2. REVIEW OF LITERATURE

Pollution may be defined as fouling of the environment. It is an undesirable change in the physical, chemical or biological characteristics of the land, air and water that may or will harmfully affect human life or that of desirable species (Odum, 1971). Each and every living organism has its specific surroundings, medium or environment to which it continuously interacts and remains fully adapted. The environment is a collective term, embarrassing all the physical and chemical conditions in which it survives. In other words the environment is the sum total of physical (abiotic) and biotic conditions influencing the responses of the organism.

Water temperature is one of the most important environmental factors. It exhibits diel and seasonal fluctuations in fresh water body. It play a vital role in determining the distribution, survival, growth, metabolism and reproduction of organisms (Fry, 1971). Verma and Mathur (1974) have stated that the distillery effluent is more toxic than mixed paper and pulp mill effluent.

Distillery effluent affects the survival and behaviour of fishes (Motwani et al., 1956; Kinne, 1960; David and Roy, 1966; Brett et al., 1969 a; Verma and Mathur, 1974; Gill and Toor, 1976; Elliott, 1976a & b; Anthony Raj et al., 1987). The effects of pollutants on survival of fishes under different salinity levels have reported by Doudoroff and Katz, (1953); Brown et al. (1968); Inglis and Davis, (1972).

Arokiasamy (1982) has stated that the toxic effects of distillery effluent may be due to its very high COD, BOD, total dissolved solids. Limited information is available regarding the effects of distillery effluent on food utilization and growth of fishes.
Haniffa and Sundaravadanam (1983) have studied the food utilization of *Barbus stigma* and *Oreochromis mossambicus* under distillery effluent stress and they found the reduction in food intake, growth and conversion efficiency.

Metelev *et al.* (1983) and Mayer and Ellersieck, (1986) have reported that the mortality of *Macrobrachium dayanam* increased with increasing temperature when exposed to distillery effluent.

Agarwal and Gatham (1988) have reported the chronic toxicity of distillery, and mixed pulp and paper mill effluents to fresh water fish, *Channa striatus* (BI).

Haniffa and Jassentha (1988) reported the survival of *Oreochromis mossambicus* when exposed to distillery effluent and stated that the distillery effluent affected the fish survival.

Pamila *et al.* (1991) observed gradual decrease in oxygen uptake when the fish *Sarotherodem mossambicus* exposed to chromium to various sub lethal concentration. Dhanapakium *et al.* (1998) studied median lethal effects of mercury and cadmium on oxygen consumption and gill histopathology of common carp *Cyprinus carpio*.

McMaster *et al.* (1994) evaluated the effects of handling and confinement stress on a number of biochemical parameters in pre spawning male white sucker collected from a bleached kraft mill effluent (BKME) exposed and a reference site. There were no effects of site or stress level on plasma cholesterol or glutamic oxalacetic transaminase activity; all other parameters were affected by either sampling stress or overnight confinement. Acute handling stress or overnight confinement created a site difference in plasma glucose, protein and 11-ketotestosterone, reversed the site effect for plasma lactate, and eliminated site differences for 17 alpha,20 beta-dihydroxy-4-pregnen-3-one. Since it is very
difficult to standardize capture and handling stress in field studies impacted by industrial effluents, biochemical differences must be interpreted carefully.

The toxicity of any chemical necessarily impairs the reproductive physiology adversely as ovaries perform the function of producing eggs and steroid hormones and testis in the production of sperms. The edible catfish *Clarias batrachus* was exposed to sub-lethal concentration of borate (0.27 ppm) for 168 hours to study the histological disorders in testis and ovary (Geetha *et al.*, 1996).

Sivakumar *et al.* (1996) observed the depletion of dissolved oxygen content in tap water and in effluent concentrations caused a stress and altered the normal oxygen consumption. The increase in the rate of oxygen consumption due to depletion of dissolved oxygen was statistically significant (*p* < 0.05). With the increase in effluent concentration, a decrease in oxygen consumption was observed in *Labeo rohita* but this decrease was not statistically significant (*p* > 0.05).

Norseth (1996) investigated that the seven toxic metals present in blood and muscle (edible portion) of certain species of fishes of river Sai and river Ganga was carried out during post monsoon period at Rae Bareli. The mean concentration of Cd, Cu, Cr, Mn, Ni, Pb and Zn in blood of Sai fishes and Gangetic fishes was 0.15, 0.08, 0.36, 0.54, 0.35, 0.13, 7.78 and 0.26, 0.15, 0.84, 0.36, 0.08, 8.24 ppm respectively, while in muscle it was 0.33, 0.46, 1.47, 1.49, 1.58, 0.42, 9.06 and 0.86, 20.38, 11.46, 11.63, 7.64, 0.33, 30.56 mg/gm, respectively.

Nanda and Behera (1996) have studied the significant reduction of red blood cell counts in *Anabas testudineous* and *Heteropneustes fossilis* exposed to cadmium and nickel respectively and they have suggested that reduction in RBC count might be due to disturbance in the metabolism of the haemopoietic organs.
An increase in the WBC counts in ekalux treated fresh water fish, *Etroplus maculates* have been reported by Sunilkumar and Nelson (1997) and they also have suggested that the significant increase in white blood cells could be due to stimulated lymphocytopenesis and enhance release of lymphocytes from lymphoid tissues such as kidney, spleen and thymus.

