Dissolved Gaseous Mercury and Radon Levels in Thermal Waters in Relation to Seismic Activity

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Abstract: Variations of radon (^{222}Rn) and dissolved gaseous mercury (DGM) in thermal water in relation to seismic activity are being studied in thermal springs at Hotavlje and Bled. The thermal spring at Hotavlje lies in the External Dinarides and Bled in the Southern Alps. The survey of radon and dissolved gaseous mercury has been under way since January 2003 at Hotavlje and since April 2003 at Bled. Radon concentration is measured every hour, while dissolved gaseous mercury is analysed monthly or immediately after an earthquake. Although some variations in concentrations of both gases have been evident, it is difficult to distinguish how much they are influenced by meteorological factors (atmospheric precipitation, barometric pressure and air temperature) and how much they are related to seismic activity.

Key words: radon (^{222}Rn), dissolved gaseous mercury (DGM), thermal water, seismic activity.

INTRODUCTION

Chemical monitoring of waters of deep origin, such as geothermal manifestations, mineral waters and deep (artesian) wells, have become widespread for earthquake prediction studies (WAKITA 1986; KING, 1994; SINGH, 1999; KOCH, 2003). Under the influence of tectonic stresses during the earthquake preparation, a zone of cracked rocks is formed in the area of the impending earthquake focal zone. The opening of microcracks in reservoir rocks due to decrease in pressure may enhance radon emanation. Carriers gases (CO_2, CH_4, N_2) are responsible for transporting trace gases (He, Rn, DGM) towards the Earth's surface, thus generating soil gas anomalies and chemical changes in groundwater (ETIOPE, 2002). A positive correlation between radon in groundwater and strain records has been found (WAKITA, 1985; ZHANG, 1999).

The first geochemical monitoring in Slovenia connected with seismic activity was carried out on thermal waters in the Ljubljana basin in the early eighties by measuring radon concentrations (Zmazek 2000). Since 1998 radon measurements were extended to other thermal waters in NW and E Slovenia (ZMAZEK, 2002A; POPIT, 2003; ZMAZEK, 2003) and in 1999 to soil gas along a presumed fault in the Krško basin (ZMAZEK, 2002b).

The radon and DGM survey has been under way since January 2003 at Hotavlje and since April 2003 at Bled. Both thermal springs are located in NW Slovenia, which is seismically the most active area. The aim of our research was to study measured chemical parameters in both thermal springs in relation to hydrological and meteorological parameters and to find possible connections with local seismic activity.

EXPERIMENTAL

Radon concentration is measured continuously on an hourly basis with a Barasol MC 450 probe (Algade, France). The detection unit is a solid-state silicon detector and the measurement is carried out by gross alpha counting. In addition to radon, water temperature and water pressure were also measured by the Barasol over the same time periods. The sensitivity of the radon detector is 50 Bqm^{-3}. Temperature is measured to an accuracy of ± 0.01 °C and pressure to ± 1 mBar.

DGM is analysed monthly or immediately after an earthquake. DGM is determined by purging 0.5 l of water sample with Hg-free nitrogen in a glass bubbler immediately after sampling. The flow of carrier gas is 500-600 ml/min. Volatile mercury species are purged for 10 min and collected on a sampling gold-coated silica trap kept at room temperature with the Hg-free argon. The sampling trap is immediately transferred to a double amalgamation CV AFS analyzer system (Tekran 2500). The detection limit of the procedure is 5 pg L^{-1}.

Meteorological and seismological data were provided by the Environmental Agency of the Republic of Slovenia

RESULTS AND DISCUSSION

Thermal water at Hotavlje rises from a 70 meter deep well at an average temperature of 20.4 ± 0.1 °C. The Barasol probe is installed in the well. The average DGM concentration between January 2003 and March 2004 was 0.73 ± 0.80 ng L^{-1} and average radon concentration (measured at the same time as DGM) was 70 ± 8 kBq m^{-3}. The time dependences displayed similar trends (Fig. 1). The correlation coefficient between radon and DGM concentration was 0.53. Five earthquakes with E / D ≤ 1.5 occurred in the vicinity of the thermal spring during the entire monitoring period. E is the distance from the epicentre to the measuring station, and D the strain radius that defines the area in which the effects of the earthquake are detectable (DOBROVOLSKY, 1979). The DGM concentration on February 12, 2003 was 2ó above the average value, while radon concentration was only a slightly above average. This increase could be due to the fact that in January and the beginning of February 2003 there was a small amount of precipitation. After that date, the DGM value decreased to below average. Radon concentration varied around the average value, and it decreased by 2ó below the average in March 2004, which could be considered as an anomaly. DGM concentration also declined at that time, but it did not reach the 2ó below the average value. This decrease in radon and DGM concentration could be influenced by the strong precipitation in February 2004 and also by the earthquake (M_L = 2.1 and E/D = 0.8) that occurred on February 11, 2004. A longer monitoring period is needed to be able to distingush changes of Rn and DGM concentration influenced by meteorological parameters from those earthquake related.

