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Impact of Industrial Effluents on The Water Quality and Aquatic Biota in Rajshahi

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IMPACT OF INDUSTRIAL EFFLUENTS ON THE WATER QUALITY AND AQUATIC BIOTA IN RAJSHAHI

A thesis

Submitted to the Faculty of Life and Earth Science, University of Rajshahi, In Fulfilment of the Requirements For the Degree of Master of Philosophy

IN

BOTANY

Submitted By

Abdullah Harun Chowdhury

N.S.T. Fellow

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PHYCOLOGY AND LIMNOLOGY LABORATORY
DEPARTMENT OF BOTANY
RAJSHAHI UNIVERSITY
BANGLADESH

DEDICATED TO

MY PARENTS
WHO OPENED MY EYES
TO THE BOUNTIES
OF NATURE

DECLARATION

I do hereby declare that the entire work submitted as a thesis towards the fulfilment for the degree of **Master of Philosophy** in Botany at the University of Rajshahi, is the result of my own investigation.

Abdullah Harun Chowdhury
04-1-99

(Abdullah Harun Chowdhury)
Candidate

CERTIFICATE

This is to certify that the research work presented in this M. Phil. thesis entitled **"IMPACT OF INDUSTRIAL EFFLUENTS ON THE WATER QUALITY AND AQUATIC BIOTA IN RAJSHAHI"** was carried out by the **N.S.T. Fellow Mr. Abdullah Harun Chowdhury**, under my supervision. It is approved as to the style and contents.

M. Zaman

(Professor M. Zaman) 04.1.99
Supervisor

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The Author

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LIST OF ABBREVIATIONS

P.P = Phytoplankton
Z.P = Zooplankton
DO = Dissolve oxygen
BOD / BOD_5 = Biochemical oxygen demand/Biological oxygen demand
COD = Chemical oxygen demand
CO_2 = Carbon dioxide
CO_3 = Carbonate
HCO_3 = Bicarbonate
TSS = Total suspended solids
TDS = Total dissolved solids
pH = Hydrogen ion concentration
NH_4 = Ammonium
NH_3 = Ammonia
$NH_4.N$ = Ammonium nitrogen
mg/l = Miligram per liter
°C = Centigrade
cm = Centimeter
M mol l^{-1} = Mole per liter
µ ohms = Micro ohms
Eh = Oxidation reduction potential
rH_2 = Oxidation reduction index
Unit/l = Unit per liter
PO_4 = Phosphate
m volt = mili volt
TH = Total hardness
Ca.H = Calcium hardness
Mg. H = Magnesium hardness
Sil = Silicate
TS = Total sulphide
Oil = Oil-grease
Tr = Transparency
AT = Air temperature
WT = Water temperature
Cl = Chloride
EC = Electric conductivity
alk = Alkalinity

ABSTRACT

The physico-chemical conditions of industrial effluents and their effects on the water quality, aquatic biota and macrovegetation at three different sampling spots in Rajshahi have been studied during the month of November'96 to October'97. Sampling spot one was a canal receiving effluent from the Rajshahi Sugar Mills at Harian, sampling spot two was two K.M away from spot one in the same canal receiving effluent from Rajshahi power house at Katakhali, where the two effluents mix and sampling spot three was in the river Padma two kilometer from spot two where the mixed effluent is discharged. Sampling was performed weekly. Multiple regression analysis have been made to establish the interrelationships between the physico-chemical and biological conditions.

Spot-1

In the effluent mixed black water at this spot, the monthly mean ranges of various physico-chemical variables and plankton were : air temperature 19.75 to 33°C; water temperature 25 to 37.3°C; transparency 6.5 to 20 cm.; TSS 120 to 430 mg/l; TDS 640 to 6160 mg/l; pH 6.1 to 7.2; DO anoxia to 1.15 mg/l; Eh 0.092 to 0.228 m Volt; rH$_2$ 8.10 to 10.21; BOD 5.2 to 16.36 mg/l; COD 892 to 2471 mg/l; electric conductivity 261.89 to 1558.17 μ ohms/cm.; chloride 26.98 to 142.06 mg/l; CO$_2$ 9 to 109 mg/l; CO$_3$ alkalinity Zero; HCO$_3$ alkalinity 76 to 556 mg/l; total hardness 230 to 604 mg/l; calcium hardness 72 to 478 mg/l; magnesium hardness 1.55 to 65.39 mg/l; NH$_4$ 0.212 to 0.74 mg/l; NH$_3$ 0.20 to 0.70 mg/l; NH$_4$.N 0.165 to 0.58 mg/l; PO$_4$ 0.008 to 0.014 mg/l; silicate zero; total sulphide 0.92 to 5.03 M mol l^{-1}; oil-grease 1.04 to 7.13 mg/l; phytoplankton abundance 27354 to 64982 units/l and zooplankton abundance 29169 to 75935 units/l. The phytoplankton were represented by 29 genera of which 10 genera belonged to Chlorphyceae, 6 genera to Cyanophyceae, 5 genera to Euglenophyceae, 4 genera to Xanthophyceae and 4 genera to Bacillariophyceae. The 30 genera of zooplankton recorded, were represented by Protozoa (19 genera), Porifera (1 genera), Rotifera (6 genera), Nematoda and Crustacea both with 2 genera. A total of 11 genera of macrophytes were recorded from this spot. The dominant genera was *Eichhornia* sp.

Spot-2

The monthly mean value range of different physico-chemical variables and plankton were : air temperature 18 to 35.8°C; water temperature 18 to 32°C; transparency 5 to 17.5 cm.; TSS 120 to 370 mg/l; TDS 400 to 2440 mg/l; pH 6.1 to 8.8; DO anoxia to 1.68 mg/l; Eh 0.085 to 0.249 m Volt; rH$_2$ 8.28 to 10.73; BOD 3.72 to 9.72 mg/l; COD 512 to 896 mg/l; electric conductivity 224.74 to 2113.78 μ ohms/cm.; chloride 25.56 to 147.68 mg/l; CO$_2$ zero to 65 mg/l; CO$_3$ alkalinity zero to

29 mg/l; HCO_3 alkalinity 71 to 338 mg/l; total hardness 72 to 534 mg/l; calcium hardness 58.8 to 315 mg/l; magnesium hardness 3.23 to 58.05 mg/l; NH_4 0.16 to 0.636 mg/l; NH_3 0.01 to 0.60 mg/l; NH_4.N 0.08 to 0.494 mg/l; PO_4 0.008 to 0.08 mg/l; silicate zero; total sulphide 0.25 to 4.18 M mol l^{-1}; oil-grease 22.36 to 175.68 mg/l; phytoplankton abundance 27462 to 79234 units/l and zooplankton abundance 33637 to 97825 units/l. The phytoplankton were represented by 31 genera of which 12 genera belonged to Chlorophyceae, 6 genera to Cyanophyceae, 5 genera to Euglenophyceae, 4 genera each to Xanthophyceae and Bacillariophyceae. The 32 genera of zooplankton recorded at this spot, were represented by Protozoa (20 genera); Porifera (1 genera); Rotifera (7 genera); Nematoda and Crustacea both by 2 genera. A total of 10 genera of macrophytes were recorded from this spot. The dominant genera was *Eichhornia* sp.

