ECOTOXICOLOGICAL AND HEALTH EFFECTS CAUSED BY PCP=S, PCDE=S, PCDD=S, AND PCDF=S IN RIVER KYMIJOKI SEDIMENTS, SOUTH-EASTERN FINLAND

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Introduction

Kymijoki, the fourth largest river in Finland, is situated in the south-eastern corner of the country. The area has long traditions in paper industry and the river has been heavily polluted by e.g. pulp mill effluents as well as the chemical industry. During the last 15 years, the general water quality of the river has improved significantly due to major renewals in the industrial processes and waste water treatment of the industry. However, remains of past emissions from chlorination of pulp industry including polychlorinated phenols (PCP) still exist in river sediments.Up to 24 000 t of wood preservative, called Ky-5, was manufactured at the upper Kymijoki from 1940 to 1984, from which an unknown amount of the product and impurities ended in the river. The product consisted mainly of polychlorinated phenols (PCP). Polychlorinated diphenyl ethers (PCDE), polychlorinated dibenzo-*p*-dioxins (PCDD) and dibenzofurans (PCDF) occurred as impurities.

The objectives of the project were to:

* examine the spatial extent of the contamination of the river Kymijoki and its estuary
* elucidate and model the transport mechanisms of pollutants
  - in river channel, and
  - accumulation into biota
* predict future trends
* investigate ecotoxicological effects on aquatic biota (benthos)
* assess human health risks
* find out the restoration needs and preconditions of the contaminated environment

Materials and methods

Samples of river and marine sediments, sedimenting material, benthic animals and fish were analysed for PCPs, PCDEs, PCDDs and PCDFs, and human milk (primipara mothers) samples were collected from the same area and analysed for PCDDs and PCDFs. Midge larvae (*Chironomus riparius*) were exposed to contaminated sediments in laboratory, and monitored for contaminant bioaccumulation and growth development. Detailed analytical methods have been described elsewhere (1,2,3).

Results and discussion

Sediments: The highest concentration of pollutants in sediments were measured at the upper course of the river. The highly chlorinated (hexa-, hepta- and octa-) congeners of PCDE, PCDD and PCDF, typical to Ky-5, dominated in river sediments. The highest PCDD/F concentrations in river sediments were up to two orders of magnitude higher than the limit values proposed for contaminated soils in Finland and can be classified as extremely contaminated with maximum areal mean concentration of above 70 000 000 pg g^{-1}(dw) as total amount of these substances and 130 000 pg g^{-1} (dw) as I-TEQ (4) (Table1). Estimates for total amount of PCDD/Fs in river and marine sediments, based on echo sensing of loose contaminated sediments and a river sediment transport model, accounted for from 16 to 21 kg of PCDD/Fs (as I-TEQ) in the contaminated area. This is an order of magnitude more than the amount of 2,3,7,8-tetrachloro-*p*-dibenzodioxin emitted to the atmosphere in Seveso in 1976 (5). The limit values for PCPs in soils were not exceeded.

Benthos: High toxicity of sediment to exposed micro-organisms and high frequencies of mentum deformities in midge (*Chironomus* spp) larval populations were measured in areas with high pollutant concentrations in sediments but in some occasions at the lower River Kymijoki as well (data not shown). Ten days exposure to sediments did not clearly affect the survival of midge larvae, but growth

