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BIOMONITORING OF INLAND WATER : PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS OF RIVER MUSI AT HYDERABAD ANDHRA PRADESH, INDIA.

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INTRODUCTION

The close dependence of man on water for life accounts for the association which has existed between him and several rivers over centuries. In the process of dependency, of using surface water for development, man has interfered so much, streams, rivers and lakes that are now, can be hardly called natural. Water was being withdrawn excessively and faunal associations and population balances have been grossly affected by disturbances, where the water flow is checked by barrier, ecological systems have been drastically changed down stream and water quality is affected by dissolved and suspended matter. Furthermore, surface water is often used for the disposal of human waste, and industrial effluents ; the organic and inorganic material thus introduced into them in this way affected the delicately balanced ecosystem.

The effect of these modifications in tropical water is not understood properly. Only limited studies have been carried out by Venkateswarulu (1976, 1981, 1986) on river Musi on the interrelationship of algal distribution. The present study was undertaken to understand the distribution of faunal components in clean and polluted zones of the river Musi for a period of two years.

RIVER MUSI

The river Krishna rises near Mahabaleshwar at 1360 m above msl and flows towards east (1400 km) to join Bay of Bengal (Figure 1). River Musi, a tributary of Krishna originates from Anantagiri hills of nearby Medak district of Andhra Pradesh. It traverses nearly 240 km and joins Krishna at Wazirabad, 40 km below Nagarjuna sagar reservoir. In the entire basin, a semi arid condition prevails and as a result, most part of the year the flow is very less. In addition, to augment the drinking water facility to the city of Hyderabad, and also to check flash floods, two reservoirs have been constructed along its cource *viz.* Himayat sagar and Osman sagar in the peripheral

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area of the city. The flow of the river is therefore, controlled by the sluice gates of these two reservoirs.

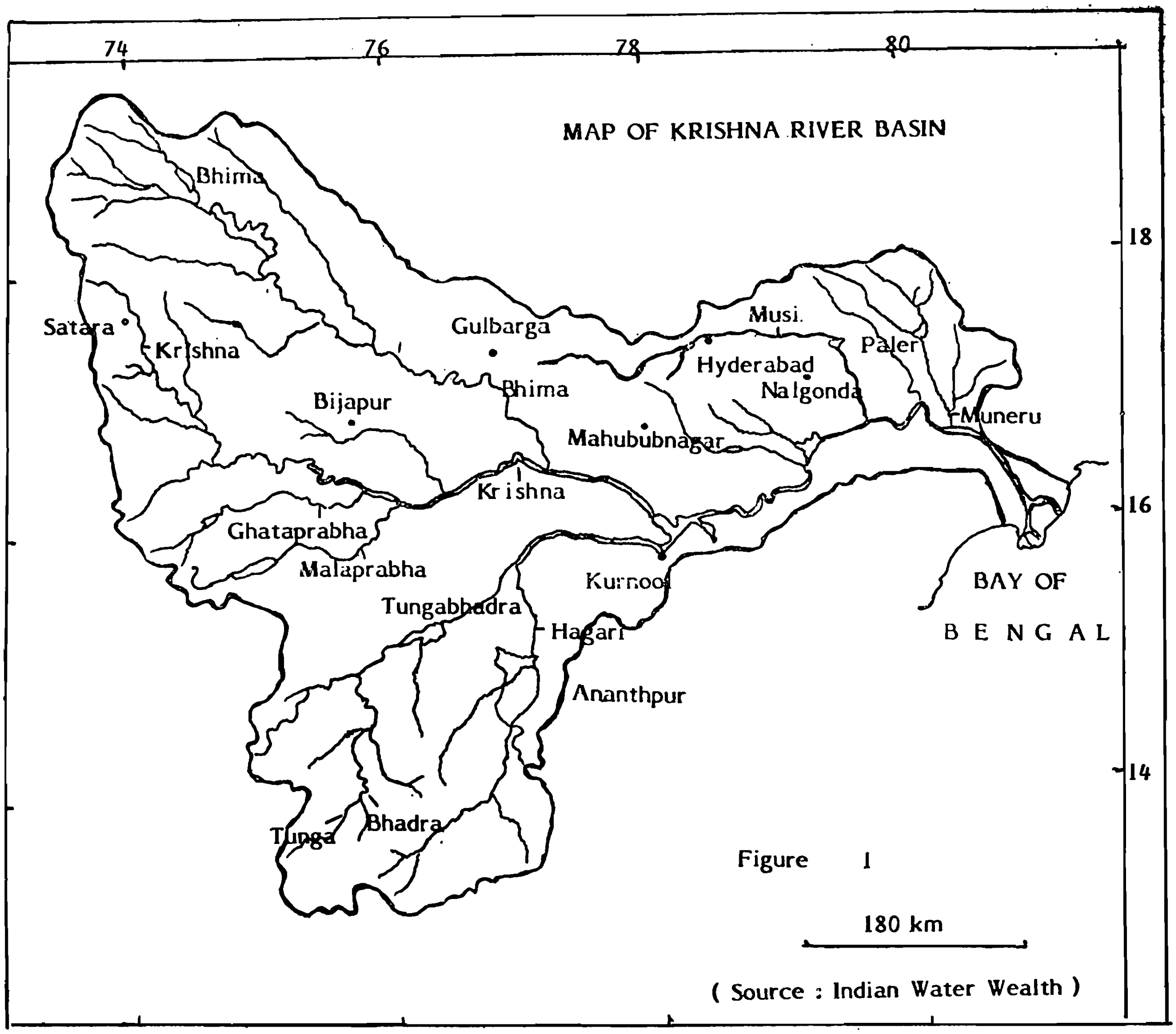

Fig. 1. Course of River Musi in the Krishna River Basin.

The river along its cource in the city flows over rocky bed and receives waste water at various points. The major source of waste water entering the river are 1. the return canal from highly polluted lake, Husain sagar passing through the middle of the city, 2. seepages from Burning ghat, sewage treatment plant, washing ghat, slaughter house, hutments on the river bed etc. and 3. effluents from automobile industry and dumping wastes from various sources along its bank ; all resulted in the deterioration of the water quality.

Sampling Stations

Sampling stations were marked for periodic collection and analysis as in figure—2. Sampling station—1 represents the area in the upper tributary receiving seepages

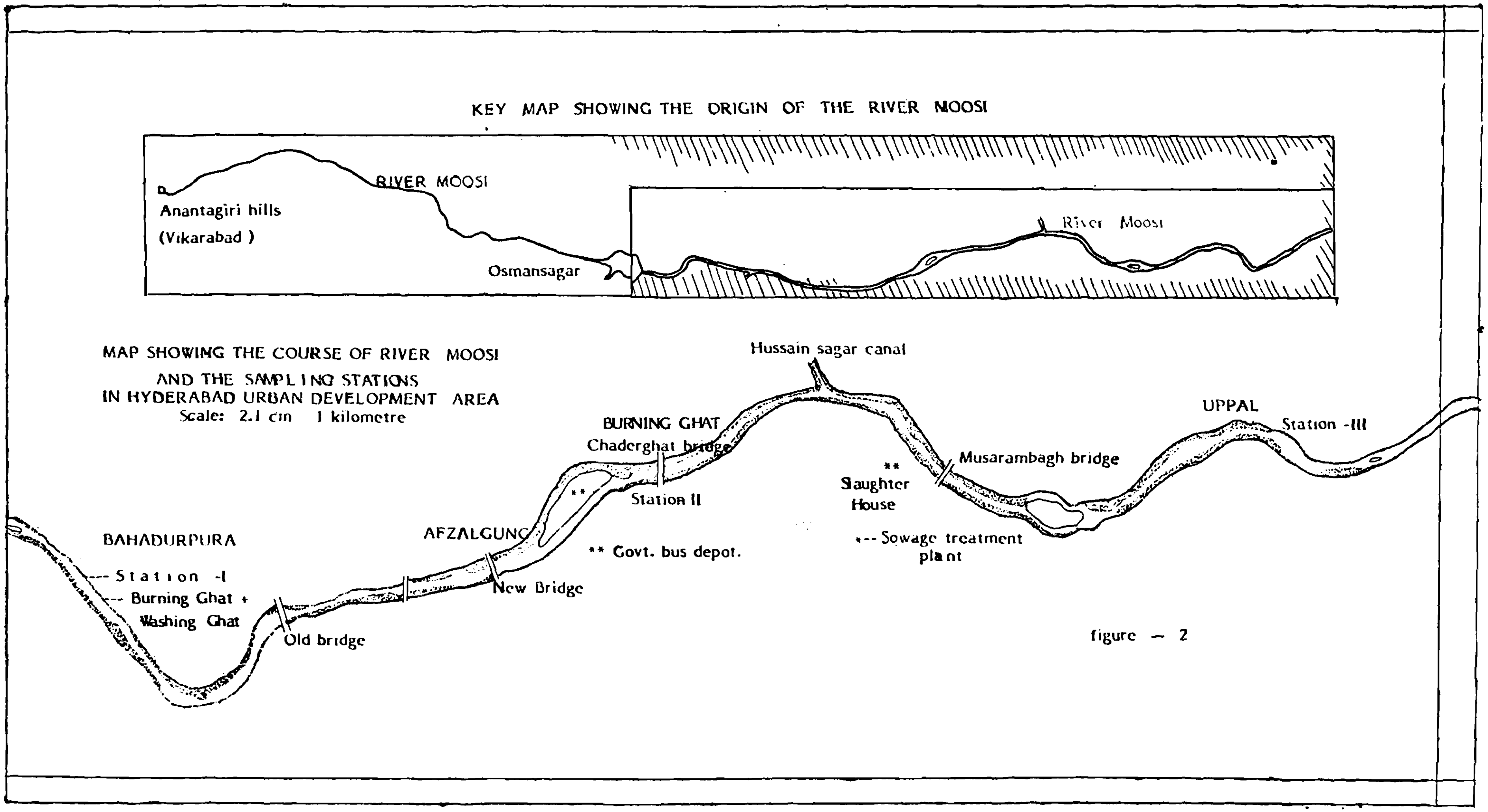

Fig. 2. Origin, course and sampling stations of River Musi.

from Mir Alam tank passing through zoo garden with substrate predominantly of of boulders and black soil. Sampling station—2 located in the middle of the city devoid of any boulders but with grass cultivation along its bank. Sampling station—3 is located on a less densely populated area, outside the city limits receiving run-off from slaughter house, sewage treatment plant, grass land, industrial and domestic wastes. A rich growth of *Eicchornia crassipes* was found as free floating plant. Moderate flow was noticed in this sampling station-4 was located at about 150 km. from the city limits, almost near its confluence with river Krishna at Dameracherla, wherein, the gauging station is maintained by the Central Water Commission.

