Perfluoroalkyl Substances (PFASs) in Remote High-Altitude Areas Around the Globe

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Introduction

Perfluorinated alkyl substances (PFASs) are widespread compounds of environmental concern. Because of their well-recognized hazardous properties, long chain PFASs have been subject to increasing regulation. One key aspect to evaluate the risk of environmental pollutants is their ability to undergo long-range transport and to accumulate in remote areas. In the past, several perfluorinated acids have been detected in snow or firn in polar regions or at European Alps. [1,2] In the present study, we investigated the presence of a broad range of PFASs in snow and lake water samples from high altitudes up to 5053 m a.s.l. at several remote sites around the globe.

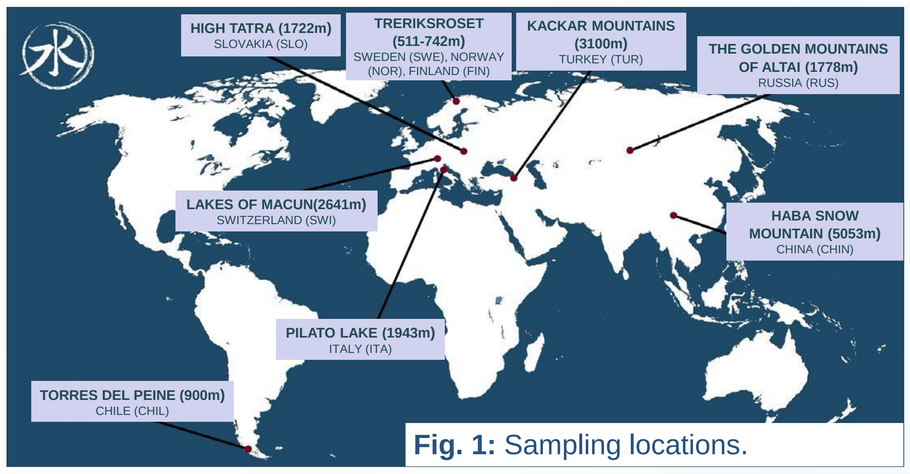


Fig. 1: Sampling locations.

Method

Snow and lake water samples were collected from 10 remote mountain areas in 2015 (Fig. 1) using pre-cleaned amber glass bottles. Overall, 23 snow and 15 water samples (including field blanks) were analyzed. Prior to the extraction, mass-labelled internal standards were added. Samples were filtered by cleaned cellulose wool which was extracted by methanol. The methanol was concentrated to about 1 mL and added to the water phase of each sample. Filtered water was extracted by SPE using a weak anion exchange resin. After application of the water sample and a washing step with an ammonia acetate buffer, PFASs were eluted using 0.1% ammonia in methanol. Prior to the instrumental analysis, eluates were concentrated to dryness, redissolved in methanol/water 1:1 (v:v) and a recovery standard ($^{13}C_4$-PFOA). Samples were measured by HPLC-MS/MS. Quantification was performed applying the isotope dilution method.

Results & Discussion

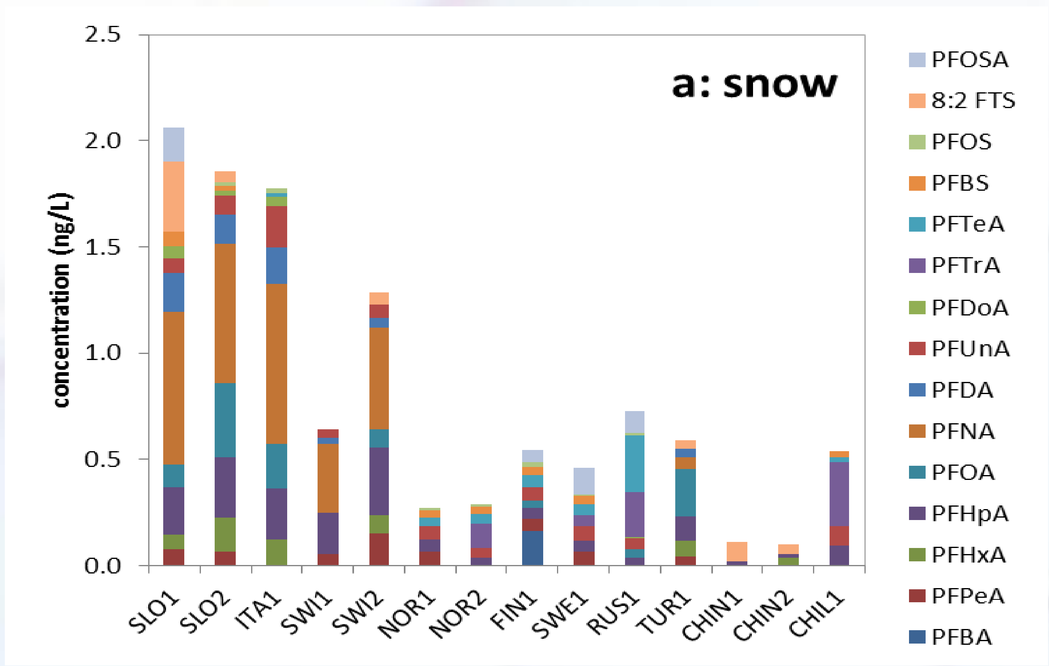
PFASs were widely detected in samples collected from remote high altitude sites visited in this study

