Geophysical Research Abstracts
Vol. 20, EGU2018-11153, 2018
EGU General Assembly 2018

Tracing water through catchments using tritium

Uwe Morgenstern (1), Mike Stewart (2), Jeff McDonnell (3), Ian Cartwright (4), and Laurent Pfister (5)

(1) GNS Science, Hydrogeology, Lower Hutt, New Zealand (u.morgenstern@gns.cri.nz), (2) Aquifer Dynamics and GNS Science, Lower Hutt, New Zealand (M.Stewart@gns.cri.nz), (3) School of Geosciences, Global Institute for Water Security, National Hydrology Research Centre, University of Saskatchewan, Canada and Northern Rivers Institute, University of Aberdeen, Scotland, UK (jeffrey.mcdonnell@usask.ca), (4) School of Earth, Atmosphere and Environment, Monash University, Clayton, Vic. 3800, Australia (ian.cartwright@monash.edu), (5) Luxembourg Institute of Science and Technology, Environmental Research and Innovation Department, Catchment and Eco-hydrology Group, Belvaux, Luxembourg (laurent.pfister@list.lu)

Two fundamental issues have compromised our mechanistic understanding of water flow dynamics through hydrologic (groundwater) systems: water celerity versus velocity, and time-variance of transit times. Using hydrographs and/or hydraulic heads allows only for model calibration based on pressure transmittance through catchments in response to rainfall (celerity). However, water and contaminant transport are determined by how quickly water moves through catchments (velocity)1. Time-variable tracer (i.e. stable isotope) input signals (seasonal or events) and their subsequent damping in ground or stream water have been used for decades to obtain transit times of the water through catchments. Use of such signals requires high-frequency (hourly/daily/weekly measurement of the tracer input and output from the hydrologic system (rain vs. stream, spring, well outflows) over time-frames of several years. However, over seasons or through rain or drought events, hydrologic systems are usually not at steady-state, complicating the estimation of transit times from input-variable signals. In addition to the high-frequency sampling, further disadvantages of time-variable signals are that they cannot 'see' water older than c. 4-5 years.

Using cosmogenic tritium as a tracer can help to overcome these problems. The age information lies in the decrease of tritium through radioactive decay at the state (time) of the hydrologic system when the sample was collected, and the half-life of tritium of 12.32 years allows estimation of mean transit times (MTT) of up to 200 years. When we collect a sample at a different state of the hydrologic system, say when younger water is discharged, then the tritium concentration will be higher, and vice versa. With only one measurement in time and space, we can characterise the hydrologic system, integrated over the whole catchment and flow-time, in its state at the time of sampling. This also allows understanding of hydrologic systems at various states2 and on large scales (rivers), with only single measurements.

Due to complexity of underground water flow paths it is difficult to assess the controls on MTT through catchments. Tritium dating of river water from c. 400 sites throughout New Zealand shows good correlation between geology and MTT of the water discharges from the various geologic formations. Basement rock catchments (greywacke, schist) discharge very young water of MTT <1 year, sand-, mud-, limestone catchments discharge moderately old water of MTT 3-50 years, and porous ignimbrite catchments discharge very old water of up to MTT > 100 years. Geology, through varying hydraulic properties, appears to be a main control on MTT. Our work shows the potential for tritium to provide new insights in catchment hydrology.

1 McDonnell and Beven (2014), Debates—The future of hydrological sciences: A (common) path forward? A call to action aimed at understanding velocities, celerities, and residence time distributions of the headwater hydrograph, Water Resour. Res., 50, 5342–5350
2 Morgenstern et al. (2010). Dating of streamwater using tritium in a post nuclear bomb pulse world: Continuous variation of mean transit time with streamflow. Hydrology and Earth System Sciences. 14:2289-2301.