Report by UWI doctoral researcher Anna Lena Kronsbein (F1)

Project number: F1

First and last name of doctoral researcher: **Anna Lena Kronsbein**

(Working) title of doctoral project: **Transformation of environmentally relevant compounds in urban lakes by aquatic invasive ecosystem engineers**

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

State of the art

Excessive loading with nutrients, and in particular phosphorus (P), has been and still is a major reason for water quality deterioration in urban freshwater ecosystems. Excessive concentration of P is the most common cause of eutrophication in freshwater lakes (Correll 1998). Consequently, lake restoration frequently requires lowering the P content by precipitation from the water column and by inhibiting P release from the sediments (Kleeberg et al. 2013). Macrozoobenthos has effects on redox zonation and increases P retention in sediments. Tube-dwelling macrozoobenthos (e.g. chironomid larvae) causes more irregular and heterogeneous redox zonation in sediments. A cylindrical redox zonation around their tubes and an increase of the specific surface of oxidized sediments has been observed (Baranov et al. 2016, Lewandowski & Hupfer 2005).

In recent years, water quality research started to focus on organic wastewater contaminants which are mostly detected in the range of trace concentrations and are highly prescribed pharmaceutical compounds and personal care products (Bai et al. 2018). The continuous release and distribution of those trace organic chemicals in the environment leads to a chronic exposure of humans and animals resulting in the possible development of antibiotic resistance, endocrine disruption and carcinogenicity (Bai et al. 2018 and references therein). Mixtures of compounds found in the environment have different effects than the single compounds (Bai et al. 2018). Trace organic chemicals can reach drinking water via contaminated surface water or induced bank filtration which has served as a cost-effective and reliable drinking water production technique since more than a century (Tufenkji et al. 2002). Especially in an urban area like Berlin with high municipal sewage water outputs and low surface water flows, there is a potential risk of drinking water contamination by some polar organic compounds when groundwater recharge and bank filtration are used in drinking water production (Heberer et al. 2002). They can travel along a water cycle from wastewater to raw waters which is especially problematic in partially closed water cycles which also exist in Berlin (Reemtsma and Jekel 2006).

Ecosystem engineers are species which can induce physical state changes in abiotic or biotic materials and therefore directly or indirectly control resource availability and are able to form their habitat (Crooks 2002). The two considered invasive ecosystem engineers in this thesis are the Quagga mussel (dreissenid mussel) and the macrophyte Nuttall's waterweed.

Dreissenid mussels are filter-feeders and can accelerate the sedimentation of contaminated suspended matter by producing pseudofaeces and faeces. Dreissenids are associated with a decrease in phytoplankton, zooplankton and profundal benthos as well as an increase of benthic algae, macrophytes and zoobenthos in the littoral zone (Karatayev et al. 2014 and references therein). This can for example result in a redistribution of P by accumulating P from the pelagic in the littoral zone as described by (Hecky et al. 2004) or with contaminants like polychlorinated biphenyls (PCB) (Macksasitorn et al. 2015). Moreover, dreissenid mussels are likely to take up trace organic chemicals, e.g. pharmaceuticals or personal care products, resuspend sediment bound pollutants like PCB, reduce the toxicity of waste water effluents and either accumulate them or excrete them via their faeces or pseurdofaeces (Binelli et al. 2015, Bringolf et al. 2010, Contardo-Jara et al. 2011, Klosterhaus et al. 2013, Macksasitorn et al. 2015, NWRRI 2016, Ozersky et al. 2015). Within zebra mussel colonies an oxygen depletion was observed at the sediment-water interface (Beekey et al. 2004). A study conducted by Ruginis et al. (2017) revealed that sediments with zebra mussels consumed more oxygen than sediments without mussels. As this effect is temperature-dependent (Karatayev et al. 2014 and references therein) it is expected that climate change further affects oxygen depletion by dreissenid mussels.

Submerged macrophytes can significantly affect physical and chemical conditions of water and sediment, alter the nutrient and carbon cycle, influence interactions in the aquatic food web, and are a food source for invertebrates (Jeppesen et al. 1998). In shallow lakes, they can stabilize clear-water conditions (Scheffer et al. 1993) with consequences for biodiversity and other ecosystem services (Hilt et al. 2017). A recent field study in Australia indicated that such macrophyte mass developments can lead to stratification in otherwise polymictic shallow lakes and change dissolved oxygen concentration profiles from vertically homogeneous oxic conditions during both the day and night to expression of night-time anoxic conditions close to the sediment (Vilas et al. 2017).

