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Effect of cadmium on the cichlid fish, *Oreochromis niloticus*: behavioural and physiological responses

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ABSTRACT

The effect of cadmium on the freshwater cichlid fish, *Oreochromis niloticus* was assessed. Various behavioural changes were observed when the fish was exposed to different concentrations (2, 4, 6 and 8 ppm) of cadmium. Its LC_{50} was 5·2 ppm. Remarkable depletions in liver/muscle glycogen and haemoglobin were observed with increasing concentrations of cadmium. It can be concluded that the aforesaid changes might be useful indicators of the toxic effects of cadmium in the environment.

INTRODUCTION

Heavy metals have long been recognized as serious pollutants of the aquatic environment. Contamination of water and the utilization of cadmium in various manufacturing processes create public health hazards. It is reported that cadmium is responsible for hypertension and renal tubule damage (Friberg *et al.* 1971; Shafi & Qayyum 1978). The toxic effects of cadmium to aquatic animals have been well documented (Bengtsson *et al.* 1975; Thorp *et al.* 1979; Woodworth & Pascoe 1982; Thorp & Gloss 1986) and the modification of biochemical and haematological factors was discussed by Larsson *et al.* (1976). Information obtained regarding the effect of environmental pollutants on aquatic animals is usually confined to the level of mortality. Numerous workers (Bansal *et al.* 1979; Hille 1982; Mustafa & Murad 1984; Zbanyszek & Smith 1984; Dheer *et al.* 1986) have reported various toxic effects on fishes. To the best of our knowledge, there appears to be no report on the effect of cadmium embodying a simultaneous study of behavioural and physiological responses. The objectives of the present study are to observe the changes in behaviour, and monitor the glycogen and haemoglobin contents in specimens of *Oreochromis niloticus* exposed to different concentrations of cadmium.

MATERIAL AND METHODS

Live specimens of *O. niloticus* were procured from the fish culture pond at Deerab, 80 km south of Riyadh. Fish (150–200 mm in length and 60–90 g body weight) were

maintained in a glass trough (75 gallon) to acclimatize to the laboratory conditions (24·0°C and water hardness of 232·58 ± 1·05 mg/l as $CaCO_3$) for one week. Fifteen fish from the glass trough were taken and placed in each of a series of circular tanks (20 l capacity). The same number of fish was kept in ordinary tap water and considered as controls. Reagent grade cadmium chloride was used as the toxicant. A stock solution (1·0 g/l) of cadmium chloride was prepared in distilled water, from which a required volume was added to the experimental tanks to obtain the test concentrations (4, 5, 6, 7 and 8 ppm). These were further checked by means of a Pye Unicam SP-190 atomic spectrophotometer. LC_{50} value was calculated during the period of 96 h.

In another experiment using cadmium concentrations of 2, 4, 6 and 8 ppm, five fishes were sacrificed from each tank after 48 h for the determination of haemoglobin and glycogen content. The method of Blaxhall & Daisley (1973) was used for the estimation of haemoglobin content in which the fish was allowed to bleed by severing the caudal peduncle and blood was transferred to glass vials containing heparin solution. After thorough mixing of heparinized blood, 0·02 ml of sample was carefully introduced in test tubes containing 4·0 ml of Drabkin's solution and allowed to stand for at least 30 min for full conversion of haemoglobin to cyanmethaemoglobin. Direct estimation of haemoglobin was noted at 540 μm and the results expressed in g Hb/100 ml of blood. For determination of glycogen content, the liver and white muscle were taken out and analysed by the method of Montgomery (1957) as used by Shamsi & Al-Akel (1986). The results are expressed in terms of μg glycogen/g wet weight of tissue. The experimental data were analysed using Student's t test.

The behavioural responses of the fish exposed to different concentrations of cadmium were recorded directly for a period of 15 min once every 6 h.

RESULTS

Behavioural changes, e.g. fast jerky movement, erratic swimming, fin flicking, and loss of equilibrium prior to death were evident in the experimental tanks. Initially, the fish seemed to be in a restless condition; this was followed by unusual lethargy and the tendency for the fish to settle motionless on the bottom of the tanks. At higher cadmium concentrations, fish showed restlessness throughout the period of the experiment.

Data for fish mortality and LC_{50} after 96 h are presented in Table 1. The regression equation relating $\log_{10}$ concentration and probit kill is also given. Table 2 shows

Table 1. Toxicity of cadmium to freshwater fish, *Oreochromis niloticus*, after 96 h

Number of fish	Concentration of cadmium (ppm)	Number of dead fish	Percentage mortality	$\log_{10}$ concentration (x)	Empirical probit (y)
15	4·0	2	13	0·602	3·8877
15	5·0	6	40	0·698	4·7467
15	6·0	10	67	0·778	5·4289
15	7·0	13	87	0·845	6·1077
15	8·0	14	93	0·903	6·4985

Regression equation: $y = -9{\cdot}4258 + 8{\cdot}3871x$.

