Overview of fish contamination by a range of perfluoroalkyl chemicals in European deep lakes

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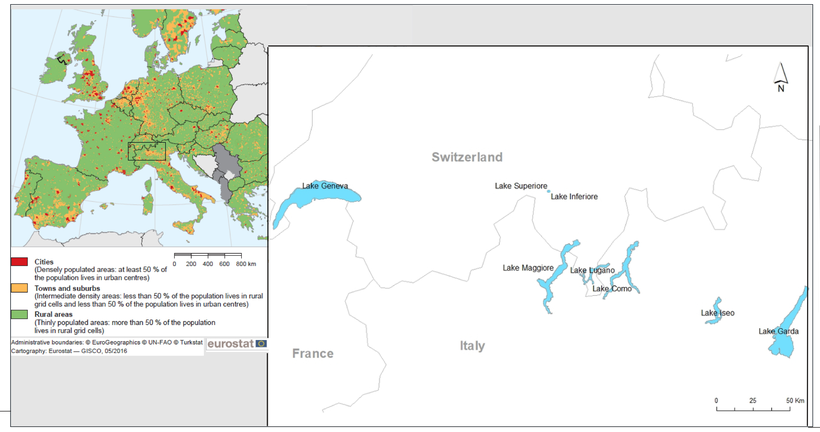
Context, goal

Monitoring studies involving fish in transboundary lakes across France, Italy and Switzerland:
Lake Geneva, Lake Maggiore, Lake Lugano
Similar monitoring studies in Italian lakes:
Lake Como (including its branch named Lecco), Lake Iseo, Lake Garda, and two remote / high altitude lakes.
Database including 7 fish species, 128 samples (fillet, liver, viscera, offal). In many cases, only fillets were analyzed.

Goals:
- to compare PFAS contamination features across these lakes;
- to look at the type of source/pressure.
- to assess the relationships between concentrations in fillet and whole-body.



Lake	Area (km²)	Max. depth (m)	Alt. (m)
Geneva	581	309	312
Maggiore	213	370	193
Lugano	49	288	271
Como	146	450	198
Iseo	61	251	186
Garda	368	350	65

Lake characteristics

Analytical methods

– Analysis according to Mazzoni *et al.* (2019) in Italian fish samples. Similar approach for Lake Geneva fish samples (Munschy *et al.*, 2013): freeze-drying, grinding, digestion (methanol/KOH), purification (SPE cartrigdes), analysis by liquid chromatography coupled with tandem mass spectrometry (LC-ESI-MS/MS)
– Compounds common to all lakes include C6-C12 PFCAs, PFHxS and PFOS; PFTrDA and PFTeDA analyzed in some lakes too; so ΣPFCAs means the sum of C6-C12 PFCA concentrations, and ΣPFASs means ΣPFCAs + [PFHxS] + [PFOS]

Mazzoni, M. *et al.* (2019) *Sci. Tot. Environ.* **653**, 351-358
Munschy, C. *et al.* (2013) *Chemosphere* 91, 233-240

Fish species sampled


Rutilus rutilus


Alosa agone


Perca fluviatilis

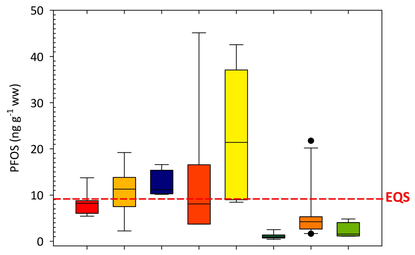

Lota lota

Most represented species: Pontic shad (*Alosa agone*, N = 32, TL = 3.8 ±0.4), burbot (*Lota lota*, N = 7, TL = 3.8 ±0.2), perch (*Perca fluviatilis*, N = 8, TL = 4.4 ±0.0) and roach (*Rutilus rutilus*, N = 9, TL = 3.0 ±0.0).

Minor species include several salmonids (whitefish - *Coregonus lavaretus*, trout - *Salmo trutta*, rainbow trout - *Onchorynchus mykiss*, Arctic char - *Salvelinus alpinus*), 2 - 3 specimens each, not accounted for in the graphs.

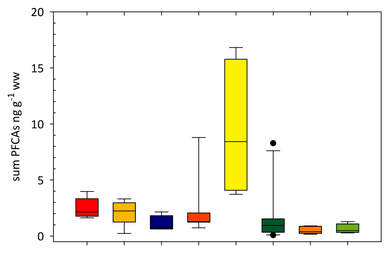
Patterns of contamination

- PFOS prominent among PFAAs,
- low concentrations in remote lakes (trout, Arctic char)
- often exceeds the environmental quality standard (EQS) i.e. 9.1 ng g^{-1} ww in fish meat.



