



Stable isotope compositions of dissolved inorganic carbon and water as indicators of basin and in-stream processes: the Vistula River, Poland

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The Vistula is the second largest tributary and a major source of pollutants to the Baltic Sea. Unlike other large European rivers, the Vistula is only partly regulated, especially in its middle reaches where the river is not channelized and is well connected to floodplains. This study was aimed at observing temporal and spatial patterns of $\delta^{13}\text{C}_{\text{DIC}}$, $\delta^{18}\text{O}$ and $\delta^2\text{H}$ in waters of the Vistula River and selected tributaries and to relate them to biogeochemical and hydrological processes as influenced by anthropogenic impacts. The isotopic analyses were accompanied by measurements of water temperature, electric conductivity, dissolved oxygen, pH, alkalinity/DIC and pCO_2 . Longitudinal profiles of the Vistula water characteristics were taken twice: in summer and in late autumn. Water samples were also collected over one year at two cross sections: in the upper reach and at river mouth. Additionally short-scale temporal and spatial variability of the measured parameters was observed in the urban section of the river in Cracow.

Isotopic signature of DIC in riverine environments is a useful indicator of the overall carbon budget. The observed patterns of $\delta^{13}\text{C}_{\text{DIC}}$ and of other water characteristics indicate carbonate weathering as the main source of DIC in the Vistula River system. Low $\delta^{13}\text{C}_{\text{DIC}}$ values in the upper reach of the river reflect in-stream processing of large loads of organic matter from wastewaters. Further downstream isotopic signature of DIC stabilizes around the range -12 to -11 per mill as soil-derived DIC pool overwhelms anthropogenic contributions in the semi-natural middle reach of the river with large self-purification capacity. Carbon cycling in the lower reach of the Vistula is disturbed by the Wloclawek Reservoir where decomposition of fine deposited or-

ganic matter is enhanced. Influence of the reservoir on riverborne carbon processing is probably related to its hydrological and meteorological conditions resulting in large variability of water characteristics downstream the reservoir as recorded at the Vistula mouth. Influence of the impoundments on carbon cycling is also reflected by large range of diurnal $\delta^{13}\text{C}_{DIC}$ variability in summer at the Cracow reach of the river.

Stable isotope composition of the Vistula waters reflects several processes operating at the basin scale, such as mixing of water masses of different origins, partial evaporation and seasonally varying contribution of surface runoff to baseflow. The measured isotopic composition of the Vistula and its tributaries waters varied in a considerably wide range (from about -10.0 to -7.8 per mill for $\delta^{18}\text{O}$ and from -70 to -57 per mill for $\delta^2\text{H}$). This variability, more pronounced in summer, has its origin in precipitation and recharge patterns in the catchment as well as in the diversity of hydrological characteristics of rivers comprising this river system. Substantial seasonality of $\delta^{18}\text{O}$ and $\delta^2\text{H}$ in precipitation over the catchment is also observed in river waters, although with considerably smaller amplitude.