# RELATIONSHIP BETWEEN ELIMINATION HALF-LIVES ($T_{1/2}$) OF 2, 3, 7, 8 -TETRACHLORODIBENZO-P-DIOXIN (TCDD) IN DIFFERENT MUSSEL AND FISH SPECIES AND THEIR LIPID CONTENT OR BODY SIZE

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## 1. Introduction

Half-lives ($t_{1/2}$) provide a convenient measure for the persistence of chemicals in living terrestrial and aquatic organisms. The rate of loss of lipophilic persistent chemicals from the fish body in most cases follows first-order kinetics.[1-5, 7-25] It was hypothesed that the depuration process would be dependent on the total lipid content of the fish. The aim of the present study is

a) to give a compilation of half-lives ($t_{1/2}$) and elimination rate constants ($k_e$) for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in different fish species at various developmental stages,
b) to investigate the relationship between $t_{1/2}$ and the lipid content (L %) of the fish, and
c) to assess the relationship between $t_{1/2}$ and the body size (g) of the aquatic organisms.

## 2. Material and Methods

The elimination half-lives ($t_{1/2}$) of TCDD in different aquatic organisms, such as mussels and fish (fathead minnows - Japanese medaka, guppies, rainbow trout, and carp) range from ca. 5 to 273 days. These $t_{1/2}$ data were determined experimentally by MUIR and YARECHEWSKI[14], Patricia SCHMIEDER[20], and PRUELL[17] or were taken from the literature[1-5, 7-11, 15, 16, 19-23] and correlated with the total body lipid content (L%) of the whole fish on a wet weight basis. In the cases for which only depuration rate constants ($k_e$ days$^{-1}$) were reported in the literature, the half-lives were calculated by the formula $t_{1/2} = 0.693/k_e$, assuming first-order kinetics. These data as well as the body weight and the lipid content of the aquatic organisms are compiled in Table 1.

## 3. Results

A log ($t_{1/2}$) vs. log (L%) plot yielded a significant linear regression equation:

$$\log t_{1/2} = 1.36 \times \log (L\%) + 0.546 \qquad (1)$$

N = 25    r = 0.874    significance level $p < 0.01$ (two tailed)

If the elimination half-lives ($t_{1/2}$ in days) of TCDD in different aquatic filter-feeders are correlated with their body weight (BW in g), the following equation (2) is obtained:

$$\log t_{1/2} = 0.306 \times \log (BW) + 1.44 \qquad (2)$$

N = 25    r = 0.781    significance level $p < 0.01$ (two tailed)

## 4. Discussion and Conclusions

1) The half-life ($t_{1/2}$) of TCDD in mussel and fish increases with the lipid content and vice versa (equation 1). 76.5 % of $t_{1/2}$ variability is explained by the total lipid content. Our results confirm the presumption of COOK et al.[4,5] and KUEHL et al.[9] that the elimination half-life of TCDD in fish is dependent on their lipid content.

2) The elimination rate constant decreases with the lipid content and vice versa.

3) The elimination half-life of TCDD in aquatic organisms is increasing with body size. This relationship is also significant and is in agreement with the presumption of COOK et al.[4]. However, only 61 % of $t_{1/2}$ variability is explained by the body size.

4) The whole body elimination half-lives ($t_{1/2}$) of TCDD and other lipophilic persistent chemicals, such as PCDDs, PCDFs, PCBs, HCB etc. in fish, mussels and other aquatic organisms are better comparable if these $t_{1/2}$ data are normalized on the basis of lipid content than normalized on a body size.

5) The first-order kinetics rate model (i.e., independent of initial concentration in the organism) is valid only if the toxic effects and the loss of body lipid during the elimination/depuration phase are not too high. Otherwise the $t_{1/2}$ values are too low. (Examples: the experiments with guppies where more than 40 % of fish died during the elimination phase)[10, 15].

6) It was shown by KLEEMAN et al.[7, 8] that fishes are able to metabolize TCDD. Therefore it is possible that the half-life of TCDD in different fish species may be also dependent on the metabolism rate.

7) The equation (1) can be used for **predicting the half-life** of TCDD in **untested** fish species, if their lipid content is known. In **adult** European eels (*Anguilla anguilla*) with 28 % lipid, the theoretical calculated $t_{1/2}$ value is 327 days. However, in **young** American eels (*Anguilla rostrata*) with 0.18 g b.wt. and 5.6 cm length containing 3.3 % lipid, the theoretical calculated $t_{1/2}$ is about 18 days. The last calculated $t_{1/2}$ value is approximately the same as for **young** bluegill sunfish of 3.4 g body weight and 3.3 % lipid content.

8) The half-lives can be used to **estimate the time ($t_e$) required to attain equilibrium** (ca. 98 %) TCDD concentration in tested and untested fish (e.g. $t_e$ of **adult** European eels: 1960 days = 5.4 years; $t_e$ of **young** American eels: 108 days). The time required to reach steady state concentration of TCDD in high lipid fish is longer than in fish with low lipid content.

