PERFLUOROOCTANE SULFONATE (PFOS) AND RELATED COMPOUNDS IN A NORWEGIAN ARCTIC MARINE FOOD CHAIN

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Glaucous gull (*Larus hyperboreus*)

Black guillemot (*Cepphus grylle*)

Polar cod (*Boreogadus saida*)

Ice amphipod (*Gammarus wilkitzkii*)

INTRODUCTION

- Perfluoroalkylated substances (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 an assessment of Norwegian Arctic marine fauna with focus on a food chain in the ice edge habitat
- Key species investigated: glaucous gull (*Larus hyperboreus*), black guillemot (*Cepphus grylle*), polar cod (*Boreogadus saida*) and ice amphipod (*Gammarus wilkitzkii*)

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.

MATERIALS AND METHODS

Sampling

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

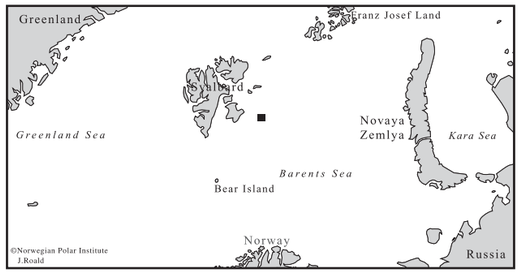

Figure 1: Study area with the sampling location marked as a square.

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 tetrahydro perfluorooctane sulfonic acid (TH-PFOS)

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
- Trophic magnification factors (TMFs) derived from PFAS vs. TL log-linear relationship
- Metabolic indices (MIs) for accumulation relative to the recalcitrant PCB-153

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

RESULTS

- 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)
- Perfluorohexane sulfonate (PFHxS), perfluorohexanoic acid (PFHxA), perfluorooctanoic acid (PFOA), perfluorononanoic acid (PFNA), perfluorodecanoic acid (PFDcA) and TH-PFOS were detected in at least two of the species studied
- 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)

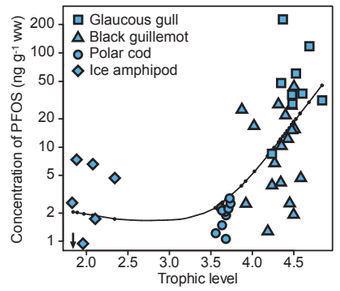

Figure 2:
Relationship between concentrations of perfluorooctane sulfonate (PFOS) and trophic level. The trendline follows predicted values of a generalized additive model.

- BMFs and TMFs showed that PFOS had the highest biomagnification propensity of the detected PFAS. The BMFs for PFOS were comparable to lipid-normalized BMFs of PCB-28, PCB-52, PCB-101, *o,p'*-DDT and PBDE-28
- Relative to lipid-normalized concentrations of PCB-153, the fluoroorganics had low bioaccumulation (MI<0.2) and their MI's were comparable to PCB-28, PCB-52, PCB-101, PCB-156, PCB-194, *o,p'*-DDT and PBDE-28 for at least one of the seabird species (Figure 3)

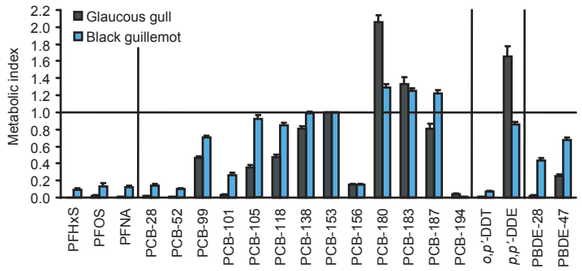

Figure 3: Metabolic index (mean + SE) for PFAS, PCBs, DDTs and PBDEs in seabirds.

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- $\Sigma PFAS_7$ concentrations showed no or minor correlation with ΣPCB_{13}, ΣDDT_5 and $\Sigma PBDE_{10}$ within individuals of glaucous gull, black guillemot and polar cod (Figure 4). However, concentrations of the lipid soluble compounds were positively correlated with each other

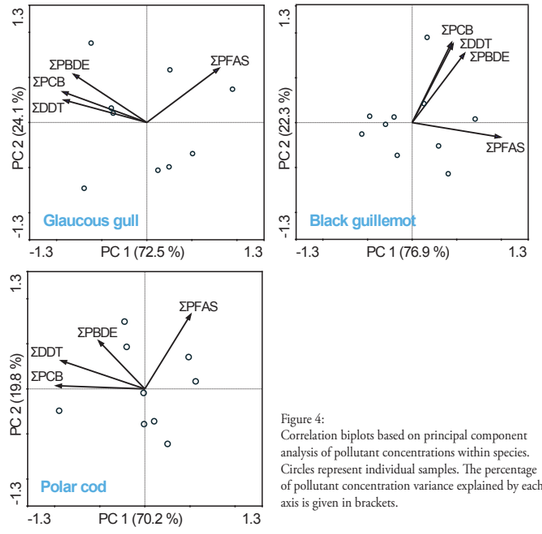

Figure 4:
Correlation biplots based on principal component analysis of pollutant concentrations within species. Circles represent individual samples. The percentage of pollutant concentration variance explained by each axis is given in brackets.

- 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 5). The four contaminant groups and trophic level were significantly positively correlated.

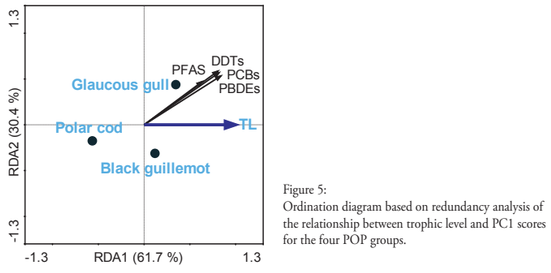

Figure 5:
Ordination diagram based on redundancy analysis of the relationship between trophic level and PC1 scores for the four POP groups.

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
- BMFs and TMFs greater than 1 for PFOS and other PFAS 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.