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DOI

[10.1016/0045-6535\(96\)00014-8](https://doi.org/10.1016/0045-6535(96)00014-8)

Publication date

1996

Published in

Chemosphere

[Link to publication](#)

Citation for published version (APA):

van Haelst, A. G., Loonen, H. E. W. M., van der Wielen, F. W. M., & Govers, H. A. J. (1996). Comparison of bioconcentration factors of tetrachlorobenzyltoluenes in the guppy (*Poecillia reticulata*) and zebra mussel (*Dreissena polymorpha*). *Chemosphere*, 32, 1117-1122. [https://doi.org/10.1016/0045-6535\(96\)00014-8](https://doi.org/10.1016/0045-6535(96)00014-8)

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COMPARISON OF BIOCONCENTRATION FACTORS OF TETRACHLOROBENZYLTOLENES IN THE GUPPY (*Poecilia reticulata*) AND ZEBRA MUSSEL (*Dreissena polymorpha*).

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(Received in Germany 24 November 1995; accepted 6 December 1995)

ABSTRACT

Preliminary bioconcentration factors (BCFs) were determined of six tetrachlorobenzyltoluenes (TCBTs) in guppies (*Poecilia reticulata*). BCFs and rate constants were derived by an iterative integration method. With this method BCFs and rate constants can be derived from experimental data of a bioconcentration test, even if the concentration in the water is not constant and steady state has not been reached. Log BCF values of TCBTs in guppies ranged from 1.67 to 2.68 L.kg⁻¹ on a wet weight basis. These values are much lower than the reported log BCF values of TCBTs in zebra mussels (*Dreissena polymorpha*) determined with the same method. Biotransformation of TCBTs in guppies as an explanation for the higher log BCF values in zebra mussel is discussed.

INTRODUCTION

Polychlorinated biphenyls (PCBs) have been widely used, because of their chemical stability, good thermal conductivity and their electrical properties. Due to this chemical stability, the use of PCBs has led to extensive environmental contamination. One of the replacements of PCBs is Ugilec 141, a mixture of tetrachlorobenzyltoluenes (TCBTs). Theoretically 96 TCBT-isomers are possible (Fig. 1).

Figure 1. Molecular structure of TCBT isomers

Ugilec 141 is used as a hydraulic fluid in the mining industry, as a dielectric fluid for capacitors, and as a cooling and isolation fluid for transformers (Poppe et al., 1988). The estimated loss of Ugilec 141 from the

German mining industry amounted up to 700 t (Poppe et al., 1988). Since 1987 evidence has been obtained for contamination of water and sediment with Ugilec 141 in the rivers Ruhr and Lippe that drain the German coalmining area in Northrhine-Westphals (Rönnfahrt, 1987; Fürst et al., 1987; Poppe et al., 1988). Fürst et al. (1987) found levels of Ugilec 141, ranging from 0.1 to 25 mg.kg⁻¹ based on eatable portion in fish from these rivers. Wester and van der Valk (1990) found levels up to 4.8 mg.kg⁻¹ of Ugilec 141 in red eel in the Dutch rivers Rhine and Meuse, draining from the German rivers (Wester and van der Valk, 1990).

Recent laboratory experiments (Van Haelst et al., 1995a) showed log bioconcentration factors (BCFs) of eight TCBT isomers in fresh water mussels ranging from 4.43 to 5.19. These bioconcentration data are in contradiction with the relatively slight bioconcentration of Ugilec 141 in fish compared with the bioconcentration of pentachlorobiphenyls (Bouraly and Millischer, 1989).

In the present study BCFs of TCBTs in guppies (*Poecilia reticulata*) are calculated for TCBTs according to a numeric iterative method (Gobas and Zhang, 1992). With this method BCFs and rate constants can be derived from experimental data of a bioconcentration test, even if the concentration in the water is not constant and steady state has not been reached. The results of the exposure experiment of TCBTs in guppies, reported elsewhere (Van Haelst et al., 1993) are used to calculate the log BCFs. These log BCFs are compared with the log BCFs of TCBTs in the freshwater mussel derived with the same method (Van Haelst et al., 1995a).

MATERIALS AND METHODS

Chemicals

The six TCBTs are numbered according to Ehmann and Ballschmiter (1989): 2,2',4,6'-Cl-5Me, no. 28; 2,2',4,6'-3Me, no. 27; 2',3,4,6'-6Me, no. 80; 2,2',4,4'-3Me, no. 21; 2,3',4,4'-5Me, no. 52; 2',3,4,4'-6Me, no. 74.

Determination of bioconcentration factors and rate constants

Uptake and elimination of TCBTs in guppies was determined during 15 and 28 days respectively. During the exposure experiment, the water was continuously loaded with TCBTs and renewed at day 9. Concentrations of TCBTs in the water and in the guppies were measured in singular at several time intervals during 15 days of exposure. Details on the experimental outline have been described elsewhere (Van Haelst et al., 1993).

An iterative integration method, as is described by Gobas and Zhang (1992), was applied to calculate the BCFs and rate constants of TCBTs in guppies (*Poecilia reticulata*) from experimental data, reported in the literature (Van Haelst et al., 1993). Bioconcentration factors derived by the iterative method are independent of the duration of the exposure experiment and of the variability in the concentration in the water. The quality of the fit of the iterative procedure is expressed as the mean deviation E between the experimental and the fitted fish concentration data.

