PFCs IN FEATHERS OF WHITE TAILED EAGLES (*HALIAEETUS ALBICILLA*) FROM GREENLAND AND NORWAY; USEFULL FOR NON-DESTRUCTIVE MONITORING?

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Introduction

The white-tailed eagle (*Haliaeetus albicilla)*, also referred to as white-tailed sea eagle (WTSE), is a large predatory bird from the Northern part of Eurasia. It is a top predator from the aquatic ecosystem and feeds mainly on marine fish, waterfowl and carrion.[1] Because of its high trophic position, the WTSE is a very interesting biomonitoring species for studying accumulation of persistent organic pollutants (POPs). The WTSE population in Greenland inhabits the southwest coast and its size was in 1990 estimated at 150-170 breeding pairs.[2] The Norwegian WTSE population belongs to the largest in the world with approximately 3000 breeding pairs.

In this study, our aim was to increase the knowledge on the analysis of perfluorinated chemicals (PFCs) in biological tissues and specifically develop a reliable method to measure PFCs in feathers and preen oil of this raptor species. Feathers have already been used successfully for monitoring of heavy metals, and recently also for POPs, but a reliable method for PFCs was not available and needed to be established[3,4]. The results gained from this research enabled us to monitor endangered raptors without harming the birds and their offspring and to better understand the fate of PFCs in birds.

Materials and methods

White-tailed eagles (n=15), found dead in West Greenland between March 1997 and January 2009, were analyzed in this study. Eight birds were juveniles, two birds in 2nd, one bird in 4th and 5th plumage and 3 birds were adults. More details on the sampling area and procedures can be found in Krone et al.[4] The birds were shipped with CITES permission from Greenland to the National Environmental Research Institute (NERI, Aarhus University, Denmark) and subsequently to the Toxicological Centre (University of Antwerp, Belgium) for analysis of POPs and to NILU (FRAM, Tromsø, Norway) for analysis of PFCs. Body feathers (n=11) and primary wing feathers (2th, 5th and 8th primary; n=46) and preen oil (n=7) was collected when available in a sufficient amount for analysis. Tissue samples were taken from the Greenland carcasses to analyze for PFCs and POPs[7]. In addition, tail feathers were sampled at active nest sites of WTSE situated in Northern Norway (n=18) in 2009. All feathers were washed with precleaned water prior to analysis.

For the analysis of PFCs in preen oil we followed a modified analytical method for PFCs in biological matrices[6]. To determine PFCs in feathers, we included a digestion step in order to resolve bound PFCs from the feathers. Approximately one gram of homogenized feather sample or 0.3 g of preen oil was spiked with internal standard (^{13}C-PFOA/PFOS) and thoroughly mixed with 10 mL methanol. After centrifugation (2000 rpm, 5 min), the supernatant was concentrated to 1.5 mL in a Rapidvap and cleaned up with ENVI-carb and glacial acetic acid. Samples were analyzed with liquid chromatography-mass spectrometry (LC-MS/TOF).

Results and discussion

For the first time, PFCs were detected in feathers and preen oil of white tailed sea eagles from Greenland and Norway. In the wing feathers from Greenland WTSE, PFOS and PFOSA were detected. In some cases, PFNA, PFUnA and PFTrA were detected in minor concentrations as well (Figure 1). The average concentrations of the

primary wing feathers #2, 5 and 8 were similar. In addition, the body feathers showed similar PFOS levels, but lower PFOSA levels.