Material and Methods

Water samples collected periodically from different sampling stations of the river are brought to the laboratory for detailed analysis for a period of two years (May 1985-

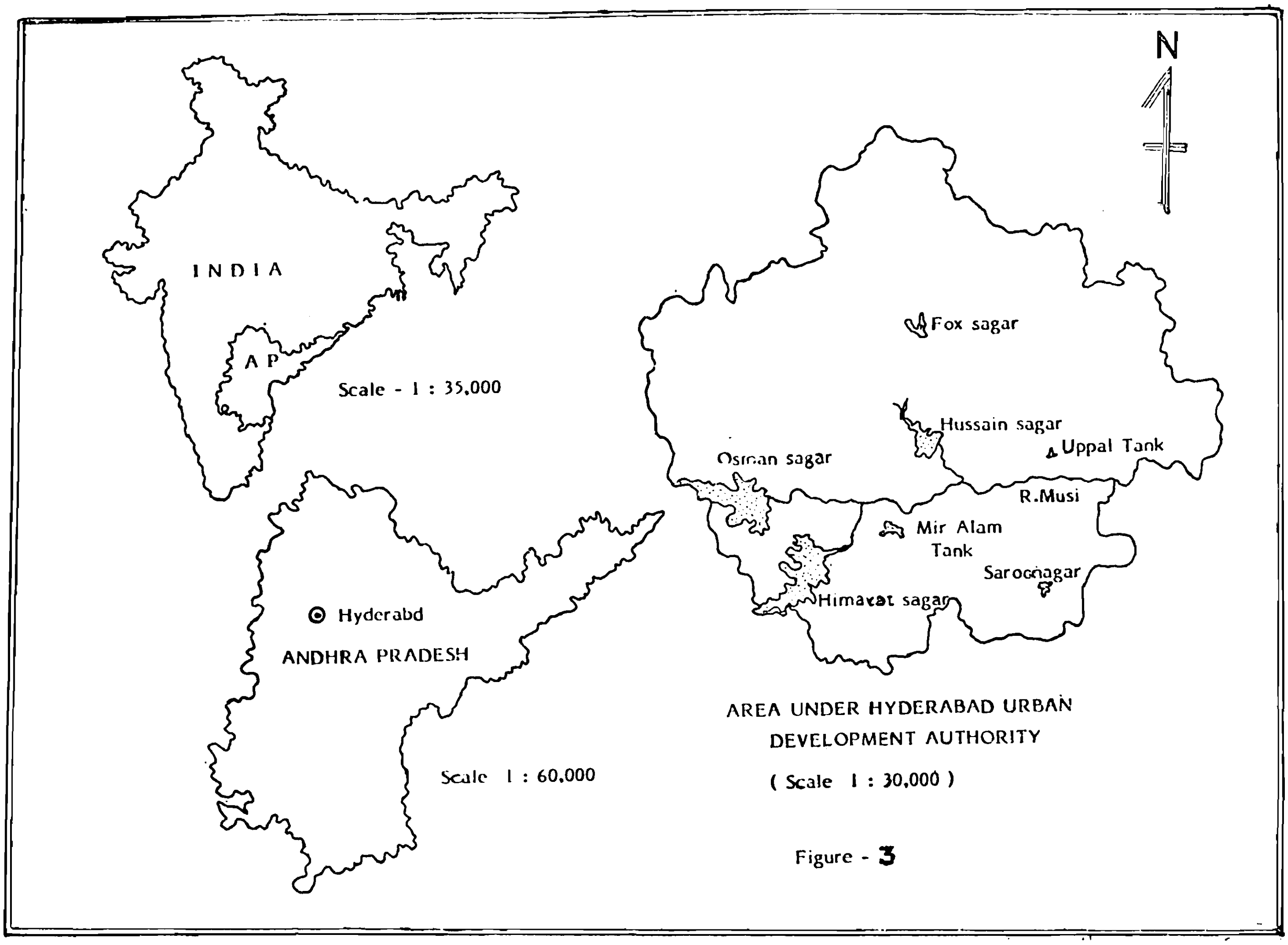

Fig. 3. Location of River Musi under Hyderabad Urban Development Authority with other reservoirs.

April 1987). Parameters such as temperature, humidity, pH, transparancy of water was measured in the field. Specific conductance, dissolved oxygen, carbondioxide, Bio-chemical oxygen demand (BOD), total hardness, carbonates, bicarbonates, chlorides, sodium, potassium, nutrients such as Nitrate-nitrogen, phosphates, sulphates are anlaysed in the laboratory as recommended by *Standard Methods*, (*A P H A*), 1985, and the results are expressed in mg/1, unless otherwise mentioned.

PHYSICAL FACTORS

a. Temperature : Hyderabad city located in the semi arid region of Andhra Pradesh, exhibits tropical climate with maximum day temperature rising to 42-45 degree Celcius during summer and minimum winter night temperature falls to 12-15 degree Celcius, the mean annual diurnal range exceeding 20-25 degree Celcius. Water temperature followed a characterstic seasonal cycle at all stations, the maximum generally in the month of April and minimum in the month of January. Gradual decrease in the surface water temperature has been noticed from October on wards upto January and at no time of the year, the temperature fell below 23 degree Celcius.

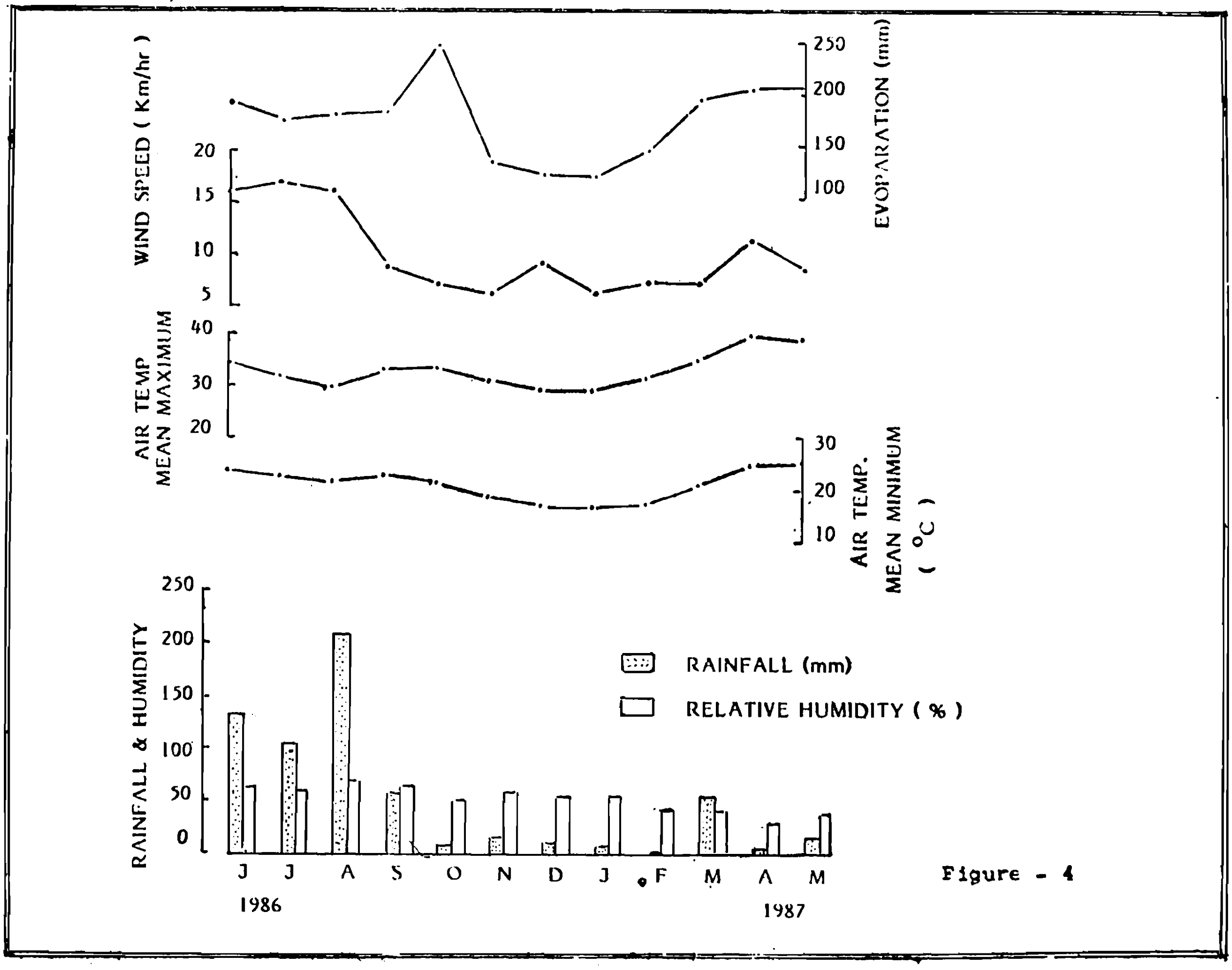

Fig. 4. Temperature, Evaporation, Rainfall and Humidity records at Hyderabad for 1986-87.

b. Sunshine Hours : Hyderabad is located in the southern peninsular part at about 510 m above msl and receives maximum light. From the study of solar radiation reaching the earth (Zafar, 1964), during January it is a 3gm/cal/cm/min, from February onwards, a slight decline is seen and balanced during July. Thus at no time of the year, the region loses radiation in excess of what is gained from Sun. If biological function is taken as a function of radiation gain, Hyderabad city could be regarded as continuously productive all through the year.

c. *Rainfall*: Hyderabad city is situated at a distance of about 265 km from eastern sea coast and as a result, the marine climate generally becomes peninsular, the air becomes drier and amount of rainfall decreases. Long term averages of rainfall in the district varies from 672-800 mm/year of which 78% is received from South-West monsoon, with an average of 48 rainy days/year. The monsoon reaches its peak during August-September and gradually decreases from October onwards.

d. *Evaporation*: The rate of evaporation dependent on both temperature and humidity as well as wind stress on the water surface. It has been estimated that the present rate of evaporation at Hyderabad is 2172 mm/year, which gives a daily average of 6 mm.

