TCDD-Toxicity and M74 Syndrome of Baltic Salmon (*Salmo salar* L.)

Jaakko Paasivirta[A], Pekka J.Vuorinen[B], Marja Vuorinen[B], Jaana Kolstinen[A], Tiina Rantio[A], Tarja Hyötyläinen[A] and Leena Welling[C]

[A]Department of Chemistry, University of Jyväskylä,
P.O.Box 35, FIN-40351 Jyväskylä, Finland

[B]Finnish Game and Fisheries Research Institute, P.O.Box 202, FIN-00151 Helsinki, Finland

[C]Institute for Environmental Research, University of Jyväskylä,
P.O.Box 35, FIN-40351 Jyväskylä, Finland

1. Introduction

Exposure to TCDD and similarly toxic chloroaromatic substances (PCDDs, PCDFs and coplanar PCB congeners) has been shown to cause mortality of fish fry in yolk sac phase of the development[1,2]. Similar yolk sac mortality called M74 syndrome occurs in natural salmon populations spawning in rivers flowing to the Baltic Sea[3]. The present study includes chemical trace analyses of Simojoki River mother salmons (SJL) and follow-up of the fate of their offspring in hatchery annually during the period 1988-92, when M74 mortality was first absent but increased steeply in 1991-92.

2. Materials and Methods

Salmon (SJL) from the Simojoki River, which is at the Northeast corner of the Gulf of Bothnia, extend their feeding migration to the southernmost parts of the Baltic Sea. When ascending to the river, the Simo Fish Farm of the Finnish Game and Fisheries Research Institute catch those salmon for production of smolts and to improve brood stocks. At stripping in October each year the color of eggs was estimated subjectively with points from 1 (most pale orange) to 5 (dark orange). The amount of stripped eggs was measured volumetrically and the numbers of eggs were calculated by knowledge from eggs per a volumetric unit. The egg lots of each female were incubated separately in the Simo Fish Farm and white (dead or unfertilized) eggs were counted a couple of days after fertilization (FER) and at the eyed stage (ES). Dead yolk-sac fry (YS) were registered continuously. Mortalities were calculated for each these developmental phases producing per cent variables FERM, ESM and YSM for offspring of each individual mother salmon. From each female salmon a piece from the left epaxial muscle was taken for organochlorine (OC) analysis immediately after stripping of eggs. Analytical procedures are published in other connections [4-8].

Statistical treatments by software package SPSS for Windows 6.1 were first done using pollutant concentrations in fresh muscles (fw). Then, some treatments were based on concentrations in lipid (lw), while lipid correlated positively and highly significantly with most chlorohydrocarbons and three toxic PCDFs observed in most samples.

3. Results and discussion

Compounds analyzed, means of concentrations (lipid basis) and time trends are listed in Tables 1 and 2. Concentrations of coplanar PCBs, PCDDs and PCDFs were also calculated as fish TCDD-equivalents (FTEQs pg/g lw) using the TEFs determined by Walker and Peterson[2] for rainbow trout. Regression lines for sums of equivalents (SFTEQs) versus year and similar regression lines for the egg color and mortalities FERM, ESM and YSM are shown in Fig. 1. Superscripts notate significances (see Table 1) of the regression coefficients.

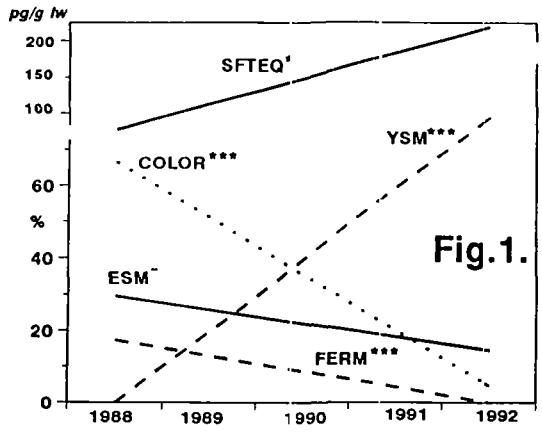

Fig.1.

