RADON IN CROATIAN SPAS

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ABSTRACT

There are ten thermal spas in Croatia and all of them provide health services for patients and visitors. Radon measurements were performed since there is a lack of data concerning natural radioactivity originated from radon and its short-lived progenies in such environments. The thermal water at two different sites (the indoor swimming pool with geothermal water and the spring) in each spa was sampled and radon concentrations were measured by AlphaGUARD radon measuring system. The obtained values were in the range of 0.7 to 19 Bq dm^{-3} and 2 to 94 Bq dm^{-3} for indoor swimming pools and springs, respectively. Integrated measurements of radon concentration in air were performed by two solid state nuclear track detectors LR-115 II (open and diffusion one) thus enabling estimation of equilibrium factor between radon and its daughters. The annual effective doses received by spa workers were found to be about 1 mSv/y (below the lower limit value of 3 mSv/y recommended by ICRP 65). The doses of patients and visitors were one or two order of magnitude lower than that of the personnel.

INTRODUCTION

Radon (^{222}Rn) is a noble α-emitting radioactive gas produced by the decay of radium (^{226}Ra), and both are members of uranium decay chain. The radon concentrations in soil gas due to continuous radium decay and different mechanisms of radon transport could be very high, with values measured up to several thousands Bq m^{-3} [Jönsson, 1997]. Large reservoirs of underground water dissolve radon, and after the water appears on the surface, radon can easily diffuse to the atmosphere. This could lead to high radon concentrations in some thermal water spas. Elevated radon level at those workplaces can cause serious health problems to workers [ICRP65, 1993; IAEA, 2003], which is why radon in spas is an interesting subject for monitoring. Consequently, there are lots of available data about such measurements [Kobal et al, 1979; Kobal and Reiner, 1987; Steinhausler, 1988; Soto et al, 1995; Planinić et al, 1996; Szerbin, 1996; Horvath et al, 2000].

The Republic of Croatia is a country rich in thermal and mineral springs. These hot springs mostly occur in the north-western and central part of Croatian territory and are considered important natural sources. Due to their therapeutic and health-improving effects, most of them are very popular with the population in the area of medical therapy and rehabilitation as well as tourism and recreation. Considering the habits of the population to use benefits of Croatian spas, it is of interest to investigate natural radioactivity originated from radon and its short-lived progeny in the spas.

The aim of this study is to measure radon concentrations in the air and water (hot springs and swimming pools) and to estimate radiation doses received by workers and tourists in Croatian spas.

EXPERIMENTAL

Radon concentrations in the air of swimming pools as well as air temperature, barometric pressure and humidity were measured by AlphaGUARD PQ2000 PRO detector (Genitron Instruments, Germany). This measuring system uses the principle of the ionization chamber; radon enters the detection area (through a progeny preventing glass fibre filter) where it is measured by α-spectrometric technique. The measurement cycle time was 10 min in the diffusion mode, and the measurement range was between 2 Bq m^{-3} and 2 MBq m^{-3} [AlphaGUARD User Manual, 1998].

Integrated measurements of radon and its short-lived progeny in the air were performed by means of the passive track etching method with the LR-115 SSNTD film, type II (Kodak-Pathé, France). The cylindrical detector cup, with the diameter and length of 9.6 cm and 9 cm, respectively, was covered with a paper filter of 0.078 kg/m^2 surface density (diffusion detector), or the detector cup was open. Radon concentration in the air (C_a) was determined as a product of the sensitivity coefficient (k) and track density of the diffusion detector (D_0). The sensitivity coefficient of the diffusion detector was k = 28.7 Bq m^{-3} / tr cm^{-2} d^{-1} and the detector background was 90 tr cm^{-2}. The measurement method with two detectors (diffusion and open one) enables determination of equilibrium factor for radon and its progeny in the air (Planinić et al., 1997).