Chemical Characterstics

a. *Dissolved Oxygen*: Dissolved oxygen is a valuable tracer for water and sensitive indicator for biological and chemical processes occuring in it. The value of oxygen was comparatively low indicating anaerobic condition. In most part of the year, the dissolved oxygen never exceeded 3.3 mg/1. Post monsoon months of September-December 1985 exhibitted no oxygen, while during 1986, it was in traces at all three sampling stations as in table—1 and 2.

TABLE 1. Values of Dissolved oxygen at 3 sampling stations for 1985-86.

Station	May	June	July	Aug.	Sept.	Octo.	Nov.	Dec.	Jan.	Feb.	March	April
I	Nil	1.0	0.5	Nil	Nil	Nil	Nil	Nil	3.2	3.0	2.2	0.9
II	0.5	0.5	0.6	Nil	Nil	Nil	Nil	Nil	0.8	Nil	Nil	Nil
III	2.1	0.6	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0.2	Nil	Nil

TABLE 2. Values of Dissolved oxygen at 3 sampling stations for 1986-87.

Station	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April
I	Nil	Nil	Nil	0.9	Nil	0.4	0.6	1.2	1.7	Nil	Nil	1.0
II	Nil	1.2	0.8	0.6	Nil	Nil	Nil	0.6	Nil	0.4	Nil	0.8
III	Nil	1.2	0.8	1.9	Nil	0.9	Nil	Nil	0.2	Nil	0.4	Nil

(Values are in mg/1)

According to present data, all sampling stations receive waste water leading to high organic matter and low oxygen values. The reason for such a condition is the application of synthetic detergents throughout the drainage basin and these detergents are ressistant to secondary sewage treatment and frequently produces a layer of surface foam, as observed at all stations, when the effluents are discharged in to the river. This foam restricts re-oxygenation and causes anaerobic condition to rise.

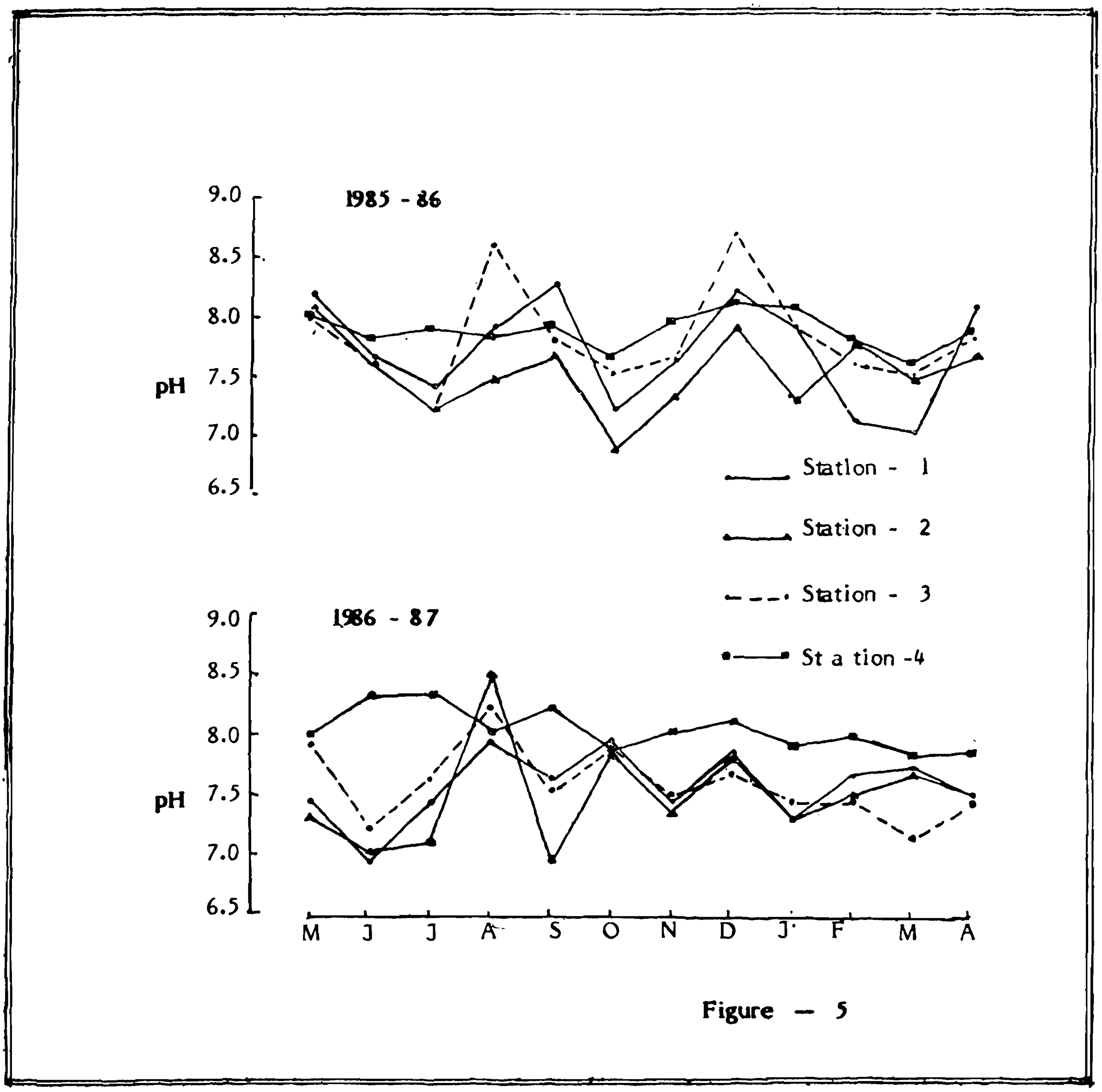

Fig. 5. Monthly variation of pH in River Musi for different sampling stations.

Running water contain typically high concentration of dissolved oxygen tending towards saturation, however, larger organic discharges perhaps adding to upstream pollution already present, causes great ecological changes (Dix 1981), resulting in a large oxygen deficit in the down stream. According to Hawkes (1981), the presence of surface active material in the sewage effluent suppresses the rate of reaeration of the receiving stream and thereby delays self purification, and this effect is greater in sluggish rivers. According to Butcher and Blum (1957), the low values of dissolved oxygen is

