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Cadmium Uptake by Fingerlings of Perch (*Perca fluviatilis*) Studied by Cd-115m at Two Different Temperatures

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Generation of energy by means of oil, coal or nuclear power causes a local temperature rise in the water recipient. In Sweden, this temperature increase seldom exceeds 10°C. A temperature rise affects the organisms in several ways, for instance by giving them a higher activity, a higher metabolic rate, and an increased rate of uptake of many elements (SORENSEN 1976, JACKIM et al. 1977, CEMBER & CURTIS 1978, EDGREN et al. 1979). Laboratory investigations concerning the effect of the temperature on the bioaccumulation of elements are often based on a limited body of material because of the complicated chemical analyses needed. Relatively few organisms that occur in Swedish waters have so far been tested from this aspect.
The use of gamma-emitting tracers and gammaspectrometry facilitates the chemical analysis and thereby enables a large body of material to be processed. Furthermore, using gamma-emitting radionuclides makes it possible to measure the uptake by whole-body counting in vivo. In the present investigation, we have tested this technique in measuring the uptake of cadmium by fingerlings of perch (Perca fluviatilis).

MATERIALS AND METHODS

During the autumn and early winter of 1978 and 1979 we placed two troughs filled with water from Lake Mälaren in a transparent plastic tent. With the use of an immersion heater the temperature in one trough was increased by 10°C. In each trough we placed a glass aquarium with a lid. The aquaria were each filled with 100 litres lake water (6.2 dH). The water was aerated and circulated by an aquarium pump and airstones. Radioactive cadmium was added as Cd-115m NO_3 ($T_{½}$ = 43 days), giving a concentration of 0.3 MBq/l (8 µCi/l) in each aquarium.
The specific activity was 13 MBq/mg Cd (0.36 mCi/mg Cd). The total cadmium concentration in the aquarium water was determined to 22 µg/l by flameless AAS. Three days after dosage the cadmium concentrations in the aquaria were constant and the fishes were added. As test fishes we used fingerling perches. Before the start the fishes were acclimatized by raising the temperature by 0.5°C/day. Twenty fingerling perches were put in each aquarium. In order to be able to measure ten of them

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as individuals we tagged them by cutting their fins. During this operation we used benzocainum (50 mg/l) as an anaesthetic. During the whole experiment the fingerling perches were fed daily with tubifex ad libitum.
The measurements of Cd-115m were performed with a (10 cm Ø x 10 cm) NaI(Tl) scintillation crystal connected to a ND-100 128 channel analyser. Each fish was measured alive for 20 minutes in a cylindrical plastic beaker (Ø = 7.5 cm h = 4 cm) filled with 100 ml natural lake water from Lake Mälaren. The distance between the bottom of the beaker and the detector surface was 3 cm and the detection efficiency for 934 keV photons emitted uniformly from a 1.3 g fish was determined to 2.5 %. The fishes were measured biweekly at the beginning and weekly at the end of the experiment. The variation in the radioactive measurements due to the movements of the fish was checked with a fish-phantom and was found to be less than 10 %. All activity values relate to the time of dosage. Temperature, pH and Cd-115m concentration in the water were measured each day. Mean temperature, mean pH and mean activity in the water are presented in Table 1. The temperature dropped 10°C during the experiment but the difference between the warm- and the cold-water aquarium was always close to 10°C.

