Radon measurements in the cave Vilenica

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Abstract

The cave Vilenica is about 1300 m long and 180 m deep. One third of the cave is open for the visitors. Radon and its daughter concentrations and also temperature and pressure have been measured at different times of the year and at different locations in the cave in order to estimate doses to visitors and guides. Radon concentrations ranging from few 100 Bqm^{-3} in the winter up to few 1000 Bqm^{-3} in the summer months. The dose rate for visitors and guides is 10 to 40 μSv/h, depends from the radon concentration.

1. Introduction

The Vilenica cave is situated near the town Sežana in the middle of the typical karst and it's probably the oldest show cave in Europe. First tourists visited the cave in the year 1633. Total length of the galleries is 1300 m. The part arranged for tourists is one gallery 450 m long and 94 m deep. Other part of the cave is accessible only to cave explorers with special equipment.

The Vilenica cave is one of caves, where a speleotherapy (1,2) will start in near future. Speleotherapy is a special kind of climatotherapy and is being used as an additional treatment for curing bronchial and asthmatic diseases of children and adults in last 40 years in many countries in Europe.

The objectives of this measurements are (i) to determine the physical parameters of the cave microclimate, important for the speleotherapy and (ii) to determine radon and progeny concentrations for dose estimation.

2. Methods

In the period from January to December 1995 monthly measurements of different parameters on the route for visitors have been investigated. Relative humidity, temperature and air flow were measured by standard digital devices. Concentrations of positive and negative ions were measured by ionometer Shomandl with the accuracy of about 10 %. Concentrations of different gases were measured by Dröger tubes. Radon and progeny concentrations were performed by radon gas monitor RGA-40 and working level monitor WLM-30 from Scintrex, Canada. Radon concentrations were measured also by track each detectors and charcoal canisters. Duration of measurements was three days for radon and progeny, measured by devices or charcoal canisters and one month or more by track detectors. All measurements were made in the middle of the cave at one place, "near the water", except radon concentrations, which were measured at 9 different places.

The visiting part of the cave has two different temperature regimes, first part about 200 m long with stronger influence of meteorological parameters from outside, where temperature changes throughout the year for few degree Celsius and second part about 250 m long with nearly the same temperature of 10 °C in all periods of the year. From September to December air velocities and temperature at 5 different places were measured, two in first and three in second part of the cave. The volume of the cave is about 200000 m^3, of the second part about 120000 m^3.

3. Results

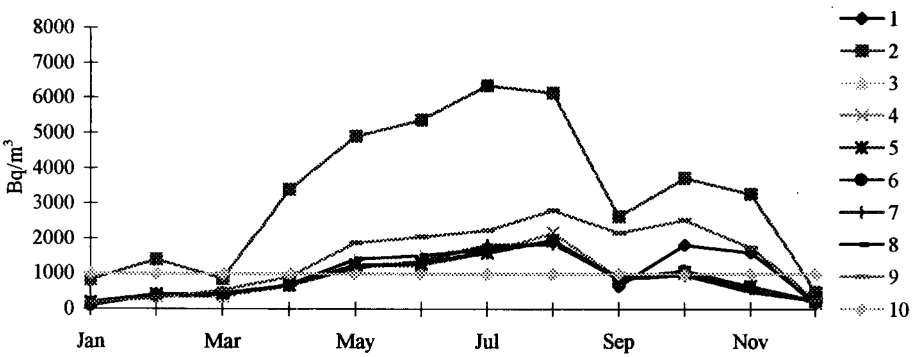
Measurements of microclimatic parameters showed us no content of ozone, sulphur dioxide, nitrate, fluoride and carbon monoxide in cave. Only carbon dioxide was detected, its concentrations were in the range of 0.05 vol % to 0.4 vol %. Temperature in the first part of the cave changed from 2 °C to 10 °C, at the point, where second part started (temperature point) was between 7 °C and 10 °C, and at the lowest part, accessible for visitors, varied from 10,5 °C to 12 °C. Air pressure was changing in a measuring period for few millibar (3-7 millibar), only in December first decreased for 6 millibar and then increased for 15 millibar. Temperature on all places slowly increased with hight. On the bottom of the Hall of the Faires is a small entrance (1m^2) in a Fabris cave. Air flow at this place is obout 30 m^3/h. Only in December changes in air velocities from 0.01- 0.08 ms^{-1} were found. It was like a breathing with a period of 30 s.

In summer months we can suppose air velocities of 0.01 ms^{-1} or less on all places in the cave. In December was air velocity at the place "temperature point" in the range of 0.03-0.1 ms^{-1} and at the entrance between 0.2-0.3 ms^{-1}. If we assume effective cross section at the temperature point of 50 m^2, air flow in summer was 2000 m^3h^{-1} and ventilation rate was less then 0.01 h^{-1}. Calculated air flow and ventilation rate in December were between 6000-10000 m^3h^{-1} and 0.03-0.1 h^{-1}, respectively.

