V SUMMARY

In India, the rivers play an important role in the life of people because these are mostly used as a source of water for drinking, bathing, irrigation, recreation and for other miscellaneous purposes. In addition, the rivers are also used as a sink for dumping of domestic waste and effluents from the industries. These have naturally threatened water quality of the rivers. All the major rivers of India are highly polluted; the worst polluted rivers in the country are the river Mahe in Baroda, the Ganges in the parts of Uttar Pradesh, Bihar and West Bengal, the river Moosi in Hyderabad, Vaigia near Madurai, the Yamuna between Delhi and Agra, the rivers Cooaum and Adiyar in Madras city. The Narmada, the Tapti, the Krishna, the Pennar, the Godavari and Suvarnarekha are also seriously polluted along different stretches. In Karnataka, the studies on the river Cauvery, Kabini and Hemavathi have revealed that they are also polluted at certain stretches. The river Tungabhadra is no exception to this. The most common pollutants of water are chemicals. Some chemicals occur naturally in water; others are introduced during water movement through geological materials. However, most problems are caused by manufactured chemicals. Industrial effluent discharged is another major contributor to chemical pollution in the riverine systems. Therefore, there is a great need for the ecological investigation on any riverine system, before it is used for the benefit of human welfare.

It is with this background, the present work was undertaken for a period of two years on the river Tungabhadra near Harihar to study the physico-chemical and biological characteristics and their inter-relationships. The work carried out deals with the occurrence and distribution of planktonic flora during the different seasons of the study period. It also deals with the impact of industrial effluent on the river water quality. Four sampling stations along the river stretch were selected to assess the water quality of the river. Station-I is located near a village
called Rajanahally; station-II near Raghavendra Swamy Mutt, station-III near the industry and station-IV near a village called Nadiharalahally.

Water samples from each of the four stations were collected at an interval of 30 days and carefully analysed for various physico-chemical parameters following the established techniques. Simultaneously, the phyto-plankton occurring at these stations were collected, identified, counted and recorded. The relationship between various physico-chemical parameters and in turn their influence on regulating the plankton population has been evaluated.

**Physico-chemical complexes:**

It is observed that, the colour of the water was clear at station-I, while it turned muddy at station-II but remained always brownish near station-III. The same colour persisted at station-IV. Air and water temperatures do not seem to fluctuate largely, although slight variations exist in different seasons. The air temperature of the sampling stations ranged between 28.91°C to 30.75°C while that of water temperature varied from 26.54°C to 28.83°C.

The river water was alkaline at station-I (7.64) and station-II (7.98), while it was more acidic at station-III (5.9) and slightly acidic at station-IV (6.2). Electrical conductivity was more at station-III followed by station-II (269 mho and 149.24 mho respectively). The turbidity values ranged from a minimum 4.0 NTU at station-I to a maximum of 70 NTU at station-III. The values were found high at station-III when compared to other stations.

Dissolved oxygen was always above 5.0 mg/l at stations I, II and IV while it was very low at station-III (1.5 mg/l). The temperature and dissolved oxygen exhibit an inverse relationship with each other.

The content of free carbon dioxide varied from a minimum of 2.9 mg/l at station-I to a maximum of 14.0 mg/l at station-III and it showed an inverse relationship with dissolved oxygen. Biological oxygen demand values were found
to be low at station-I (1.0 mg/l) and high at station-III (154.0 mg/l). In general, biological oxygen demand is found more during summer and less during rainy seasons. Chemical oxygen demand ranged between 2.9 mg/l at station-I to a maximum of 21 mg/l at station-III. Seasonally, it was high during summer at station-III.

Total solids ranged between 212 mg/l at station-I and 3200 mg/l at station-III. pH and total solids remained proportional to each other except at station-III wherein, they behave indifferently.

Total hardness reached a maximum of 162 mg/l at station-II and recorded to be low at station-I (74.0 mg/l). Seasonwise and stationwise, their behaviour is rather irregular.

Bicarbonates varied between 1.1 mg/l and a maximum of 14.9 mg/l. Carbonates were absent for the major part of the study and whenever present, their concentration was very low and ranged from 0.5 mg/l to a maximum of 0.83 mg/l. Carbonates and pH are inversely related, bicarbonates and calcium go hand in hand.

