GASIR Jahrestagung der Arbeitsgemeinschaft stabile Isotope e.V.
15. – 17. Oktober 2014

Hydrologie und Hydrogeologie

Artificial deuterium labeling for a quantification of groundwater recharge in semi-arid regions

Matthias Beyer[1,3], Marcel Gaj[1], Paul Koeniger[1], Josefina Hamutoko[2], Heike Wanke[2], Christoph Lohe[1] and Thomas Himmelsbach[1]

[1] Federal Institute for Geosciences and Natural Resources (BGR), Hanover, Germany
[2] University of Namibia (UNAM), Windhoek, Namibia
[3] Institute of Water Resources Management, Hydrology and Agric. Hydr. Engineering, Leibniz University Hanover, Germany

Proper estimations of groundwater recharge rates are essential for a sustainable management of water resources. Numerous methods are available (Scanlon et al., 2002); however, their applicability and reliability varies greatly depending on available data, spatiotemporal scales and climatic conditions within the studied area. The peak-displacement method (Saxena & Dressie, 1984; Leibundgut et al., 2009) has been used extensively to estimate groundwater recharge rates in regions, where a distinctive seasonal variation of the stable isotopes oxygen-18 (^{18}O) and deuterium (^{2}H) in precipitation is present (Saxena, 1984; Adomako et al., 2010) . In semi-arid climates with only one rainy season this prerequisite is eventually not fulfilled; hence this simple and reliable method cannot be applied. In this study we present results of an artificial deuterium labeling experiment ($^{2}H_2O$, 70%) in order to estimate groundwater recharge with the peak-shift method and characterize water movement during and after a synthetic rain event.

The study was carried out in the framework of the SASSCAL project (Southern African Science Service Centre for Climate Change and Adaptive Land Management) in the Niipele catchment of the Cuvelai-Etosha Basin in Northern Namibia. Experiments were carried out at two locations with different soil and vegetation types: A forest site ('Eenhana') with deep sandy soil and a shrub-/woodland site ('Okongo') characterized by dark loamy sand underlain by a thick layer of calcrete. At both locations, soils were first saturated to trigger typical rainy season conditions and avoid immediate evaporation of the deuterated water. Subsequently, 500 ml of $^{2}H_2O$ was applied homogenously over a 0.25 m^2 test plot at 25 cm depth. Finally, a 10 mm artificial rain event was applied onto the plot. Soil samples were collected every 10 cm to a maximum depth of 7.4 m with an Eijkelkamp hand auger after 1, 2 and 10 days as well as after the rainy season. From these, soil water was extracted in the laboratory and subsequently analyzed for $\delta^{2}H$ concentrations using a Picarro L2120-i cavity-ringdown (CRD) water vapor analyzer after vaporization and with a Los Gatos DL 100 directly in the field. Additionally, gravimetric water content and soil hydraulic properties were determined in the lab.

We found groundwater recharge rates of 9mm at Eenhana and 4mm at the Okongo site for the rainy season 2013/2014 (total rainfall at both sites: ~600 mm). The injected deuterium peaks travelled from 2.3 m to 5.5 m and from 0.5 to 0.9 m, respectively. Extremely high saturated conductivities (1700 cm/d and 1000 cm/d) were found at both sites. Potential for groundwater recharge, however, is markedly reduced at Okongo due to presence of the calcrete layer. The study shows that through the injection of $^{2}H_2O$, the peak-shift method can successfully be applied in semi-arid environments. Even with small amounts of $^{2}H_2O$ applied, the tracer peak could be detected after one whole rainy season. The experiments demonstrate a valuable, hence cheap and reliable, technique to estimate groundwater recharge rates in semi-arid regions and areas with low data availability. Further validation of the method regarding spatial and temporal scales is needed.

Adomako, D., Maloszewski, P., Stumpp, C., Osae, S., & Akiti, T. T. (2010). Estimating groundwater recharge from water isotope (δ 2 H, δ 18 O) depth profiles in the Densu River basin, Ghana. *Hydrological Sciences Journal*, *55*(8), 1405–1416. doi:10.1080/02626667.2010.527847.

Leibundgut, C., Maloszewski, P., & Kuells, C. (2009). *Tracers in Hydrology*. Chichester, UK: John Wiley & Sons, Ltd. doi:10.1002/9780470747148.

Saxena, R. K. (1984). Estimation of groundwater recharge and moisture movement in sandy formations by tracing natural oxygen-18 and injected tritium profiles in the unsaturated zone. *Nordic Hydrology*, 235–242.

Saxena, R. K., & Dressie, Z. (1984). Estimation of groundwater recharge and moisture movement in sandy formations by tracing natural oxygen-18 and injected tritium profiles in the unsaturated zone. In *IAEA Symposium* (pp. 139–150).

Scanlon, B. R., Healy, R. W., & Cook, P. G. (2002). Choosing appropriate techniques for quantifying groundwater recharge. *Hydrogeology Journal*, *10*(1), 18–39. doi:10.1007/s10040-0010176-2.