Journal of Environmental Biology **April 2007,** 28(2) 245-249 (2007)

Impact of industrial effluents on the biochemical composition of fresh water fish *Labeo rohita*

D.V. Muley*, D.M. Karanjkar and S.V. Maske

Department of Zoology, Shivaji University, Kolhapur-416 004, India

(Received: Decemebr 16, 2004 ; Revised received: May 10, 2005 ; Accepted: June 16, 2005)

Abstract: *In acute toxicity (96 hr.) experiment the fingerlings of freshwater fish Labeo rohita was exposed to tannery, electroplating and textile mill effluents. The LC_0 and LC_{50} concentrations were 15% and 20% for tannery effluents, 3% and 6% for electroplating effluents and 18% and 22% for textile mill effluents respectively. It was found that, electroplating effluent was more toxic than tannery and textile mill wastes. After acute toxicity experiments for different industrial effluents, various tissues viz. gill, liver, muscle and kidney were obtained separately from control, LC_0 and LC_{50} groups. These tissues were used for biochemical estimations. The glycogen content in all the tissues decreased considerably upon acute toxicity of three industrial effluents except muscle in LC_{50} group of tannery effluent and kidney in LC_{50} group of textile mill effluent, when compared to control group. The total protein content decreased in all tissues in three effluents except gills in LC_{50} group of tannery effluent, kidney in LC_{50} group of electroplating effluent and kidney in LC_0 group of textile mill effluent. In general total lipid content decreased in all tissues after acute exposure when compared to control group. The results obtained in the present study showed that, the industrial effluents from tannery, electroplating and textile mills caused marked depletion in biochemical composition in various tissues of the fish Labeo rohita after acute exposure.*

Key words: *Labeo rohita, Acute toxicity, Industrial effluents, Biochemical composition*

Introduction

The industrial wastes generally contains high quantities of dissolved and suspended solids, organic and inorganic chemicals, high BOD and COD, oils and grease, besides toxic metals which cause deleterious effects on the freshwater fish when discharged in to water bodies.

Shaffi (1980) studied the effect of various concentrations of electroplating waste on various tissue glycogen and serum glucose lactate level of nine fish species. Srivastava (1982) studied comparative effect of copper, cadmium and mercury on tissue glycogen of cat fish *Heteropneustes fossilis***.** Chitra (1983) studied the effect of urea stress on protein metabolism of the fish *Sarotherodon mossambicus* in brain, liver, muscle and gill tissues. Lawe and Nivmi (1984) studied effect of cadmium on glycogen reserves and liver size in rainbow strout *Salmo gairdneri.*

Jana *et al.* (1986), reported increased protein content in liver, kidney, stomach, intestine, muscle, testis and ovary when fish *Clarius batracus* was exposed to heavy metal pollutants. Jana and Bandopadhyaya (1987) reported the effect of heavy metal on some biochemical parameters in fish, *Channa punctatus.* Effects of tannery effluents on the muscle and liver glycogen in fish *Sarotherodon mossambicus* was studied by Natarajan (1989). Rajan (1990) recorded that, protein, carbohydrate and lipid contents decreased significantly in muscle, liver and intestine of *Cyprinus carpio* when exposed to sublethal concentrations of textile mill effluent. Joseph *et al.* (1992) studied the effect of toxicity of nickel on protein content in tissue of *Cyprinus carpio communis* (Linn.). Decrease in protein, free amino acids and free sugars of haemolymph was more, when the fresh water ptawn, *Macrobrachium idella* was exposed to higher concentration of tennery effluents (Subramanian and Varadaraj, 1993). Ambrose *et al.* (1994), also observed decline in carbohydrate, protein and lipid contents of gill, liver, intestine and kidney of *Cyprinus carpio* var. *communis* under the toxic stress of sublethal concentration of composite tannery effluent. Maruthi and Subba Rao (2000) recorded significant decrease in glycogen, total protein and lipid in both liver and muscle tissue of fish with an increase in effluent concentration after exposure of fish, *Channa punctatus* (Bloch) to distillery effluent.

