter of the air inlet is 20 mm. The air flow rate is 40 L/min, and it is controlled by air flow meter. The air in the device frame changes within 25 seconds. The 800 W powered air pump sucks the air through filter band "Fiberglaz" with diameter of 50 mm. The air is sucked through the part of filter band which is between a suction channel and a radiometer. The band is stopped during the measurement period. When the measurement process is over, the band is overwound so that the "clean" (i. e. without radon progenies) part of the filter appears above the radiometer and the air suction channel of the pump. The radiation of the particles settled on the filter is measured with the radiometer GM-45.

The radiometer GM-45 is a light and extremely sensitive detector of the ionizing radiation. It contains a Geiger-Müller counter which is sensitive to alpha, beta and gamma radiation (alpha above 3 MeV, beta above 50 keV, gamma above 7 keV). The diameter of isinglass is 42 mm. The RAD (Radiation Acquisition and Display) programme is installed in the device. The usage of RAD programme enabled the data to be stored and transferred into MS Excel programme for processing.

The radiometer is fixed so that the filter band through which the air is sucked moves beside the radiometer measurement window.

Electronic stopwatches TS-ED1 are set, and the time of suction and filter band turning are programmed. After setting the hours when the measurements are automatically carried out, the device can operate permanently.

The bias of radon short-lived decay products measuring method was evaluated. It depends on the efficiency changes of the filter band, the speed of air flow through it, exposition time and the concentration of progeny in the air. The established bias was not higher than 6%.

During the study the meteorological parameters (temperature, relative humidity, wind speed and direction) were measured by PC Radio Weather Station. The temperature in the range from −30.0 °C to +70 °C is measured with accuracy of ±1 °C, wind speed in the interval 0–60 m/s is measured with accuracy ±0.3 m/s and wind direction resolution is 5 degrees. The sensors of temperature, relative humidity, wind speed and direction were located about 100 m from the Baltic Sea. Temperature and relative humidity, wind speed and direction were measured in the height of 3.5 m from the ground. Outdoor relative humidity range was from 20% to 100%, resolution – 1%. Atmospheric pressure: the range for absolute pressure from 800 hPa to 1 100 hPa, resolution 1 hPa, accuracy ±1 hPa.

Activity concentration of radon decay products and all information from the Weather Station are automatically sent and recorded to the computer.

RESULTS AND DISCUSSION

During the first and latest days of the experiment the territory of Lithuania was influenced by anticyclone. The temperature varied from 20 to 38 °C, and relative humidity – from 25 to 100%.

During the experiment low-speed winds dominated, and the wind speed higher than 5 m/s was recorded only for 2% of the entire observation time (Fig. 3). During the experiment a long period of calm (11%) was recorded, and 15% of the observation time when the wind speed was lower than 1 m/s was also fixed. Usually, the wind direction from the sea is most common, while the wind from the continent is significantly less frequent, i. e. approximately several times (Girgždienė, Girgždys, 2001). However, the non-typical situation in respect of wind dominated during our experiment. During the research, the wind from the Curonian Spit, i. e. south-east and east (39% and 18% of the observation time, respectively) were measured, while winds from the Baltic Sea (west-north) were observed relatively seldom (30% of the time).

