REVIEW OF LITERATURE
Studies on running waters are in many ways less advanced than those on standing waters and it seems worth making clear, here, some of the reasons for this situation. The relatively poor state of knowledge is certainly in part due to economic reasons. The water industry has been on the whole less interested in rivers and streams than those of lakes and reservoirs and so fewer people have worked on the former. However, the main reasons are associated with special features of the habitat. Changes in a lotic environment are often both more rapid and less predictable than in a lentic one. Factors such as floods and desiccation which frequently play a major role in the former are only seldom encountered in the latter. A somewhat different problem in the study of algae in lotic environments is that there is little in the nature of a theoretical framework which could be used to bring together data from diverse studies and thus give some perspective on the subject as a whole. Although rivers can be classified in a variety of ways, they do not fall into such distinct hydrological types as do lakes. Rivers do not encounter any such dramatic, but regular, annual discontinuities in the environment, as occur in temperate lakes when thermoclines are formed or broken (Whitton, 1975). Thus, whatever
little work has been done on ecology of running waters, has been compiled by Hynes (1970). It was only in the middle 70's that some of the major projects on running waters were undertaken.

Researches on Mackenzie and Procupine river watersheds were conducted by Bruskill et al. (1975). They observed that the magnitude of annual transport rates of suspended sediments (SS) and particulate carbon (PC), nitrogen (PN) and phosphorus (PP) were largely controlled by watershed area, relief, forest cover and precipitation. They further observed that large watershed rivers transported large amounts of SS, PC, PN and PP per unit watershed area, than do small watershed rivers and streams. Further, that the increase in the rate of supply of sediments and other particulate elements to streams and rivers, caused by technological disturbances and deforestation of the watershed, would likely be proportional to the land area of terrain disturbances and deforestation; and that small watershed streams will suffer proportionately greater sediment supply increments from a given terrain disturbance compared to larger rivers. Ball and Bahr (1975) in an intensive survey of Red Cedar river covering hydrology, water chemistry, periphyton, aquatic macrophytes,
macrouvertbrates, benthos and fish found that
sewage-treatment plant effluents and urban run
off were the main sources of phosphorus; for nitrogen
the largest sources were run off and leaching from
agricultural lands. Campbell et al. (1975) compiled
physical and chemical data on river, stream and lake
waters; bottom, shore and bank sediments and rates of
transport of dissolved and suspended elements at
selected stations in the Mackenzie and Porcupine water-
sheds during 1971-1974. It was only data supplement
and interpretation of the physical and chemical data
and its relation to parallel biological studies was not
attempted. For for river and other tributaries too an
assessment of water quality characteristics only was

The objectives before any project on river
quality assessment should be: 1) to define the character,
inter-relationships and apparent cause of existing river-
quality problems; and 2) to devise and demonstrate the
analytical approaches and the tools and methodologies
needed for developing water quality information that
will provide a sound technical basis for planners and
managers to use in assessing water quality problems
and evaluating management alternatives (Greeson et al., 1977).
Sutcliffe and Carrie (1973a) while working on the mountainous streams in the English-Lake District found high calcium content associated with periods of low precipitation and vice versa; concentration progressively increased downwards and also that the calcium. Again (1973b) working out the sources of different ions, atmosphere (rainfall) was recorded as being the principal source of Na while geological sources in the catchment area were secondary. Although the input of K from the atmosphere was relatively uniform throughout the year, its output in stream water followed a marked annual cycle with minimum concentrations in mid-summer and maximum in mid-winter. For this behaviour of K, they put forth the assumption that during spring and summer, this element was retained in the catchment and was slowly released during autumn and winter which in turn suggested an intimate connection between K and growth and decay of vegetation. Precipitation accounted for only 10% of Ca, geological sources being the primary contributors. Factors responsible for regulating the concentrations of elements in mountainous streams of the Northeastern United States were worked by Vitousek (1977), coming to the conclusion that dilution of chloride and sulphate were controlled primarily by precipitation inputs and concentration by evapotranspiratic
those of sodium and silicon and to a lesser extent of Ca and Mg were controlled mainly by rock weathering while concentrations of nitrate and potassium were regulated by plant uptake. In Hogan river, Ca and Mg ions originated in part from the catchment area soils and the main source of soluble salts, appeared to be precipitation (Muir and Johnson, 1976). Capblancoq and Fourenq (1976) recorded an increase in the mineral content of river. Lot downstream and flow determined the fluctuations and variations in its content. Bertru (1977) made a study of composition of rain waters over a period of twelve months and compared the analyses with those of stream waters. Analyses were made for Na, K, Ca, Mg, Cl and SO₄. He showed that the composition of stream appeared to be very dependant on that of the precipitation though the composition of rain water is in turn partly dependant on geographical location and perhaps in part on atmospheric pollution. Johannesen and Henriksen (1976) in their experiments with snow melt water chemistry demonstrated that a concentration occurs of the pollutants in the receiving waters during the snow melt process in spring. The pollutants released during the first phase of the snowmelt cause sudden changes in the water quality of
streams and lakes. An ion imbalance does not necessarily imply imprecise analytical work but can result from chemical reactions between different unaccounted species in natural waters. The reaction between silica and the carbonate/ bicarbonate anions is one reason for the apparent lack of ion balance (Johnson et al., 1979).