Considering the above facts, the present study is aimed to assess the effect of industrial effluents on the biochemical composition of gill, liver, muscle and kidney of the fish *Labeo rohita.*

Materials and Methods

Survey was made for the selection of the industrial effluents for the present investigation in and around Kolhapur. Finally, three industrial units *viz.* textile mill, tannery and electroplating industry were selected.

The effluents from textile mill, tannery and electroplating industries at Kolhapur were collected monthly and brought to the laboratory in 25 liters container for metal analysis and toxicological studies. The effluent were analyzed for different heavy metals using Atomic Absorption Spectroscopy (Perkin Elmer model No. 3030, USA)

Corresponding author: E-Mail: drdvmuley@yahoo.com, Tel.: +91-231-2607122 (R), +91-231-2609248-49 (O)

Biochemical studies: After acute toxicity (96 hr.) experiments for above mentioned three industrial effluents, alive fishes (collected from Govt. fish farm) were immediately sacrificed (5 from each group) from control, LC_0 and LC_{50} group separately to obtain gill, liver, muscle and kidney. The pooled samples of these organs were properly blotted; weighed and used for biochemical estimations *i.e.* total glycogen (De Zwaan and Zandee, 1972), total protein (Gornall *et al.,* 1949) and total lipid (Barnes and Blackstock, 1973). Level of significance at $p<0.05$ and $p< 0.001$ was, statistically calculated by using student 't' test.

Heavy metal analysis: In textile mill effluent, the concentration of nickel was maximum followed by zinc, aluminium and copper. In electroplating effluent the concentration of chromium was maximum followed by zinc, copper, cadmium, aluminium, nickel and lead. In tannery effluent the concentration of chromium was maximum followed by nickel, zinc, cadmium, copper, aluminium and lead.

Results and Discussion

Total glycogen: Glycogen level in different tissues of fish was as follows:

Tannery effluent: Changes in the total glycogen in gill, liver, muscle and kidney of *L. rohita* exposed to tannery effluent after acute exposure for 96 hr are shown in Table 1. The glycogen content in all the organs decreased considerably upon acute exposure to 15% of tannery effluent. Although the relative decrease varied from tissue to tissue, the percent depletion was more significant ($p<0.001$) in gill (58.13) followed by liver (54.91) and less significant ($p<0.05$) in kidney (26.11) and muscle (18.47).

In LC_{50} group there was more significant ($p<0.001$) percent depletion in the levels of glycogen in liver (75.25). Less significant $p<0.05$) decrease in glycogen content was in gill (32.17) and muscle (13.39). There was nonsignificant increase in kidney (2.77) in the glycogen due to lethal concentration (20%) of tannery effluent.

Electroplating effluent: Changes in the glycogen in various tissues of *L. rohita* exposed to electroplating effluent after acute exposure for 96 hr. are shown in the Table 1. The glycogen content in all the tissues decreased considerably upon acute exposure to 3% of electroplating effluent. Although the relative decrease varied from tissue to tissue, the percent depletion was more significant ($p<0.001$) in liver (41.50), whereas less significant ($p<0.05$) in muscle (17.88) followed by kidney (11.64). There was non significant decrease in glycogen level in gill (4.83).

In LC_{50} group significant ($p<0.001$) percent depletion in the glycogen level was observed in muscle (42.24) and in liver (40.05), whereas less significant ($p<0.05$) in kidney (30.93). Non significant depletion in glycogen content was observed in gill (5.60) as compared to control upon exposure to lethal concentration of 6% electroplating effluent.

