Isotope composition of precipitation in Croatia and Slovenia – Basic data for groundwater studies

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Abstract: Long-term records of isotope composition (^{3}H, δ^2H, δ^{18}O) for stations Zagreb and Ljubljana, as well as 2-year-long records in monthly precipitation samples at several stations along the Adriatic coast are presented. Special attention is paid to different patterns of seasonal variations at different stations and their correlation with the climate.

Key words: precipitation, tritium, stable isotopes, Adriatic coast

Introduction

Modern studies of groundwater resources and water cycle in nature include determination of isotope composition of groundwater, surface water and precipitation. As the recharge of groundwater is due to precipitation mainly, it is of utmost importance to know isotope composition of precipitation, and its seasonal and spatial variations. Monitoring of isotope composition of precipitation includes measurements of radioactive isotope tritium (^{3}H) and stable isotopes (^{2}H, ^{18}O) in monthly precipitation samples.

Isotope composition of precipitation at Zagreb (Croatia) and Ljubljana (Slovenia) have been performed since 1976 and 1980[1], respectively, within the Global Network for Isotopes in Precipitation (GNIP)[2] organized jointly by the Isotope Hydrology Section of the International Atomic Energy Agency (IAEA) and the World Meteorological Organization (WMO). Within the IAEA Co-coordinated Research Program "Isotopic Composition of Precipitation in the Mediterranean Basin in Relation to Air Circulation Patterns and Climate" the network has been extended to several stations along the Adriatic coast. Sampling of monthly precipitation has been performed since September 2000 at the following stations: Malinska on Krk Island, Zadar, Komiža on Vis Island, Dubrovnik, and Zavižan on Mt. Velebit (alt. 1594 m) in Croatia, and Portorož-Airport and Kozina in Slovenia (Fig. 1). The sampling sites are situated in areas characterized with three different types of climate:

Figure 1. Sampling sites in Croatia and Slovenia for monthly precipitation samples
Continental stations: Zagreb, Ljubljana. North-Adriatic stations: Portorož, Kozina, Malinska. Mid-Adriatic stations: Zavižan, Zadar. South-Adriatic stations: Komiža, Dubrovnik

(i) in the northern part continental climate prevails, (ii) in the mountainous middle part, mostly karst area, colder continental climate dominates, and (iii) the area along the Adriatic coast is controlled by the Mediterranean climate. The corresponding meteorological data (precipitation amount and mean monthly temperature) have been also recorded and correlated with the isotope data.

RESULTS AND DISCUSSION

Tritium activity concentrations in monthly precipitation are presented in Fig. 2. The presented results cover the period until the end of 2001 for maritime stations and Ljubljana, and until the end of 2002 for the Zagreb station, but the sampling has been continuing in 2003, too. Seasonal variations at the two continental stations (Fig. 1a) are typical for the continental stations of the Northern Hemisphere[2]. The minimal activities in winter approach in the last years the natural, pre-bomb tritium level. Seasonal variations at maritime stations of mid- and south-Adriatic (Fig. 1c, 1d) are less pronounced (reaching 1.4 Bq/L in summer) than those at the continental and north-Adriatic stations (Fig. 1a, 1b) that reach summer maxima of 2.2 Bq/L. No local tritium contamination has been observed.

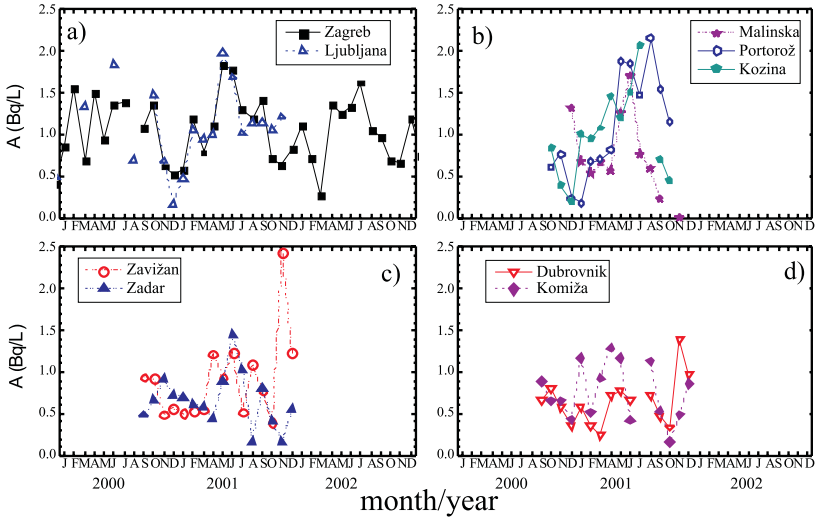

Figure 2. Tritium activity concentration in monthly precipitation samples. a) mid-Adriatic coast, b) south Adriatic, c) north Adriatic, d) continental stations

The stable isotopic composition of precipitation shows different patterns of seasonal variations at continental and maritime stations, as show examples in Fig. 3. The continental stations show larger seasonal variations in the stable isotope content (e.g., seasonal variations equal to 13 ‰ and 5 ‰ in $\delta^{18}O$ at stations Zagreb and Dubrovnik, respectively) due to larger temperature variations. The distinct altitude effect is observed at the station Zavižan (~0.2 ‰ in $\delta^{18}O$ per 100 m altitude difference). At this station the two types of climate, the Mediterranean and the continental, are mixing. The isotope pattern of precipitation reflects such a mixing: tritium distribution is close to the nearest maritime station Zadar (Fig. 2a), while the seasonal variations in stable isotopes are close to the continental pattern (Fig. 3a).

