CHAPTER FOUR

DISCUSSION AND CONCLUSIONS

Fish is an important source of food to man from the time immemorial. A large human population depends on fisheries as a livelihood in our country. Particularly freshwater fisheries have a special significance because of their role as locally available and economically cheap supply of animal protein to poor rural people. Freshwater fisheries also provide employment to a large population. Therefore any decline in the freshwater fish resource has direct socio-economic impact on human population particularly on the poor fishermen community.

Rapid and unplanned industrialization in the recent past in rural Maharashtra has created several problems, the most important being the water pollution. The water quality of most of the streams and rivers of this region is considerably degraded due to pollution affecting the health conditions of millions of people. There have been increasing reports of epedemics of the water borne diseases like gastro, jaundice, diarrhea etc., which have become chronic in many villages on the banks of the rivers and rivulets, Panchganga river is one of them.

A growing public awareness has been observed about the riverine pollution due to sugar and distillery industry for some years and recently due to the introduction of paper mills.

Panchganga River System (PRS) suplies water for drinking, irrigation and other purposes to millions of people in two cities, ten medium and large towns and seventy six villages. There are six sugar factories, four distilleries and one paper mill which are known to affect the water quality of the river and the biota of the river ecosystem. Due to the pollution the fish catch from the river has been continuously on decline in quality and quantity (Pawar, 1988). Panchganga river a few decades ago, was known for its fish diversity which was represented by 71 fish species (Kalawar and Kelkar, 1956).

In the last 15 years there had been reports of repeated unpredicted mass fish mortalities in the areas receiving the effluents from sugar factories. This has resulted in the disappearence of a good number of commercial varieties of fish like Labeo fimbriatus completely (Samant 1988, personal communication). Also the reduction in annual fish yields have forced the traditional fishermen to search for alternative occupations (Pawar 1988). The fishermen and local people agitated on several occasions against the pollution caused by sugar and paper industry and a number of court cases have been filed against concerned industries by public authorities and water pollution board. But inspite of this there has been no change in the situation for years.

The present research problem was undertaken with the objectives to 1) observe the effects of Sugar and distillery and paper mill effluents on test fish from river Panchganga, 2) to try to determine the water quality criteria for fish based on Minimum Permissible Concentration (MPC) of the effluent and 3) to try to find out indicator fish species to develop a locally suitable and simple early warning system.

In the studies on the important abiotic factors like DO, pH, CO_2, hardness and turbidity it was observed that there was direct correlation between the increase in the effluent concentrations and values of the abiotic factors. However, there was no significant impact of temperature fluctuations, on the test fishes as all the species used in the experiment were warm water species and the experiments were conducted with in the prescribed limits i.e. 23°C to 27°C temperature of tho medium (Albaster and Lloyd, 1982).

The sugar and distillery effluent lowered the pH and DO values and increased hardness, free CO_2 and suspended particles in the medium. Anaerobic conditions due to release of spentwash have been reported by Banerjea and Motwani (1960). Low pH due to increased effluent has been reported by David and Ray (1966). According to some workers discharge of spentwash results in the precipitation of ferric ions, which affect the respiratory activities in fish by choking their gills through fine deposition, Klein (1972), Verma and Dalela (1975).

The paper mill effluent also increased hardness and suspended particles in the medium. However, there was little increase in carbon-di-oxide and no significant alterations in pH levels. Higher concentrations of effluent reduced dissolved oxygen to a significant level. . Reduction in oxygen levels due to paper mill effluent has also been reported by Banerjea and Karamchandani (1956), Verma et al. (1977) and Ganapati and Chako (1951).