Motivation and research idea

As described Quagga mussels and Nuttall's waterweed are likely to alter oxygen concentrations at the sediment-water interface and thus redox conditions. As redox conditions at the sediment surface can determine nutrient availability (Kleeberg et al. 2013) and potentially affect the elimination of trace organic chemicals during induced bank filtration (Filter et al., 2017), we are led to the assumption that invasive ecosystem engineers affect surface water and bank filtrate quality directly and indirectly.

Scientific project relevance

This project combines several stressors of an urban environment and investigates their combined effects onto water quality. There will be a focus on chemical stressors on the one hand, i.e. the group of polar organic compounds and phosphorus compounds and on the other hand biological stressors, i.e. the invasion of non-native species into aquatic ecosystems. For urban areas which have a partially closed water cycle like e.g. the city of Berlin, it is of utmost importance to maintain a good surface water quality to be able to gain drinking water via bank filtration.

Research demands

The following scientific questions are designed to be answered during this project:

1) What effects do Quagga mussels and Nuttall's waterweed have on the redox conditions at the sediment surface and within the upper sediment layers?
2) How can Quagga mussels and Nuttall's waterweed change the retention and/or degradation of polar organic compounds?
3) How are the phosphorus binding forms in the sediment altered in the presence of Quagga mussels and Nuttall's waterweed?

Objectives

This doctoral thesis aims at elucidating how invasive ecosystem engineers such as Quagga mussels and Nuttall's waterweed can affect surface water and bank filtrate quality in urban freshwater lakes via changed redox conditions in the upper sediment layers.

Work programme incl. proposed research methods

<u>WP 1</u> ***'Redox conditions'***

In-situ measurements of oxygen content in the littoral and profundal zone are planned. They will be conducted within mussel carpets respectively dense stands of Nutall's waterweed and reference areas (no mussels and no waterweed) with the help of a microprofiler in the eutrophic, urban shallow Lake Müggelsee.
Sediment cores will be taken from the same sites as the in-situ oxygen content measurements. The cores will be incubated and measured regarding their oxygen content and redox potential as well as other electron acceptors like nitrate, sulfate and bioavailable iron. For site selection in the littoral zone piezometers are used in order to assure that surface water infiltration takes place at that selected site.
It is planned to conduct an ex-situ column experiment (Fig. 1). The columns are slightly modified for the shallow and deep littoral zone. They are filled with a mixed sample of either undisturbed littoral or profundal sediment. On top of the sediment is a layer of either Quagga mussels or Nuttall's waterweed (treatment) or nothing (control column). It is planned to analyze the effect of mussel layers with increasing thickness on the redox conditions in the sediment. The upper part of the column is completely filled with lake water. The columns are semi-closed. The experimental set-up for the shallow littoral approach (Fig. 1 a) has an inlet for infiltrating lake water and an outlet, which simulates bank filtration via gravity. The planned experimental set-up for the deep littoral approach (Fig. 1 b) includes a lateral lake water flow to guarantee constant oxygen content and avoid algae growth.
Different temperature treatments within this experimental set-up could give hints on how climate change might further affect oxygen depletion at the sediment-water interface due to invasive ecosystem engineers. These results can be used within a modelling approach to extrapolate on a broader scale.

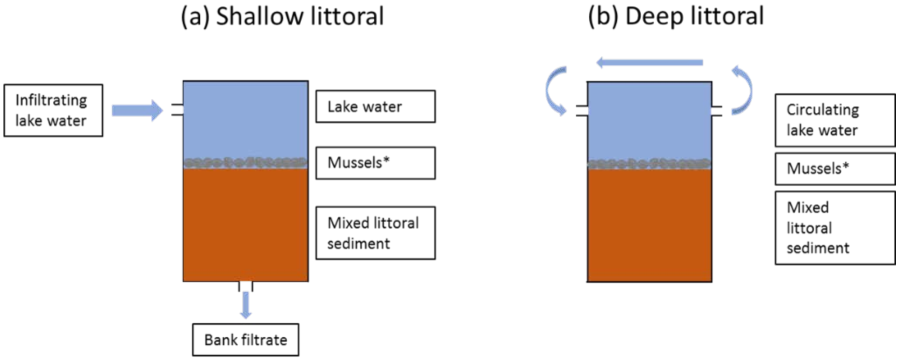

*Figure 1: Planned column experiment for the littoral (a) and the profundal (b) zone. *Layer of mussels or macrophytes.*

