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Runoff characteristics of the upper Danube basin: conclusions from long-term environmental isotope records

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The Danube, with a catchment area of 817 000 km^2, a length of 2857 km and a long-term discharge at its mouth of about 6500 m^3/s is the second largest river in Europe. The catchment area at Vienna (Upper Danube Basin) is about 103 000 km^2. The mean annual flow rate is around 1900 m^3/s, with a seasonal variation typical of alpine rivers (a minimum of 1300 m^3/s in November and a maximum of 2700 m^3/s in July.

The catchment upstream of Vienna can be divided into three sectors:

- The sector upstream of Passau: This sector represents about one half of the study area. The mean annual flow rate at Passau is around 670 m^3/s (35 % of the flow rate at Vienna), with a maximum in March (880 m^3/s) and a minimum in October (520 m^3/s). The mean altitude of this sector is relatively low compared to the Alpine regions. Groundwater discharge is the main mechanism forming base flow in this part of the river. The period of high water is mainly controlled by precipitation and melting during late winter and early spring.
- The catchment area of the Inn river: The Inn, which enters the Danube at Passau, has a hydrological regime typical of alpine rivers. It is the most important tributary in this sector, contributing 725 m^3/s (38 % of the flow rate at Vienna) and thus doubling the flow rate when it merges in the Danube. Maximum flow rates are observed in June/July (1200 m^3/s) and a minimum in January (400 m^3/s).
- The sector between Passau and Vienna. Along this stretch other alpine rivers,

with a mean annual flow rate of about 505 m^3/s (27 % of the flow rate at Vienna), enter the Danube. These rivers are characterized by a hydrological regime similar to that of the Inn, with maximum flow rates in May/June (800 m^3/s) and a minimum in January (270 m^3/s).

The amount of precipitation in the Upper Danube Basin shows a distinct gradient with the altitude. It rises from 650-900 mm/a in the lowland areas to more than 3000 mm/a in the high mountain ranges exposed to the west and north. For the stations located in the lowland areas, summer precipitation represents more than 60 % of annual precipitation. For high-altitude stations, winter precipitation is more important, although it is stored on the surface as snow cover until spring and summer, when melting takes place.

Isotope signals in river discharge can potentially contribute to better understanding of the continental portion of the hydrological cycle including information such as water origin, mixing history, water balance, water residence times, surface-groundwater exchange, and renewal rates. Coupled measurement of isotope fluxes and volumetric discharge is also useful for tracing progressive changes in basin hydrology related to climate or land use changes, and can be applied as a diagnostic variable for constraining atmospheric circulation models and hydrological models.

The ^3H and ^{18}O high-resolution time series of the Danube at Vienna is one of the worldwide longest of a large river (RANK and PAPESCH 1996, RANK et al. 1998).

It demonstrates that not only short-term signals but also long-term changes of isotope ratios in precipitation are transmitted through the catchment and can be detected in the river water. Thus stable isotopes – ^2H, ^{18}O – can be used as independent tracer to simulate transport processes in river systems. Because of the relatively low amplitude of long-term changes of $\delta^{18}O$ (δ^2H) in precipitation and in river water, this approach is useful to assess the mean transit time of the fast component of the flow. For the Danube, the mean transit time derived from comparisons of $\delta^{18}O$ trend curves for precipitation and river water at Vienna is around 1 a.

The different isotopic behaviour of tributaries from different parts of the catchment area reflects differences in the geographical and hydro-meteorological parameters, like altitude of the drainage areas, spatial and temporal precipitation distribution, source of air moisture, infiltration characteristics, residence times of ground- or lake waters in the drainage areas, evaporation processes and others. The long-term changes in the isotope records - e.g. increase of $\delta^{18}O$ during the eighties – may help to trace hydro-climatic changes in these areas, which otherwise would be difficult to detect. The main reason for this increase during the eighties is probably an increase of the environmental temperature. But also poor snow covers in the drainage areas during some winters and changes in the winter/summer distribution of precipitation play a certain role for the long-term changes of isotope records

The time series of tritium in the Danube were modeled using the lumped parameter approach. The comparison of measured and modeled ^{3}H contents in the river revealed that the best fit which could be obtained (mean residence time of 3 a) is still not satisfactory.

Short-term ^{3}H peaks in the Danube, probably due to releases from nuclear power plants, offer a possibility to study the travel velocity and the dispersion process of a pollution pulse along the river. .

References

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