The effective cross section at the entrance is about 20 m^2. Air flow and ventilation rate in summer were the same like at the temperature point, in December air flow was between 10000-15000 m^3h^{-1} and ventilation rate in range form 0.05-0.1 h^{-1}. If we take into account equation from Wilkening and Watkins (3), $Q = \lambda V(C_{max}-C)/C$, and insert values for radon concentrations, we obtain for air flow in December at the temperature point and at the entrance the value of 9000 m^3h^{-1} and 11000 m^3h^{-1}, respectively. Results are in good agreement with measured values of air flow.

Concentrations of positive ions were changing from 3000-11000 per cm^3 and negative ions from 3000-9000 per cm^3. The difference between concentrations of positive and negative ions was higher by higher radon concentrations.

Radon concentrations at different places in the cave were nearly the same in different measuring periods (Fig. 1), except at the place The dance Hall. This is a very big hall on the entrance in the cave. We didn't measure radon concentration in the hall but in small crack (about 30 cm^2). We suppose the crack lids to a big unknown hall with higher radon concentrations.



Legend:

1 The entrance	6 Above the hall of the Faires
2 The dance hall	7 Before the hall of the Faires
3 Under the Red hall	8 The hall of the Faires
4 Red hall	9 On the bottom of the hall of the Faires
5 Near the water	10 Annual average

Fig. 1. Radon concentrations in the Vilenica cave in the period Jan - Dec 1995

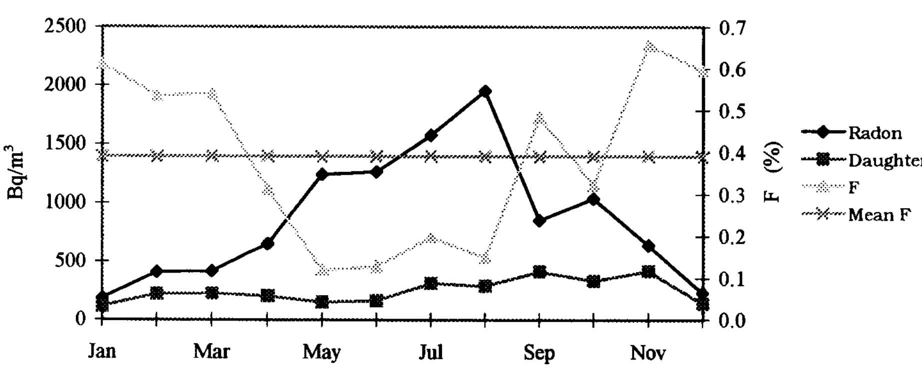


Fig. 2. Monthly radon and daughter concentrations and equilibrium factor in Vilenica cave at the place near the water

Higher values were measured on the bottom of the Hall of the Faires, where radon cames through the small entrance from the Fabris cave. This is a big cave with higher content of clay and higher temperature. This are main reasons for higher radon concentrations on the bottom of the cave, accessible for visitors, which has no clay only washed limestone. Radon concentrations at these place were 20-50 % higher then on other measuring places, depends from the period of the year. We suppose this is a main radon source.

Radon concentrations in cave were higher in summer then in winter, mean value was 980 Bqm^{-3}. The lowest values were in December and January. In first and last months of the year the wetter was changing, measured radon concentrations at different times could be different form presented values. In September it was very cold wetter in the time of measurements (less than 10 °C), what is a reason for lower radon concentrations. Radon concentrations in cave increased from January to August, and then decreased from September to December, like mean outdoor temperature. Different temperature gradient between the cave air and outdoor air produced higher or lower ventilation rate.

On the Figure 2 radon and daughter concentrations at the place "near the water" are presented. Radon progeny concentrations were nearly the same in the first half of the year, then increased about two times from July to November and then sharply decreased in December. Equilibrium factor between radon and daughter was about 4 times lower in summer then in winter months.

The measurements which have been made in Postojna cave (4) showed very low aerosol concentrations, between 2000-4000 per cm^3. The activity median aerodynamic diameter AMAD was 250 nm (σ_g=1.6). A quite high activity fraction (30%) was found in the nucleation size range between 4 and 80 nm. Unattached fraction f_p was between 10 and 15 %.

We didn't measure aerosol size distribution and unattached fraction in different periods of the year, but we suppose that in winter time fresh air brings more aerosols from outside into the cave. Because of higher ventilation rate in winter time the air in the cave is mixing faster and more radon decay products can claimed with aerosols what produces higher equilibrium between radon and progeny. This explains differences in equilibrium between radon and daughters; we will prove it with measurements next year.

4. Dose estimates

Our dose calculation based on three different models, ICRP 50 (5,6), Jacobi-Eisfeld (J-E) and James-Birchall (J-B). For AMAD and unattached fraction we take into account values from Postojna cave, fp=0.1 and AMAD 0.2 μm. The dose rate is 10 to 40 μSv/h, depends from the radon concentration. If we suppose 1000 to 2000 working hours per year and mean progeny concentration of 250 mWL, annual dose is about 20 mSv from J-E and 30 mSv from J-B model. If we suppose new dose convention 5 mSv/WLM, annual dose lies between 10-15 mSv.

In future we will measure unattached fraction and aerosol size distribution of radon daughters, for more precisely dose estimation and for understanding the differences in equilibrium factor.

5. References

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