Bull. Environm. Contam. Toxicol. 25, 841-845 (1980)

Efficiency and Rate of Elimination of Polychlorinated Biphenyls from Waste Waters by Means of Algae

Karel Véber[1], Jarka Zahradník[1] and Ivo Breyl[2]

[1] *Biotechnological Laboratory of Institute of Microbiology CSAS, Třeboň, Czechoslovakia;* [2] *State Veterinary Institute for Game, Jihlava—Horní Kosov, Czechoslovakia*

Polychlorinated biphenyls (PCBs) are being detected in an ever increasing number of components of the environment and accumulate in natural ecosystems.

The occurrence and accumulation of PCBs are the subject of many studies while the kinetics of their sorption by organisms, and possible methods related to the decontamination of the environment, are studied much less extensively.

The currently available results show that the commonly encountered concentrations of PCB residues do not give rise to dangerous acute toxicity; a higher risk, however, is represented by chronic toxicity due to accumulation of PCBs in organisms and in food chains. The high coefficient of accumulation of PCBs in microorganisms such as algae could be utilized for the decontamination of the most important environmental components such as drinking and feed water as well as the water from economically exploited reservoirs. The technological solution of the problem would require further applied research.

The data on the tolerance of algae towards PCB residues are controversial and hardly comparable owing to differences in the parameters of cultivation experiments. The values of accumulation ratios in different algae also differ.

SODERGREN (1971) found no appreciable damage to Chlorella cells even in saturated aqueous solutions of PCB; he found a 88% elimination of PCB from the medium. UREY et al. (1976) reported that PCBs do not inhibit the growth of Chlorella on short exposure. On the other hand, GLOOSCHENKO & GLOOSCHENKO (1975) found an inhibition of growth of Scenedesmus and other algae already at 1 ppb PCB. MOSSER et al. (1972) found inhibition of diatomes at 10 - 100 ppb; EWALD et al. (1976) determined the ID_{50} for the growth of the most resistant alga under study to be 4.4 ppm PCB. KEIL et al. (1971) found a 1000-fold accumulation of PCB in algae as compared to their medium.

This study is concerned with the efficiency and kinetics of elimination of PCB residues by microscopic algae. The experiments were carried out in southern Bohemia under outdoor conditions on open cultivation devices. The results point to one of the real possibilities of elimination of PCB residues from water environments.

0007-4861/80/0025-0841 $01.00

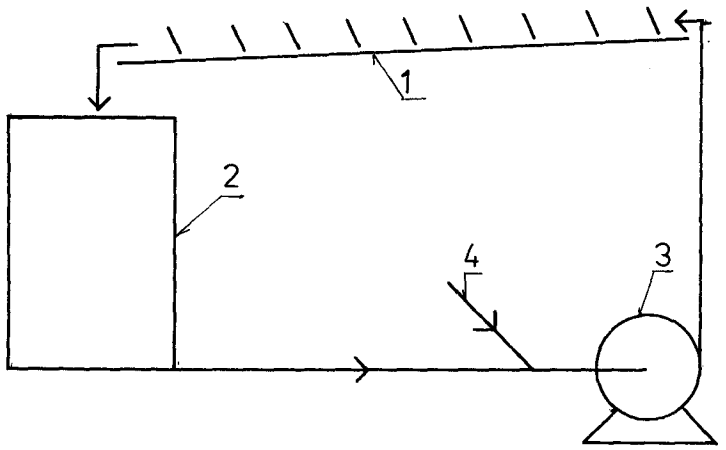

Fig. 1: Cultivation device. 1. Cultivation surface with transverse baffles (side view). 2. Retention tank. 3. Suspension pump. 4. CO_2 supply.

MATERIALS AND METHODS

Waste water used for cultivation came from a municipal water treatment plant and from large-scale piggery. It contained about 25% of biogenic and trace elements as compared with the synthetic medium for algae according to SŠETLÍK (1968) and, on average, 40.5 ppb PCB.

Cultivation device is shown in Fig. 1. Algal suspension was left to flow down the cultivation surface (1) equipped with a system of transversal glass baffles. The cultivation surface was tilted lengthwise by 3% and oriented towards south and its area was 2 m^2. Underneath the lower rim of the cultivation surface was a calibrated retention tank (2) which could accommodate the whole volume of algal suspension, i.e., 150 L, and served for measurement and adjustments of suspension volume. During circulation, the suspension was pumped from the bottom of the tank by means of a pump (3) and delivered on the upper lip of the cultivation surface. Carbon dioxide was introduced in front of the pump by feed line (4).

The device operated outdoors, the suspension circulated overnight, only without CO_2 supply. The thickness of algal suspension layer on the cultivation surface was 4 cm.

Once a day a volume of the suspension corresponding to the chosen dilution rate was withdrawn and replaced by the same volume of waste water. Evaporation losses were made up by tap water. The dilution rates tested were in the range 0.1 - 0.5 day^{-1}.

The algal strains under study included: Scenedesmus acutus (in 1978) and Chlamydomonas geitleri (in 1979). Before experiments, both strains were tested as to their growth characteristics in a medium according to SŠETLÍK (1968).

The algal suspension removed daily during each experiment according to the selected dilution rates was kept in a refrigerator; after the experiment the supernatant was decanted and the sediment was lyophilized to obtain samples for PCB assay. The samples for determination of PCB content in the waste water tested were also prepared by lyophilization of an appropriate volume of the water.

