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ORIGINAL RESEARCH ARTICLE

Effect Of Electroplating Industrial Effluent Chromium On Bimodal Respiratory Rhythm Of The Air-Breathing Cat Fish *Mystus cavasius* (Ham)

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ABSTRACT

Effect of sublethal (0.25%) concentration of electroplating Industrial effluent chromium on bimodal respiratory rhythm of *Mystus cavasius* (Ham) was studied. Result revealed that at sublethal concentration the respiratory rhythm was significantly disrupted. The significance of the results is discussed from a chronotoxicological point of view.

Key Words: Chromium, *Mystus cavasius*, Bimodal respiration, aerial and aquatic respiration.

INTRODUCTION

Most organisms adapt the timing of their physiology to the cyclic changes of their environment using intrinsic timekeeping systems called circadian clocks. In the absence of external cues, circadian clocks can sustain rhythms of about 24 hours hence the name circadian, meaning ‘about a day’ - for extended periods of time. Environmental cues can reset daily the phase of molecular internal rhythms, ensuring that the organism’s behaviour remains tied to the rhythms in its environment. The main resetting cue for animals is light, provided by the day-night cycles (Cermakian and Sassone-Corsi, 2000; Reppert and Weaver, 2001 and Young and Kay, 2001).

Two sources of oxygen are potentially available to fishes. While most use only dissolved oxygen (water breathing or aquatic respiration), others (Lowe-McConnell 1975) have the ability to obtain oxygen from the atmosphere (air breathing or aerial respiration). All air-breathing fishes also use dissolved oxygen to some extent (bimodal breathing), but vary considerably in the proportional use of each respiratory mode (Johansen 1970; Rahn and Howell 1976; Singh 1976). Some species have reduced gills and, even in normoxic water, must use some atmospheric oxygen to meet their total oxygen demands (obligate air breathers). Other bimodal species have a greater water- breathing capacity, and air breathing is not required to meet their total oxygen demand, even under moderately hypoxic conditions (facultative air breathers). Physiological studies of short- term changes in respiratory partitioning have revealed two broad classes of controlling factors: those that influence total oxygen demand, e.g., temperature, activity, and ration, and those that influence the efficiency of oxygen uptake, e.g., the partial pressure of dissolved oxygen and carbon dioxide (Johansen 1970; Singh 1976; Kramer 1983).

Bimodal air-breathing fishes are noted for their resistance to environmental stress and aquatic hypoxia (Dehadrai and Tripathi, 1976). A number of attempts have been made earlier to relate respiration to ecology in Indian air-breathing fishes (Saxena, 1963; Dehadrai and Tripathi, 1976). Respiratory strategies appear to have important implications for many other aspects of a species physiology, behaviour and ecology (Kramer *et al* 1978). Ballintijn, C (1987) reported that respiratory rhythm apparently originates in a diffuse respiratory pattern generator in the reticular formation, and this remains functional under anesthesia. Brainerd (1994) has suggested separate origins for air-pumping mechanisms in actinopterygian fishes (derived from the suction feeding/coughing pumps) and sarcoptergian lung fish and amphibians (the branchial irrigation

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pump). For water - breathing fish, toxicity of a wide range of substance increases as dissolved oxygen (DO) decreases (Lioyd, 1961). The increase in toxicity is due to an increased rate of ventilation in hypoxic water. But in bimodally breathing fish, hypoxic conditions cause a decrease in toxicity. At low oxygen levels these fishes shut gill ventilation and rely mainly on air-breathing (Graham *et al*., 1978). Several studies have shown that oxygen (O_2) consumption of dogfish (*Scyliorhinus canicula*) gill tissue is significantly inhibited following *in vivo* lethal and sublethal treatment of Zinc (Tort *et al.*, 1982). It also affects cardiac and ventilatory rhythms (Hughes and Adeney, 1977). Hughes and Singh (1970 b) have reported that *Anabas* consumes a little more O_2 from air (54%) than from water (46%) of its total O_2 uptake (11.34 ml/kg /hr) during bimodal respiration. *Clarias* also consumes more O_2 from air (58%) than from normoxic waters (42%) and its total O_2 consumption is 93.4 ml/ kg/ h (Singh and Hughes, 1971). In *C. gachua* the major portion of the O_2 requirement was met by the air-breathing organ and gills plays a minor role to the time of about 21% only in the gaseous exchange (Natarajan, 1979). *Boleophthalmus boddaerti* of 7.96 g body weight extracted only 41.8% through aerial route (Biswas *et al*., 1979). *Mystus gulio*_consumes nearly 76% of total O_2 demand through skin and gills (Natarajan, 1979).