Textile mill effluent: Changes in the glycogen in various tissues of *L. rohita* exposed to textile mill effluent after acute exposure for 96 hr. are shown in the Table 1. The glycogen content in all the tissues decreased considerably upon acute exposure to 18% textile mill effluent. Although the relative decrease varied from

Table - 1: Effect of industrial effluents on glycogen content in various organs of the fish *Labeo rohita* after acute exposure (mg / 100 mg wet tissue)

Organ	Tannery effluent			Electroplating effluent			Textile mill effluent		
	Control	LC_0	LC_{50}	Control	LC_0	LC_{50}	Control	LC_0	LC_{50}
Gill	0.516 ± 0.031	0.216** ± 0.031 - (58.13)	0.350** ± 0.040 - (32.17)	0.517 ± 0.004	0.492$^{N.S.}$ ± 0.020 -(4.83)	0.488$^{N.S.}$ ± 0.015 -(5.60)	0.495 ± 0.002	0.236** ± 0.012 -(52.32)	0.150** ± 0.010 -(69.69)
Liver	3.500 ± 0.020	1.578** ± 0.026 -(54.91)	0.866** ± 0.051 -(75.25)	3.910 ± 0.006	2.287** ± 0.020 -(41.50)	2.344** ± 0.007 -(40.05)	3.215 ± 0.008	2.248* ± 0.006 -(30.07)	3.101$^{N.S.}$ ± 0.012 -(3.54)
Muscle	0.433 ± 0.031	0.353* ± 0.026 -(18.47)	0.491* ± 0.031 (13.39)	0.587 ± 0.007	0.482* ± 0.046 -(17.88)	0.339** ± 0.008 -(42.24)	0.383 ± 0.003	0.147** ± 0.006 -(61.61)	0.312* ± 0.012 -(18.53)
Kidney	0.180 ± 0.050	0.133* ± 0.031 -(26.11)	0.185$^{N.S.}$ ± 0.031 (2.77)	0.181 ± 0.008	0.161* ± 0.022 -(11.64)	0.125* ± 0.004 -(30.93)	0.185 ± 0.009	0.131* ± 0.011 -(29.18)	0.223* ± 0.006 (20.54)

The values in parenthesis are percent change
* = $p<0.05$; ** = $p<0.001$; N.S. = Non significant ; ± = S.D. of five animals

Table - 2: Effect of industrial effluents on protein content in various organs of the fish *Labeo rohita* after acute exposure (mg / 100 mg wet tissue)

Organ	Tannery effluent			Electroplating effluent			Textile mill effluent		
	Control	LC_0	LC_{50}	Control	LC_0	LC_{50}	Control	LC_0	LC_{50}
Gill	20.40 ± 2.776	15.66** ± 3.205 -(23.25)	24.93* ± 4.240 (22.20)	22.66 ±4.240	21.53$^{N.S.}$ ±4.240 -(4.98)	19.26* ±1.602 -(15.00)	19.26 ±5.778	13.60* ±5.552 -(29.38)	12.46** ±4.240 -(35.30)
Liver	12.33 ± 1.602	11.73$^{N.S.}$ ± 1.602 -(4.86)	10.20$^{N.S.}$ ± 2.776 -(9.97)	14.73 ± 4.240	13.60$^{N.S.}$ ± 2.776 -(7.67)	13.60$^{N.S.}$ ± 2.776 -(7.67)	13.60 ± 2.776	14.73$^{N.S.}$ ± 4.240 (8.30)	12.46$^{N.S.}$ ± 1.602 -(8.38)
Muscle	26.06 ± 4.240	22.66* ± 1.602 -(13.04)	18.13* ± 1.602 -(30.42)	23.80 ± 2.776	15.86* ± 4.240 -(33.66)	13.60** ± 5.552 -(42.85)	24.93 ± 4.240	21.53* ± 5.778 -(13.63)	17.00* ± 2.776 -(31.80)
Kidney	18.53 ± 1.602	13.60* ± 2.776 -(26.60)	14.73* ± 3.205 -(20.50)	17.00 ± 7.344	15.86$^{N.S.}$ ± 4.240 -(6.70)	19.26* ± 4.240 (13.29)	17.00 ± 2.776	20.40* ± 2.776 (20.00)	14.73* ± 4.240 -(13.35)

The values in parenthesis are percent change
* = p<0.05 ; ** = p<0.001 ; N.S. = Non significant ; ± = S.D. of five animals

Table - 3: Effect of industrial effluents on lipid content in various organs of the fish *Labeo rohita* after acute exposure (mg / 100 mg wet tissue)