TABLE 1. Major chlorohydrocarbons ng/g lw in epaxial muscles of the Simojoki River mother salmon. Period = years of the N samples analyzed. x = Overall mean, sd = standard deviation. Trend = degrease [-], increase [+] or no trend. Sig. = significance of the trend by stepwise multiple regression (dependent variable = conc. in fresh muscle (fw); explanatory variables year, lipid, weight and length): - p > 0.1, O p=< 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

Abbr.	N a m e or explanation	Period	x	sd	N	Trend	Sig.
α-HCH	α-hexachlorocyclohexane	1988-92	11.0	9.3	73	[-]	***
γ-HCH	γ-hexachlorocyclohexane (lindane)	1988-92	11.6	13.3	73	[-]	***
HCBz	hexachlorobenzene	1988-92	166	65.5	73	[+]	O
OXY	oxychlordane	1988-92	38.0	24.6	73	[-]	***
TRANS	trans-chlordane	1988-92	14.8	20.8	73	no	-
CIS	cis-chlordane	1988-92	149	71.7	73	no	-
NONA	trans-nonachlor	1988-92	153	79.5	73	[-]	*
SCHL	OXY+TRANS+CIS+NONA	1988-92	355	165	73	no	-
DDE	metabolite of the insecticide DDT	1988-92	3420	2840	73	no	-
DDD	metabolite of the insecticide DDT	1988-92	1210	740	73	[-]	*
DDT	insectiside	1988-92	800	740	73	[-]	*
SDDT	DDE+DDD+DDT	1988-92	5410	4040	73	no	-
PCC	insecticide toxaphene (complex mixture)	1988-92	1420	1050	73	[-]	***
SPCB	Sum of polychlorobiphenyls analyzed as Clophen A-60	1988-92	4970	2830	73	[-]	***
CB28	2,4,4'-trichlorobiphenyl	1990-92	33.1	26.3	34	[-]	***
CB52	2,2',5,5'-tetrachlorobiphenyl	1990-92	99.8	61.8	34	no	-
CB101	2,2'4,5,5'-pentachlorobiphenyl	1990-92	507	283	34	no	-
CB105	2,3,3',4,4'-pentachlorobiphenyl	1990-92	140	109	34	[-]	**
CB118	2,3',4,4',5-pentachlorobiphenyl	1990-92	380	229	34	no	-
CB138	2,2',3,4,4',5'-hexachlorobiphenyl	1990-92	929	529	34	no	-
CB153	2,2',4,4',5,5'-hexachlorobiphenyl	1990-92	912	516	34	no	-
CB180	2,2',3,4,4',5,5'-heptachlorobiphenyl	1990-92	252	166	34	no	-

TABLE 2. Toxic PCDDs, PCDFs, planar PCBs and PCDEs ng/g lw in epaxial muscles of the Simojoki River mother salmon. For notations see Table 1.