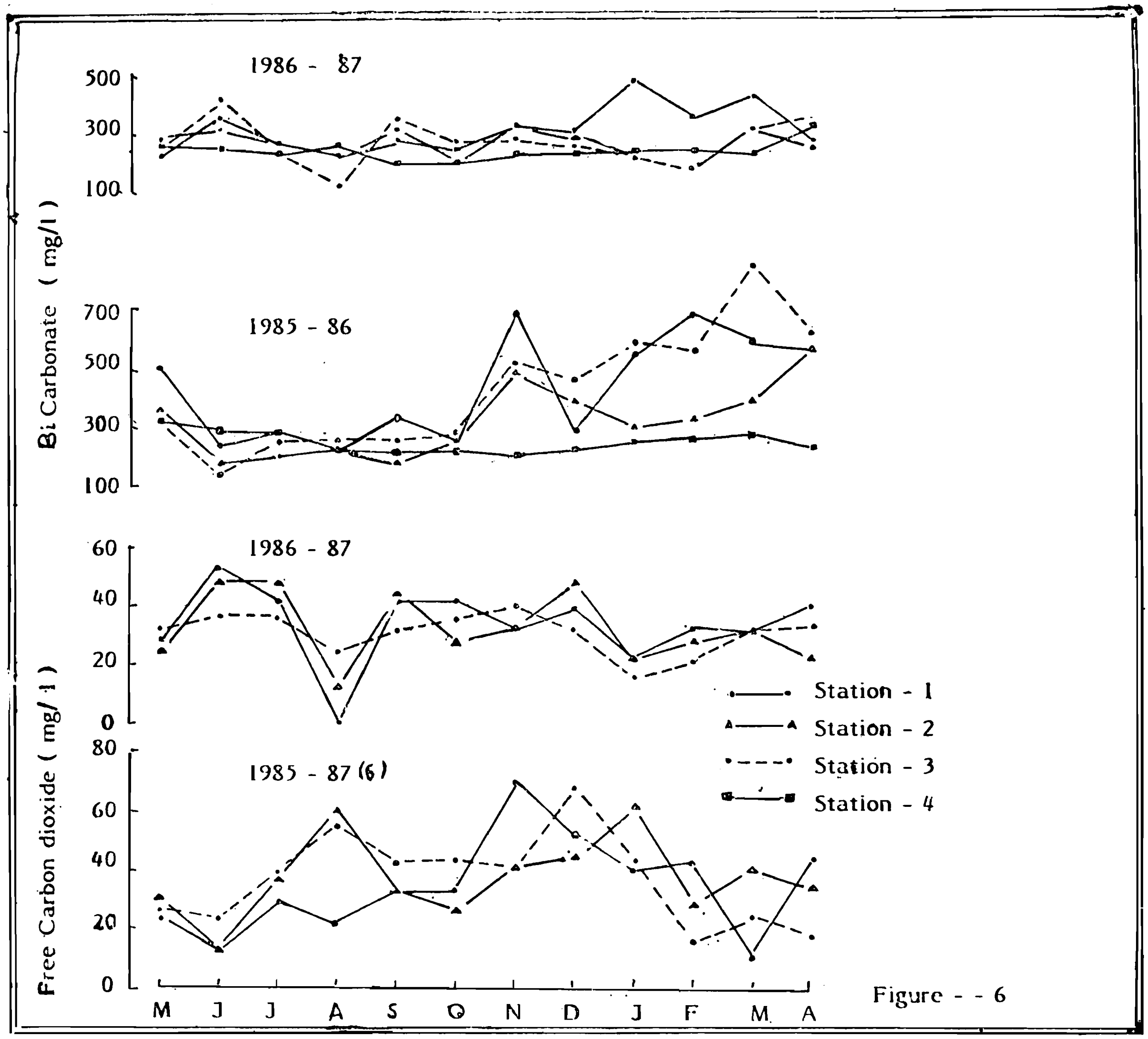

Fig. 6. Monthly variation of Free Carbon Dioxide and Bicarbonate in River Musi.

generally associated with high organic matter and due to the active aerobic bacteria, dissolved oxygen content is known to fall down below the sewage outfalls.

Unlike lake ecosystems, river water quality cannot be characterised by the concentration of nutrients only (Wong et. al. 1979), however, dissolved oxygen content which plays a vital role in supporting aquatic life in running water is succeptible to slight environmental changes. A similar condition is already noticed (Hynes 1966), that high organic pollution also lead to local depletion, frequently eliminating certain elements from the fauna. In the present case also, the occurence of faunal components are restricted to organisms capable of living anaerobic condition, such as Chironomids, musquito larvae, a few hemipterans such as *Diplonychus* and *Laccotrephes* species.

b. Carbonate and Bicarbonate : Carbontes are absent in water and the total alkalinity available was in the form of bicarbonate, the values of it varied between 150-900 mg/1 as in figure 6. According to Rutner (1957), accumulation of large quantity of bicarbonate during summer may be due to the liberation of carbon dioxide in the process of decomposition of bottom sediments which resulted in the conversion of insoluble carbonate into soluble bicarbonate. Present investigation is in confirmity with the work of Rao and Govind (1964), that the water having carbonates was devoid of carbon dioxide and vice versa. The absence of carbonates was mainly related to the absence of macrophytes, phytoplankton and decomposition of organic matter.

c. Carbon dioxide : Carbon dioxide is present at all stations throughout the year, the maximum was 68.91 mg/1 and the minimum was 9.98 mg/1 (Figure 6). The presence of large quantity of carbon dioxide at every sampling station is the effect of microbial activity of converting organic waste into water and carbon dioxide because the respiratory activity is nearly absent due to absence of biota. From the earlier work of Venkateswarulu (1968), carbon dioxide values appear to be negligible and are found only in the lower stretches of the river, which was mainly due to the presence of phytoplankton. However, in recent years, anthrapogenic activity has added considerable material resulting in the change of water condition.

d. pH : pH of the water vary widely between different rivers and streams and influenced by carbonate-bicarbonate alkalinity and the concentration of carbon dioxide (Talling 1976). In the present case, the pH of the water was found to be in the alkaline range and the values are in figure 5. The pattern of fluctuation was almost irregular at all three sampling stations for a major part of the year and comparatively lower values were obtained during summer months except at sampling station—1 during 1986 April. The decline in pH during summer months is normally due to the surplus amount of carbon dioxide in water. A similar inverse relationship between pH and free carbon dioxide has been reported earlier by Rao and Govind (1964) and Zafar (1964).

TABLE 3. River Musi—pH changes at different sampling stations

Sampling stations	*1985-86*	*1986-87*
Station—1	7.48 (6.9-7.9)	7.52 (7.0-8.2)
Station—2	7.74 (6.9-8.5)	7.42 (6.8-8.0)
Station—3	7.81 (7.1-8.2)	7.55 (7.2-8.7)
Station—4	8.02 (7.6-8.4)	7.95 (7.8-8.3)

(Values are in mg/1)

e. Chloride : Chloride content of the river varied from 90-590 mg/1 indicating a significant portion of human and animal refuse entering into the river, causing high degree of pollution. From the study, that the up stream and mid stream indicated a high degree of variation, and the down stream showed a normal curve except for the month of October 1985 at all sampling stations. The high degree of chloride at all places was due to the anthrapogenic activity and absence of seasonal variation was due to the absence of river flow, except for station 3 and 4 which showed a near uniform value due to moderate flow.

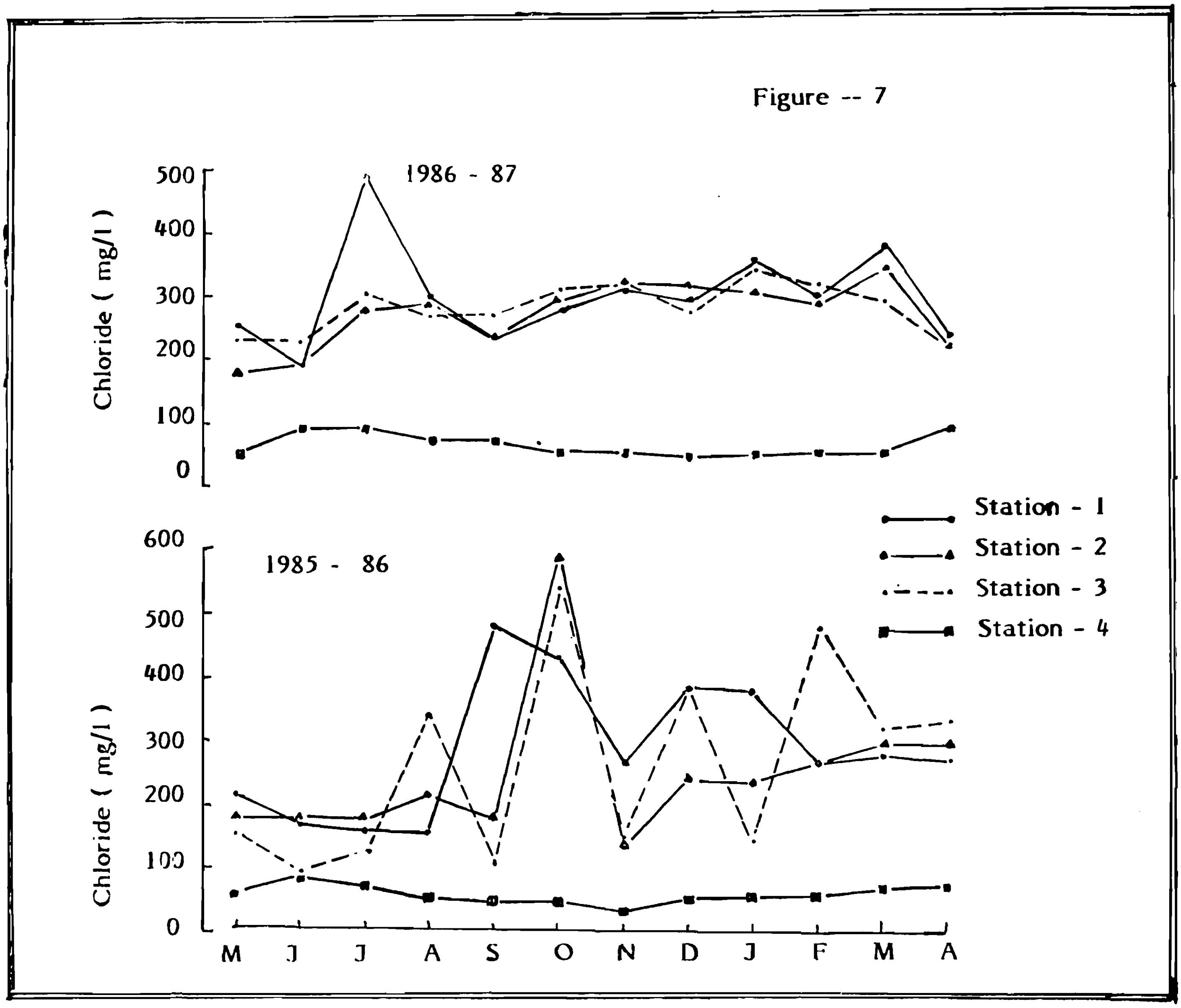

Fig. 7. Chloride concentration for different sampling stations of River Musi.

Klein (1957) found a direct correlation between chloride content and pollution level and therefore, higher value of chloride in the river showed high degree of pollution. According to Munawar (1970) higher value of chloride is an index of pollution of animal origin. Several investigators such as Blum (1957), Hawkes (1957), Venkateswarulu

(1986), Somashekar (1988) have reported sharp increase in chloride content at sewage polluted stretches of the river.

f. Specific conductance and Total Dissolved solids : Conductivity which measures the total ionic composition of water and therefore, its overall chemical richness is vital as it indicates the biogenic potential of any body of water. In the present observation, anthrapogenic influences by way of effluents and sewage released into the river appears to be more responsible and values always exceeded 1000 mmho/cm at all sampling stations. The electrical conductivity of any water is roughly proportional to the concentration of dissolved major elements and the conductivity is often employed as it correlates closely with the dissolved solids. On the basis of this, the values of dissolved solids so calculated exceeded 700 mg/1 on an average and showed a positive increase from the month of December.