The LR-115 SSNT detectors were preliminarily exposed in spas 1, 2 and 4 (Figure 1) at pay-offices, usually at the entrance of the swimming pools, for four months during winter season (from November 2003 to March 2004), then etched in 10% NaOH aqueous solution at 60 °C (333 K) for 120 min. Afterwards, detector tracks were counted visually using a microscope of

10x16 magnification. One year long exposure of the detectors at nine selected spas was started at April 2004.

The radon measurements in water were performed with the AlphaGUARD device with the AquaKIT module. The samples of water were collected in April 2003 and 2004 from thermal springs and swimming pools in the spas chosen for the investigation. The samples were put in glass containers of 200 ml, with sealed openings and security mechanisms to avoid the leaking of radon during transport. The measurement itself includes water degassing and pumping of the radon-bearing air into the AlphaGUARD ionization chamber, whereby standardized procedure for quick measurement was used.

RESULTS AND DISCUSSION

Figure 1 shows the locations of ten selected spas at which the radon measurements were meant to be performed. However, the management of the Istarske Toplice (spa No. 10 at Fig. 1) didn’t allow the investigation to be conducted (water sampling and detector exposure) in their spa. The results of the radon measurements by AlphaGUARD measuring system in the air and water (from swimming pools and thermal springs) are shown in Table 1. The continuous measurements of radon concentrations in the air at swimming pools throughout one hour were in the range of 17 Bq m^{-3} (spa No. 2 in Table 1) to 90 Bq m^{-3} (spa No. 6) in the year 2004. The similar values were obtained in 2003.

The highest radon concentration was found in the spa No. 6 and is shown in Figure 2. The measurement was performed at night when the pool was closed (the ventilation rate was assumed to be the lowest). No tendency of radon increasing under these conditions was observed.

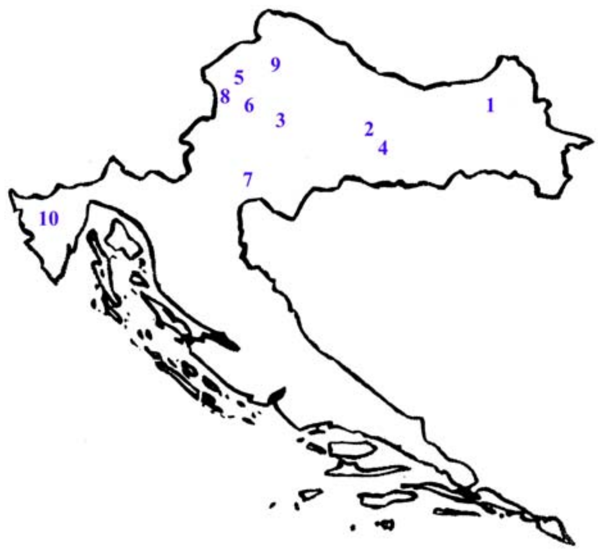

Figure 1. Locations of ten selected Croatian spas chosen for the radon measurements.

Table 1. The results of the radon measurements by AlphaGUARD measuring system, in air (c_a / Bq m^{-3}), swimming pool water (c_w – pool / kBq m^{-3}) and thermal spring water (c_w - spring / kBq m^{-3}).