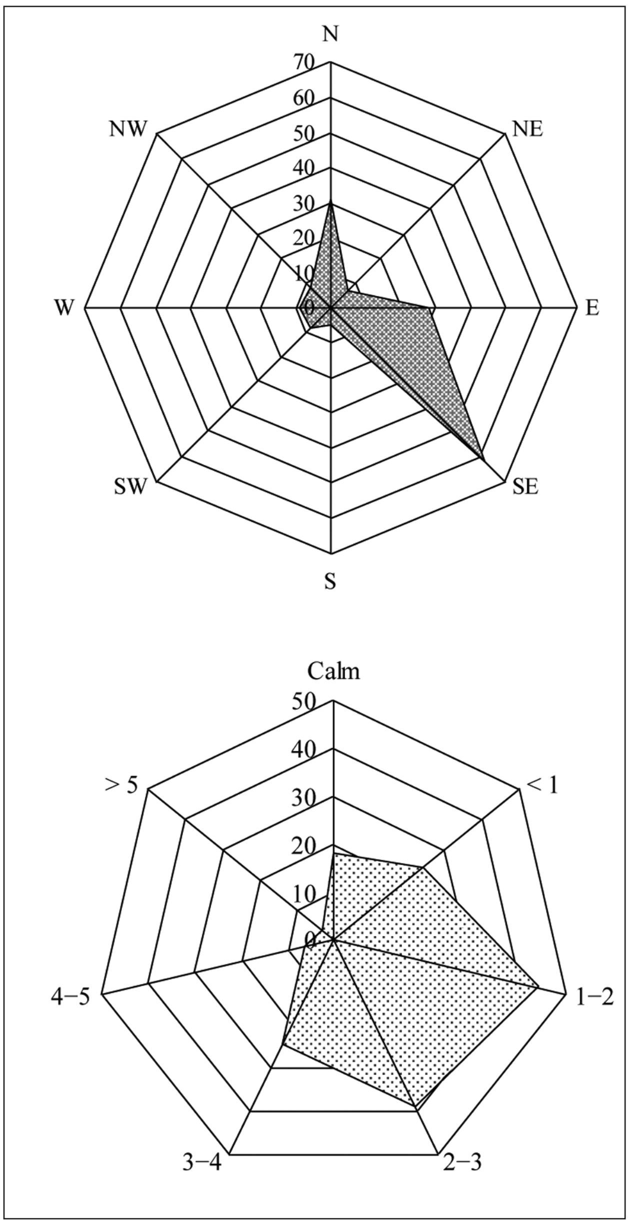

Fig. 3. Percentage concentration of wind direction (a) and wind speed, m/s (b) from different sectors in Juodkrantė during the investigation period

During the measurement period, activity concentration of radon short-lived decay products varied from 2 to 16 Bq/m^3. The measured average activity concentration of radon decay products was 7 Bq/m^3 (Fig. 4).

Figure shows that the increase of temperature causes the decrease in the amount of radon short-lived decay products. The increase of the activity concentration of the radon decay products early in the morning is described by the corelation of the emanation increase during the night with the decreasing temperature. Negative corelation between radon short-lived decay products activity concentration and the temperature was determined (–0.77).

Air radioactivity starts to increase approximately from 10–11 p. m. The maximum value is reached from 5 a. m. to 6 a. m. just before the sunrise, meanwhile the minimum values are observed at about noon. This might be explained by the fact that variation in activity concentration of radon decay products is influenced by the intensity of air turbulence. In the daytime, the sun heats up the earth surface and the positive temperature gradient occurs above the earth surface. In the evening, when the heat of the sun is not so effective, the positive temperature gradient is constantly shifting towards the negative one. A slow variation in temperature is frequent for the night period. The temperature gradient significantly decreases and is time-variable close to the surface of the ground, i. e. 0.1–0.2 metres above it. At this moment, the increase in activity concentration of radon decay products continues and reaches the maximum value. After the sunrise, the air temperature is constantly increasing, and the temperature gradients decrease in all layers. Moreover, temperature inversion is typical for this period.