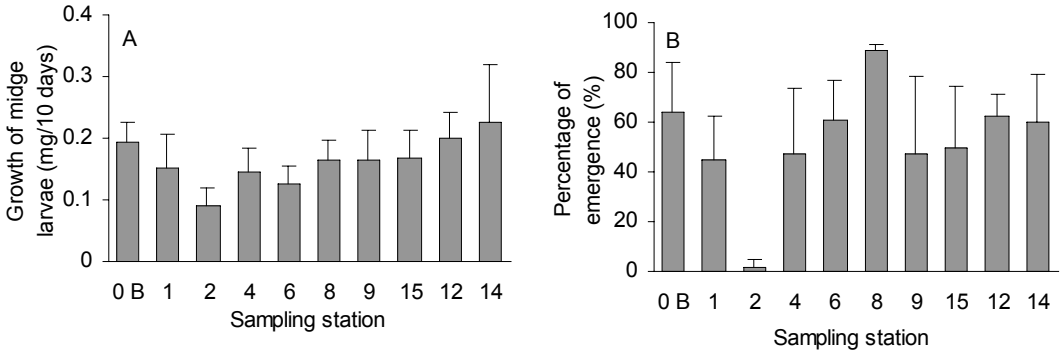

Figure 1. The growth and development of midge larvae (*Chironomus riparius*) at different locations. Stations 0B and 1upstream pollution source, stations 2-14 downstream.

and development tended to be slower in the most contaminated sediments from the upper course of the river (Figure 1).

Fish: The fish muscle showed highly elevated levels of PCDEs, but none or only slightly elevated PCDD/F and PCP levels compared with the levels in the same species in Finnish freshwater and in the Baltic Sea (6) (Table 1). Baltic salmon and herring show an order of magnitude higher level of PCDD/Fs than river Kymijoki fish. Ky-5 impurity congeners could be observed in fish in Kymijoki river, but only occasionally in the estuary. Concentrations in liver were orders of magnitude higher than in muscle for most of the contaminants (6).

Humans: The concentrations of PCDD/Fs in the milk samples of mothers did not differ from levels in other locations in Finland (7,8) (Table1).

Table 1. Concentrations of PCDD/Fs, PCDEs and total PCPs (min-max) in sediment (pg g^{-1}, dw), fish

muscle (pg g^{-1}, fw) and human milk (pg g^{-1}, lipid) at different study areas. Human milk samples are compared with studies at other locations (8).

			min-max
Upstream Ky-5 manufactory			
Sediment	3	PCDD/F	800 - 120 000
		I-TEQ	10 - 440
	□	PCDE	300
	□	PCPs	11 000
Fish	□	PCDD/F	1.3 - 41.8
		I-TEQ	0.2 - 5.2
	□	PCDE	0 - 2 800
	□	PCPs	500 - 2 100
Human milk			
Reference			
Helsinki-Kuopio	□	PCDD/F	118 - 559
1994		I-TEQ	6.1 - 34
Downstream Ky-5 manufactory			
Sediment	□	PCDD/F	120 000 - 190 000 000
		I-TEQ	500 - 350 000
	□	PCDE	1 000 - 500 000
	□	PCPs	2 000 - 720 000
Fish	□	PCDD/F	2.4 - 138.3
		I-TEQ	0.2 - 2.9
	□	PCDE	100 - 50 700
	□	PCPs	0 - 4 300
Human milk			
	□	PCDD/F	65 - 375
		I-TEQ	6.1 - 23
Estuary and coastal area			
Sediment	□	PCDD/F	1 000 - 530 000
		I-TEQ	10 - 200
	□	PCDE	< 1 000
	□	PCPs	12 000 - 190 000
Fish	□	PCDD/F	0.5 - 67.1
		I-TEQ	0.1 - 1.9
	□	PCDE	0 - 39 000
	□	PCPs	0 - 2 300
Salmon, herring	□	PCDD/F	10.5 - 39.5
		I-TEQ	3.4 - 14.9
		PCDE	1 700 - 4 600
		PCPs	0 - 3 800
Human milk	□	PCDD/F	136 - 370
		I-TEQ	7.0 - 23

Conclusions

The results do not support any restrictions for Kymijoki fish use due to PCDD/Fs, but revealed possible high exposure levels to populations of frequent consumption of Baltic fish. The highly increased PCDD/F- and PCDE-levels in river sediments pose an ecotoxicological risk to benthic fauna as well as a human health risk if exposed through negligent handling of dredged materials.

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