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A straightforward estimation of the spatial distribution of groundwater transit times in catchments.

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Quantification of the groundwater transit time distribution is fundamental for the prediction of the fate of diffuse pollution in catchments. We propose a straightforward method to estimate the spatial and statistical distribution groundwater transit time in lowland catchments with homogeneous, horizontal aquifers. The method is based on the notion that in an isotropic aquifer, the age of a water parcel increases logarithmically with depth. Under this assumption, the groundwater transit time depends on groundwater recharge rate (N), aquifer dimensions (thickness (D) and width (X)), aquifer porosity (n), and distance from the divide. The mean transit time $T$of groundwater infiltrating in a model gridcell is given by:

$$\bar{T} = D \cdot \frac{n}{N} \left(\frac{x_2}{\Delta x} \ln \left(\frac{X}{x_2} \right) - \frac{x_1}{\Delta x} \ln \left(\frac{X}{x_1} \right) + 1 \right)$$

Where x_1 and x_2 are the distances from the divide to the respective upgradient and downgradient cell boundaries and Δx is the gridcell size.

The method was tested and applied to the 901 km^2 large Ahja catchment in south-eastern Estonia (Mourad, 2008). Using spatial data on land cover, drainage network and aquifer properties and a simple water balance model to estimate the groundwater recharge rate, we calculated the spatial distribution of groundwater transit time at a spatial resolution of 100 m. For the lower-order streams (Strahler stream order ≤ 3), we related the in-stream logtransformed dissolved inorganic nitrogen (DIN) concentration during baseflow conditions (summer 2002) to the calculated proportion of groundwater from agricultural areas with transit times between 12 and 50 years. The period between 12 and 50 years before 2002 represents the period that fertilizer application in Estonia was considerably more extensive than in the periods before and after. The relation was positive and statistically significant ($n = 37$; $R^2 = 0.49$; p-value: 0.000). This case study illustrated that it is not only important, but also readily possible, to derive information on groundwater transit times and implement this information in hydrology-based models of diffuse pollution at the catchment scale.

References

Mourad, D.S.J. 2008. Patterns of nutrient transfer in lowland catchments – A case study from northeastern Europe. Utrecht: KNAG, Netherlands Geographical Studies 370.