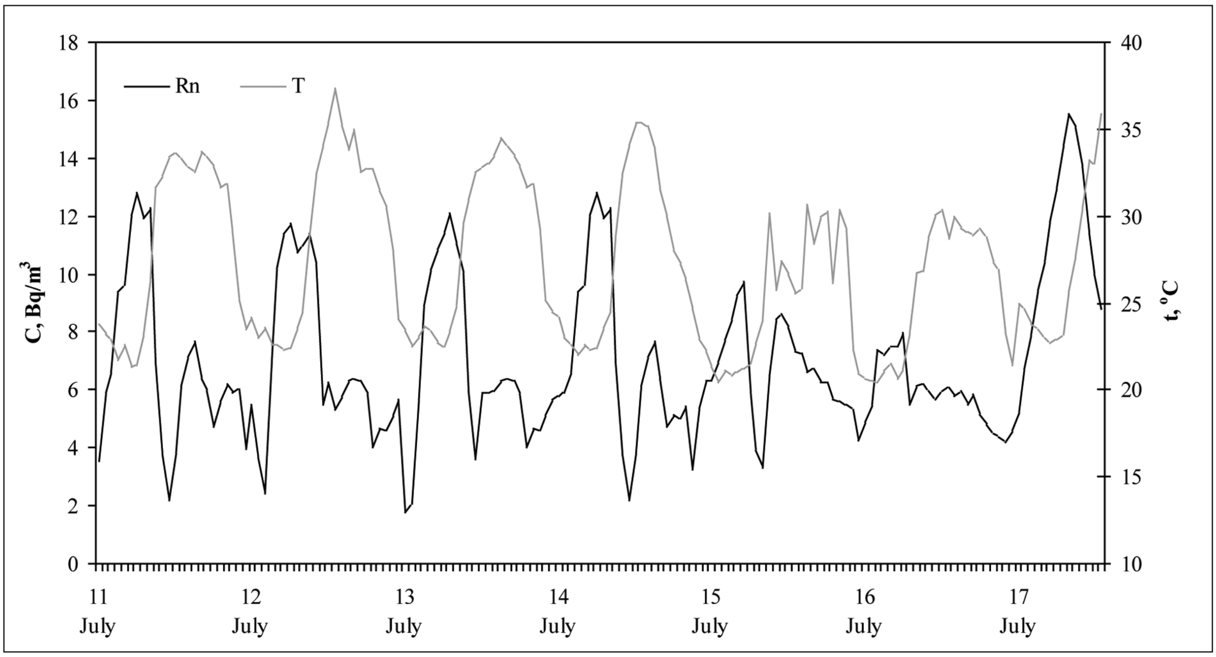

Fig. 4. Time course of radon activity concentration and temperature

When the weather is calm and fine, the conditions favourable for accumulation of the pollutants on the ground level of the atmosphere occur and in such cases their concentrations may significantly increase. Such conditions can occur when the weather is determined by the anticyclone (a region of high atmospheric pressure): the weather is calm, windless and rainless. During the period of our experiment such weather dominated. Only on 15–16 July the cyclone approached the territory of Lithuania (Fig. 5, marked in red).

The activity concentration of radon decay products decreased during the rainy period. This is because the radon decay products usually