Snow Samples (Fig. 2a):

- PFASs were detected at all sites. Except for 6:2 FTS, all investigated PFASs were quantified in one or more samples, PFCAs at higher frequencies and concentrations (conc.) than PFSAs, with PFNA often observed at the highest conc. (up to 0.755 ng/L melted snow)
- Highest total PFAS conc. were observed in Central Europe (High Tatra (SLO) > Monti Sibillini (ITA), Macun Lakes (SWI)), lowest conc. were observed at Haba Snow Mountains (China (CHIN))
- Odd-chain PFCAs were observed more often and at higher concentrations than even-chain PFCAs indicating atmospheric breakdown of volatile precursors (e.g. FTOH) as a potential source
- Concentrations were in the same order as published [2]

Water samples (Fig 2b):

- Except for 6:2 FTS, 8:2 FTS, PFOSA, PFDeS, PFHpS, PFHxS & PFTriA, all investigated PFASs were quantified in one or more sample, PFCAs at higher frequencies and conc. than PFSAs. Different from snow samples PFBA or PFPeA often were the dominant PFAS, followed by PFOA
- Highest total PFAS conc. were observed at Macun Lakes (SWI), followed by Altai (RUS) and High Tatra (SLO); lowest conc. were observed at Haba Snow Mountains (China(CHIN))
- Conc. of short-chain PFASs in the water samples (up to 1.118 ng/L) were higher than those in snow samples and those of long-chain PFASs, particularly from CHIL, RUS and SWI
- Concentrations were in the same order as published [3]



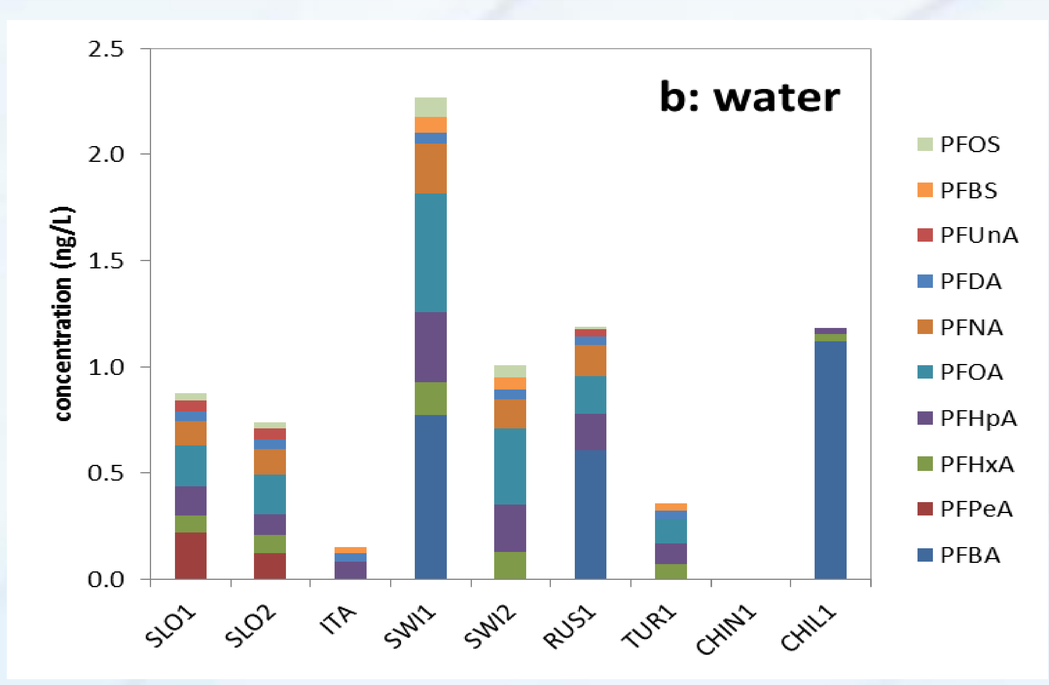


Fig. 2a/b: PFAS in snow and lake water of high altitude sites.

References: [1] Young et al. (2005), EST; Environ Int. 69:166-176. [2] Kirchgeorg et al. (2013); Env. Pollut. [3] Loewen et al. (2008); EST. **Acknowledgement:** We gratefully thank Uli Kallee.

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