Design Project – SIE 2025

Analysis of PFAS pollution in the snow of Swiss ski resorts

Manon Bernard & Beatrice Bossi | Timothée Steiner, Summit Foundation | Florian Breider, EPFL GR-CEL

Context

- PFAS: **synthetic chemicals** used in most industries.[1]

→ Unique properties: **water repellent, heat resistance**...[2]

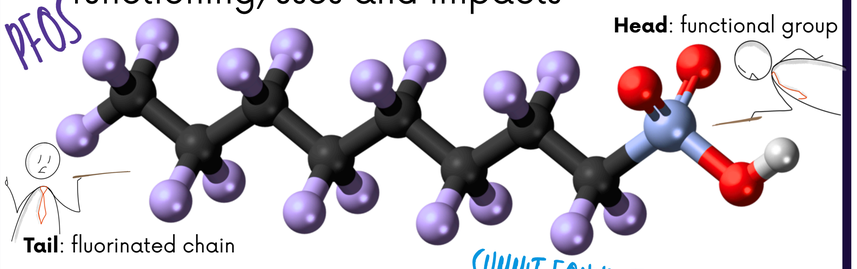
- **Increasingly** detected in the **environment.**[3]
- Associated with **negative health impacts.**[4]
- Studies in Scandinavia, the USA & Austria pointing out **implication of fluorinated ski waxes on PFAS presence in mountains.**[5,6,7]
- Since season 2023-2024 **ban on fluorinated waxes** by FIS for **competitions.**[8]
- **Switzerland**: PFAS studied in soils and groundwater, not yet in the context of skiing.

Objectives

- **Identify** and eventually **quantify** the extent of **PFAS contamination** in selected Swiss ski resorts.
- Analyse for a **relationship** between **contamination & environmental factors.**
- **Explore best practices** for future research
  - Testing methods to study PFAS in snow
  - Highlight potential **participative citizen sciences projects.**

Methods

- **Literature review:** understanding of PFAS functioning, uses and impacts



- **Sampling campaign**
  - Collection of samples in 28 resorts, **pairs of samples 1 from the slope & 1 from background**
  - **Observation of environmental factors**: business of resort, snow cannons, temperature, quality of snow cover

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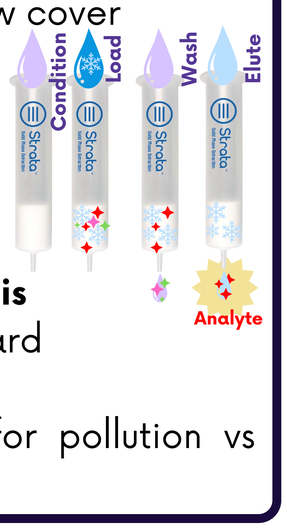
- **Laboratory analysis**
  - Pre-conditioning
  - Solid Phase Extraction
  - LCMS
  - → Snowmelt & bottle rinse



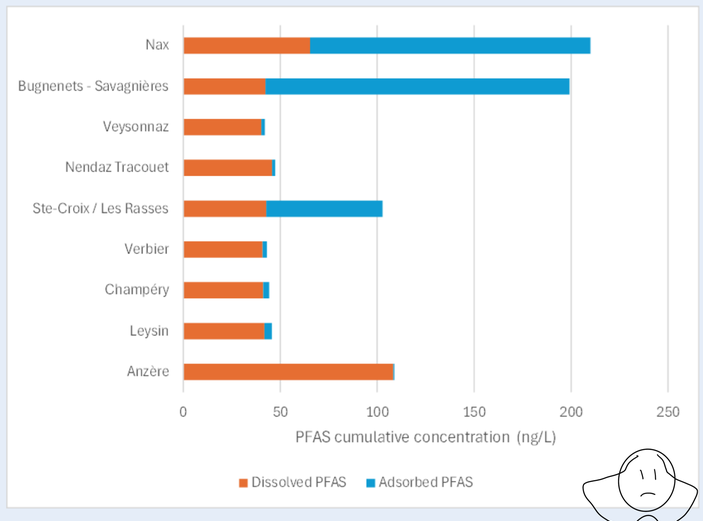
- **Quality control & data analysis**
  - Recovery of internal standard
  - Errors in manipulations
  - Correlation & heatmaps for pollution vs environmental factors

Results

PFAS on the slopes:

- All **25 types of PFAS** analysed were **detected**, mostly **<LOQ** (0,4 ng/L).
- **[6:2 FTS]**, known PFOS substitute, up to **106,78 ng/L** (literature: 279 ng/L on a competition track)[6], but also **4:2 FTS, PFBS, PFOA, PFOS** quantified.