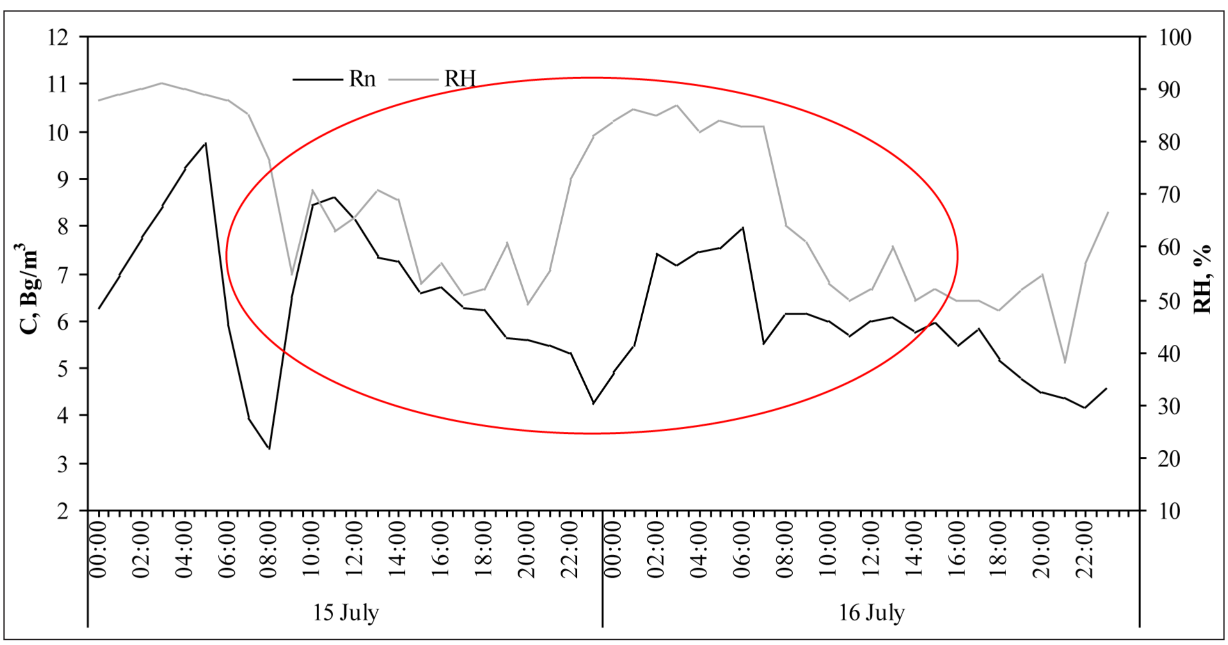

Fig. 5. Variation of radon activity concentration and relative humidity

associate with the aerosol particles which are always present in the air and the fall washes them out from it.

An analysis of interrelations among activity concentration of radon short-lived decay products and wind speed had been carried out. Activity concentration of radon decay products decreased with the increase of wind speed: then radon gas is more efficiently dispersed in the atmosphere. However, it had been established that in this case the concentration of radon decay products was more influenced by wind direction (low-speed winds dominated during the experiment).

The impact of the wind direction on variation in activity concentration of radon decay products has been estimated (Fig. 6).

The maximum value of activity concentration of radon short-lived products had been observed when the wind blew from the continent, and the minimum value has been observed when the wind blew from the sea. This shows soil being the largest source of radon, as is the case in Lithuania and other countries. Therefore, when wind blows from the sea radon gas diffuses in the atmosphere.

Following the analysis of variations in wind direction and speed, humidity and temperature, it had been established that during several days of the experiment, i. e. from 11 to 14 of July, the meteorological phenomenon called breeze occurred on the seacoast of Neringa. During this period, the variations in activity concentration of radon decay products coincided with daily periodic change of wind direction (Fig. 7).

Breezes are variable winds present along coastlines of seas, oceans, large rivers and lakes and changing their direction twice a day (Fig. 8). During daylight hours, the land gets heated up faster than water and a lower pressure zone forms above the land. Therefore, a daytime breeze blows from the water to the heated coast. At night, the reverse process occurs: the land gets cooled faster than the water, a high pressure zone forms above the land, thus the wind blows from the land to the water.

Local winds, i. e. breezes, are not a frequent phenomenon in the region of the Baltic Sea. The processes of global air mass transports mostly override their action. Breezes may form on the Baltic seashore under the condition of anticyclone when the wind is weak. In such a way, a particular air circulation occurs: the wind blows from the coast or to the coast on the ground level, while its direction in the higher layers of the atmosphere is reverse. Breezes may occur along the coastline of several up to several dozens kilometres depending on the temperatures differences between the heated and cooled surface of the sea and the land. Thus, variation in radon concentrations on 11–14 of July may be explained by the effect of breeze on their production.

