International Journal of Advanced Research in Engineering Technology & Science

ISSN: 2349-2819

Email: editor@ijarets.org Volume-11, Issue-8 August – 2024 www.ijarets.org

HYDROBIOLOGICAL STUDIES ON RIVER GANGA AT BUDAUN, U.P., INDIA

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ABSTRACT

An attempt has been made in the present study to correlate the periodicity of algae in the river Ganga at Badaun with chemical and physical factors of the water. The river represents a special type of habitat being located in the open countryside and cultivation of crops near by the people inhibiting these localities. Observations were continued for a period of 12 months accompanied by fortnightly analyses of water and study of different groups of algae of the river Ganga. River Ganga is fundamentally in the type and amount of biologically important dissolved substances and silt that accumulate in them through drainage.

Drainage mainly from the tilled soil of the agricultural and similar sources it further contaminated to a considerable extent by sewage effluent, from bathing and washing of clothes as well as wadding by cattles. All these increase the degree of water pollution of the river Ganga by the organic matter of animal origin.

Key Words: Hydrobiology, Periodicity, Physico-chemical parameters, phytoplankton.

INTRODUCTION

Today Most of the rivers all over the world receive millions of liters of sewage, domestic wastes, industrial and agricultural effluents containing substances varying in characteristics from simple nutrients to highly toxic substances, Polluted state of the water resources has led to the steady decline in fisheries and has also affected the irrigated land. The increasing population, urbanisation and industrialization, particularly in the last few decades have created the most serious problems of waste accommodation and consequently the environmental pollution. The harmful wastes not only adversely affected the fisheries, undetermined agriculture production, soil beaches and water courses but also seriously pollute the water resources and lead to variety of health hazards.

Studies in relation to water pollution of rivers have attracted the attention of several workers in India and abroad. Studies pertaining to river water pollution are nainly related to physico-chemical analysis of water, phytoplankton, zooplankton, algae and heavy metal pollution etc. Water is man’s own creation, there is growing consciousness to save the crops and aquatic control measures, with the constant demand of the freshwater aquatic resources of the globe there has been a "compounding of the interrelationships between algae and man". Our knowledge about the distribution and periodicity of phytoplankton and other algae of river in relation to habitat conditions is scantly in India and abroad but for a few observations on small concrete, reservoirs, artificial ponds, lakes or rivers. (Fritsch 1907, 1935, 1945; Fritsch and Rich, 1913; West and West, 1912; Butcher, 1924; Atkins and Harrie, 1924; Atkins, 1926; Eddys, 1927; Wiebe, 1930; Pearsell, 1932 1942; Lind, 1938; Meloche *et al*., 1938; Daily, 1938; Ganapati, 1940; Chandier, 1942; Gonzalves and Joshi, 1946; Patrick, 1948; Prescott, 1948, 1968; Chu and Tiffany, 1951; Komarvosky, 1953; Rao, 1955; Suxena, 1955; Blum, 1956, 1957; Cairns, 1956; Singh, 1959; Das and Srivastava, 1959; Chakrabarty *et al*., 1959; Philipose, 1959; Singh, 1960; Carter, 1960; Jackson, 1961; Sreenivasan, 1964; Zafar, 1964, 1967, 1968; Pahwa and Mehrotra, 1966; George, 1966; Patrick *et al*., 1967; Singh, 1968; Chapman, 1968; Biswas, 1969; Munawar, 1970, 1972; Sreenivas, 1970; Ahigren, 1970; Bradbury, 1971; Fogg and Walsby, 1971; Kumar and Singh, 1971; Bharati and Hosmani, 1973; Kant and Kachroo, 1974; Boyd and Prather, 1975; Agarwal *et al*., 1976; Arumugam et al., 1981; Shukla et al., 1989; Pandey and Habib, 1989; Habib *et al*., 1989, 1991; Habib and Pandey, 1989; Habib and Chaturvedi, 1993; Habib, 1993).

In the investigations cited above, reveal diversity and complexity of the problems involved, further water of all the tropical countries have not yet been thoroughly investigated. Most of the available literature on tropical waters portray either (a) a picture of the physical, chemical and biological conditions existing at a specific time or (b) are records of occurrence without adequate descriptions of the habitat and the relative abundance of individual organisms of each species. No attempt has been made to determine the exact relationship between the biota and the habitat during the different season or seasons of a year. They are not helpful in furnishing correct information relating to thermal stratification and circulation which forms the substructure upon which whole frame work of biological productivity of lakes, ponds, rivers etc. rests. Knowledge of these and other biological factors is necessary where control of the productivity of this water is of urgent and practical importance as in India. Water bodies like rivers, lakes, pond etc. are of great economics importance to man for the water and organisms that abound in them. Man has been using them with little or no consideration for their ecology. Freshwater bodies (like river Ganga) are being used for these purposes. of the freshwater bodies should aim at maintaining them in useful form at a high productive level with the provision for a high rate of removal of plants and animal for human consumption. The algae play an important role in the biological productivity of the vegetation of river; very little work has been done on the factors which govern the growth of algae in the rivers. As no detailed hydro biological work on algae has been done so far in this district,

MATERIAL AND METHODS

Surface samples at different places for the chemical analysis of the water were collected from each sampling station at monthly interval in large plastic car buoys of one liter capacity between 8-10 a.m. Care was taken to prevent undue shaking of the samples and also against sunlight while transporting them to the laboratory. Sample for estimation of dissolved oxygen was collected in 250 ml bottle and fixed immediately. Certain factors were analysed immediately and the remaining water was kept in an air cool chamber at a temperature lower than the temperature at which collected. Samples for the estimation of Silica and other gases were collected in Thermos flasks. The physico-chemical analysis of water was done following standard methods (APHA, 1985).

Samples for the estimation of phytoplankton were collected at an interval of 30 days. One liter plastic car buoys were employed for this purpose of collection. An approximate amount of 40 ml 4% formaldehyde was added to the sample, which were sedimented in glass columns (Welch, 1952). The amount sedimented was further r educed to 20 ml on centrifugation and on certain occasions when the phytoplankton population was thin it was adjusted to 10 ml. Such samples were preserved and stored in small vials of suitable volumes. From samples thus preserved, one drop from each vial was mounted and five high power fields one in each corner of the cover slip and one at the center were taken at random on each slide, and all the algae in each field were counted. Thus, free floating and attached algae present in 50 fields obtained on 10 slides were estimated numerically.

OBSERVATIONS

CLIMATIC CONDITIONS OF THE RIVER AREA

The mean monthly data of air temperature, water temperature, rainfall, pressure, weather, wind velocity, evaporation and relative humidity for the period of observations are presented in Table-1.

