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Lethal Toxicity of Cadmium to *Cyprinus carpio* and *Tilapia aurea*

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There have been several studies of the lethal toxicity of cadmium to freshwater fishes, but further information is required on a number of points. For example, Alabaster and Lloyd (1980), in their review of cadmium toxicity, drew attention to the fact that the shallow slope which is characteristic of the cadmium toxicity curve makes interspecific comparisons difficult. They also pointed to the paucity of information on cadmium toxicity to non-Salmonid European species. As part of a study of the water quality requirements of cultured fish species in the Mediterranean, we here report the lethal toxicity of cadmium to two such species, the common carp Cyprinus carpio, and Tilapia aurea, for which little information has previously been reported.

MATERIALS AND METHODS

Fish were obtained from a commercial fish farm and acclimated to laboratory conditions for at least two weeks before the experiments began. The toxicity tests were carried out under static conditions in glass aquaria containing 30 L of gently-aerated test solution. Ten fish were exposed to each concentration of cadmium tested (0.1, 0,2, 0,5, 1, 2, 5 and 10 mg L^{-1} for C. carpio; and additionally, concentrations of 20, 40, 60 and 100 mg L^{-1} for T. aurea). The dilution water was drawn from the laboratory's recirculating water system which contains approximately 50 m^3 of dechlorinated, settled, filtered and conditioned tap water. Experiments with C.carpio were conducted at a temperature of 22 ± 2°C, and with T. aurea at 19 ± 2°C; the relatively low temperature for Tilapia was chosen because of the very high growth rate and food requirements of Tilapia species at higher temperature. Chemical characteristics of the dilution water were monitored daily for the first seven days, and thereafter two or three times per week. The results are shown in Table 1. The test solutions were renewed daily. Cadmium was administered as analytical grade $Cd(NO_3)_2$ from a stock solution containing 1000 mg Cd L^{-1}. Cadmium concentrations in the test tanks were monitored twice daily for the first seven days (before and after renewal of the test solutions), daily for the second week and thereafter two to three times per week. Samples were taken in 50 mL acid-washed polyethylene bottles, and acidified with sufficient analytical grade concentrated HCL (a few drops) to reduce the pH to

approximately 1. Cadmium concentrations were measured using a Perkin-Elmer atomic absorption spectophotometer with automatic background correction. The accuracy of the determination was checked periodically by analysing ten replicate sub-samples of a stock solution containing 1 mg Cd L^{-1}. Overall the procedure gave a mean value of 98% of the nominal concentration, with a coefficient of variation of 1.4%. The fish were starved for two days before the experiments began, and for the first seven days of the experiment. Thereafter it became apparent that the experiments were likely to last several weeks, and fish were fed to satiation on commercial pelleted food once every two days, one to two hours before the test solution were renewed.

Table 1. Chemical conditions during the toxicity tests. Figures shown are mean values with 95% confidence limits in parentheses.

	C. carpio	T. aurea
pH	8.3 (8.2-8.4)	8.1 (8.0-8.2)
Hardness (mg L^{-1} as $CaCO_3$)	157 (151-163)	146 (138-154)
Bicarbonate alkalinity (as mg L^{-1} $CaCO_3$)	108 (100-116)	106 (98-114)
Carbonate alkalinity (as mg L^{-1} $CaCO_3$)	12.8 (12.1-13.5)	0.5 (9.8-11.2)

Mortalities were recorded daily. For each concentration, percentage mortality (probit scale) was plotted against elapsed time (logarithmic scale). Median survival times and their 95% confidence limits were calculated by the procedure of Litchfield (1949), and plotted against the concentration of cadmium (log/log scales) to give the toxicity curves. Curves were fitted to the points by eye.

The initial weights and lengths of the fish (± one standard deviation) were: C. carpio, weight 3.2 ± 0.4 g, length 5.5 ± 0.3; T. aurea, weight 3.1 ± 0.3 g, length 5.3 ± 0.3 cm. The experiment with C. carpio was terminated after 38 days and T. aurea after 42 days. No control mortalities occured within these periods in either experiment.

RESULTS AND DISCUSSION

Total cadmium concentrations in the experimental tanks, as determined by atomic absorption spectophotometry, were in all cases within ± 10% of the nominal levels. However slight precipitation was occasionally noted in tanks containing concentrations of 10 mg L^{-1} and above.

The toxicity curves for the two species tested are shown in Fig. 1. In neither case was lethal threshold concentration established

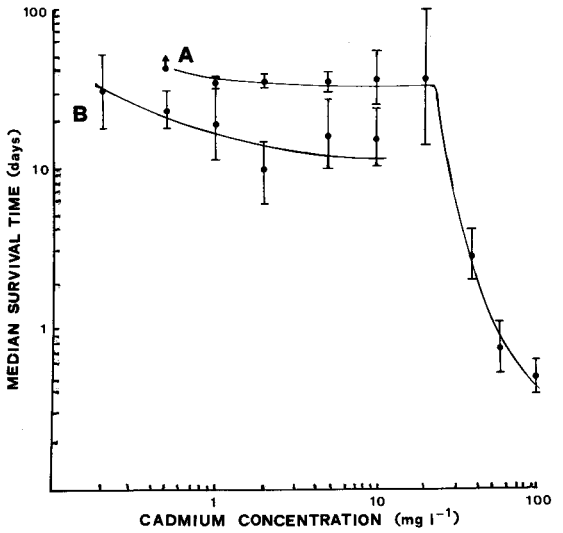

Figure 1. Toxicity curves for Tilapia aurea (A) and Cyprinus carpio (B) exposed to cadmium. Logarithmic scales are used for both axes. Vertical bars represent 95% confidence limits.

