Report by UWI doctoral researcher Lena-Marie Kuhlemann (W1)

Project number: W1

First and last name of doctoral researcher: **Lena-Marie Kuhlemann**

(Working) title of doctoral project: **Ecohydrological controls on urban groundwater recharge: an isotope-based modeling approach**

Name of supervisors: Prof. Dr. Dörthe Tetzlaff (IGB and Humboldt University Berlin, University of Aberdeen), Prof. Dr. Chris Soulsby (University of Aberdeen, IGB Berlin), Prof. Dr. Birgit Kleinschmit (TU Berlin)

2. Description of doctoral project and research results achieved to date:

Motivation

With more than half of the world's population and about 73% of the people in Europe currently living in urban areas (UN 2015), the management of water resources in cities is of special interest. In urban areas, the natural hydrological cycle is affected by various components and modifications (Fig. 1). More precisely, urbanization often leads to a modification of rainfall, changes of the regimes of both local and major rivers, declining water levels in aquifers and possible subsidence as a result of water abstractions, and changes in water pathways or the timing and magnitude of water flows (Douglas & James 2015). Especially the modification of urban surfaces changes the natural circulation of water as large impermeable surfaces encourage rapid runoff and decrease infiltration (Fletcher et al. 2013; Douglas & James 2015). Therefore, the investigation of urban water interfaces on various spatial scales and the quantification of fluxes and transformations of matter and energy within urban water flows play a key role in the water cycle and in the improvement of a sustainable water resource management in urban areas (Gessner et al. 2014).

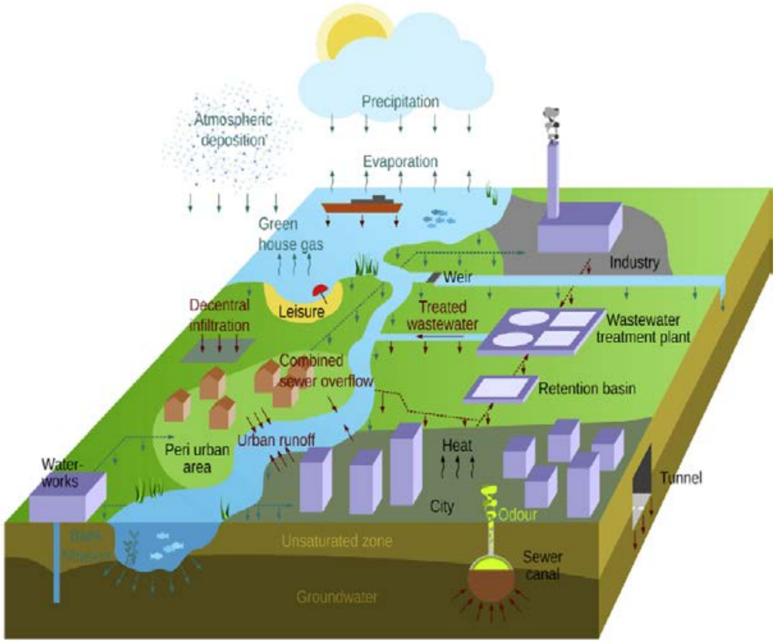

Fig. 1: Processes and elements within the urban water cycle [1, Gessner et al. 2014]

A typical example for the impacts of urbanization on a hydrological system is the city of Berlin. The freshwaters in the Berlin-Brandenburg area have been modified by anthropogenic impacts for centuries and experienced a transformation of both the hydraulic and ecological status of rivers and lakes (Nützmann et al. 2011). Changed land use and water management measures like drainage, drinking water supply and re-filling of open-cast mining pits have intensified the impacts on water resources, especially in the Spree basin (Merz and Pekdeger 2011]. Additionally, the area is located in one of the driest areas in Germany with only 500 to 600 mm of annual rainfall and predictions indicating a further decrease in the face of climate change that will result in the disturbance of groundwater recharge until 2055 (Gerstengarbe et al. 2003]. Overall, the alteration of water quality and quantity has created challenges for a sustainable management of freshwater resources in the Berlin-Brandenburg area from an ecohydrological point of view (Nützmann et al. 2011].

Current State of Work

To investigate water fluxes in the hydrological cycle, environmental tracers can be applied. Stable isotopes of water, for instance, are affected by meteorological processes and provide characteristic fingerprints of a water's origin (Clark and Fritz 1997). Unlike most chemical tracers, they behave relatively conservative in reactions with catchment materials and can therefore provide information about the water sources, time and location of the recharge, hydraulic connections or flow paths, and biological processes within the catchment (Kendall and McDonnell 1998).

Additionally, the spatial distribution of isotopic variations in the environment can be represented by isoscape ("isotope landscape") maps or models. For hydrogen and oxygen isotopes in water, the resulting patterns can reflect water transport and evaporation or condensation processes to trace water cycling (Bowen 2010). However, both the application of tracers like stable isotopes and the conduction of velocity studies are needed to sufficiently describe the changing nature of catchment responses and storage characteristics under different wetness conditions (McDonnell and Beven 2014).

While the use of isotope tracers in water science has been an established method for many years, their application in ecohydrology is still relatively new and is currently facing essential research challenges.