TABLE 1: Elimination Rate Constant ($K_e$) and Half-Lives ($t_{1/2}$) of 2,3,7,8-Tetrachlorodibenzo-p-dioxin in Different Mussel and Fish Species with their Body Weight, and Lipid Content (%).[1-5, 7-11, 15, 16, 19-23]

| Fish Species | Average body weight (g) and stage/age | Lipid content (L) Mean ± SD (%) | T (°C) | $K_e$ [a] ($d^{-1}$) | $t_{1/2}$ [b] (d) |
|---|---|---|---|---|---|
| Carp<br>(*Cyprinus carpio*) | 1500<br>(1 year) | 17.1 ± 1.3<br>22.2 ± 1.7 | 20 | 0.00254 | 273 |
| Carp<br>(*Cyprinus carpio*) | 20<br>20<br>20 | a) 9.6<br>b) 8.5<br>c) 5.5 | 25<br>25<br>25 | a) 0.0083<br>b) 0.0129<br>c) 0.0144 | a) 84<br>b) 58<br>c) 48 |
| Yellow perch<br>(*Perca flavescens*) | 20<br>(15 - 25) | 19 ± 3 | 18 ± 2 | 0.0055 | 126 |
| Japanese medaka<br>(*Oryzias latipes*) | 0.30<br>(0.19 - 0.43) | 10<br>(7.7 - 14.3) | 25 | 0.0045 | 154 |
| Rainbow trout<br>(*Oncorhynchus mykiss*) | 100<br>(90 - 120) | 12.5 | 18 ± 2 | 0.00825 | 84 |
| Rainbow trout<br>(*Oncorhynchus mykiss*) | 46.2 ± 12.5 | 11.4<br>8.9 ± 0.95 | 10 ± 1 | 0.012 | 58 ± 5 |
| Rainbow trout<br>(*Oncorhynchus mykiss*) | a) 20.8<br>b) 19.4<br>c) 18.4 | 8.5<br>8.5<br>8.5 | 10 | a) 0.00808<br>b) 0.00883<br>c) 0.0084 | a) 85.8<br>b) 78.5<br>c) 82.5 |

TABLE 1 (continued).

| Fish<br>Species | Average body weight (g) and stage/age | Lipid content (L) Mean ± SD (%) | T<br>(°C) | $K_e$[a]<br>($d^{-1}$) | $t_{1/2}$[b]<br>(d) |
|---|---|---|---|---|---|
| Rainbow trout<br>(*Oncorhynchus mykiss*) | a) 0.53<br>b) 0.49<br>c) 0.42<br>d) 0.45[c]<br>swim-up fry | a) 2.6<br>b) 2.6<br>c) 2.6 | 12 ± 1 | a) 0.047<br>b) 0.041<br>c) 0.043<br>d) 0.015[c] | a) 15 ± 3<br>b) 17 ± 2<br>c) 16 ± 2<br>d) 48 ±13[c] |
| Fathead minnows<br>(*Pimephales promelas*) | 1.0<br>young adult | a) 9.5<br>b) 9.5 | 25<br>25 | a) 0.012<br>b) 0.013 | a) 58<br>b) 53 |
| Lake trout<br>(*Salvelinus namaycush*) | 0.16<br>swim-up fry | 4.2 | 8 ± 0.5 | a) 0.0187<br>b) 0.0198 | a) 37<br>b) 35 |
| Lake whitefish<br>(*Coregonus clupeaformis*) | a) 11.5<br>b) 15.1<br>c) 14.6 | a) 8.0<br>b) 7.7<br>c) 7.9 | 10 | a) 0.02056<br>b) 0.0176<br>c) 0.0152 | a) 33.7<br>b) 39.3<br>c) 45.6 |
| Guppy (male)<br>(*Poecilia reticulata*) | 0.085 ± 0.018<br>(1 year) | 5.1 ± 1.3 | 22 | 0.046 [d] | 15.1 [d] |
| Fathead minnows<br>(*Pimephales promelas*) | 0.75<br>(0.5 - 1.09)<br>juvenile | 3.55<br>3.6 ± 0.8 | 21 - 23 | 0.048 | 14.5 |
| Guppy (female)<br>(*Poecilia reticulata*) | 0.91 ± 0.21 | 9.7 ± 2.4 | 24.8 ± 0.6 | 0.049 [d] | 14.1 [d] |
| Goldfish<br>(*Carassius auratus*) | 2.5 | 0.5 | 22 | 0.146 | 4.7 |
| Clam<br>(*Macoma nasuta*) | 1.9 ± 0.4 | 0.4 | 18 - 22 | 0.117<br>0.112 | a) 5.9<br>b) 6.2 |

a) Elimination (= depuration) rate constant for the whole fish.
b) Half-life: $t_{1/2} = \ln 2/K_e = 0.693/K_e$.
c) Outlier - not used to calculate the regression equation (1) and (2).
d) Not used for regression analysis because a high amount of fish died during the elimination phase.[10, 15]

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