TABLE 1. Conditions in the aquaria during the experiment

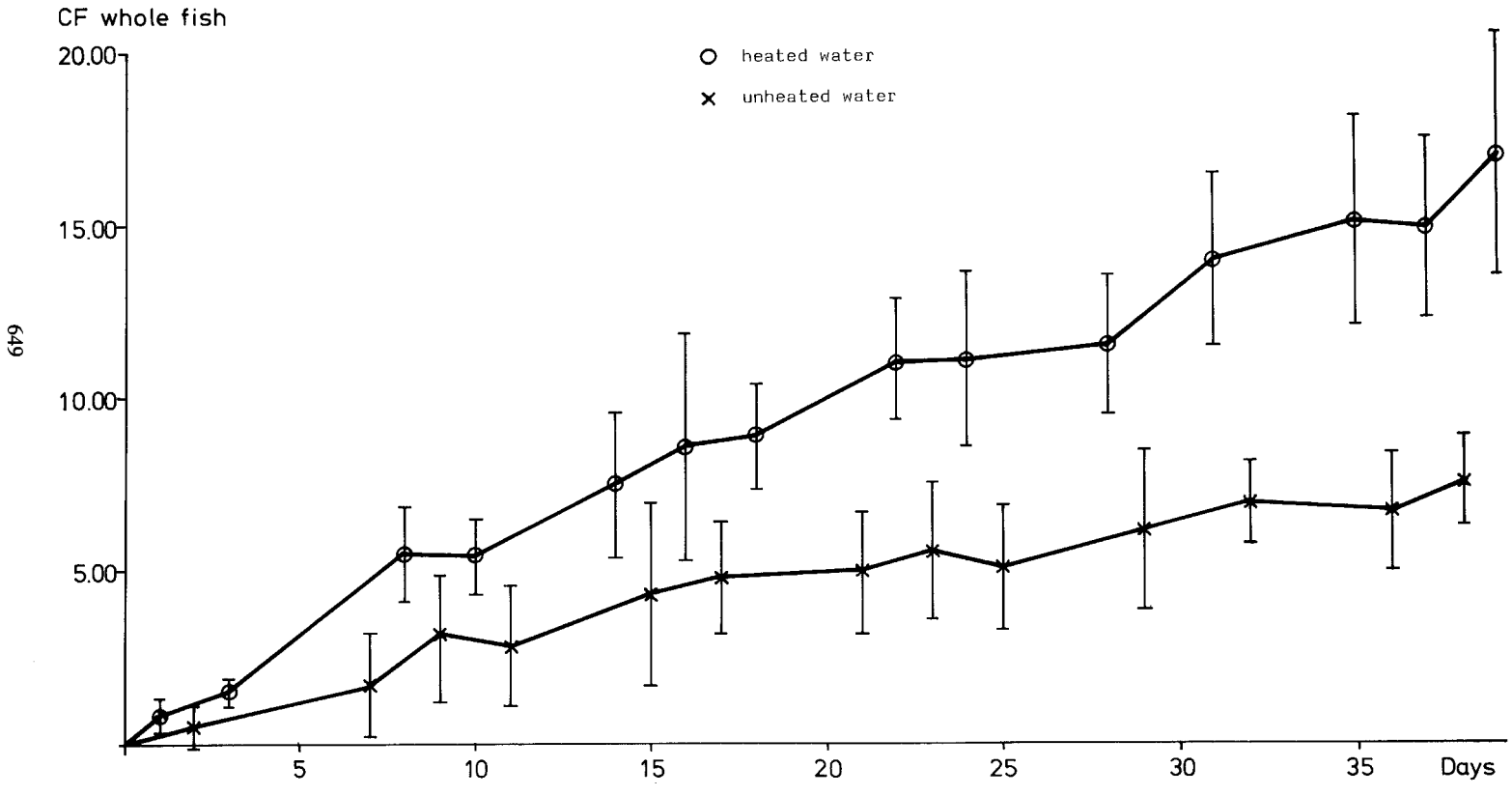
		warm-water aquarium	cold-water aquarium
Water	pH	8.1 ± 0.7	8.0 ± 0.7
	temperature, °C	15 ± 3	5 ± 3
	activity, pulse/min	560 ± 50	600 ± 20
Mean weight of fish, g		1.2 ± 0.4	1.4 ± 0.4
" length of fish, cm		5.5 ± 0.5	5.6 ± 0.6

Three fishes died during the experiment owing to careless handling. After 40 days' accumulation the fishes were put in fresh lake water for 25 days to check whether any elimination of Cd-115m could be observed. The fishes were then dissected and the different tissues were digested in HNO_3 and H_2O_2 and analysed for total cadmium and Cd-115m by flameless AAS and Ge (Li)-gammaspectrometry, respectively. The same technique was used on 0.5 g dry weight of tubifex used as food during the experiment. The tubifex contained 0.03 mg Cd/kg d.w.

