Science of the Total Environment 407 (2009) 4174–4183

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Assessment of emerging and traditional halogenated contaminants in Guillemot (*Uria aalge*) egg from North-Western Europe and the Baltic Sea

Hrönn Jörundsdóttir [a,*], Anders Bignert [b], Jörundur Svavarsson [b], Torgeir Nygård [c], Pál Weihe [d], Åke Bergman [a]

[a] Department of Environmental Chemistry, Stockholm University, SE-106 91 Stockholm, Sweden
[b] Department of Contaminant Research, Swedish Museum of Natural History, Box 50007, SE-104 05 Stockholm, Sweden
[c] Norwegian Institute for Nature Research, Tungasletta 2, N-7485 Trondheim, Norway
[d] Department of Occupational Medicine and Public Health, Faroese Hospital System, Tórshavn, Faroe Islands

ARTICLE INFO

Article history:
Received 8 December 2008
Received in revised form 23 March 2009
Accepted 23 March 2009
Available online 22 April 2009

Keywords:
PCB
PBDE
HBCDD
BCPS
Metabolites
Spatial trend

ABSTRACT

Persistent organic pollutants (POPs) are readily detected in biological samples at remote sites in the Arctic and sub-Arctic due to long-range transport from source areas. The aim of this study was to investigate the presence of POPs, polybrominated contaminants and their metabolites in guillemot (*Uria aalge*) eggs from Iceland, the Faroe Islands, Norway and Sweden to assess spatial trends of these compounds in the Arctic and sub-Arctic areas of Europe. Egg samples were extracted, and cleaned for chemical analysis. Concentrations of PCBs, 4,4′-DDE and β-HCH were an order of magnitude higher in eggs from the Baltic Proper compared to eggs from the North Atlantic. Concentrations of HCB were of the same magnitude at all sites, ranging from 160 to 520 ng/g fat. Concentration of BCPS was 100 times higher in eggs from the Baltic compared to eggs from the North Atlantic and seems therefore to be special regional problem. Concentrations of PBDEs were lower in eggs from the North Atlantic compared to eggs from the Baltic Proper but the difference was not as large as for PCBs and 4,4′-DDE. HBCDD showed the same spatial trend as PCBs, where the concentrations in eggs from the Baltic Proper were an order of magnitude higher than in eggs from the North Atlantic. OH-PCB and $MeSO_2$-PCB metabolites of PCBs, showed the same trend as the parent compounds while spatial trends of $MeSO_2$-DDE and OH-PBDEs, metabolites of 4,4′-DDE and PBDEs, respectively, differed from the trend of the parent compounds. This may be due to two factors; firstly, the limited ability of birds to metabolise DDT, and secondly, to natural production of OH-PBDE, respectively. Guillemot is suggested as a monitoring species for circumpolar monitoring.

1. Introduction

The Baltic Sea is a semi-enclosed sea and it has a historic record as one of the most contaminated marine environments in the world. The wildlife in the Baltic Sea has been severely affected and several symptoms have been observed that are linked to environmental contamination. Amongst these symptoms is decrease of shell-thickness and impaired viability of white-tailed sea eagle (*Haliaeetus albicilla*) eggs reported by Helander et al. (2002) and followed up later (Helander et al., 2008). The reproductive impairment of grey seal (*Halichoerus grypus*) and ringed seal (*Phoca hispida*) with their habitat in the Baltic Sea is well known (Helle et al., 1976a,b; Bergman and Olsson 1985; Olsson et al., 1994) as well as poor physical condition among these seals (Wiberg et al., 2002). Due to these factors, the Baltic Sea is one of the most studied areas in the world concerning environmental contaminants. One of the measurements taken to study this situation was establishing the environmental monitoring program at the Swedish Museum of Natural History in Stockholm. Over the last 40 years, the Museum has continuously monitored contaminants to assess the environmental quality in the region. Several marine and terrestrial species are collected every year and analyzed for contaminants, generating a long time series of useful data. One of the species included into the monitoring program is the guillemot (*Uria aalge*) where both tissue and eggs are sampled. The fat content of the guillemot egg is high (10–14%) with low variability (Bignert et al., 1995) and sea birds at the same trophic level as the guillemot show no age related accumulation of persistent organic pollutants, i.e. age of the maternal bird has no effect (Henriksen, 1995; Donaldson et al., 1997; Ólafsdóttir et al., 2005). Further, there are several studies published, using guillemot eggs as a monitoring matrix for the Baltic Sea (Sellström et al., 2003; Holmström et al., 2005; Jörundsdóttir et al., 2006) showing that this is an excellent species for monitoring. There are numerous studies on chlorinated and brominated organic pollutants in North-

* Corresponding author. Department of Environmental Chemistry, Stockholm University, SE-106 91 Stockholm, Sweden. Tel.: +46 8 163914; fax: +46 8 163979.
E-mail address: ake.bergman@mk.su.se (H. Jörundsdóttir).

0048-9697/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.scitotenv.2009.03.026

Western Europe (Table 1) but there are still data gaps regarding e.g. the sub-Arctic region.

Even for the extensive research on the environmental condition of the Baltic Sea, the status of many emerging pollutants in North-Western Europe is poorly known. The aim of the present study was to expand the knowledge of the Nordic environment, and determine the concentrations of numerous persistent organic pollutants (POPs) and emerging brominated compounds in guillemot eggs and try to elucidate spatial trends in North-Western Europe. A previous study of perfluorinated compounds in North-Western Europe indicates that the pathways of these compounds to the European sub-Arctic are complicated (Löfstrand et al., 2008). Further, our last objective is to study metabolites of these compounds and examine the relation between metabolite and parent compound in relation to spatial trends.

