

EGU23-4369, updated on 02 Jan 2024

<https://doi.org/10.5194/egusphere-egu23-4369>

EGU General Assembly 2023

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Navigating the Danube: A data-driven approach to evaluate the impact of inland shipping on faecal pollution

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Introduction: Inland navigation has seen explosive growth over the past few decades, leading to increasing concerns about its environmental and health impacts. Coastal waters are usually monitored for wastewater contamination by maritime traffic, but little is known about faecal pollution caused by the inland waterways transport in large rivers. The Danube River in Europe is a very popular destination for cruise ship trips. The extent to which the faecal pollution in the Danube is caused by shipping traffic in general and the growing number of cruise ships specifically is still largely unknown. The Danube River Information Service (DoRIS) has been established to track ship traffic and provide data for monitoring in Austria. This database allows the estimation of the faecal pollution potential of ships with a high level of spatial and temporal resolution for the first time.

Methodology: An approach was developed to investigate the potential contribution of various ship categories to faecal pollution in the Danube River (Lower Austria) by combining water quality monitoring data with ship traffic data. The ship traffic data was extracted from DoRIS using a Python-based programming language code and sorted into three categories (cruise, passenger, and freight ships). Water quality monitoring was conducted at 11 transects along a 223-kilometre Danube River reach in Lower Austria. In collaboration with local authorities, each river transect was sampled at 5 points across the profile for one year at monthly intervals. The faecal indicator bacterium *E. coli* along with physio-chemical water quality parameters was analyzed for all samples. Theoretical faecal impact scenarios were developed using data on average daily ship traffic and factors such as ship type, onboard wastewater treatment facilities, onboard passenger capacity, and seasonal fluctuations of cruise tourism. To evaluate the influence of local and

regional shipping traffic on the faecal pollution dynamics, a statistical correlation analysis was performed using data from the entire river reach and ship berthing stations.

Results: The faecal impact scenario analysis, revealed that the shipping industry had the same degree of maximum pollution potential as treated municipal wastewater. In case of improper onboard wastewater treatment, faecal pollution can be substantial. According to water quality monitoring, 94% of the samples had low to moderate faecal pollution, while none were classified as high. As a result, no significant increase in *E. coli* concentrations was detected throughout the 223 km long river stretch. However, at one of the 11 river transects, significant variations in the *E. coli* concentration were detected. After conducting a correlation analysis using statistical parameters for the whole river reach, we found no significant correlation between *E. coli* concentrations and any of the investigated ship counting metrics or ship types. Nonetheless, *E. coli* concentration was found to be significantly higher at one of the cruise ship berthing stations.

Acknowledgement: The research was funded by Amt der Niederösterreichischen Landesregierung, Abteilung Wasserwirtschaft (WA2) and the GFF Niederösterreich mbH (LS19-016 Future Danube). We would like to thank collaboration partners from the government of Lower Austria and the Austrian shipping inspectorate.