Table-1- Showing air temperature, water temperature, rainfall, relative humidity, evaporation, wind velocity and pressure for the year 2022-23 (Nov 2022 to Oct 2023)

Factors

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Air temperature (^{0}C) maximum	28.2	22.7	21.8*	23.0	31.4	26.0	34.1	40.7**	39.0	36.5	32.0	31.0
Air temperature (^{0}C) minimum	14.6	8.2	9.7	10.6	16.1	12.0	23.1	27.4**	26.0	24.0	24.0	22.0
Water temperature (^{0}C) maximum	23.5	18.3*	18.5	20.6	27.7	27.0	33.2	35.8**	32.7	29.0	30.5	29.5
Water temperature (^{0}C) minimum	15.8	11.5*	11.7*	14.2	17.4	19.7	23.1	27.2**	26.5	23.5	25.4	24.0
Rain fall (mm)0.56	0.71	0.4	0.4	0.1*	0.4	1.6	1.4	1.8	6.4**	2.6	1.2	
Relative humidity (%)	72.9	67.48	72.7	86.0	51.0	92.0**	30.7*	44.5	84.0	91.0	68.0	72.0
Evaporation (mm)	0.74	0.57*	1.21	1.2	35.5	1.8	5.4	11.9**	2.3	4.6	1.8	2.2
Wind velocity (km/h)	1.6*	1.96	2.46	7.0	4.7	8.0	3.7	4.2	9.0	11.2**	8.0	8.0
Pressure (m/bar)	994.1	996.2	1072.4**	982.8*	990.5	987.6	988.0	992.2	998.7	999.8	997.1	998.6

** Minimum Value*
*** Maximum Value*
Sources : Meteorological Department.

PHYSICO-CHEMICAL FACTORS

The periodic changes of the physical and chemical factors of water during the period of present investigation (2022-23) a re given in Table-2.

Table-2. Showing seasonal variations in the dissolved nutrients, temperature, pH and visibility in the water of Ganga River, Badaun for the year 2022-23 (Nov 2022 Oct 2023)

Factors	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Nitrogen nitrage (ppm)	0.024	0.014	0.016	0.002*	0.0284	0.024	0.024	0.0286**	0.018	0.018	0.024	0.019
Ammonia (ppm)	0.019	0.012	0.0085*	0.0132	0.0884**	0.0241	0.0235	0.0282	0.0562	0.0472	0.0456	0.054
Albuminoid nitrogen (ppm)	0.008*	0.014	0.012	0.023	0.024**	0.023	0.023	0.023	0.023	0.016	0.015	0.01
Silica (ppm)	11.5*	14.6	14.8	15.5	16.8	16.9	16.5	17.5	17.8	17.9**	15.5	16.8
Phosphate (ppm)	0.046	0.0466	0.476**	0.082	0.068	0.082	0.0482	0.0462	0.052	0.056	0.048	0.042*
Chloride (ppm)	12.62*	13.62	14.51	16.95	16.42	15.8	18.5	20.26	19.86	20.82**	18.62	16.84
Free CO_2 (ppm)	184.6	192.4	245.0**	198.8	108.6*	146.4	140.0	128.6	194.8	136.6	174.8	190.4
Total alkalinity (ppm)	182.4	220.4	236.5	275.7**	208.4	167.6	184.4	135.4	96.2	94.65*	156.8	218.8
Bicarbonate (ppm)	182.4	220.4	209.9	245.3**	173.6	128.1	146.0	135.4	96.2*	94.65	128.2	172.2
Carbonate (ppm)	Nil	Nil	26.6*	30.4	34.6	39.5**	38.4	Nil	Nil	Nil	28.6	24.6
Total iron (ppm)	0.04	0.014*	0.028	0.029	0.23**	0.03	0.04	0.04	0.036	0.016	0.094	0.06
Dissolved oxygen (ppm)	10.6**	5.6*	5.9	7.0	7.6	5.8	6.2	6.0	7.2	6.9	6.2	8.4
Dissolved organic matter (ppm)	4.26	3.28	4.25	3.46	4.84	3.48	7.8**	7.6	5.42	3.42	3.26*	3.43
Total hardness (ppm)	140.2*	168.6	192.4	208.4	212.4	218.2**	202.2	218.0	217.2	214.4	212.4	216.4
Total solids (ppm)	142.0	84.0*	98.0	122.0	248.0	284.0	132.0	212.0	293.0**	248.0	168.0	174.0
Suspended solids (ppm)	28.0	16.0*	34.0	90.0	80.0	97.0	38.0	76.0	131.0**	54.0	56.0	48.0
Dissolved solids (ppm)	122.0	68.0	64.0	32.0*	168.0	187.0	94.0	136.0	164.0	194.0**	112.0	126.0
Water temperature (^{o}c)	19.65	14.9*	15.1	17.4	22.55	23.35	28.15	31.5**	29.6	26.25	27.95	26.75
Hydrogen ion Concentration (pH)	7.8	8.6	8.5	8.2	8.5	8.8	9.2**	8.4	7.8*	8.5	8.0	8.5
Transparency (inches)	5.72	5.81	8.02**	7.64	7.82	7.64	7.74	6.42	5.74	5.62*	7.92	6.42
Calcium (ppm)	10.52*	14.23	13.25	16.28	17.21	17.48	16.47	19.42**	16.49	14.65	15.62	16.63
Magnesium (ppm)	0.26	0.24	0.32	0.24	0.28	0.22*	0.34	0.28	0.42**	0.39	0.24	0.29

* Minimum value
** Maximum value

ALGAL COMPOSITION

The periodicity of phytoplankton of river Ganga is given in the Table-3. The arrangement of their presentation is based on that of Fritsch (1935, 45). In a year round study of the river, 276 species of algae belonging to 93 genera were recorded. Out of these 169 species belonging to Chlorophyceae 45 of Cyanophyceae, 27 to Bacillariophyceae and 31 to Euglenineae

RESULTS AND DISCUSSIONS

PHYSICO-CHEMICAL FACTORS

(PERIODICITY AND INTERRELATIONSHIP)

The temperature is basically important for its effects on the chemistry and biological reactions in the organisms present in water. At higher temperature metabolic activity of the organism increase, requiring more oxygen but at the same time the solubility of oxygen decreases, thus accentuating the stress. Organisms in water have varying sensitivities to temperature. Temperature is also very important in the determination of various other parameters such as pH, saturation level of gases and various forms of alkalinity etc. The overall sequence of rise and fall of water temperature was almost the same with minor differences. During rainy season, the water temperature decreases. This can be explained on the basis of lesser period of isolation, frequent clouds, high percentage of humidity, high current velocity, increased turbidity and high water levels. In summer low water levels, clear atmosphere and higher isolation from the sun resulted in the rise of temperature of water. Thermal stratification in river is related to the difference between the surface and bottom temperatures and the presence or absence of strong winds. Ruttner (1953) stated that temperature is one of the factors which affect the quantity levels of oxygen. The attainment of maximum levels of Dissolved Oxygen during winter months in the river might be due to relatively low temperature of the water and sudden fall in dissolved oxygen value during summer months could be due to general rise in temperature. It was shown by Lakshminarayana (1965) that the temperature variations of the river Ganga were controlled through changes in the density of water. In general, periodic variations of temperature of water were indirectly controlling the phytoplankton production.

