Investigation of per- and polyfluorinated alkyl substances (PFASs) in water from lake and river at Lys Glacier in Italy – Greenpeace Italy

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1. Introduction

Greenpeace Italy started two expeditions in 2024 and 2025 to collect water samples in the Lys river and the Lys lake at the foot of the Lys Glacier in the Monte Rosa mountain massif. The aim of the investigation in the remote high mountain is to examine the extent to which the glacier's meltwater is contaminated with poly- and perfluorinated alkyl substances (PFASs). It has to be noted that this is not a systematic study but a randomized survey.

Because persistent chemicals like PFASs degrade only very slowly they undergo several transport mechanisms and are widespread across the entire globe. Especially in cold regions they can be deposited and accumulated and they can be mobilized with melting processes in the shrinkage of the cryosphere due to global warming. Several scientific studies on water bodies, snow and ice in remote areas show increasingly contamination with chemicals from the group of PFASs and other persistent organic pollutants (POP). However, there are only few studies related to PFASs findings in the region of the Lys glacier so far.

The long-range atmospheric transport (LRAT) of some PFASs to remote areas has been studied scientifically for several years. Particularly those PFASs known to have toxic properties such as the long chained perfluorinated alkyl acid PFOA or sulfonate PFOS are commonly found in snow and water.[1] Studies discuss several possible ways that PFASs are distributed in the environment.[2] Some PFASs, specifically ionic PFASs like PFOA and PFOS, can be transported through the atmosphere bound to suspended particles and washed out and deposited with rain and snow in high mountains, for example. Volatile compounds such as short chain PFASs like TFA, PFBA and nonionic polyfluorinated fluorotelomer alcohols (FTOH) and sulfonates can be transported in the atmosphere over long distances. FTOHs are precursor substances, during long-range transport they are subject to atmospheric oxidation, they can be transformed into perfluorinated alkyl acids or sulfonates which can then be deposited in high mountains. Finally, ocean currents may play an important role by transporting PFAS globally, for example to the Arctic and Antarctica.[3]

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[1] Cai M, Yang H, Xie U, Zhao Z, Wang F, Lu Z, Sturm R, Ebinghaus R (2012). Per- and polyfluoroalkyl substances in snow, lake, surface runoff water and coastal seawater in Fildes Peninsula, King George Island, Antarctica J. Hazard. Mater. 209–210: 335–342.
https://doi.org/10.1016/j.jhazmat.2012.01.030

[2] Gawor A, Shunthirasingham C, Hayward SJ, Lei YD, Gouin T, Mmereki BT, Masamba W, Ruepert , Castillo LE, Shoeib M, Lee SC & Harner T, Wania F (2014). Neutral polyfluoroalkyl substances in the global Atmosphere. Environ. Sci.: Processes Impacts, 2014, 16, 404
https://pubs.rsc.org/en/content/articlepdf/2014/em/c3em00499f

[3] Arulananthan A, Vilhelmsson OÞ, Karsten U, Grossart H-P, Sigurbjörnsdóttir A, Rolfsson Grossart H-P, Sigurbjörnsdóttir A, Rolfsson Ó, Joerss H and Scholz B (2025) Per- and polyfluoroalkyl substances (PFAS) in the cryosphere – occurrence, organismic accumulation, ecotoxicological impacts, transformation, and management

Recently, several studies focusing on a particularly mobile substance from the class of PFASs have been published. Tetrafluoroacetate (TFA) is the substance with only two carbon atoms and therefore the shortest molecular structure in the chemical group of PFASs. TFA is very mobile in the environment, very persistent (vMvP) and not biodegradable. The European Chemicals Agency (ECHA) currently reviews the classification of TFA as a toxic to reproduction substance.[4] The main sources of TFA are its release as a metabolite from pesticides (e.g. flufenacet), refrigerants from heat pumps and refrigerators (F-gases such as tetrafluoroethane) and the chemical industry itself.[5]

Ten years ago, in 2015, Greenpeace International (GPI) sent eight expedition teams to remote areas to collect samples from lakes, snow and ice in high mountains in five continents. One of the sampling sites was located in the Swiss Alps at the Macun Lakes, about 200km from the Lys Glacier.[6] The study shows that PFASs are widely spread over the globe, they have been detected in samples from all sampling sites.

Figure 1: The Lys Glacier (sampling site in 2024 and 2025) in the Alps is part of the Monte Rosa Mountain Massif. The Macun Lakes (sampling site in 2015) are part of the Swiss National Park, the distance to the Lys Glacier is approximately 200km.

strategies. Front. Environ. Sci. 13:1559941. Volume 13, 2025, doi: 10.3389/fenvs.2025.1559941 https://doi.org/10.3389/fenvs.2025.1559941

[4] European Chemical Agency ECHA, Registry of CLH intentions until outcome, Sodium Trifluoracetate, June 2025 https://echa.europa.eu/de/registry-of-clh-intentions-until-outcome?p_p_id=disslists_WAR_disslistsportlet&p_p_lifecycle=1&p_p_state=normal&p_p_mode=view&_disslists_WAR_disslistsportlet_javax.portlet.action=searchDissLists

[5] See CHEM Trust's summary on what PFAS are and where they come from: https://chemtrust.org/wp-content/uploads/FAQ-Green-Transition-2024_January_2025.pdf

[6] Greenpeace (2015). Footprints in the snow - Hazardous PFCs in remote locations around the globe (2015). https://www.greenpeace.org/static/planet4-international-stateless/2015/09/2a086e17-rae_report_08_2015_english_final.pdf

There have been other investigations specifically on snow, ice and water from glaciers, e.g. in polar regions and in Svalbard.[7] These studies show that long-range atmospheric transport (LRAT) of PFAS is likely the major deposition pathway for PFASs and POPs in the snow of glaciers and their melting waters.