The pervasive occurrence of vanadium in nature and its use in various industrial processes has increased its inputs in the environment. This has prompted us to elucidate the impact of vanadium on aquatic environment, the primary body for industrial effluent discharge. The energy response of the fish, *Clarias batrachus*, its haematological status including haemoglobin (Hb), haematocrit (Ht), leutocrit (Lt), mean corpuscular haemoglobin (MCH), mean corpuscular volume (MCV), mean corpuscular haemoglobin concentration (MCHC) etc. Chakraborty *et al.* (1998) have observed general health conditions to be significantly hampered leading to deleterious alterations in the general metabolism of the fish following long term exposure to vanadate. The increase in muscle and tissue lactic acid (2-12 folds) in association with decrease in pyruvic acid (72% in muscle; 26% in liver) reflects a shift towards an anaerobic metabolism of the fish. They conclude that vanadium could be toxic for the fish in question under long-term exposure at the doses under observation (2-10 mg/l).

Piscine haematology is useful in assessing the health and general conditions of the animal subjected to changing environmental conditions. The increasing input of xenobiotics into the environment has elicited growing concern regarding their possible ecological impact. A particular problem with a heavy metal is its persistence. They can not be eliminated from aquatic ecosystem but they persist in sediments (Bhavani *et al.*, 1999). The problem of mercury pollution is of paramount importance and it has a direct bearing on pisciculture and human health.
Agricultural, industrial and domestic wastes water containing ammonia brings about major changes in aquatic ecosystems. It is a menace directed essentially to freshwater fishes. Study determines the toxic effect of waste water on protein content of *Channa punctatus* (Ravindarn *et al.*, 1999).

Different haematological parameters in both young and adult *Labeo rohita* (Ham.) due to long-term exposure (90 days) of cadmium (Cd) induced at various sublethal concentrations were studied. Decrease or increase of values of different parameters in both age groups of fish was recorded during different experimental periods. The possible cause of variations in these parameters has been discussed by Sinha, (1999).

The adverse effect of heavy metals is due to the non-degradation of metals leading to accumulation in tissues and an interaction of the metal with a protein or enzyme leading to changes in physiologic and metabolic processes. The metalloids, and high concentrations of transitional metals, tend to accumulate in different tissues of body, and hence become bioaccumulated (Yazdandoost and Katdare, 1999).

Adult pre-spawning, spawning and post-spawning fish *Labeo rohita* were sublethally (1/5th 96 h LC<sub>50</sub>) exposed to methyl parathion. Accumulation of methyl parathion in the fish muscle and gonad GC were studied by Kumar and Sanjib, (2000). The accumulation of the pesticide residue occurred in the order muscle < testes < ovary. The trend of accumulation suggests that the pre spawning and spawning ovary appears to be the important target organ of methyl parathion.

Sivani and Rao (2000) investigated that the records quantitative accumulation of heavy metals in the fish *Oreochromis nilotica* exposed to waste water. They were carried out by atomic absorption spectrophotometric method.
Lead and cadmium showed nearly equal pattern of accumulation in all the organs: copper accumulated more in liver and ovary.

Patil and Dhande (2000) have reported that the decreased RBC count may be due to the inhibition of erythrocyte production or increase in the rate of erythrocyte destruction. They have reported a decrease in TEC and Hb in the fish *Channa punctatus* after exposure to sublethal concentration of industry waste.

Malik and Malik Amrita (2000) carried out some selective physico-chemical parameters in the effluent of Modi Distillery at Modinagar (District-Ghaziabad) at three sampling sites fixed at effluent treatment plant of Modi Distillery. They observed that the temperature varied from 28.04 to 79.72°C, total solids ranged 1212.33 to 34534.30 mg/l, pH ranged 3.99 to 7.08, DO varied from nil to 0.015 mg/l. The effluent treatment includes the primary treatment and secondary treatment and subsequent dilution of the effluent after treatment to make a final discharge.

The physico-chemical characteristics of sugar mill effluent, discharged from Tummapala sugar factory, Anakapalli (Andhra Pradesh), and their impact on local fish, *Channa punctatus* were observed by Avasn Maruthi and Ramakrishna Rao, (2001). High values of BOD and COD reveal the presence of high concentration of biodegradable organic matter in the effluent. The harmful effects of effluent were also studied with respect to survival of fish. The consequential demand on organic reserves is analyzed and established.

The influence of temperature variation on the humoral immune response using the plaque-forming cell (PFC) assay in freshwater fish *Channa punctatus* (Bloch) was investigated by Fatima et al. (2001). The fish was exposed to 1% concentration (v/v in water) of paper and pulp mill effluent under standard laboratory conditions in glass aquaria. Effect of effluent exposure on the organ
weight and organ cellularity was also evaluated. In general, lower temperature in winter produced a subdued response in control as well as experimental group. At higher temperature of summer and rainy seasons, an elevated response was observed. Long-term exposure also caused significant reduction (p < 0.05) in the weights of lymphoid organs (spleen, head kidney, and total kidney). These results show a suppressive effect of chemical constituents of paper and pulp mill effluent on the immune functions. Furthermore, results demonstrated that though modulatory effect of the temperature on immune functions is recognized, it was not a major contributory factor to the elevated immunotoxicity of paper and pulp mill effluent in the seasons of high temperature.

The physiological and histological changes in *Tilapia siltii* (Gerv.) after exposure to sublethal concentrations of the effluent of the Egyptian Copper Works have been investigated by Senthilkumar (2001). The results of acute toxicity lest showed that the LC$_{50}$ was 25 cm$^3$/dm$^3$, which means that this wastewater is highly toxic. The results of physiological and histological changes in *Tilapia zillii* (Gerv.) showed that, fish were under considerable stress during exposure to sublethal doses of this wastewater. Physiological response of fish revealed significant disturbances in respiratory system, fish metabolism, and ionic osmoregulation. Pathological changes attributed to heavy metals were observed in the gills, liver, and kidney.

