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# Long-term tritium monitoring to study river basin dynamics: case of the Danube River basin

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During the last five decades, isotope concentrations (O-18, D, tritium) have been extensively measured in precipitation, surface- and ground-waters to derive information on residence times of water in aquifers and rivers, recharge processes, and groundwater dynamics. The unique properties of the isotopes of the water molecule as tracers are especially useful for understanding the retention of water in river basins, which is a key parameter for assessing water resources availability, addressing quality issues, investigating interconnections between surface- and ground-waters, and for predicting possible hydrological shifts related to human activities and climate change. Detailed information of the spatial and temporal changes of isotope contents in precipitation at a global scale was one of the initial aims of the Global Network of Isotopes in Precipitation (GNIP), which has provided a detailed chronicle of tritium and stable isotope contents in precipitation since the 1960s. Accurate information of tritium contents resulting of the thermonuclear atmospheric tests in the 1950s and 1960s is available in GNIP for stations distributed world-wide. Use of this dataset for hydrological dating or as an indicator of recent recharge has been extensive in shallow groundwaters. However, its use has been more limited in surface waters, due to the absence of specific monitoring programmes of tritium and stable isotopes in rivers, lakes and other surface water bodies. The IAEA has recently been compiling new and archival isotope data measured in groundwaters, rivers, lakes and other water bodies as part of its web based Water Isotope System for Data Analysis, Visualization and Electronic Retrieval (WISER). Recent additions to the Global Network of Isotopes in Rivers (GNIR) contained within WISER now make detailed studies in rivers possible.

For this study, we are re-examining residence time estimates for the Danube in central Europe. Tritium data are available in GNIR from 15 Danube monitoring sites in Germany, Austria, Slovakia, Hungary, Slovenia and Serbia. Most of these sites have continuous stable isotope and tritium records of over 10 years. The longest and most complete record of isotopes in precipitation and the Danube is from Vienna, which contains continuous tritium and stable isotope records since the 1960s. Previous estimates of residence time using tritium in the upper Danube are about 3-5 years (Rank et al., 1998, Yurtsever, 1999). However, these estimates were based on a tritium record up to 1995 and some of the parts of the observed time series were not represented well by the models. We are now re-evaluating the upper Danube residence time using a complete record covering the entire tritium transient created by atmospheric nuclear weapons testing (1964-2005). Several combinations of lumped parameter models are being tested using MULTIS and LUMPY. The models assume two main water components in parallel; a "fast" component that represents water with a short residence time (less than one year), resulting from recent precipitation and fast runoff, and a "slow" or "old" component representing discharge of older groundwaters to the river. Preliminary results obtained during this exercise, as well as those determined using other environmental tracers, are providing new insights into the age distribution of water in the upper Danube. Initial calculations with the complete tritium record for Vienna suggest that the mean residence time is substantially older than previous estimates. This study also demonstrates the value of the GNIP/GNIR/WISER dataset for examining dynamics of surface water systems.