There are only few studies on contamination of snow or water samples from the Lys glacier. One study shows contamination of snow from the glacier with perchlorinated biphenyls (PCB)[8]. Like PFASs, PCBs are persistent and distributed across the globe by LRAT. Samples from snow and ice cores from the Lys glacier and two other glaciers in the Italian Alps have been used to study transport mechanism of current used pesticides (CUP) and other persistent organic pollutants (POP).[9]

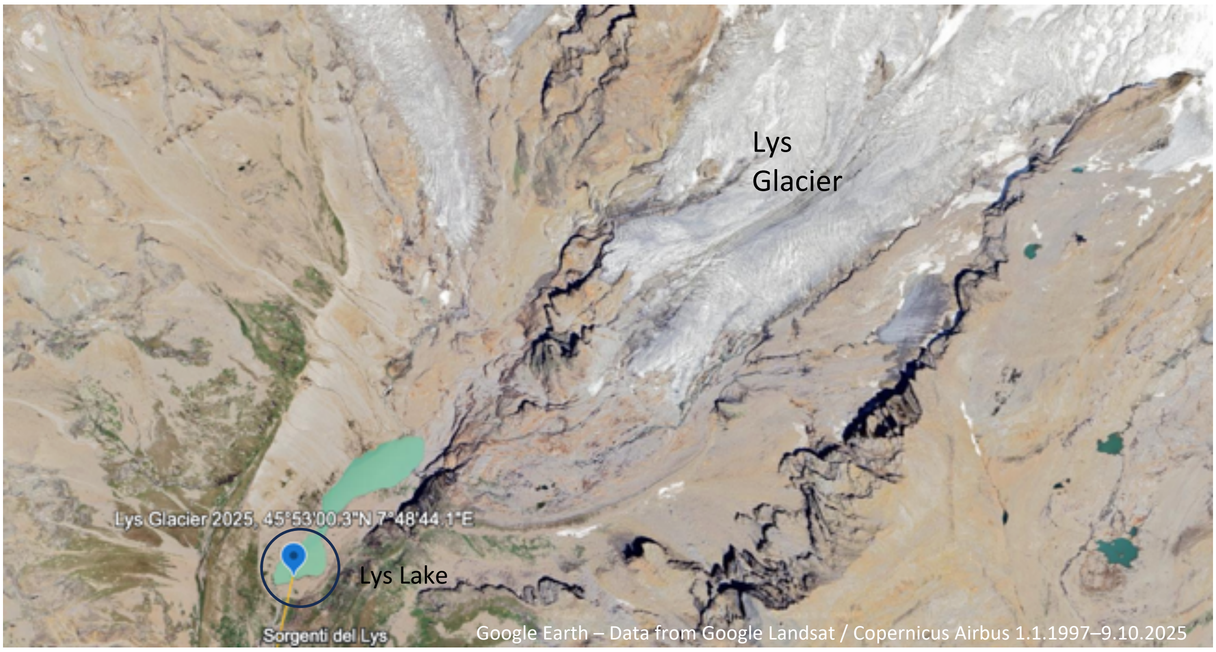

Figure 2: The Lys Lake is located at the foot of the Lys Glacier, filled with meltwater and feeding the outflow, the Lys river.

The worrying consequences of the spread of PFAS are evident, for example, in studies that show contamination of the most important foodstuff, drinking water. Greenpeace Italy

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[7] Kwok K, Yamazaki E, Yamashita N, Taniyasu S, Murphy M B, Horii Y, Petrick G, Kallerborn R, Kannan K, Murano K, Lam P (2013), Transport of Perfluoroalkyl substances (PFAS) from an arctic glacier to downstream locations: Implications for sources, Science of The Total Environment, Volume 447, 2013, 46-55 https://doi.org/10.1016/j.scitotenv.2012.10.091

[8] Villa S, Vighi M, Maggi V, Finizio A, Bolzacchini E (2003), Historical Trends of Organochlorine Pesticides in an Alpine Glacier. Journal of Atmospheric Chemistry 46: 295–311, 2003. https://www.researchgate.net/publication/231315746_Historical_profile_of_polychlorinated_biphenyls_PCBs_in_an_Alpine_Glacier

[9] Ferrario C, Finizio A, Villa S (2016). Legacy and emerging contaminants in meltwater of three Alpine glaciers. Science of the Total Environment 574, 350-357. 2016. doi: 10.1016/j.scitotenv.2016.09.067 https://boa.unimib.it/retrieve/handle/10281/199127/287624/phd_unimib_709299.pdf

recently showed that 76% of 260 samples of drinking water from publicly accessible taps are contaminated with PFASs.[10,11]

Per and polyfluoroalkyl substances (PFASs)

PFASs, also known as 'forever chemicals', are a group of man-made chemicals that have been used in many industrial and consumer products since the 1940s due to their unique properties such as heat resistance and oil and water repellency. PFASs are found, for example, in consumer goods such as ski wax, water-repellent outdoor clothing, grease-repellent coatings and packaging such as pizza boxes and baking paper, as well as in stain-resistant carpets and car seats. PFASs are also widely used in technical applications due to their high chemical and temperature resistance. However, these chemicals also have harmful properties that pose a risk to human health and the environment. PFASs are mobile and persistent, meaning they are not biodegradable in the environment. In addition, some PFASs are toxic and bioaccumulative, meaning they can accumulate in animal organisms and the human body. PFASs can enter the body through drinking water or food such as fish, seafood and vegetables, posing a long-term health risk.
The PFASs chemical group is divided into ionic PFASs and nonionic PFASs, based on the polarity and electrical charge of the respective molecule. Ionic PFASs such as PFOA and PFOS are less volatile and travel long distances attached to particles or via waterways. Nonionic PFAS such as fluorotelomers (FTOHs) and the ultra-short Trifluoracetate (TFA) can be transported over long distances in a gaseous state in the atmosphere. When deposited FTOHs can be transformed into ionic PFASs.