No.	Spa	c_a (Bq m^{-3})		c_w - pool (kBq m^{-3})		c_w - spring (kBq m^{-3})	
		2003	2004	2003	2004	2003	2004
1.	Bizovačke	10.9 ± 9.1	23.0 ± 9.0	0.79 ± 0.26	1.05 ± 0.33	2.02 ± 0.41	2.62 ± 0.49
2.	Daruvarske	40.0 ± 19.0	17.3 ± 10.3	3.58 ± 0.64	2.71 ± 0.51	7.93 ± 0.96	6.65 ± 0.85
3.	Ivanić Grad		28.1 ± 13.0		3.55 ± 0.56		2.10 ± 0.46
4.	Lipik	42.2 ± 18.2	28.3 ± 13.0	2.26 ± 0.44	1.96 ± 0.41	6.07 ± 0.82	5.21 ± 0.71
5.	Krapinske	6.6 ± 15.3	80.0 ± 34.0	6.44 ± 0.80	7.38 ± 0.88	7.78 ± 0.89	6.72 ± 0.85
6.	Stubičke	109.0 ± 9.0	91.0 ± 8.0	18.60 ± 1.79	15.22 ± 1.37	82.07 ± 5.10	93.79 ± 5.84
7.	Topusko		40.5 ± 18.3		2.71 ± 0.46		34.02 ± 2.44
8.	Tuheljske	50.2 ± 11.2	22.4 ± 12.8	1.43 ± 0.32	0.73 ± 0.40	4.99 ± 0.63	4.42 ± 0.64
9.	Varaždinske	28.0 ± 10.0	22.1 ± 12.7	2.15 ± 0.44	1.59 ± 0.49	18.66 ± 1.60	10.49 ± 1.05
10.	Istarske						