Chlorides reached a maximum of 115.9 mg/l and to a minimum of 16.9 mg/l. The content of chloride was more at station-III, which is polluted. Sulphate content fluctuated between a minimum of 52 mg/l and a maximum of 378 mg/l and is high during winter season and low during rainy season. Calcium and magnesium were in the range of 10.0 mg/l - 102.0 mg/l and 3.9 mg/l - 19.0 mg/l respectively. Sodium fluctuated between 42 mg/l - 86 mg/l while potassium ranged between 8 mg/l - 26 mg/l.

It is found that at all the stations, sodium invariably greater than calcium. The sequence of relative concentration is Sodium > Calcium > Potassium > Magnesium. Interestingly, magnesium is found to be least of all cations at all stations.
Iron concentration is low and varied between 0.02 mg/l and 0.08 mg/l while that of phosphate values fluctuated from 0.06 mg/l to 0.21 mg/l. Phosphate and dissolved oxygen do not exhibit any relationship with each other.

Both nitrite and nitrate are more at station-II and less at station-I. Seasonally, they were high during summer.

The ammonical nitrogen content did not exceed 2.7 mg/l even though station-II and station-III received domestic and industrial waste respectively. Fluoride ranged between 0.4 mg/l and 0.9 mg/l.

Silicates were recorded in the range of 0.42 mg/l to 0.60 mg/l and were high during summer months and low during winter in station-I and station-IV, while it is low in rainy at station-II and III. In general, the content of silica was barely detectable. The content of dissolved organic matter was found to be low. Dissolved organic matter and nitrates show a positive relationship with each other.

All the physico-chemical parameters estimated in the river Tungabhadra near Harihar were compared with ISI and WHO standards stipulated for drinking purpose. All the parameters are within the permissible limit except at station-III and station-IV.

**Periodicity and Distribution of Phytoplankton:**

In the present investigation, phytoplankton were studied for their distribution and periodicity. Five groups of phytoplankton have been recorded in the river stretch under investigation. They are Chlorococcales, Desmids, Diatoms, Blue-greens and Euglenoids. Only one species of Rhodophyceae has also been recorded. Diatoms constituted the total bulk of planktonic population representing 43.40% followed by blue-greens with 29.48%. Chlorococcales occupy third place with 17.29%. Desmids were recorded to be the least representing as 2.01%.
Chlorococcales are found to be accelerated by dissolved organic matter, free carbon dioxide and bicarbonate in lower concentration. Dissolved oxygen does not show a clear bearing on the distributional pattern of Chlorococcales. Chlorococcales and total solids have an inverse relationship. In general, 18 genera and 41 species were recorded. Of which, Scenedesmus dimorphus, Scenedesmus bijugatus, Scenedesmus protruberan, Schroderia setigera, Ankistrodesmus falcatus, Chlorella vulgaris, Dictyosphaerium pulchellum, Korshikoviella limnetica, Pediastrum simplex, Pediastrum duplex and Tetraedron muticum were found to be common at all the stations. Seasonwise, chlorococcales were found more during summer.

Desmids were represented by only 2.05%, occupying the last position in their number. In all, 7 genera and 21 species were recorded. Calcium and dissolved organic matter coupled with high dissolved oxygen favour the abundance of desmids. They are found to thrive when there is lower concentration of nitrates and phosphates. The occurrence of higher amount of total solids at station-III did not support the maximum growth of desmids.

Seasonally, desmids are high during summer and low during winter season. Closterium remarginatum is the only representative that occurred at all stations, with its varying numbers. Cosmarium corda, Staurastrum sebaldi and Staurastrum hexacerum were the dominant forms recorded at station-I and station-II.

Diatoms form the basic bulk of the planktonic population in the river stretch and represented by 43.40%. They dominated at station-I and station-II. In general, 40 genera and 54 species were recorded. Of which, Amphora ovalis, Cymbella affinis, Eunotia gracilis, Fragellaria construens, Gomphonema sphaerophorum and Navicula dicephala appeared as dominant forms. Calcium does not seem to have an impact on diatom population. Acidic pH favours the reduction in diatom population, while alkaline waters are found to promote their
abundance. Higher amounts of dissolved oxygen supported diatomic population at station-I and station-II. Low carbon dioxide favours the abundance of diatoms. Periodicity of diatoms indicates that they are rich both qualitatively and quantitatively at station-I and station-II. Seasonally, they are rich in summer season and poor in winter season except at station-I.