2. Sampling and Analysis

Two sampling expeditions have been conducted. The first sampling took place on 12th of October 2024, water from the Lys river has been collected. The sampling spot is located in a distance of approximately 1.6km downstream to the glacier lake, the source of the river, see figure 3. The second sampling took place on 17th of July 2025, water from the southern shore of the lake at the glacier was collected.

Two samples of water were collected in each expedition. On site two plastic lock & lock containers were filled, the sample volume was 2 liters each.

At the sampling site all sample bottles have been wrapped separately in aluminum foil before transport and storage.

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[10] Greenpeace Italia, 22.01.2025: Acque senza Veleni
https://www.greenpeace.org/static/planet4-italy-stateless/2025/01/4bbb41f2-report_def_a_s_v_2025-1.pdf

[11] Greenpeace Italia, 09.10.2025: Pfas, analisi di Greenpeace Italia sulle acque minerali: Contaminazione presente in sei marche su otto
https://www.greenpeace.org/italy/comunicato-stampa/29045/pfas-analisi-di-greenpeace-italia-sulle-acque-minerali-contaminazione-presente-in-sei-marche-su-otto/
https://www.greenpeace.org/static/planet4-italy-stateless/2025/10/1517fe65-20250805_gpit_bottledwater_en_final_a_2.pdf

In both samplings field blanks have been taken. An empty sampling container has been transported to the sampling site, was opened and closed again without filling the container with water. The field blank container was then treated in exactly the same way as the samples. In the lab the field blank containers were rinsed with ultra clean water that then was analysed for PFASs.

Distance from sampling site 17.07.2024 to sampling site from 12.10.2024 is approximately 1630 meters.

The following samples were collected and analysed for PFASs:

Location	Sample ID	GPS	Date of Sampling	Packaging (indicated on bottle)
River Lys below Lys-Glacier, 1.6km downstream Lys Lake 2001m altitude	S1	45°52'08''N 7°48'27''E	12.10.2024	Lock & lock bottle, plastics, sample volume 2L
River Lys below Lys-Glacier, 1.6km downstream Lys Lake 2001m altitude	S2	45°52'08''N 7°48'27''E	12.10.2024	Lock & lock bottle, plastics, sample volume 2L
	Field blank		12.10.2024	Lock & lock bottle, plastics, sample volume 2L
Lake at Lys Glacier 2353m height	A	45° 53‘ 0.2688‘‘N 7°48’44.1‘‘E	17.07.2025	Lock & lock bottle, plastics, sample volume 2L
Lake at Lys Glacier 2353m height	B	45° 53.0031‘ 007° 48.7472	17.07.2025	Lock & lock bottle, plastics, sample volume 2L
	Field blank		17.07.2025	Lock & lock bottle, plastics, sample volume 2L

Table 1: List of samples and location data from two sampling expeditions to the Lys Glacier in 2024 and 2025

