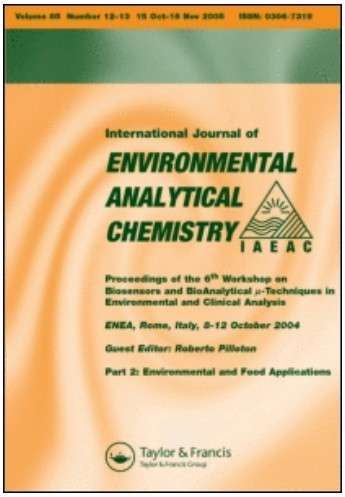

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The Cumulation of Zinc and Cadmium in Fish (Poecilia reticulata)

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Zinc-65 and cadmium-115 m were used for the investigation of the uptake and the release of zinc and cadmium in fish. It has been found that the uptake of these elements directly from water is relatively low. Zinc and cadmium, consumed by fish in food, are released with the biological half-time 0.25 ± 0.05 days (94%) and 65 ± 9 days (6%) for zinc, 0.25 ± 0.05 days (98.5%) and 36 ± 6 days (1.5%) for cadmium. The comparison with data obtained for mercury species shows that the cumulation of these elements in fish increases in the order cadmium, zinc, inorganic mercury (II), phenylmercury and methylmercury.

KEY WORDS: Radioanalytical methods, zinc, cadmium, fish, Poecilia reticulata.

INTRODUCTION

In our previous papers the cumulation of methylmercury,[1] phenylmercury and inorganic mercury[2] in fish (Poecilia reticulata) has been investigated. This study has shown that it is possible to calculate the concentration of individual mercury species in fish using experimentally determined cumulation and release constants.[3]

In the continuation of these investigations the uptake of zinc and cadmium by fish directly from water or sorbed on food and the release of both elements has been studied in order to compare the cumulation of zinc, cadmium and mercury species.

EXPERIMENTAL

Reagents and apparatus

Unless otherwise stated, all reagents were of analytical reagent grade purity.

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Solution of radionuclides were prepared from the stock solutions of zinc-65 (Swierk, Poland; initial specific activity 10 GBq/g Zn) and cadmium-115 m (Amersham, England; initial specific activity 5–10 GBq/g Cd) by the dilution with tridistilled water to the appropriate concentration.

Labelled fish food was prepared as follows: an appropriate volume of neutralized solution of zinc-65 or cadmium-115 m, containing 0.1–0.5 mg of zinc or 10–20 mg of cadmium, was mixed with 1 g of commercial fish food (dry zooplankton containing Daphnia sp. and Cyclops sp.) and air dried at room temperature. Fish Poecilia reticulata were of age 3–10 months. The scintillation counter with NaI(T1) crystal was used for the radioactivity measurements.

Procedures

The uptake of zinc and cadmium from water as well as sorbed on fish food and the release of both elements was studied at 25°C in a similar manner as described in previous communication.[1]

RESULTS AND DISCUSSION

Uptake of zinc and cadmium from water and its release

Uptake of zinc and cadmium by fish directly from water was found to be relatively low, however, both elements were sorbed on the skin of the fish. The value of the cumulation constant K_w was lower than 1 day^{-1}, which means that after one day of the exposition the concentration of both elements in fish was lower than that in water (K_w for methylmercury and phenylmercury species equals to 237 ± 67 and 212 ± 49 days^{-1}, respectively).[1,2] The biological half-time T of zinc was found to be 61 ± 10 days (release or clearance constant $\lambda = \ln 2/T = 0.0114$ days^{-1}), that of cadmium 35 ± 5 days ($\lambda = 0.0198$ days^{-1}).

The concentration of both elements in fish, c_f, taken up directly from water can be calculated according to the equation[1,2]

$$c_f = \frac{K_w c_w}{\lambda}(1 - e^{-\lambda t}) \tag{1}$$

where c_w denotes the concentration of the metal in question in water, t is the time of the exposition in days.

The maximum concentration of zinc in fish (for $t \to \infty$) will be thus lower than $90\,c_w$, that of cadmium lower than $50\,c_w$. Considering the mean concentration of zinc and cadmium in unpolluted rivers to be 20 and 0.2 ppb,[4] respectively, the maximum concentration of zinc in fish will be lower than 1,800 ppb for zinc and of cadmium 10 ppb. The cumulation of phenylmercury

and especially methylmercury directly from water is substantially higher: the maximum concentration of total mercury in fish is 5.5×10^3 times higher than the concentration of phenylmercury in water;[2] for methylmercury the maximum cumulation factors equals[1] to 4×10^4.

