Environment & Ecology 27 (2) : 718—722, 2009
© Copyright by MKK Publication 2009 *ISSN 0970-0420*

Effect of Cadmium on Oxygen Consumption and Schooling Behavior of the Fish *Labeo Rohita*

K. M. DAMODARA GOWDA[1], N. K. SUBBALAKSHMI[2] , VIJAYA MALA NAIR[3], SHRIKANT H. PALIL AND A. P. KRISHNA[1]

[1]*Department of Physiology, K. S. Hegde Medical Academy, Mangalore, Karnataka, India*
[2]*Department of Physiology, Center for Basic Sciences, Kasturba Medical College Mangalore, Karnataka, India*
[3]*Department of Applied Zoology, Mangalore University, Mangalore, India*
E-mail : damodar001@gmail.com

Abstract

Cadmium is known to be an extremely toxic cumulative poison and has been defined as a stock pollutant. The present study investigated the effect of cadmium on rate of oxygen consumption and behavioral response in Indian major carp, *Labeo rohita* exposed to three sublethal cadmium concentrations for 15 days. Short-term static toxicity test was run to determine LC_{50} (96 hours) of cadmium in *Labeo rohita*, which was 1.799 ppm ; 30%, 60% of LC_{50} and LC_{50} were selected for experimental purposes which corresponded to 0.5397, 1.0794 and 1.799 ppm, respectively. Rate of oxygen consumption was determined by Winkler's method. Schooling behavior was observed and documented once in 5 days. Control group was also run. Student's *t*-test (paired) was employed to find the effect of sublethal toxicity of cadmium on rate of oxygen consumption. In the control group there was significant increase in rate of oxygen consump-tion. But, significant decrease in rate of oxygen consumption was observed in all the fishes exposed to all the sublethal concentrations of cadmium. The normal schooling behavior of the fish was disrupted on exposure to sublethal concentrations of cadmium. Thus the study demonstrates that sublethal concentrations of cadmium ranging from 30% of LC_{50} to LC_{50} deplete oxygen consumption and impaired behavio-ral responses in *Labeo rohita.*

Key words : Sublethal cadmium toxicity, Oxygen consumption, Schooling behavior, *Labeo rohita.*

Water pollution is a problem of great concern all over the globe. Increased human activity by way of industrialization has resulted in eco-physiological stress on the aquatic environment (1). Cadmium (Cd) is relatively a rare element that occurs naturally in ores together with zinc, lead and copper, became commercial in 20th century due to agricultural and industrial applications (2). Together with other heavy metals such as lead, mercury and arsenic it has been considered a main threat to human health (3, 4). Cadmium is mainly used in electroplating industries, production of pigments and in the manufacture of thermoplastic stabilizers. The indiscriminate and wide-spread discharge of these industrial wastes ultimately reaches the aquatic environment and affects the life. Heavy metals such as cadmium are concentrated in the surface micro-layer by transport of particle associated bubbles (5). Since most of the materials become trapped in the sediments and incorporated mainly into organic matter, most of the cationic forms have very little chance of leaving an estuarine and coastal area in solution. The varied concentration of cadmium is reported to be present in lakes and sea water. The concentration observed in tropical lake Karaiba, Zimbabwe was 1.9 ppm (6). In Bay of Bengal concentration of cadmium ranged from 4.5 to 9.2 ppm (6). In the Arabian Sea much higher concentration of cadmium is reported. The level of cadmium reported in Arabian Sea measured at Pakistan was 440 ppm (7).

Table 1. Mean variation in rate of oxygen consumption following 15 days exposure to sublethal concentration of cadmium in *Labeo rohita.* * = Increased ; ** = Decreased.

Change in rate of oxygen consumption (mean difference ± SD)			
Control	30% of LC_{50}	60% of LC_{50}	LC_{50}
2.18±0.01*	0.43±0.006**	9.42±0.02**	20.32±0.01**

Table 2. Behavioral response on 0 day in control and experimental group. + = Present ; – = Absent.

