Dioxins and non-ortho PCBs in Atlantic salmon, *Salmo salar*, from major Norwegian and Russian salmon rivers

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Introduction

The global distribution of persistent organochlorine compounds (POCs) such as polychlorinated dibenzo-p-dioxins (PCDDs), dibenzofurans (PCDFs) and biphenyls (PCBs) and the accumulation in aquatic food chains are well established. Especially fatty fish, such as herring, mackerel and salmon, may contain appreciable amounts of POCs and may in certain cases constitute the major source of human exposure to POCs. In a joint Norwegian and Russian program (1), the population of Atlantic salmon, *Salmo salar*, is surveyed in two of the most important salmon rivers in Norway and on the Kola Peninsula in Russia, respectively (Table 1). In order to get information about regional pollution and feeding habits of the different populations, concentrations of PCDDs/ PCDFs and non-ortho PCBs were determined in juvenile and adult Atlantic salmon caught in the respective rivers.

Materials and Methods

Sites and Sampling

Table 1. Location of the four rivers chosen for study of Atlantic salmon

Name	Location	Recipient	Annual Catches (t)
Orkla	South Trondelag, Central Norway	Norwegian Sea	9
Alta	Finnmark, Northern Norway	Norwegian Sea	13
Kola	Central Kola Peninsula, Russia	Barents Sea	25
Varzuga	South-Eastern Kola Peninsula, Russia	White Sea	72

Juvenile Atlantic salmon (mean age 3 yrs) were caught by electrofishing in all four rivers and adult species were collected by sports fishermen (Norway) or commercial catch (Russia) during ascent. Pool samples were prepared from 10 individual adult salmon and from 10-21 juvenile salmon for each of the four locations.

Determination of PCDDs, PCDFs and non-ortho PCBs
The extraction and sample clean-up was carried out using a chromatography system as described by Smith et al. (2), consisting of a column (30 cm x 4.5 cm ID) filled with potassium silicate/ silica gel followed by a glass column (2,5 cm x 1,2 cm) containing 50 mg activated carbon (AX-21) dispersed on glass fibers. About 20 g homogenised salmon filet were spiked with $^{13}C_{12}$-labeled 2,3,7,8-substituted PCDDs/PCDFs and PCB-77, PCB-126 and PCB-169 and ground with Na_2SO_4. The mixture was placed on top of the first column and eluted onto the carbon column by cyclohexane/dichloromethane (1:1, v/v). PCDDs, PCDFs and non-ortho PCBs were eluted from the carbon column in the reversed direction with toluene. The crude fraction was further purified by chromatography on two Pasteur pipettes in series filled with acidic silica and basic alumina, respectively. Gas chromatography/high-resolution mass spectrometry analyses were performed on a Hewlett-Packard 5890 Series II GC connected to a VG AutoSpec MS (EI, selected ion monitoring, resolution 10000) as described in detail elsewhere (3,4).

Toxic equivalency factors
Levels expressed in 2,3,7,8-TCDD toxic equivalents (TE) were calculated by using the International equivalency factors (I-TEFs) for PCDDs and PCDFs (5) and the 1993 WHO-TEFs for the PCBs (6).

Results and Discussion
The congener profiles for PCDFs/PCDDs and non-ortho PCBs in samples from adult and juvenile Atlantic salmon from the four rivers are shown in Figure 1, A-D. The PCDD/PCDF profiles for juvenile Orkla (A) and juvenile and adult Alta salmon (B) are similar showing a dominance of HpCDD and OCDD. In contrast, the profile for adult salmon from Orkla (A) is quite different. The samples from the Russian rivers (C and D) are characterised by a higher content of PCDFs compared to OCDD. The non-ortho PCBs show a similar profile in all samples with higher concentrations found in adult vs. juvenile salmon except for the Kola samples which also show the highest PCB concentrations of all the samples.

The total TE vary from 16.7 to 84.9 pg/g lipid in juvenile salmon and 44.3 to 73.9 pg/g lipid in adult Atlantic salmon. There is no obvious difference in total TE neither between juvenile and adult salmon nor between Norwegian and Russian samples. However, the contributions to the TE from PCDDs, PCDFs and non-ortho PCBs vary between the samples (Figure 2). For juvenile salmon from the two Norwegian rivers, PCDDs make a major contribution to the TE, while the non-ortho PCBs contribute most in adult Atlantic salmon. For both Kola samples, the contributions from non-ortho PCBs dominate while for Varzuga, PCDFs give the largest contribution.