As pointed out by Bowen (2010), the accuracy of the isoscape approach and especially the effects of the fractionation of water isotopes during uptake by the biosphere remain somewhat uncertain.

It is suggested that the application of a dual isotope approach to test the "two water world" hypothesis, i.e. the separation of water used by trees and the mobile water, should be a primary focus in future isotope research. Consequently, the conduction of high-resolution sampling of mobile, plant and soil water in catchments is essential to "fill the gap" of water partitioning between plants and soil (McDonnell 2014).

First attempts to address this issue have been made in several studies of the "VeWa" (Vegetation effects on water flow and mixing in highlatitude Ecosystems) project [2]. By obtaining high-resolution isotope data, input-output characterizations have been performed to determine the effects of partitioning, runoff processes and ecohydrological separation of different waters within a catchment (Tetzlaff et al. 2015). Including such high-resolution stable isotope data from precipitation, stream, ground and soil water sampling as well as hydrometric data into a physically based, fully distributed model, e.g. the EcH_2O model (Maneta and Silverman 2013), has shown to be a promising approach to characterize dynamics and spatial-temporal patterns of water fluxes and, consequently, water ages within a catchment (Kuppel et al. 2018). The application of these approaches which have, so far, primarily been used in northern catchments, to an urban environment is the essential focus of this PhD project.

Future Work planned

The overachieving goal of topic W1 – "Ecohydrological controls on urban groundwater recharge: an isotope-based modeling approach" – is to understand the partitioning processes of water at the interface of atmosphere, biosphere, pedosphere and hydrosphere and their effects on groundwater recharge in urban environments. An essential part of this investigation is the application of stable water isotopes as fingerprints in urban water cycling. Combining these isotope tracers with hydrometric data will facilitate the investigation of both celerities (speed of the rainfall-runoff response) and velocities (mass fluxes) of water flow within catchments as suggested by McDonnell and Beven (2014). Additional hydroclimatic data from Eddyflux towers will help to quantify evapotranspiration fluxes, which are essential to closing the urban water balance (Fletcher et al. 2013). To achieve these goals, the project comprises three linked work packages (WPs).

The aim of WP 1 is the quantification of isotopic characteristics in the catchment of the river Erpe at Berlin's eastern extent. The Erpe catchment, which is logistically easily to reach and characterized by different land cover types of different permeability, is representative for many urban catchments influenced by anthropogenic activities. Several previous investigations (e.g. Gücker et al. 2006; Lewandowski et al. 2011; Schaper et al. 2018) provide a broad database for future investigations. However, an investigation of stable water isotopes within this catchment was not yet conducted and will facilitate the identification of water sources, ages and pathways to quantify inputs and outputs of the catchment.

In WP2, the influencing factors on the partitioning of rainfall into evapotranspiration ("green water fluxes) and into runoff and groundwater recharge ("blue water fluxes") will be investigated. The role of different urban land surfaces and vegetation types on isotope transformations will be assessed. For this, the partitioning in contrasting but representative soil-vegetation units with different degrees of permeability will be investigated. Considering the variability of different land surfaces within the often semi-permeable urban catchments it is hypothesized that the stable water isotopes will allow the quantification of heterogeneity in spatial and temporal patterns of water sources and fluxes of evaporation and groundwater recharge under different urban surfaces.

While Work Packages 1 and 2 investigate isotopic characteristics at the smaller catchment and plot scale, the aim of Work Package 3 is the quantification of water fluxes (inputs and outputs) at a large spatial scale

within the urban catchment of Berlin by quantifying the isotopic characteristics of surface and subsurface waters within the city. Performing seasonal sampling campaigns of precipitation, surface water and groundwater samples for water isotope analysis will facilitate the quantification of larger scale isoscapes of the area of Berlin. These will provide the basis for a novel understanding of the integrated effects of abstractions, effluent discharge, urban runoff and evaporation losses within Berlin's major water bodies.
By combining the results of these approaches, it is expected to gain a more complex insight of the water fluxes within the urban environment of Berlin and fill the gap in understanding the water partitioning processes at urban water interfaces.

Bibliography

Online Resources

[1] https://www.uwi.tu-berlin.de/menue/urban_water_interfaces/ (accessed 26/7/18)

[2] https://www.abdn.ac.uk/geosciences/departments/geography-environment/vewa-640.php (accessed 10/8/2018)

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3. Comments on the qualification programme and supervision strategy:

The events and courses planned during the PhD project are listed below. Attendance of further elective courses and events is planned and will be decided during the next months.

Planned participation in the following Research Training Group events: 1. Core courses • Urban interface processes – fluxes, transport, interactions (3 ECTS) • Urban freshwater ecology (3 ECTS) • Modelling and measuring concepts of interface processes (3 ECTS) 2. Elective courses (9 ECTS, selection still in progress) 3. UWI lectures 4. Other UWI events • Summer School with Exposé Presentation (18. – 20.09.2018)
Research stays or internships at other research institutions both at home and abroad:
Planned participation in conferences, congresses, etc., at home and abroad: 2019: - EGU General Assembly 2019 (07. – 12.04.2019, Vienna, Austria) - AGU Fall Meeting (09.-13.12.2019, San Francisco, California) - PGR Catchment Science Summer School 2019 or 2020 (Birmingham, UK) 2020: - EGU General Assembly 2020