Smith and Davis (1975) recorded a close correlation between daily maximum and minimum water temperature and the equivalent air temperature, in a small upland stream, except for relative short periods during snowmelt and peak flow.

Manny and Wetzel (1973) during their studies on a hard water stream came to the conclusion that sub-surface runoff accounted for most of the dissolved organic matter concentrations in the stream. Larson (1976) elucidating on dissolved organic matter of a low-coloured stream recorded maxima in autumn and late winter. The highest observed concentrations occurred on a day of heavy rain following a major autumn leaf fall. The secondary maxima may have been associated with thaw, winter fertilization practices or other factors. Wetzel and Manny (1972) working with an
experimental hard-water stream observed that bacterial populations decomposed labile organic carbon and nitrogen compounds in the leaf (hickory and maple) leachate within 72 hours and concluded that the processing capacity of woodland streams for natural dissolved organic compounds is much greater than previously believed. Lush and Hynes (1978) conducted experiments in which leachates of dead sugar maple and white cedar leaves were added to a small stream. The organic matter was removed at a remarkably high rate of approximately \(0.5 - 1.1 \text{ gm m}^{-2} \text{h}^{-1}\).

Talling (1957) working on river White Nile recorded a gradual increase in the concentrations of silicate and phosphate as water passed downstream. In river Tamagawa, Temura et al. (1974) reported an increase in water temperature, BOD, chloride, inorganic nitrogen and phosphorus while dissolved oxygen decreased. Vasishth and Sra (1979) dealing with biological characteristics of Chandigarh waste waters in relation to the physico-chemical factors found that the unpolluted waters differed from polluted ones in having low temperatures as well as lower concentrations of \(\text{NO}_2\), \(\text{NO}_3\), \(\text{PO}_4\) and \(\text{Cl}\) and higher \(\text{pH}\) and dissolved oxygen concentrations. Campbell (1978) during his investigations of an organically polluted urban stream recorded water tempera-
ture increasing downstream as the flow decreased. 
BOD values were higher in spring and summer which were attributed to short heavy bursts of rainfall washing organic material in the stream. Low oxygen concentrations and high ammonia content was recorded to be characteristic of polluted regions of river Cuyahoga by Olive and Price (1976). Litav and Agami (1976) found that with increasing levels of pollution, nitrogenous compounds especially of ammonium and phosphate increased while oxygen decreased. In river Moosi, Venkateswarlu (1969 a) recorded low oxygen concentrations during summer coinciding with high content of ammonia which recorded an inverse relation with nitrate. Summer high chloride values were observed. Maximum values for DOM too were recorded in summer, depicting a direct relation with water temperature. Nitrate recorded higher concentrations during rains attaining maximum values in winter and decreasing to minimum during summer months. Further an inverse relationship between nitrate and nitrite at unpolluted stations and direct relation between the two at polluted stations was exhibited. Dissolved oxygen content was maximum in winter and minimum in summer and a direct relationship was detected between oxygen and nitrate.