*Clarian batrachus*, fish were exposed to sublethal concentration of commercial carbofuran for 144 hr. Total lipids and free fatty acids were determined in liver, muscle kidney and ovary at an interval of 24, 72 and 144 hr during exposure and after the release into toxicant free water. The results showed an alteration in free fatty acid content in different tissues of the fish. The elevated levels returned to almost control values after transfer of fish into carbofuran free water (Ghousia and Shantha, 2001).
Experiments were conducted to study the effect of mercuric chloride, mercuric bromide and mercuric iodide on the oxygen consumption of fish *Oreochromis mossambicus*. Oxygen consumption of fish was found to be decreased in all the three halogenated mercuric compounds when compared to the control. Halogenated mercuric compounds inhibited the respiratory activity of the fishes (Nisha *et al.*, 2001).

Static renewal bioassay tests were conducted to determine the lethal toxicity of phenol and para-cresol to a freshwater fish, *Oreochromis mossambicus*. The 24, 48, 72 and 96-hour LC$_{50}$ values for phenol were found to be 42.0, 39.0, 37.0 and 35.0 mg/liter, respectively. The 24, 48, 72 and 96-hour LC$_{50}$ values for para-cresol were found to be 32.0, 30.0, 29.0 and 28.0 mg/liter, respectively. The oxygen consumption of the fish decreased significantly in both the toxicants at higher concentrations (Kanabur and Sannadurgappa, 2001).

The impact of grossly polluted waters of the Budha Nallah (BN) on the flesh quality of a few fish species inhabiting river Satluj following its confluence with the river has been studied by Kaur Tejinder and Saxena (2001). The results have shown a significant decline in the extractable proteins content, carbohydrates and total lipid contents in the flesh of these fish species collected from region.

The uses of organophosphate pesticides in crop fields are highly toxic to the aquatic organisms including fish. In the present study, LC$_{50}$, LC$_{99}$, LT$_{50}$ and maximum allowable toxicant concentration (MATC) to the related species of a broad spectrum pesticide triazophos has been evaluated at 96 hours using the fish *Clarias batrachus* as a test animal (Maheshwari *et al.*, 2001).

The eighteen untreated and nineteen treated effluent samples from seven pesticide industries were collected and tested for their toxicity exposing the zebra fish (*Brachydanio rerio*) to determine the toxicity factor (TF) value. Study revealed
that the primary and secondary treatment to the effluent has helped to some extent in reducing the toxicity. Ruparelia et al., (2001) suggests that the treated effluent samples from some of the pesticide industries were still toxic to fish and requires further treatment/dilution for the survival of the fish.

The effect of sublethal concentration of cadmium, zinc and pesticides on the rate of uptake of glucose, fructose and amino acid tryptophan by the intestine of the freshwater teleost fish *Channa punctatus* and *Heteropneustes fossilis* has been studied by Shukla Vineeta et al. (2001). Fishes exposed to sublethal concentration of cadmium and zinc (1.12 and 4.0 ppm, respectively) showed decrease in the rate of tansport of glucose and fructose, which was more marked after 30 days as compared to 15 days in the two fishes.

Fresh water bivalve, *Parreysia cylindrica* were exposed to acute and chronic doses of carbaryl. Progressive decrease in amylase, invertase and lipase activity in the hepatopancrease was observed in carbaryl exposed bivalve. The protease activity was increased after carbaryl stress which can be due to the increased lysosomal protease (Bhalchandra Waykar and Lomte, 2002).

Gautam and Gautam Kalpana (2002) made investigation on the biology and haematology of fish *Channa punctatus* after exposure to endosulfan and diazinon. The toxic effects of these pesticides made ill effects on the biology and haematology of fishes. Significant decreases in the body and tissue weights were observed. A reduction in number of leucocytes shows immunological response due to the toxic effects of these pesticides.

Nanda et al. (2002) reported that the air breathing fishes were exposed to paper mill effluent to study the toxicity level. The 96-hour LC$_{50}$ values were found to be 63.09, 80.35 and 8128% for *Anabas testudineus, Channa punctatus* and *Clarias batrachus*, respectively.
Effect of dimethoate and minocil (commercially formulated pesticides) on the protein and amino acid concentration in serum and liver in *Channa marulius* (Ham.) exhibited notable alterations. Dimethoate and monocil pesticides caused significant increase in protein and decrease in amino acid concentrations in serum and liver of the fish (Prasad Bijay Bhushan *et al.*, 2002).

Changes in the total protein and free amino acids in the ovaries of two freshwater fishes, *Barilius bendelisis* and *B. burna* by subjecting them to increasing sub-lethal concentration and duration of exposure to sevin were studied by Kamble *et al.* (2002). The results are discussed in relation to the concentration of the most commonly used pesticide in this region.

Ramaiyan and Paulpandian (2002) observed the decrease in haemoglobin content and reduction of RBC throughout the exposure period when the fish *Channa punctatus* was exposed to non-lethal concentration of cadmium chloride.