Abbr.	N a m e or explanation	Period	x	sd	N	Trend	Sig.
DD1	2,3,7,8-tetrachlorodibenzo-p-dioxin	1988-92	nd		40		
DD2	1,2,3,7,8-pentachlorodibenzo-p-dioxin	1988-92	##		40		
DD3	1,2,3,4,7,8-hexachlorodibenzo-p-dioxin	1988-92	nd		40		
DD4	1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	1988-92	nd		40		
DD5	1,2,3,7,8,9-hexachlorodibenzo-p-dioxin	1988-92	nd		40		
DD6	1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin	1988-92	nd		40		
DD7	octachlorodibenzo-p-dioxin	1988-92	nd		40		
DF1	2,3,7,8-tetrachlorodibenzofuran	1988-92	.139	.082	40	no	-
DF2	1,2,3,7,8-pentachlorodibenzofuran	1988-92	.0197	.0182	40	[+]	**
DF3	2,3,4,7,8-pentachlorodibenzofuran	1988-92	.174	.135	40	[+]	*
DF4	1,2,3,4,7,8-hexachlorodibenzofuran	1988-92	nd		40		
DF5	2,3,4,6,7,8-hexachlorodibenzofuran	1988-92	nd		40		
DF8	1,2,3,4,6,7,8-heptachlorodibenzofuran	1988-92	nd		40		
DF9	1,2,3,4,7,8,9-heptachlorodibenzofuran	1988-92	nd		40		
DF10	octachlorodibenzofuran	1988-92	nd		40		
CB77	3,3'4,4'-tetrachlorobiphenyl (coplanar)	1988-92	13.8	17.7	40	no	-
CB126	3,3',4,4',5-pentachlorobiphenyl (coplanar	1988-92	3.38	3.02	40	[+]	*
CB169	3,3',4,4',5,5'-hexachlorobiphenyl (coplanar)	1988-92	0.45	0.48	40	no	-
DE47	2,2',4,4'-tetrachlorodiphenyl ether	1990-92	12.9	10.7	31	no	-
DE66	2,3',4,4'-tetrachlorodiphenyl ether	1991-92	2.05	1.35	17	no	-
DE85	2,2',3,4,4'-pentachlorodiphenyl ether	1990-92	1.44	1.54	31	no	-
DE89	2,2',3,4,6'-pentachlorodiphenyl ether	1991-92	0.68	1.06	17	no	-
DE99	2,2',4,4',5-pentachlorodiphenyl ether	1990-92	7.02	6.03	31	no	-
DE100	2,2',4,4',6-pentachlorodiphenyl ether	1990-92	1.31	1.39	31	no	-
DE118	2,3',4,4',5-pentachlorodiphenyl ether	1990-92	0.94	0.99	31	no	-
DE137	2,2',3,4,4',5-hexachlorodiphenyl ether	1990-92	0.79	0.87	31	[-]	*
DE138	2,2',3,4,4',5'-hexachlorodiphenyl ether	1990-92	0.61	0.93	31	no	-
DE140¤	2,2',3,4,4',6'-hexachlorodiphenyl ether	1990-92	0.65	1.01	31	no	-
DE147¤	2,2',3,4',5,6-hexachlorodiphenyl ether	1991-92	6.64	4.79	17	[-]	**
DE153¤	2,2'4,4',5,5'-hexachlorodiphenyl ether	1991-92	¤ (see 147)				
DE154	2,2',4,4',5,6'-hexachlorodiphenyl ether	1991-92	3.45	4.40	31	no	-
DE167¤	2,3',4,4',5,5'-hexachlorodiphenyl ether	1990-92	¤ (see 140)				
DE180¤	2,2',3,4,4',5,5'-heptachlorodiphenyl ether	1990-92	0.96	0.99	31	no	-
DE181¤	2,2',3,4,4',5,6-heptachlorodiphenyl ether	1990-92	¤ (see 180)				
DE182	2,2',3,4,4',5,6'-heptachlorodiphenyl ether	1991-92	1.81	1.21	17	no	
DE184	2,2',3,4,4',6,6'-heptachlorodiphenyl ether	1991-92	2.86	1.73	17	[-]	*
DE187	2,2',3,4',5,5',6-heptachlorodiphenyl ether	1991-92	&&				
DE196	2,2',3,3',4,4',5,6'-octachlorodiphenyl ether	1990-92	2.25	2.86	31	no	-
DE197	2,2',3,3',4,4',6,6'-octachlorodiphenyl ether	1991-92	3.31	2.34	17	[-]	*
DE203	2,2',3,4,4',5,5',6-octachlorodiphenyl ether	1991-92	0.52	0.68	17	[-]	**
DE204	2,2',3,4,4',5,6,6'-octachlorodiphenyl ether	1991-92	1.24	0.96	17	no	-

¤Due to superposition of the GC/MS peaks the following six congeners could only be identified as either/or pairs: DE140/167, DE147/153 and DE180/181

nd = non-detectable (< .008 ng/g lw) in all samples

= detected in two samples 1990: .0202 and .0149 ng/g lw, in others < 0.008 ng/g lw.

&&= detected in two samples 1991: 1.36 and 1.85 ng/g, in others < 0.05 ng/g lw.

Principal component analysis (PCA) loadings of three most significant PCs for variables YEAR, FERM, YSM and lw concentrations of the major chlorohydrocarbons. PCDDs, PCDFs and coplanar PCBs are shown in Fig. 2. Another PCA where two PCs were extracted was done for concentrations of the OCs only. The resulting PC scores for each sample are shown in Fig. 3.