Spot-3

The range of monthly mean value of different physico-chemical variables and plankton were: air temperature 23.25 to 37°C; water temperature 18 to 32°C; transparency 6 to 56 cm..; TSS 60 to 340 mg/l; TDS 280 to 1380 mg/l; pH 6 to 8.6; DO 2.34 to 8.52 mg/l; Eh 0.116 to 0.393 m Volt; rH_2 10.05 to 14.56; BOD 1.7 to 4.22 mg/l; COD 132 to 455 mg/l; electric conductivity 185.07 to 479.72 μ ohms/cm.; chloride 35.5 to 66.03 mg/l; CO_2 zero to 7 mg/l; CO_3 alkalinity zero to 14 mg/l; HCO_3 alkalinity 59 to 123 mg/l; total hardness 75 to 200 mg/l; calcium hardness 29.4 to 130.2 mg/l; magnesium hardness 4.22 to 39.58 mg/l; NH_4, NH_3 and NH_4.N always zero; PO_4 zero to 0.0052 mg/l; silicate 0.004 to 0.158 mg/l; total sulphide 0.08 to 1.01 M mol l^{-1}; oil-grease zero to 1.83 mg/l; phytoplankton abundance 22998 to 91656 units/l and zooplankton abundance 3990 to 63684 units/l. The phytoplankton were represented by 26 genera of which 5 genera belonged to Chlorophyceae, 3 genera to Cyanophyceae, 14 genera to Bacillariophyceae, 2 genera each to Euglenophyceae and Xanthophyceae. The 21 genera of zooplankton recorded at this spot, were represented by Protozoa (6 genera), Rotifera (6 genera), Cladocera(5 genera) and Copepoda (4 genera). The aquatic macrovegetation was very poor. No rooted emergent or free floating hydrophytes were recorded at this spot.

The physico-chemical conditions indicate that the effluent laden water of the study zone was highly polluted. The phyto-and zooplankton and the macrovegetation have been severely affected by highly polluted condition of water as indicated by their lower abundance values in the study zone. The recorded phyto-and zooplankton and macrophyte members were found to be highly pollution tolerant. The common macrophytes and plankton occurring in the adjacent unpolluted water bodies were not found in the study spots. The water quality of the river Padma at this study site did not fit well with the IWQS and DWQS (WHO 1998).

CHAPTER ONE

INTRODUCTION

INTRODUCTION

INTRODUCTION

The inland fresh water ecosystems, both lentic and lotic contribute a greater fraction towards the resources of available water in the globe which is now being increasingly subjected to great stress from various anthropogenic exploitations. The physico-chemical and biological characteristics of open water depends upon a number of factors including the location of water bodies, type of sewerage and municipal waste disposal, localized and increased number of human population in the surroundings and their activities. This results in the addition of enormous quantity of organic and inorganic nutrient in the water systems. The enrichment of nutrients also occurs increasingly in the water systems due to the disposal of industrial effluent from the adjacent areas, which may support the growth of macrophytes and microbes or zeopardize the entire ecosystem depending upon the degree of pollution there.

Recently, there is a universal realization of pollution hazards in the aquatic ecosystems including the wetlands which has given much impetus to holistic researches on water qualities and the flora and fauna in these habitats. The uninterrupted confluence of the industrial effluent in the water or river systems, is likely to affect the biotic diversity there in, and self purification may or may not operate depending upon the intensity of their pollution content and level. The river systems carry the load of dangerous pollutants and the same water is used in urban supplies, domestic and irrigation purposes and for the consumption of the pet animals which cause health and other hazards.

The phenomenon of water pollution has been described as any physical or chemical change in water which can deteriorate its quality and adversely affect the organisms in it. Water pollution is the alteration of any body of water having losses of any of its values as a natural resource (Milo Moore 1960). The industrial wastes and effluents which come in the water bodies, produce physical, chemical and biological characteristic changes in water (Vollen Wider 1979). Some pollutants and contaminants produce temporary effect on water whereas others have a long standing effect. Such physico-chemical and biological changes that occur in water, generally due to the addition of poisonous substances, suspended particles, non toxic salts, water deoxygenating substances, heating of water by the addition of hot water released by industrial installation etc. The reduction of oxygen and presence of poisonous waste affect the prevailing biota including the fish population, plankton communities and other aquatic lives.

Bangladesh is a small, developing and densely populated country in the third world. Its total area of open fresh water resources including rivers, canals, beels, jheels, haors, lakes, ponds, swamps, ditches etc. is about 35.663 KM^2 (Ameen 1987, Duijvendijk 1987, Rahman 1988, Khondker 1994, 1995). During the recent years Bangladesh has been on the progress in the field of rapid industrialization. Due to the absence of proper and scientific method of disposal of the industrial wastes and effluents, dumping or discharge is done onto the land or into the nearby water courses, usually small streams and rivers, practically without pretreatment. In Bangladesh almost all small and large industrial establishments are located on the bank of rivers in the country side, which includes paper and pulp mills, rayon mills, tanneries, fertilizer factories, pharmaceutical and chemical complexes, jute and textile mills, soap factories, cement industries, sugar mills, power stations, shipyards etc. Every day these industries discharge large quantities of their untreated or partially treated solid and liquid waste and effluent, directly or indirectly through discharge channels, to the rivers or other natural water systems as a result of which the ecosystem balance of these places are being adversely affected and the entire biota becomes exposed to potential danger.

In the past few years, a good number of sugar mills have been established in the country mainly in the Rajshahi, Rangpur, Dinajpur, Faridpur, Bogra, Jessore, Kushtia and Mymenshing regions where intense sugarcane cultivation is practiced. No report is yet available about the nature and extent of damage done to the ecosystem by the effluent released by them. The sugar mills effluent consists of washing from sugarcane, pulppress and condensers, limecake, molasses and oil from machineries which are released to rivers, ponds directly or through canals connecting them . These effluents also contain a large number of organic and inorganic compounds. Some of which may produce toxic substances by decomposition. Butcher (1931, in klein 1962) reported in a study on the discharge of seasonal wastes from a beat sugar factory in the river lark, the fishes surfaced and died, the invertebrates were almost completely wiped out. Butcher (1946) also found that the abundance of animals in the first 5 miles was much lesser and large number of oligochaeta on the next 8 to 17 miles from the source of effluent in pottery towns. Verma and Shukla (1969) reported that due to the addition of a sugar mills effluent, the CO_2 concentrations of the receiving stream becomes very high (30.2mg/l) which is lethal to fish. In India Banerjea and Motwani (1960) observed that sugar mills constantly discharge sulfur - reducing bacteria which produce hydrogen sulphide, a gas, highly toxic to fish and another aquatic lives.