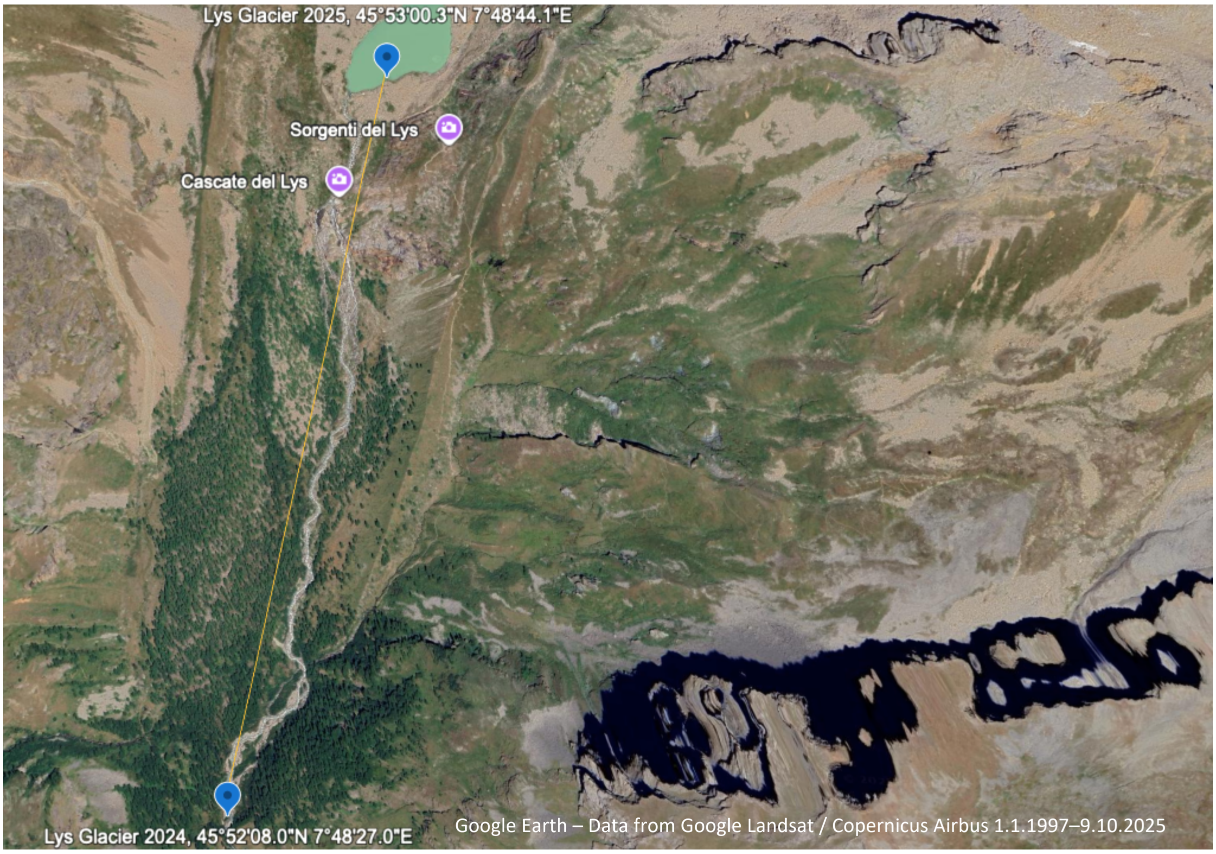

Figure 3: Locations of the samplings. During the sampling in October 2024 water of the Lys River was collected. The river is the outflow of the lake at the foot of the Lys glacier in the Italian Monte Rosa Mountain Massif. The sampling in July 2025 collected water of the Lys Lake which is feed by melting water from the Lys glacier

The contents of the bottles were tested for PFASs in an independent commercial laboratory in Germany. The lab has accreditation for the analysis method used for identification and quantification of PFASs in low concentrations in water, snow and ice samples. The samples were tested for the substances listed in Table 1. The table shows (with the CAS identification code for each substance), the limit of quantification (LoQ) as specified by the lab.

In the laboratory the samples (see table 1) were prepared and processed. Extraction was performed using Solid Phase Extraction (SPE), identification of the listed 32 PFASs (see table 2) using High-Performance Liquid Chromatography and Tandem Mass Spectrometry (HPLC-MS/MS) and isotopedilution method for quantification based on the regulation DIN 38407-42:2011-03.[12]

The laboratory examined substances that are commonly used but also substances that are used as substitutes for particularly hazardous substances such as PFOA and PFOS. These

[12] a description of the used method can be found here, in german: https://www.gdch.de/fileadmin/downloads/Netzwerk_und_Strukturen/Fachgruppen/Wasserchemische_Gesellschaft/DEV/vdok_f42.pdf

substitutes include, for example, ADONA, GenX and F53-B.[13] There is no accreditation for the examination of these substances.

Parameter	CAS	LOQ (ng/l)
Perfluoro-n-butanoate (PFBA)	375-22-4	<0.2
Perfluoro-n-pentanoate (PFPeA)	2706-90-3	<0.03
Perfluorohexanoate (PFHxA)	307-24-4	<0.03
Perfluoroheptonate (PFHpA)	375-85-9	<0.02
Perfluorooctanoate (PFOA)	335-67-1	<0.2
Perfluorononanoate (PFNA)	375-95-1	<0.01
Perfluorodecanoate (PFDA)	335-76-2	<0.2
Perfluoroundecanoate (PFUnA)	2058-94-8	<0.04
Perfluorododecanoate (PFDoA)	307-55-1	<0.02
Perfluorotridecanoate (PFTrA)	72629-94-8	<0.02
Perfluorotetradecanoate (PFTA)	376-06-7	<0.02
Perfluorohexadecanoate (PFHxDA)	67905-19-5	<0.5
Perfluoroctadecanoate (PFODA)	16517-11-6	<0.5
Perfluorobutanesulfonate (PFBS)	375-73-5	<0.04
Perfluoropentanesulfonate (PFPeS)	2706-91-4	<0.04
Perfluorohexanesulfonate (PFHxS)	355-46-4	<0.06
Perfluoroheptanesulfonate (PFHpS)	375-92-8	<0.02
Perfluoroctanesulfonate (PFOS)	1763-23-1	<0.03
Perfluorononanesulfonate (L-PFNS)	35192-74-6	<0.05
Perfluorodecanesulfonate (PFDS)	355-77-3	<0.02
Perfluoroundecanesulfonate (L-PFUnS)	749786-16-1	<0.1
Perfluordodecanesulfonate (L-PFDoS)	79780-39-5	<0.1
Perfluorotridecanesulfonate (L-PFTrS)	791563-89-8	<0.1
1H,1H,2H,2H-Perfluorodecan-solfonate (8:2 FTS)	39108-34-4	<0.01
1H,1H,2H,2H-perfluoro-1-esanesolfonate (4:2 FTS)	757124-72-4	<0.06
1H,1H,2H,2H-perfluoro-1-octanesulfonate (6:2 FTS)	27619-97-2	<0.01
1H,1H,2H,2H-perfluoro-1-dodecanesolfonate (10:2 FTS)	108026-35-3	<0.05
GenX - 2,3,3,3-Tetrafluoro-2-(1,1,2,2,3,3,3-heptafluoropropoxy)propanoic acid (HFPO-DA)	62037-80-3	<0.05
ADONA - Dodecafluoro-3H-4,8-dioxanoate	919005-14-4	<0.5
11-Chloroperfluoro-3-oxaundecanesulfonic acid (F-53 B MIN)	73606-19-6	<0.01
9-Chlorohexadecafluoro-3-oxanonane-1-sulfonate (F-53 B MAJ)	756426-58-1	<0.01

Table 2: List of PFASs that were analysed in the water samples from the Lys Glacier

3. Results

Table 3 summarises the results of the analyses for PFASs in water samples from the Lys glacier. The concentrations are expressed in nanograms per liter of water (ng/l). No tests have been

[13] Cheng C, Zhu X, Li J. Omelas-Soto N, Wang Y (2025). Emerging PFAS alternatives: Unveiling environmental fates and ecological risks. Energy & Environmental Sustainability. https://doi.org/10.1016/j.eesus.2025.100041 https://www.sciencedirect.com/science/article/pii/S3050745625000409?via%3Dihub

carried out on the material used to produce the sample bottles. However, the analysis of field blank shows that there is no PFAS contamination from plastic material of the sampling bottles.