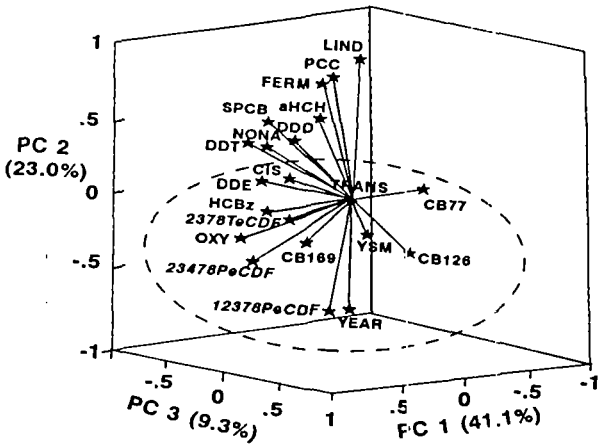

Fig. 2.
PCA for YEAR, FERM, YSM, major chlorohydrocarbons (Table 1), toxic PCDFs and coplanar PCBs (Table 2) in 40 samples from 1988-92. Plot of variable loadings of the three most significant PCs.

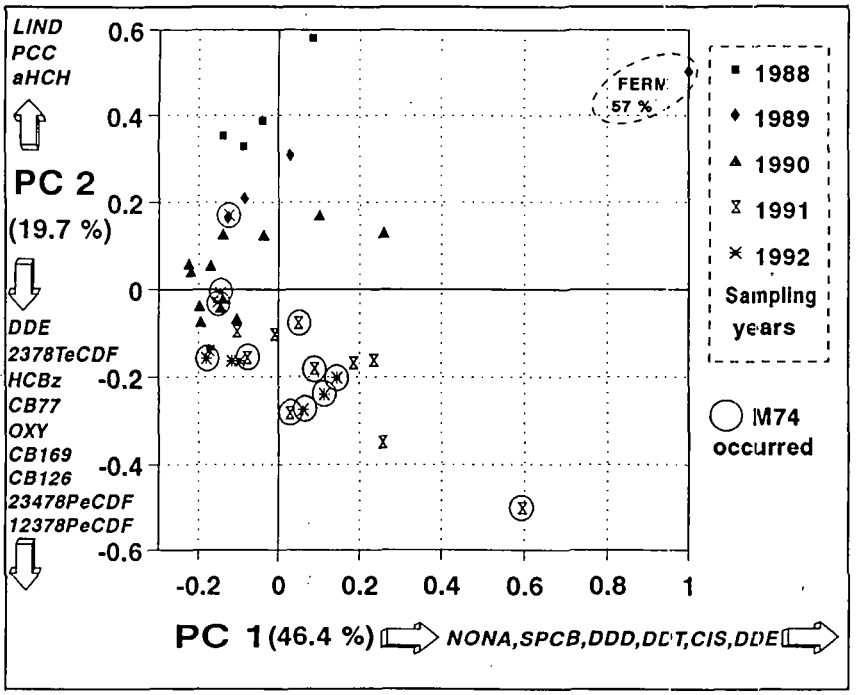

Fig. 3. PCA for major chlorohydrocarbons (Table 1), toxic PCDFs and planar PCBs (Table 2) in 40 samples from 1988-92. Scores of the extracted two PCs for each sample.

One specimen in 1989 had exceptionally high levels of major chlorohydrocarbons and 57 per cent FERM, which is seen as outlier point in Fig. 3. Both PCAs indicated a connection of YSM with toxic PCDFs, coplanar PCBs but also with OXY, HCBz, DDE, and CIS. PCDEs were included in further PCA for 31 samples (Table 2). This analysis indicated connection of YSM with DE118. This congener has the highest AHH induction among the PCDE congeners studied, thus far[9].

Although the trends of major chlorohydrocarbons were in large part significantly decreasing (Table 1), YSM and the concentrations of DF2 (12378PeCDF), DF3 (23478PeCDF), CB126 (33'44'5PeCB) and SFTEQ were significantly increasing (Fig. 1 and Table 2). Accordingly, trends, in addition to PCA, support that TCDD-type of toxicants might participate in occurrence of the M74 syndrome. The decrease of egg color (Fig. 1) could originate from TCDD-type inhibitory effect of the pollutants to the carotenoid metabolism of salmon or their food (smaller Baltic fish). TCDD related toxicants might also cause thiamine deficiency, which could be the final reason to death of the yolk sac fry[10].

5. References

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