Rainbow trout were exposed to a secondary treated, thermomechanical/bleached kraft pulp and paper effluent in 12,000-L, flow-through exposure tanks at an environmental research facility located at a pulp and paper mill in Kawerau, New Zealand. Trout (age, 2+ years) were obtained from a local hatchery and exposed either to upstream river water or a nominal concentration of 12% (v/v) effluent diluted in upstream river water. Three treatment groups were used: Effluent exposure that started approximately three months before gonadal growth (eight-month total exposure), effluent exposure that started approximately halfway through gonadal development (two-month total exposure), and trout exposed to reference water alone for the total duration of the experiment. Trout were sacrificed just before spawning; exposure, growth, and reproductive endpoints were assessed during and at the termination of the experiment. Thus, this study has shown an impact of pulp mill effluent exposure on the reproductive physiology of female trout that appeared to be hormonally mediated. Furthermore, the effect could only
be manifest when the exposure was initiated before the start of gonad development (Van den Heuvel and Ellis, 2002).

Static bioassays reveal that the LC50 96 hour of dairy effluent for a freshwater fish *Oreochromis mossambicus* was 50% of the effluent. The fish were reared in different sublethal concentrations (10 and 15%) of the effluent for 30 days. Various biochemical constituent in three tissues (gill, liver, muscle) of the fish were estimated. These concentrations were found to decrease depending on the dose of the effluent (Amudha *et al*., 2002).

Toxicological effects of some biochemical parameters of freshwater fish *Channa punctatus* (Bloch), under the stress of nickel (NiSO4 6H2O), at various concentrations of 10, 20, 30 and 40 ppm for 30 days were observed by Desai Himadri Sekhar *et al*., (2002). Gradual decrease in the levels of liver protein and liver ascorbic acid due to proteolysis and liver glucose breakdown respectively was observed. There was also gradual decrease in the brain protein level showing significant alterations but the brain ascorbic acid level showed no significant alterations.

Nagarajan and Shasi Kumar (2002) studied the effect of sago effluent and observed that the LC50 values of *Labeo rohita* for 72 hours in treated and untreated sago effluent 35% and 3% respectively. *Labeo rohita* reared in 15% treated sago effluent recorded maximum conversion rate of 18.80 mg/g/day and conversion efficiency is 37.61%.

Studies on respiratory metabolism of fish *Oreochromis mossambicus* (Peters) exposed to different concentrations (5,10,20 and 40%) of pulp and paper mill effluent were done for a period of 15 days and there was a marked decrease in oxygen consumption rate from control. Difference in oxygen consumption rate of
the fish in different concentration was significant ($F=63.1, P<0.001$) whereas the difference between the days was insignificant ($F=2.75$) (Prasanta et al., 2002).

Sponza et al., (2002) investigated that the acute toxicity of textile and metal industry wastewaters by traditional and enrichment toxicity tests and emphasize the importance of toxicity tests in wastewater discharge regulations. The enrichment toxicity tests are novel applications and give an idea whether there are potential toxicity or growth limiting and stimulation conditions. The toxicity test results were assessed with chemical analyses such as COD, BOD, color and heavy metals. It was observed that the toxicity of the effluents could not be explained by using physicochemical analyses in 5 cases for metal and 4 cases for the textile industries. The results clearly showed that the use of bioassay tests produce additional information about the toxicity potential of industrial discharges and effluents.

Wild female and male white sucker (Catostomus commersoni) inhabiting an area receiving pulp mill effluent had reduced hepatic levels of retinol, didehydroretinol, retinyl esters, and didehydroretinyl esters, while vitamin E levels were unaffected. The ability of the extracts to displace retinoic acid did not appear to be linked to the pulping or treatment processes. These results suggest that pulp mill effluent may impact the retinoid system of fish at multiple sites, either by decreasing hepatic retinoid stores or through contributing additional ligands (from the wood furnish) that can bind to RA receptors (Alsop et al., 2003).

Smolders et al. (2004) studied that the toxicological impact of two effluents, one household wastewater treatment effluent (Effluent 1) and one industrial effluent (Effluent 2), on the receiving aquatic ecosystem using two test species under both in situ and laboratory conditions. Zebra mussel (Dreissena polymorpha) and common carp (Cyprinus carpio) were exposed under laboratory conditions in an online monitoring flow-through system (receiving different concentrations of Effluent 2) and under in situ conditions along the pollution gradient established by
these two effluent discharges. Under laboratory conditions, increasing concentrations of the industrial effluent (Effluent 2) had a negative effect on both zebra mussel and carp energy reserves and condition. Under in situ conditions, the same negative impact of Effluent 2 was observed for zebra mussels, while effluent 1 had no apparent effect on exposed zebra mussels. The incorporation of indirect, ecological effects, like changes in food availability, provides considerable benefit in understanding and predicting effects of effluents on selected species under realistic exposure conditions.

Vutukuru (2005) determined the acute toxicity of hexavalent chromium and its toxicological effects on survival, physiological, hematological and biochemical parameters of the widely consumed Indian major carp, *Labeo rohita*. The metal also induced significant decrease (p<0.001) in the hematological parameters of the fish like total erythrocyte count, hemoglobin percent and absolute value Mean cell hemoglobin (MCH) both at the end of 24h and 96h exposure indicating anemia. Appreciable decline in the biochemical profiles such as total glycogen, total lipids and total protein contents of the fish was also observed. However, the decrease in protein content was significant only at the end of 96h. This study reflects the extent of the toxic effects of hexavalent chromium and the metal induced cumulative deleterious effects at various functional levels in the widely consumed freshwater fish, *Labeo rohita*.