The comparative study of concentrated spentwash and paper mill effluent revealed following facts.

i) 10 % spentwash reduced pH levels of water from 7.5 to 5.5, i.e. from near neutral to acidic while 100 % paper mill effluent changed it slightly from neutral to alkaline i.e. from 7.5 to 8.0.

ii) 10 % spentwash increased hardness of water from 41.66 to 399.2 mg $CaCO_3$/lit, while 56 % paper mill effluent changed hardness of water from 41.66 to 190.96 mg $CaCO_3$/lit.

iii) The 10 % spentwash increased turbidity of water from 6 to 350 JTU while change in turbidity values in paper mill effluent were from 6 to 188 JTU in 56 % concentration.

iv) The 10 % concentration of spentwash decreased dissolved oxygen values from 6 mg/lit to a low level of 1.0 mg/lit in 48 hr and absent at 96 hr. In the same period 80 % paper mill effluent lowered DO level to 0.1 mg/lit.

v) A large quantity of free CO_2 was produced by spentwash. In 56 % concentration of paper mill effluent 49 mg/lit of free CO_2 was recorded while in only 10 % of spentwash an exceptionally high CO_2 value of 400 mg/lit was observed. According to Doudoroff (1957) the free CO_2 values are rearely above 25 ppm even in polluted waters. In spite of the high values of CO_2 found in the spentwash mixtures fishes survived at 3.2 % concentration. Which was unusual as persistant CO_2 concentrations between 100 to 200 ppm, is known to rapidly kill moderately susceptible freshwater fishes in well oxygenated waters and concentrations between 50 and 100 ppm can cause immediate distress (Doudoroff, 1957).

The apparent explanation to these unusually high values of CO_2 is as follows, the parameter was recorded in freshly collected effluent and immediately prepared samples, without any time interval and before introduction of test fish. Due to the high values of free CO_2, above saturation level, in the test medium the gas may be starting to dissipate in the air after the medium was prepared. The initial agitation of the fishes and turbulance created in the test medium due to their constant movements must be helping the process of "freeing" of the saturated gas at the surface layer from the test medium.

The comparison of the two effluents studied revealed that the effects of spentwash even at lower concentrations were more acute than paper mill effluent. Also according to Ketkar (1984) the characteristics of pulp mill effluents are not as intense as distillery effluents.

The behaviour of any organism is considered as the response to the stimulus and therefore an abnormal behaviour indicates that the stimulus could be harmful. Hence behaviour of fish in this respect may be informative. Whenever the fish encounters a pollutant its behavioural pattern could throw light on the nature of the pollutant. The fish will react to the effluent according to the characters of the components and their intensity. If the pollutant is less harmful the fish, after its initial restlessness would resume the normal activities. On the contrary if the pollutant is severe the fish would show abnormal behaviour. Therefore it is possible to determine the nature of the toxicant which will be helpful in detecting and establishing the causes of mortality in fish in the natural environments.

Literature available on fresh water fish behaviour is.

limited Skidmore and Tovell (1972), Basak and Konar (1976) and Chatterjea _et al._ (1983). There is no particular information on fish behaviour of the test fish species as response to the two pollutants studied during the present investigations.

In the behavioural studies on the impact of effluents on fish it was observed that the loach _L.guntea_ showed agitated and rapid vertical movements, and at the terminal stage it stood diagonally in static position at the bottom. The common rabora _R.daniconius_ became dull and swam slowly in the effluent. The giant danio _D.acquipinnatus_ lost its peculiar chasing pattern; the glass fish _C.nama_ and the loach _B.striata_ were found lying on sides, in medium concentrations of the effluent. Similar observations of rolling on sides were observed in rainbow trout. _Salmo gairdnerii_ and cutthroat trout _S.clarkii_, when exposed to acute toxicities of ammonia (Thurston _et al._, 1981). The loach _B.striata_ showed a peculiar movement of floating on back, such a type of behaviour was also noticed in rainbow trout and cutthroat trout when exposed to acute ammonia toxicity by the same worker. The catfish _M.malabaricus_ although a bottom dweller was found during the experiments, restricted to the water surface. It displayed sinous movements and at the terminal stage it was observed standing diagonally at the bottom. All these peculiar movements were not observed during the period of fish acclamatization and in the control acquaria during the experiments. Therefore they could be alabelled as abnormal behaviours and considered to be the indications of unhealthy state to which the fish were exposed.

Frequent visits to the surface and gasping for air at the final stages was noticed in almost all the test fish species. This clearly indicated the low levels of dissolved oxygen in the medium obstructing breathing of fish. Suffocation accompanied with air bubbles as was noticed in C.fulungee and T.mossambica was an indication of toxic nature of the pollutants according to Metelev et al. (1983). Thus by observing behaviours, the type of environmental conditions in which the fish was exposed could be predicted.