PCB assay was performed on a gas chromatograph with an electron capture detector with Sc^3H. The glass column was 1.2 m long, packed with 1.5% OV-17 + 1.95% QF-1 on 80/100 mesh Chromosorb W. The resulting chromatograms of the samples were identical with chromatograms of a mixture of PCB manufactured in Czechoslovakia under the trademark DELOR 106 and containing 60% (w/w) chlorine. This commercial preparation was therefore used as standard for calibration. To verify the results, the PCB were also assayed by thin-layer chromatography with a reversed phase.

Extraction of PCB from algal biomass was done according to HRUŠKA & KOCIÁNOVÁ (1978) by the method used for determination of organochlorine pesticides in organic materials.

RESULTS AND DISCUSSION

Both the waste water and the algal biomass growing in this water were found to contain considerable amounts of PCB. The interference of organochlorine pesticides was not observed, probably owing to a large excess of PCB over the pesticides. The efficiency and speed of PCB elimination was calculated for each dilution rate from the original content of PCB, the content of the substance in lyophilized algal biomass, biomass weight, length of cultivation and selected dilution. At all dilutions a considerable efficiency was observed concerning the removal of PCB residues from the water (cf. Table 1).

TABLE 1

Alga	Cultivation period	Dilution rate day^{-1}	PCB elimination efficiency %	Elimination rate mg day^{-1}
S. acutus	Jun. 24-Jul. 19	0.1	100	0.68
	Jul. 29-Aug. 9	0.2	67	0.69
	Aug. 25-Sep. 5	0.3	80	0.97
	Sep. 9-Sep. 16	0.5	45	1.36
C. geitleri	May 22-May 29	0.1	84	0.67
	May 29-Jun. 5	0.2	73	0.89
	Jun. 6-Jun. 12	0.3	64	1.31
	Jun. 13-Jun. 19	0.5	100	3.37

The average daily temperature was 19.8°C during the experiments with S. acutus and 17.8°C with C. geitleri (during the day). Night temperatures were not recorded. The pH value of the suspension

fluctuated between pH 6.3 and 8.3. No growth inhibition was observed at low PCB concentrations in the medium; the rate of elimination grew with increasing proportion of waste water in the medium. Table 1 indicates in both algal strains under study a certain trend to a decreased efficiency of PCB sorption with increasing dilution rate. The trend is not completely clear-cut and may reflect also the effect of weather in individual periods on the photosynthetic activity of the cultures. The trend cannot be also irrevocably ascribed to the inhibitory effect of increasing PCB concentration in the medium since the waste water may also contain other components inhibiting algal growth.

The PCB content in dry algal biomass at a maximum dilution rate was 213 mg kg^{-1} (S. acutus) and 157 mg kg^{-1} (C. geitleri). For comparison, we analyzed also algae of different origin from other cultivations. The biomass of the alga Scenedesmus obliquus cultivated in an inorganic medium outdoors in a pilot-plant device in southern Bohemia was found to contain 45 mg kg^{-1}, samples of laboratory cultures of Chlorella vulgaris up to 72 mg kg^{-1}, a sample of S. obliquus from a heterotrophic cultivation, 95 mg kg^{-1}; samples of S. obliquus grown in an outdoor industrial device in southern Bulgaria showed negative results of analyses in 1976 - 1979. Algae of genus Chlorella, grown experimentally in water from south-Bohemian ponds and in drain water from ameliorated plots, contained also up to 10 mg PCB per kg biomass.

The results point to a wide occurrence of PCB residues in the environment and confirm the considerable accumulating ability of algae for these substances.

The mechanism of sorption is not quite clear. UREY et al. (1976) found that the accumulating ability with regard to PCB is retained also by dead algal cells and the process may thus represent absorption in lipid cell components or simple adsorption phenomena.

The results permit the following conclusion. The presence of PCB in waste waters, at least up to the above concentration, does not preclude the semicontinuous cultivation of unicellular algae during which a major part of the substances in accumulated in the algal biomass. C. geitleri seems to be more efficient in the elimination process than S. acutus. The process can be carried out successfully under variable outdoor climatic conditions; a scale-up of the process could give rise to a promising technology of decontamination of some contaminated waters in suitable concrete cases. The liquidation of the relatively small volume of algal mass with accumulated PCB would be technologically very simple.

REFERENCES

EWALD W.G., J.E. FRENCH and M.A. CHAMP : Bull. Environ. Contam. Toxicol. 16, 71 (1976).
GLOOSCHENKO V. and W. GLOOSCHENKO : Can. J. Bot. 53, 623 (1975).
HRUŠKA J. and M. KOCIÁNOVÁ : Průmysl potravin 29, 49 (1978) (in Czech).

KEIL, J.E., L.E. PRIESTER and S.H. SANDIFER : Bull. Environ. Contam. Toxicol. 6, 156 (1971).
MOSSER J. L., N.S. FISHER, T.C. TENG and C.E. WURSTER : Science (Wash.) 175, 191 (1972).
SĚTLÍK I. : In: NEČAS J. and LHOTSKÝ O. (ed): Ann. Rep. Algolog. Lab. Třeboň for 1967: 71 (1968).
SODERGREN A. : Oikos 22, 215 (1971).
UREY J.C., I.C. KRICHER and I.M. BOYLAN : Bull. Environ. Contam. Toxicol. 16, 81 (1976).