Oakes *et al.* (2005) investigated the temporal onset of reactive oxygen species (ROS) damage and changes in circulating sex steroids in immature rainbow trout exposed over 21 days to two pulp-mill effluents. Exposure to effluent from a bleached sulfite mill produced increases in 2-thiobarbituric acid reactive substances (TBARS), ethoxyresorufin O-deethylase (EROD) activity, hepatic free iron, and significant depressions in hepatic ascorbic acid. Impairments in pregnenolone production relative to cholesterol availability suggest an effect of sulfite-mill effluent early in the steroidogenic pathway. Induction of vitellogenin in immature
fish exposed to effluent from this mill, relative to waterborne 17 beta-estradiol treatments, indicated sulfite-mill effluent contained constituents capable of binding the estrogen receptor. Exposure to a kraft-mill effluent also elevated hepatic TBARS, tissue normalized fatty acyl-coenzyme A oxidase (FAO) activity, and hepatic free iron while producing commensurate declines in hepatic ascorbic acid. Plasma testosterone, 11-ketotestosterone, and 17 beta-estradiol were elevated with kraft-mill effluent exposure, but no changes in vitellogenin induction were observed. In summary, effluent from bleached sulfite and bleached kraft mills yielded similar oxidative stress responses, but marked differences were observed in the endocrine-disrupting potential of each effluent.

The acute and chronic effects of secondary-treated effluent from a New Zealand pulp and paper mill were assessed using both long-term adult and early life stage (ELS) laboratory exposures of rainbow trout. The relative impact of maternal exposure versus ELS exposure by a comparison of directly exposed eggs and larvae with the eggs and larvae of exposed adult trout that were reared in reference water was assessed by Ellis et al. (2005). These results demonstrate that this pulp and paper mill effluent is more likely to elicit indirect impacts on progeny size through chronic exposure of adults to effluent during gonadal recrudescence rather than through direct exposure of early life stages to effluent.

The impacts of distillery effluent on carbohydrate metabolism of *Cyprinus carpio* were studied by Ramakritinan et al. (2005) at different days (7, 14, and 21 days) in the ambient temperature at 28°C. Oxygen consumption in the fish decreased with increasing effluent concentrations as well as duration of exposure period. Effluent concentrations and exposure durations (days) had a significant effect on oxygen consumption of tested fish. Total carbohydrate, glycogen content and SDH enzyme activity decreased gradually and significantly in muscle, liver and brain tissues of *C. carpio* exposed to different sublethal concentrations.
Reduction in glycogen content was greater in liver tissue i.e., 54.1% in 0.2% effluent concentration on the 21\textsuperscript{st} day of exposure.

Orrego \textit{et al.} (2005) investigated that the effect of pulp mill effluent discharges, immature \textit{Oncorhynchus mykiss} were exposed to river sediments in the laboratory for 29 days. Three sampling areas were defined in a spatial gradient in the river: Pre impact, impact, and post impact zones relative to the pulp and paper mill discharge areas. Ethoxyresorufin-O-deethylase activities were significantly higher in fish exposed to impact and post impact sediments when compared to those exposed to pre impact sediments, and higher levels of vitellogenin were observed in the plasma of female fish exposed to impact and post impact sediments. Histological analysis of the gonadal tissue showed an induction of gonadal maturation in fish exposed to sediment coming from the impact and post impact zones (oocytes in a vitellogenic state). Finally, the biomarker approach showed evidence that the sediment associated with pulp mill effluent discharges produces some effects in fish under laboratory conditions.

Gills of Pb-treated fish accumulated maximum industrial waste metal followed by liver and muscle; however, Cd accumulation was maximum in liver followed by gill and muscle. When the fish were exposed to the combined doses of Pb and Cd, uptake of both these metals were found to be in order to liver>gill>muscle. Liver and muscle displayed declined activities of acid phosphates and alkaline phosphates under Pb and Cd exposures whereas the combined treatment of both these metal elevated acid phosphates and alkaline phosphatase activity in liver and declined in the muscle (Rugmony \textit{et al.}, 2005).

Acute toxicity of Nickel on freshwater fish \textit{Labeo rohita} using static bioassay method was studied by Mahalakshmi and Muniyan, (2005). Median lethal concentration for 3, 6, 12, 24, 48, 72 and 96 h were 99.59, 89.39, 66.74, 52.63, 44.26, 33.61 and 28.21 ppm respectively. The sign of toxicity on the behaviour of
the fish *Labeo rohita* was studied for 96 hours. Loss of equilibrium, hyper and hypo activity, changes in opercular movement, changes in orientation and locomotion, mucus coating on the body, loss of equilibrium and erratic swimming were observed.

The coastal environment of West Bengal, recognized as the most diversified and productive ecosystem among all the maritime states of India, faces organic pollution from domestic sewage and urban and industrial effluents leading serious impacts on biota. An overall common trend in bioaccumulation was revealed with the following decreasing order: Zn>Mn>Cu>Cr>Se>Hg with few exceptions. Both species dependent variability and temporal variations were pronounced. A high degree of organ specificity was evident in the bivalves where gill and mantle exhibited higher metal accumulation due to ion exchange property of the mucous layer covering these organs. Variability between closely related species is a reflection of different uptake rates, physiology and impact of environmental factors (Saha *et al*., 2006).

Caging experiments were conducted using hatchery-reared, immature, female rainbow trout (*Oncorhynchus mykiss*) in three previously defined areas of the Biobio River (south central Chile) representing a pollution gradient from the pulp and paper mill discharges area: a pre-impact area (upstream area, reference location), an impact area (area directly influenced), and a post impact area (downstream area, less influenced). These results, generated by an in situ approach, confirmed our group's findings for trout exposed to sediment in the laboratory: discharges of pulp mill effluent in the Biobio River are associated with the effects evaluated at different biological levels (Orrego *et al*., 2006).