Ahl (1960) in his studies of chemical conditions of
Osbysjon recorded a late summer maxima for $\text{K}_2\text{MnO}_4$ consumption (DOM) while phosphorus increased with increasing temperature. He further recorded an increase in silica in the bottom water as the oxygen concentration began to fall. Working on Columbia river estuary Haertel et al. (1961) recorded nitrate and phosphate high levels in winter and depletion in summer. Kar (1974) carried out a preliminary study of different rivers and lakes in the Ivory Coast and elucidated the after effects of damming the rivers, reporting that the water temperature as also the phosphate content may show an upward trend while as oxygen concentration dropped as the river ceased to flow. Imvoore (1970) working on river Niger related the high alkalinity and salinity values with lower water levels and vice-versa; among cations $\text{Ca}$ predominated. He further recorded the changes when the flow of the river was stopped. The temperature of the stagnant water was relatively higher than that of the flowing water and that pH, $\text{Ca}$, $\text{Na}$ and bicarbonate content of such waters was higher. On the other hand, the concentrations of dissolved oxygen and chloride dropped when the river ceased flowing. The variations in the phosphate content of the flowing water were more noticeable while for
that of stagnant water, the values were more constant. Shetty et al. (1961) working on Hooghly-
Matlah Estuarine system recorded the peaks of salinity coinciding with those of temperature in June.
In Zambezi river, Hall et al. (1977) found that the variations of dissolved oxygen throughout the sampling period inversely follow the variations of water temperatures. The peak values of alkalinity were recorded during dry season. Nitrite concentrations during the flood season was twice as large as those observed during the dry season. The high ammonia concentration recorded during the floods probably originated from the decomposition of organic material which was carried into the river. Nitrate came predominantly via rain water. Suspended solids were dependent on flood regime.
Vass et al. (1977) in their hydrobiological studies of river Ichamal found the river isothermal, slightly alkaline and the water remained well oxygenated throughout the year but the concentrations were higher during winter and spring. Oxygen peaks were recorded in February with depressions in September by Chakraborty et al. (1959) in river Jumna. Alkalinity as well as chloride showed higher values between December and July, fall in values occurring as a result of rainfall. Nitrate and
phosphate followed almost same trend, the concentrations of latter were always lower. Later Ray et al. (1966) in their ecological studies of rivers Ganga and Jumna found dissolved oxygen peaks during winter in both the rivers. Total alkalinity and salinity had their peaks during summer when the water level was the lowest. Silica values were highest during the summer. Nitrate resembled phosphate in the seasonal variations, the peaks were formed during summer and monsoons. Simonsen and Harrimoes (1978) presented a mathematical model for oxygen fluctuations in a river reach, involving photosynthesis, total community respiration and reaeration. Further an analogy was established between diurnal oxygen - fluctuations and diurnal pH - fluctuations. Stenstrom and Poduska (1980) investigated the effects of dissolved oxygen concentration on the rate of nitrification in the waste water treatment systems. Dissolved oxygen concentration requirements for nitrification are not well defined and a broad range of dissolved oxygen half saturation co-efficients have been reported. They proposed that several factors may be responsible for this reported variability.

The existence of plankton in streams was apparently first reported around 1892. Zacharias
(1896) recorded from several German rivers, a long list of algae which he referred to as potamoplankton. Much later, a review of the literature concerning ecology of river algae was presented elucidating on the relationship between algae and different physical and chemical factors (Blum, 1950). Desimachary and Dweltz (1961) in their X-ray diffraction studies of diatoms came to the conclusion that silica present in diatom frustules is crystalline co-quartz and in addition there is present an organic component which may possibly be a protein. There is possibility of pectin too being present. Greenberg (1964) in river Sacramento recorded a gradual increase in total number of plankters, as the water progressed downstream. Diatoms were predominant in all seasons except that at a number of downstream stations, green algae were numerous in mid summer. Temperature was the single most important factor affecting plankton development, however, stream flow velocity and BOD also were responsible for their variations, upto some extent. Haertel et al. (1969) working on Columbia River estuary observed phytoplankton populations to be mainly controlled by light, nutrients and river flow. A strong correlation was recorded between phosphate and plankton while little correlation existed between nitrate and plankton. Nitrate was at times sufficiently low to be limiting and the possibility remains that the plankton were using some other nitrogen
source, possibly ammonia perhaps excreted by zooplankton. Diatoms dominated the phytoplankton in river Jumna (Chakraborty et al., 1959) and the optimum conditions for their growth appeared to be obtained in April while as June favoured the growth of Chloro and Cyanophyceae. Turbidity, current and influx of rain water had detrimental effect on plankton. Alkalinity had inverse relation with phytoplankton. Further phosphate seemed to have more significant inverse relation with plankton than nitrate.

Katnasabapathy (1975) in his studies on Gomkab river found Bacillariophyceae, the dominant group followed by Chlorophyceae and Cyanophyceae. He further stressed the importance of periphyton in stream total phytoplankton.

In Hooghly Matlah estuary, Shetty et al. (1961) observed phytoplankton showing two peaks, one during June- August and another during November- January. Diatoms were invariably responsible for all the observed peaks and their peaks corresponded with those of the total plankton. Vase et al. (1977) in river Jhelum did not find any significant variation among phytoplankton from different stations. Ayamnu (1973) in his studies of river Avon found upper stations "too fast" to support a rich planktonic flora and the numbers increased downstream. The plankton was dominated by diatoms which formed peaks in spring presumably closely related to reduced flow
rate and an increasing light/temperature regime. The abrupt decline suggested silicate limitation. The Chlorophyceae peak in summer was possibly related with high temperatures. The diatom peaks occurred throughout the stream at the same time showing no obvious downstream movement, however, later the growth became patchy. In river Moosi, Venkateswarlu (1969, b) reported a correlation between percentage of diatoms and high average concentrations of silicate and dissolved oxygen. However, at other stations, faster currents of water limited the percentage of diatoms. In addition, high organic matter too seemed to be unfavourable for their multiplication as also low dissolved oxygen. On the other hand, blue green algae was reported in abundance with high organic content and low oxygen concentrations, together with low pH. Euglenoids occurred where DOM and total iron concentrations were comparatively higher coupled with low pH. Chlorophyceae dominated where the water was rich in dissolved oxygen and poor in DOM. Beattie et al. (1970) in their observations recorded decrease in silicate content correlating with diatom bloom. In rivers Ganga and Jumna, phosphate and nitrate followed an inverse relationship with phytoplankton while as silica did not show any significant relationship especially with diatoms. Rainfall had an adverse effect on plankton populations. In both the rivers diatoms were
the dominants (Ay et al. 1966). Lam (1979) while working on dynamics of plankton growth in Waikato river found it overwhelmingly dominated by diatoms. In his experiments, on the effects of various nutrient enrichments on plankton in cultures, he found that green algae replaced diatoms as being the dominant group, when NO₃ and PO₄ were added. His experiments also demonstrated the lower light and temperature requirements of the diatoms. The river Waikato too favoured the development of diatoms as their growth was not limited by the lower concentrations of NO₃ and PO₄ in its waters which on the other hand were limiting to blue-green algae growth, requiring higher concentrations. In addition, the high silica content favoured diatoms. The river fast flow too seemed to discourage the growth of green and blue green algae. 

