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Modelling of the PFAS emissions into Upper Danube

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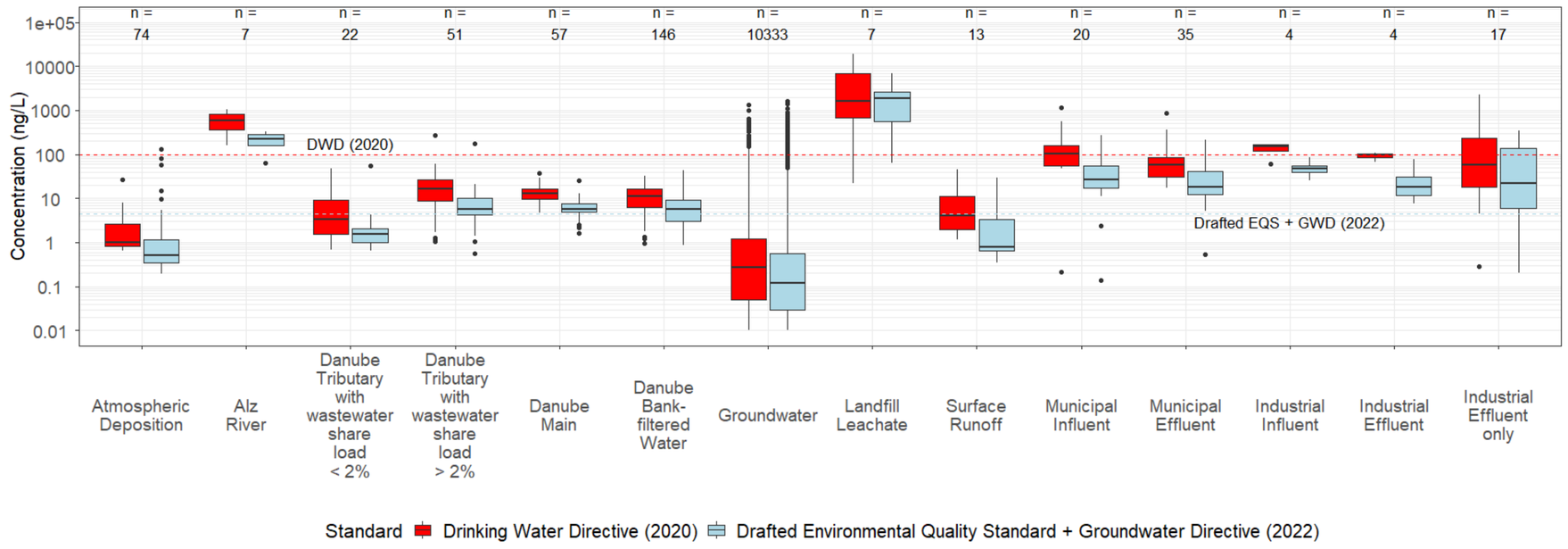
Introduction

- Under the EU PROMISCES project Case Study #2, we investigate and quantify the sources and transport of PFAS pollution in the upper Danube basin (down to Budapest), and their behavior during bank filtration (check the presentation from Oudega et al.).
- A 1-year monitoring was conducted in the Danube, its tributaries and bank-filtration sites, as well as various input pathways across six matrices -- riverwater, groundwater, atmospheric deposition, surface runoff, wastewater and landfill leachate.
- The monitoring results further contribute to the implementation of the emission model MoRE (Fuchs et al., 2017), as part of the substances-specific input concentrations together with data from DHm3c inventory (check poster from Kittlaus et al.)

Figure 1. Sum of PFAS calculated according to:

1) EU Drinking Water Directive (2020) – standard level 0.1 µg/L;
2) Drafted Environmental Quality Standard & Groundwater Directive (2022) - standard level of 4.4 ng/L

Datasource*: PROMISCES Monitoring (2023); DHm3c Inventory (2024 – check poster from Kittlaus et al.); Umweltinstitut Vorarlberg (2021); Umweltdaten des Landes Oberösterreich (2023); BML (2023)*



MoRE model

- Temporal coverage: Annual time step for 2016-2021, with possibility to extend the timeframe.
- Spatial coverage: upper Danube catchment, subdivided into 526 analytical units ranging from 1.5 – 3000 km2.
- The Wflow model, developed by Deltares (van Verseveld et al., 2022), was adapted to meet the requirements of MoRE on hydrological parameters for this case study.
- Data on land cover and landuse, soil loss, population, sewer systems, wastewater treatment plants, industrial direct emitters, landfills and aerodromes were gathered from various sources.
- In total, 11 pathways were implemented. Two new pathways were developed to emphasize PFAS emissions via groundwater affected by landfills and by firefighting training activities at aerodromes.
- Additionally, the diffuse input from the legacy polluted PFAS production site at Gendorf (Alz, as shown in *Figure 1*) was considered a separate pathway due to its significant impact.
- Different PFAS compounds display varying sources compositions and emission levels.
- Preliminary results underscore the importance of specific pathways in the upper Danube region.