Fig. 8. Rate of discharge of water from River Musi to River Krishna at the confluence point and its relation with chloride.

The innert organic and inorganic material released into the river from various sources adds significant contribution to the specific conductance and dissolved solids. This is clearly visible from the black colour of the water. According to Claussen (1973) such suspended solids interfere with the self purification of water by dimnishing light penetration and hence the photosynthetic activity and damage fisheries by silting over food organisms. Probably due to this, planktonic and benthic populations have been highly destroyed in the river. Absence of many freshwater fauna in the river Musi can therefore, be attributed to the high specific conductance as normally inland water having a range of 150-500 mm ho/cm support a good fish fauna (Ellis 1937).

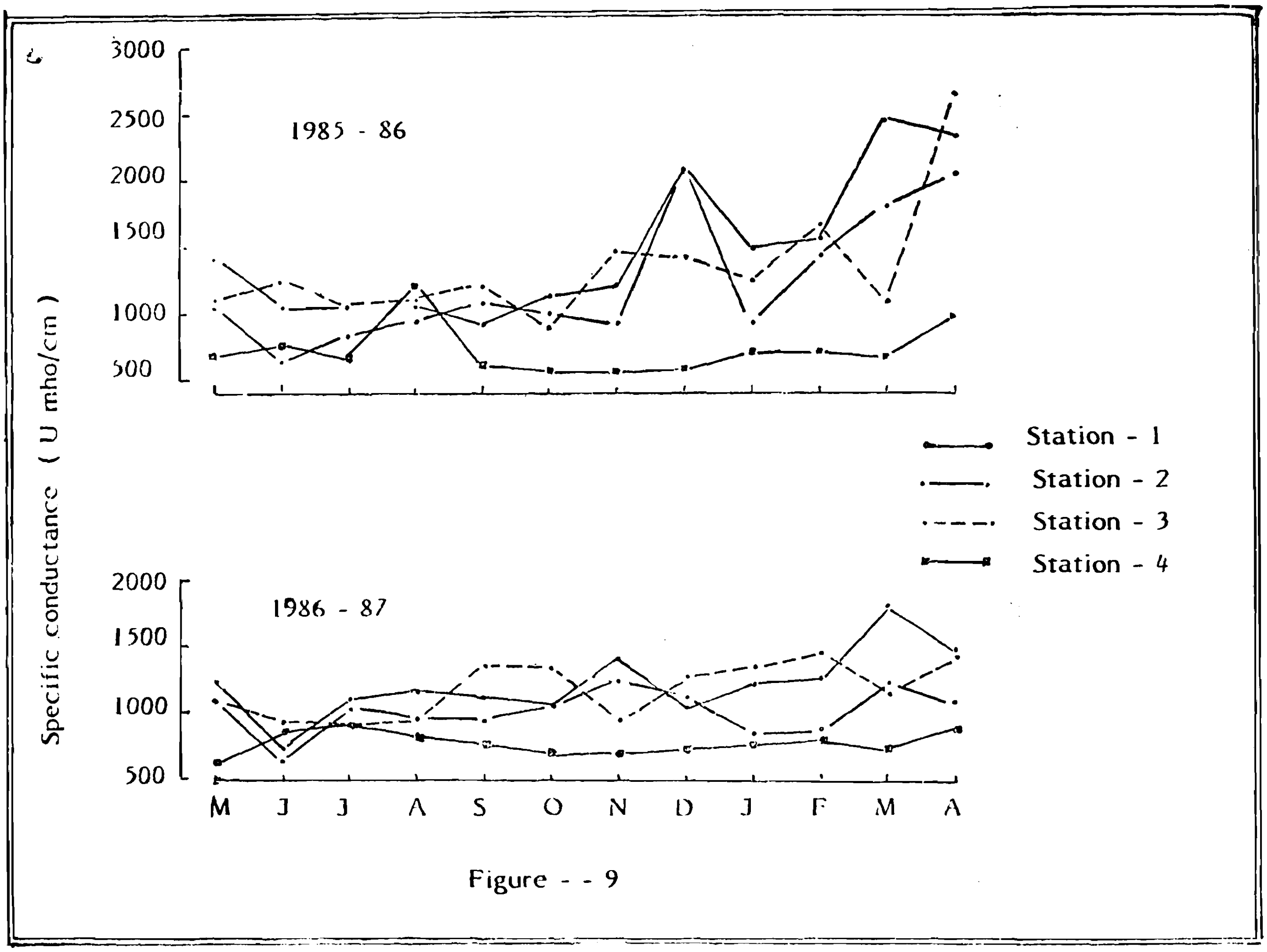

Fig. 9. Specific conductance of water at different sampling stations.

g. Sodium Absorption Ratio (SAR) : Importance of sodium absoption ratio is well understood, as it provides an indicator of effect of sodium in the soil. This (SAR) is evaluated in terms of Sodium Absorption which is defined as :

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

On the basis of the salinity diagram, the water in the polluted zone of the river Musi falls under C_3 S_1 with medium to high conductivity and low S A R. Similar condition was noticed even in the down stream near the confluence with the river Krishna at about 150 km. down stream, indicating it quality (Less suitability) for irrigation. Generally C_1 S_1 or C_2 S_2 are are considered excellent for use in irrigation.

h. Biochemical Oxygen Demand (*B O D*) : B O D values of the river varied from 54-109 mg/l and range of variation at different sampling stations showed that highest value was 96, 102 and 109 mg/l respectively in stations 1, 2 and 3. A steady increase in the values were observed at all sampling stations from the post monsoon months of September and highest during summer months. Absence of seasonal variation and comparatively higher values in the river during all seasons of the year is indicative of high organic pollution due to discharge of waste water from various points. A similar condition exists in the river Cauvery (Somashekar 1988) and in the river Ganges at Kanpur (Mahajan, 1988) resulting in the degradation of water quality.

i. Nutrients : Concentration of nutrients *viz.* Nitrogen and phosphorous are important in standing water and running water as they are directly related to the biological productivity. Nitrogen is one the important nutrient for plants, however excess of this element in water results in eutrophication. Phosphorous, an another nutrient, limits the growth of phytoplankton. The source of nitrate in the river Musi, is from the run-off received at several points and not geologically as the water passes through laterite soil and granite rocks, which are poorer in nitrate content. This is in confirmity with the work of Whitton (1972), that the rivers draining primarily agricultural area, land drainage is the major source of nitrogen and chloride where as the industrialised and urbanised catchments, the major portion of these ions are derived from effluents. The nitrate fluctuated in a narrow range but showed a similar trend at all sampling stations except down stream of the river (sampling station—4) and summer months showed maximum level in water and minimum during rainy season indicating the effect of temperature and dilution respectively. Loss of nitrate by denitrification is the reason for their low values. However, according to Ganapati (1943) and Zafar (1964) deficiency of oxygen or the absence of proper organisms are being the prime factors responsible for the incomplete oxidation of the free ammonia accounting for the low nitrate values.

Values of phosphate obtained in the river water are on the higher side as in the table and this is due the sewage contamination and application of synthetic detergents containing Glycero-polyphosphate. According to Chakraborty et. al. (1959), Pahwa and Mehrotra (1966), many Indian rivers exhibitted lower concentration of phosphate than nitrogen, therefore, the present trend of increased amount of phosphate is due to the application of detergents and biodegradation of these compounds is comaratively less, as evidenced in the present case at Sampling station-4, which is about 150 km. from others points (0.65-1.45 mg/l).

j. Sulphate : Sulphur is an essential element to all life and enters the biomass as sulphate. Sulphate deficency can inhibit algal population directly by hindering chlorophyll synthesis (Cole, 1979), The Concentration of sulphate in the river water was low in area with less flow and anaerobic condition. This was mainly because of