In Bangladesh, power generating stations are major energy producing instalations. During the past few years a number of power generating stations have been established by Bangladesh Power Development Board in different parts of the country including Rajshahi District. Most of these power generating stations depend on High Speed Diesel (HSD) for power generating processes. They release their waste oil to river or other water bodies directly or through canals connecting them. The drainage water from these power stations is a mixture of cooling water, High Speed Diesel oil and lubricating oil (CRB - 40). About 10 to 15 % HSD and lubricating waste oil of the total mixture is expected in the effluents and the proportion of diesel oil and lubricating oil is estimated about 1:5 (Rajshahi power stations source). The physical, chemical and biological factors of a water body are changed by oil content and cooling water (Bhouyain 1983, Klein 1962, Mishra *et al.* 1992), Plankton members may be coated with oil and destroyed and bird population, fish, worms, crabs and other aquatic biota are severely affected by oil pollution (WPCP 1975, Trivedi and Raj 1992, Mironov 1969, McCauley 1966).

To these context it has become essential to evaluate the physical, chemical and biological conditions of industrially polluted water for future pollution abatement programme and also for rating the pollution tolerant organisms including the phyto-and zooplankton. A probe into the effects of effluent on invertebrates, vertebrates animals and macrovegetation is to taken into active consideration during the present study .

The present study was conducted with a view to estimating the physico-chemical and biological conditions, macrovegetation of the canal which receives the entire effluent from the Harian sugar mill and Khatakhali power generating station in Rajshahi, which open into the river Padma at a distance of 5 KM from the industrial site.

AIM AND OBJECTIVE OF THE WORK

The research work was undertaken to achieve the following objectives during the sugar production period and beyond it :

1. Estimation of the physico-chemical conditions of the water body when sugar mills are in function (beyond the production period).
2. Estimation of the physico-chemical conditions of the mixed effluent.
3. Estimation of the physico-chemical conditions of the effluent of power station when the sugar mills are closed down after the production periods.
4. Estimation of the content and abundance of the effluent tolerant phyto- and zooplankton in sugar mills and power stations effluents.
5. Estimation of the content and abundance of phyto-and zooplankton in the river Padma where the effluents in discharged.
6. To know macro-vegetations of the effluent rich canal water (sugar production and non production period).
7. Analysis of bottom soil of the effluent receiving canal (sugar production and non production period).
8. Analysis of the bottom soil of Padma river site, where the effluent is discharged (sugar production and non production period).
9. To evaluate the level of pollution of Padma water at the discharge point.

REVIEW OF LITERATURE

Although a number of investigation on the pollution of open water by different industrial wastes and other organic and inorganic wastes have been done in Bangladesh by pollution control experts and scientists (WPCP 1975, EPC 1980, Anonymous 1975, Bhouyain 1979, 1983, Begum and Zahangir 1993, Amin *et al.*1979, Islam *et al.*1994, Islam and Haroon 1995, Reazuddins 1992, Talukder *et al.*1994, Rahman 1992, Chowdhury 1995, Chowdhury *et al.* 1994, 1996, Hussainy and Abdul 1967, Paul 1981). Vertually no detailed work have been done on the pollution of water by effluents of sugar mills and power generating stations in the country. In Australia, Pearson and Penridge (1987), in Mauritius Ramjeawon and Baguant (1995), in India Banerjea and Motwani (1960), Kumar *et al.*(1974), Rana (1977), Baliarsingh *et al.*(1992), Verma and Shukla (1969), Butcher (1946), Klein (1962) have conducted some works on the pollution of water by sugar mills wastes and made some observations on the pollution tolerant algae and other aquatic lives. Many workers in India and other countries including Mishra *et al.*(1992), Trivedi and Raj (1992), Trivedi (1993), Rana (1977), Mishra and Trivedi (1993), Thresh *et al.*(1944), Gautam (1990), APHA (1989), WPCP (1975), Ambasht (1990), EPC (1980), Andrews (1972), Kumar *et al.*(1974), Shubert (1984), Venkateswarulu and Reddy (1985), Haslam (1990), Baliarsingh *et al.*(1992), Nandan and patel (1983), Rao (1977), WHO (1982), Welch (1952), Palhareya *et al.*(1993), Sengar *et al.*(1985) Sinha *et al.*(1992), Rahman (1992), Paul (1981), Pandey (1980), Palmer (1969), Khondker (1994, 1995), Arora (1961, 1966), Cairns (1968), Cairns *et al.*(1972), David (1957), Doudoroef and Katz (1950), Gaufin and Tarzwell (1972), Goodnight (1973), Hoak (1959), Hynes (1960), Ito and Kuwada (1964), Klein (1962), Mackay (1969), Mackenthun (1969), Motwani *et al.*(1956), Smith and Oseid (1973), Seth and Bhaskaran (1950), McCauley (1966), Mironov (1969), Vellenwider (1979), Tourbier and Pierson (1976), Godfrey *et al.*(1985), Athie and Cerri (1986), Raddy and Smith (1987), Wiegleb (1978, 1984), Best (1982), Kohler (1977), Melzer (1976, 1981). The physico-chemical conditions of effluent laden water, abundance and diversity of the plankton community, invertebrate populations and macrosvegetations have been used as indicator of level of pollution in their works.

