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The driving factors of per- and polyfluorinated alkyl substance (PFAS) accumulation in selected fish species: The influence of position in river continuum, fish feed composition, and pollutant properties

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Highlights

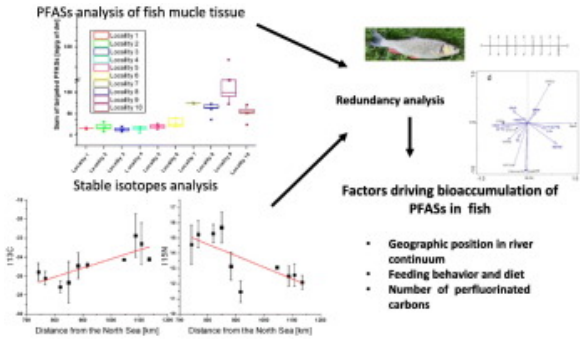
- Geographical trends of PFAS contamination were found in the Czech largest rivers.
- Bioaccumulation of PFAS in fish and isotopic ratios were studied.
- PFAS concentrations increased downstream and were positively correlated with $\delta^{15}N$.
- Relationship between accumulations and species with different diets was revealed.
- Molecular mass and fluorine number play crucial roles in PFAS bioaccumulation.

Abstract

Per- and polyfluorinated alkyl substances (PFASs) represent a group of highly recalcitrant micropollutants, that continuously endanger the environment. The present work describes the geographical trends of fish contamination by individual PFASs (including new compounds, e.g., Gen-X) assessed by analyzing the muscle tissues of 5 separate freshwater fish species from 10 locations on the Czech section of the Elbe River and its largest tributary, the Vltava River. The data of this study also showed that the majority of the detected PFASs consisted of long-chain representatives (perfluorooctane sulfonate (PFOS), perfluorononanoic acid, perfluorodecanoic acid, and perfluoroundecanoic acid), whereas short-chain PFASs as well as other compounds such as Gen-X were detected in relatively small quantities. The maximum

concentrations of the targeted 32 PFASs in fish were detected in the lower stretches of the Vltava and Elbe Rivers, reaching 289.9 ng/g dw, 140.5 ng/g dw, and 162.7 ng/g dw for chub, roach, and nase, respectively. Moreover, the relationships between the PFAS (PFOS) concentrations in fish muscle tissue and isotopic ratios ($\delta^{15}N$ and $\delta^{13}C$) were studied to understand the effect of feed composition and position in the river continuum as a proxy for anthropogenic activity. Redundancy analysis and variation partitioning showed that the largest part of the data variability was explained by the interaction of position in the river continuum and $\delta^{15}N$ ($\delta^{13}C$) of the fish. The PFAS concentrations increased downstream and were positively correlated with $\delta^{15}N$ and negatively correlated with $\delta^{13}C$. A detailed study at one location also demonstrated the significant relationship between $\delta^{15}N$ (estimated trophic position) and PFASs (PFOS) concentrations. From the tested physicochemical properties, the molecular mass and number of fluorine substituents seem to play crucial roles in PFAS bioaccumulation.

Graphical abstract



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Keywords

PFASs; PFOS; River continuum; $\delta^{15}N$; Fish

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> …Recently, numerous studies have reported that PFAS are ubiquitous in various environmental compartments, including air, water, soil, and wastewater sludge, due to their large-scale and long-term usage all over the world (Crone et al., 2019; Lai et al., 2019; Yu et al., 2020; Rankin et al., 2016; Kaboré et al., 2018; Cui et al., 2020; Barisci and Suri, 2021; Cai et al., 2022). More importantly, studies have shown that PFAS are environmentally persistent and bio-accumulative, therefore, they can be taken up by organisms and biomagnified through the food chain to wildlife and humans (Hori et al., 2004; Haukås et al., 2007; Lam et al., 2014; Teunen et al., 2021; Semerád et al., 2022). Thus, PFAS have attracted increasing international concern for human health and the environment as contaminants of emerging concern due to their environmental persistency, bioaccumulation, widespread distribution, and potential toxicity (Fujii et al., 2007; Qi et al., 2016; Wei et al., 2018; Sunderland et al., 2019; Fenton et al., 2021; Li et al., 2015)….

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