The PFAS concentrations in the lake water samples (July 2025) are higher than in the samples taken (October 2024) from the Lys river, approximately 1.6 km downstream of the lake.

The sum of all identified PFASs in samples from the Lys-Glacier vary in a range from 1.87ng/l (Lys-2) for the water from the stream collected in 2024 to a concentration of 3.08ng/l (Lys-3 A) in the lake water collected during the sampling expedition in 2025.

Short Chain PFAS (C4-C6)

Dominating substance in all four water samples is the short chain PFAS perfluorobutanoate PFBA (C4) in a concentration range from 0,767ng/l in the sample from July 2025 to 0.88ng/l I the samples from October 2024. Another C4-PFAS, perfluorobutanesulfonate PFBS, was identified in water from lake and river but in significantly lower concentration, 0.13ng/l in the lake water (Lys-3 A) and 0.13ng/l (Lys-1) re. 0.11ng/l (Lys-2) in the stream.

Short chain C5-PFAS (PFPeA) was detected in all four samples, the concentration in the lake was 0.13ng/l in Lys-3A and also 0.13ng/l in Lys-4B, comparable to the concentration in the river water (0.12ng/l in Lys-1 and 0.1ng/l in Lys-2).
C6-PFAS (PFHxA) was detected in the lake (0.36ng/l and 0.29ng/l) also in the samples from the downstream (0.18ng/l and 0.14ng/l). The C6 sulfonate (PFHxS) was not detected.

The ultra short chain PFAS Trifluoroacetate (TFA) has not been analysed.

Long Chain PFAS (C7-C14)

Highest concentrations for long chain PFASs have been quantified for C7- and C8-substances, both substances were detected in samples from the stream water and from the lake water at the Lys-Glacier. The PFHpA concentration in the sample from 2024 is 0.30ng/l (Lys-1) and 0.26ng/L (Lys-2), in the sample from 2025 collected from the lake the concentration is 0.53n/l (Lys-3A) and 0.54ng/L (Lys-4B).

The toxic substance PFOA was quantified with 0.24ng/l (Lys-1) and 0.21ng/l (Lys-2) in the stream water from 2024 and in higher concentration in the lake in 2025 with 0.41ng/l (Lys-3A) and 0.36ng/l (Lys-4B).

C9 and C10-PFASs were identified in higher concentration in the sample from the lake compared with the results in the river water collected in 2024. The samples from the lake show PFNA (C9) in concentration of 0.28ng/l (Lys-3 A) and 0.23ng/l (Lys 4 B), in the river the lab found 0.12ng/l (Lys-1) and 0.11ng/L (Lys-2). PFDA (C10) was detected in the lake water in a concentration of 0.14ng/l in Lys-3 A and 0.08ng/l in Lys-4 B. In the river water the concentration of PFDA was 0.04ng/l in Lys-1 and 0.03ng/l in Lys-2. PFUnA (C11) was found only in one sample (Lys-3 A) from the lake.

PFOS was detected in all four samples, however, in concentrations near the Limit of Quantification (LoQ). All four water samples tested contained PFOA and PFNA, like PFOS substances from the specifically regulated PFAS-4 group (PFOA, PFOS, PFHxS, PFNA) in significantly higher concentration above LOQ.

PFAS	**River water LYS 1, 12-10-2024**	**River water LYS 2, 12-10-2024**	**Lake water A = LYS 3, 17-07-2025**	**Lake water B = LYS 4, 17-07-2025**
Per-/polyfluorinated Alkyl Substance	45°52'08''N, 7°48'27''E	45°52'08''N, 7°48'27''E	45° 53‘ 0.2688‘‘N, 7°48’44.1‘‘E	45° 53.0031‘N, 007° 48.7472‘E
	ng/L	ng/L	ng/L	ng/L
PFBA	**0.88**	**0.88**	**0.81**	**0.78**
PFPeA	**0.12**	**0.10**	**0.13**	**0.13**
PFHxA	**0.18**	**0.14**	**0.36**	**0.29**
PFHpA	**0.30**	**0.26**	**0.53**	**0.54**
PFOA	**0.24**	**0.21**	**0.41**	**0.36**
PFNA	**0.12**	**0.11**	**0.28**	**0.23**
PFDA	**0.04**	**0.03**	**0.14**	**0.08**
PFUnA	< 0.04	< 0.04	**0.09**	< 0.04
PFDoA	< 0.02	< 0.02	0.03	0.01
PFTrA	< 0.02	< 0.02	< 0.02	< 0.01
PFTA	< 0.02	< 0.02	< 0.03	< 0.02
PFHxDA	< 0.5	< 0.5	< 0.59	< 0.39
PFODA	< 0.5	< 0.5	< 0.88	< 0.59
PFBS	**0.13**	**0.11**	**0.13**	< 0.04
PFPeS	< 0.04	< 0.04	< 0.03	< 0.02
PFHxS	< 0.06	< 0.06	< 0.09	< 0.06
PFHpS	< 0.02	< 0.02	< 0.03	< 0.02
PFOS	**0.03**	**0.03**	**0.11**	**0.05**
L-PFNS	< 0.05	< 0.05	< 0.04	< 0.03
PFDS	< 0.02	< 0.02	< 0.03	< 0.02
L-PFUdS	< 0.1	< 0.1	< 0.04	< 0.03
L-PFDoS	< 0.1	< 0.1	< 0.07	< 0.05
L-PFTrDS	< 0.1	< 0.1	0.09	< 0.05
4:2-FTS	< 0.01	< 0.01	< 0.02	< 0.01
6:2-FTS	< 0.06	< 0.06	< 0.09	< 0.06
8:2-FTS	< 0.01	< 0.01	< 0.02	< 0.01
10:2-FTS	< 0.05	< 0.05	< 0.03	< 0.02
ADONA	< 0.5	< 0.5	< 0.88	< 0.59
GenX	< 0.05	< 0.05	< 0.09	< 0.06
F-53 B MAJ	< 0.01	< 0.01	< 0.15	< 0.1
F-53 B MIN	< 0.01	< 0.01	< 0.15	< 0.1
Sum of identified PFAS	2.04	1.87	3.08	2,47