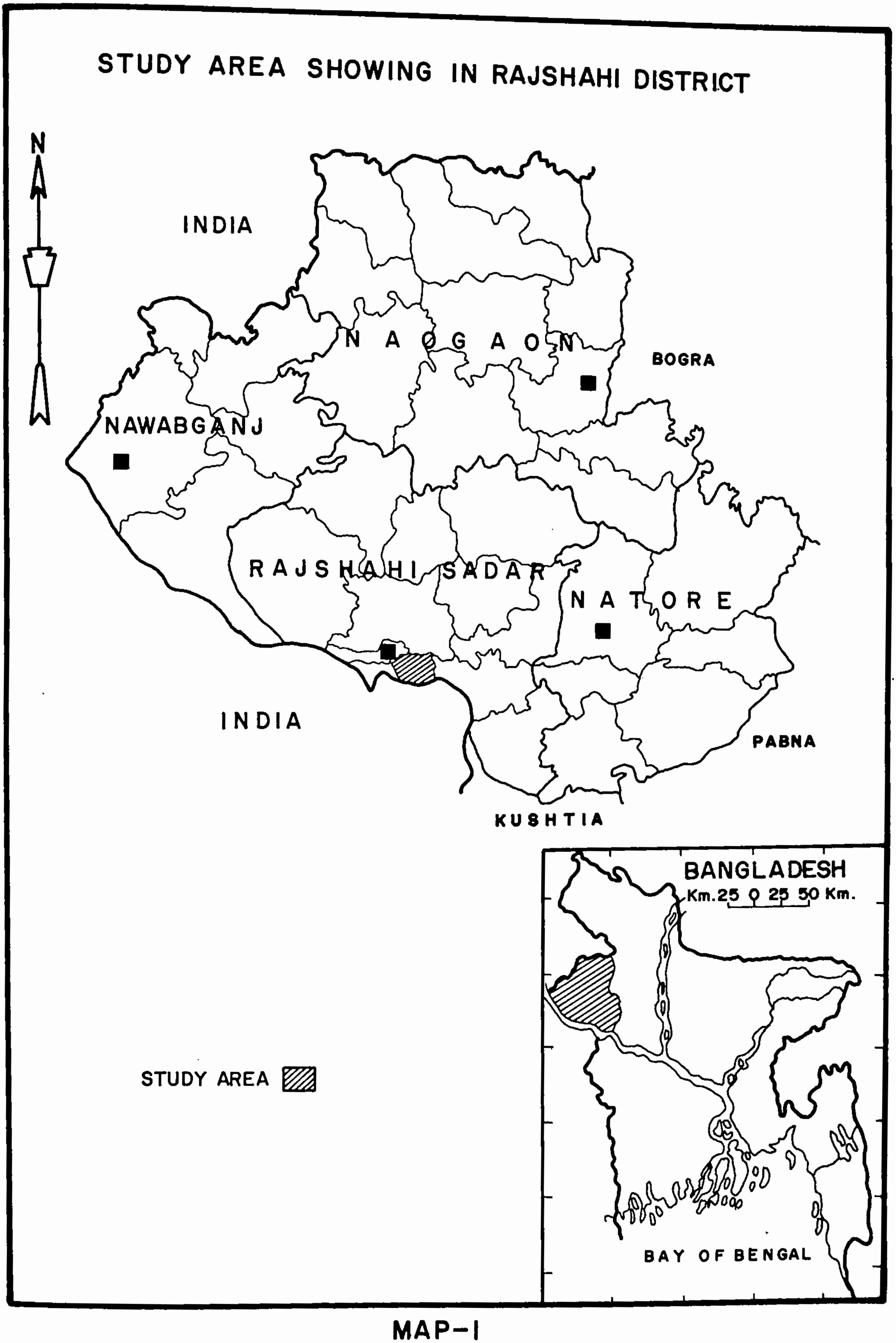
GEOGRAPHICAL LOCATION AND CLIMATE OF RAJSHAHI

Rajshahi is situated in the northern part of the Bangladesh flanked by the fringe of the greater Barind tract on the North and Bhar (VOR) basin on the south and east. It lies between 24.6° to 25.2° north latitude and 88.2° to 89.2° east longitude and is elevated above the sea level by 8-10 meters.

The climate of Rajshahi district where the study site under observations are situate, is characterized by great of heat, cold and moderate rainfall owing to its geographical situation, which ensures it against the direct action of disturbing influences such as sea in the south, strong monsoon current in East and Himalayas to the north.

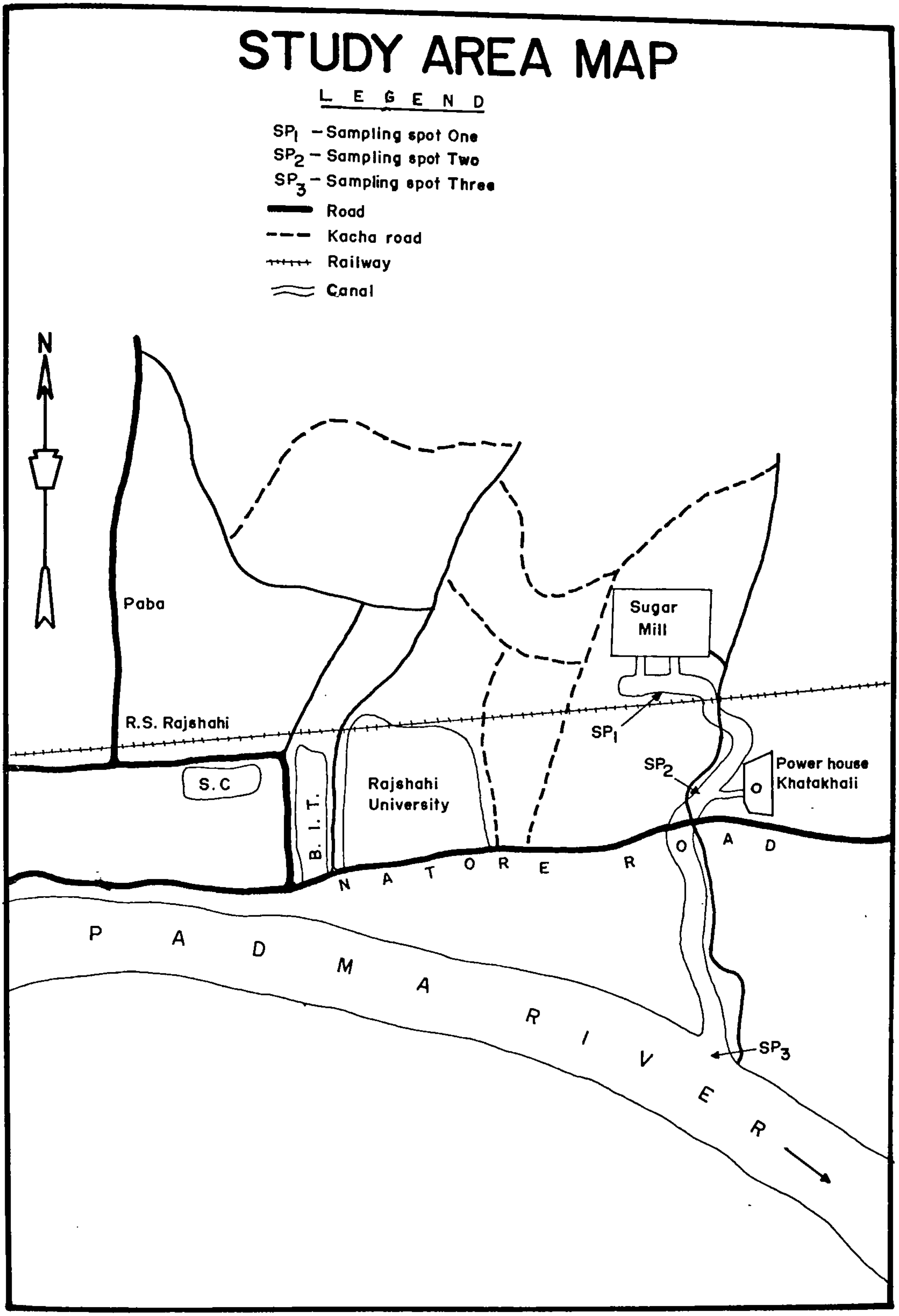
The hot season commences early in the March with the ceasation of the northerly wind. South westerly wind prevails during the closing days of March and whole of April when moderate to gusty storms are of frequent occurrence with the rise of atmospheric temperature. Southerly wind prevails in May and south-easterly wind in the monsoon from June to the middle of October when cool nights begins to give indications of the approach of winter.