RESULTS

The reported experimental data used in the iterative integration method are shown in Figure 2A and B. The concentration of TCBTs in the water decreased between and after the water renewal of the test solution at the ninth day (Fig. 2A). The aqueous concentration of TCBTs was in between 0.15 and 0.0009 $\mu\text{g.L}^{-1}$ for the different congeners, which is below their maximum water solubility (0.14-18 $\mu\text{g.L}^{-1}$, Van Haelst et al., 1995b). Figure 2B shows a slight uptake of TCBTs in guppies during the 15 days of exposure. The concentrations of TCBTs in guppies are expressed on a wet weight basis. All concentrations of TCBTs in Figure 2A and Figure 2B represent one sample.

Figure 2. Concentrations of TCBTs in water (A) and guppies (B) during the accumulation experiment.

In Table I the results are shown of the calculated log BCFs, rate constants and mean deviation of 6 TCBTs in the guppy and the reported log BCF values and mean deviations of these 6 TCBTs in zebra mussels (Van Haelst et al., 1995a). The log BCFs are expressed on a wet weight basis. The log BCFs in zebra mussel are the mean of two log BCFs with range derived from separate test systems. Log BCFs in guppies appeared to be much lower than the log BCFs of TCBTs in zebra mussels. The mean deviation (E), in this study is higher than the mean deviations of approximately 10% reported by Gobas and Zhang (1992) and 15-20% reported by Van Haelst et al. (1995a).

Table I Uptake rate constants k_1 ($L \cdot kg^{-1} \cdot d^{-1}$), elimination rate constants k_2 (d^{-1}), log BCF ($L \cdot kg^{-1}$ w.w.) and the mean deviation E (%) of TCBTs in guppies (this study) and reported log BCF values ($L \cdot kg^{-1}$ w.w.) of TCBTs in zebra mussels (Van Haelst et al., 1995a) derived by the iterative integration method (Gobas and Zhang, 1992).

TCBT ^a	guppy				zebra mussel ^b	
	k_1	k_2	log BCF	E	log BCF	E
28	249.69	1.186	2.32	31	4.83 (± 0.01)	15 (± 6)
27	98.33	1.043	1.97	58	5.19 (± 0.15)	16 (± 5)
80	147.67	1.226	2.12	29	4.43 (± 0.05)	16 (± 7)
21	147.14	3.128	1.67	42	4.58 (± 0.26)	19 (± 8)
52	329.25	0.690	2.68	32	4.53 (± 0.06)	16 (± 5)
74	262.94	1.032	2.41	23	4.66 (± 0.07)	20 (± 5)

^a Numbering according to Ehmann and Ballschmiter (1989) and in order of elution

^b Mean log BCF and E of two values from duplicate bioconcentration experiments with range

DISCUSSION

The log BCFs in guppies and zebra mussels shown in Table I are expressed on a wet weight basis. However, it has been argued that concentrations of various organic compounds accumulated in organisms are determined by the organisms lipid compound (Geyer et al., 1985; Chiou 1985). Therefore, to compare different species for bioaccumulation of hydrophobic compounds, their log BCFs should be expressed on a lipid weight basis. To express the log BCFs in guppies and zebra mussels on a lipid weight basis, the wet weight based BCFs, shown in Table I, are divided by the average lipid content. As no lipid content is measured in this study, the mean lipid content of $9.4 \pm 2.4\%$ of female adult guppies (*Poecilia reticulata*) from the same hatchery, reported in the literature (Loonen et al., 1995), is used. The mean lipid content of zebra mussels during the exposure experiment (Van Haelst et al., 1995a) was $4.35 \pm 1.05\%$. The resulting log BCFs on a lipid weight basis ranged from 2.70 to 3.71 and from 5.79 to 6.55 for guppies and zebra mussels, respectively. The bioconcentration in guppies is lower than predicted by polynomial relationships between BCF and n-octanol/water partition coefficients (Connell and Hawker, 1988), whereas the log BCFs in zebra mussels seem to be in agreement with the polynomial relationship (Van Haelst et al., 1995a). One of the explanations for the reduced bioconcentration of hydrophobic TCBTs in guppies might be biotransformation processes. Several relatively high biotransformation rates were found for various hydrophobic compounds in different fish species (Lech and

Bend, 1980; Kleinow et al., 1987; Sijm and Opperhuizen, 1988; Rappe et al., 1991; De Wolf et al., 1992; Cooper et al., 1992). Also Bouraly and Millischer (1989) proposed biotransformation as an explanation for the slight accumulation of Ugilec 141 in fish, while, no biotransformation was shown for a mixture of pentachloro-biphenyls in the same accumulation experiment. Moreover, Livingstone and Farrar (1984) suggested that although bivalves do possess a mixed function oxidase system, their biotransformation capability is lower compared to that of fish. This would explain the much larger BCF values in zebra mussels (Van Haelst et al., 1995a) compared to the BCF values in guppies, calculated in this study.

Therefore, it might be concluded that the bioconcentration potential of TCBTs is species dependent: the bioconcentration factor is lower than predicted by $\log K_{ow}$ in guppies, in contrast, high bioconcentration factors are observed in zebra mussels.

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