The behaviour of blue-greens was found to be rather peculiar. Of the four stations, station-III is considered to be a polluted one, harboured a maximum number of blue-greens. *Lyngbya martensiana, Merismopedia tenuissima, Merismopedia elegans, Merismopedia punctata* and *Oscillatoria acuta* are the most dominant forms that were recorded at all the stations. In general, 9 genera, 17 species were observed. Dissolved organic matter at higher concentration, acidic pH, high temperature and high calcium appear to have a significant bearing on the distribution of blue-greens at station-III. Blue-greens are represented by 29.48%. No bloom formation was noticed during the period of investigation. Seasonwise, their behaviour was not well marked.

Euglenoids occupied fourth place in their dominance and were represented by 7.806%. Stations-II, III and IV were rich in euglenoids, while station-I contained lower number of euglenoids. A total of 4 genera and 26 species were recorded during the study. Of which, *Euglena oxyuris, Phacus circumflexus, Phacus cylindricus* and *Trachelomonas superba* occurred at all the stations. High temperature, phosphate and iron favoured the development of euglenoids at station-III. No uniform behaviour has been noticed with regard to their periodicity during different seasons at all stations.

*Compsopogon* is the only representative of fresh water Rhodphyceae that appeared all through the period of study at station-III. However, it was not recorded in the rest of the stations under study.

Pollution index value obtained reveals that station-III is highly polluted, station-II and station-IV are moderately polluted and station-I is less polluted.
With regard to the fish population, in the stretch under study, they were recorded only at stations-I and II and were never found at stations-III and IV.

Physico-chemical parameters are significantly inter-correlated with one another. It has been further analysed for simplification and few important parameters which explain most of the parameters have been identified which are calcium, total solids, dissolved organic matter, sulphate, biological oxygen demand and turbidity. Water temperature shows significant relationship with ammonical nitrogen, phosphate, iron, potassium nitrite and nitrate and negative relationship with dissolved oxygen and silica. $pH$ shows negative correlation with biological oxygen demand, total hardness, turbidity, free carbon dioxide, carbonates, bicarbonate chlorides, phosphate, sulphate, iron, potassium, nitrite, but positive relation with silica. Biological oxygen demand has positive correlation with total solids, calcium, turbidity, free carbon dioxide, carbonate, bicarbonate, chloride, dissolved organic matter, Ammonical nitrogen, phosphate, sulphate, electrical conductivity and chemical oxygen demand. Total solids have positive relation with magnesium, calcium, turbidity, free carbon dioxide, bicarbonates, carbonate, chlorides, dissolved organic matter, sulphate, electrical conductivity, chemical oxygen demand. Total hardness has positive correlation with carbonate, bicarbonate, ammonical nitrogen, potassium, nitrite, nitrate negative with silica. Calcium shows positive relation with magnesium, turbidity, free carbon dioxide, carbonate, bicarbonate, fluorides, dissolved organic matter, sodium and chemical oxygen demand but negative with silica.

The group chlorococcales shows negative correlation with most of the physico-chemical parameters while desmids and diatoms show positive relationship with $pH$, dissolved oxygen, silica. Blue greens and Englenoids show negative correlation with dissolved oxygen, silica and positive correlation with most of the parameters.
The inter-correlation between different groups of phytoplankton indicate that chlorococcales show a positive relationship with bluegreens followed by diatoms, euglenoids and desmids. Desmids have negative correlation with bluegreens and euglonoids and positive relation with diatoms. Whereas, diatoms have negative relation with euglonoids and blue-greens. Blue-greens have positive correlation with euglonoids.

All over the world, people are migrating to cities expecting improved standards of living. The additional urban population in less developed regions in the next few years roughly equal to the current total population in India. This tendency puts extreme stress on water supply and sanitation authorities. Water scarcity makes recycling and rainwater harvesting as city grows. Achieving safe sanitation for all would demand Herculean efforts. A technical flow of water through the city is a necessary condition not only for the survival of the population in such artificial surroundings, but also for the functioning of hospitals and other city components.

Water supply and sanitation are essential precondition for stability. In addition, severe industrial pollution may threaten the stability of cities. There are new signs of city collapses where accessible water is beyond usability. In certain catastrophic situations, provision of safe water supply is an essential component in the efforts of rescue and help in stability. Therefore, functioning water supply and waste management systems, whether natural or man-made are crucial for the stability of a city.