TURBIDITY

Turbidity of water is actually the expressions of optical property in which the light is scattered by te practices present in the water. Turbidity in natural waters is caused by clay, silt, organic matter, phytoplankton and other microscopic organisms. Turbidity determinations do not correlate with the actual amount of suspended matter as the scattering of light is highly dependent on the size, shape and refractive index of the particles. A reduction in turbidity is associated with a reduction in suspended matter and microbial growth. Turbidity in natural waters restricts light penetration for photosynthesis. Turbidity was the minimum during the month of August, maximum in during the month of January.

HYDROGEN ION CONCENTRATION (PH)

Most natural waters are alkaline due to the presence of sufficient quantities of carbonates. pH of water gets drastically changed from time to time due to the exposure to air, biological activity and temperature changes in pH occur due to disposal of industrial wastes, acid mine drainage, etc. In natural waters, pH also changes diurnally and seasonally due to variation in photosynthetic activity which increases the pH due to consumption of CO_2 in the process. River Ganga was highly alkaline throughout the year. The seasonal variations of pH in river Ganga show a range “between 7.8 to 9.2”.

Blum (1956) stated that the majority of flowing waters are neutral to alkaline in nature. During July and August the dissolved oxygen level in water went on rising with the rise in pH and reached its maximum in May. On the contrary the chemical factors like nitrates and phosphates showed a downward trend during the same months, indicating thereby that pH could not be considered as an important factor in the productivity of river Ganga. This finding is in concurrence with the observations of Eddy (1934), Chakrabarty *et al.*, (1959).

NITRATE

Nitrate represents the highest oxidized from of nitrogen. Most of the surface waters are, deficient in nitrate. The most important source of the nitrate is biological oxidation of organic nitrogenous substances which come in sewage and industrial wastes or produced indigenously in the waters. Domestic sewage contains very high amount of nitrogenous compounds. Run-off from agricultural field is also high in nitrate. Atmospheric nitrogen fixed into nitrates by the nitrogen fixing organisms is also a significant contribution to nitrates in the water. High amounts of nitrates are generally indicative of pollution. In the waste treatment systems high amounts of nitrate denote the aerobic conditions and high stability of the wastes. Although high concentrations are useful in irrigations but their entry into the water resources increase the growth of nuisance algae and trigger eutrophcation. Nitrates are the richest during the immediately following the periods of rainfall. The present study reveals no seasonal periodicity of nitrates. Nitrates remain high throughout the year in river Ganga and its main source is the drainage water. The higher values of nitrates during rainfall are due to addition of nitrates in the form of run off. Nitrate depletion in winter and summer may be due to the photosynthetic activity of the algal phytoplankton or may be due to oxidation of organic compounds (Blum, 1956). There exists a close relationship between the rise in the concentrations of nitrates and chlorides. The rise of nitrate seems to influence the rapid sprouting in the summer forms of floating aquatic. The minimum value of nitrate recorded in February may be either due to dilution in the accumulated rain water or its consumption in the production of post monsoon bloom.

FREE AND SALINE AMMONIA

Ammonia of mineral organ is rare in natural waters. The most important source of ammonia is the ammonification of organic matter. Sewage has large quantities of nitrogenous matter, thus its disposal tends to increase the ammonia content of waters. Occurrence of ammonia in the waters can be accepted as the chemical evidence of organic pollution. If only ammonia is present, pollution by sewage must be very recent. The occurrence of NO_2 with ammonia indicates that some time has been lapsed since the pollution has occurred. If all the nitrogen is present in nitrate form, a long time has been passed after pollution because water has purified itself and all nitrogenous matter has been oxidized. Ammonia in higher concentration is harmful to fish and other biota. It is also toxic to even Man at higher concentrations. The toxicity of ammonia increases with pH because at higher pH most of the ammonia remains in the gaseous form. The decrease in pH decreases its toxicity due to conversion of ammonia into ammonium ion which is much less toxic than the gaseous form. It is value reaches maximum in the rain season and the seasonal variation is almost identical in the river. The increase in value in the fresh waters is due to the addition of sewage effluents Rao (1955); Zafar (1964) and Agarwal et al. (1976). A summer maxima for free and saline ammonia has been shown by the studies of Allanson (1961) and Venkateswarlu (1970). Agarwal et al. (1976) have observed a direct relation between free and saline ammonia and all humanoid nitrogen and observed a summer maximum for albuminoid ammonia.

ALBUMINOID NITROGEN

In the waste treatment systems, high amounts of nitrate denote the aerobic conditions and high stability of the wastes. Although high concentrations are useful in irrigation but their entry into the water resources increase the growth of nuisance algae and trigger eutrophcation. Albuminoid nitrogen values remained low throughout the year in Ganga River. There is an inverse relation between nitrates and albuminoid nitrogen when the latter is maximum, the nitrate nitrogen is very low or at a minimum (Lind, 1938).

SILICA

The silica refers to silicon in natural waters, where it is usually represented as $H_4\ SiO_4$ or $Si\ (OH)_4$ and silica acid. Since it is a weak acid, it is included as a non-ionic species. Despite it's over abundance in nature, it occurs in meager quantities in water. This is due to silica sources being resistant to chemical weathering processes. The solubility of silica has been found to be more at high pH or high temperature. Silica finds widespread industrial application in glass making, silicates, abrasives ceramics, metal works and petroleum products and hence it may come in the waste water form from these industries. Use of water containing excess of silica may form 'glassy scales' in boilers. Silica concentration is also very important in regulation of growth of diatoms in fresh and marine waters. The silica content of Ganga River showed changes throughout the year. The curves for the river show well defined maxima 0.23 (March) and minima 0.014 (December). The results of present study are in conformity with those of Singh (1960).

PHOSPHATES

Phosphorus in the natural freshwater is present mostly in inorganic forms such as $H_2PO_4^-$, HPO_4^{-2} and PO_4^{-3}. Phosphorus being an important constituent of biological systems may also be present in the organic forms. The major sources of phosphorus are domestic sewage, detergents, agricultural effluents with fertilizers, and industrial waste waters. The higher concentration of phosphorus, therefore, is indicative of pollution. In the presence of oxygen, phosphate co-precipitate with the complex insoluble oxides of iron and manganese. The net tendency of phosphorus in waters is to get precipitated and lost to the sediments, resulting in the overall decrease of phosphorus in the water. During the seasonal cycle when reducing conditions prevail in the bodies of water, some of the phosphorus returns into the soluble form with the formation of ferrous and manganous forms from their respective oxidized forms. The prime concern of phosphorus lies in its ability to promote the growth of nuisance algae and eutrophcation. Phosphorus as such is not harmful to the organisms. The quality criterion for phosphorus in waters is only to check nuisance growth of algae and process of eutrophcation. The high values of phosphate during the rains may be due to the addition of phosphate through drainage. The high values of phosphate can be attributed to the formation or accumulation of inorganic phosphates and also to the substantial additions of phosphate through agricultural drainage and sewage from the neighboring areas (Blum, 1956). During the later part of the winter and the early part of the rainy season, the phosphate content remained low. This might be due to photosynthesis of the algal phytoplankton and also delayed rains and floods carrying depleted phosphate matter (Atkins, 1926; Pearsall, 1932). Nitrates and phosphates are the raw materials for protein synthesis and thus are of great significance in the study of river productivity.