Organ	Tannery effluent			Electroplating effluent			Textile mill effluent		
	Control	LC_0	LC_{50}	Control	LC_0	LC_{50}	Control	LC_0	LC_{50}
Gill	0.523 ± 0.124	0.366* ± 0.205 -(30.01)	0.333** ± 0.249 -(36.32)	0.654 ± 0.008	0.522* ± 0.016 -(20.18)	0.312** ± 0.016 -(52.29)	0.482 ± 0.142	0.412* ± 0.020 -(19.52)	0.365* ± 0.048 -(24.27)
Liver	0.753 ± 0.249	0.701$^{N.S.}$ ± 0.124 -(6.90)	0.656* ± 0.081 -(12.88)	0.801 ± 0.016	0.638* ± 0.008 -(20.34)	0.823$^{N.S.}$ ± 0.029 (2.74)	0.672 ± 0.033	0.653$^{N.S.}$ ± 0.040 -(2.82)	0.623$^{N.S.}$ ± 0.065 -(7.29)
Muscle	0.563 ± 0.124	0.292** ± 0.081 -(48.13)	0.240** ± 0.163 -(57.37)	0.682 ± 0.020	0.427** ± 0.033 -(37.39)	0.478* ± 0.286 -(29.91)	0.424 ± 0.024	0.213** ± 0.044 -(49.76)	0.198** ± 0.024 -(53.30)
Kidney	0.660 ± 0.163	0.416** ± 0.169 -(36.96)	0.246** ± 0.249 -(62.72)	0.761 ± 0.026	0.535** ± 0.033 -(49.14)	0.519* ± 0.012 -(31.80)	0.532 ± 0.024	0.346* ± 0.029 -(34.96)	0.211** ± 0.046 -(60.33)

The values in parenthesis are percent change. * = p<0.05 ; ** = p<0.001 ; N.S. = Non significant ; ± = S.D. of five animals

tissue to tissue, the percent depletion was more significant (p<0.001) in muscle (61.61) and gill (52.32) and less significant (p<0.05) in liver (30.07) followed by kidney (29.18).

In LC_{50} group there was significant (p<0.001) percent depletion in the glycogen content in gill (69.69). There was less significant (p<0.05) depletion in glycogen level in muscle (18.53), whereas slight increase in kidney (20.54) was observed. Non significant depletion in glycogen level was observed in liver (3.54) due to lethal concentration of 22% of textile mill effluent.

Total protein: Protein level in different tissues was as follows:

Tannery effluent: Changes in total protein in gill, liver, muscle and kidney of *L. rohita* exposed to tannery effluent after acute exposure for 96 hr are shown in Table 2. Total protein content decreased significantly (p<0.05) in kidney (26.60) followed by gill (23.25) and muscle (13.04). There was non significant decrease in protein in liver (4.86) upon acute exposure to 15% of tannery effluent.

In LC_{50} group there was less significant decrease (p<0.05) in muscle (30.42) and kidney (20.50). There was significant (p<0.001) increase in gill (22.20) while non significant decrease in protein was observed in liver (9.97) as compared to control upon acute exposure to lethal concentration (20%) of tannery effluent.

Electroplating effluent: Changes in total protein in gill, liver, muscle and kidney of *L. rohita* exposed to electroplating effluent after acute exposure for 96 hrs are shown in Table 2. Total

protein content in all the tissues decreased considerably upon acute exposure to 3% electroplating effluent. Although the relative decrease varied from tissue to tissue, the percent depletion was significant ($p<0.05$) in muscle (33.36), whereas, there was non significant decrease in protein level in liver (7.67) followed by kidney (6.70) and gill (4.98) due to sub lethal concentration (3%).

In LC_{50} group, there was significant decrease in protein content of all tissues except kidney upon exposure to lethal concentration of 6% electroplating effluent. The percent depletion in protein content was more significant ($p<0.001$) in muscle (42.85) and less significant ($p<0.05$) in gill (15.00) while, non significant decrease was observed in liver (7.67). There was significant ($p<0.05$) increase in kidney protein (13.29).