Behavioral response	Con-trol	Exposed fish 30% LC_{50}	60% LC_{50}	LC_{50}
Normal active movement	+	+	+	+
Escape reflex	–	–	–	–
Floating on its lateral	–	–	–	–
Sluggish movement	–	–	–	–
Curved tail movement	–	–	–	–
Surfacing behavior	–	–	–	–
Peeling of scale and appearance of skin lesions	–	–	–	–
Opercular move-ment (coughing)	–	–	–	–

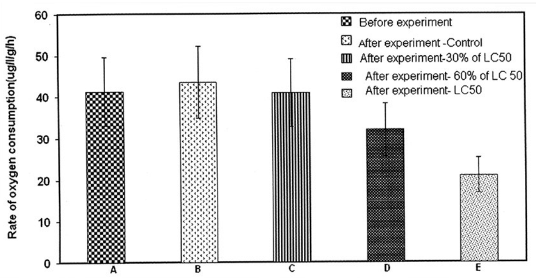

Figure 1. Effect of 15-day exposure to sublethal concentration of cadmium on rate of oxygen consumption in *Labeo rohita*. Values are mean ± SD. Sample size in each group n=6. A=control before experiment ; B = After experimental period—control ; C = After experimental period —30% of LC_{50} ; D = After experimental period —60% of LC_{50} ; E = After experimental period—LC_{50}. P value for group B, C, D and E compared to group A.

Fishes are generally sensitive to cadmium poisoning. For fish, the lethal concentration of cadmium in water is known to range from 0.01 to 10 ppm depending on many factors (8). In sufficient concentrations, cadmium exerts its toxic effects on fish by coagulating external gill mucus causing anoxia and altered salt balance (9). In recent years, the emphasis on toxicity testing in marine organisms has been moving towards sublethal tests, as they can provide much more relevant information in assessing the long term effects of pollutants imposed on the ecosystem. Earlier, we demonstrated that significant depletion in total protein, glycogen and lipid content occurs in *Labeo rohita* on 15-day exposure to sublethal cadmium toxicity ranging from 0.5397 to 1.799 ppm (10). The present study was undertaken to investigate the effects of sublethal concentration of cadmium toxic-

Table 3. Behavioral response on day 5 in control and exposed fish. + = Present ; – = Absent ; * = Slightly decreased ; **=Appreciably decreased.

Behavioral response	Con-trol	Exposed fish 30% of LC_{50}	60% of LC_{50}	LC_{50}
Normal active movement	+	*	*	**
Escape reflex	–	+	+	+
Floating on its lateral	–	–	+	+
Sluggish movement	–	–	+	+
Curved tail movement	–	–	+	+
Surfacing behavior	–	–	+	+
Peeling of scale and appearance of skin lesions	–	–	+	+
Opercular move-ment (coughing)	–	–	+	+

Table 4. Behavioral response on day 10 in control and exposed fish. + = Present ; – = Absent ; * = Slightly decreased ; ** = Appreciably decreased ; *** = Very much decreased.

Behavioral response	Con-trol	Exposed fish 30% of LC_{50}	60% of LC_{50}	LC_{50}
Normal active movement	+	*	**	***
Escape reflex	–	+	+	+
Floating on its lateral	–	–	+	++
Sluggish movement	–	–	+	++
Curved tail movement	–	–	+	++
Surfacing behavior	–	–	+	++
Peeling of scale and appearance of skin lesions	–	–	+	++
Opercular movement (coughing)	–	+	++	++

Table 5. Behavioral response on day 15 in control and exposed fish. – = Absent ; + = Present ; ++ =Appreciably present ; +++ = Very much present. ** = Appreciably decreased ; *** = Very much decreased.

Behavioral response	Control	Exposed fish 30% of LC_{50}	60% of LC_{50}	LC_{50}
Normal active movement	+	**	***	***
Escape reflex	–	+	+	+
Floating on its lateral	–	+	++	+++
Sluggish movement	–	+	++	+++
Curved tail movement	–	+	++	+++
Surfacing behavior	–	+	++	+++
Peeling of scale and appearance of skin lesions	–	+	++	+++
Opercular movement (coughing)	–	++	+++	+++

ity on rate of oxygen consumption and behavioral responses in a major Indian carp namely *Labeo rohita.* We chose *Labeo rohita* as a model species because it is a cultivable Indian major carp, economically important and is widely used for human consumption. A small dose of this metal in fishes will lead to bio-magnification in human body due to continuous consumption.