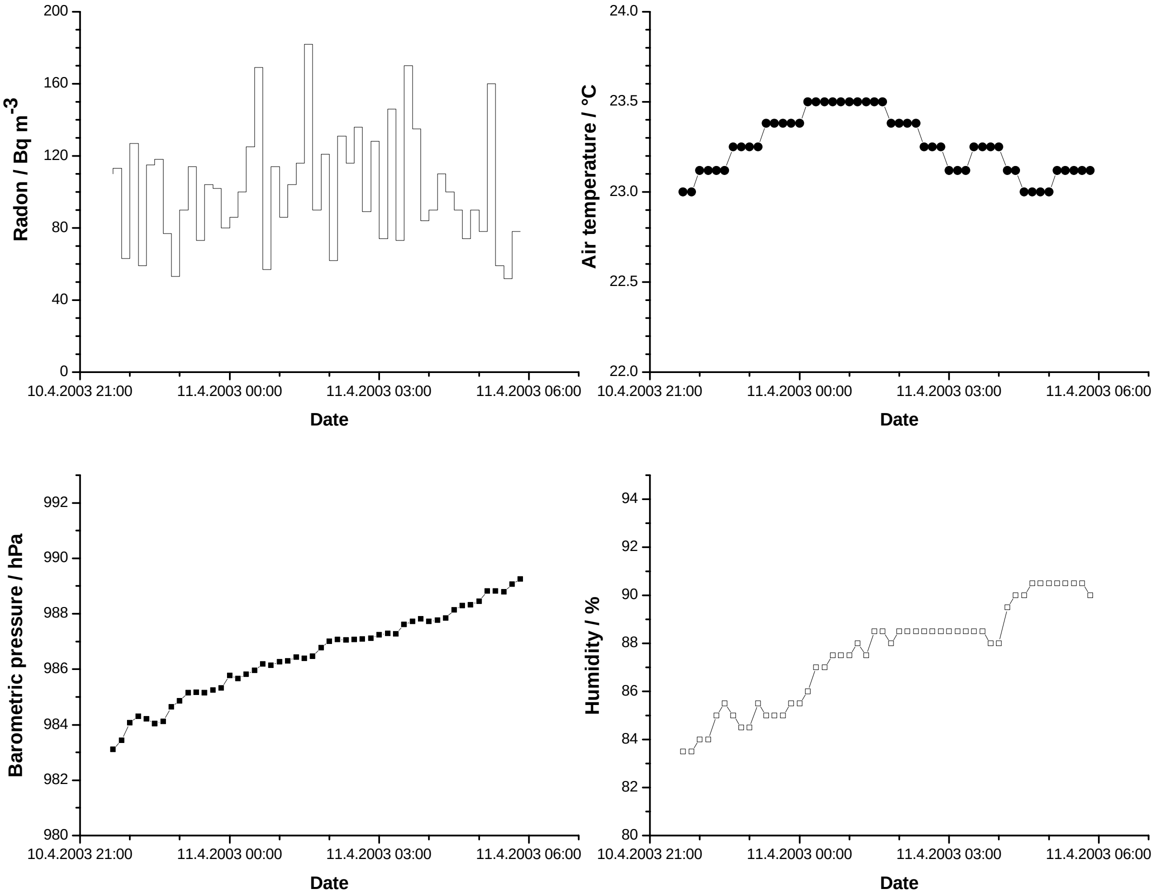

Figure 2. Radon concentration, air temperature, barometric pressure and humidity in swimming pool air of spa No. 6 (Stubičke Toplice, Table 1) measured by AlphaGUARD detector at night on April 10-11, 2003.

Radon concentrations measured in water samples taken from two different sites (thermal spring and swimming pool) in every spa are presented in Table 2. In most spas there is more than one thermal spring but the water samples were taken from those used for supplying swimming pools with hot water. In the spas the water is distributed from the springs to the pools through various different systems of pipes and it is clear that in most cases the radon concentrations in pool waters are lower then those in springs. This primarily occurs because of the radon decay and the fact that the pools are usually filled with fresh thermal water two or three times a week. The values obtained from pools were in the range from 0.7 to 18.6 kBq m^{-3} in 2003 and 2004. At the same time, the radon measurements at springs showed concentrations from 2 to 94 kBq m^{-3}. The values indicated that the radon levels in geothermal water of Croatian spas were not high when compared to some Spanish or Hungarian spas [Soto et al., 1995; Szerbin, 1996].

