Bull. Environ. Contam. Toxicol. (1998) 60:949-955

Bulletin of Environmental Contamination and Toxicology

Bioaccumulation Patterns of Zinc, Copper, Lead, and Cadmium in Grey Mullet, *Mugil cephalus* (L.), from Harbour Waters of Visakhapatnam, India

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Received: 10 November 1997/Accepted: 15 April 1998

Bioaccumulation patterns of metals in fish tissue can be utilised as effective indicators of environmental metal contamination (Atchison et al., 1977; Larsson *et al.*, 1985). Fish exposed to high concentrations of trace metals in water may takeup substantial quantities of these metals. Visakhapatnam harbour situated on the east coast of India is highly polluted (Ganapati and Raman, 1973) and is a threat to fish fauna (Ganapati and Raman, 1976; Panduranga Rao *et al.*, 1990; Sultana and Srinivasa Rao, 1994).

The present paper deals with bioaccumulation of Zn, Cu, Pb and Cd in different organ systems of grey mullet, *Mugil cephalus*, a detritus feeder living in contaminated waters of the harbour. A comparision is also made with *M. cephalus* collected from the relatively uncontaminated waters of Gostani estuary (Bhimilipatnam), 35 Km north of the harbour.

MATERIALS AND METHODS

Visakhapatnam harbour is a natural harbour situated on the east coast of India (17°41' N 83°17' E) and the water ways have no circulation other than tidal effect The effluents from near by industries, a petroleum refinery, a fertiliser plant and a lead and zinc smelter are discharged into North-Western arm (S_2) of the inner harbour through surface drain known as Meghadri Gedda. The city's domestic sewage also drains directly into the Northern arm (S_3) of the inner harbour. The inner harbour is thus a stagnant pool of pollutants accumulated because of indiscriminate discharge of industrial and domestic waste waters.

M. cephalus were collected at monthly intervals for a period of one year (from March 1986 to February 1987) from both the stations of inner harbour, however samples from the Gostani estuary (S_1) at Bhimilipatnam (17°54' N 83°28' E) were collected only during 1986 summer and the specimens were used as control.

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Muscle, gill, alimentary canal, liver and kidney were removed, dried, ashed and digested in HNO_3. The concentrations of Zn, Cu, Pb and Cd were estimated with Atomic Absorption Spectrophotometer (Perkin - Elmer -380). The water samples at all the three stations were analysed for Zn, Cu, Pb and Cd concentrations through ammonium pyrrolidine dithio-carbomate (APDC) and methyl iso-butyl ketone (MIBK) extraction followed by back extraction into HNO_3(Brooks *et al.,* 1967; APHA, 1985). Significance of the differences in metal concentration values between the fish from control and contaminated stations were tested statistically ($p < 0.05$) by employing the student's t-test. Concentration factor (CF) was measured as the ratio between mean metal concentration in the sample and its mean concentration in the ambient water.

RESULTS AND DISCUSSION

The data on the metal concentration in the water samples as well as in the different organs of *M. cephalus* from the three stations (S_1, S_2 and S_3) are summarised in table 1. The concentration factor (CF) of metals is considered as an index of accumulation of the metal in the organs in relation to concentration in the ambient water and the same for different metals in various organs were delineated in table 2.

Of the four metals studied here, Zn and Cu are essential elements while Pb and Cd are non-essential elements for most of the living organisms (Trieff, 1980). Zn being an essential element for normal growth, reproduction and longivity of animals, its accumulation in the fish organs was very high when compared with the other three metals. Cu, the other essential metal was also relatively at greater concentration when compared with the other non-essential metals (Pb and Cd).

Irrespective of whether the metal is an essential or non-essential, the accumulation levels of all the four metals in different organs were always significantly greater than the levels in the ambient waters. Thus S_2 appears to be highly contaminated where the accumulation of the metal in the fish organs were also high.