The effects of a thermomechanical (TMP)/bleached kraft pulp and paper mill effluent (BKME), dehydroabietic acid (DHAA), hypoxia and combinations of hypoxia and effluent on juvenile rainbow trout. Reduced swimming performance
was found for fish exposed to 70% TMP/BKME. Moderate increases in mean cell hemoglobin concentration at 70% TMP/BKME and blood glucose at 30% and 70% TMP/BKME were also seen. The opposite trend for glucose was found for DHAA-exposed fish, where a slight decrease in glucose was seen at 110 and 250 µgL(-1) DHAA. The third experiment examined the effects of 15% v/v TMP/BKME exposure at 2.5 and 5.0 mgL(-1) dissolved oxygen (DO) for 4 weeks. The study demonstrated physiological effects in rainbow trout exposed to varying concentrations (15-70% v/v) of a TMP/BKME and no substantial effects of DHAA exposure. With the exception of the reduced swimming performance in fish exposed to TMP/BKME, the observed effects are considered relatively small in magnitude but are occurring at concentrations of effluent that occur in the receiving environment (Landman et al., 2006).

The textile effluents have been proved to impart adverse effects on humans, animals and plantation. Karthikeyan et al. (2006) reported that the impact of textile effluents on a proteinous edible fresh water fish Mastacembelus armatus by examining the changes in the ionic regulations of some selected tissues like liver, kidney and muscle before and after exposure to the Acid Blue 92 (CI.No. 13390). Mastacembelus armatus were exposed to sub lethal concentration of textile dye - Acid Blue 92 (CI.No. 13390) for a period of 35 days. After the exposure period it was observed that a decrease in concentration of Sodium and Chloride ions and an increase in concentration of potassium, Calcium and magnesium ions. The magnesium ion concentration increased, but only slightly, when compared to the fluctuations of the other ions. The cationic concentrations of the test individuals indicate that the impact of textile effluents has an adverse effect the ionic regulations.

Yadav et al. (2007) observed the industrial activities pose threat to the life of aquatic organisms in many ways. Their research communication presents an account of the impact of fertilizer industry effluent upon the levels of protein and
the activity of lactate dehydrogenase (EC 1.1.1.28, LDH), a terminal key enzyme in glycolytic pathway, in different organs of a fresh water teleost fish, *Channa striatus* (Bloch). The effect of effluent on the activity of LDH and protein content in different body tissues of the fish was dependent on concentration and duration of exposure. The significant reductions in the activity of LDH and level of protein in fish tissues due to treatment with the fertilizer industry effluent indicated the possibility of impairments in energy metabolism and protein turnover, respectively, in *C. striatus*.

In acute toxicity (96 hr) experiment the fingerlings of freshwater fish *Labeo rohita* was exposed to tannery, electroplating and textile mill effluents. The LC₀ and LC₅₀ 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 the electroplating effluent was more toxic than the tannery and the textile mill wastes. After acute toxicity experiments for different industrial effluents, various tissues viz. gill, liver, muscle and kidney were dissected out separately from control, LC₀ and LC₅₀ groups. The results obtained in the 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 (Muley et al., 2007).

Prabakaran et al. (2007) investigated the effect of chronic exposure to sublethal concentrations of tannery effluent (TE) on the specific immune response and nonspecific immunity in tilapia, *Oreochromis mossambicus*. The effluent from the tannery was collected directly from a chrome-tanning factory situated in Dindigul district, Tamil Nadu, India. Apart from chromium (88.2 ppm), the effluent contained appreciable amount of calcium carbonate and sodium sulphate. In their study shows, that exposure to sublethal concentrations of TE, can lead to adverse effects on selected immune reactions in tilapia. Further, these findings may be
important in terms of monitoring fish health and risk assessment during periods of fluctuating levels of pollutants in the natural and farm environments.

Cadmium (Cd), one of the twenty three heavy metal toxicants, is widely used in Ni-Cd batteries manufacture, metal and mining industry, dentistry etc. because of its non-corrosive nature. Cd is released in considerable amounts through industrial effluents into soil, surface and ground water systems. These excess amounts in addition to naturally occurring levels gradually build up to toxic levels causing damage to the biota of the aquatic ecosystem. Cd was found to interfere with many protein and carbohydrate metabolisms by inhibiting the enzymes involved in the processes. Preliminary experiments were conducted to choose concentrations that resulted in the mortality of the fish in the range of 10-90%. The elevated levels of glucose are apparently indicative of the organism’s response to the toxicant stress (Sobha et al., 2007).

Anthropogenic influence on the fish parasite fauna in lakes is studied. Three types of the influence are considered, namely pollution by industrial effluent, anthropogenic eutrophication, and development of aquaculture. Their effects on the fish parasite fauna were found to be different (Rumiantsev, 2008).

Toxic activity of mercury chloride was tested in vivo on fresh water fish *Catla catla*. Acute toxicity tests were conducted to measure the impact of toxicity on the fishes within a short period at the various concentrations of HgCl₂ (0.1, 0.5, 1, 1.5, 2, 2.5 and 3mg/L). The protein and carbohydrate were estimated using Anthrone by standard methods and enzymes such as Na⁺-K⁺, Mg²⁺ and Ca²⁺ adenoxide triphosphatases were determined by Prasath and Arivoli (2008). The biochemical estimation values of carbohydrates in muscle, intestine and brain showed significant values with P<0.05. The activity of Mg²⁺ adenoxide triphosphatases in muscle, intestine and brain was studied and the maximum depletion was observed at 96h, 72h and 72h, respectively. Regarding activity of
Ca\textsuperscript{2+} adenoxide triphosphatases in muscle, the maximum depletion of this enzyme activity in muscle was observed at all exposure periods, except 96h. In intestine, enzyme activity was gradually decreased in all exposure and an increase was found during 96h. In brain, the enzyme activity was observed at all exposure periods except 96h.