Textile mill effluent: Change in the total protein in various tissues of *L. rohita* exposed to textile mill effluent after acute exposure (96 hr) are shown in Table 2. The protein content significantly ($p<0.05$) decreased in gill (29.38) and muscle (13.63), whereas, there was significant ($p<0.05$) increase in kidney (20.00) and non significant increase in liver protein (8.30) upon acute exposure to 18% of textile mill effluent, as compared to control.

The protein depletion was significant ($p<0.001$) in gill (35.30), while less significant ($p<0.05$) in muscle (31.80) and kidney (13.35). There was non significant decrease in protein content in liver (8.38).

Total Lipid: Lipid level in different tissues was as follows:

Tannery effluent: Changes in the total lipid content in various tissues of *L. rohita* exposed to tannery effluent after acute exposure for 96 hrs is shown inTable 3. The lipid content in all the tissues decreased considerably upon the acute exposure to 15% of tannery effluent. Although the relative decrease varied from tissue to tissue, the percent depletion in lipid content was more significant ($p< 0.001$) in muscle (48.13) and kidney (36.96), while it was less significant ($p<0.05$) in gill(30.01). There was non-significant decrease in liver (6.90) as compared to control.

In LC_{50} group there was significant ($p<0.001$) depletion in lipid content in kidney (62.72), followed by muscle (57.37) and gill (36.32), while less significant ($p<0.05$) in liver (12.88), due to lethal concentration (20%) of tannery effluent.

Electroplating effluent: Changes in total lipid content in various tissues of *L. rohita* exposed to electroplating effluent after acute exposure for 96 hrs is shown in Table 3. The lipid content of all the tissues decreased considerably upon acute exposure to 3% of electroplating effluent. The relative decrease in lipid content varied from tissue to tissue. The percent depletion in lipid content was more significant ($p<0.001$) in kidney (49.14) and muscle (37.39), while it was less significant ($p<0.05$) in liver (20.34) and gill (20.18) as compared to control upon exposure to lethal concentration (6%) of electroplating effluent.

Textile mill effluent: Changes in total lipid content in various tissues of *L. rohita* exposed to electroplating effluent after acute exposure for 96 hrs is shown in Table 3. The lipid content in all the tissues decreased considerably upon acute exposure of 18% of textile effluent. Although the relative decrease varied from tissue to tissue, the percent depletion in lipid content was more significant ($p<0.001$) in muscle (49.76), while it was less significant ($p<0.05$) in kidney (34.96) followed by gill (19.59). There was non significant decrease in lipid level in liver (2.82) as compared to control.

In LC_{50} group there was significant ($p<0.001$) depletion in lipid content in kidney (60.33) and muscle (53.30) while it was less significant ($p<0.05$) in gill (24.27). There was non-significant depletion in lipid level in liver (7.29) as compared to control.

In present study, in general there was decrease in lipid content of all the tissues at sublethal and lethal concentrations due to tannery effluents, while electroplating effluent showed similar effect at sublethal and lethal concentrations except liver.

In present study, there was depletion in glycogen in lethal and sublethal concentration of tannery, electroplating and textile mill effluents. The finding can be correlated with the similar effect due to different effluent shown by Balaji and Chockalingam (1991); Amudha and Mahalingam (1999); Maruthi and Rao (2000). This decrease in tissue glycogen may be due to glycolysis for production of energy to overcome toxic effect of the effluents. Decrease in glycogen has also been suggested by Shaffi (1978), to explain depletion in glycogen. Similar depletion in glycogen content in this study may be attributed to its utilization to meet high energy demand created by stress of effluents. This could have happened by rapid glycogenolysis and inhibition of glycogenesis through activation of glycogen phosphorylase and depression of transferase (Jha and Pandey, 1989; Jha and Jha, 1995 a, b).