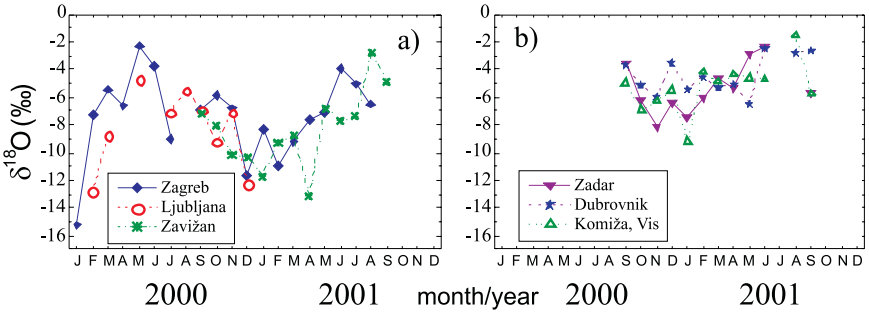

Figure 3. Seasonal distribution of $\delta^{18}O$ in monthly precipitation samples. a) continental stations, b) mid- and south-Adriatic stations

Correlation of $\delta^{18}O$ and $\delta^{2}H$ with mean monthly temperature (T) is good for all stations. In Fig. 4 we show the $\delta^{18}O$ *vs*. T correlation obtained for the period 2000-2001, and the values of the slope (K) and the correlation coefficient (R) for each station separately. For the Zagreb station, the long-term (1976-2001) correlation line is shown. The long-term slope for the Zagreb station is 0.3 ‰ $\delta^{18}O$ per °C[1]. Similar values are obtained for north- and mid-Adriatic stations, while for the south-Adriatic stations the slope is lower.

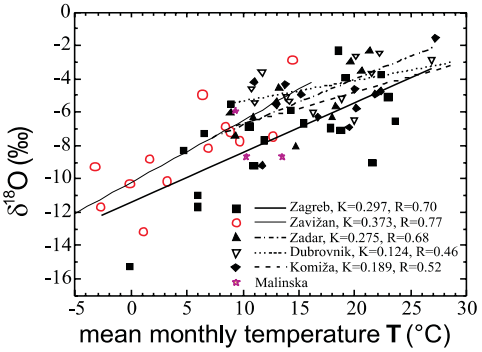

Figure 4. Relation between $\delta^{18}O$ and mean monthly temperature (T) at stations in Croatia
Symbols: monthly values. Lines: linear fits. K: slope of the linear regression line for each station, R: correlation coefficient

The correlation between $\delta^{18}O$ and $\delta^{2}H$ is very good for each station (Fig. 5) and obtained data fit very well to the "Global Meteoric Water Line", $\delta^{2}H = 8\ \delta^{18}O + 10$, shown as GMWL in Fig. 5. The observed scattering of the data at individual station in Figures 4 and 5 can be attributed to short monitoring period.

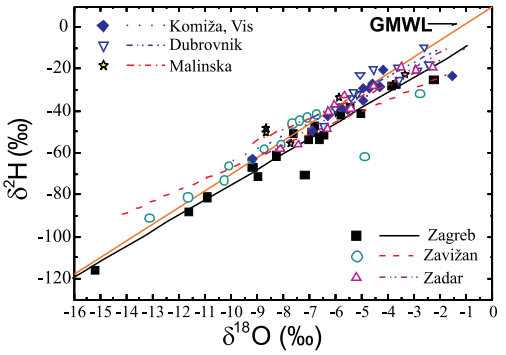

Figure 5. The relation between $\delta^{2}H$ and $\delta^{18}O$ at stations in Croatia
Symbols: monthly values. Lines: linear fits; e.g., local meteoric water lines. GMWL: Global Meteoric Water Line

CONCLUSIONS

We presented here isotope (^3H, δ^2H, $\delta^{18}O$) distribution in monthly precipitation at several continental and maritime stations in Croatia and Slovenia for the period 2000-2002. Tritium activity concentration at the north Adriatic coast is similar to that at the typical continental station Zagreb, while at the south-Adriatic stations the seasonal variations are less pronounced and the mean yearly activities are lower. Long-term tritium record (since 1976 in Zagreb) and the recent data for the maritime stations show that the winter tritium activity concentrations in the atmosphere approach the natural level, which was established before the bomb-tests after the World War II.
Stable isotope content of precipitation reflects the temperature distribution at the particular site and the temperature coefficient ($\delta^{18}O$ *vs*. T) has been calculated for each station. Relation between $\delta^{18}O$ and δ^2H is close to the Global Meteoric Water Line.
For more detailed analysis of interactions between continental air and maritime air, seasonal variations, relation between isotope content and meteorological data as well as comparison with other Mediterranean stations, we have to continue with isotope measurements for, at least, next two years.

Acknowledgements

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