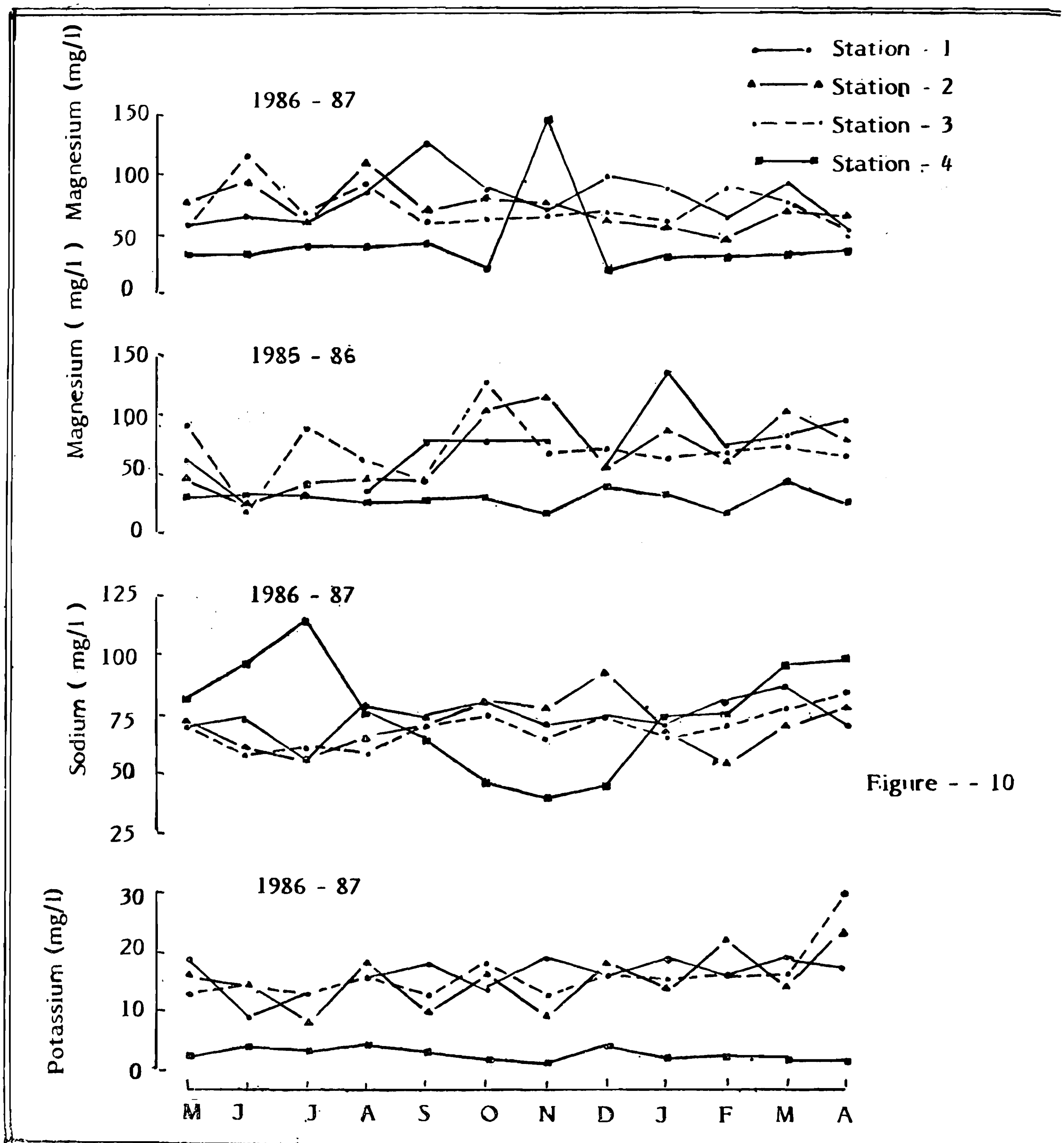

Fig. 10. Variation in monthly concentration of Sodium, Potassium and Magnesium.

the reduction of sulphates as hydrogen sulphide. According to Poste Gate (1954), many bacteria reduces sulphate to sulphide under anaerobic condition thus releasing abnoxious hydrogen sulphide and blackening mud and sand, as this gas combines with iron forming ferrous sulphide, the bacteria causing such a reaction are *Desulpho desulphuricans*. This condition appears to be same in the river Musi, with sulphate concentration varying from 2.65-6.2 mg/l in the polluted zone and above 60 mg/l in the down stream. The source of sulphate is mainly from the run-off of the catchment area and hence concentration increases with the increase of discharge or river flow.

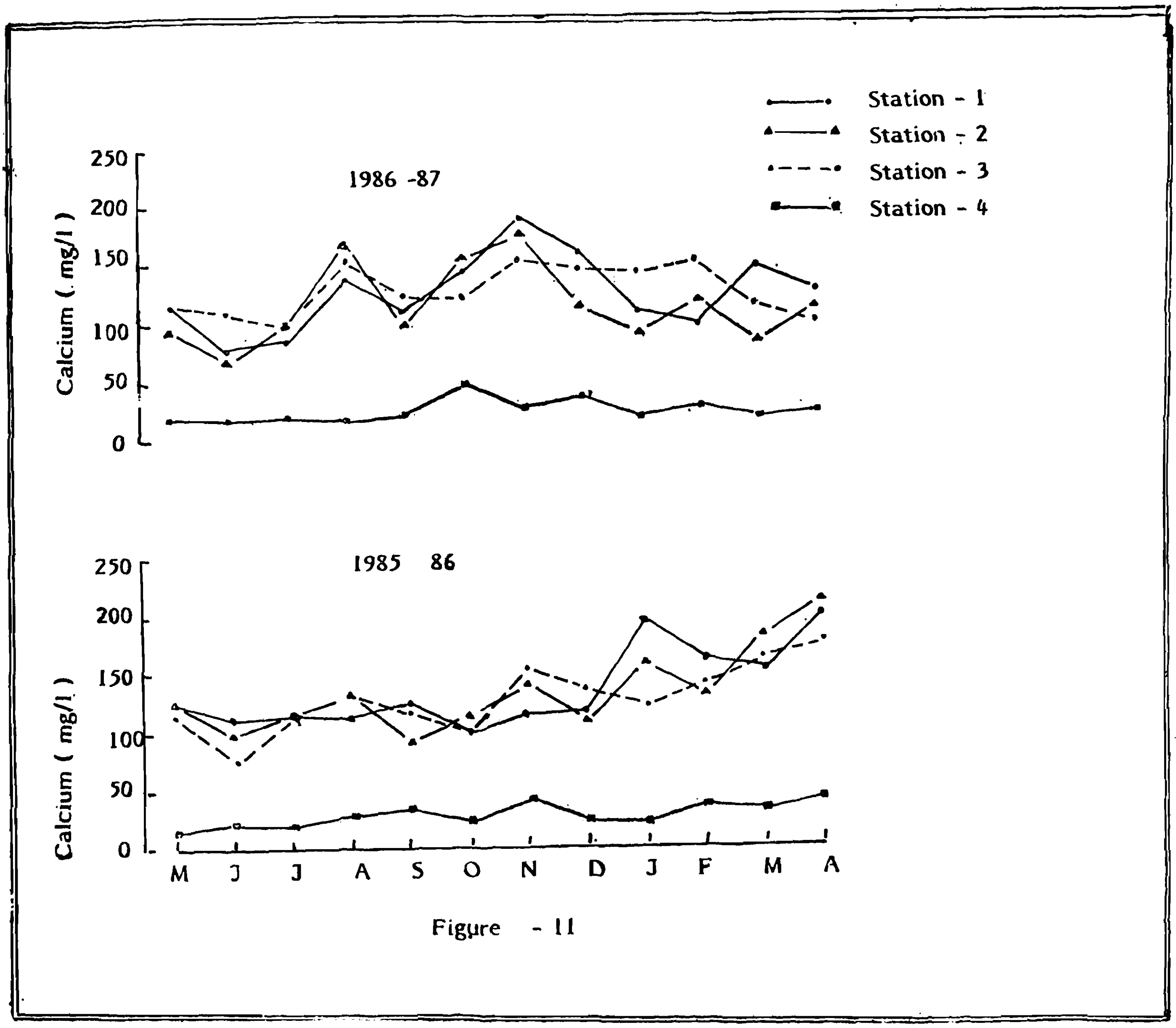

Fig. 11. Concentration of Calcium in River Musi.

k. Ionic composition : Calcium and magnesium are two important cat ions imparting hardness to the water, in comparison to monovalant sodium and potassium. These ions are normally leached from different types of rocks. In temperate climate, as in river Wye, the major ions such as of calcium, magnesium, sodium, potassium and bicarbonate are generally lowest during winter and higest during summer (Whitton, 1972). However, in tropics, the ionic composition found to vary according to the river flow or alteration in the catchement area.

Based on the averages, the ionic composition of the river Musi was found to be $Ca^{++} > Mg^{++} > Na^{+} > K^{+}$ in the polluted zone and $Na^{+} > Mg^{++} > Ca^{++} > K^{+}$ in the unpolluted zone, among anions $HCO_3^{--} > Cl^{-} > SO_4^{=}$ at all sampling sampling stations. The ionic composition of river Musi, even differed from that of river Cauvery in the South and Jhelum in the North ($Ca^{++} > Na^{+} > Mg^{++} > K^{+}$) in the polluted and unpolluted zones.

TABLE 4. Seasonal variation of Nitrate and Phosphate at different sampling stations of the river Musi for the Year 1986-87.

Sampling stations	June-Sept. 1986		Oct.-Jan. 1986-87		Feb.-May 1987		Average Yearly	
—	Nitrate	Phosphate	Nitrate	Phosphate	Nitrate	Phosphate	Nitrate	Phosphate
Station-1	0.052	0.186	0.237	0.490	0.168	0.465	0.131	0.363
Station-2	0.079	0.195	0.207	0.475	0.339	0.530	0.180	0.413
Station-3	0.088	0.209	0.770	0.522	0.269	0.423	0.176	0.386
Station-4	0.002	1.450	0.040	0.650	0.056	1.260	0.04	1.15

TABLE 5. Seasonal variation of sulphate in river Musi at different sampling stations for the Year 1986-87.

Sampling Stations	Oct.-Jan. 1985-86	Feb.-May 1986	June-Sept. 1986	Oct.-Jan 1986-87	Feb.-May 1987
Station-1	6.20	3.16	4.12	6.00	5.30
Station-2	3.50	4.59	3.50	3.50	2.35
Station-3	3.65	6.12	2.60	2.85	2.65
Station-4	22.00	51.00	100.00	40.50	39.00

(Values are in Mg/1)

IMPACT OF ANTHRAPOGENIC ACTIVITY ON THE RIVER MUSI

Rivers differs from that of lacustrine environment by having unidirectional, continuous motion over an area extended often with rocky stretches and variable soil composition. In the process, aquire mineral components, solids and solutions from a wide range of their basin (Rzoska 1978) and thus creates a different condition for life. Impact of man has so profound effect on the nature of rivers, streams and tributaries, especially in recent years, it is extremely difficult to find any river or stream which has not altered for his benefit. This has been ably achieved by the way of construction of dams and reservoirs. In tropical countries, these problems are further aggravated by the unseasonal rains, unprecedented extreme climatic conditions such as high temperature, low humidity and high rate of evaporation.