Seasonal range of atmospheric temperature of Rajshahi has been recorded as a maximum of 42°C and a minimum of 4°C round the year. Usually the monsoon season commences from the mid April and persists upto September. The frequency and amount of rainfall increases as the months proceeds, till the end to the monsoon period. Heavy rainfall (200-300 m.m) is recorded in this season. Other seasons are marked by scanty or no rainfall.



STUDY AREA SHOWING IN RAJSHAHI DISTRICT

MAP-I


STUDY AREA MAP
LEGEND
SP1 – Sampling spot One
SP2 – Sampling spot Two
SP3 – Sampling spot Three
Road
Kacha road
Railway
Canal
N
Paba
Sugar Mill
R.S. Rajshahi
SP1
SP2
Power house Khatakhali
S.C
B.I.T.
Rajshahi University
NATORE ROAD
PADMA RIVER
SP3

MAP–2

CHAPTER - TWO

GENERAL DESCRIPTION OF SUGAR MILLS, POWER STATION AND THE RIVER PADMA

GENERAL DESCRIPTION OF SUGAR MILLS, POWER STATION AND THE RIVER PADMA

RAJSHAHI SUGAR MILLS

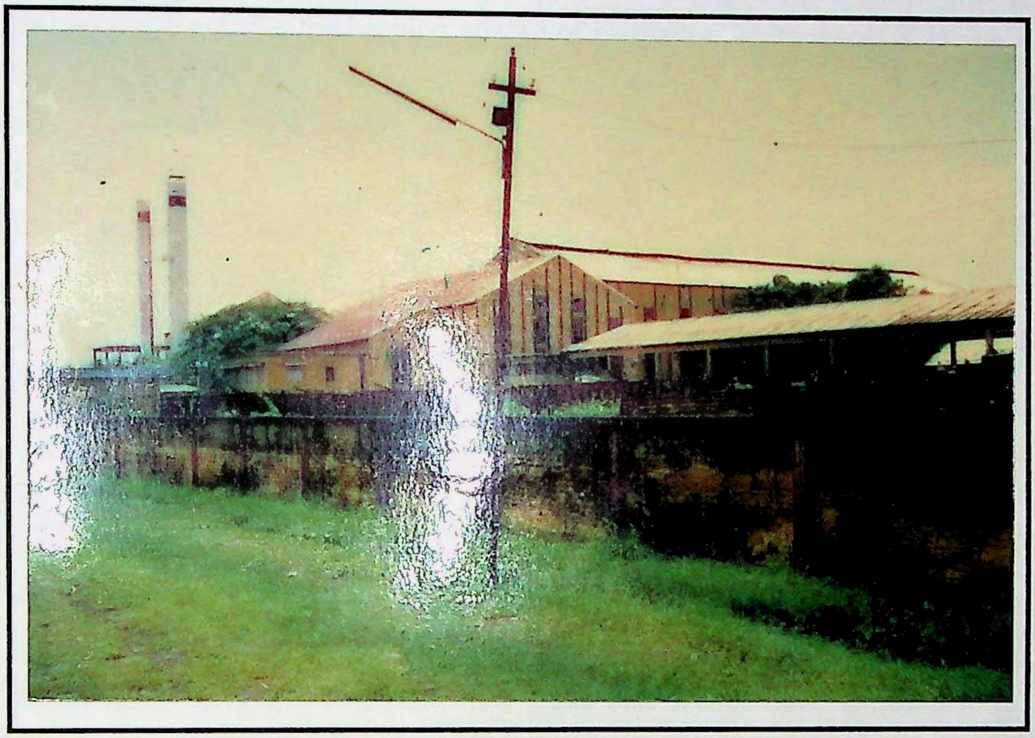
In terms of the production capacity, Rajshahi sugar mills is the second largest mill of "Bangladesh Food and Sugar Corporation." It was established in 1963, but the mill began its production from 1965-66 season. Primarily its annual production capacity was 10160 metric tons. The present production capacity is 20000 metric tons annually. Sugarcane bagasse is the only fuel source of this industry. The crushing rate is 2000 metric tons of sugar cane per day. Gradual steps are followed to produce sugar from sugarcane. These are as follows :

At first, the cane is cut into pieces for breaking hard structure and rupturing the cells by the mechanical knives which then enters into the fibrizer. The fibrizer is more efficient than the knives which ruptures the uncut as well as cut cane for finer preparation. The fibrized cane appears fluffy which adds in achieving both higher capacity and extraction of juice.

Mixed juice is weighted in weighment scale and the bagasse is used as fuel for boiler for steam generation and subsequently electricity is generated in power turbine. The bagasse is also used in North Bengal Paper Mills for manufacturing paper. Mixed juice is heated up to the temperature 70-75°C to accelerate the chemical reaction in clarification, precipitation of some colloids, gums, pectin etc. and to avoid turbidity. The pH is maintained at 4.2 and the juice is treated with sulphur dioxide gas (0.05% sulphur on cane) and milk of lime (0.13% lime on cane) simultaneously to maintain pH 7.1 - 7.2.

Sulphur dioxide bleaches the colouring matters to accelerate lime reaction properly and to neutralize the excess milk of lime by forming calcium sulphite. Milk of lime precipitate the non sugar present in the juice as calcium salt of non sugar and to form calcium phosphate for floc formation in precipitated mud.