Iceland is a volcanic island in the North Atlantic sub-Arctic, located between Greenland and Norway. It is a country with approximately 300 000 inhabitants with limited industrial activities compared to other European countries. The major industries are agriculture and fisheries, accompanied with aluminium production by electrolysis, an alloy factory and a few smaller industries. The Faroe Islands are located northwest of Scotland, a cluster of 18 islands with a population of approximately 48 000 inhabitants and with no large industry except for fishery. The use of pesticides and other organohalogenated compounds in these locations has been very limited. The origin of most organohalogen compounds found in the biota is therefore most likely due to long-range transport (Law et al., 2003; Wania, 2003; Ólafsdóttir et al., 2005). The Northern Norwegian coast and Arctic region is scarcely populated with only a few industries. The use of pesticides and other organohalogenated compounds has also been limited but these areas are closer to source regions of POPs. The monitoring of coastal pollutants in these countries is less comprehensive than in Sweden, but several studies of contaminant assessments have been done over the years, as presented in review articles concerning the environmental situation in the Arctic and sub-Arctic (Muir et al., 1999; AMAP, 2004; Riget et al., 2004; Fisk et al., 2005). Most studies show that concentrations of POPs and other organohalogen compounds are lower in these regions compared to the Baltic Sea (Table 1), but the distribution is sometimes more complicated than predicted (Löfstrand et al., 2008).

Our original hypothesis is that organohalogen concentrations are high close to densely populated and industrialized areas and lower in remote regions. Stora Karlsö is an island located in the Baltic Sea and represents a sampling site closer to the "sources" of the pollutants. Sample sites in Iceland, The Faroe Islands and Norway are less populated and represent remote areas.

One of the emerging contaminants is bis(4-chlorophenyl) sulfone (BCPS), a chemical that has mainly been analyzed for in the Baltic area, including Latvian waters (Olsson and Bergman 1995; Valters et al., 1999; Norström et al., 2004; Jörundsdóttir et al., 2006). BCPS has also been detected in the Canadian and Norwegian Arctic (Letcher et al., 1995; Verreault et al., 2005). To our knowledge, this is the first spatial trend study on BCPS outside the Baltic Sea Region. It is a study stretching both west and north from the Baltic and it includes both well known POPs and emerging chemical pollutants.

2. Materials and methods

2.1. Samples

Guillemot eggs were collected from Iceland (Vestmannaeyjar, 2002, Latitude (Lat): 63.4, Longitude (Long): −20.3), from Sweden (Stora Karlsö, 2003, Lat: 57.3, Long: 18.0), from the Faroe Islands (Sandøy, 2003, Lat: 61.8, Long: −6.8) and from three locations in Norway (Sklinna, Lat: 65.2, Long: 11.0, Hjelmsøya, 2005, Lat: 71.1, Long: 24.7 and Bjørnøya, 2005, Lat: 74.4, Long: 19.0) (Fig. 1). The eggs are taken as a human food source in Iceland and the Faroe Islands, but only for research purpose in Sweden and Norway. Ten eggs from every location were used. The egg content was blown out from the shell through a drilled hole, homogenised and stored frozen (−80 °C) in pre-cleaned glass jars at the Specimen Bank of the Swedish Museum of Natural History until chemical analysis was performed. The samples also include fulmar (*Fulmarus glacialis*) eggs from Vestmannaeyjar, Iceland, used in a pilot study and prepared as a homogenate in the same manner as the guillemot eggs.

2.2. Chemicals

A mixture of 16 PCB congeners (CB-28, 52, 101, 105, 118, 128, 138, 146, 153, 156, 170, 180, 183, 187, 189 and 200), 1,1,1-trichloro-2,2-bis(4-

Table 1
Concentrations (ng/g fat) of organohalogens in wildlife from North-Western Europe are presented, with the exception that PFOS is given in ng/g wet weight.

Region/species	POPs								
	4,4′-DDE	CB-153	HCB	β-HCH	BDE-47	HBCDD	BCPS	PFOS	Reference
Greenland									
Common eider (liver)			71						Vorkamp et al. (2004c)
Glaucous gull (liver)	14 000	7300	1400	200					Cleemann et al. (2000)
Black guillemot (egg)	$\sum^{a}$ 1300		390	$\sum^{b}$ 170	52				Vorkamp et al. (2004b)
Brünnich guillemot (liver)	140		110	9.3	6.7				Johansen et al. (2004)
Iceland									
Common eider (muscle)	$\sum^{a}$ 450		29						Ólafsdóttir et al. (2001)
Black guillemot (muscle)	$\sum^{a}$ 900		260	$\sum^{b}$ 14					Ólafsdóttir et al. (2001)
Glaucous gull (liver)									
Common guillemot								16	Löfstrand et al. (2008)
The Faroe Islands									
Fulmar (egg)	2800	2500	330		4.3				Fängström et al. (2005)
Common guillemot (egg)								15	Löfstrand et al. (2008)
Norway									
Brünnich guillemot (yolk sac)	2300	580	710	48	60	35			Murvoll et al. (2007)
Common eider (yolk sac)	78	77	50	4.9	0.74	6.2			Murvoll et al. (2007)
Common guillemot (egg)								85	Löfstrand et al. (2008)
The Baltic Sea									
Common guillemot (egg)	10 000	2200		600			1000		Jörundsdóttir et al. (2006)
Common guillemot (egg)					89	140			Sellström et al. (2003)
Common guillemot (egg)								400	Löfstrand et al. (2008)
Common guillemot (egg)	10 000	2300	620	170	60	170		1000	Bignert et al. (2008)

[a] Sum of 4,4′-DDT, 4,4′-DDE, 3,3′-DDD and 2,4′-DDT.
[b] Sum of α-, β- and γ-HCH.