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Integrating residence time data in mixing cell modeling – Application to the Lower Kuiseb Dune area

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With few exceptions, only limited hydrologic data are available in regions with the highest scarcity of water. Especially in basins with limited data on hydrogeological structure, it is difficult to accurately characterize groundwater flow systems and their recharge sources. Therefore, estimation of available water resources in drylands requires methods that are based on existing data and on information that can be obtained with affordable efforts. Even in desert regions chemical and isotope data are often available or can be obtained quickly.

In this study a mixing cell approach was extended by a method incorporating mean cell residence times derived from 14C to further constrain and validate the modeling results. This extended approach was used to model the groundwater system of the Lower Kuiseb Dune area in Namibia. The Kuiseb is a 560 km long ephemeral river crossing the Namib Desert from east to west. Transmission losses from the riverbed during flood events are an important source of groundwater recharge to the underlying aquifer system. Hydrochemical data from 13 wells in the area were used. End members were identified as sources for groundwater found in the Lower Kuiseb, including inflow from the crystalline basement plateau north of the Kuiseb as well as floodwater from the Kuiseb River. A conceptual groundwater recharge and flow model was developed, and then inverse mixing cell modelling was carried out using hydrochemical tracers. This approach generally allows for several possible solutions and leads to model equifinality. After completing the inverse modeling, a forward mixing cell model was developed by varying the mean residence time of each cell to fit calculated 14C data to the measured 14C data.

With the additional use of 14C in the mixing approach the number solutions could be narrowed down for most of the different cells. As a important result it was possible to calculate the fractions of floodwater in the different cells of the aquifer beneath the Kuiseb. The floodwater fraction was shown to be between 85.2% and 98.2% for the upper aquifer cells and between 61.0% and 75.2% for the lower aquifer cells. This results show also that there is an important amount of recharge by sources except floodwater.

This new approach joins previously developed methods solely based on conservative mixing or residence time optimization. Is very useful in reducing equifinality in the mixing cell modelling and gave important and new insights in the sources of groundwater recharge in the Lower Kuiseb aquifer system.