The data generated during the present investigation has clearly indicated that the river stretch near Harihar City is polluted as a consequence of the discharge of the effluent. The quality of water has been deteriorated causing the elimination of the biological components particularly fish fauna. Therefore, it is imperative that the industrial effluent has to be treated carefully to such an extent that the chemical load in the effluent is removed completely. If this is achieved, it
is possible to restore the river system from further damage and deterioration of the water quality.

Suggestions to treat the effluent effectively are:

The treatment plant, which is now operating is not capable of reducing the chemical load completely and to avoid high expenditure, the system, works hardly. Regarding the efficiency of the treatment plant, it is noted that it can not take up the effluent load for proper treatment. Therefore, the unit has to be modernized. It is necessary to install online dissolved oxygen meter to record the oxygen readings of the effluent. The industry has to take up measures to establish an anaerobic lagoon for the biological treatment of the effluent.

In order to minimize the solid waste disposal problems, the surrounding areas where fly ash is dumped, be given impervious soil cover and suitable type of green belt vegetation to be developed. Installation of flow measuring devices for inlet and outlet points of the treatment units is very essential. For pH, a continuous monitoring arrangement has to be provided. In aerobic lagoons, all aerators should be operated (presently four out of ten are working). The depth of anaerobic lagoon should be increased at least by another 1.5 mts to avoid silting and to get the desired reduction in biological oxygen demand level (At present, the depth is only 3 mts and is already silted). The combined effluent should be given treatment in an anaerobic lagoon and an aeration tank; the process will be more efficient and compact to the existing plant.

Further, the effluent has to be treated according to the standards fixed by the pollution control boards before it is discharged into the river. Even after that, there should be a constant monitoring of the water quality. If the authorities do not follow the regulations stipulated by the Pollution Control Board, they should be punished through the environmental laws.
The authorities of Harihar Municipality should be instructed to set up a sewage treatment plant at the earliest for the treatment of municipal waste. Nowadays, the dumping of solid waste on the banks of the river is a common practice. This should be completely banned without any delay as it contributes pollution load into the river.

Agricultural practices are quite common near the banks of the river which bring about lot of run-off into the river, containing residues of fertilizers and biocides which contaminate the water, thereby deteriorating the quality of the river water. Hence, such agricultural operations near the banks should be minimised. In place of chemical fertilizers, the farmers should be advised to use biofertilizers, which do not cause any harmful effect on the quality of water. The authors when enquired about the impact of water pollution, most of the villagers of Nadiharalahally complained about the health hazards like peeling of skin, frequent occurrence of skin rashes, irritation and itching of skin. Therefore, awareness among public with regard to water pollution should be created through mass media programmes. Eco-clubs and environmental-protection communities are to be set up at the village level to educate the people about the importance of water and its sustainable use.

As on today, the two upstream stations are moderately polluted and if proper measures are adopted, the water quality could be improved. If controlling measures are not taken up right now, the quality of water further deteriorates. While the rest of the two downstream stations are highly polluted. In this context, it is very necessary to take measures for preventing irreversible damage to the quality of water.

On the basis of percent plankton and percent chemical concentration station-I and station-II are rated as productive, while stations-III and IV are chemically productive with relatively less percentage of phytoplankton. Since all the stations of the present river stretch are basically productive, they are amenable
for exploitation for the benefit of human population, provided the pollution load is eliminated.

The challenge is to provide a new and improved basis for the conservation, rational and sustained utilization of the aquatic resources. This, however, can not be pursued in isolation. It calls for deliberations by environmental planners, social scientists and biologists, so as to give a holistic approach to the developmental needs.

Future success of water pollution control programmes in this country depend on how far best we can improve our city sanitation. The 4-R concept of ‘Recycling, Renovation, Recharge and Reuse’ has been successfully tried in developed countries for treatment of waste water. In case of industrial waste the adoption of low waste or no waste (LWNW) technology is inevitable for increasing treatment cost which can be achieved by the following programmes:

- Use of cleaner technology through process modifications and material substitution and
- Recovery of valuable materials from waste water and recycling of water through cascade mechanism.

In the case of prevention of pollution, judicious siting of industries keeping the practice of basinwise water quality management should not be lost sight off. Above all, the techniques of environmental auditing by both the industries and the pollution control boards need to be upgraded for better pollution control and management. If this is achieved, we can prevent further deterioration of the water quality in riverine systems.