The effects of fish farming activities on the aquatic environment were evaluated by studying the water quality of twelve rivers located in northeast Spain. In order to avoid any misinterpretation due to watershed location and seasonality, a stratified statistical analysis was performed. The results show significant decreases in pH and dissolved oxygen, in contrast to chemical oxygen demand, ammonia, phosphates and microbiological parameters, which significantly increased downstream from the fish farm discharges. Other significant variations were also found for conductivity and temperature. According to the European and local regulations concerning to support fish populations, our results fell within the allowable limits for salmonid waters. Nevertheless, they suggest that further investigations should be carried out to study the ecological interactions between farmed and wild fish populations (Ruiz-Zarzuela et al., 2009).

The physiological, biochemical and histological changes in *Channa punctatus* after exposure to sublethal concentrations of the effluent of the Distillery industry have been investigated by Raveendran *et al.*, (2009). The results of acute toxicity test showed that the LC\textsubscript{50} was 25 cm\textsuperscript{3}/dm\textsuperscript{3}, which means that this wastewater is highly toxic. The results of physiological, biochemical and histological changes in *Channa punctatus* showed that, fish were under considerable stress during exposure to sublethal doses of this wastewater. Physiological response of fish revealed significant disturbances in respiratory system, fish metabolism, and ionic osmoregulation. Biochemical changes, protein, lipid and carbohydrate were recorded. Pathological changes attributed to effluents were observed in the gills, liver, and kidney.
The physiological and biochemical changes in *Catla catla* after exposure to sublethal concentrations of the Tannery industry effluent have been investigated for the period of 28 days. Two different concentrations of tannery effluents were used to carry out the experiment viz. 25 cm$^3$/dm$^3$ and 50 cm$^3$/dm$^3$. The results of physiological and biochemical changes in muscles and blood of *C. catla* showed that, fish were under considerable stress during the exposure periods to the sublethal doses. The results obtained in the present study showed that, the industrial effluents from tannery caused marked depletion in the biochemical composition of muscles and blood parameters of fish *C. catla* after the exposure period (Boominathan and Raveendran, 2009).

Tannery waste is one of the most complex and putrescible organic industrial waste causing huge amount of water pollution. Through the excessive organic load present in tannery waste the oxygen content of the waters is depleted, which leads to the death of fish and other aquatic animals. In India, Tamil Nadu is one of the largest exporters of leather. The impact of tannery effluent of fishes to changes on various biochemical parameters viz. protein, carbohydrate and lipid content of the various tissues such as muscle, liver, ovary, skin, gill, brain, heart, intestine of control fish, *C. punctatus* affline has been studied by Ramamurthy et al., (2009).

Yadav et al. (2009) reported that the impact of fertilizer industry effluent upon the levels of protein and the activity of lactate dehydrogenase (EC 1.1.1.28, LDH), a terminal key enzyme in glycolytic pathway, in different organs of a fresh water teleost fish, *Channa striatus* (*Bloch*). The fish exposed to different sublethal concentrations of fertilizer industry effluent (3.5, 4.7 and 7.0% v/v) equivalent to 1/20th, 1/15th and 1/10th of LC$_{50}$ value (70% v/v) for varying treatment periods (96 h and 15 days) exhibited decrease in the level of protein (8–76%) in different organs of the effluent treated fish. At highest effluent concentration (7% v/v) treatment for short (96 h) or long (15 days) duration, the liver of the fish registered significant ($p < 0.001$) decrease (62–76%) in protein content as compared to
control, whereas other organs of the fish showed only 38–52% decrease in the level of protein. The effect of effluent on the activity of LDH and protein content in different body tissues of the fish was dependent on concentration and duration of exposure. The significant reductions in the activity of LDH and level of protein in fish tissues due to treatment with the fertilizer industry effluent indicated the possibility of impairments in energy metabolism and protein turnover, respectively, in *C. striatus*.

The toxicity of sublethal concentrations of effluents from a soap and detergent industry on African catfish *Clarias gariepinus* using a renewable static bioassay were investigated by Ayandiran *et al.*, (2009). The trend of bioconcentration of metals in the muscle and gut of the test organisms differs significantly (p < 0.05) and it followed the order, gut > muscle. The result revealed that the muscle had the least concentration of manganese at 0.1 x 10⁻³ mg/kg and 10.7 x 10⁻³ mg/kg recorded for zinc as the highest. While the highest iron concentration of 15.80 x 10⁻³ mg/kg was recorded in the gut tissues of *C. gariepinus*, but mercury had the least concentration of 1.00 x 10⁻³ mg/kg. It was revealed that fish can bioaccumulate heavy metals from a polluted environment, which may result in impairment of natural population size; thus consumption of fish from such polluted environment should be discouraged.