Diatome vulgare was reported to occur only where water was flowing swiftly and was absent from sheltered areas downstream, Saline river, Michigan (Blum, 1960). Whitford (1960a) reported some algae e.g. Oedogonium muskie, throughout the year in some rapids from southern U. S. A. while a number of others e.g. Chaetophora was confined to them only in summers. Hickel (1973) studying phytoplankton dynamics in ponds of Kathmandu observed plankton of cool season comprising almost
entirely of diatoms and these started decreasing as the temperature began to rise while green algae increased and the mass development of different "a-algae" occurred. Further, she found that with the onset of monsoons, there was a marked decrease in plankton counts. Kai (1973) carrying research on rivers & lakes of Ivory Coast recorded that the diatoms dominated the major floods while blue green algae predominated during the dry months. The dominance and abundance of blue green algae during the dry season was possibly closely linked with high organic matter content of the water at that time and their ability to synthesize organic nitrogenous compounds from the ammonium and products. In river Niger, too diatoms predominated after the major floods while blue green algae thrived best during the dry season having high organic matter content, (Imevbore, 1970). In river Tamagawa, Temaka et al. (1974) reported diatoms to be dominant in summer and green algae and diatoms in winter. An increase in sessile algae standing crop with increasing pollution was recorded. Munawar (1974) working on the freshwater ponds of Hyderabad recorded the phytoplankton maxima mostly in the winter and the minima during the monsoon or rainy season. Diatoms
dominated the phytoplankton of all the ponds in all seasons. An inverse relationship between Diatomeae and Cyanophyta and Diatomeae and Euglenineae was observed. In the sewage affected ponds, the numbers of plankton were highest and the members of Cyanophyta and Euglenophyta were important in such ponds. Again (1974 b) while working on the periodicity and species composition of unicellular and colonial phytoplankton found these to be related with the fluctuations in the physico-chemical parameters. Cyanophyceae developed profusely when the temperatures rose or were fairly high. Higher concentrations of Ca and Mg seemed to favour their growth. Sewage pond was more suitable for the development of Volvocales, as they seemed to require higher concentrations of No₃ and PO₄. Chlorococcales grew abundantly when the temperatures were comparatively higher and the nitrate content was low. Desmidales were observed to grow at lower concentrations of nitrates and higher temperatures, their behaviour towards Ca was erratic. Diatoms developed profusely when the temperatures were relatively lower. An inverse relationship was observed between diatom abundance and albuminoid ammonia, so was the case with silica too. Rai and Kumar (1977) found that high concentrations of No₃ and PO₄
were required for the peak development of Cyanophyceae; whereas in case of Chlorophyceae no definite relationship was recorded with the same nutrients. However, the pH was high throughout the Chlorophycean growth period. Euglenophyceae thrived well with low oxygen and high organic content and preferred slightly acidic conditions. High organic content seemed to favour the growth of diatoms. The total nitrogen content was very high during their growth peaks but at the same time chloride content did not seem to play a key role in the biology of diatoms. Rai (1978) during his research on Ganges reported Chlorophytes flourishing better at unpolluted stations and these tend to dominate at relatively high temperatures. The behaviour of Cyanophytes was quite different from Chlorophytes with regard to the pollution stress as their numbers went on increasing with an increase in pollution while in case of latter these went on decreasing. Some of the algal forms e.g. Schizomeris and Stigeoclonium were exclusively present in polluted waters whereas the same waters never supported the growth of Cylindrotheca and Gyrosigma. Low levels of dissolved oxygen and high of BOD favoured the growth of euglenoids. Nygaard (1977) working on motile fresh water algae recorded the abundance of euglenoids in water strata characterized by subdued
light and low oxygen concentrations. Safar (1959) recorded euglenoids, oxidizable organic matter going almost hand in hand and dissolved oxygen too affected their periodicity indirectly as it had its effect on the concentrations of ammonia and nitrite; the higher concentrations of these seemed to have toxic effects on euglenoids. Williams (1964) observed that samples with high standing crop (productivity) usually show low species diversity. Heavy stream flow was recorded to be a prime factor governing populations of plankton. Diatoms showed a preference for cooler temperatures, further high calcium - hardness values produced higher standing crops. He further stressed the importance of diatom as pollution indicators. Abdel Karim and Saeed (1976) while studying distribution of Melosira granulata in River White Nile, with reference to certain environmental variables recorded a noticeable decrease in nitrate values coinciding with the onset of multiplication of the species. No apparent correlation was observed with other variables like pH and phosphate, although the latter followed Melosira in recording a decrease. A noticeable decrease from surface to bottom was observed. Pronounced stratification of the alga was evident during certain months but without apparent correlation with any of the factors analyzed.
McCartney and Goldman (1979) in their studies with marine phytoplankton cultures came to the conclusion that in nutrient depleted waters, bacterial degradation and animal (zooplankton) excretion products provide the required amount of nitrogenous material for the normal growth curve of phytoplankton. Rice (1954) working with the cultures of planktonic algae concluded that antagonistic substances arising from the metabolism of plankton were important, at least in fresh water ponds, in influencing the seasonal fluctuations in total phytoplankton numbers and in numbers of each species and in inducing a definite succession of the phytoplankton. Kneeshel and Kalf (1976) carrying their research on productivity and population dynamics of some fresh water plankton diatom species observed that cell growth was determined primarily by photosynthetic rate which seemed to be controlled by nutrient supply. Cell growth determined only the maximum possible population growth rate while losses, primarily through sinking, determined the actual population size. Sinking seemed to be largely a function of death rate which was thus the factor ultimately controlling the size of the diatom populations in Lac Hertel. Maguire andNeill (1971) determined the relative productivity of individual cells in a mixed phytoplankton community by $^{14}$C autoradiography. Their data allowing the
estimation of the relative contribution of each of the component species to the total community production illustrated the size specific production of the cells of each of these species and could further suggest predictions concerning future successional developments of the community. Schindler (1976) reported nutrient inputs to be an important factor in controlling freshwater production and nutrient input in turn recorded a correlation with latitude which may possibly explain the correlation between latitude and production observed by earlier investigators elsewhere. Smiley (1976) in his studies with unicellular microorganisms found that the subsistence quotas of phosphorus and nitrogen were dependent on cell size. These findings he attributed to the fact that the subsistence quota of a particular nutrient represents the amount of the nutrient associated with those structural and metabolic components that are essential to cellular integrity and viability and since the absolute amounts of most of these components probably increases with increase in cell size and since both phosphorus and nitrogen are essential constituents of most, the similar size dependence for both is expected. Welch et al. (1978) in their laboratory experiments with natural phytoplankton found that the addition of Po4 resulted in maximum plankton
growth while as NO\textsubscript{3} did not seem to affect them much. The growth rate of natural assemblages of phytoplankton too seemed to be relatively unaffected by the NO\textsubscript{3} concentration; at even low concentrations of NO\textsubscript{3}, the growth rate was clearly a function of PO\textsubscript{4}.