Alimentary canal and gills can be considered as the interface of the organism and its ambience. The former is the system which receives directly from the ambient source and the latter is the site directly exposed to the ambient conditions and also is known for its excretory functions even for some metals like Zn (Nakatani, 1966; Matthiessen and Brafield, 1977). Thus, the levels of the metals observed in gills and alimentary canal have varied widely among different stations.

Table 1 Bioaccumulation of metals in the different organ systems of *Mugil cephalus* from the three stations

Metal / Station	Metal content in the ambient water		Metal concentration in the different organ systems				
			Alimentary canal	Gill	Liver	Kidney	Muscle
Zinc							
S1 (n = 10)	17.60	$\bar{X}$ ± SE	122.74±22.70	73.49±12.18	108.86±16.10	69.04±18.19	6.56±1.73
		(Range)	(10.47-246.66)	(28.57-139.00)	(40.63-176.90)	(9.62-181.71)	(1.70-18.77)
S2 (n = 36)	1600.00	$\bar{X}$ ± SE	133.79±12.89	119.75±12.40	157.33±15.82	143.11±16.51	24.35*±2.82
		(Range)	(26.56-372.07)	(11.54-359.38)	(9.97-442.86)	(21.86-405.66)	(5.83-84.30)
S3 (n = 10)	1000.00	$\bar{X}$ ± SE	133.07±25.35	119.38±25.29	131.68±18.25	155.60*±42.71	22.04±2.19
		(Range)	(18.22-290.42)	(21.65-296.46)	(66.84-268.68)	(ND-375.00)	(9.58-34.08)
Copper							
S1 (n = 10)	ND	$\bar{X}$ ± SE	1.53±0.39	1.99±0.56	2.91±0.86	0.86±0.53	0.50±0.21
		(Range)	(ND-3.73)	(ND-6.16)	(ND-6.86)	(ND-5.28)	(ND-2.22)
S2 (n = 36)	20.00	$\bar{X}$ ± SE	10.15*±1.48	6.92±1.18	25.17*±5.13	15.06*±4.07	1.99*±0.74
		(Range)	(0.44-41.07)	(ND-33.85)	(ND-82.21)	(ND-122.09)	(ND-24.18)
S3 (n = 10)	15.00	$\bar{X}$ ± SE	12.12*±3.93	7.83±1.90	12.70*@±3.07	7.73*@±2.12	1.65*±0.46
		(Range)	(1.69-46.26)	(0.94-22.87)	(2.67-36.74)	(ND-22.44)	(0.11-4.40)

contd.....

Table 1 contd...........

Metal / Station	Metal content in the ambient water		Metal concentration in the different organ systems: Alimentary canal	Gill	Liver	Kidney	Muscle
Lead							
S1 (n = 10)	ND	$\bar{X} \pm SE$ (Range)	0.93±0.63 (ND-1.89)	9.43±1.86 (ND-17.78)	1.57±0.89 (ND-7.81)	0.40±0.28 (ND-2.57)	1.22±0.64 (ND-6.45)
S2 (n = 36)	50.00	$\bar{X} \pm SE$ (Range)	12.30*±2.69 (ND-80.21)	16.98±1.32 (ND-34.12)	11.90*±3.75 (ND-87.42)	13.48*±3.16 (ND-73.81)	3.12*±0.71 (ND-17.44)
S3 (n = 10)	30.00	$\bar{X} \pm SE$ (Range)	11.34*±3.79 (ND-34.50)	12.77±2.19 (ND-23.86)	9.12@±2.97 (ND-26.02)	10.09*@±3.01 (ND-25.28)	3.36±0.89 (0.59-10.32)
Cadmium							
S1 (n = 10)	ND	$\bar{X} \pm SE$ (Range)	0.53±0.30 (ND-2.86)	0.51±0.21 (ND-1.84)	0.60±0.38 ND-3.92	0.29±0.19 (ND-1.83)	0.16±0.09 ND-0.89
S2 (n = 36)	20.00	$\bar{X} \pm SE$ (Range)	1.45±0.22 (ND-4.96)	2.23*±0.25 (ND-7.11)	2.22±0.35 (ND-9.26)	3.13*±0.56 (ND-11.63)	0.51*±0.19 (ND-6.24)
S3 (n = 10)	15.00	$\bar{X} \pm SE$ (Range)	1.13±0.36 (ND-3.30)	1.77±0.30 (ND-3.15)	2.25*±0.84 (ND-7.63)	2.79@±0.51 (ND-5.00)	0.21@±0.10 ND-1.07