WP 2 ***'Retention and/or transformation of polar organic compounds'***

Measurements of polar organic compounds in the sediment and the overlying surface water are planned in three urban lakes, all recently invaded by Quagga mussels and Nuttall's waterweed. Available data on polar organic compound concentrations (kindly provided by the Berliner Wasserbetriebe (BWB)) indicate that Lakes Tegel and Wannsee can serve as contaminated sites while Lake Müggelsee can serve as a reference site with little or no contamination of polar organic substances. Furthermore, mussels will be collected as pooled samples from Lake Tegel (as contaminated site) and Müggelsee (as reference site) and analyzed regarding their ability to accumulate selected polar organic compounds in their tissue. Polar organic compounds will be measured via high performance liquid chromatography with tandem mass spectrometry (HPLC-MS/MS). Mussel tissue will be analyzed according to Contardo-Jara et al. (2011) and water samples will be analyzed according to Schaper et al. (2018). Alternatively, if no measurable accumulation of polar organic compounds is observed, measurement of the induction of stress proteins, e.g. heat shock proteins in the mussel tissue, can give indications whether the mussels suffered from stress due to polar organic compounds (Contardo-Jara et al. 2011, Fent 2003).
To answer research question 2 the same columns are used as described in Figure 1. Since bank filtration mainly takes place in the littoral zone of a lake (Massmann et al. 2008) the experimental set-up shown in Figure 1 a is used in this work package. Polar organic compounds will be added to the water flowing through the columns in increasing concentrations in a range measured in urban surface waters. It is planned to use isotope-labelled compounds to better understand the pathway of transformation and to establish a mass balance. Possible applied substances are valsartan, oxipurinol, acesulfame, gabapentin and carbamazepine. All of those substances, except acesulfame, have been found in the bank filtrate of Berliner Wasserbetriebe (BWB 2018) and are therefore relevant substances in Berlin's surface waters.

WP 3 ***'Phosphorus retention in sediments affected by invasive ecosystem engineers'***

Sediment cores will be taken at Lake Müggelsee. Reference cores will be taken at sites where neither Nuttall's waterweed nor Quagga mussels are present. Additionally, cores will be taken at a site where Quagga mussels are present and at another site where Nuttall's waterweed is present. The cores will be analyzed regarding their P-content and the different P-binding forms. With the help of a Van Veen Grab Sampler the reference site and a site where Quagga mussels are present will be sampled to analyze if chironomid larvae and Quagga mussels occur simultaneously or if chironomid larvae are driven off their habitat. Consequences of these changes in the abundance of tube-dwelling invertebrates and filter-feeding bivalves for shallow urban lake water quality can be tested using the ecosystem model PCLake extending the approach used in Hölker et al. (2015).

Collaboration

Collaboration on pharmaceutical removal in and their effect on the aquatic environment is planned with Birgit Müller (H1). Further collaborations are planned with Nasrin Haacke (W2) on diffuse pollution and the ability to use the Quagga mussel as a bioindicator and with Niranjan Mukherjee (H4) on microbial communities.

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3. Comments on the qualification programme and supervision strategy:

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
    - IGB: Time Management carrer planning & optimize your scientific advisers & network (28.09.2019)
    - IGB: Introduction to experimental design & basic statistics (15.-22.10.2018)
    - TU: English academic writing (11./12.03.2019)
    - DGPT: Analytische Toxikologie, Fremdstoffmetabolismus/Toxikokinetik (5 day courses, every year)

Research stays or internships at other research institutions both at home and abroad:
To gain a better understanding of the ecotoxicity and fate of polar organic compounds in complex environmental samples I would like to do an internship at the Ecotox Centre, EAWAG, Switzerland. Alternatively, further knowledge can be gained in the project on catchment and drinking water micropollutant water quality at the Queensland Alliance for Environmental Health Sciences, Brisbane, Australia (former National Research Centre for Environmental Toxicology).