Phytoplankton distribution and abundance in various tributaries of the Colorado river was investigated by Grayston and Sommerfeld (1979). Low values were recorded for both species richness and abundance, which they attributed to the physical characteristics of the tributaries i.e. increased turbidity and sediment load, high current velocity and less age of water. Water temperature as well as nutrient levels did not appear to be limiting factors, however, correlations between several dominant algal species and certain physicochemical factors e.g. temperature, nitrate, calcium, potassium, pH and total dissolved solids were observed. Wilhm et al. (1978) working with periphyton of some creeks and rivers of Oklahoma recorded low species diversity values in areas receiving effluents, and high values characterized clean-water areas. Low dissolved oxygen as well as high turbidity decreased the diversity values. Earlier (1979) Litav and Agami too recorded the same observations while Olive and Price
(1976) noticed clean waters of Cuyahoga river harbouring twice as many "taxa" as the polluted ones. Kaesler and Herricks (1976) stressed the advantages of Brillouin's equation for species diversity and preferred it over Shannon's equation. His studies further indicated that small sample size gave as useful diversity index as large one and the former had the advantage of reducing the cost of stream surveys. Again Kaesler et al. (1978) laying emphasis on the use of small replicated samples observed that the diversities at generic levels may provide as much information about community as species diversity.