In present study, there was decrease in protein content of all organs in sub lethal concentration (LC_0) while, decrease in lethal concentration (LC_{50}) except gill for tannery effluent. For electroplating effluent at sublethal and lethal concentration there was decrease in protein content in gill, liver and muscle except kidney. For textile mill effluent there was decrease in protein content in gill and muscle except liver and kidney at sublethal concentration and decrease in all organs in lethal concentrations.

Significant decrease in total protein content indicates that, stress due to effluent treatment induces proteolysis. Stress has been reported to accelerate protein metabolism in man and animals (Nichol and Rosen, 1963). Protein decrease may be due to stress in fish as protein is likely to undergo hydrolysis and oxidation through TCA cycle to meet the increased demand for energy caused by the stress (Somnath, 1991). Increase in liver protein may be due to increase in synthesis of detoxification enzymes as suggested by Chitra (1983).The alteration in the

tissue protein, in the present study suggests disturbance in the physiological activity.

The depletion in the hepatic total lipid could be due to their active mobilization towards the blood and/or tissue metabolism (Murthy *et al.,* 1994). The decrease might be due to the utilization of lipid to meet the additional energy requirement under stress (Rao *et al.,* 1985). Toxic substances might have accumulated in the brain of fish, causing disintegration of nerve cells, clotting of blood and reduction in transport of oxygen to brain (Panigrahi and Misra, 1980). Loss of lipids noticed in this study may be due to inhibited lipid synthesis and mobilizing the stored lipid, either through β oxidation or through a gradual unsaturation of lipid molecules as suggested by Jha (1991).

The observations from the present study showed that, these effluents at sublethal and lethal concentrations altered the biochemical composition (glycogen, protein and lipid) of the various organs of test fish, due to utilization of biochemical energy to counteract the toxic stress caused due to heavy metals present in effluents.

References

Ambrose, T., L. Cyril, A Kumar, S. Vixent and R. Lambert: Biochemical reponse of *Cyprinus carpio* (*communis*) to toxicity of tannery effluent. *J. Ecobiol.*, **6(3)**, 213-216 (1994).

Amudha, P. and S. Mahalingam: Effect of dairy effluent on the body consumption of *Cyprinus carpio (*Cyprinidae). *J. Ecotoxicol. Environ. Monit.*, **9(1)**, 03-08 (1999).

Balaji, A . and S. Chokalingam: Effect of sub lethal concentration of dairy effluent on an air breathing fish, *Channa punctatus*. *Acad. Environ. Biol.* 75-80 (1991).

Barnes, H. and J. Blackstock: Estimation of lipid in marine animals, detail investigation of sulphophospho vanillin method. *J. Exp. Mar. Biol. Ecol.,* **12**, 103-118 (1973).

Chitra, K. C.: Induction of biosynthesis of proteins and amino acids in the tissue of *Sarotherodon mossambicus* under ambient urea stress. *Indian J. Comp. Anim. Physiol.,* **1(2)**, 37-39 (1983).

De Zwaan and D. I. Zandee: Body distribution and seasonal changes in glycogen content of the common sea mussel *Mytilus edulis*. *J. Environ. Biol.,* **7(2),** 149-154 (1972).

Gornall, A. G., J. C. Bardwill and M.M. David: Determination of serum protein by means of the burette reagent. *J. Biol. Chem.,* **177**, 751- 766 (1949).

Jana, S. and S. Bandopadhyaya: Effect of heavy metal on some biochemical parameters in the freshwater fish, *Channa punctatus* (Bloch). *Environ. Ecol.,* **5**, 488-490 (1987).

Jana, S., S.S. Shana., M. A. Choudhari and D. K. Choudhari: Heavy metal pollutant induced changes in some biochemical parameters in the freshwater fish *Clarias batrachus*. *Acta Physiol. Hung.,* **68(1)**, 39-44 (1986).

Jha, B. S.: Alteration in the protein and lipid content of intestine, liver and gonads in the lead exposed freshwater fish *Channa punctatus* (Bloch). *J. Environ. Ecoplan.,* **2(3)**, 281-284 (1991).