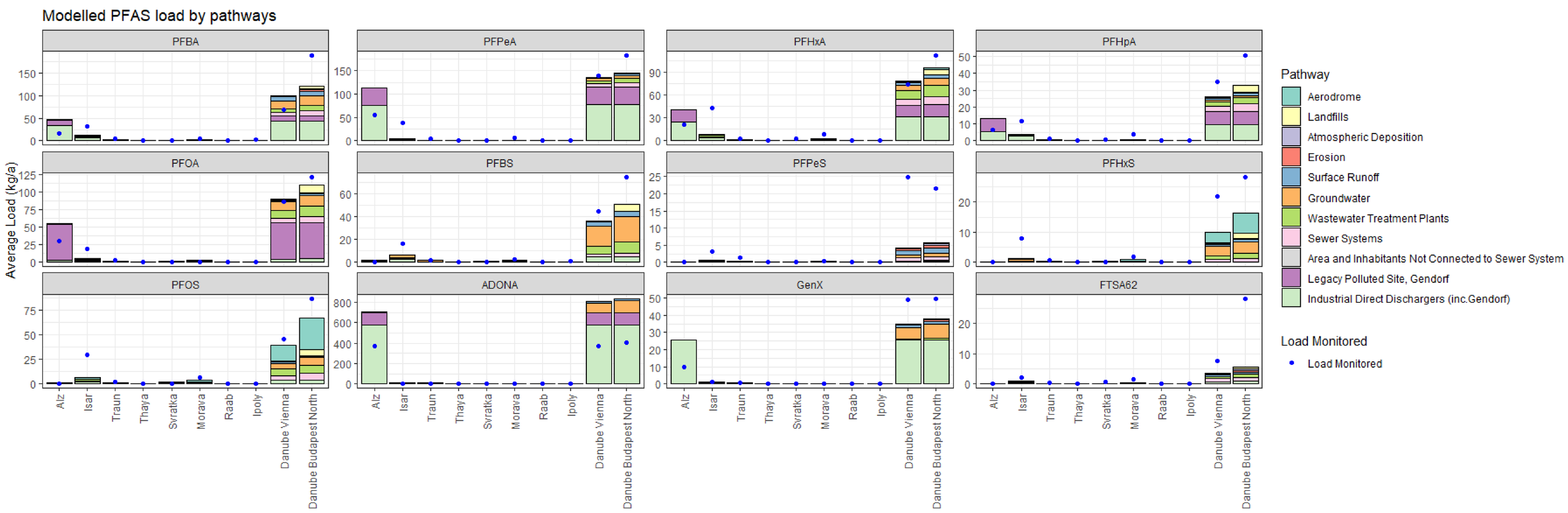


Figure 2. Bar plot showing total emission contributed by different pathways from the MoRE model. Load calculated from monitoring activities is displayed as blue dots. X-axis shows the chosen river with validation locations: Alz – Oberpiesing, Isar – Landau, Traun - Lichtenegg, Thaya - Hevlín, Svratka - Židlochovice, Morava - Lanžhot, Raab - Neumarkt, Ipoly - Ipolytölgyes, Danube - Vienna, Danube – Nagymaros, Budapest North

Outlook

- The regionalized pathway analysis is still being revised and enhanced for the full set of 18 PFAS.
- Maps with risk analysis will be provided to identify rivers with high pollution levels.
- The MoRE model will be broadened for scenario evaluations, from the impacts of climate change, to the effectiveness of various regulation in controlling PFAS emissions.

Reference: BMLRT (2022): Nationaler Gewässerbewirtschaftungsplan 2021 (GZ 2022-0.270.788). Bundesministerium für Landwirtschaft, Regionenund Tourismus. Wien. Österreich; Fuchs, S. et al., (2017) Modelling of regionalized emissions (more) into water bodies: An open-source river basin management system. Water (Switzerland) 9. ; Kittlaus, S. et al., (2022) Coupling a pathwayoriented approach with tailor-made monitoring as key to well-performing regionalized modelling of PFAS emissions and river concentrations. Sci. Total Environ. 849; Umweltdaten des Landes Oberösterreich(2023): PFAS-Konzentrationen im Grundwasser; Umweltinstitut Vorarlberg (2021): Per- undpolyfluorierte Alkylsubstanzen (PFAS) in Vorarlberg. Amt der Vorarlberger Landesregierung(Ed.), Bregenz; van Verseveld, W. J. et al. (2022) Wflow_sbm v0.6.1, a spatially distributed hydrologic model: from global data to local applications, Geosci. Model Dev. Discuss.