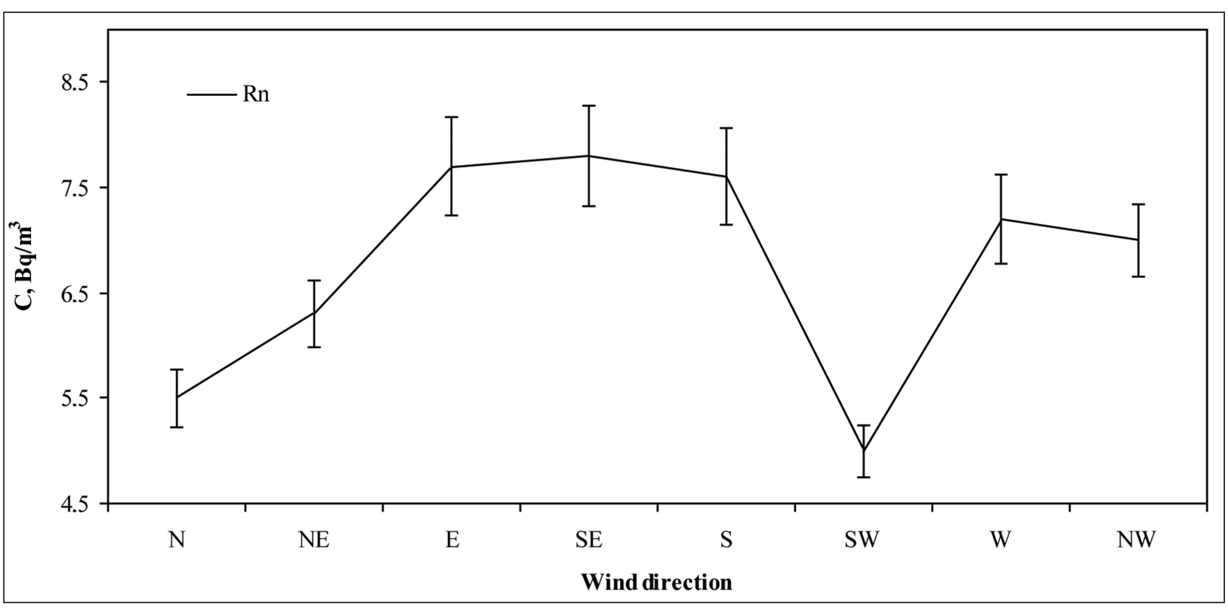

Fig. 6. Relationship between wind direction and radon activity concentration

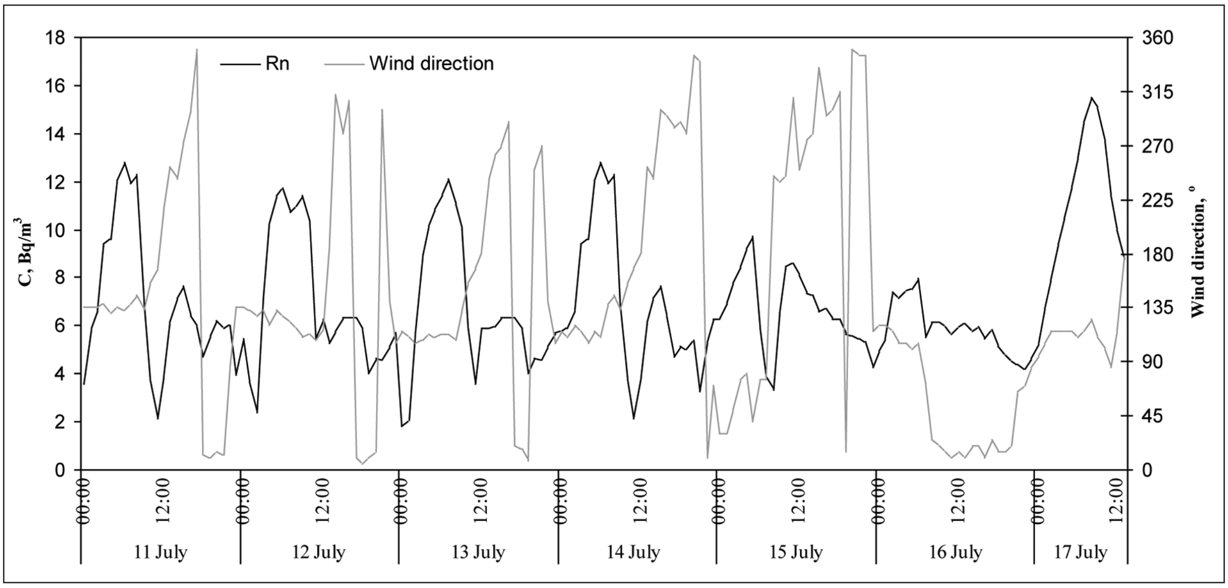

Fig. 7. Variations of radon activity concentration and wind direction

Meteorological situation also influences the activity concentration of radon and its short-lived products, therefore a direct relation exists between activity outdoor and indoor. There were permanent measurements done outdoor and indoor of the buildings (Porstendorfer et al., 1994). It was determined that given a low air turbulency, the maximum of the radon activity concentration outdoor was observed, which had an impact on forming of the radon activity concentration maximum indoor.

By some other authors (Girgždys et al., 1988; Desideri et al., 2007) activity concentration of the radon and the concentration of the ozone were measured simultaneously. It was determined that with cloudless air the correlation coeficient of these measures often exceeded 0.86 and that this is related to the fact that vertical flows of the radon and ozone near the ground are inverse.

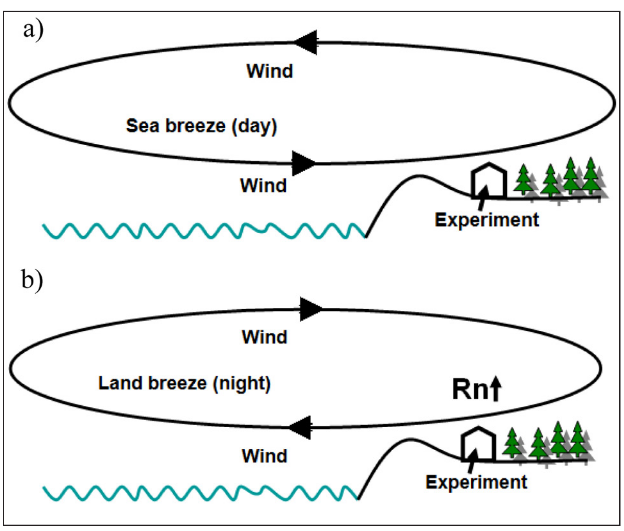

Fig. 8. Breeze circulation scheme: a) daytime, b) night

CONCLUSIONS

1. It has been found that meteorological parameters as temperature, relative humidity, atmospheric pressure had most important influence on the activity concentration of radon decay products.