DISSOLVED OXYGEN

Dissolved oxygen is one of the most important parameters in water quality assessment and reflects the physical and biological processes prevailing in the waters. Its presence is essential to maintain the higher forms of biological life in the water, and the effects of a waste discharge in a water body are largely determined by the oxygen balance of the system. Non polluted surface waters are normally saturated with dissolved oxygen. Oxygen can be rapidly removed from the waters by discharge of the oxygen demanding wastes. Other inorganic reductions such as hydrogen sulphide, ammonia nitrates, ferrous iron, and other oxidizale substances also tend to decrease dissolved oxygen in water. Low oxygen in water can kill fish and other organisms present in water. Low oxygen concentrations are generally associated with heavy contamination by organic matter. In such conditions oxygen, sometimes, totally disappears from the water. Oxygen saturated waters have a pleasant taste while the waters lacking oxygen have an insipid taste. For boiler waters, high concentration of oxygen is undesirable as it will accelerate the corrosion at high during rains and highest during winter. Periods of high temperature nearly coincide with low oxygen content, a feature noted by Gonzalves and Joshi (1946) and Singh (1960). The present study reveals a reduction in dissolved oxygen content in river. Blum (1957) and Venkateswarlu (1970) stated that low values of dissolved oxygen are usually associated with high organic matter. Swale (1964) reported that dissolved oxygen content of waters at the river Lee to vary from 6 ppm whereas in tropical waters of Africa. The oxygen content of the river water showed an almost inverse correlation with free Carbon-di-oxide content, a feature noted by Lakshminarayana (1965) and Vyas and Kumar (1968).

DISSOLVED ORGANIC MATTER

The values of dissolved organic matter remain higher in river. Values remain low during late rainy season and the following winter months and the maximum is reached in summer and early winter months in river are (Singh, 1960) than the plant and animal remains with in the river itself. In river the maxima for dissolved oxygen observed from potassium permanganate are attained in the mid summer months, when the rains are yet to start. Although the values are fairly high in the beginning of rains, the decline starts in the late rainy months when considerable rain washings are added to the water from the surrounding areas. This suggests that although a considerable amount of addition of organic matter in these water takes place, during the rainy months, it is certainly not responsible for the high values in the early and mid summer months. It is, therefore, probable that the decay of plant and animal remains, due to high summer temperature, is responsible for the high oxidisable organic content in water. Gonzalves and Joshi (1946) noted increase in organic matter with the onset of hot weather. A clear elucidation of the relationship between the oxidisable organic matter and dissolved oxygen was given by Pearsall (1932).

CHLORIDE

Chlorides occur naturally in all types of w waters. In natural freshwaters, however, its concentration remains quite low and is generally less than that of sulphates and bicarbonates. The most important source of chloride in the waters is from the discharge of domestic sewage. The chloride concentration serves as an indicator of pollution by sewage. Industries are also important sources of chloride. A chloride is highly soluble with most of the naturally occurring cations and does not precipitate, sedimented and cannot be removed biologically in treatment of waters. It is harmless up to 1500 mg/1 concentration but produces a salty taste at 250-500 mg/1 level. It can also corrode concrete by extracting calcium in the form of calcite. Magnesium chloride water generates hydrochloride acid after heating, which is also highly corrosive and create problems in broilers. During summer the values of chloride concentrations were very high whereas in the rainy season they remained low. Although in winter there was a gradual rise in the chloride content and on the onset of summer the maxima was again attained. The chloride content remain higher, a fact which is suggestive ofa greater pollution by organic matter of animal origin in the former. The seasonal variations in the chloride range from a maximum (20.82) to a minimum (12.62). During the present study the maximum values in the winter and early summer can be attributed to reduced flow. A direct correlation between chlorides and water temperature has been observed in the present investigation, since both of them rise and fall almost identically. Further, with increase in the chloride concentration, the nitrates and phosphates also rise.

TOTAL ALKALINITY

Since carbonate alkalinity is absent from November to December and June to August, the total alkalinity during the period of absence of carbonate alkalinity in the river Ganga is due only to bicarbonate alkalinity. Mostly there seems to be an inverse relationship between carbonate and bicarbonates. The total alkalinity curve runs parallel to that of bicarbonate alkalinity throughout the year. This may be due to the predominant contribution of bicarbonate alkalinity towards total alkalinity. Just like bicarbonate alkalinity, total alkalinity shows a minimum in monsoon season (August) and maximum in winter and early summer.

CARBONATES

The values for carbonate remain low as compared to bicarbonate alkalinity. A very close and direct relation between pH and carbonate has been observed in the present study, since both of them rise and fall together during different months of the year. This observation is in concurrence with the view that the water rich in carbonate are more alkaline (Zafar, 1964).

BICARBONATE

The bicarbonate alkalinity remains at much lower value throughout the year. Maximum value is attained in the winter (February) and early summer and minimum in rainy season. Alanson (1961) also observed that eutrophic waters exhibit higher concentration of bicarbonates.

TOTAL HARDNESS

Hardness is the property of water which prevents the lather formation with soap and increases the boiling point of waters. Principal cautions imparting hardness are calcium and magnesium. However, other cautions such as strontium, iron and manganese also contribute to the hardness. The anions responsible for hardness are mainly bicarbonate, carbonate, sulphates, chloride, nitrate and silicates. In general, values are highest in early summer and lowest during the rainy season. Sewage contaminated rivers contain significantly higher values of total hardness. Moss (1972) also stated an increase in hardness with increased eutrophcation of freshwaters. A marked resemblance was observed between calcium, magnesium curve and total hardness. However, free carbon-dioxide and total hardness are not correlated.

FREE CARBON DIOXIDE

In summer free carbon-di-oxide values were higher and on the onset of rainy season, there was sudden fall and gradual rise by the middle of August again followed by a steep fall in the beginning of September. Later, although the values rose slightly, relatively low values of free CO_2 were maintained throughout the year culminating in the lowest values in March and maximum in January Higher values of free carbon-di-oxide recorded in summer might have been due to deoxygenation a feature observed by Talling (1957) while investigation the white Nile. The overall picture indicates an inverse relationship between the oxygen consumption and carbon-di-oxide production, although variations are not markedly periodic. No precise relationship with carbonates, bicarbonates and pH was noted. However, the rise in temperature could be correlated with the increase in the CO_2 levels (Talling, 1957). The same relationship was observed with reference to temperature, water level and transparency of water i.e. whenever there was a rise in these factors there was a corresponding increase in carbon-di-oxide concentration.

IRON

Iron is one of the most abundant elements of the rocks and soil. Iron occurs in two valence forms—iron (II), ferrous and iron (III), ferric. Reduced iron is generally more soluble than oxidized iron. Water bodies generally have higher concentrations of iron at the bottom due to the prevailing reducing conditions. Iron content in the waters attained highest maxima in the rainy season and a sub maximum during the winter. All the iron present in the water was in ferric form, since the waters were highly alkaline, when the solubility of iron is very low, that's why the ferrous iron could not be detected.

