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title: **Using environmental tracers to characterize recharge conditions in the strongly exploited aquifer system of the North China Plain**

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INTRODUCTION AND STUDY AREA

The North China Plain (NCP) is one of the most densely populated regions in eastern Asia. Increasing exploitation of the NCP aquifer system has led to a decline of groundwater levels since the 1970s. Despite several studies addressing the water balance in the NCP (e.g. Chen et al., 2005; Kendy et al., 2004), considerable uncertainty with regard to recharge mechanisms and rates as well as vertical and horizontal flow velocities remains. In this study, we employ the ^{3}H–^{3}He method to determine the age structure in the recharge area. The study focuses on the piedmont plain around the city of Shijiazhuang. It is based on a ~120 km transect starting at the eastern rim of the Taihang Mountains, crossing the piedmont plain in south-eastern direction, and extending into the central part of the NCP (Fig. 1). This section is part of a longer transect sampled for a paleoclimate study (Kreuzer et al., 2009).

Figure 1. Map of the study area in the North China Plain showing sampled wells

RESULTS AND DISCUSSION

Although we only have a composite age profile for the entire recharge area, it seems possible to derive an overall vertical velocity and thus a recharge rate from the slope of the age-depth relationship (Fig. 2), where the depth of the saturated zone is used to account for the fact that ^{3}H-^{3}He ages only reflect the groundwater residence time in the saturated zone.

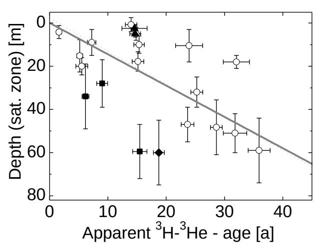

Figure 2. Vertical profile of the apparent ^{3}H–^{3}He age versus saturated depth

Excluding a few wells from the mountain area and a depression cone around Shijiazhuang, linear fits to the "regular" samples (open symbols) yield a well-defined slope of about 1.5 m/a.

This value reflects the relative vertical velocity by which the water moves ahead of the falling water table and hence the rate of annual water input. This input is due to areally distributed infiltration and can be translated into a recharge rate of 0.3 m/a (using an effective porosity of 0.2).

Despite this substantial active recharge, the system is in net discharge because the pumping rate equivalent to about 0.5 m/a exceeds the recharge rate. The deficit between pumping for irrigation and recharge of about 0.2 m/a explains the mean observed groundwater table descent of ~ 1 m/a. The $\delta^{18}O$-values of the modern samples show a decreasing trend with ^{3}H–^{3}He age, i.e., an increasing trend with time over the past 40 a. This recent enrichment trend is probably the result of the anthropogenic impact on the recharge regime, such as less seasonality in the recharge, a higher contribution of enriched water from the adjacent mountain area, or evaporation during flood irrigation in the pumping and re-infiltration cycles. Unusually high ΔNe values in some of the modern samples from the recharge area may be related to increased seasonal water table fluctuations due to pumping.

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