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Uptake of Polychlorinated Biphenyls (PCBs) by the Macroalga, *Cladophora glomerata*

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Chlorinated hydrocarbons are taken up by phytoplankton (Biggs et al. 1980; Södergren and Gelin 1983) and aquatic macrophytes (Mrozek et al. 1980; Strek and Weber 1982). Phytoplankton rapidly sorb, for instance, polychlorinated biphenyls (PCBs) from the water and the uptake initially follows a first order kinetics. In macrophytes, the compounds may be taken up from the sediment via the roots (Mrozek and Leidy 1981) or directly from the water (Strek and Weber 1982).

PCBs are also taken up by attached, filamentous algae e.g. Cladophora sp. (Särkka et al. 1978; Anderson et al. 1982; Mowrer et al. 1982). Apart from Cladophora's high contribution to the total primary production in North European lakes and brackish water areas, it's massive growth has been recorded in areas receiving sewage effluents. Such effluents may include industrial discharges that contain PCBs.

Due to the lipophilic and adsorptive properties of PCBs the compounds associate to particles (Larsson 1984). In aquatic environments the major fraction is found in the sediment (Beeton et al. 1979). When associated with the sediment the compounds are partly inactivated, but may redistribute to the water by several processes, e.g. bioturbation (the activity of benthic macroinvertebrates in the sediment) and desorption (Södergren and Larsson 1982; Larsson 1983).

Are PCBs in the sediment available for uptake by macroalgae, such as Cladophora sp. ?

To answer the question the levels of PCBs in C. glomerata was followed for two growing seasons in a large, outdoor model system, in southern Sweden.

MATERIALS AND METHODS

The study was carried out from May 1983 to October 1984. The algae was grown in an outdoor pool (diameter 7.3 m, volume 50 m^3) to which 5 to 6 tons of PCB-contaminated (Clophen A 50, an industrial mixture of PCBs containing 50-70 individual compounds) lake sediment was added. Water from a eutrophic river was continuously flowed (50 m^3/month) through the pool. Detailed information of the experimental set-up are given by Larsson (1985).

Replicate samples were taken from several stands of C. glomerata and the samples were stored in aluminium-foil at -20 ^{o}C. Samples of C. glomerata were

taken from up-stream the experimental area and kept as reference.

The levels of PCBs in the water were determined twice a month in 1983 and monthly in 1984 (Larsson, 1985). At the same time samples for pH, conductivity, turbidity, water colour and alkalinity were taken.

The algal samples were washed with distilled water (purified with hexane) three times to remove attached particles. The weight was determined at 60 °C (24 h) and at 105 °C (24 h). About 5 g of C. glomerata (dried at 60 °C) was knife-homogenized in 10 ml of acetone and 10 ml of hexane was added. The mixture was treated in an ultra-sonic bath for 10 minutes. The hexane was separated with 50 ml NaCl-solution (2%) and the remaining aliquote rinsed with 2 x 2 ml of hexane. The hexane-portions were combined, evaporated to 500-1000 µl and cleaned-up with sulphuric acid (Södergren 1973).

The PCB-content of the extracts was determined by capillary- gaschromatography /ECD (Okla and Wesén 1984).

RESULTS AND DISCUSSION

The chemistry of the river was reflected in the water of the experimental pond (conductivity 40-45 mS/m, alkalinity 2-3 meqv/l, pH 7.5-9.0, turbidity 2-20 JTU and water colour 10-20 mg Pt/l) with conditions typical of a northern, eutrophic water course.

PCBs that were released from the sediment (containing 2.7 µg PCBs/g dry weight) to the water of the pond was taken up by C. glomerata (Tab 1, Fig 1). Concentrations of PCBs in the algae decreased from 3.5 µg/g dry weight in 1983 to 0.2 µg/g in August, 1984. Reference samples of algae from the river contained lower levels (0.016 µg PCBs/g dry weight, n=2).

Nutrients are taken up through the cell-membrane by the macroalgae. The uptake process is fast (minutes) and the algal internal pool of, for instance, phosporous rapidly equilbrate with concentrations in the water (Auer et al. 1982). Phosporous in old algal cells may be partitioned to growing cells of the algal stand. The fast uptake indicate an initial sorption (partitioning) process.

A similar uptake process may be expected for PCBs to the algae as the compounds are lipophilic and adsorptive (Nau-Ritter et al. 1982). If a partitioning process governs the uptake it should be concentration-dependent and thus follow PCB levels in the water. Further, if a sorption process dominates principally the same PCB-compounds and the same proportion of PCB-compounds would be taken up by the algae that is present in the water (Anderson et al 1982). In the experimental pond, C. glomerata accumulated the same PCBs and the same proportion of PCBs that were present in the water.

Levels of PCBs in the algae were higher in 1983 compared to 1984 as concentrations of PCBs in the water were higher the first year, indicating a partitioning process. Consequently, concentrations of PCBs in the water principally determined levels in the algae.