TOTAL SOLIDS

Dissolved solids denote mainly the various kinds of minerals in the water. However, if some organic substances are also present, as more often in polluted waters, they may also contribute to the dissolved solids. Dissolved solids do not contain any gas and colloids. In natural waters, dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, sulphates, phosphates and nitrates of calcium magnesium, sodium potassium, iron and manganese etc. In the polluted waters, the concentrations of these substances increase depending upon the type of pollution. The determination of dissolved solids does not give a clear picture of the kind of pollution. There is an inverse relationship between total hardness and total solids in the river Ganga.

CALCIUM

Calcium is one of the most abundant substances in the natural waters. Being present in high quantities in the rocks, it is leached to contaminate the water. The quantities in natural water generally vary from 10 to 100 mg/1 depending upon the type of the rocks. Disposal of sewage and industrial wastes are also important sources of calcium. It has got a high affinity to adsorb on the soil particles; therefore, the caution exchange equilibria and presence of other cautions greatly influence its concentration in waters. Natural softening of the water takes place when water percolates to aquifers due to the exchange by sodium ions. Concentration of the calcium is reduced at higher pH due to its precipitation as $CaCO_3$ (Lehr et al., 1980). The calcium content was high during the winter season which might be due to its higher solubility at low temperature and during pre-monsoon due to run-off from the catchments areas of the river. The calcium content and total alkalinity were high in the river Ganga, which is indicative of its eutrophic nature. The gradual rise in the calcium content from February to June is due to rapid oxidation of the organic matter in the substratum and the subsequent fall in July and August due to its dilution with rain water.

MAGNESIUM

Magnesium also occurs in all kinds of natural waters with calcium, but its concentration remains lower than that of calcium. The principal sources of magnesium in the natural waters are various kinds of rocks.

Sewage and industrial wastes are also important contributors of magnesium. The concentration of magnesium depends upon exchange equilibria and presence of the ions like sodium. Natural softening of water occurs during percolation through soil by exchange with sodium ions. Magnesium is supposed to be non-toxic at the concentrations generally met within natural waters. Concentration as high a 500 mg/1 impart an unpleasant taste to the water thus rendering it unpalatable. Magnesium adds to the hardness of the water. The maximum is attained in the month of July and minimum values record in the month of April.

ALGAL PERIODICITY AND INTERRELATIONSHIP

During the present study, therefore, the algal periodicity has been worked out in detail. The quality and quantity of phytoplankton vary from season to season. The maximum number of species was observed during winter season while the maximum quantity of phytoplankton occurred during the summer season. With the advent of rainy season, however, there is a slight decrease due to disappearance of a few genera belonging to the Chlorococcales and diatoms. There is however, no decrease in the number of genera of Cyanophyceae. During late rainy season (September and October) there is a sudden increase in the number of genera of the Chlorococcales, diatoms and to a lesser extent of the blue-green algae, which lead to the attainment of highest plankton peak (Fritsch, 1935-45; Vyas and Kumar, 1968). During the early winter season (November and December), because of the disappearance of a large number of Chlorococcales and some blue greens, there was a fall in plankton density. Finally due to an increase in the number of genera of diatoms and the Chlorococcales there is a second peak of a lower magnitude during the winter months (January and February). The numbers of species decrease throughout the summer months up to June. The month of July was the poorest in the quantity as well as quantity of plankton because of the disappearance of a large number of green as well as blue-green algae. The highest numbers of genera of phytoplankton are present in September and October. The number of genera of diatoms, blue green algae and Chlorococcales continue to increase till the maximum is reached in the month of February.

CHLOROCOCCALES

Although a large number of Chlorococcales were recorded and some of them were even present in some abundance, this order on the whole never formed a conspicuous feature of phytoplankton of the river. They show one peak in June only. A few forms show a marked periodicity. High atmospheric or water temperature along with bright sunshine is considered to be the important factor in the periodicity of Chlorococcales (Butcher, 1924). In the present data also water temperature appears to play a somewhat important role in the periodicity of Chlorococcales. There is every possibility that the oxidisable organic matter plays an important role in the periodicity. Low oxidisable organic matter in the presence of high temperature acceleraters the growth of Chlorococcales and desmids but if it is high, the Cyanophyceae attain dominance.

As river is characterised by higher concentrations of dissolved oxygen and albuminoid nitrogen it may be inferred that Chlorococcales prefer habitats richer in oxygen and nitrogenous organic matter. Gonzalves and Joshi (1946); Zafar (1964) and Munawar (1970) attribute the higher percentage of Chlorococcales to high values of dissolved oxygen. Gonzalves and Joshi (1946) higher pH values of water are favorable for the growth of Chlorococcales. The Ganga River has rich growth of Chlorococcales shows pH average around 8.4. pH is invariably an index of dissolved calcium in water. Thus it may be inferred that the lower concentration of calcium accompanied by higher pH is responsible for the development of certain Chlorococcales. It is noteworthy that the river water is moderately rich in calcium and also possesses many forms of Chlorococcales. This may suggest that for the development and growth of many forms of Chlorococcales, calcium deficiency coupled with higher pH is conductive but certain species can occur even in calcium rich waters provided. The species of Scenedesums, Tetraedron and Ankistrodesmus are influenced by the concentration of oxidisable organic matter.

EUGLENINEAE

In the present investigation the water temperature, pH and total iron appear to play important role in the periodicity of Euglenineae but very high summer temperature seen to be unfavorable for their growth. Most important contributions on the distribution of Euglenineae are Lind (1938), Gonzalves and Joshi (1946), Komarvosky (1953), Rao (1955), Zafar (1964), Singh (1960), Philipose (1959) and Munawar (1970). The relationship of Euglenineae and such ecological factors as temperature, organic matter, albuminoid nitrogen and iron have been emphasized in the literature. In the present study, the river water harbours the highest percentage of Euglenineae in the total algal population. It is also evident that the river has higher average concentrations of free carbon-di-oxide which indicate that Euglenineae prefer higher concentrations of free carbon-di-oxide for their abundant growth. This is in accordance with the observations of Singh (1960). Munawar (1970) reported higher concentration of free carbon dioxide to be favorable for the development of Euglenineae. It is also very important to note that the establishment closes relationships of free carbon dioxide to iron forming an ecological complex with dissolved oxygen, phosphate and sulphur. It is, therefore, quite possible that these organisms are also closely associated with dissolved oxygen, iron, phosphate complex. This view is supported in the present investigation by the higher concentration of free carbon-di-oxide and phosphate and dissolved oxygen deficiency very often observed in river is apparently beneficial in the development of Euglenineae as it results in the release of phosphorus and iron in water. The higher percentage of Euglenineae in river suggests that this group prefer higher concentrations of dissolved organic matter. This is in accordance with the observations of Gonzalves and Joshi (1946), Zafar (1964) and Munawar (1970) who correlate the fluctuations in euglenoid population with organic matter. The river supports 45 species of Euglenineae belonging to *Euglena*, *Phacus* and *Trachelomonas*. The pH of water shows as inverse relationship with the periodicity of this group. It appears that pH of water below 8.0 is quite favorable for their development. Euglenineae and total iron occur hand in hand but sudden fluctuations here and there do suggest that there are some other factors in the medium which influence their growth.