Islam and Naron (1975) recorded an inverse relationship between phyto- and zooplankton in the river Buriganga. Samples taken from the river Niger before and after impoundment and from the river Swashi were analyzed for changes in numbers and species composition of zooplankton. Lake Kainji showed much greater development of zooplankton than in the rivers. The Cladoceran Doinia minor and the rotifers Brachionus falcatus and B. caudatus were relatively more abundant in the rivers than in the lake whilst the reverse was true of Boeina spp. and Propodiaptomus bicornatus (Clarke, 1976). Inouye et al. (1975) working with aquatic insects and fishes in the river Kioniote found that Horoco steindachneri collected from dammed lake was thin while the
individuals from the rapid or streamlet was fat. Results of Dumnicica and Pasternak (1976) suggested that composition of Oligochaeta communities depended not only on the type of the bottom, speed of water current and pollution carried by the river but also on some chemical properties of water which were connected with the substratum of the river bed e.g. hardness or Ca and Mg content. It seemed that the degree of water purity was more important for the occurrence of some species of Oligochaeta in rivers and streams than the type of the bottom while on the other hand habitat played the least important role in the distribution of other species. It was also observed that species of similar correlation coefficients usually occurred together. Marshall and Winterbourne (1979) reported total numbers and biomass of invertebrates to be the highest at the most enriched sites. Lair (1960) in his study on rotifer fauna of the river Loire observed that in warmed up waters, some species had abundant numbers and their diversity also increased. Sharma (1960) presenting a taxonomic account of some species of gastrotrichs observed that all these preferred habitats with detritus and decaying organic material.

It was in 1959 that Hyne stressed the need for the use of invertebrates as indicators of river
pollution, Rosenberg and Snow (1975) worked out the effects of sedimentation on aquatic organisms. They recorded an immediate reduction of 70% in the standing crop of benthic invertebrates. A positive increase in drift was shown at all concentrations of suspended sediment by macrobenthic invertebrates but not by zooplankton and total invertebrates and so usefulness, of macrobenthic invertebrate community in determining sediment pollution, has been stressed. Earlier (1974) Rosenberg used immature Chironomidae as indicators of total community diversity, in a study of the effect of dieldrin on community diversity of macroinvertebrate and came to the conclusion that Chironomidae diversity was not a good indicator of total diversity and because of this inconsistency of the correlation co-efficients, the possibility of using these as an indicator of overall diversity must be discarded. Sprules (1977) stressed the importance of crustacean zooplankton communities in assessing the limnological status of a water body. Stutzer (1976) in river Brentberg, found a trend towards increased pollution downstream. He recorded orthocladiinae in significant numbers throughout the study period, at all the stations except downstream where aeration was low with purification impaired.
Here, the percentage of Orthoisaladiinae decreased while the annelids increased, the clear indicators of pollution. Oligochaeta communities and their numbers were used by Dumnicka (1978) in determining the degree of pollution of river Hida and its tributaries. In the upper course of the river Hida, with no inflow of wastes, the characteristic communities of small lowland rivers were present, the number of Oligochaeta was small and the number of species high. On the other hand, very strongly polluted river Bobrza was manifested by the mass development of sewage forms and there was a decrease in the number of species. Further, he found that at pure water stations, the Oligochaeta communities differ distinctly so that the species occurring as dominants at one habitat are dominants at the other. A prominent part in their distribution was played by the character of the bottom i.e. the size of the particles and the content of organic matter in the sediment. On the other hand, at polluted stations, the communities were very similar for all habitats. A large content of organic matter as well as unfavourable oxygenic conditions inhibited the development of many species so that only sewage forms developed in masses. Black Warrior River was found to be eutrophicated as the species diversity value was low (Ratnasahapathy and Beason, 1977).

Eutrophication was also suggested by the...
dominance of bacteria and organic detritus feeders, Keratella, Codonella and Tintinuidium among the zooplankton as also the high density of phytoplankton.

Man's activities on various rivers can produce varying results in terms of water quality and erosion on the banks and beds. During the construction of dams and power plants, dredging is common and will of course give rise to a locally increased turbidity and concentrations of suspended sediments. According to suspended load measurements, a probable increase in erosion of about 30% was estimated for the river Angermanalven from dam to the delta (Nilsson, 1976). Vernet and Johnson (1974) reported Mg to be the primary trace metal contaminant in the Rhone River system; Cu, Zn and Pb were having localized elevated levels. In River Liffey estuary sediment too, trace metal enrichment was found to be localized. This metal enrichment was accompanied by an increase in the organic carbon, nitrogen and humic acid levels (Jones and Jordan, 1979). Paul and Pillai (1976) observed river Periyar subject to a host of pollutants such as acids, alkalies and their salts; trace metals and radionuclides, from a number of chemical industries. Proximity of different out falls and poor lateral mixing in the river were responsible for high
local aquatic concentrations. Monsoon "flushed out" the river into the back water area and translocation of sediment was the major factor in the transport of pollutants.

Klepper (1976) used cross-section multiple regression to test the importance of nitrogen-fertilizer-use for variations in the nitrate nitrogen concentrations in various tributaries of the Sangamon river. The regression results were not clear cut but did lend support to nitrogen-fertilizer use as an important explanatory variable for variations in nitrate nitrogen concentrations. Broadbent and Rauschkolb (1977) have stressed the need for such management practices (in an agricultural system) that will ensure greatest nitrogen uptake efficiency (applied as fertilizers) resulting both in environmental protection and also healthy food production. Ghako and Krishnamurthy (1954) found that "manuring" resulted in blooms of algae e.g. Oscillatoria, Scenedesmus, Euglena, Phacus and Brachionus. Fertilization with manure resulted in an increase in biomass of blue-greens and green with diatoms ranking next to them ( Watnabe et al. 1960).