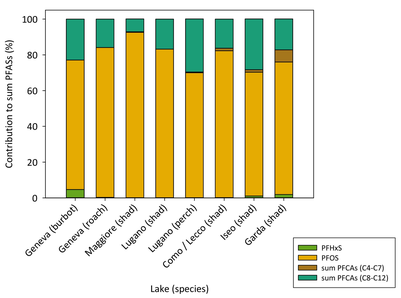
Distribution of PFOS concentrations in fish fillets across lakes

- Long chain PFCAs (≥ C8) often detected, concentrations well below those of PFOS

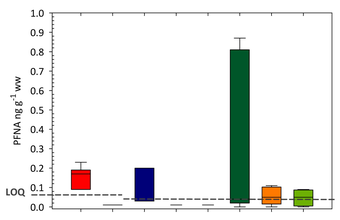


Distribution of ΣPFCAs across lakes

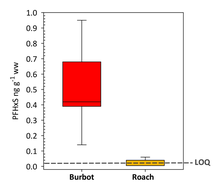
- Individual PFCA (e.g. PFNA) as well as ΣPFCAs distributions suggest different contamination sources.
- PFAA bioaccumulation not only controlled by chain-length, but also influenced by ecological factors (*e.g.* species habitat, diet) ➔ *e.g.* ΣPFCAs in Lake Lugano, PFHxS in Lake Geneva



Mean contamination profiles



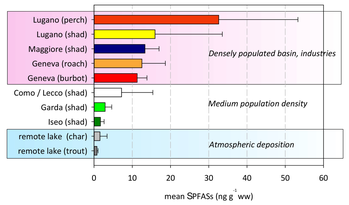
Distribution of PFNA across lakes



PFHxS distribution in two species from Lake Geneva

∑PFASs in lake fish is related to the degree of urbanization, based *e.g.* on DEGURBA classification (degree of urbanization, according to Eurostat, https://ec.europa.eu/eurostat/web/degree-of-urbanisation/background).

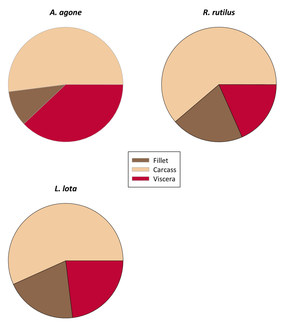
– Class 1 (cities) 1.8 - 2 - 14% + Class 2 (towns and suburbs) 35 - 21 - 43 % for L. Maggiore, L. Geneva and L. Lugano respectively.
– Class 1 ≈ 1.6 % (Como) or absent, Class 2 19 - 24 % for L. Como, L. Iseo and L. Garda.



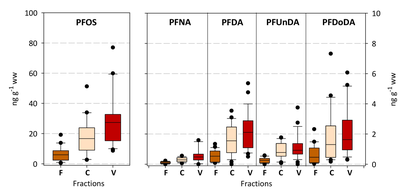
Mean ∑PFASs in fillet according to anthropic pressure gradient

Distributions in fish fractions

For 25 fish individuals (10 shad, 1 trout, 7 roach and 7 burbot), several fractions were analyzed, *i.e.* fillet, viscera, liver (sometimes) and offal.



PFOS average mass fractions in three species



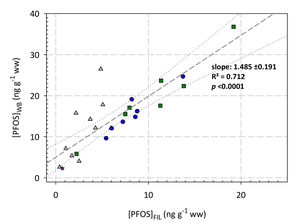
Concentration distributions according to fractions

Whatever the species and PFAS, concentrations in viscera > carcass > muscle.

Relative load contributions vary according to species (higher SDs in shad).

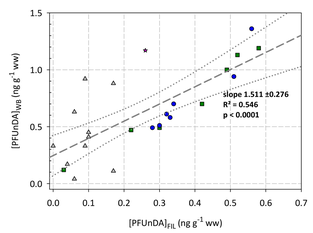
Whole-body (WB) concentrations were calculated as the sum of concentrations in fractions * the respective masses divided by the total mass

Correlations (Spearman) were found for PFOS, PFNA, PFDA, PFUnDA and PFDoDA.



Linear regression for PFOS concentrations (Fillet - WB)

Graphs (and R^2) suggest however that the fit could be better on a species-specific and ecosystem-specific basis.



Linear regression for PFUnDA concentrations (Fillet - WB)

	Slope	Intercept	R^2	*p*-value
PFOS	1.48 ±0.19	5.02 ±1.53	0.712	<0.0001
PFNA	1.06 ±0.40	0.12 ±0.05	0.273	0.018
PFDA	1.55 ±0.19	0.37 ±0.13	0.731	<0.0001
PFUnDA	1.51 ±0.28	0.25 ±0.09	0.546	<0.0001
PFDoDA	1.87 ±0.08	0.15 ±0.07	0.963	<0.0001

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