CYANOPHYCEAE

Blue-greens are known for their ability to develop in an extremely wide range of conditions. Ecological distribution of Cyanophyceae has been discussed by Fritsch (1907), Pearsall (1932), Prescott (1948), Gonzalves and Joshi (1946), Komarvosky (1953), Rao (1955) Komarvosky (1953) and Philipose (1959) concluded that Cyanophyceae increase in algal populations even when nitrates and phosphates were low. Hutchinson (1967) rightly points out that it is not clear as to what organic compounds are needed in the nutrition of Cyanophyceae. The present data confirms the observation of Pearsall (1932), Philipose (1959). The River Ganga having the highest percentage of Cyanophyceae exhibits, the lowest yearly average of nitrates and phosphate. It may be that the rise in nitrates and phosphates accelerates the growth of algal forms other than Cyanophyceae, particularly diatoms and green algae. Such a growth in the overall algal population results in over shadowing the increase of blue-greens and their relative percentage goes down in the algal samples. Great importance has been attached to the higher concentrations of dissolved organic matter by Gonzalves and Joshi (1946) and Rao (1955) in the development of Cyanophyceae. Singh (1960) has inferred that in tropical waters, changes in the concentrations of oxidisable organic matter do not influence the development of blue-greens as its concentration never falls down to a level to become a limiting factor for their growth. The distribution of Cyanophyceae may be taken to be influenced by factors other than oxidisable organic matter. The present data suggest that calcium is possibly one of these factors. The Ganga River shows the highest development of Cyanophyceae along with the highest average of calcium. Such an assumption is supported by the fact that several Cyanophyceae grow profusely on calcareous substrate including the shells of Molluscus and Corals etc.

Desmids

Desmids are represented mainly by the species of *Cosmarium*, *Euastrum*, *Closterium*, *Pleurotaenium* mainly. They show two peaks in the river. They occur in June and in December-February. Fritsch and Rich (1913) and Hodgetts (1922) contended that the temperature and concentration of water are important factors in the periodicity of desmids. According to Butcher (1924) desmids give two pulses in the river Wharf. *Gonatozygen aculeatum* along with certain species of *Closterium* and *Cosmarium* are present in the summer maxima together with some Chlorococcales. In the second maxima which are in the winter, *Closterium ehrenbergii* and *Cl. tumidum* appeared again. Desmids are more during summer months. This is more or less in agreement with Butcher (1924). It is also interesting to note that West and West (1912) and Pearsall (1932) have also recorded more desmids in the lakes in summer. In the present data the total solids in water and the number of desmids go more or less hand in hand. This is in conformity with the observations of Fritsch and Rich (1913). The pH of water is also considered to be one of the important factors influencing the growth of desmids. Joshua (1886), Storm (1924) and others contended that acidic waters support rich desmid-flora. Van Oye (1934) on the other hand, points out that the desmids increase with the rise in pH. Although Van Oye's view more or less fits into the present investigation are so negligible that one cannot stress much on this point. The present study has the highest percentage of desmids. Calcium is also considered to be an important factor in influencing the distribution of desmids and according to Pearsall (1932) desmids occur in calcium deficient lakes. In the present river, however, the behavior of desmids to calcium is erratic. The river with its highest percentage of desmids is considerably rich in calcium. This may indicate that amongst desmids there are species which can tolerate even higher percentages of calcium. The species of *Closterium*, *Pleuotaenium*, *Cosmarium*, *Desmidium*, *Gontozygen*, *Spondylosium* and *Staurastrum* occurring in the river may be regarded as calcium tolerants. Zafar (1964) has also noted similar behaviour of *Euastrum insulare*.

DIATOMS

The river differed in oxidisable organic matter, nitrogen and phosphorus. They harboured different diatom forms and differed in the average bulk of diatoms and their percentages in the overall phytoplankton populations. Ganga River with high concentrations of oxidisable organic matter, nitrogen and phosphorus possessed only 27 sp. of diatoms, which formed about 65.9% of the phytoplankton. This suggests that a number of diatom species avoided the highly polluted water. This observation is in confirmity with that of Hustedt (1932), who observe that diatoms do not attain greater development in polluted waters. The data further suggests that even higher concentration of phosphorus and nitrogen were not helpful in sustaining a rich diatoms flora, If the water happened to be polluted. Only a few forms like *Navicula anglica* and *Nitzschia clausil* multiplied profusely in the polluted water of river. In contrast to these, forms like *Cymbella cymbiformis, Gomphonema sphaerphorum, Nitzschia angustata* and *Navicula tuscula* could be regarded as forms avoiding polluted conditions. A few forms showing indifference towards the concentration of organic matter also occurred in water and *Gomphonema parvulum* and *Cymbella tumida* were possibly most prominent in this respect. This was possibly due to the higher concentration of bicarbonates which indicates the greater concentration of calcium. Zafar (1964) and the frequent rise of carbon-di-oxide. The importance of higher calcium content in the water for the development of diatoms has been emphasised by Pearsall (1932) and Zafar (1964). The other important factors emphasised are nitrate, phosphate, silicate, calcium, sodium, oxidisable organic matter and pH. The % of diatoms are particularly s tricking in river, since this river is considerably rich in nitrates, one may infer that diatoms prefer waters rich in nitrates (Hustedt, 1939). According to Patrick (1948), "It is the nitrate form of nitrogen which is mostly utilised by diatoms."

Although many of the factors cited above may influence the development of these species, the role of oxidisable organic matter and nitrate, appears to be more substantial, as the fluctuations in the yearly average concentrations of these factors correspond with those of diatoms. Nitrate nitrogen has been given the importance in diatom ecology by Hustedt (1939), Patrick (1948), Komarvosky (1953) and Rao (1955). In Ganga river a marked relationship is noticed between certain diatoms with dissolved oxygen and free carbon-di-oxide. The river has the lowest average concentrations of dissolved oxygen and harbours a large number of the species of *Cyclotella*, *Cococoneis*, *Gomphonema*, *Navicula*, *Gyrosigma*, *Nitzschia* and *Surirella*. *Nitzschia clausii* forms the major bulk of the diatom populatin. Patrick (1948) thinks that "Carbon-di-oxide, like oxygen is a substance which is undoubtedly important for diatom growth, but as yet little is known about the specific requirement of diatoms for it". It may be particularly, mentioned that in the river almost throughout the year one or the other species of this genus are more dependent on free carbon-di-oxide of water as compared to the other diatoms occurring in Ganga river. The culture studies carried out by Patrick (1948) have indicated a similar behaviour of *Nitzschia linearis* towards free carbon-di-oxide. Ganga river is characterized by high averages of dissolved oxygen, albuminoid ammonia and low calcium content, shows a considerable growth of *Synedra ulna*, *Gyrosigma spenceri*, *Cymbella ventricosa*, *G. sphaesophorum*, *Epithemia argus and Surirella linearis*. These diatoms increase in number, when calcium content falls down. One may regard these as calciophobes and euoxybionts (Patrick, 1948), due to their sensitivity to calcium and preference for oxygen. On the other hand, *Synedra ulna* seems to be favoured by higher concentrations of calcium as it grows in large numbers when the calcium content is high. This is accordance with the views of Patrick (1948) who observes that "all species of *Synedra* seems to like some calcium, but it seems especially important for the development of *Synedra ulna* and its varieties".