In the present investigations, most of the abnormal behaviours of the test fishes were more prominently noted in Sugar and Distillery Effluont while the same werc comparatively less prominent in paper mill effluent. This was perhaps because of the different nature and degree of toxicity of components in the two effluents.

An abundant secretion of mucous especially around gill sites and signs of hemorrhage at some areas indicate poisons with local effects (Metelev et al., 1983). In the present studies abundant secretion of mucous was noticed particularly when the fish were exposed to spentwash. This is also observed by Davis (1973) in the impact of paper mill effluent on sockeye salmon. During the studies, signs of hemorrhage at gill sites were noticed in case of loach L.guntea and the catfish M.malabaricus in catfish signs even of subcutaneous hemorrhage were noticed. These observations indicated that spentwash contains components with local effects which cause mechanical injuries to the gills. This perhaps was the reason why fishes reacted strongly in spentwash as they have immediate effects.

Both, behavioural studies and physico-chemical observations revealed that the spentwash had drastic effects on the receiving water and was more toxic to fishes than the paper mill effluent.

Whenever fish mortalities occur, in the natural freshwater systems after death studies would be useful for the detection of the cause of mortality. Because the secretion of mucous and signs of hemorrhage would indicate the possible cause and mortality i.e. whether the mortality was due to spentwash or paper mill effluent. The observations in the catfish studied would be particularly significant as the species could be used as an indicator of the type of pollution.

The results of bioassays clearly indicated the toxicity of the effluent. The results were used to find out the most sensitive species and also for the determination of the Maximum Permissible Concentrations (MPC) of the effluents to be released in the aquatic medium.

On the basis of LC_{50} values the fishes studied could be grouped as Sensitive, Resistant and Intermediates. In case of spentwash fishes having 48 hr LC_{50} value for less than 2 % conc. were considered as sensetive. Those above 3 per cent conc. as resistant and those falling between these two ranges as intermediates. Similarly, for paper effluent the sensitive species were those which had 48 hr. LC_{50} value below 10 per cent conc., resistant sp. had 48 hr. LC_{50} value above 20 per cent conc. and intermediates fell between these two ranges.

The table no. 29 shows that the catfish M.malabaricus was the most sensitive species for spentwash (48 hr $LC_{5}0$ 1.07 % conc.) and for the paper mill effluent (48 hr. LC_{50} 7.58 % conc.). Among all the test fish species studied, the cichlid T.mossambica was the most resistant species for spentwash (48 hr LC_{50} 3.17 % conc.) and the guppy L.reticulatus was the most resistant species in paper mill effluent (48 hr LC_{50} value 75.88 % conc.).

From the observations made during the experiments it became clear that sensitivity and resistance of an individual species differ in different pollutants.

The two effluents when compared on the basis of LC_{50} values, certain similarities and astonishing differences were revealed. As far as the sensitivity is concerned it is the catfish M.malabaricus which was sensitive for both the effluents. Therefore it can be considered as an indicator fish species of Sugar and distillery and paper mill pollution. While L.guntea and T.mossambica were most resistant to both the effluents. Similarly the carp C.fulungee, the common rasbora R.daniconius, the bitter carp P.sophore were intermediate in their response towards both the effluents. Differences were noted in some species such as the giant danio D.aequipinnatus, the hill stream fish G.gotyla and the loach B.striata. These fishes were sensitive to spentwash but were intermediate to paper mill effluent.

The interesting observations were made in case of guppies. The guppies L.reticulatus were most resistant to paper effluent (48 hr. LC_{50} values 75.88 per cent conc.) but the same species was found sensitive towards spentwash (48 hr. LC_{50} value barely 1.11 per cent conc.). The guppies when exposed to paper effluent had been found to survive even at negligible oxygen conc. i.e. less than 1.5 mg/lit where other fishes failed to survive. The fish was able to survive at such low oxygen concentrations perhaps because of its potentiality to use the surface film by coming to the water surface and nibbling at it without taking in air, this was also recorded by Brown (1957). On the contrary in spentwash, comparatively at higher oxygen concentration, the fish was unable to survive. This may be atributed to other factors, the important being the poisons with local effects damaging the gills, which the tiny fish was unable to withstand.

