International groundwater event

Henry Darcy Lecture 2009 & Isotopes and tracers in hydrology

Thursday 5 November 2009
13.30–18.00 hrs

VU University Amsterdam
Institute of Education of the Medical Centre
(Gebouw Medische Faculteit)
Van der Boechorststraat 7
1081 BT Amsterdam (▶Map)
Room A301

Tentative programme

13.30	Welcome and Introduction to environmental isotopes and tracer hydrology *– Professor Stefan Uhlenbrook, VU University Amsterdam and UNESCO-IHE Institute for Water Education*
14.00	**Environmental Tracers in Modern Hydrogeology: Reducing Uncertainty in Ground Water Flow Estimation** *– Dr. Peter Cook, 2009 Darcy Lecturer, CSIRO Land and Water*
15.00	Break
15.20	Multitracing of artificially recharged Rhine River water in the coastal dune aquifer system of the Western Netherlands *– Dr. Pieter Stuyfzand, KWR and VU University Amsterdam*
16.00	Degassing of $^{3}H/^{3}He$, CFCs and SF_6 by denitrification in the Netherlands *– Dr. Ate Visser, Deltares*
16.30	Reception

Free entrance, but registration required: vincent.post@falw.vu.nl.

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2009 Darcy Lecturer: Peter Cook

The 2009 Henry Darcy Distinguished Lecturer Peter Cook, Ph.D., is a senior principal research scientist with CSIRO Land and Water. He received a B.A. in geography from Australian National University in 1986 and a Ph.D. in Earth sciences from Flinders University of South Australia in 1992. Between 1992 and 1994, Cook carried out post-doctoral research at the U.S. Department of Energy and University of Waterloo, Canada, before returning to Australia. Cook's research interests span the fields of ground water hydrology, ecohydrology, isotope hydrology, and unsaturated zone flow, but have mostly focused on the use of environmental tracers, including the integration of tracer and hydraulic methods. Specific research projects have involved estimation of aquifer recharge, quantification of ground water discharge to streams and wetlands, prediction of stream and ground water salinisation rates, and assessment of ground water-dependent ecosystems. He has cowritten books on environmental tracers and ecohydrology.

"Environmental Tracers in Modern Hydrogeology: Reducing Uncertainty in Ground Water Flow Estimation" is the title of Cook's Darcy Lecture. Environmental tracers can reduce uncertainty of hydrogeological predictions in all environments, but are particularly valuable in highly heterogeneous systems, where spatial variations in aquifer hydraulic conductivity may range over several orders of magnitude, and so hydraulic approaches are inherently uncertain. Despite the rapid growth of environmental tracers during the past few decades and their adoption by the research community, they are not widely used in routine hydrogeological assessments. This lecture illustrates the potential of environmental tracers through illustration using field sites in North America and Australia, and discusses methods for bridging the gap between research and practice.

Quantitative hydrogeology is often traced back to Darcy who, in the mid-19th century, observed a linear relationship between flow rate and hydraulic gradient, the proportionality constant later becoming known as hydraulic conductivity. Even today, ground water flow rates are most frequently determined as the product of measured hydraulic gradients and hydraulic conductivities, the latter determined using pumping tests. Although the last 150 years have seen considerable improvement in interpretation of pumping tests, and understanding of isotropy and heterogeneity, estimation of aquifer hydraulic conductivity values at appropriate scales remains a significant source of uncertainty. Within the past few decades, however, environmental tracer methods have been developed that can provide independent estimates of ground water flow rates, which have helped to overcome some of the problems associated with hydraulic approaches, particularly in heterogeneous systems. However, despite the ability of environmental tracers to constrain conceptual models of ground water systems and significantly reduce uncertainties in prediction, the methods are underrepresented in hydrogeological textbooks and are still not widely used for hydrogeological assessment.