The present data also indicate that the species of diatoms, present in river appear to be quite sensitive to higher concentration of chloride and increase when the salinity of water registers a fall. It is in accordance with Zafar (1964) who pointed out that high sodium chloride content inhibits the development of *Mastogloia Gyrosigma distortum* smith. But these species appear to be capable of withstanding the higher concentrations of sulphides. There is every possibility that the development of *Gomphonema parvulum*, *Cymbella ventricosa*, *C. tumida*, *Gyrosigma spencerii* and *Synedra ulna* is favoured by the organic pollution. Philipose (1959) has shown that *S. ulna* and Gomphonema acuminatum are favoured by pollution.

ACKNOWLEDGEMENTS

The author is thankful to Professor (Mrs.) Vidyavati, Ex. Vice Chancellor, Katatiya University, Warangal, Andhra Pradesh for her kind co-operation throughout the present investigation.

REFERENCES

Agarwal, D.K., S.D. Gaur, I.C. Tiwari, Narayanswami, N. & S.M. Marwah 1976. Physico-chemical characteristics of Ganga water at Varanasi. *J. Environ. Health, 18: 201.*

Allanson, B.R., 1961. Investigations into the ecology of polluted inland waters in the Transvaal. Part 1. *Hydrobiologia, 18:1.*

Ahlgren, G., 1970. Limnological studies of lake Norrviken, a eutrophicated Swedish lake : II. Phytoplankton and its production. Schwig. *Z. Hydrol., 32: 353.*

APHA, AWWA, WPCF, 1985. Standard methods for the examination of water and waste water. *15 ed. New York, U.S.A.*

Arumugam, P.T. & J.I. Furtado, 1981. Eutrophication of a Malaysian reservoir, effects of agro-industrial effluents. *Trop. 22: 271.*

Atkins, W.R.G., 1926. Seasonal changes in the silica content of natural waters in relations to the phytoplankton. *J. Mar. Biol. Assoc. U.K., 14:89.*

Atkins, W.R.G. & H.I. Harrie, 1924. Seasonal changes in the water and heleoplankton of fresh water ponds. *Sci. Proc. Ray. Dublin Soc. 18:1.*

Biswas, S., 1969. Hydrobiology of the volta river and some of its tributaries before formation of volta lake. Ghana *J. Sci., 8:152.*

Bharati, S.D. & S.P. Hosmani, 1973. Hydrobiological studiesin ponds and lakes of Dharwar (Yemmekori pond). Part 1. *J. Kar. Univ. Sci. 17:132.*

Blum, J.L., 1956. The ecology of river algae. *Bot. Rev. 22: 292.*

Blum, J.L. 1957. An ecological study of the algae of saline river, Michigan. *Hydrobiol. 9:361.*

Boyd, C.E. & E.E. Prather, 1975. Sudden mortality of massive phytoplankton bloom. *Weed Science 23(1):61.*

Bradbury. J.P., 1971. Limnology of Zuni salt lake, New Mexico. Geol. Soc. Amer. *Bull. 82:379.*

Butcher, R.W., 1924. The plankton of the river Wharfe (Yorkshire). *Naturalist. 175:211.*

Cairns, J., 1956. Effect of increased temperatures on aquatic organisms. *Industr. Wastes 1: 150.*

Chakraborty, R.D., P. Roy and S.B. Singh, 1959. A quantitative study of plankton and the physico-chemical conditions of river Jammu at Allahabad in 1954-55. Indian *J. Fish. 6: 186.*

Chandler, D.C., 1942. Limnological studies of Western lake Erie III. Phytoplankton and physical chemical data from November, 1939 to November, 1940. *Ohio. J. Sci. 42:24.*

Champman, V.J. & D.J. Champman, 1973. The algae. Macmillan and *Co., New York.*

Chu. Hao-jan & L.H. Tiffany, 1951. Distribution of fresh water Chlorococcaceae in Szechwan, China. *Ecology 34(4): 709.*

Daily, W.A., 1938. A quantitative study of the phytoplankton of lake Michigan collected in the vicinity of Eoanston. III ionois. Butler Univ. *Bot. Studies 4: 65.*

Das. S.M. & V.K. Srivastava, 1959. Quantitative studies on fresh water plankton III. Quantitative composition and seasonal fluctuations in plankton composition. Proc. Nat. Acad. *Sci. India., 29:174.*

Eddys, S., 1927. Growth of diatoms in relation to dissolved gases. Trans. Illinois State *Acid. Sci. 20:53.*

Fritsch, F.E., 1907. A subaerial and fresh water algal flora of tropics. A phyto-geographical and ecological study. Ann. *Bot. 21:235.*

Fritsch, F.E., 1935-45. The structure and reproduction of the Algae.Vol. I and & II. *Cambridge Univ. Press, Cambridge, U.K.*

Fritsch, F.E., & F. Rich, 1913. A four years observation of a fresh water pond (Barton's pond) near Harpenden. *Ann. Biol. Lacustre 6:1.*

Fogg, G.E. & A.E. Walsby, 1971. Buoyancy regulation and growth of planktonic blue-green algae. MIH Internat. *Vereing. Limnol. 19: 182.*

Ganapati, S.V., 1940. The ecology of a temple tank containing a permanent bloom of Microcystis aeruginosa (Huetz.). J. Bombay Nat. *Hist. Soc. 42(1): 65.*

George, M.G., 1966. Comparative plankton ecology of five fish tanks in Delhi, India, *Hydrobiol. 27:81.*

Gonzalves, E.A. & D.B. Joshi, 1946. Freshwater algae near Bombay I. The seasonal succession of the algae in a tank at Bandra. J. Bombay Nat. *Hist. Soc. 46(1) : 154.*

Habib, I., 1993 Hydrobiological studies on river Shankha at Badaun with reference to algal indicators of water pollution. *Nat. Environ. 10(2):55.*

Habib, I. & U.C. Pandey, 1989. Limnological studies on Shankha river at Bareilly- Preliminary observations. *Vegetos 2(2) : 192.*

Habib, I. & U.K. Chaturvedi, 1993. Periodicity, density and productivity of phytoplankton of Shankha river, Bareilly. *Adv. Plant Sci. 6(1) : 110.*

Habib, I., U.C. Pandey & M. Mazhar, 1989. Certain physico-chemical factors and phytoplankton of Ram Ganga river at Badaun district (UP). *Him. J. Env. Zool. 3:251.*