Methods

This work was carried out in the Department of Applied Zoology, Mangalore University after getting approval from the concerned ethical committee of the institution. Fingerlings of *Labeo rohita*, ranging in size from 2.80—3.20 cm were obtained from the Department of Fisheries, Karkala and maintained in glass aquarium of size 1.2 × 1.5 m under laboratory condition. Then fingerlings were transferred and acclimatized for 4 days in the aquarium containing the tap water at pH 7.5. The water was renewed daily to avoid contamination. Fish were fed once in 24 hours.

The toxicant used was cadmium chloride. Since cadmium is fairly stable ; its solution was prepared once in 10 days.

The tests were done after 96 hours for finding toxic range of the metal to fingerlings. Lethal concentration was determined by short term static bioassay (11). About 30 liters of the test medium with concentrations of cadmium at 0.1, 1, 5, 10 and 50 ppm were taken in each of the five aquariums (of size 0.6 × 0.3 m.) Ten acclimatized fish were introduced into each of the aquarium. The water was renewed every 24 hours and mortality was recorded at every 12-hour intervals for 96 hours.

The LC_{50} value was calculated using the method of Spearman- Karber (11).

Sublethal toxicity tests were conducted in six fingerlings of *Labeo rohita* exposed to cadmium concentrations at LC_{50}, at 30% and 60% of the LC_{50} value for a period of 15 days to assess effect on oxygen consumption. The behavioral responses of the fish were recorded on days 0, 5, 10 and 15. The observation on control fish was also made simultaneously. The tests were conducted in duplicate along with the control set. The rate of oxygen consumption was estimated before and at the end of 15 days. The rate of oxygen content was determined by Winkler's method (12).

On day 0 about 10 liters of stored tap water premeasured for dissolved oxygen content was taken in a jar and fresh fingerlings were introduced. After one hour dissolved oxygen content was measured. From the difference in oxygen content, rate of oxygen consumption was calculated. At the end of 15 days of study period, rate of oxygen consumption was estimated once again by introducing control and experimental fish into fresh tap water for one hour.

Data were analyzed by Student's paired *t*-test. Statistical significance was assessed at 1% of probability.

Results

All fish died within 2 hours of exposure to cadmium at 5 ppm. The LC_{50} was found to be 1.799 ppm. The sublethal toxicity at 30% and 60% of LC_{50} were 0.5397 ppm and 1.0794 ppm respectively.

Average rate of oxygen consumption in water before and after experimental period is shown in Figure 1. Mean difference in rate of oxygen consumption in control and exposed fish is shown in Table 1. In the control fish, rate of oxygen consumption increased significantly ($P<0.01$, Fig. 1). In the exposed fish, there was significant decline in oxygen consumption on exposure to all the sublethal concentrations of cadmium ($P<0.01$, Fig. 1).

The control fish maintained more or less compact schooling behavior. The fish exposed to all the sublethal concentrations of cadmium showed disruption in schooling behavior. With the increase in concentration and duration of exposure to cadmium disruption in schooling behavior was more severe. The various behavioral responses recorded on day 0, 5, 10 and 15 are given in Tables 2 to 5.

Discussion

Oxygen is important for all biological oxidations, especially for the formation of ATP by oxidative phosphorylation. It is an important reactant in carbohydrate, lipid and protein metabolism (13). Oxygen consumption is a valuable indicator of sublethal stress. In the present study, increased oxygen consumption was observed in the control group. In contrast to this, in exposed fish oxygen consumption declined significantly following 15-day exposure to sublethal concentration of cadmium. Further, this decline in oxygen consumption was found to be greater in fish exposed to higher concentration of cadmium. Thus the study demonstrates the toxic effect of cadmium on oxygen consumption in *Labeo rohita.* Decrease in oxygen consumption could be due to the reason that the cadmium might inhabit respiration by causing excess mucus production, which reduces the efficiency of gaseous exchange (14).

The control fish maintained more or less compact schooling behavior during the experimental period. But the disrupted schooling behavior was observed in exposed fish. Restlessness, surfacing, increased opercular beats and loss of balance observed in the present study were similar to the toxic effect reported in *Labeo rohita* treated with an organophosphate insecticide, dimethyl-parathion (15).