within the duration of the experiments. For Tilapia, however, further experiments in progress in this laboratory indicate that the lethal threshold concentration lies between 0.1 and 0.5 mg L^{-1}; in an experiment to investigate the sublethal toxicity of cadmium to T. aurea, negligible mortality occurred among a population of 150 fish exposed to 0.1 mg Cd L^{-1} for 3 months. Both curves, however, display a common characteristic of cadmium toxicity to fish, namely that there is a region of the curve in which the median survival time does not change, or changes only very slowly, over a wide range of cadmium concentrations (Alabaster and Lloyd 1980).

This point is clearly illustrated in Fig. 2, in which the curves obtained from the present experiments are compared with published curves for other species, all redrawn to the same scale. Notwithstanding differences in experimental conditions (e.g. of temperature and water hardness), the comparison is informative, particularly in relation to the continuing practice of expressing lethal toxicity in terms of median lethal concentrations for a single specified exposure period (e.g. 96-h LC50, 7-day LC50 etc). The curves indicate that for Salmo gairdneri a 7 day LC50 value could reasonably be expected to lie between 0.01 and 1.0 mg L^{-1} (Ball 1967); for T. aurea, a 35-day LC50 could lie between 0.7 and 20 mg L^{-1}; and a 14-day LC50 for G. aculeatus could lie between 0.2 and 2.0 mg L^{-1} (Pascoe and Cram 1977). Although the limitations of toxicity data expressed in this form have been widely known for many years and were clearly emphasized in the authoritative

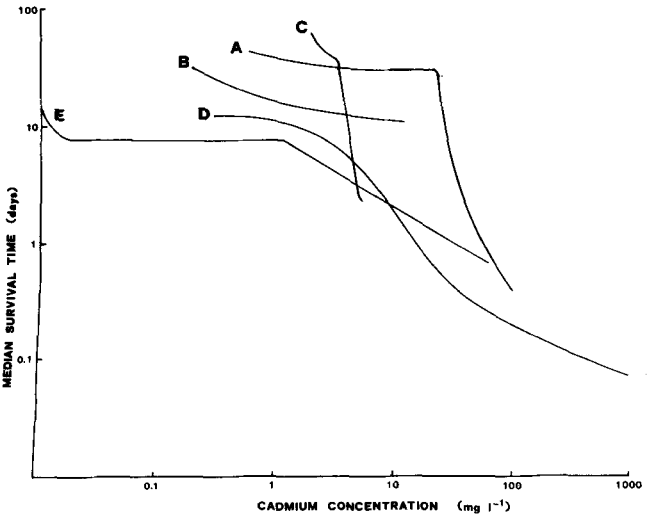

Figure 2. Toxicity curves for five fish species exposed to cadmium, redrawn to the same scale. Logarithmic scales are used for both axes.
A: Tilapia aurea
B: Cyprinus carpio
C: Noemacheilus barbatulatus (Solbe and Flook, 1975)
D: Gasterosteus aculeatus (Pascoe and Cram, 1977)
E: Salmo gairdneri (Ball 1967)

review of Sprague (1969), unfortunately many authors continue to express results in this form. While it is true that for many poisons, LC50 values derived from experiments of relatively long duration approximate to lethal threshold values, for cadmium this does not appear to be the case; indeed lethal threshold concentrations for cadmium do not appear to have been clearly established for any species.

The difficulty of interspecific comparisons is further illustrated by the curve for Noemacheilus barbatulatus (Solbe and Flook 1975). From Fig. 2 it can be seen that in a three day experiment, N. barbatulatus would be equal in sensitivity to S. gairdneri. After 8-10 days, the same species would appear approximately equal in sensitivity to G. aculeatus; after 12-14 days, to C. carpio; and after approximately 35 days, to T. aurea. Thus it appears that reliable comparisons of the sensitivity of different species to cadmium can only be made on the basis of complete toxicity curves; and that comparisons based on LC50 values, of however long duration, are likely to be misleading. We suggest that the majority of published data on lethal cadmium toxicity (expressed as LC50 values) may be subject to error of up to two orders of magnitude. Therefore it is not surprising that it is difficult to draw conclusions from the existing literature of cadmium toxicity to aquatic species (Alabaster and Lloyd 1980). An example of the variability to be found therein is the earlier report of Rehwoldt et al. (1972) that the 96-h LC50 of cadmium to C.carpio was 0.24 mg L^{-1}, about two

orders of magnitude lower than is indicated by the present results. There do not appear to have been any previous reports of cadmium toxicity to Tilapia spp.

It is important to note that similar reservations should be expressed in relation to data on the effects of environmental conditions upon lethal cadmium toxicity.

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