Title MSc project: The (N)itrogen- and (P)hosphorus-related grey water footprints of industrial and domestic water use – a global analysis of the past and future

Assignment number: 07.24 **Internal project**

Head graduation committee
Prof. dr. Markus Berger or Dr. Maarten Krol

Daily supervision
Dr. Lara Wöhler

Required courses: desired is the Water Footprint Assessment course, the integrated water management course and the water quality course; interest in working interdisciplinary

Involved organisations: internal **Start of the project:** flexible

Short description project aim and motive:
A smart and fair management of global freshwater resources is a key challenge to assure a sustainable future where demands of both nature and humanity (for food, energy and other commodities) are met. To address this future challenge, it is crucial to understand human pressure on freshwater resources through both water consumption and pollution. The water footprint (WF) measures this pressure and accounts for consumptive (known as green and blue WFs) as well as degradative (known as grey WF) water use. In 2012 the WF of humanity has been estimated for the first time (Hoekstra and Mekonnen, 2012). This included the green, blue and N-related grey WF resulting from industry, domestic and agricultural use. The study covered a time span from 1996 to 2005. Evidentially, this research covers only a short time span, is rather outdated by now, and does not allow any predictions on the future developments of the WF. Hence, an update study is needed. The proposed master thesis project aims to update and expand the grey WF of industry and domestic use – a crucial sub-part of the humanity's WF. Pollutants considered should be N and P, but the inclusion of more pollutants is possible. The aim is to produce a global gridded (5x5 arc minute resolution) dataset which covers the time span 1990-2019. Moreover, a projection of the WF (e.g. for the year 2050) should be conducted, considering socio-economic as well as climatic developments.

Research objective
The research objective of this project is to: 1) estimate the N- and P-related grey WFs from industry and domestic use at global level for a historic time period; 2) estimate the N- and P-related grey WFs from industry and domestic use at global level for a future projection.

Method
The grey WF method has been described in detail (Hoekstra et al., 2011) and is well established in scientific literature. Two global studies that assess the grey WF of N and P for the time period from 2002 until 2010 exist (Mekonnen and Hoekstra, 2015, Mekonnen and Hoekstra, 2018), but have not been previously considered to account the WF of humanity. We suggest using the methods of mentioned studies as a basis to calculate the N- and P-related WFs for industry and domestic use in this study. For the domestic use, both N and P loads result as a fraction of dietary protein consumption, considering excretion, and removal from waste water treatment. For industry, emissions are estimated as ratio of the domestic loads of urban households. This rather simplistic approach could be extended by introducing sub-sector specific approaches, e.g. with help of Malik et al. (2022). Input data for the grey WF estimations should be researched from literature. The future projections should base on global projections such as those from IPCC, which include shared socioeconomic pathways (SSPs) representative concentration pathways (RCPs).

Expected result
The project aims to estimate the grey WFs associated with nitrogen (N) and phosphorus (P) from both industrial and domestic sources at a global scale. This estimation covers historical data from 1990 to 2019 as well as a projection for the future. The research intends to produce global gridded datasets (covering also comprehensive visualization in maps) containing WFs per pollutant (N and P), per sector (industry and domestic) and per time period.

References

Hoekstra, A. Y., Chapagain, A. K., Aldaya, M. M. & Mekonnen, M. M. 2011. The Water Footprint Assessment Manual: Setting global standards, London, Earthscan.

Hoekstra, A. Y. & Mekonnen, M. M. 2012. The water footprint of humanity. Proc Natl Acad Sci U S A, 109, 3232-7, 10.1073/pnas.1109936109.

Malik, A., Oita, A., Shaw, E., Li, M., Ninpanit, P., Nandel, V., Lan, J. & Lenzen, M. 2022. Drivers of global nitrogen emissions. Environmental Research Letters, 17, 015006, 10.1088/1748-9326/ac413c.

Mekonnen, M. M. & Hoekstra, A. Y. 2015. Global Gray Water Footprint and Water Pollution Levels Related to Anthropogenic Nitrogen Loads to Fresh Water. Environ Sci Technol, 49, 12860-8, 10.1021/acs.est.5b03191.

Mekonnen, M. M. & Hoekstra, A. Y. 2018. Global Anthropogenic Phosphorus Loads to Freshwater and Associated Grey Water Footprints and Water Pollution Levels: A High-Resolution Global Study. Water Resources Research, 54, 345-358, 10.1002/2017wr020448.