Uptake of zinc and cadmium sorbed on food and its release

Two kinds of experiments were carried out. In the first serie 10–15 fishes were fed for one hour with food labelled with zinc-65 or cadmium-115 m. After that the fishes were washed with distilled water, fed by the non-active food for 40–70 days and measured *in vivo* for their radioactivity. The mean values of the release of zinc and cadmium by fish are given on Figure 1 in comparison with those of inorganic mercury (II)[2] and methylmercury.[1] From this Figure it follows that about 94% of zinc and 98.5% of cadmium consumed were released within two days (the calculated half-time for both elements $T = 0.25 \pm 0.05$ days, $\lambda = 2.8$ days^{-1}) whereas $6 \pm 2\%$ of zinc and $1.5 \pm 0.5\%$ of cadmium were released with much longer half-time. For the precise determination of these half-times, fishes were fed for 19 days with food containing zinc-65 or cadmium-115 m; after that time they were fed with non-active food for 40–70 days and their radioactivity was measured *in vivo*. The mean value (12 fishes were measured for each metal) of the biological half-time for zinc equals to 65 ± 9 days ($\lambda = 0.0107$ days^{-1}) and that for cadmium 36 ± 6 days ($\lambda = 0.0193$ days^{-1}).

The concentration of zinc in fish, taken up from food, can be expressed

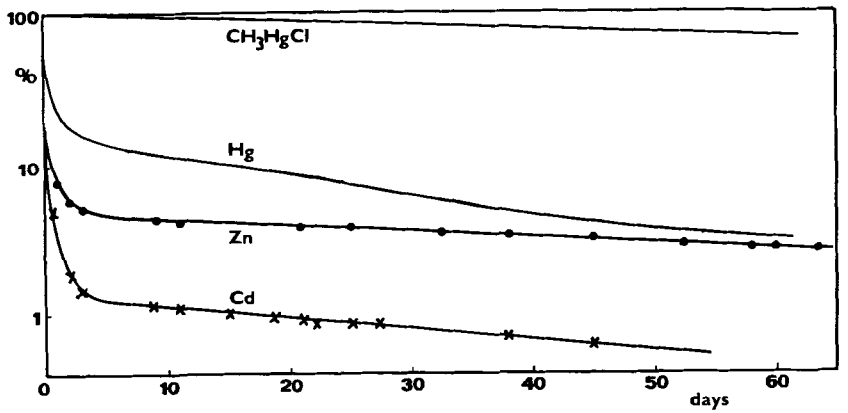

FIGURE 1 The release of zinc and cadmium in comparison with that of methylmercury and inorganic mercury (II) after a short time feeding.

according to[3]

$$c_f = 0.94\frac{K_m c_{Zn}}{2.8}(1-e^{-2.8t}) + 0.06\frac{K_m c_{Zn}}{0.0107}(1-e^{-0.0107t}) \quad (2)$$

where K_m denotes the mean weight of food (in g) consumed daily per g of fishes, c_{Zn} is the concentration of zinc in food.

For the uptake of cadmium the following expression is valid:

$$c_f = 0.98\frac{K_m c_{Cd}}{2.8}(1-e^{-2.8t}) + 0.015\frac{K_m c_{Cd}}{0.0193}(1-e^{-0.0193t}) \quad (3)$$

where c_{Cd} denotes the concentration of cadmium in fish food.

From the above equations it follows that the maximum concentration of zinc in fish is $6\,K_m c_{Zn}$, whereas that of cadmium is $1.1\,K_m c_{Cd}$. Supposing that the ratio of c_{Zn}/c_{Cd} in fish food is the same as in water (i.e. about 100) then the concentration of cadmium in fish is about 500 times lower than that of zinc; this conclusion is in a general agreement with the actual content of zinc (13–44 ppm,[5] 6–51 ppm[6]) and cadmium (10–130 ppb,[5] 110–650 ppb,[6] 2–40 ppb,[7] 16–175 ppb[8] and 10–140 ppb[9]) found in different types of river or sea fish.

The maximum concentration of mercury species cumulated from food are higher: $7\,K_m c_{Hg}$ for inorganic mercury (II),[2] $26\,K_m c_{PhHg}$ for phenylmercury[2] and $160\,K_m c_{MeHg}$ for methylmercury[1] (c_{Hg}, c_{PhHg} and c_{MeHg} denote the concentration of inorganic mercury, phenylmercury and methylmercury in fish food respectively).

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