Sulphinited juice is again heated to 102-105°C in secondary heater for rapid settling of the precipitation of non sugars as mud in the clarifier, converting soluble calcium bisulphite into in soluble calcium sulphite, preventing the formation of micro-organism in the door clarifier. In the door clarified mud and clear juice separate by settling and the clear juice is fed to the evaporator for evaporation and mud to the Rotary vacuum filter (R.V.F) for filtration to



Photograph 1- External view of Rajshahi Sugar Mill at Harian.

recover sugar in it. The mud is mixed with bagacito in the proportion of 70:30 and it is fed to R.V.F for filtration by using vacuum (12″ - 14″) mercury and spraying hot water to minimize filter loss. The filter cake can be used in cane fields as manure and sometimes as fuel and the filtrate is added to mixed juice. The clarified juice obtained from the door clarifier is fed into the multiple effect evaporator (M.E.E) which is operated under vacuum and using steam to evaporate around 80% water and the concentrated juice is called syrup. The brix (% dissolved solid) of syrup is maintained at about 55-60°C. The syrup is bleached by using sulphur dioxide gas to remove the colouring matter formed in syrup and the pH of syrup is maintained around 5.5 which plays a significant role for keeping quality of plantation white sugar (P.W.S). It also reduces the viscosity of syrup. According to the purity of syrup, 3-boiling scheme is adopted to crystallize out sugar as far as possible from syrup and subsequent mother liquor. There are three boiling schemes area, A, B and C and their product is called A- massecuite, B-massecuite and C-massecuite respectively. (Sugar crystals together with mother liquor is called massecuite).

Crystals and mother liquor from massecuite are separated by centrifuge machine. A - massecuite is charged in the centrifuge machine and washed with water and steam. The sugar is discharged on the hopper. Then it is cooled around 40°C and graded and bagged in the capacity of 100/50 kg. bags. The mother liquor obtained from A- massecuite is boiled for B-massecuite preparation, B-massecuite is centrifuged to get B-Sugar i.e. seed and B-molasses is used for C-massecuite boiling, C-massecuite is centrifuged to get C-sugar which is melted and used as syrup. The mother liquor obtained from C-massecuite after centrifuging is called final molasses. This molasses is stored in closed steel tanks and can be used as raw material for alcohol manufacture and animal feed.

This mill discharge 45 metric tons of polluted and 360 metric tons of unpolluted effluents per hour during the production period. Polluted effluents are said to contain washings of mill house, juice headers, various weighing scale, tanks, vacuum filter cleanings, centrifuge floors and other boiling house floor. Unpolluted effluents by mill bearing cooling water, discharge from power turbine oil cooling system, boiler blow down, otherwise cooling system, surplus condensate overflow and surplus condenser water overflow. The effluent is collected in a canal by two pacca drains. The mill has no facilities for effluent treatment. Its production period depends on supply of sugarcane every year. (Mill source)

RAJSHAHI POWER STATION

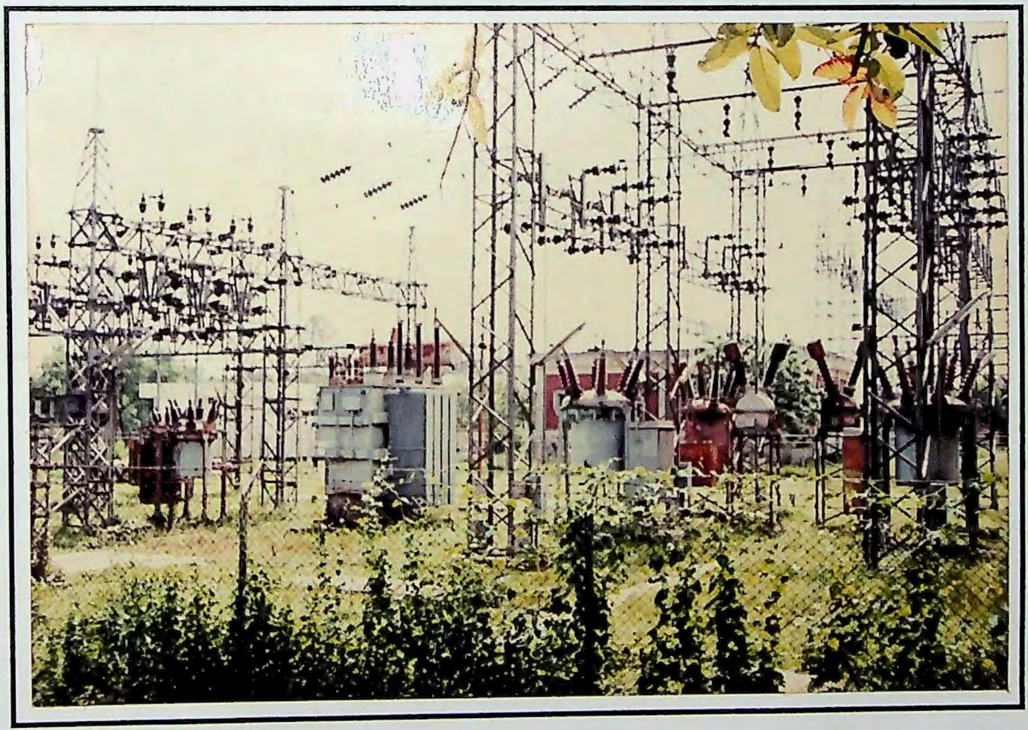
Rajshahi Diesel Power Station is one of the isolated power stations of Bangladesh Power Development Board. This power station has three power generating units each of 1170 KVA, MKV diesel engine. The diesel engines are driven by High Speed Diesel Oil (HSD). The engines are of 8SRL 1794, BHP type made by the English Electric Co.

Initially Rajshahi Power Station was started with three 1170 KVA generating units. But later on, three more units of 500 KVA were installed during 1984 which are not in operation due to shortage of spare parts (station source). The three 1170 KVA generating units whose operation is accomplained in three different stages starting with compressed air system which is required to apply air pressure on the piston head of the diesel engine. When the diesel engine is started by compressed air, fuel oil (High Speed Diesel) is injected through injection Nozzle. Therefore the engine is under running condition with speed. The 11 KV generator is excited by pilot executor through control panel. When 11 KV power in the generator is generated, then the unit is tied or synchronised with the 11 KV grid system. So the machine is at this stage, running with load. Water cooling system is also provided with the engine to reduce the temperature of the engine.

Rajshahi Diesel Power Station is mainly a standby power generating station due to high generating cost of 4.20 Taka per unit. Bangladesh Power Development Board sells electrical energy at the rate of 2.00 Taka per unit. The annual generation of this station is 40,50,000 units (kilo watt hour). This power generating station can supply power only for a small area.

The power house has no effluent treatment plant. The effluent of this power house is a mixture of cooling water, high speed diesel oil and lubricating oil-CRB-40 are discharged by a steel pipe into a canal. A small percentage of high speed diesel oil and lubricating oil is mixed with drained cooling water some portion of which is collected by pump and stored in a safe place for sell. About 5 to 10 percent of HSD and lubricating wasted oil of the total mixture is expected and the proportion of the diesel oil and lubricating oil is estimated about 1:5. The rest of the effluent passes down the canal.

Photograph 2- External view of Rajshahi Power Generating Station.