Ludwig (1972) worked out the deleterious effects caused in rivers and lakes, by domestic sewage
inflows. Sewage-treatment-plant effluents and also river mine were reported to be the most important pollutants of the river Kromme Rijn (Selman and Sleuten, 1978). Pieczynska et al. (1975) observed that domestic sewage inputs resulted in the considerable increase in the concentrations of minerals and organic substances and this in turn led to the mass growth of various filamentous algae. Further, their field experiments proved that the rate of biocoenoses destruction under the influence of sewage inputs is twice as fast as the process of biocoenoses reconstruction.

Investigating the effects of various components of water pollution on the behaviour of some aquatic macrophytes, of two Coastal rivers of Israel, Agami et al. (1976) transplanted the species of clear water sections into the polluted sites in the same rivers. Five species died shortly afterwards, whereas two survived uninjured. Detergents seemed to constitute the main factor in degeneration and eventual death of the species while as other factors like anaerobiosis and increased levels of NO₃ and PO₄ had no effect on the plants. They further suggested the possible use of certain aquatic macrophytes as indicators of varying levels of pollution.

A massive fish kill in the James River which was caused by the discharge of chlorinated effluents was
recorded by Rellanca and Bailey (1977). In the first year, the chlorine levels were high enough to result in an acute kill of massive proportions and in the preceding year the comparatively lower levels resulted in the development of chronic symptoms i.e. development of broken backs. Chronic toxicity possibly led to the modification of bone structure. Their studies further indicated that a reduction of chlorine dose to the minimum required for disinfection could be effective in protecting aquatic organisms also during critical stages of their life. Madison Metropolitan wastewater effluent effects on water quality of Badfish Creek, Yahara River and Rock River were determined by Lee (1977). In all the rivers, he reported an increase in inorganic nitrogen and soluble orthophosphate above the critical levels which may lead to toxicity to fish and to excessive growth of algae.

Watanabe et al. (1972) carried out the limnological survey of the Saigawa reservoir which pointed to its oligotrophic nature but the eutrophic plankton species e.g., Asterionella formosa and Microcystis elegans were reported in abundance. To explain this contradictory phenomenon, they assumed that due to heavy rains, nutrients accumulated on the soil surface flowed
At a stretch into streams and the flowing of this allochthonous nutrients into the reservoir in a comparatively short time, from the catchment area might have resulted in such an eutrophication as shown by the abundant occurrence of eutrophic species. Limnobiological studies of Godani gawa and Kakehashi-gawa rivers revealed that the pollution (of mine) was so severe that no living thing was encountered and with decreasing pollution, the biotic productivity was recognised to recover, though the organisms found were limited qualitatively as well as quantitatively, (Sumita and Watanabe, 1973). In river Azurya, the standing crop of micro-organisms decreased as the quantity of silt covering the bed increased, in proportion to the increase of turbidity (Watanabe and Kamijo, 1974).

Using attached organisms on submerged stones, to study pollution of Sai-gawa river and its tributaries, Kamijo and Watanabe (1975) concluded that pollution in these progressed from the bottom layer.

Butcher et al. (1937) were the first to use the artificial substrata (glass) for studying the effects of different pollutants on the algal community of a river and for comparing the water quality of different rivers or a single river on passing downstream. Using a specially developed continuous
sampler termed diatometer, a graphic method for demonstrating the effects of pollution was followed by Patrick et al. (1954). In a river not adversely affected by pollution, many species were represented by a few individuals, a few species had many individuals and a few species were very rare. When their distribution was plotted with species as the ordinate and individuals per species as the abscissa, on a log scale, the shape of the curve approached a truncated log normal curve. Pollution eliminated more sensitive species and as a result of the reduced inter-specific competition, more tolerant species became more abundant; the height of the mode on the curve decreased and the tail became longer. Beck (1955) developed a biotic index (I) which had been used to provide a quantitative expression of the degree of organic pollution. The value of the index was a function of the number of intolerant (Int.) and facultative (Fac.) species at a sampling station. \[ I = 2 \times \text{Int.} + \text{Fac.} \] Since the number of intolerant species was multiplied by 2, the value of the index would be high in clean-water areas. Williams (1962) used circle graphs, bar graphs, line graphs and tables to present his data on plankton population and to compare percentage occurrence of plankton at polluted and unpolluted stations. He
concluded that pollution altered the normal population pattern and the organisms served as important indicators of water quality. Palmer (1969) reviewed the literature concerning algae tolerating organic pollution and compiled a list of genera and species which had been reported to be pollution tolerant and developed algal pollution indices, for use in rating water samples for high or low organic pollution. Hoseini and Bharati (1980) in their studies used Palmer's method for the rating of waters for different degrees of pollution and concluded that the indices developed generally hold good. Armme (1971) developed a method for comparing two river water samples which took only a few hours. This involved continuous monitoring of the oxygen metabolism of a planktonic test organism *Scenedesmus obliquus* and so could be used for rapid study of the biological effects of complicated waste effluents. Morgan (1977) devised an automatic biological monitoring system which utilized the fact that fish opercular rhythms increase under toxic conditions. An inbuilt visual alarm system could serve as an advance warning of the development of a critical toxic condition. Downing (1971) described methods which could be used to predict the effects of polluting discharges on rivers and discussed their shortcomings and the possible ways in which these could be modified.
The advantages of planktonic diatoms for assessing the diversity was stressed by Williams (1972), as their species can be accurately identified by wall structures; they are always present in samples being either dominant or among the dominants and these are present usually throughout the year. Kamat (1981) laid emphasis on the application of diatoms and diatom populations for the water quality assessment. Venkateswarlu (1981) too advocated the importance of algae as being the useful indicators of river water quality and pollution and gave a list of algae occurring in polluted and unpolluted waters. He further stressed the need for the proper identification of diatoms by experts; as diatoms are the dominants in rivers, these can be more useful in assessing the water quality in such environments.

