Title MSc project: The grey water footprint of pathogens

Assignment number:
21.22

Internal project

Head graduation committee
Prof. dr. Markus Berger

Daily supervision
Dr. Lara Wöhler

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

Involved organisations: internal

Start of the project: flexible

Short description project aim and motive:
Pathogenic pollution of water resources is a global problem, leading to serious disease outbreaks among people using these water resources for drinking, domestic use or recreational purposes (Pandey et al., 2014). Emission sources for pathogens are diverse (e.g. domestic animals, wildlife, humans), and often a variety of sources exist within one watershed (Pandey et al., 2014). This makes modelling emission loads, their distribution and fate challenging and scientifically interesting at the same time.
Diverse modelling approaches exist to predict pathogenic pollution in environmental waters (Pandey et al., 2014). In this assignment such approaches should be reviewed and applied for a number of selected pathogens to estimate freshwater loads in a chosen area. Besides the pathogenic emissions themselves, it can be relevant to include substances promoting pathogen propagation (e.g. organic matter) in the assessment. Next to deriving the pollutant loads, a threshold concentration for each of the pathogens needs to be determined. While diverse risk assessment for different pathogens exist (Garner et al., 2021, Mena and Gerba, 2009), there is no standard approach to quantify maximum allowed concentrations for ambient waters (used for diverse purposes), which should be done as part of this assessment.

Research objective
The research objective of this project is to estimate the grey water footprint of selected pathogens (e.g. specific bacteria or viruses) from various sources within a chosen area. Hereto an approach to model emission pathways should be developed to derive the pathogen load to the aquatic environment. Moreover, maximum allowed concentrations for pathogens should be researched and/or derived depending on the existing state of the art.

Method
As a method it is suggested to use the grey water footprint as an indicator of freshwater pollution, which denotes the theoretical volume of water needed to dilute an emission until quality standards are reached. It is defined as the load of pollutant divided by the difference between the maximum allowed and the natural background concentration (Hoekstra et al., 2011). There have been numerous studies estimating the grey water footprint of diverse pollutants (e.g. nitrogen (Mekonnen and Hoekstra, 2015), phosphorus (Mekonnen and Hoekstra, 2018), pesticides (Vale et al., 2019) or pharmaceuticals (Wöhler et al., 2020)), but modelling the grey water footprint of pathogens is new.

Expected result
The project will shed light on the different ways to model the emission and environmental distribution of pathogens and in this way, address a health problem of growing global concern. Precisely, it quantifies grey water footprints of (selected) pathogens from different sources at a justified spatial resolution. To understand the relevance of pathogenic pollution in ambient waters, results can be compared to those from other grey water footprint studies.

References
Garner, E., Organiscak, M., Dieter, L., Shingleton, C., Haddix, M., Joshi, S., Pruden, A., Ashbolt, N. J., Medema, G. & Hamilton, K. A. 2021. Towards risk assessment for antibiotic resistant pathogens in recycled water: a systematic review and summary of research needs. *Environmental Microbiology,* 23**,** 7355-7372, https://doi.org/10.1111/1462-2920.15804.

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

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.

Mena, K. D. & Gerba, C. P. 2009. Risk Assessment of Pseudomonas aeruginosa in Water. *In:* WHITACRE, D. M. (ed.) *Reviews of Environmental Contamination and Toxicology Vol 201.* Boston, MA: Springer US.

Pandey, P. K., Kass, P. H., Soupir, M. L., Biswas, S. & Singh, V. P. 2014. Contamination of water resources by pathogenic bacteria. *AMB Express,* 4**,** 51, 10.1186/s13568-014-0051-x.

Vale, R. L., Netto, A. M., Toríbio De Lima Xavier, B., De Lâvor Paes Barreto, M. & Siqueira Da Silva, J. P. 2019. Assessment of the gray water footprint of the pesticide mixture in a soil cultivated with sugarcane in the northern area of the State of Pernambuco, Brazil. *Journal of Cleaner Production,* 234**,** 925-932, 10.1016/j.jclepro.2019.06.282.

Wöhler, L., Niebaum, G., Krol, M. & Hoekstra, A. Y. 2020. The grey water footprint of human and veterinary pharmaceuticals. *Water Research X,* 7**,** 100044, https://doi.org/10.1016/j.wroa.2020.100044**.**