Chromium appears to pass through readily the gill membrane and accumulates rapidly in various tissues at higher levels than in the gills (Holdway, 1988), including the brain, gall bladder, gastro-intestinal tract, intestine, kidney, opercular bone, spleen and stomach (Buhler *et al*., 1977; Van der Putte *et al*., 1981 b). Studies on the circadian rhythm of bimodal oxygen consumption in air-breathing fishes are limited (Natarajan, 1987; Rani, 1994; Vijayalakshmi, 1996 and Mallikaraj, 2004). Practically nothing is known about the diurnal variations in the respiratory metabolism of *Mystus cavasius* and the modulation of the same by waste water exposure.

MATERIALS AND METHODS

Healthy adult fish *Mystus cavasius* (14 - 22 gm weight and 12 - 18 cm length) were collected and acclimated to the laboratory conditions with softened tap water under the following conditions: Ca, 0.725 mm; Mg, 0.135 mm; pH 7.1 ± 0.4; D.O, 7.4 ± 0.2 mg/ l. Water was checked daily for NH_3, nitrite, and nitrate and replaced every 2 days for half of the volume. Water was filtered with a trickling filter and biological kits were used for NH_3, nitrite and nitrate measurements to ensure that levels never exceeded 0.1, 1 and 20mg l^{-1}, respectively. The percentage survival of *M.cavasius* at various concentrations of waste water was determined by adopting the procedure laid down by Doudoroff and Katz (1953) for industrial waste waters. The test medium was changed daily (Sprague, 1971) to maintain the constant toxic concentration. The LC_{50} value was obtained by Finney (1971). 1/3 of sublethal concentration (0.25%) was selected for sublethal treatment. The circadian rhythm of bimodal O_2 consumption of control and waste water exposed fish was determined at 3 hr intervals over a single 24 hr period using the setup and procedures described already (Natarajan, 1987). The statistical significance of difference between control and treated groups of different exposure period were tested by using students‘t’ test (Zar, 1984).

RESULT AND DISCUSSION

Under laboratory conditions the control fish exhibited a clear-cut respiratory rhythm (**Table-1**). Bimodal respiration in *M. cavasius* is strongly rhythmic. The unimodal peak period of maximum O_2 consumption through gills and air-breathing organs (ABO) occurs at 0600 hr. From 1800 hr onwards the ABO’s play an increasing role in obtaining more O_2 from the air. However, very low aerial O_2 consumption was recorded at 0900 and 1200 hr. The O_2 consumption from water and air showed a maximum at 0600 h. The aquatic / aerial ratio in all these observation exceeds 1.84. The 24 hr Chromium exposure shifted the peak period of total maximum O_2 uptake to 0000hr (**Table 2**). The 72 hr treatment altered the peak period of maximum O_2 consumption to 1200 hr (**Table 3**). But, sublethal exposure significantly reduced the O_2 uptake. This reduction has got no correlation with the time of the day. In the air-breathing mud eel *Amphipnous cuchia* (Ojha *et al.*, 1979), peak hours of O_2 uptake were the dusk (16 - 18 hr) and the dawn (04 - 06 hr). However, in *Channa marulius* (Patra *et al.*, 1979), the higher O_2 uptake was recorded during mid-night. The diurnal rhythm of bimodal O_2 uptake in the goramy (*Osphronemus olfax*: Natarajan, 1984), shows an unimodal peak period at 1200 hr.

Similarly, in the intestinal air-breather (*Lepidocephalus thermalis*: Natarajan, 1984) the peak period was obtained at 18 hr. Maximum O_2 consumption of *Gobiusculus flavescens* (Thetmeyer, 1997) was recorded during the day. Similarly, feeding rhythms (Boujard and Leatherland, 1992), locomotory rhythms (Sanchez – Vazquez and Tabala, 1998) and biofuel rhythms (Figueroa *et al.*, 2000) were also reported for teleost. The light /dark alternation seems to be an important synchronizer for all these changes. However, the peak period of O_2 consumption was completely eliminated in the toxified fish. Interestingly, a marked inhibition was noted at 1500 hr and 0900 hr. Since the aquatic environment is severely polluted, dependence on aerial respiration is the only way for the survival of fish. This is clearly reflected in the increased rate of aerial respiration in the chromium exposed fish. The unimodal peak period was completely shifted to some other hour. The fish never regained or restored its original peak period in acute or chronic exposure. From chrono-toxicological points of view, the present findings are very useful. Application or discriminate release of Chromium concentrations will significantly alter the physiological rhythm of fish.