Table 3: Results of the investigation of PFASs in water samples from the lake and river at the Lys Glacier

Concentration listed as <0.xx means the PFAS has not been identified, concentration is below the limit of Quantification (LOQ).
In both field blanks no PFAS has been identified, all results are <LOQ.

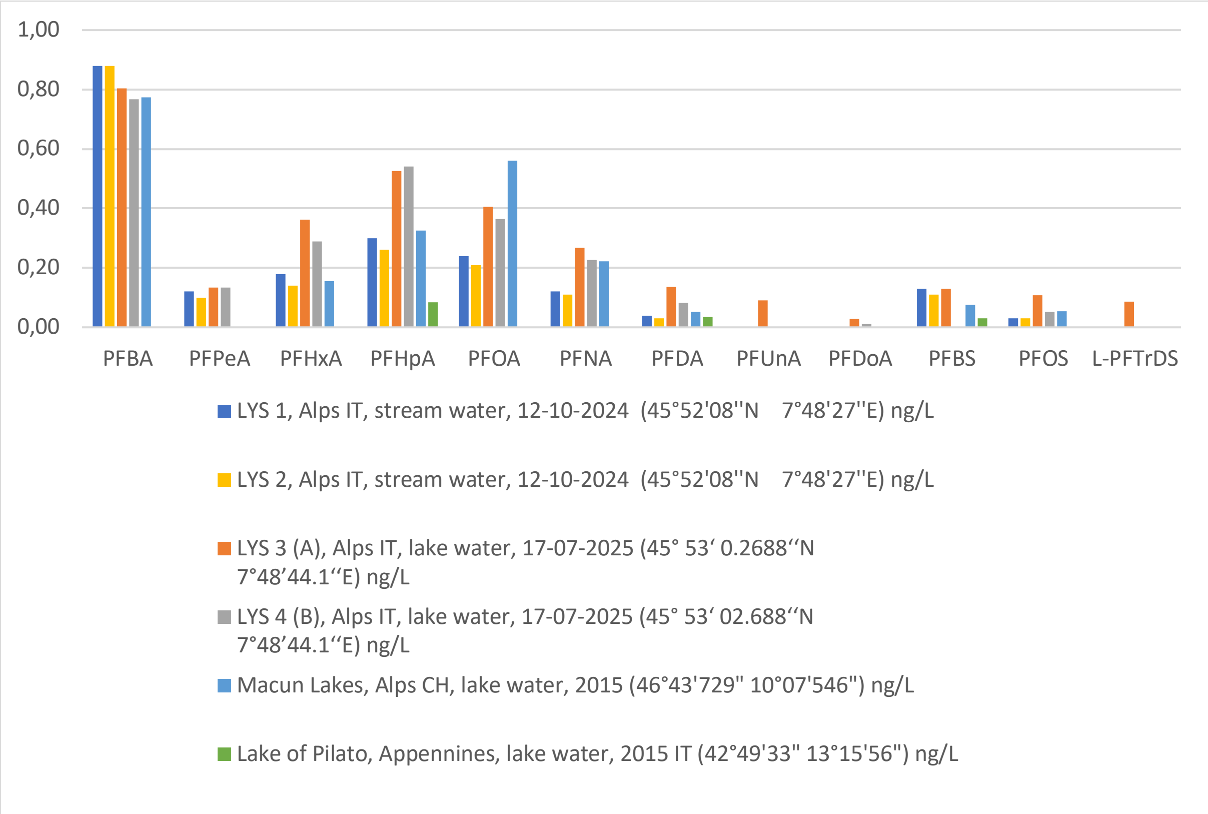

Figure 2: Results for PFAS analysis in water samples from Lys-Glacier in Italy. Shown are the concentrations of PFASs in water from samplings in October 2024 and July 2025.
For comparison the results are shown from investigations in water from the Macun Lakes and Lake of Pilato, both conducted in 2015.[14]

4. Assessment criteria and evaluation of measurement results

There are no environmental quality standards for PFASs in melt water. There are several studies on PFASs in water and snow samples from remote areas. Most of these studies focus on arctic and antarctic polar regions. There are only few studies looking into samples from the Alps.