$\bar{x}$ = mean ; SE = Standard error of the mean ;
* = Significant ($P < 0.05$) when compared with S_1;
Metal accumulation values are given in µg/g;

n = number of fish examined
@ = Significant ($P < 0.05$) when compared with S_2(Student's t-test)
ND = not detectable; .

Table 2 Mean concentration factor (CF) of the different heavy metals in the different organs of *M. cephalus* at S_1, S_2 and S_3

Tissue	Station	Zn	Cu	Pb	Cd
Muscle	S_1	1.093	1.000	-	-
	S_2	0.015	0.010	0.062	0.026
	S_3	0.022	0.110	0.112	0.014
Gill	S_1	12.248	3.980	-	-
	S_2	0.075	0.346	0.340	0.112
	S_3	0.119	0.522	0.426	0.120
Alimentary canal	S_1	20.460	3.060	-	-
	S_2	0.084	0.507	0.250	0.70
	S_3	0.133	0.808	0.378	0.075
Liver	S_1	18.140	5.820	-	-
	S_2	0.098	1.260	0.238	0.111
	S_3	0.132	0.850	0.304	0.150
Kidney	S_1	11.510	1.720	-	-
	S_2	0.089	0.750	0.269	0.156
	S_3	0.156	0.515	0.336	0.186

CF was calculated as the ratio between mean metal concentration in the sample and its mean concentration in the ambient water.

Of the remaining three organs, liver, kidney and muscle, liver in most of the cases and in the control station, occupied the first place in the potential for accumulation followed by kidney. This was true for all metals except for Cd, which had high accumulation in the kidney.

Liver appears to be one of the important site for metal bioaccumulation as was also evident from some of the earlier studies. Wiener and Giesy (1979) has recorded 548.1 µg/g (dry wt.) of Cu in the liver of a bowfin, *Amia calva;* Kureishy (1981) has reported 441.5 ppm (wet wt.) of Zn in the liver of seer fish, *Acanthocybium solandri;* Hilmy *et al.* (1985) has reported 33.0 µg/g (dry wt.) of Cd in the liver of *M. cephalus.* Thomas *et al.* (1985) have suggested that *in* Rainbow trout, *Salmo gairdneri* 99% of the Cd burden is taken by the liver. Though the present results confirm the high potential of the liver, but differ with the observations of Thomas *et al.* (1985) as kidney also has shown good potential for accumulation of the metals. The results of the present study broadly suggest that *M. cephalus* growing in metal contaminated waters in all probability could accumulate metals in their bodies in quantities enough to cause toxicity to the consumers. Further, the metal content in the liver and kidney of *M. cephalus can* be used as indicator in the rapid assessment of the metal contaminated waters and the data in the present study substrantiate the observations of Handy (1992) and Pelgrom (1995) that metal concentrations in the organs of fish rather than the metal concentrations in the water are suitable for environmental monitoring especially when trying to relate the toxicity of metal to the biological function of specific organs.

Acknowledgements : Our thanks are due to the head of the Department of Zoology for providing facilities. One of US (R. S.) is thankful to U.G.C. for financial assistance. We are also thankful to Prof. K. Srinivasa Rao and Dr. K. Kameswara Rao for their help in preparation of the manuscript.

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