Jha, B. S and A. K. Jha: Biochemical profiles of liver, muscle and gonads of the freshwater fish *Heteropneustis fossilis* under chromium stress. *In*: Toxicity and monitoring of xenobiotics (*Eds*: R. Prakash and P. Sood). Venus Publishing House, New Delhi. pp. 127-137 (1995a).

Jha, B. S and A. K. Jha: Biochemical effect of nickel chloride on the liver and gonads of the freshwater climbing perch *Anabus testiduneus* (Bloch). *Proc. Nat. Acad. Sci. India,* **65B**, 39-46 (1995b).

Jha, B. S and S. Pandey: Alteration in the total carbohydrate level of intestine, liver and gonad induced by lead nitrate in the fish *Channa punctatus*. *In*: Environmental risk assessment (*Eds*: Y. N. Sahai, P. N. Deshmukh, T. A. Mathai and K. S. Pillai). *The Academy of Environmental Biology.* pp. 207-211 (1989).

Joseph, T. A., S. M. Sebastin and S. Raja: Toxicity of nickel on protein content in tissue of *Cyprinus carpio* (Linn). *Indian J. Environ. Hlth.,* **34(3)**, 236-238 (1992).

Lawe, J. L. and A. J. Nivmi: Short term and long term effect of cadmium on glycogen reserves and liver size in rainbow trout (*Salmo* gairdneri, Richardson). *Arch. Environ. Contam. Toxicol.,* **13**, 759-763 (1984).

Maruthi, Y.A. and M.V. Subba Rao: Effect of distillery effluent on biochemical parameters of fish *Channa punctatus* (Bloch). *J. Environ. Pollut.,* **7(2)**, 111-113 (2000).

Murthy, K. V., M. Bhaskar and S. Govindappa: Studies on lipid profile of fish liver on acclimation to acidic medium. *J. Environ. Biol.,* **15(4)**, 269-273 (1994).

Natarajan, A. V.: Effects of tannery effluents on the muscle and liver glycogen in a fish *Sarotherodon mossambicus*. *The Indian Zoologists,* **13(1, 3)**, 147-151 (1989).

Nichol, C. A. and F. Rosen: *In*: Advances in enzyme regulation (*Ed*: G. Weber) Vol. 1, Pergamon Press, Oxford. p. 341 (1963).

Panigrahi, A. K. and B. N. Misra: Toxicological effects of sublethal concentration of inorganic material on the freshwater fish *Tilapia mossambica*. *Arch. Toxicol.,* **44(4)**, 269-278 (1980).

Rajan, M. R.: Sub lethal effects of textile mill effluent on protein, carbohydrate and lipid content of different tissues of fish *Cyprinus carpio*. *Environ. Ecol.,* **8(1)**, 54-58 (1990).

Rao, K. S. P., K.R.S. Rao, I.K.A. Sahib and K.V.R. Rao: Combined action of carbaryl and phenthoate on tissue lipid derivative of muscle of *Channa punctatus* (Bloch). *Ecotoxicol. Environ. Saf.,* **9(1)**, 107- 111 (1985).

Shaffi, S. A.: Cadmium intoxication on tissue glycogen content in three freshwater teleost. *Cirr. Sai.,* **47**, 868-870 (1978).

Shaffi, S. A.: The acute industrial toxicity of fresh water fish. *Toxicol. Lett.* (AMST), **5(3/4)**, 183-190 (1980).

Somnath, B.: Effect of acute and sub lethal concentration of tannic acid on the protein, carbohydrate and lipid levels in the tissue of the fish *Labeo rohita*. *J. Environ. Biol.,* **12(2)**, 107-112 (1991).

Srivastava, D. K.: Comparative effects of copper, cadmium and mercury on tissue glycogen of catfish *Heteropneustis fossilis*. *Toxicol. Lett.,* **11**, 135-140 (1982).

Subramanian, M.A. and G. Varadaraj: Impact of tannery effluent on the biochemical constituents in the haemolymph of the freshwater prawn. *Macrobrachium idella* Heller. *J. Environ. Biol.*, **14(3)**, 255-259 (1993).