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Determination and validation of age structures as an improved measure of hydrological dynamics

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The distribution of mean residence times is often used for quantifying aquifer vulnerability or for making predictions of travel times in case of environmental accidents. In general, the mean residence time is given as a single measure of hydrological dynamics based on the application of exponential-, dispersion- or piston-flow models. In most cases, however, the distribution of residence times is more complex. A method is proposed for deriving complex multi-peak age structures using analytical element models (AEM). HINKE & SNYDER (1997) used chlorofluorocarbons in combination with particle tracking to determine the presence or absence of modern water. This approach has been adapted to analytical element models (STRACK & HAITJEMA, 1981; HAITJEMA, 1985) and extended to a quantitative distribution of flow volumes versus respective residence times. The natural flow system is described with an AEM representing aquifer information (transmissivity, porosity) and boundary conditions (recharge rates and location of rivers, drains and wells). The position of a high number of particles is tracked and analysed in order to define flux inspections lines at specific flow isochrones (e.g. 1 day, 30 days, 1 a, 5a, $>$50 a). From the flow volumes passing these isochrones detailed age structures can be derived. This approach is validated using age information from several environmental tracers with complementary dating ranges. This approach has been applied to the characterization of an alluvial aquifer in the Southern Black Forrest, the ‘Zartener Becken’. A multi-peak distribution of residence times was determined with maxima at 70 days, 2-4 years and more than 15 years. The modelled output was validated with several environmental tracers: time series of oxygen-18 have been used to quantify the percentage of flow with residence times less than a year, chlorofluorocarbons (CFC-11, 12, 113) and SF_6 provided information on residence times ranging from a few to about 50 years. The validation for

further age ranges (more than 50 years) – while being irrelevant and therefore omitted – could be included into this approach using Carbon-14 data. With these results it is possible to describe complex and multi-peak age distributions. Age structure data are more detailed than bulk mean residence times derived from exponential-, dispersion-, and piston flow models and are of specific use in terms of vulnerability and pollutant travel times.

References

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