The toxicity of commercial detergent effluent (containing Linear Alkylbenzene Sulfonates), a household cleaning agent was investigated with emphasis on histopathological effects using Juvenile African mud fish (*Clarias gariepinus*) with the mean weight 1.7 ± 0.2kg and standard length of 8.3 ± 0.3 cm. After series of range finding test, the fishes were exposed to lethal concentrations 0.00 mg/L, 0.01 mg/L, 0.02 mg/L, 0.03 mg/L, 0.04 mg/L and 0.05 mg/L and as well as sub-lethal concentrations 0.000 mg/L, 0.002 mg/L, 0.003 mg/L, 0.004 mg/L, .005 mg/L and 0.006 mg/L of detergent effluent for 56 days in a renewal bioassay procedure. The median lethal concentration (LC50) values for lethal and
sublethal tests were 0.0166 mg/L and 0.0038 mg/L respectively. Respiratory disturbance, erratic swimming, loss of equilibrium, lethargies and sudden fish death were observed in the exposed fish and these varied greatly with differences in concentration of the toxicant and this shows that mortality increases with an increase in concentration. The differences observed in the mortalities of *C. gariepinus* at varying concentrations were significant (*p* < 0.05), an indication that mortality could be a factor of concentration and time of exposure. The liver of the control fish showed normal parenchyma appearance of hepatocyte with normal staining patterns of the cell. In the treated fishes, there was congestion of central vein, vacoulation of hepatocyte, cellular infiltration and cellular necrosis. Detergent effluent is highly toxic to *C. gariepinus* juveniles, who are more susceptible to this household cleaning agent effluent; therefore, an indiscriminate discharge of this effluent to the surrounding should be discouraged (Ogundiran *et al.*, 2010).

Chezhian *et al.* (2010) deals with the toxicity of common mixed effluent of SIPCOT Industrial Estate on histopathological changes of gills and biochemical changes in gills, hepatopancreas and muscle of an important estuarine fish *Lates calcarifer*. When fish was exposed to 10, 15 and 20% effluent concentrations, alteration in the structure of gills was observed. In fish exposed to 10% concentration, swelling, hyperplasia, hypertrophy and proliferation of chloride cells of gills were observed, but in 15% effluent, lifting up of the epithelium and lamellar fusions were seen. In 20% effluent treated fishes, disintegration of epithelial cells, desquamated epithelium, haemorrhage and complete damage of epithelial cells of both primary and secondary lamellae were observed. Overall reduction in total protein, total DNA, total RNA, glycogen content, protein bound sugars and total lipid of gills, hepatopancreas, and muscle was observed. The biochemical changes were higher in 20% effluent treated fish than that of 15 and 10% effluent treated fish. The result of their study recommends proper dilution of the effluent before its discharge.
Radhakrishnan and Hemalatha (2010) investigation has been conducted to understand the hazardous effect of sublethal concentration of cadmium chloride solution (0.8ppm) on the histology of the liver of the fish *Channa striatus* for a period of 45 days. The histopathological changes induced in the liver were cytoplasmic vacuolization of the hepatocytes, blood vessel congestion, inflammatory leucocytic infiltration and necrosis. All these alterations in liver histology can be considered to monitor the water contaminated with heavy metal salt.

Patil *et al.* (2010) determined that the heavy metal (Cadmium) concentrations in Gills, liver, skin in the Rohu (*Labeo rohita*). Heavy metal concentration varied significations depending upon the type of fish tissues and locations. Bioaccumulation of Cadmium the fish Rohu (*Labeo rohita*) was investigated after exposed to two sub lethal concentration of Cadmium (1/10th-0.27ppm and 1/3th -0.91ppm of the 96h LC50) for 7th, 14th, 21st and 28th days. The highest/maximum level of accumulation of Cadmium was seen in the liver whereas the lower level of accumulation of Cadmium had been accumulated in the Gills at the end of 28 days of exposure period. The above investigation revealed that the rate of accumulation of cadmium was dose and time dependent.

The effects of effluent from tanning industry and its toxicity on survival, histopathological changes of snake-head, *Channa punctatus* were studied by Mohanta *et al.* (2010). Effluents are so toxic that fishes cannot survive in it even for two hours. Even dilution of the effluents by fresh water, had the same effects. However, when the fish was kept in the diluted effluents after treated with bacteria, it survived for longer period. It was also found that fishes survived longer periods after adding small quantities of glucose to the treated effluents. Fishes were dissected after 29 days of treatment to study the histopathological changes in the liver, kidney, intestine and stomach. Swelling and vacuolated formation of the hepatocytes and congestion and dilatation of sinusoidal space were observed in the
liver. In the kidney, renal tubules were severely damaged, which caused disintegration of glomeruli. Increases in Bowman's space and tubular lumen were also observed. Degeneration of columnar epithelium, necrosis at the tips of the villi and distortion of basement membrane and goblet cells were recorded in the intestine and stomach.

The physiological, biochemical and haematological changes in *Channa punctatus* after exposure to sublethal concentrations of the copper sulphate of the heavy metal have been investigated by Ramamurthy and Raveendran (2010). The toxicity effect of the two-ppm copper sulfate with respect to behaviour, and haematological paramaters of the fish *C. punctatus* studied. They observed Red blood cell count and haemoglobin content were decreased 0.9% with the increasing concentrations of the copper sulfate. However, the white blood cell count was increased 1% with increasing concentrations of the copper sulfate. A dissimilar relationship was established with respect to RBC and WBC. The constant increase in the differential count clearly indicates that the heavy metal stress certainly stimulate the white blood cells to produce more at all times of exposure. Biochemical changes of protein, lipid and carbohydrate were recorded. Such fish when consumed as food leads to the deposition of the heavy metal in the soft tissues of the human body leading to exposure to a health effects.