The larger difference in the TE profiles between juvenile and adult Atlantic salmon in the Norwegian rivers (Figure 2) indicate a stronger influence of local environmental factors on the exposure of the juvenile fish compared to the Russian sites. The distinction of the TE profile of the adult Varzuga salmon from the three other adult profiles confirms the hypothesis that Varzuga Atlantic salmon uses different feeding areas.

Figure 1. Profiles of PCDDs/PCDFs and non-ortho PCBs in Atlantic salmon from two Norwegian (Orkla, Alta) and two Russian rivers (Kola, Varzuga).

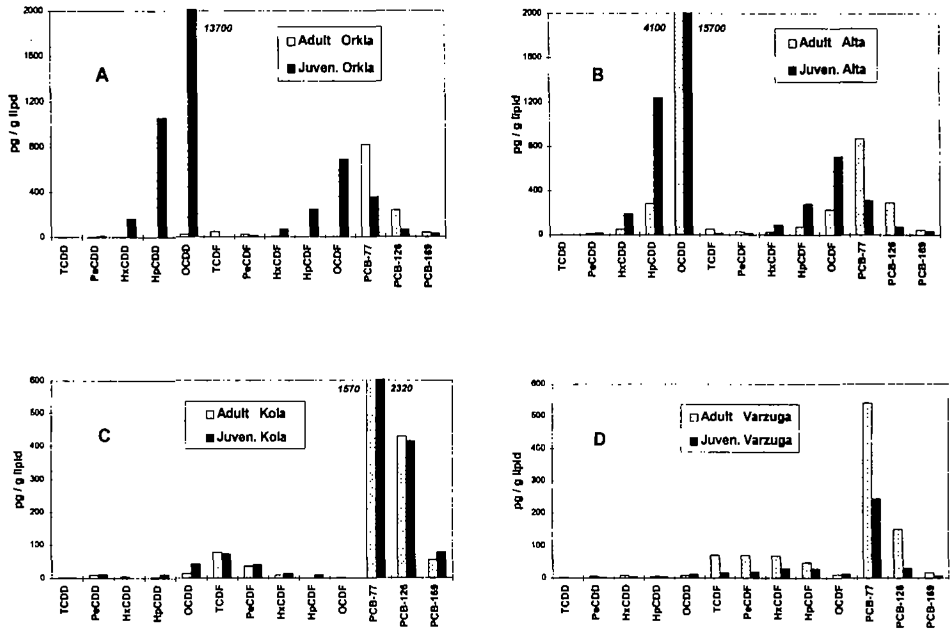
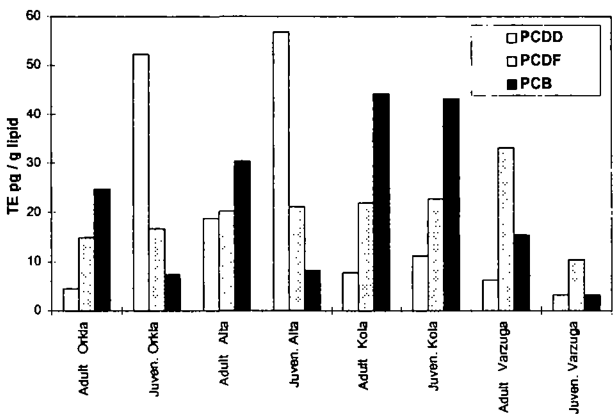


Figure 2. Contribution of PCDDs, PCDFs and non-ortho PCBs to TE in the 8 different samples of Atlantic salmon.



The PCDD/PCDF concentrations in TE on fresh weight basis in adult Atlantic salmon from this study are similar to those found in other samples from Norway, including farmed salmon. However, concentrations expressed as TE per g lipid weight are considerably higher in wild salmon compared to farmed salmon (Table 1).

Table 2. PCDD/PCDF related TE (pg/g fat) in adult Atlantic salmon

Location	Type	Lipid content (%)	TE (pg/g fresh wt.)	TE (pg/g lipid)	Reference
Orkla/Alta	wild	3.7	1.0	29.2	This study
Kola/Varzuga	wild	2.1	0.7	34.6	This study
Southern Norway	wild	4.7	0.8	17.3	7
Northern Norway	farmed	16.7	0.9	5.3	8

In conclusion, there seems to be a large difference in distribution of TE between PCDDs, PCDFs and non-ortho PCBs in juvenile and adult Atlantic salmon from the Norwegian rivers, but not for the Russian rivers. This indicates a stronger influence of local environmental factors on the contamination load of the Norwegian rivers.

Acknowledgements

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