A recently published study identified that the release of PFASs, other persistent organic pollutants, microplastics and heavy metals and emerging contaminants can be attributed to the climate crisis.[15] Investigations on ice core samples from Svalbard identified perfluorobutanoate (PFBA), perfluorooctanoate (PFOA) and perfluorononanoate (PFNA) as

[14] Greenpeace (2015), Footprints in the Snow, op.cit.
[15] Kumar, R., Pippal, P.S., Raj, A. *et al.* Toxic Contaminants in Glacial Meltwater and Their Impact on the Environment and Human Health. Water Conserv Sci Eng **10**, 54 (2025). https://doi.org/10.1007/s41101-025-00379-8

the dominant compounds found in ice core samples. Taking PFOA, PFNA and perfluorooctane-sulfonate (PFOS) as examples, higher concentrations were detected in the middle layers of the ice cores representing the period of 1997-2000. Average PFAS concentrations were found to be lower in surface snow and melted glacier water samples, while increased concentrations were observed in river water downstream near the coastal area. Downstream of the glacier local sources (e.g., skiing activities) were identified in the downstream locations. [16]

In the atmospheric environmental samples mostly found LRAT-substances are nonionic PFASs including 6:2, 8:2, and 10:2 fluorotelomer alcohol (FTOH) and acrylates (FTAs). Beside these substances methyl and ethyl perfluorooctane sulfonamides (MeFOSA and EtFOSA) and methyl and ethyl perfluorooctane sulfonamidoethanols (MeFOSE and EtFOSE) were identified. [17,18] Due to their physicochemical properties ionic PFASs like the long chain PFOA or PFOS are likely transported in the atmosphere bound to particulate matter.[19] Recently published, since 2000 the occurrence of PFBA is increasing for example in antarctica ice core samples.[20]

For assessment of the samplings at the Lys glacier we compare the results of this study with the Greenpeace investigations from 2015 of PFAS in snow and water samples in remote areas of five continents[21]. In the study from 2015, Greenpeace expeditions collected samples of lake water from remote mountain areas. One sampling site was in the Alps at the Macun Lakes in the Swiss National Park at 2600 meters. Another sample was from the Lake of Pilato in Apennines (Monti Sibillini Italy) at 1950 meters. Beside these two, in 2015 six other expeditions took place at the Haba Snow Mountains in China; the Altai Mountains in Russia, Torres del Paine in Patagonia, Chile; the Kackar Mountains in Turkey; the High Tatras in Slovakia. The sampling site at Macun Lakes in the Swiss Alps is about 200 km north east of the Lys Glacier. The distance from Lake of Pilato in the Apennines to Lys lake in the Alps is approximately 500 km. In the 2015 study samples from the Lake of Pilato show concentrations of PFAS which are significantly lower than in the Alps region. In general lake water samples show persistent PFASs that have accumulated over the years, resulting in concentrations that are significantly higher than in snow samples, with concentrations of short chain PFASs in the

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[16] Kwok K, Yamazaki E, Yamashita N, Taniyasu S, Murphy M B, Horii Y, Petrick G, Kallerborn R, Kannan K, Murano K, Lam P (2013), Transport of Perfluoroalkyl substances (PFAS) from an arctic glacier to downstream locations: Implications for sources, Science of The Total Environment, Volume 447, 2013, 46-55, https://doi.org/10.1016/j.scitotenv.2012.10.091

[17] Dreyer A, Weinberg I, Temme C, Ebinghaus R (2009): Polyfluorinated Compounds in the Atmosphere of the Atlantic and Southern Oceans: Evidence for a Global Distribution, Environmental Science & Technology 2009 43 (17), 6507-6514, DOI: 10.1021/es9010465
https://pubs.acs.org/doi/10.1021/es9010465

[18] Cai M, Xie Z, Möller A, Yin Z, Huang P, Cai M, Yang H, Sturm R, He J, Ebinghaus R (2012): Polyfluorinated compounds in the atmosphere along a cruise pathway from the Japan Sea to the Arctic Ocean. Chemosphere Vol 87 (9), 989-997
https://doi.org/10.1016/j.chemosphere.2011.11.010

[19] Xie Z, Zhang P, Wu Z, Zhang S, Wei L, Mi L, Kuester A, Gandrass J, Ebinghaus R, Yang R, Wang Z (2022) Legacy and emerging organic contaminants in the polar regions. Sci Total Environ 835:155376.
https://doi.org/10.1016/j.scitotenv.2022.155376

[20] Garnett J, Halsall C, Winton H, Joerss H, Mulvaney R, Ebinghaus R, Frey M, Jones A, Leeson A, Wynn P. (2022). Increasing Accumulation of Perfluorocarboxylate Contaminants Revealed in an Antarctic Firn Core (1958–2017). Environmental Science & Technology 2022 56 (16), 11246-11255 , DOI: 10.1021/acs.est.2c02592
https://pmc.ncbi.nlm.nih.gov/articles/PMC9386903/pdf/es2c02592.pdf

[21] Greenpeace (2015), Footprints in the Snow, op.cit.

water of most remote lakes higher than that of long chain PFASs. In water samples from Patagonia, Russia and Switzerland, the short-chain C4, C5 and C6 compounds were found in concentrations of up to 1.1 ng/l. Similar findings are reported in studies from lake water analysis in the USA[22] or in Austria/Alps[23].

The samples from the Lys Glacier reported here show concentrations of short chain PFAS like PFBA in the range from 0.77ng/l - 0.88ng/l, similar to the concentration of 0.77ng/l quantified in 2015 in samples from the Macun Lakes. The concentration of PFBA in all four samples from the Lys Glacier does not much vary and is similar to what was found in 2015 in water from the Macun Lakes.

Other ionic PFAS like PFPeA, PFHxA, PFHpA have been detected in all four samples from the Lys area, in higher concentration in samples from lake water collected in 2025 compared to concentrations found in samples from the Lys river collected in 2024. The concentrations found for these chemicals are higher or similar to what has been found in water from the Macun Lakes in 2015.