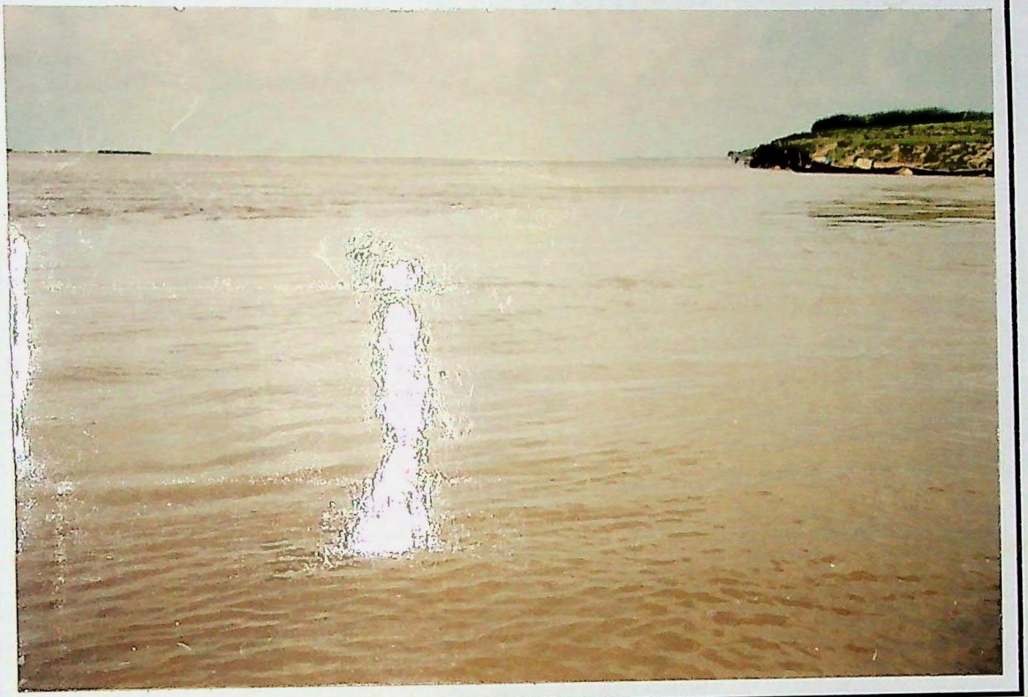


Photograph 3- Power Grid Line of Rajshahi Power Generating Station.

THE RIVER PADMA

The Padma is the largest and most important river in our country. Original source of this river is the Ganges of the Himalayans in India. It enters into Bangladesh through the north-western side of the country e.g. Rajshahi district is known as the Padma. As a major part of the Ganga, Padma deviates from "Farakka" point in India and flows through Bangladesh and ends in a number of estuarian flows in the Chandpur district to discharge its water load in the Bay of Bengal. River Jamuna meets the Padma at Goalonda point, and flows together to the Bay of Bengal as Jumuna with many estuarian channels. Rajshahi town is situated on the left bank of this river. It lies between 24.6° to 25.3° north latitude and 88.2° to 89.2° east longitude. Now its water flow is seriously effected by the Farakka Barage in Indian state of west Bengal. The average channel depth of different places of this river is 8 to 12 meters during the monsoon period.

The bed of the river is sandy in Rajshahi. Towards the lower region, the bed is muddy to sandy-muddy. In the rainy season a large amount of sands and muds run down into the river with rain water. Numerous tributaries connect the river on its right and left banks. A large number of population depend on this river for their living. This river has controlled and shaped the lives of the human population on its plains. They used the water for various domestic and agricultural purpose etc. Hundreds of small and large number of industrial units discharge their effluents directly or indirectly into this river. The town has a dense population and hence a large sewage system has developed which also drains into the river. Every year a large number of engine boat, small ships, cargo etc. ply through this river and enough waste and oil spills from this vessels to pollute the water of this river, which has not yet been assessed and monitored for environmental conservation and ecotechnological strategies.



Photograph 4- Natural View of Padma River.

CHAPTER THREE

MATERIALS AND METHODS

MATERIALS AND METHODS

MATERIALS

Weekly sampling was carried out from the month of November 1996 to October 1997, at three sampling spots. An average of the collected data from the three spots were done. Detail description of the location of industry, the river Padma are given in the chapter two.

DESCRIPTION OF THE SAMPLING SITE

SAMPLING SPOT-1

The first sampling spot is situated 40 meters away from the sugar mill and lies within the mill campus. The canal at this location is about 4-5 meters wide with an average depth of one meter. The entire place is shaded by large trees. The banks are steep high without any slop.

SAMPLING SPOT-2

It is located at Katakhali 60 meters away from power station, where the effluent is discharged in the canal stream through a steel pipe. Both the discharged effluents of sugar mills and the power station intermingle at this location. Average depth of this location was found to be one meter which rises during the rainy season.The distance between SP_1& SP_2 is about 2KM

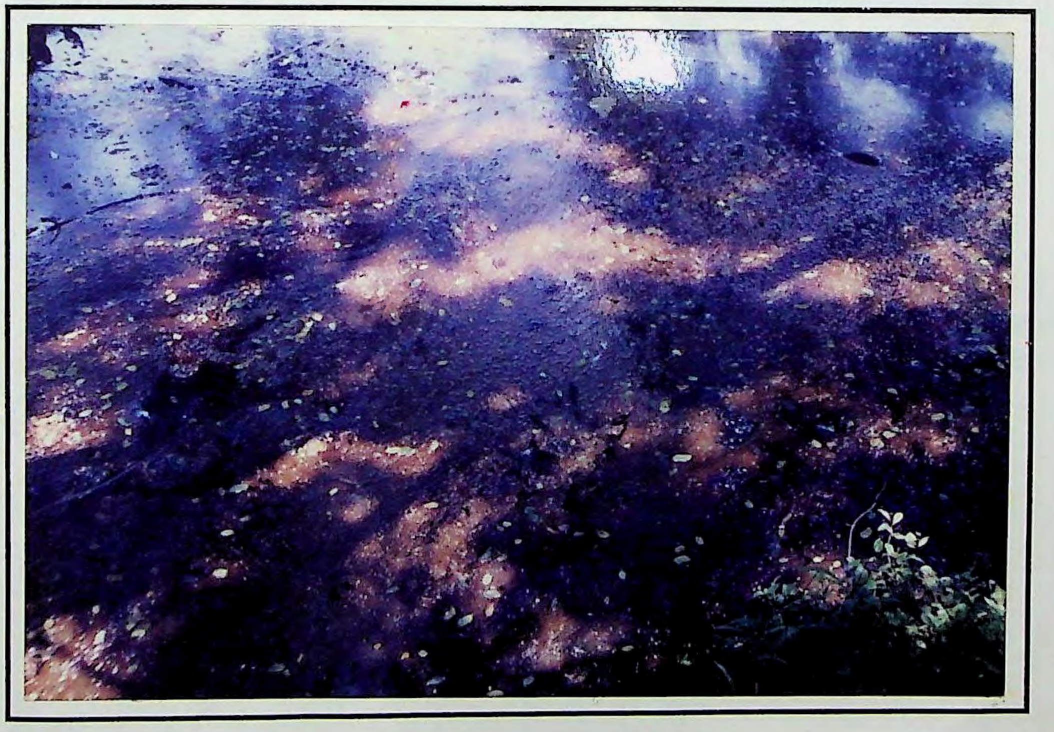
SAMPLING SPOT-3

It is situated south of katakhali near village Shahapur in the river Padma where the mixed effluents is discharged in the river water. The depth of water at this location varied from 4-7 meters with a maximum of 10 meters during the rainy season. The distance between SP_2 and SP_3 is about 3 KM.