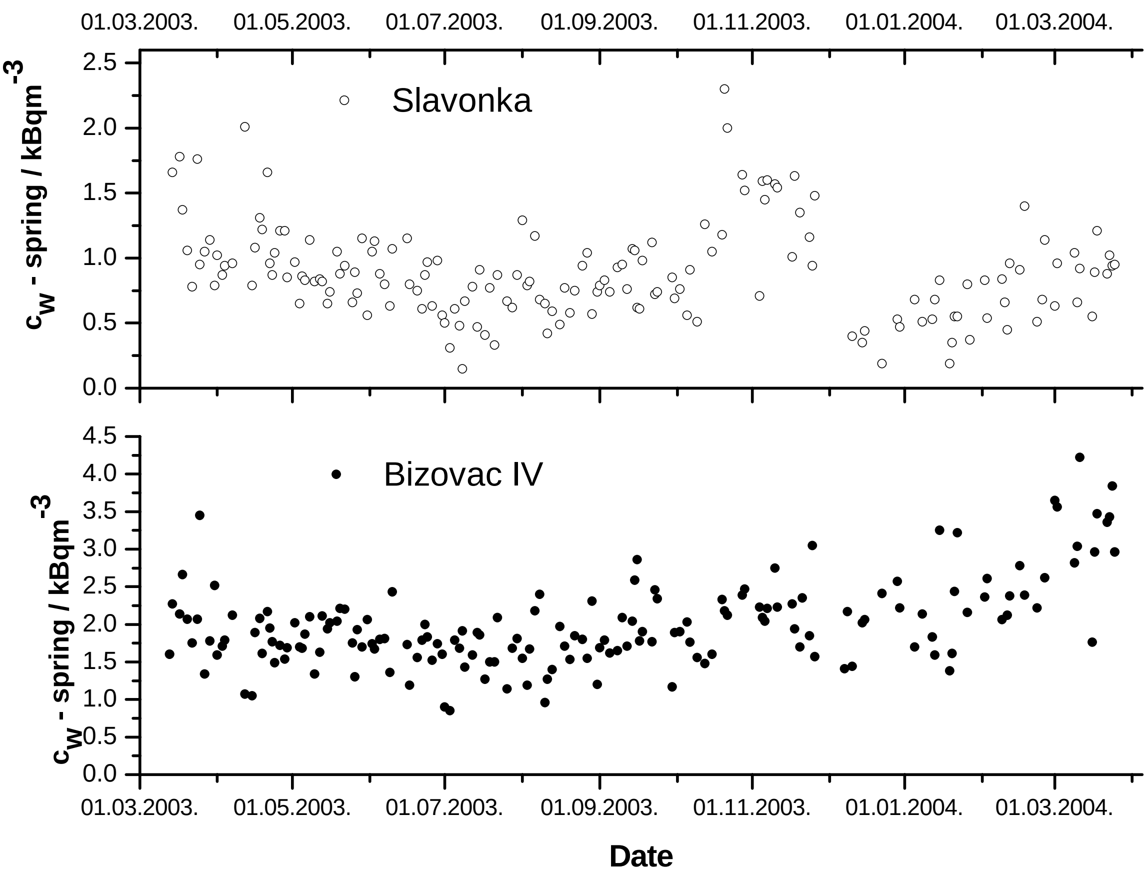

Figure 3. Seasonal variations of radon concentrations in waters from two different thermal springs ("Slavonka" and "Bizovac IV") in Bizovac spa (Spa No. 1 in Figure 1)

There might be a danger of inaccurate results and, consequently, wrong interpretations in case of infrequent grab-sampling of water; therefore, an investigation of seasonal radon variations was conducted. The water of two springs of Bizovac spa was sampled and the results are shown in Figure 3. The samples were taken every two days (on average) during a one-year period, and the average value of radon concentration for 170 measurements at springs "Slavonka" and "Bizovac IV" was 0.89 kBq m^{-3} and 1.94 kBq m^{-3}, respectively. The measurement error in the applied quick measurement procedure for the determination of radon in water was about 20%. The seasonal radon variations in the springs were not observed.

In order to assess the dose equivalent for workers and tourists, an integrated long-term measurement (during one year) of radon in the air with SSNT detectors were started in April 2004. The preliminary results for the four-month exposure of these detectors in spas 1, 2 and 4 (Figure 1) recorded the radon concentrations of 42.8, 651.4 and 79.0 Bq m^{-3}, respectively. Although, short- and long-term measurements were not performed at the same places (short-term were taken in the indoor swimming pools, whereas long-term were taken at the pay-offices at the entrances of the pools), it is obvious that there is a large discrepancy between the short- (about 30 Bq m^{-3}) and long-term (650 Bq m^{-3}) measurement results for spa 2. As it is known, an exposure of 1 hour to a radon gas concentration of 1 Bq m^{-3} at an equilibrium factor of 0.4 corresponds to an effective dose of 3.2 nSv [IAEA, 2003]. Hence, if we suppose the radon concentration in the spa No. 2 was 650 Bq m^{-3} during the whole year (which is the worst scenario) a worker, with 2000 working hours, would receive the effective dose equivalent of 4.16 mSv / y at the workplace (which is below the limit value of 6 mSv / y recommended by ICRP65). Likewise, the effective dose equivalent received by the workers in spas No. 1 and 4 would be 0.28 and 0.50 mSv / y, respectively.

CONCLUSION

Radon measurements in the air and geothermal water of nine Croatian spas were performed and the results of the radon concentrations in the air of indoor swimming pools are in the range from 17 to 90 Bq m^{-3}.

The radon concentrations measured in water samples taken from thermal springs and swimming pools are in the range from 2 to 94 kBq m^{-3}, and from 0.7 to 18 kBq m^{-3}, respectively.

The seasonal radon variations in geothermal water of two springs of Bizovac spa were not observed.

Estimation of the effective dose equivalent received by spa workers produce the results below 1 mSv / y (0.3 mSv / y for spa No. 1 and 0.5 mSv / y for spa No. 4), except for the spa No. 2, where the effective dose equivalent is 4.16 mSv / y (in the worst case).

The values of doses as well as radon concentrations in the air and geothermal water indicate that radon concentrations in Croatian spas are in acceptable range considering the recommendations for workplaces made by ICRP65.

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