Table.1.Circadian rhythm of bimodal O_2 uptake ($mlO_2kg^{-1}hr^{-1}$) of *M. cavasius* (15 – 20g; N = 6) at 28° ± 1°C, I – Day.

Time of day (Hr)	Aquatic	Aerial	Total	% Aquatic	% Aerial	Aquatic ---------- Aerial
0600	90.32 ± 2.01	37.65 ± 3.02	127.97 ± 3.14	70.58	29.42	2.40
0900	80.40 ± 3.11	26.50 ± 4.00	106.90 ± 3.40	75.21	24.79	3.03
1200	76.15 ± 5.00	28.11 ± 3.46	104.26 ± 4.02	73.04	26.96	2.71
1500	75.19 ± 2.94	30.18 ± 5.18	105.37 ± 3.80	71.36	28.54	2.49
1800	72.00 ± 3.00	31.50 ± 4.01	103.50 ± 3.00	59.57	40.43	2.29
2100	73.06 ± 2.88	31.00 ± 2.95	104.06 ± 2.82	70.21	29.29	2.45
0000	70.18 ± 3.00	30.15 ± 1.17	100.33 ± 2.51	59.95	40.05	2.33
0300	75.90 ± 6.00	33.20 ± 2.94	109.10 ± 4.06	59.57	40.43	2.29

N = Number of fishes

Each value is the mean of 6 individual determinations ± indicates SE

Table 2. Effect of chromium rich (0.25%) effluent exposure (24 hr) on the circadian rhythm of bimodal O_2 uptake ($mlO_2kg^{-1}hr^{-1}$) of *M.cavasius* (10–20g; N = 6) at 28° ± 1°C.

Time of day (Hr)	Aquatic	Aerial	Total	% aquatic	% Aerial	Aquatic ------------- Aerial
0600	69.40 ± 1.82	31.40 ± 4.00	100.80 ± 2.65	58.85	41.15	2.21
0900	70.10 ± 2.19	30.15 ± 2.44	100.25 ± 2.30	59.93	40.07	2.33
1200	65.19 ± 3.00	28.19 ± 1.65	93.38 ± 2.16	59.81	40.19	2.31
1500	71.30 ± 2.80	31.40 ± 2.00	102.70 ± 3.05	69.43	30.57	2.27
1800	69.60 ± 3.05	33.19 ± 2.17	102.79 ± 3.00	57.71	42.29	2.09
2100	66.17 ± 2.84	36.05 ± 1.94	102.22 ± 2.51	54.73	45.27	1.84
0000	67.20 ± 3.00	35.90 ±1.79	103.10 ± 2.21	55.18	44.82	1.87
0300	66.15 ± 2.76	33.80 ± 3.67	99.95 ± 2.74	56.18	43.82	1.96

$P<0.05$. Each value is the mean of 6 individual determinations ± indicates SE

The signs + or – indicate percent increase or decrease over control

Table 3. Effect of chromium rich (0.25%) effluent exposure (72 hr) on the circadian rhythm of bimodal O_2 uptake ($mlO_2kg^{-1}hr^{-1}$) of *M.cavasius* (10 – 20g; N = 6) at 28° ± 1°C.

Time of day (Hr)	Aquatic	Aerial	Total	% aquatic	% Aerial	Aquatic ------------ Aerial
0600	61.15 ± 3.00	38.15 ± 2.00	99.30 ± 2.30	51.58	48.42	1.60
0900	66.17 ± 2.91	33.20 ± 1.80	99.37 ± 2.80	56.59	43.41	1.99
1200	65.00 ± 4.00	37.15 ± 2.60	102.15 ± 3.43	53.63	46.37	1.74
1500	64.15 ± 2.91	35.00 ± 4.06	99.15 ± 3.32	54.70	45.30	1.83
1800	62.00 ± 1.86	36.00 ± 3.19	98.00 ± 2.80	53.27	46.73	1.72
2100	60.94 ± 2.00	35.19 ± 4.00	96.13 ± 3.05	53.39	46.61	1.73
0000	59.05 ± 1.65	36.00 ± 2.15	95.05 ± 2.46	52.13	47.87	1.64
0300	60.30 ± 1.96	35.00 ± 2.90	95.30 ± 2.48	53.27	46.73	1.72

$P<0.05$. Each value is the mean of 6 individual determinations ± indicates SE

The signs + or – indicate percent increase or decrease over control

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