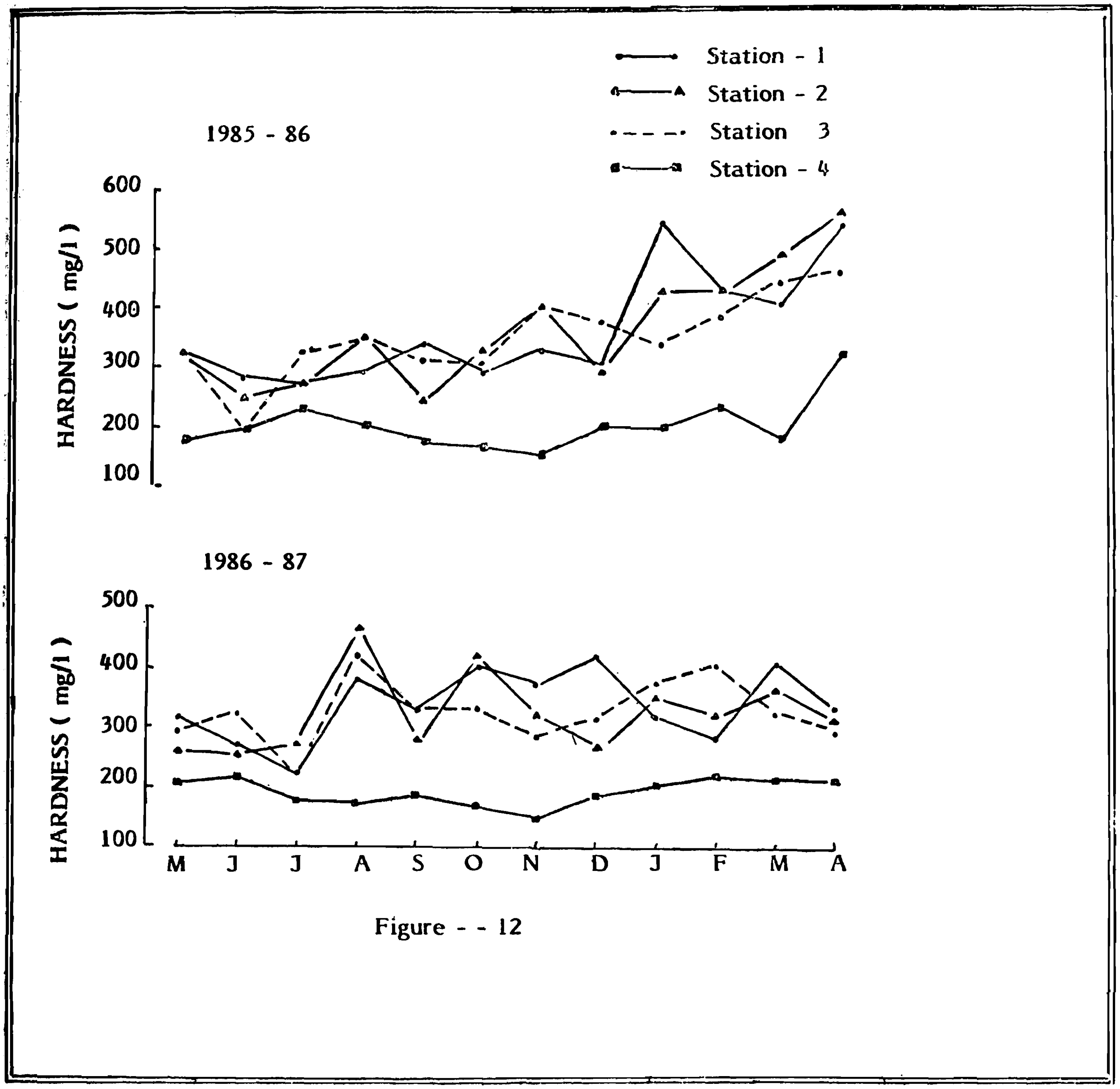

Fig. 12. Seasonal variation of hardness of water samples of River Musi.

Impact of human settlement, degradation of water quality and exccessive exploitation resulted in the imbalance of freshwater ecosystem. The initial effect of this on a stream or river is to degrade the physical quality of water, as the deterioration is more pronounced, a shift to chemical degradation is biologically induced in terms of number and variety of organisms. The intial effect of anthrapogenic activity on river Musi is felt by way of deterioration of water quality, alteration in the habitat structure and elimination of large groups of vertebrtes and invertebrates.

The exact reason for the elimination of such a diverse group is not known, however, it can be assumed that fishes are usually eliminated for long stretches by severe organic pollution particularly ammonia, sulphide and cyanide, apart from low oxygen tension as in the present case. Low oxygen tension enhances the toxicity of most poisons, and high degree of suspended solids in the river have serious effect on the spawning sites of many fishes. According to Ellis (1937), the specific conductivity of inland water of supporting good fish fauna lies between 150-500m mho/cm where as in the present case exceeds 1000m mho/cm in the polluted zone and exceeds 700m mho/cm in the down stream.

Impact on phyto-zooplankton :

Pollution of organic matter is very complex, as it involves not only deoxygenation of the water, but also addition of suspended solids. Organic wastes such as saw dust, wood fibre, fibruos textile waste, which are capable of slow bacterial breakdown produces deoxygenation and sewage fungus. Suspended solids tend to eliminate algae and plants and they alter the fauna by blanketting over stream bed (Hynes 1966). This is evident from the work of Venkateswarulu (1968, 1974, 1986), a shift in the algal population in the river Musi is noticed especially in the polluted zone (Bacillariophyceae > Cyanophyceae > Euglenophyceae > Chlorophyceae during 1961-63 and Chlorophyceae > Bacillariophyceae > Cyanophyceae > Euglenophyceae in 1973-74).

The plankton of the river has completely altered during the recent years with gradual deterioration in the water quality as evidenced in the earlier chapters with very few species of phytoplankton, especially belonging to cyanophyceae, euglenophyceae, abundant sewage fungus and bacterial flora (Bacterial counts ranged from 23×10^3 to 10^4/ml with an average of 10×10^2/ml). Similarly zooplankton analysis showed avery limited abundance (2-22/100 ml). Zooplankton community showed the presence of pollution tolerant copepods and cladocerans and on rare occassions with rotifera. The cladocera recorded belongs to *Diaphanosoma*, *Ceriodaphnia cornuta*, *Moina micrura* ; copepoda belonging to *Mesocyclops* and *Diaptomus* and rotifera having *Keratella* and *Brachionus* species. Among protozooans the river water exhibitted several colonial members such as *Carchesium*, *Vorticella*, and *Stentor* and ciliates like *Paramoecium*, *Euplotes*, *Stylonychia*, *Colpodium* and *Lynotus* species.

Impact on invertebrates :

Usually according to Hynes 1966, in the polluted zone of the stream or river, the tolerant species are replaced by abundant "Pollution fauna" consisting of largely sludge worms (Tubificidae), blood worms (Chironomidae) and water louse (*Ascellus* species). In the present case, larval groups of several invertebrates such as Chironomidae and Diptera (Mosquitoes) were found in abundant number. Only on few occassions, Odonate and Mayfly larvae were observed in the unpolluted puddles found on the bank of the river, belongs to *Pantala, Crocothemis, Diplocodes and Trithemus* species. Hemiptera such as *Diplonychus, Laccotrephes* (*Nepa*) and *Microvelia* were found in abundant number among the macrophytic vegetation of *Eicchornia crassipes.*

Another striking feature of the river is the total absence of molluscan members in the polluted zone, where as several species of *Lamellidens, Parreysia, Lymnaea, Bellamia, Indoplanorbis* are abundant in the upper stretches of the river especially in the impounded area. Invertebrates characterstic of fast flowing water such as gerridae, simulidae, macro-invertebrates such as crustacean were totally absent in the polluted zone. Macrobenthic invertebrates were also absent due to suspended, dissolved solids and microbial activity with deoxygentation.

Absence of many insect species was mainly due to the presence of surface active material in the sewage effluent, which suppresses the rate of reaeration of the receiving stream and therey delays self purification (Dix, 1981). The effect is greater in sluggish rivers, especially in the present case. Further more, many aquatic insects are associated at some stage in their life cycle with air water interface, the affect of surface active agents on the surface tension might be expected to affect such insects. Also, the presence of foam on surface water due to high levels of phosphates would affect the emergence of egg laying activity of many insects.

Impact of pollution on the river Musi.

The capacity of the river to cope up with the pollution load, depends on oxygen balance, resulting from the compition between the demands imposed by the oxidisable material and the existing oxygen resources and capacity of reaeration (Anandavalli & Krishna swamy (1988). A high degree of self purification capacity appears to be feature of tropical ecosystem. The self purification powers of the rivers of Northern India especially Ganges are high on account of shallow depth, turbulent flow, prolific biological activity and the deposition of organic matter on the river beds, but converse appears to be true in South Indian rivers. This is true due to dry and lean seasons, the chemistry of the water vary enormously resulting in the variation of seasonal abundance and diversity of fauna.

Suspended solids and sediments, falling on the eroding substrata fillup the interstices between stones, thus depriving the cryptic animals of their hiding place. Slow flow also coat these suspended material over the stones and so render ineffective to various holdfast mechanisms of stone fauna (Hynes 1966). It is found, that all or most fauna disappears and are replaced by burrowing or tube dwelling animals, such as worms and chironomid larvae. Suspended and dissolved solids also interfere in the self purification of water by diminishing light penetration and reducing the photosynthetic activity. The concentration of organic matter, free ammonia and phosphates released by the decomposition of particulate organic matter with high microbial demand for dissolved oxygen has increased the concentration of toxic substances in the river Musi. The river Musi being a small tributatry with a limited capacity of dilution to the pollutants, it is not surprising that it exhibits severe reaction to effluents entering in it.