Habib, I., Pandey, U.C. & U.K. Chaturvedi, 1991. Periodicity, density and productivity of phytoplankton of Ganga river, Badaun (UP). India *Science and Culture, 57(12): 291.*

Hodgetts, W.J., 1922. A study of some of the factors controlling the periodicity of fresh water algae in nature. *New Phytol, 31(1): 15.*

Hustedt, F. 1939. Systematic and okologische untersuchungen Uben diatomeen von Java Baliund Sumattra Arch. *Hydrobiol. 16:1.*

Hutchinson, G.E., 1967. *A treastise on limnology. Vol. 1 and II. John Wiley and Sons, London.*

Jackson, D.F., 1961. Comparative studies on phytoplankton photosynthesis in relation to total alkalinity. *Verh. Int. Ver. Limnol. 14: 125.*

Joshua, W., 1986. Burmese desmidieae with descriptions of new species occurring in the neighbourhood of Rangoon. *J. Linn. Soc. London. 21: 634.*

Kant. S. & P. Kachroo, 1974. Limnological studies in Kashmir lakes, seasonal dynamics of phytoplankton in Dal and Nagina. *Indian Nat. Sci. Acad. 40(1): 77.*

Komarvosky, B., 1953. A comparative study of the phytoplankton of several fish ponds in relation to some of the essential chemical constituents of the water. *Bull. Res. Counc. Israel 2(4): 379.*

Kumar, H.D. & H.N. Singh, 1971. A text book on algae. *Affliated East-West Press Pvt. Ltd., New Delhi. pp.1.*

Lakshminarayana, J.S.S., 1965. Studies in the phytoplankton of river Ganges, Varanasi, India Pt. I. Physico-chemical characteristics of river Ganges Pt. II. The seasonal growth and succession of the plankton algae in the river Ganges. *Hydropologia 25: 119.*

Lehr, J.H., T.E. Gass, W.A. Peltyjohn & J. DcMarre, 1980. Domestic Water treatment. *McGraw-Hill Book Co., London.*

Lind, E.M., 1938. Studies in the periodicity of the algae in the Beau Chief ponds, Shaffield. *J. Ecol. 26: 257.*

Moss, B., 1972. The influence of environmental factors on the distribution of freshwater algae. An experimental study, *J. Ecol. 60: 917.*

Munawar, M., 1970. Limnological studies o n fresh water ponds of Hyderabad, India-II. The Biocenose. *Hydrobiol. 36(1): 105.*

Munawar, M., 1972. Ecological studies of Eugleninae in certain polluted and unpolluted environments. *Hydrobiol. 39(3): 307.*

Pahwa, D.V. & S.M. Mehrotra, 1966. Observations of fluctuations in the abundance of phytoplankton in relation to certain hydrological conditions of river Ganga. *Proc. Nat. Acad. Sci. India 348: 157.*

Palmer, C.M., 1969. A comparative rating of algae tolerating organic pollution. *J. Phycol. 5: 78.*

Pandey, U.C. and Habib, I. 1989. Physico-chemical complexes and their relationship with macrophytes of Baghla lake. *Vegetos. 2(1): 108.*

Patrick, R., J. Cairns & S.S. Roback, 1967. An ecosystematic study of the f auna and flora of the Sakannale river. *Proc. Acad. Nat. Sci., Philadelphia, 118: 109.*

Pearsall, W.H. & E.M. Lind, 1942. The distribution of phytoplankton in some north west Irish Loughs. *Proc. Roy. Irish Acad. 738:1.*

Philipose, M.T., 1959. Fresh water phytoplankton of inland fisheries. Proc. Symp. Algol., I.C.A.R., New *Delhi, pp. 272.*

Prescott, G.W., 1968. The Algae *: A Review, Houghton Mifflin Co., Boston.*

Rao, C.B., 1955. on the distribution of algae in a group of six small ponds. *J. Ecol. 43: 291.*

Ruttner. F., 1953. Fundamentals of limnology. *University of Toronto Press.*

Singh, M.M., 1968. Phytoplanktonic periodicity in a small lake near Delhi-2, seasonal fluctuations of the main groups of phytoplanktons. *Phykos 7(2): 126.*

Singh, R.N., 1960. Role of Blue-green algae in Nitrogen economy of Indian agriculture. *I.C.A.R., New Delhi.*

Singh, V.P., 1959. Phytoplankton ecology of the inland waters of Uttar Pradesh. *Proc. Symp. Algol, I.C.A.R., New Delhi pp. 243.*

Shukla, H.M., I. Habib & U.C. Pandey, 1989. Algal flora of sewage pond- Quantitative, qualitative and periodical occurrence of Cyanophyceae. *Geobios new Reports 8:16.*

Sreenivasan, A., 1964. Limnological studies of tropical impoundments II. Hydrobiological features and plankton of Bhavanisagar Reservoir (Madras State) for 1961-62. *Proc. Indian Acad. Sci. 598-53.*

Sreenivasa, A., 1970. Limnology of tropical impoundents, a comparative study of the major reservoirs of Madras State (India). *Hydrobiologia 36(3): 443.*

Storm, K.M., 1924. Studies in the ecology and geographical distributions of fresh water algae and plankton. *Rev. Algal. 1: 127.*

Suxena, M.R., 1955. Freshwater Eugleninae from Hyderabad, India. I. *J. Indian bot. soc. 34:430.*

Swale, E.M.F., 1964. A study of the phytoplankton of calcareous river. *J. Ecol., 52: 433.*

Talling, J.F., 1957. The longitudinal succession of the water characteristics in white Nile. *Hydrobiologia, 9: 73.*

Van Oye, P., 1934. Quelques donnees Sur-1 ecologie des Desmidiees. *Bull. Soc.Roy. Belg. 67: 65.*

Venkateswarlu, V., 1970. An ecological study of the algae of the river Moosi, Hyderabad (India) with special reference to water pollution. *Hydrobiologia 35:45.*

Vyas, L.N., 1968. Studies in phytoplankton ecology of Pichhola lake, Udaipur. *Proc. Symp. Rec. Ad. Trop. Eco. Part-I. 334.*

Welch, P.S., 1952. Limnology. *McGraw Hill Book Co., New York.*

West, W. & G.S. West, 1912. On the periodicity of phytoplankton of some British lakes. *J. Linn. Soc. Bot. 40:395.*

Wiebe, A.H., 1930. Investigation in plantation production in fish ponds. *Bull. U.S. Bur. Fish 46: 137.*

Zafar, A.R., 1964. On the ecology of algae in certain fish ponds of Hyderabad, India. II. Distribution of unicellular and colonial forms. *Hydrobiol. 24(4): 556.*

Zafar, A.R., 1967. On the ecology of algae of certain fish ponds of Hyderabad, India. III. The periodicity. *Hydrobiol. 30: 96.*

Zafar, A.R., 1968. Certain aspects of distribution pattern of phytoplankton in lakes of Hyderabad. Proc. *Symp. Rec. Adv. Trop. Ecol. pp. 368.*