RESULTS AND DISCUSSIONS

Fig. 1 shows the increase of the concentration factor during the uptake of cadmium. The concentration factor, CF, is defined as $CF = \frac{\text{concentration of radionuclide in fish}}{\text{concentration of radionuclide in water}}$. No equilibrium in the uptake was reached during the whole period, i.e. 6 weeks. Other authors have found that the uptake of

Fig. 1. The accumulation of Cd-115m by fingerling perch at two different temperatures (Δt = 10°C). Mean concentration factor ± standard deviation of ten fishes.



cadmium in fish does not reach an equilibrium until after 10 -20 weeks (KUMADA et al. 1973, CEARLEY & COLEMAN 1974, BENOIT et al. 1976). However, we could not continue the uptake for a longer period, since we were anxious to get good statistics in measuring the radioactivity during an elimination period also.

The magnitude of the whole-body concentration factor of cadmium in fish is reported to be varying. The whole-body concentration factor in this experiment was after 39 days lower by one power of ten than that found by KUMADA et al. (1973), the same order of magnitude as found by PASCOE and MATTEY (1977), and one power of ten higher than that found by EISLER (1974). However, differences must be expected, since different fish species, different exposure times and concentrations, and different experimental waters were used.

Fig. 1 also shows that the temperature groups have significantly different concentration factors. A temperature rise of 10°C very often results in a doubling of the uptake rates of noxious substances, but greater or smaller effects are frequently noted (PENTREATH 1976, SORENSEN 1976, JACKIM et al. 1977). In our experiment the Q_{10}, defined according to PROSSER and BROWN (1962), was 2.2, which is of expected magnitude.

After 39 days' uptake the fish were put in natural lake water containing about 0.5 µg Cd/l. The purpose was to investigate the rate of elimination of cadmium. However, the small amount of radioactivity in the fish and the short physical half-life of Cd-115m resulted in values which within a rather short time came increasingly close to the detection limit. Therefore, after 25 days in the natural lake water the experiment was discontinued. Twelve fishes were dissected for different organs, and the organs were digested and analysed for radioactivity and cadmium. The results of the analysis are presented in Table 2.

TABLE 2. Distribution of Cd in different tissues of perch expressed as percentage of whole-body activity, concentration of radioactivity Bq/g d.w. ± counting standard deviation, concentration of cadmium mg Cd/kg d.w., and specific activity MBq/mg Cd

Tissue	% distr.	Bq/g d.w.	*mg Cd/kg d.w.	MBq/mg Cd
Muscle	1.2	480 ± 40	0.1	5
Liver	43.4	59500 ± 1200	5.0	12
Kidney	1.6	54500 ± 2200	9.0	6
Gut	6.9	5880 ± 350	1.1	5
Gills	11.3	27000 ± 1400	3.6	8
Bone	0.8	1800 ± 200	0.4	4
Skin	6.9	4000 ± 200	0.6	7
Rest	27.8	4950 ± 150	0.6	8

(*the st.dev. can be up to 25 %)

As can be seen in the table, the liver has the highest share of the body burden. Cadmium seems to be most concentrated in the liver and the kidney, but owing to the low weight of the

kidney it has a low share of the body burden.
The specific activities in the tissues are lower than that in the test water. If the biological half-life of cadmium in fish is as long as reported by KUMADA et al. (1973) and BENOIT et al. (1976), i.e. 10-12 weeks, that will mean that isotopic equilibrium had not yet been reached when the uptake was discontinued.

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