Fish come to the surface of water more frequently for the purpose of breathing air. Therefore, the increased surfacing behavior along with engulfment of air observed in the present study could be regarded as an indication of oxygen deficiency and enhanced rate of respiration. The experimental fish occasionally tried to jump out of water. Moreover, increased cadmium toxicity caused increased rate of opercular movement (coughing), slimy body and fish progressively became sluggish and lethargic. They exhibited abnormal swimming movements including loss of orientation. Coughing in treated fish might serve in clearing the gills off the mucus debris for proper breathing. The peculiar behavior of trying to jump out of the medium could be an escape phenomenon (16). These behavioral responses could be the indication of their fight against stress, which could have resulted from hypersensitivity of the neural mechanisms and the hyper secretion of stress hormones (17).

Results demonstrate the toxic effect of cadmium in sublethal concentration on rate of oxygen consumption and schooling behavior of *Labeo rohita*, an important aquatic fauna. The abnormal behavior exhibited by the exposed fish could be taken as a useful indicator in assessing the extent of pollution by the metal.

References

1. Sehgal R. and A. B. Saxena. 1986. Toxicity of zinc to viviparous fish *Lebistes reticulatus* (Peters). Bull. Environ. Contam. Toxicol. 36 : 888—894.
2. Thijssen S., J. Maringwa, C. Faes, I. Lambrichts and E. V. Kerkhove. 2007. Chronic exposure of mice to environmentally relevant, low doses of cadmium leads to early renal damage, not predicted by blood or urine cadmium levels. Toxicology 229 : 145—156.
3. Jarup L. 2003. Hazards of heavy metal contamination. Br. Med. Bull. 68 : 167—182.
4. World Health Organization (WHO). 2000. Cadmium. Air quality guidelines, 2nd edition. WHO, Reg. Off. for Europe, Copenhagen, Denmark.
5. Duce R. A. 1972. Enrichment of heavy metals and organic compounds in the surface micro-layer of Narragasett Bay, Rhoda island. Science 176 : 161—163.
6. Fitchko J. and T. Hutchison. 1975. A comparative study of heavy metal concentration in water mouth sediments around the great lakes. J. Great Lakes Res. 1 : 46—78.
7. Rezaul H., J. U. Ahamad and D. A. Chowdhury. 2005. Seasonal variation of heavy metals concentration in surface water of the rivers estuaries of Sundarban mangrove forest. Poll. Res. 24 : 463—472.
8. Scheveigen G. 1957. The toxic action of heavy metal salts on fish and organisms on which fish feed. Arch. Fish Crei Wess 8 : 54—78.
9. Carpenter K. E. 1927. The lethal action of soluble metallic salts on fishes. Brit. J. Exp. Biol. 4 : 378—390.
10. Damodara Gowda K. M., V. M. Nair, N. K. Subbalak-

shmi. 2008. Effect of 15 days exposure to sublethal concentrations of cadmium toxicity on the level of metabolic fuels in Indian major carp, *Labeo rohita.* Thai J. Physiol. Sci. 21 : 18—25.

11. Martin A., R. Hamilton, C. Russe and R. V. Thurston. 1977. Trimmed Spearman- Karber method for estimating median lethal concentrations in toxicity bioassays. Environm. Sci. and Tech. 2 : 14—18.
12. Carpenter J. H. 1965. Accuracy of the Winkler's method for dissolved oxygen content. Limnol. and Oceanography. 10 : 135—140.
13. Ganong W. F. 2005. Review of medical physiology, 22nd edition.
14. Cheung S. G., Y. Richard and H. Cheung. 1995. Effect of heavy metals on oxygen consumption and ammonia excretion in green lipped mussels (*Perna viridis*). Mar. Poll. Bull. 31 : 385—386.
15. Bengeri K. V. and K. M. Shivaraj. 1984. Toxicity of dimethyl parathion to freshwater fish, *Labeo rohita* and oxygen uptake rate of exposed fish. Environ. Ecol. 2 : 1—4.
16. Abhilash R. and V. R. Prakasham. 2005. Toxic physico morphological and behavioral responses of *Oreochromis mossambicus* exposed to commercial grade endosulfan. Environ. and Ecol. 23S : 234—238.
17. Bandhyopadhyay M. P. and A. K. Aditya. 2002. Xenobiotic impact on sensitivity in *Anabas testitudineus.* J. Ecobiol. 14 : 117—124.