The toxic substance PFOA has been detected in significant concentrations between 0.21ng/l and 0.41ng/L in all four samples. The concentration in the lake water is higher compared to the water from the river. In the Greenpeace study from 2015 only the water samples from the Alps (the Macun Lakes) contained PFOA, at 0.56ng/l, water samples from sampling sites in other continents did not show PFOA.

The very persistent and toxic substance PFOS has been detected in all four samples from Lys glacier detected, in a concentration similar to what has been found in 2015 in the water from the Macun Lakes.

Overall, the sum of concentrations of PFASs in water samples from Lys lake (2.47/3.08ng/l) and Lys river (1.87/2.04ng/l) are slightly higher than the range that has been reported in other studies from glacier meltwaters. For example, in a study on glacier of the Tibetan Plateau[24] the total concentrations of perfluoroalkyl acids (PFAAs) were 1,413pg/l for glacial ice, followed by 1,277pg/l for meltwater runoff, 980pg/l for lake water, and 616pg/l for rain.

Like what has been found at the Lys glacier, in the Tibetan glacier perfluorobutanoic acid (PFBA) is dominant in runoff. However, lake and river water at Lys glacier contain less proportions of perfluorobutane sulfonate and perfluorooctane sulfonate compared to what has been found in the Tibetan glacier meltwater.

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[22] Furdui VI, Stock NI, Ellis D, Butt CM, Whittle DM, Crazier PW, Reiner EJ, Muir DCG, Mabury SA (2007): Spatial Distribution of Perfluoralkyl Contaminants in Lake Trout from the Great Lakes. Environ. Schi.Technol. 41 (5) 1554-1559

[23] Clara M, Weiss S, Sanz-Escribano D, Scharf, Scheffknecht C (2009): Perfluorinated alkylated substances in the aquatic environment: An Austrian case study, Water Research 43: 4760-4768

[24] Chen M, Wang C, Wang X, Fu J, Gong P, Yan J, et al. (2019). Release of perfluoroalkyl substances from melting glacier of the Tibetan Plateau: Insights into the impact of global warming on the cycling of emerging pollutants. Journal of Geophysical Research: Atmospheres, 124, 7442–7456. https://doi.org/10.1029/2019JD030566

5. Conclusion

The results of the study presented here show that water in the alpine Italian region at the Lys glacier are significantly contaminated with forever chemicals: in all four samples, substances from the group of per- and polyfluorinated substances (PFAS) were detected. The concentrations found are in the range of existing comparable studies from alpine or high mountain regions across the globe.

As Greenpeace did a random sampling at the Lys glacier, not a systematic investigation, the conclusions have to be drawn carefully. The results for these four water samples from the lake and the river show contamination with PFASs similar to what has been found in the study that Greenpeace International conducted in the Alps ten years ago. Sources for the occurrence of PFAS in remote areas are long-range atmospheric transport (LRAT), ocean currents and direct human contamination. Given that only few comparative studies of PFAS in alpine regions exist, more investigations on the contamination of melting glaciers and their runoff waters are needed.

PFASs are persistent and can be transported over long distances, in high mountain regions they can be washed out of the atmosphere by rain and snow and deposited. Due to the properties of PFASs, this cannot be prevented as long as these chemicals are produced and widely used. Even if the production of PFASs would be drastically reduced, these persistent substances will remain detectable in environmental matrices for a long time to come. They can only be removed from the environment at great expense. Due to climate crisis glacial melting is recognized as one of the major sources for theses substance, recently published reviews show[25,26,27]. Melting water from glaciers feeds lakes and the outflow transports PFASs into the rivers running downhill to waterbodies that e.g. can be the source for drinking water. For comparison, monitoring Lake Iseo, a southern Alpine Italian lake, revealed that DDT sediment concentrations increased sharply approximately 20 years after the ban of this pesticide, a persistent chemical used in agriculture. This may have been caused by glacial retreat due to global warming[28]. Ongoing glacial melt and increasing occurrence of emerging pollutants in glacier will increase the risks of the entry of pollutants like PFASs to freshwater sources.

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[25] Wu J, Zhuang Y, Dong B, Wang F, Yan Y, Zhang D, Liu Z, Duan X, Bo Y, Peng L (2024). Spatial heterogeneity of per- and polyfluoroalkyl substances caused by glacial melting in Tibetan Lake Nam Co due to global warming, Journal of Hazardous Materials, 478 (2024), 135468, https://doi.org/10.1016/j.jhazmat.2024.135468.

[26] MacInnis J J, Lehnherr I, Muir D C G, Quinlan R, De Silva A O (2019), Characterization of perfluoroalkyl substances in sediment cores from High and Low Arctic lakes in Canada, Science of The Total Environment, Volume 666, 2019, 414-422, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2019.02.210.et al. a https://www.sciencedirect.com/science/article/abs/pii/S0048969719306989

[27] Hartz W F, Björnsdotter M K, Yeung L W Y, Hodson A, Thomas E R, Humby J D, Day C, Jogsten I E, Kärrman A, Kallenborn R (2023). Levels and distribution profiles of Per- and Polyfluoroalkyl Substances (PFAS) in a high Arctic Svalbard ice core, Science of The Total Environment, Vol 871, 2023, 161830, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2023.161830

[28] Bettinetti R, Galassi S, Guilizzoni P, Quadroni S (2011). Sediment analysis to support the recent glacial origin of DDT pollution in Lake Iseo (Northern Italy), Chemosphere, Volume 85, Issue 2, 2011, 163-169, ISSN 0045-6535, https://doi.org/10.1016/j.chemosphere.2011.06.037.