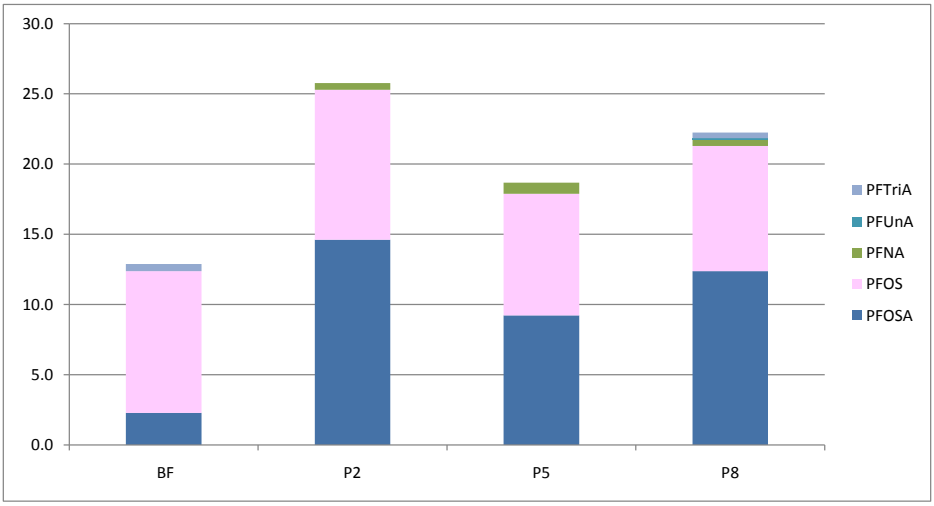

Figure 1: Median PFC levels (ng/g dw) in feathers of WTSE from Greenland (BF: body feathers; P2-8: primary wing feathers).

Preen oil was analysed in order to investigate if PFCs might be applied on the feathers during preening. Despite the high lipid content (25-96%) of preen oil, PFOS could be detected in all cases (Table 1). When correlating the major detected PFCs, PFOS and PFOSA in feathers and preen oil, a positive correlation between PFOS in preen oil and in body feathers can be found (r^2=0.89; $p<0.05$), but not for wing feathers. One explanation could be that body feathers are more often preened or less exposed to air and water and therefore reflect the preen oil PFOS concentrations more closely. Wing feathers, on the other hand, might be more affected by other PFC sources (uptake via the air/water/ airborne particles).

PFOSA was not detected in preen oil, but in some body feathers and to a higher degree in wing feathers, as well. This, and the fact that no correlations were found between PFOSA and the two different kinds of feathers, suggests a second exposure route for PFCs besides the preen oil in WTSE from Greenland.

As can be seen in the abstract of Jaspers et al., no PFOSA was detected in the different tissue samples (when comparing the same individuals), supporting an external source for the PFOSA feather contamination [7]. PFOSA, a neutral lipophilic chemical, exhibits biomagnification in marine food webs and can be formed by the formation of *N*-EtPFOSA [8]. PFOS and PFOSA were the main PFCs detected in air samples (particulate and air phase) in the Canadian Arctic [9]. Additionally, PFOSA was one of the major PFCs found in open sea water sampled in the East Greenland Arctic Ocean [10]. Seeing that WTSE feathers have large surface areas treated with preen oil, they might have very suitable capabilities to adsorb PFOSA out of the air and water (precipitation and seawater). If the exposure to PFOSA is mainly external, the immedeate toxilogical threat to the birds would be minimal.

Table 1: Median concentrations (ng/g wet weight) of PFCs in preen oil and body/wing feathers of WTSE from Greenland and tail feathers from Norway.

	Preen oil	Body feather (GL)	Wing feather (GL)	Tail feather (N)
n	7	11	46	25
PFOS	18	8.3	9.4	12.5
PFNA	< LOQ	< LOQ	0.6	< LOQ
PFOSA	< LOQ	1.9	12.1	3.5

In the tail feathers collected in Norway, we find a similar PFC pattern and levels comparable to the feathers collected from birds from Greenland, pointing to a comparable exposure and/or preening habits.

In summary, our findings indicate that the preen gland and subsequently feathers represent an additional excretion route for PFCs in birds due to the regular molting and preening habits. Especially aquatic birds need to preen their feathers continuously to ensure the water repellent characteristics of the feathers to guarantee their ability to fly after contact with water.

In general, feathers from top predatory birds could be useful to investigate the PFC exposure in the ecosystems in a non-destructive manner. Especially endangered species could benefit from this non-invasive approach. It should though be emphasized that PFOSA contamination of Greenland sea-eagles may not be of toxicological concern as the exposure is possibly due to external air/water born sources. How far the PFC content in feathers is directly correlated to the body burden of the individual birds needs to be further investigated.

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