The fishes C.nama and M.malbaricus were found equally sensitive in both the effluents, this was striking because the perch which although appeared fragile was reported to be actually a hardy fish (Hora and Mukerji, 1938). Therefore its sensitivity towards both the effluents could not be explained.

The sensitivity of the catfish M.malabaricus is puzzling because they are capable of amphibious respiration. They can respire with gills like most other fishes in addition they can inhale atmospheric air, whenever the water goes foul or oxygen deficient, a facility enjoyed by many tropical fishes. Therefore, in effluents, where oxygen deficiency is one of the chief problems, it is expected that fishes having amphibious respiration should withstand better than the ones without it. The sensitivity of the fish could be explained as follows :

Respiration in fishes is carried out normally 1) with a gaseous exchange at gill level and 2) in addition to this by taking in atmospheric air directly in buccal cavity where it oxygenates the blood. It is the second property that makes the amphibious fish capable of withstanding foul medium and oxygen deficient areas. The fishes having these two modes of respirations if placed in a water tank across which a net is inserted below the water surface so as to prevent their access to the atmosphere. In the first category i.e. where oxygen is absorbed at the gills, the fish remain unaffected whereas those in the second category the amphibious fishes die due to blood poisoning (Day, 1958). Therefore, it appears that the catfish would withstand the effluent which merely depleted the oxygen in the ambient circumstances. But, when the effluents are accompanied with toxic substances chances of blood poisoning in buccal cavity are more due to the large surface area for the absorption of poisons; and as both spentwash and paper effluent contain toxic substances the catfish is bound to die earlier despite the advantage of amphibious mode of respiration. Possibility of toxic action through lining of mouth has been discussed by Ellis (1937).

The hill-stream fish G.gotyla is an inhabitant of rapidly flowing waters and in such fishes oxygen demand is high. Therefore, these fishes were very sensitive to oxygen deficiency. Therefore as per expectations the fish was sensitive towards spentwash and by fractions only it was included in intermediate group in the paper effluent (48 hr. LC_{50} 10.00 % conc.).

The loach B.striata has been found sensitive towards spentwash and intermediate towards paper effluent. When compared with its allied species L.guntea, the loach B.striata seems to be more sensitive. Thus it appears that taxanomically allied fishes need not have the same response to a pollutant. The sensitivity of B.striata towards spentwash can be explained on the basis that Botias have a disliking towards acidic mediums which prove lethal (McInery & Gerard, 1966).

While the bitter carp P.sophore, the common **rasbora** R.daniconius and carp C.fulungee are intermediate in response towards both the effluents. Although these fishes are commonly found in river waters they also inhabit standing waters. In general, fishes inhabiting fast waters and with high metabolic rate are more sensitive to dissolved oxygen fluctuations while those adapted to standing water and with low metabolic rate are resistant (Metelev et al., 1983), this explains their less sensitivity to the test pollutants.

In the present investigations 48 hr LC_{50} values were used as a criteria to determine minimum permissible concentration (MPC) of pollutants in the receiving waters. Usually, effluents associated with 1 to 10 % of the LC_{50} value concentrations is assumed as the permissible concentration so as to avoid any loss of fish (FAO, 1971). In the present investigation the 48 hr LC_{50} values of M.malabaricus are taken to determine the permissible concentration because it had been found the most sensitive species against both the effluent i.e. Sugar and Distillery Effluent and Paper Mill Effluent. The 48 LC_{50} value of M.malabaricus against spentwash was 1.07 mg/lit while 7.58 mg/lit against Paper Mill Effluent. 1/10th of these two values are 1 and .75 mg/lit. Therefore it is recommended that the concentration of spentwash should not exceed .1 mg/lit and paper mill effluent should not exceed .75 mg/lit in receiving waters of Panchganga river. Water quality criteria maintained on this basis will safegaurd the fish and fisheries of the river in future, from the adverse effects of the two effluents.

The objectives of these tests were to establish an approximate permissible concentration of a substance likely to be hazardous to fish and fisheries in the natural fresh water environment. Results obtained rom such tests are only a rough guidelines to the ecological implications of the appearance of this substance in the environment and can not be used for an accurate prediction of the risks involved because accumulative toxicity can not be predicted from acute toxicity bioassay results.