Thermal water at Bled wells out in the basin at Grand Hotel Toplice. It displays CO_2 bub-

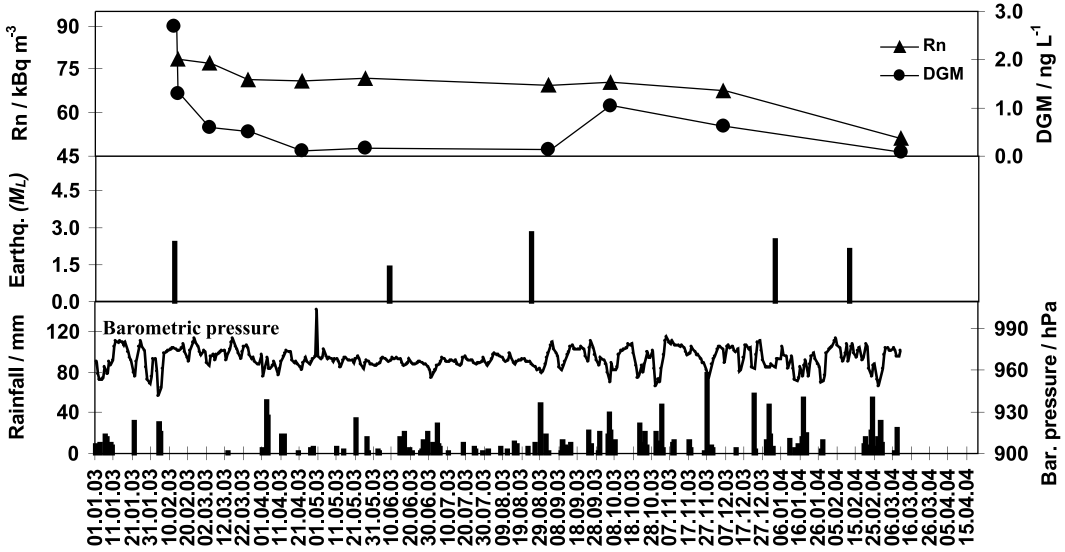

Figure 1: The top graph shows the radon and DGM concentrations at the thermal spring at Hotavlje between January 2003 and March 2004; the second shows earthquakes and the third rainfall and barometric pressure.

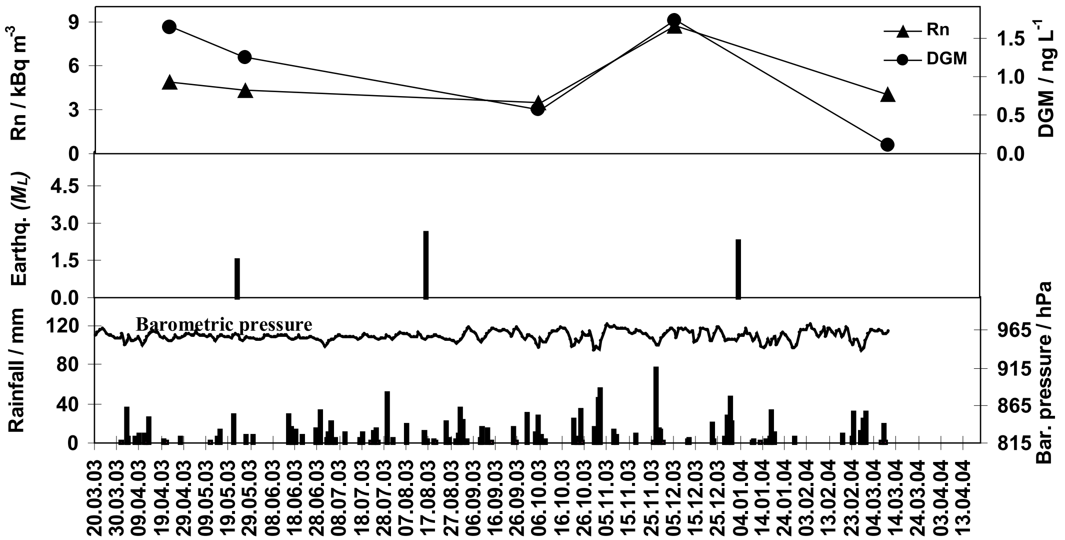

Figure 2: The top graph shows the radon and DGM concentrations at the thermal spring at Bled between April 2003 and March 2004; the second shows earthquakes and the third rainfall and barometric pressure.

bling activity and has an average temperature of 21.9 ± 0.2 °C. The Barasol probe is installed at the bottom of the collecting basin, from where the water is pumped into the swimming pool. The average radon concentration between April 2003 and March 2004 was 5 ± 2 kBq m^{-3} and the average DGM concentration 1.06 ± 0.70 ng L^{-1}. The correlation coefficient between radon and DGM concentrations was 0.67. The time dependences showed similar trends (Fig. 2), varying around the average values. No anomalous values were observed. Rainfall and barometric pressure did not greatly influence either measured chemical parameter. The possible influence of the three earthquakes that occurred during the April 2003 and March 2004 on radon and DGM variation is considered to be negligible, since the thermal spring was more than 2 strain radii outside the area in which effects of the earthquake are in principle detectable.

CONCLUSION

Radon and dissolved gaseous mercury concentrations are being monitored in two thermal springs located in NW Slovenia. Our research was focused primarily on changes in radon and DGM concentrations connected with the precursory period of seismic activity. Non-seismic interferences by meteorological parameters (average daily barometric pressure and daily atmospheric precipitation) were also considered.

At Hotavlje, some variations in concentrations of both gases have been evident, but it is difficult to distinguish influences of meteorological factors from those related to seismic activity. At Bled the variation of both chemical parameters was less significant. A longer monitoring period at both locations is needed to be able to study the relation to seismic activity. Because radon and dissolved gaseous mercury time series indicate similar trends, continuation of this study appears to be justified.

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