Guidelines for the disposal of dangerous and toxic wastes so as to minimize or prevent environmental and water pollution, were presented by Hudd (1976). Lee et al. (1976) putting forth their views on eutrophication of water bodies discussed the importance of phosphorus over nitrogen and carbon as being the key limiting element for the growth of algae. So the eutrophication control measures
should be directed towards the control of phosphorus from point sources e.g. domestic and industrial waste waters, as well as from non-point sources e.g. atmosphere, agricultural run off as also urban and rural drainage. Waste water treatment plants have been effective in reducing phosphorus concentrations from point sources while as control from non-point sources requires a much better understanding of the quantities of the available phosphorus obtainable from each source and the cost controlling this available phosphorus. Young et al. (1979) examining the effects of nutrients on the water quality of shallow rivers found that by lowering the nutrient supply, the desirable oxygen levels could be maintained and also there would be a decrease in plant growth rate. But in rivers supporting a sizeable community of aquatic plants, the suggestion to incorporate a quantitative biomass control measure has been put forth.

Tourbier and Pierson, Jr. (1976) edited a full volume on biological control of water pollution elucidating the advantages of the biological control which include removal of inorganic substances from waste water; degradation of highly toxic organic substances like phenols; neutralization of alkaline
and acid waste waters; improvement of the quality of water polluted by food processing wastes; aeration of water through photosynthesis; aeration by plants of water by taking oxygen into their upper stalks and giving it off through their submerged lower stalks, provision of habitat for other living things (crustaceans, insects and fish) which themselves purify water; reduction of the volume of waste waters by transpiration; mechanical filtration of suspended solids through plant root structures and attenuation of pathogenic organisms etc. An activated sludge pilot plant to achieve low nutrient (\( \text{NO}_3 \) and \( \text{PO}_4 \)) concentrations in the effluents by biological means was designed by Simpkins and McLaren (1976). In the experiments with phosphorus removal from sewage, McLaren and Wood (1976) achieved almost complete elimination of phosphorus by incorporating an anaerobic stage in the nitrifying denitrifying activated sludge plants.

Self purification of running waters (after pollution by sewage) in a ditch with a small depth was studied by Brink (1968). He found that during low flows of summer and winter the self purification was satisfactory but during high flows,
it was not so as the sedimented sludge too was carried away with the current. However, if accumulated sludge was regularly removed, the oxidation ditch could work continuously. Flow velocity has been found as the determining factor for self-purification in rivers (Wuhrmann et al., 1975). In their model rivers, as the velocity decreased, the self-purification too recorded a decrease; this they attributed to the fact that the substrate transport from the flowing wave to the receptors on organism surfaces responsible for active uptake was considerably inhibited as the flow velocities were reduced.

In India the work done on rivers is meagre and a few detailed studies have been carried out by Vieswas (1942-43) on river Moodi; Chako and Gamapathi (1944) on Adyar; Ganapathi and Chamo (1951) on Godavary; Chako et al. (1953) on Malampuzha; Dutta et al. (1954) on Hoogly estuary; Roy (1955) on Hoogly; Chakravarty et al. (1959) on Jumna; Shetty et al. (1961) on Hoogly - Katlan estuary; Sakeumarayama (1965) on Ganges; Ray et al. (1966) on Ganga and Jumna; Venkateswarlu (1969 a and b) on Moodi; Rai (1976) on Ganges and etc.
In the state, from Kashmir there has been only one published record of studies on rivers (Jass et al., 1977 on Jhelum) and from Jammu Anand (1979) has presented only a list of blue green algae occurring in Gadigarh stream. There is also an unpublished record on the Jhelum from this department (Kaul, 1961).