2. The measurements of the activity concentration of radon decay products gave the possibility to identify the presence of a breeze phenomenon on the Curonian Spit in summer during extreme weather events.
3. The evident influence of the wind direction on the time course of activity concentration of radon decay products was estimated under the coastal conditions.

Received 8 October 2012
Accepted 10 December 2012

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RADONO SKILIMO PRODUKTŲ TŪRINIO AKTYVUMO KAITA KURŠIŲ NERIJOJE

Tirta radono skilimo produktų tūrinio aktyvumo kaita atmosferos priežemio sluoksnyje Kuršių nerijoje. Vertintas meteorologinių parametrų poveikis šių teršalų kaitai. Matavimo laikotarpiu radono trumpaamžių skilimo produktų tūrinis aktyvumas kito nuo 2 iki 16 Bq/m^3, o išmatuotos tūrinių aktyvumų vertės dienos ir nakties metu skyrėsi nuo 3 iki 10 kartų. Nustatyta, kad meteorologiniai parametrai – temperatūra, santykinis oro drėgnis bei vėjo kryptis ir greitis – daugiausia nulemia radono skilimo produktų kaitą atmosferos priežemio sluoksnyje. Gauta neigiama koreliacija (–0,77) tarp radono skilimo produktų ir temperatūros bei teigiama koreliacija (0,8) tarp radono skilimo produktų ir santykinio oro drėgnio. Pastebėta, kad radono skilimo produktų tūrinio aktyvumo pokyčius nulėmė periodiška vėjo krypties kaita – brizas, retas reiškinys Baltijos jūros regione.

Raktažodžiai: radono skilimo produktai, tūrinis aktyvumas, meteorologiniai parametrai, Kuršių nerija