Table 2. Changes in haemoglobin in *Oreochromis niloticus* after 48 h at different concentrations of cadmium

Concentration of cadmium (ppm)	Haemoglobin (g/100 ml)
Control	8·586 ± 0·376
2·0	7·781 ± 0·235
4·0	7·306 ± 0·211
6·0	6·708 ± 0·477
8·0	5·974 ± 0·234

Statistical analysis according to Student's t test:

Control *versus* 2 ppm = significant at $P < 0{\cdot}01$

Control *versus* 4, 6 & 8 ppm = significant at $P < 0{\cdot}001$

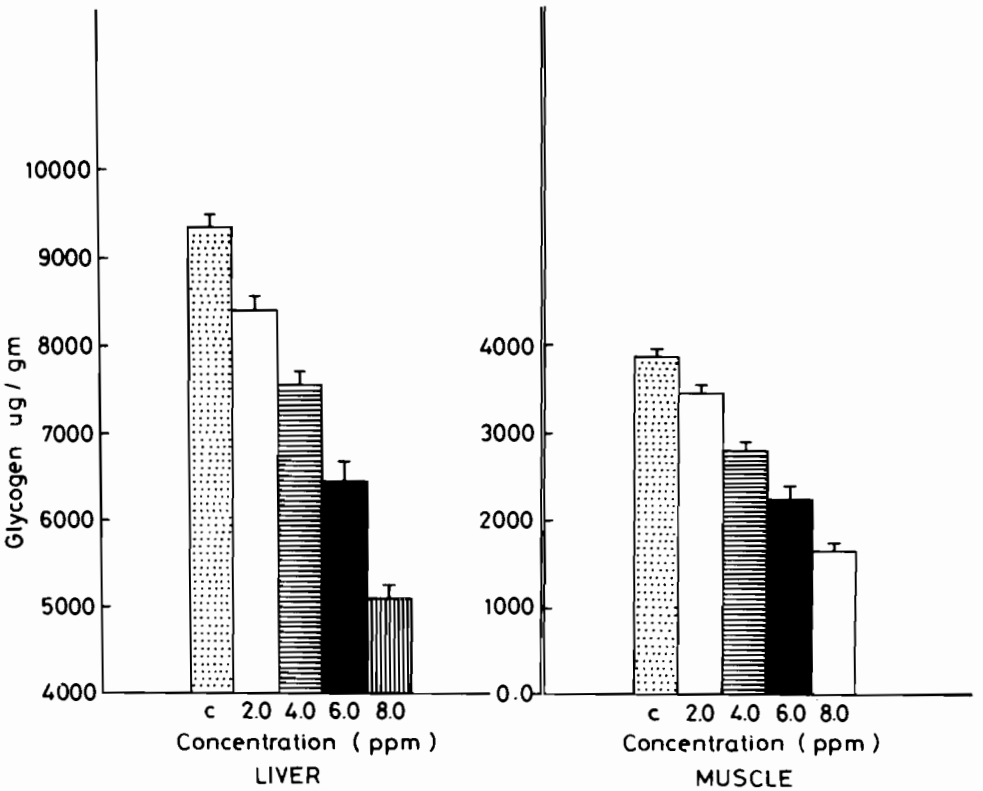

Fig. 1. Change in the glycogen content of liver and muscle of *Oreochromis niloticus* at different concentrations of cadmium.

that the haemoglobin levels tend to decrease with increase of cadmium concentration. Fig. 1 presents the glycogen content of the liver and muscle as affected by cadmium levels after 48 h. It is clear that increased cadmium concentrations caused a significant drop in glycogen levels of both liver and muscle.

DISCUSSION

The fish showed clear symptoms of toxicity as the concentration of cadmium increased. The observed behavioural changes are probably due to the manifestation of disturbances in physiological mechanism, which according to Marler & Hamilton (1966) initiate and maintain behaviour. These findings agree with those of Mustafa & Murad (1984). Cadmium as a toxic element causes asphyxia which disturbs the oxygen supply at the tissue level and causes severe anaerobic stress, resulting in the breakdown of tissue glycogen necessary to meet the energy demand in the muscle. The asphyxic condition in fish results in increased swimming and muscular activity which require energy. The depleted tissue glycogen could have resulted because of its utilization for supplying the energy to the fish under stressed condition. This is confirmed by the fact that all stress conditions invariably lead to retardation of growth and alter the physiological mechanism. If the stressed condition continues long enough, mortality ensues (Dheer *et al.* 1986).

Apart from the physiological changes, cadmium also affects the haematopoietic tissues, spleen and kidney (Wood & Yasutake 1955; Iwama *et al.* 1986). Thus, the destruction of these tissues is likely to result in decreased blood cell production and a subsequent reduction of red blood cell (RBC) count, which may have reduced the haemoglobin concentration. Such reduction can also be obtained by the process of haemodilution through a net uptake of water in freshwater fishes (Hickman & Trump 1969). The process of haemodilution is followed by an increase of white blood corpuscles (WBC), perhaps due to the increase in circulating neutrophils in response to the increasing tissue damage by certain toxic compounds. Another causative factor for the reduction of haemoglobin is probably the inhibition of haemopoietine secretion from the haemopoietic organs due to the toxic substances, thus halting the production of RBC.

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تأثير كلوريد الكادميوم على سلوك وفسيولوجية سمك البلطي

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خلاصة

أجريت دراسة لمعرفة تأثير الكادميوم على سلوك وفسيولوجية سمك البلطي عند تركيزات مختلفة . وقد تبين انه كلما زاد تركيز الكادميوم انخفضت نسبة النشا الحيواني والهيموجلوبين في كل من الكبد والعضلات ، كما لوحظت تغيرات سلوكية مختلفة .

وقد كان معدل التركيز القاتل لنصف المجموعة هو ٥,٢ جزءا بالمليون . ومن هذه الدراسة يمكن استنتاج مقدار التركيز الضار للكادميوم في البلطي ، والذي قد يكون مؤشرا لدور الكادميوم كملوث للبيئة .