There are a large number of environmental tracers, all with different properties and hence different potential uses. While environmental tracers that readily undergo chemical reactions can sometimes be used to determine reaction pathways, tracers that behave more conservatively may yield information on transport processes. Calculation of ground water residence times is one of the more common applications. Tracers that can be used for this purpose include radioactive isotopes, which decay at a known rate (e.g., 14C, 3H), tracers that are produced and accumulate in the subsurface (e.g., He), and tracers that are neither produced nor consumed in the subsurface, but have a variable and well-known input history (e.g., CFCs, SF6). Ground water residence times in unconfined aquifers can be used to infer aquifer recharge rates, whereas in confined aquifers they allow quantification of horizontal flow velocities. Tracers present in much higher concentrations in ground water than in surface water have great potential for quantifying ground water discharge to surface water. In particular, dissolved gas tracers such as radon and helium will rapidly volatilise from surface water and so provide important tracers of recent ground water inflow. Radon (with a half-life of 3.8 days), in particular, can be used in quantifying rates of ground water discharge to streams, wetlands, and to the ocean, and also to determine the rate of water exchange between a river and its underlying hyporheic zone.

Multitracing of artificially recharged Rhine River water in the coastal dune aquifer system of the Western Netherlands

The coastal dunes of the Western Netherlands are locally recharged by pretreated Rhine River water in order to supply drinking water to large cities like Amsterdam, The Hague, Leiden, Haarlem and Alkmaar. This happens on a large scale since 1955, when the drawdown of groundwater tables and aquifer salinization became unacceptable. Ecological interests and both national and EU legislation now compel the water utilities to monitor the expansion of the resulting artificial groundwater bodies amidst the surrounding, natural dune groundwater.
That monitoring requires, however, multitracing techniques in order to unambiguously identify the infiltrated Rhine water amidst coastal dune groundwater, because both watertypes show a large variation in water quality yielding overlapping tracer contents. In addition, the identification is becoming more difficult due to a reducing contrast between both waters.

In his contribution Pieter Stuyfzand shows the performance of various environmental tracers, both single and in various combinations (multitracing), for diverse levels of the aquifer system. Uncertainties in the discrimination are quantified.

Results of mapping the extension of the infiltrated Rhine water are shown, with special attention to so-called rain water lenses on top of laterally migrating Rhine water, groundwater dating and hydrological information (hydraulic conductivity, dispersivity) as derived from the observed spatial patterns.

Dr. Pieter Stuyfzand is a Principal Research Scientist with KWR Watercycle Research Institute (former Kiwa; Nieuwegein, The Netherlands; 3 d/week) and a Full Professor of Chemical Hydrogeology at VU University Amsterdam (2 d/week). His main research interests regard managed aquifer recharge, coastal aquifer systems, hydrological and hydrochemical system analysis, chemical dating and multitracing of groundwater.
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Degassing of $^3H/^3He$, CFCs and SF_6 by denitrification in the Netherlands

Groundwater dating has proven to be a valuable tool for environmental research, for example for the demonstration of trend reversal in groundwater quality. Modern groundwater dating techniques are based on the transport of dissolved gases in groundwater, such as noble gases, CFCs or SF_6. These tracers are chemically inert, but are sensitive to the formation and flow of a gas phase below the groundwater table. A gas phase below the groundwater table, for example as the result of a geochemical reaction, causes secondary partitioning between the water and gas phase and obstructs the conservative transport of groundwater age tracers. Ordinary methods to interpret groundwater age tracers are then no longer valid.

Since 2001, a total of 95 screens of the groundwater quality monitoring network in Brabant, the Netherlands, located 10 or 25 m below the surface have been sampled for $^3H/^3He$; 34 of which have also been sampled for CFCs and SF_6. About half of these samples showed the effects of noble gas depletion (degassing). The absence of nitrate in degassed samples indicated that denitrification had causes degassing. CFCs appeared to be subject to significant degradation in anoxic groundwater and SF_6 was highly susceptible to degassing. Therefore $^3H/^3He$ appears to be the most reliable method to date degassed groundwater.

Dr. Ate Visser has recently received his PhD for his thesis «Trends in groundwater quality in relation to groundwater age». He is currently employed by the applied research institute Deltares in Utrecht. His research interests include the use of environmental tracers and groundwater dating in research projects concerning groundwater quality.
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This event is co-organized by the VU University Amsterdam, the Netherlands National Committee IHP-HWRP (UNESCO & WMO), The Netherlands' Chapter of the International Association of Hydrogeologists (IAH), the Netherlands Hydrological Society (NHV) and the US National Ground Water Research and Educational Foundation (NGWREF).