Estimating Annual PFAS Loads in WWTP Influent Using a Source-Based Modelling Approach

N. Krlovic[1]*, E. Saracevic[1], M. Zessner[1] and O. Zoboli[1]

Institute for Water Quality and Resource Management, TU Wien, Austria

nikola.krlovic@tuwien.ac.at

Per- and polyfluoroalkyl substances (PFAS) are a class of persistent chemicals, whose impact has been observed in various environmental compartments. Wastewater treatment plants (WWTPs) are a major emission pathway of PFAS into the aquatic environment. Given the various sources of these chemicals that can contribute to WWTP loads, including a broad variety of consumer product use (Glüge et al., 2020), as well as recirculated PFAS from the environment (Cousins et al., 2022), it is important to properly quantify and assess the relevance of individual contributions of different sources in the wastewater influent.

The goal of this study was to develop a scalable, source-based modelling framework of PFAS load quantification within the municipal wastewater influent, and afterwards apply and validate it on a case study urban environment in a large central European city. 5 carboxylic (PFCA) and 2 sulfonic (PFSA) based groups were selected, including PFHxA, PFHpA, PFOA, PFNA, PFDA , PFHxS and PFOS. This set of chemicals was selected in order to assess compounds that are represented by differing chemical properties, and due to the fact that these compounds are well represented in the literature in terms of source concentrations, allowing for a reliable mass balance calculation. The quantification of individual loads was carried out by coupling an extensive literature review on prior research results pertaining to the concentration of PFAS in various media with location-specific data including water consumption and detailed water balance of the WWTP catchment, consumer statistics and paved surface area, among others. To validate the resulting Material Flow Analysis (MFA) model, a year long sampling campaign of both the influent and effluent of the WWTP of the studied area was conducted in 2022, and samples analysed using liquid chromatography mass spectrometry (LCMS).

The percentage of annual loads were explained in the range of 40% to 90% of influent loads measured at the WWTP, with PFCAs yielding higher explained percentages compared to the PFSAs. This approach allowed for an insight into the proportion of different contributors in terms of loading, with respect to different PFAS. Preliminary results indicate that PFCAs have a higher degree of variability of sources. For example, PFOA exhibited a 60% load contribution from recirculated sources, and 40% stemming from consumer products. Conversely, PFSA loads consisted mostly of recirculated PFAS (>90%). Additionally, the study found that the load attributed to consumer products depended on the magnitude of precursor transformation, individual chemical characteristics and the resulting stock accumulation of substances in the system during product lifetime, indicating a need to include an array of variables when computing the final load entering the WWTP in a given year. Lastly, the sampling campaign in this study confirmed prior findings relating to poor removal of PFAS in the WWTP effluent (Lenka, Kah and Padhye, 2021), (Kruskall-Wallis test, $p > 0.05$), meaning that assessment of PFAS originating from WWTP can be initiated at the source of entry into the sewer system, rather than at the effluent.

References

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