Figure 1: concentration of different kinds of PFAS found in the snowmelt samples per location in ng/l, including a treshold of 0.4 ng/l representing the LOQ of the study.



- PFAS contamination **adsorbed onto** the **glass containers**, mainly: **PFHxA, HFPODA, PFUnA,** but 6:2 FTS and 4:2 FTS prevail.
- Taking adsorbed PFAS into account, contamination is highest in the samples from **Nax, Bugnenets – Savagnières,** up to **200 ng/L.**

Figure 2: total PFAS concentration of the snow samples with repartition of dissolved and adsorbed PFAS, cumulative values per location in ng/L.

Background samples:

Lost due to **issues** in the **analytical procedure**: **internal standard recovery**, reasons still unknown (long storage time? evaporation of volatile PFAS? errors in the procedure?)

Table 1: recovery rates of internal standard of different lab days.

	Samples 8/5	Samples 8/4	Samples 16/4
6:2 FTS	**(84 ± 12)%**	(8 ± 14)%	(1 ± 0)%
PFOA	**(73 ± 13)%**	(6 ± 8)%	(1 ± 1)%
PFOS	**(62 ± 12)%**	(7 ± 11)%	(1 ± 0)%

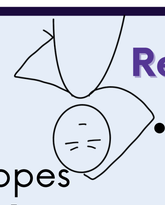
Impact of environmental conditions:

- **More PFAS detected** in snow sample when **temperature** is **low.**
- Possible adsorption of PFAS with high **log Kow** (i.e. PFDA) onto the **soil.**

Citizen science project:

- **Series of events**: lectures, serious games, sampling campaigns, open lab sessions.
- Goal: **involve public** into scientific research and **provide data** for further analyses of PFAS contamination in the mountains.

Conclusion



- **Many PFAS detected** on Swiss slopes but generally in very **low concentrations**, similar to literature, except for **6:2 FTS**. [7]
- Different PFAS expected to prevail (i.e. PFOA and PFOS): **effect of regulation**?
- **Physiochemical properties** of PFAS determine **if** and **where** PFAS will be found in snow samples.

Recommendations:

- **Adjust sampling protocol** to improve precision and reduce contamination.
- **Reduce storage time** of samples before analysis.
- Further investigate **limitations of procedure** used.
- Analyse **soil** from ski slopes and common **ski waxes**.
- Take **atmospheric deposition** of PFAS into account.

[1]Gaines, L. G. T. (2022). Historical and current usage of per- and polyfluoroalkyl substances (PFAS): A literature review. American Journal of Industrial Medicine, 66(5), 353–378. https://doi.org/10.1002/ajim.23362 **[2]** Leung, S. C. E., Wanninayake, D., Chen, D., Nguyen, N., & Li, Q. (2023). Physicochemical properties and interactions of perfluoroalkyl substances (PFAS) - Challenges and opportunities in sensing and remediation. The Science of the Total Environment, 905, 166764. https://doi.org/10.1016/j.scitotenv.2023.166764 **[3]** Per- and polyfluoroalkyl substances (PFAS) - ECHA. (2025). https://echa.europa.eu/hot-topics/perfluoroalkyl-chemicals-pfas **[4]** Panieri, E., Baralic, K., Djukic-Cosic, D., Djordjevic, A. B., & Saso, L. (2022). PFAS molecules: a major concern for the human health and the environment. Toxics, 10(2), 44. https://doi.org/10.3390/toxics10020044 **[5]** Plassmann, M. M., Denninger, A., & Berger, U. (2011). Environmental occurrence and fate of semifluorinated n-alkanes in snow and soil samples from a ski area. Chemosphere, 85(9), 1458–1463. https://doi.org/10.1016/j.chemosphere.2011.08.028 **[6]** Carlson, G. L., & Tupper, S. (2020). Ski wax use contributes to environmental contamination by per- and polyfluoroalkyl substances. Chemosphere, 261, 128078. https://doi.org/10.1016/j.chemosphere.2020.128078 **[7]** Müller, V., Costa, L. C. A., Rondan, F. S., Matic, E., Mesko, M. F., Kindness, A., & Feldmann, J. (2023). Per and polyfluoroalkylated substances (PFAS) target and EOF analyses in ski wax, snowmelts, and soil from skiing areas. Environmental Science: Processes & Impacts, 25(12), 1926–1936. https://doi.org/10.1039/D3EM00375B **[8]** International Ski and Snowboard Federation. (2024, October 31). FIS widens scope of fluor testing after successful first season. FIS. https://www.fis-ski.com/inside-fis/news/2024-25/fis-widens-scope-of-fluor-testing-after-successful-first-season

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