Perfluorooctane sulfonate (PFOS) and related compounds in a Norwegian arctic marine food chain

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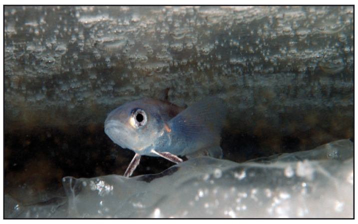
Introduction

- Per- and polyfluorinated alkyl substances (PFAS) are a group of anthropogenic chemicals, some of which have been manufactured for more than 50 years. These organic surfactants are used as stain repelling agents
- PFAS are widely distributed over the northern hemisphere, including the Arctic (Giesy & Kannan 2001, Martin et al. 2004)
- The most pervasive fluoroorganic reported in both humans and wildlife is perfluorooctanesulfonate (PFOS)
- Studies from the Canadian Arctic indicate biomagnification of PFOS in aquatic food chains (Martin et al. 2004, Tomy et al. 2004)
- The present study is the first comprehensive survey of perflouroorganic contamination in a Norwegian Arctic marine food web
- Key species investigated: ice amphipod (*Gammarus wilkitzkii*), polar cod (*Boreogadus saida*), black guillemot (*Cepphus grylle*) and glaucous gull (*Larus hyperboreus*)

Objective

The main objective of this study was to assess whether PFAS show similar bioaccumulative behaviour as lipid soluble POPs in Arctic marine food chains, particularly emphasizing the potential for biomagnification.

Ice amphipod (Gammarus wilkitzkii). Photo: Bjørn Gulliksen/University of Tromsø.



Polar cod (Boreogadus saida). Photo: Bjørn Gulliksen/University of Tromsø.

Black guillemot (Cepphus grylle). Photo: Kit Kovacs & C. Lydersen/Norwegian Polar Institute

Glaucous gull (Larus hyperboreus). Photo: Hallvard Strøm/Norwegian Polar Institute.

Materials and Methods

Sampling

All organisms were collected in the Barents Sea marginal ice zone during summer 2004 (Figure 1). Samples were obtained from whole ice amphipods and livers of seabirds and polar cod.

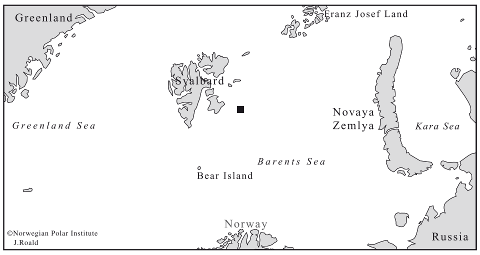


Figure 1: Study area with the sampling location marked as a square.

Chemical analyses

PFAS analysis

- Extraction was performed applying a screening method (Berger & Haukås 2005)
- Extracts were analyzed for perflorinated sulfonates (4), carboxylates (8), perfluorooctane sulfonamide (PFOSA), and 6:2 fluorotelomer sulfonate (6:2 FTS)

Lipid soluble POP analysis

- Extracts were analyzed for PCBs (13), DDTs (5) and PBDEs (10)

Data treatment

Trophic level and magnification calculations

- Trophic levels (TL) based on the ratio of stable nitrogen isotopes ($\delta^{15}N$)
- Biomagnification factors (BMFs) based on predator-prey concentrations

Statistical analyses

- ANOVA and Tukey's HSD tests for differences between species and sexes
- Linear regression model and generalized additive model to determine the influence of trophic level on POP concentrations
- The Shapiro-Wilks' W test for normality

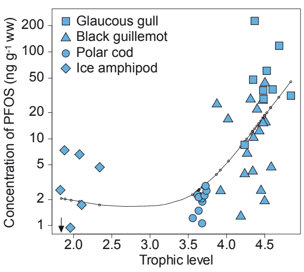


Figure 2: Relationship between concentrations of perfluorooctane sulfonate (PFOS) and trophic level. The trendline follows predicted values of a generalized additive model.

- Principal component analysis investigating POP patterns within species
- Redundancy analysis relating POP concentrations to trophic level

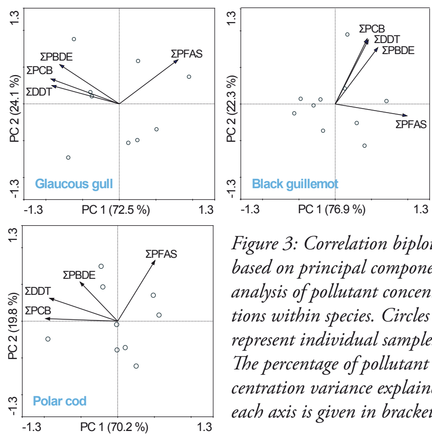


Figure 3: Correlation biplots based on principal component analysis of pollutant concentrations within species. Circles represent individual samples. The percentage of pollutant concentration variance explained by each axis is given in brackets.

Results

- Significant amounts of per- and polyfluorinated compounds were found in ice amphipods, fish and seabirds from the Barents Sea food web
- PFOS displayed the highest concentration among the fluoroorganic compounds, and was the only PFAS detected in all four species. Mean concentrations (ng g^{-1} ww) of PFOS increased in the order polar cod liver (2.02) < whole ice amphipod (3.85) < black guillemot liver (13.5) < glaucous gull liver (65.8)
- 6:2 Fluorotelomer sulfonate (6:2 FTS), perfluorohexane sulfonate (PFHxS), perfluorohexanoic acid (PFHxA), perfluorooctanoic acid (PFOA), perfluorononanoic acid (PFNA) and perfluorodecanoic acid (PFDcA) were detected in at least two of the investigated species
- No correlation was found between PFOS concentrations and trophic level within species. Nevertheless, a significant nonlinear relationship was established when the entire food chain was analyzed (Figure 2)
- BMFs showed values >1 for PFHxS, PFOS, PFNA and ΣPFAS in the majority of predator-prey relationships
- $\Sigma PFAS_7$ concentrations showed no or minor correlation with $\Sigma PCB1_3$, ΣDDT_5 and $\Sigma PBDE_{10}$ within individuals of polar cod, black guillemot and glaucous gull (Figure 3). However, concentrations of the lipid soluble compounds were positively correlated with each other
- Redundancy analysis showed that 67% of the total variance in concentrations of PFAS, PCBs, DDTs and PBDEs in the liver samples could be explained by trophic level (Figure 4). The four contaminant groups and trophic level were significantly positively correlated.

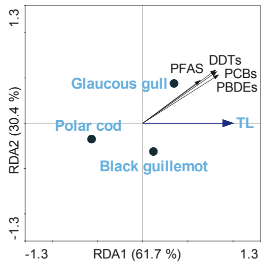


Figure 4: Ordination diagram based on redundancy analysis of the relationship between trophic level and PC1 scores for the four POP groups.

Conclusions

- The significant nonlinear relationship showing an increase in liver wet weight concentrations of PFOS with trophic level suggests that PFOS has potential for biomagnification in species of the Norwegian Arctic marine food chain
- Liver based magnification factors displayed value >1 PFHxS, PFOS, PFNA and ΣPFAS, imply that there is a trophic transfer of these persistent compounds
- The significant redundancy analysis indicates that the degree of trophic transfer of PFAS is comparable to that of PCBs, DDTs and PBDEs
- Quantification of bioaccumulation and biomagnification of PFAS is based on models and standards developed for lipid soluble compounds and might thus lead to biased results. The quantification approach to accumulation and trophic transfer of PFAS should therefore be assessed in further studies.

Acknowledgements

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