TABLE 6. Water quality standards specified by Bureau of Indian Standards (Tolerance limits) in comparision to water quality parameters of river Musi in polluted and unpolluted zone.

Parameters	Uustream 1	Polluted zone	Down stream	A	B	C	D	E
1. pH	7.6-8.3	6.90-8.5	7.80-8.3	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.0-8.0
2. Dissolved oxygen	7.3	Traces	—	6.0	5.0	4.0	4.0	—
3. Biochemical Oxygen Demand	2-4	76.0	—	2	3	3	—	—
4. Total Coliform	—	10×10^4	—	50	500	5000	—	—
5. Odour	Nil	Sulphide	Nil	Unobjectinable				
6. Taste	Taste-less	Irritating	—	Tasteless				
7. Sp. Conductivity	258	1125	711	—	—	—	1000	2250
8. Total Hardness (as Ca Co)	136	329	201	300	—	—	—	—
9. Calcium hardness	77	242	56	209	—	—	—	—
10. Magnesium hardness	59	140	60	100	—	—	—	—
11. Iron	—	—	6.01	0.3	—	1.5	—	—
12. Chlorides	32	279	55.0	250	—	600	—	600
13. Sulphate	Trace	3.8	40.0	400	—	400	—	1000
14. Nitrate-Nitrogen	Nil-2.2	0.15	6.04	20	—	50	—	—
15. Free Carbon dioxide	Nil	32	6.0	—	—	—	6.0	—
17. Total Dissolved Solids	160	720	440	500	—	1500	—	2100
18. Sodium Absorption Ratio	—	—	2.15	—	—	—	—	2.6

(Note : Values are in mg/l except Ss. Conductance—Umhos/cm)

Unstream—1—Impounded area of the river such as Osman sagar. Polluted Zone—Sampling spots in the city limits ; Down Stream—At the confluence with River Krishna at Damercherla ; A—Drinking water sources without conventional treatment but after disinfection ; B—Outdoor bathing ; C—Drinking water sources with conventional treatment followed by disinfection ; D—Fish culture and wild life propagations ; E—Irrigation, Industrial cooling and controlled waste disposal.

TABLE 7. River Musi—Seasonal variation in Chemical characterstics for the year 1985-86 for different sampling stations.

Parameters	June—September 1985				June—September 1986			
	1	2	3	4	1	2	3	4
pH	7.70	7.40	7.80	8.20	7.45	7.38	7.62	7.90
Sp. Conductance	1025	980	1140	796	915	1000	1080	844
Total Diss. Solids	645	633	615	478	557	640	684	634
Bicarbonate	200	172	244	261	283	279	275	232
Chloride	244	172	184	61	300	234	261	78
Calcium	114	107	110	25	102	109	114	22
Magnesium	40	37	49	31	108	111	80	39
Sodium	—	—	—	74	69	63	62	90
Potassium	—	—	—	4.4	14.0	12.5	14.0	3.7
Sulphate	—	—	—	40	4.12	3.5	2.6	100.0
Hardness	296	284	296	200	300	320	320	190
BOD	—	—	—	—	62	60	64	—

Ionic composition :

June—September 1985:
Station 1 to 3 : $Ca^{++} > Mg^{++}$ and $HCo_3^{--} > Cl^-$
Station 4. $Na^+ > Mg^{++} > Ca^{++} > K^+$ and $HCo_3^{--} > Cl^- > SO_4^- > Co_3^-$

June—September 1986:
Station 1 to 3 : $Ca^{++} > Mg^{++} > Na^+ > K^+$ and $HCo_3 > Cl > So_4$
Station 4. $Na^+ > Mg^{++} > Ca^{++} > K^+$ and $HCo_3^{--} > SO_4^- > Cl^-$

TABLE 8. River Musi-Seasonal variation in chemical characterstics for the year 1985-86 for different sampling stations.

Parameters	October 1985 to January 1986				October 1986 to January 1987			
	1	2	3	4	1	2	3	4
pH	7.72	7.42	7.92	8.00	7.58	7.45	7.60	8.15
Sp. Conductivity	1250	940	1250	585	1186	1044	1222	7C0
Total Diss. Solids	800	595	940	331	758	667	780	440
Bicarbonate	437	358	461	226	240	280	260	247
Chloride	363	243	380	44	306	306	291	45
Sulphur	6.2	3.5	3.65	22	6.00	3.5	2.85	40.5
Calcium	140	140	127	28	151	133	142	34
Magnesium	86	88	82	30	85	68	62	54
Sodium	—	—	—	50	73	78	69	47
Potassium	—	—	—	2.00	17.00	14.50	15.10	2.50
Hardness	382	388	354	178	377	337	326	176
B O D	—	—	—	—	79	82	84	—

Ionic Composition :

October 1985 to January 1986:
Station No. 1 to 3 : $Ca^{++} > Mg^{++} >$ and $HCo_3^{--} > Cl^- > So_4^-$
Station No. 4 : $Na^+ > Mg^{++} > Ca^{++} > K^+$ and $HCo_3^{--} > Cl^- > So_4$

October 1986 to January 1987:
Station No. 1 to 3 : $Ca^{++} > Na^+ > Mg^{++} > K^+$ and $HCo_3 > Cl^- > So_4$
Station No. 4 : $Mg^{++} > Na^+ > Ca^{++} > K^+$ and $HCo_3^- > Cl^- > So_4^-$

TABLE 9. River Musi-Seasonal variation in chemical characterstics for the year 1986-87 for different sampling stations.

Parameters	February 1986 to May 1986				February 1987 to May 1987			
	1	2	3	4	1	2	3	4
pH	7.40	7.50	7.70	7.90	7.55	7.50	7.30	7.80
Sp. Conductivity	1890	1590	1620	733	1485	1024	1335	718
Total Diss. Solids	1210	1062	1035	493	950	676	840	490
Bicarbonate	530	391	563	260	360	261	290	277
Chloride	265	323	275	60	298	280	275	53
Sulphate	3.16	4.59	6.12	51	5.3	2.35	2.65	39
Calcium	156	153	146	39	124	103	117	22
Magnesium	72	78	59	30	64	58	70	41
Sodium	69	72	68	85	78	66	76	85
Potassium	19	16.1	12.8	2.25	17.0	19.5	19.0	2.3
Hardness	419	432	390	235	342	333	342	205
B O D	92	90	86	—	85	87	87	—

Ionic Composition

February 1986 to May 1986:

Station 1 to 3 : $Ca^{++} > Mg^{++} > Na^{+} > K^{+}$ and $HCo_3^{--} > Cl^{-} > So_4^{-}$

Station No. 4 : $Na^{+} > Ca^{++} > Mg^{++} > K^{+}$ and $HCo_3^{--} > Cl^{-} > So_4$

February 1987 to May 1987:

Station 1 to 3 : $Ca^{++} > Na^{+} > Mg^{++} > K^{+}$ and $HCo_3^{--} > Cl^{-} > So_4^{-}$

Station No. 4 : $Na^{+} > Mg^{++} > Ca^{++} > K^{+}$ and $HCo_3^{--} > Cl^{-} > So_4^{-}$

TABLE 10. Yearly averages of chemical characterstics from the polluted zones of the River Musi during various year.

Parameters	1961-63	1973-74	1981-82	1985-86	1986-87
pH	7.95	7.29	7.4	7.70	7.50
Carbonate	2.88	Nil	Nil	Nil	Nil
Bicarbonate	331.15	—	447.45	395	287
Chloride	40.75	146.44	108.0	265	279
Dissolved Oxygen	3.09	0.6	Nil	0.5	0.40
Calcium	—	—	45.18	131	121
Magnesium	—	—	27.18	66	69
Sodium	—	—	27.18	—	15.6
Potassium	—	—	23.75	—	15.6
Nitrate-Nitrogen	0.39	0.13	0.7	—	0.165
Phosphate	0.855	0.32	11.5	—	3.86
Silicate	16.75	8.7	15.6	—	13.6
B O D	—	—	—	—	76

(Source : 1961-62, 1973-74 & 1981-82, V. Venkateswarulu & 1985-87, Ramakrishna)

TABLE 11. River Musi—Chemical characterstics of the River in the polluted Zones of the City and Down stream (Near the confluence with the River Krishna at Dameracherla).

	1985-86		1986-87	
	In city limits	Down stream	In city limits	Down stream
pH	7.70	8.02	7.50	7.95
Carbonate	3.50	7.33	Nil	Nil
Bicarbonate	395	253	288	240
Chloride	265	55.3	279	60.1
Sulphate	—	40.3	3.9	57.3
Dissolved Oxygen	0.5	—	0.4	—
BOD	—	—	76	—
Calcium	131	28.08	121	26
Magnesium	66	30.0	73	41.3
Sodium	—	71.25	69	72
Potassium	—	2.90	15.6	2.78
Nitrate	—	0.04	0.165	0.26
Phosphate	—	1.15	3.86	0.888
Silicate	—	—	13.6	32.83
Hardness	360	201	329	192.08
Conductivity	1345	711	1127	762.8
Total Diss. Solids	858	440	721	512.9
Sodium Absroption Ratio	—	C_2S_1	C_3S_1	C_3S_1
Ionic composition :				
Cation	$Ca^{++} > Mg^{++}$	$Na^{+} > Mg^{++} > Ca^{++} > K^{+}$	$Ca^{++} > Mg^{++} > Na^{++} > K^{+}$	$Na^{+} > Mg^{++} > Ca^{++}K^{+}$
Anion	$HCo_3^{--} > Cl^{-} > Co_3^{--}$	$HCo_3^{--} > Cl^{-} > SO_4^{-}$	$HCo_3^{--} > Cl^{-}$ SO_4^{-}	$HCo_3^{--}Cl^{-} > SO_4^{-}$

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