The growth rate of C. glomerata was maximal in the beginning of the growing

Table1. PCBs in C. glomerata grown in an experimental pond with contaminated sediment. Mean of two replicate samples.

Date	PCBs	PCBs	
	µg/g dry weight (60°C)	µg/g dry weight (105°C)	
1983			
18 August	1.25	3.55	(3.25-3.84)
4 October	3.22	3.34	(3.17-3.50)
18 October	1.29	2.16	(1.83-2.48)
1984			
12 April	1.51	3.36	(3.22-3.50)
14 May	1.17	1.20	(1.07-1.33)
13 June	0.73	1.06	(0.99-1.14)
19 July	0.39	0.88	(0.62-1.14)
31 July	0.12	0.40	(0.38-0.43)
20 August	0.15	0.17	(0.12-0.22)
Reference (July 1983)	0.001	0.016	(0.011-0.020)

season (in June, as recorded by visual observations) and the highest biomasses were obtained one or two months later (in July/August). At this time in 1983, PCB concentrations in the water reached maximal values during the study. Consequently, high levels of PCBs in the macroalgae were recorded. In the autumn both the algal-biomass and levels of PCBs in the water decreased. However, algal stands from the period of high PCB levels still remained and therefore levels of PCBs in C. glomerata decreased only slowly.

From December to the beginning of April the experimental pond was covered with ice. In April, high levels of PCBs were recorded in short, brown filaments of the over-wintering forms of C. glomerata. Their distribution in the pond was sparse. As no metabolism and elimination has been recorded in algae (Hutzinger et al. 1974) I suggest that these filaments had equilibrated with high PCB levels in the water during the summer of 1983.

The growing season for the alga began in May/June, 1984 and in June a dense algal mat covered the sediment of the pond. This growing biomass equilibrated with the levels of PCBs in the water which were lower compared to 1983. Levels of PCBs thus decreased in the macroalgae.

Cladophora sp. is common in water courses of Northern Europe and North America and have become a nuisance in the Laurentian Great Lakes (Auer et al. 1982). Due to the rapid uptake of PCBs by the algae and the accumulation and maintainance of the substances in the tissues for a long time, even a short

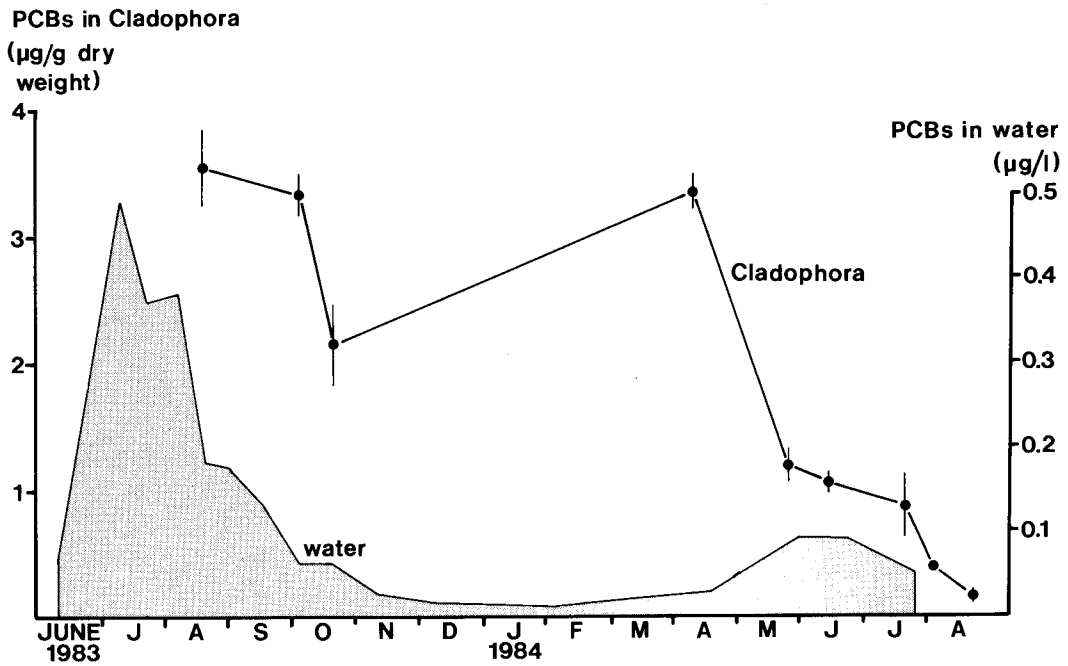

Figure 1. Concentrations of PCBs in C. glomerata and in the water of the experimental pond.

exposure of PCBs may result in a considerable pool stored in Cladophora. The pool of PCBs in the algae may be transferred to grazing fish or contaminate the detritivoral food chain. Filamentous algae may therefore serve as a 'residual' compartment for PCBs, and possibly also for other chlorinated hydrocarbons, making them available for organisms.

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