COLLECTION OF SAMPLE

Water samples were collected from a depth of 10-25 cm. below the surface using a 250 ml. glass stoppered bottle. Plankton samples were collected by a plankton net of no. 20 silk bolting cloth. Algal samples and hydrophytes were collected manually.

Photograph 5- Effluent Discharge Drain of the Sugar Mill.



Photograph 6- Part of the Polluted Canal With Floating Scum (spot-1).

Photograph 7- Part of the Polluted Canal without Floating Hydrophytes and with Merginal Vegetation (spot-1).

Photograph 8- Part of Shaded Polluted Canal (spot-1).

Photograph 9- Hydrophytes (Aquatic weeds, *Spirodela* sp., *Lemna* sp., etc.) of highly polluted water in the canal

Photograph 10- Hydrophytes (*Eichhornia* sp., *Colocasia* sp., etc.) of highly polluted water in the canal

Photograph 11- Hydrophytes (*Jussiaea* sp., *Eichhornia* sp. etc.) of Highly Polluted Water in the Canal (spot-1).

METHODS

PHYSICAL CONDITIONS

AIR AND WATER TEMPERATURE

A centigrade mercury thermometer with the range of 0°C to 120°C and a digital thermometer (model no. 950' range -10 to +110°C) were used to note the air and water temperature simultaneously at the time of sample collection.

WATER COLOUR AND ODOUR

The water colour was observed visually while the odour was noted by smelling.

TRANSPARENCY

To obtain transparency, a secchi disc was slowly lowered into the water, under a shade until it has just disappeared and the depth was noted. Then the disc was slowly raised until it has just reappeared. This depth was also noted. The average of the two depths gave the transparency value expressed in centimeter (cm.).

TOTAL SUSPENDED SOLIDS (TSS)

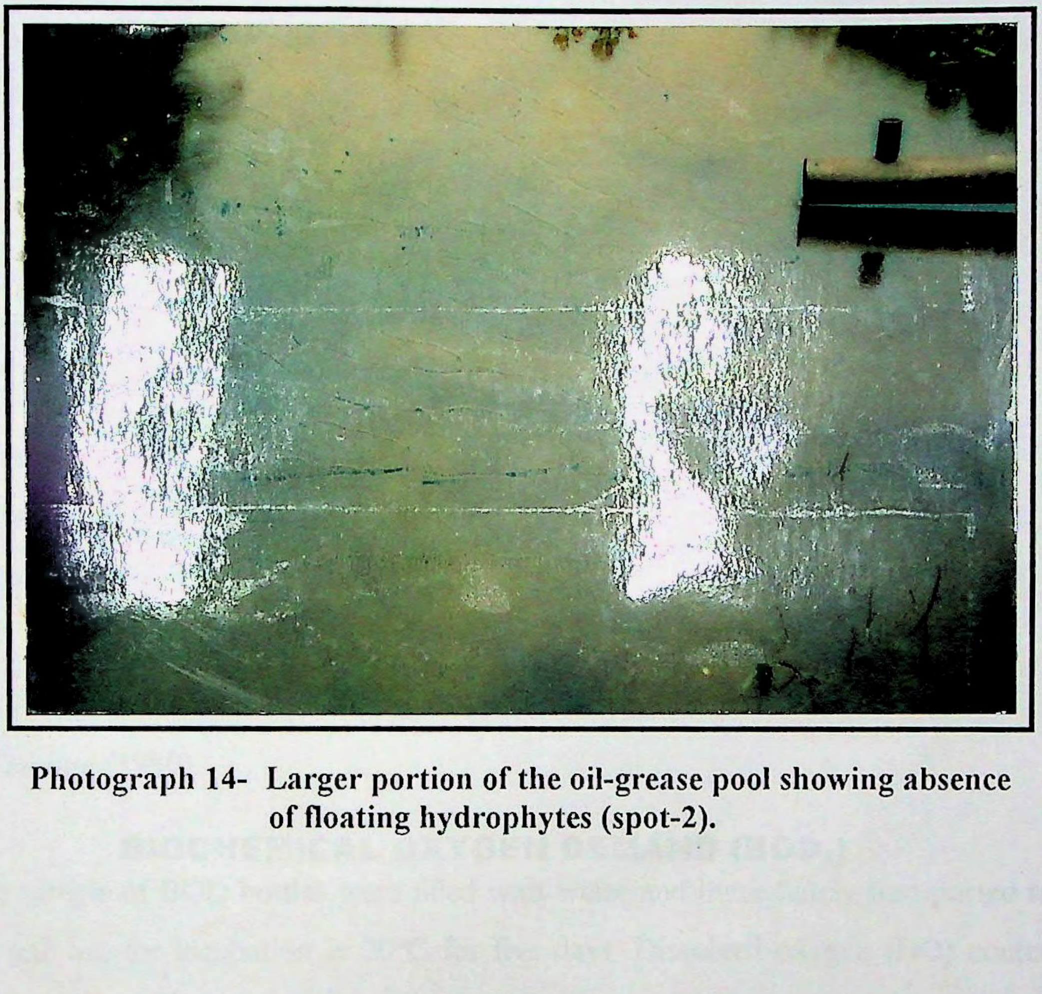
At first a filter paper was dried at 105°C oven temperature and weighted. Then a thoroughly mixed 250 ml. sample was filtered through the weighted filter paper. The filter paper was allowed to dry completely in the oven at the same temperature and reweighted. The change in the weight gave the TSS value for 250 ml. of water sample which was duly calculated for one liter. This obtained data is the total suspended solids. (Expressed as mg/l) (Ambasht 1990).

TOTAL DISSOLVED SOLIDS (TDS)

A glass beaker was dried at 105°C oven temperature and weighted, then 250 ml. of the filtrate from TSS experiment was taken in this beaker and placed it into the oven at the same temperature. After the complete evaporation of the filtrate the dry weight of the beaker was taken and calculated for a value of weight in one liter of water sample. This result is the total dissolved solids expressed as mg/l (Ambasht 1990)

Photograph 12- Discharge pipe showing release of power house effluent (spot-2).

Photograph 13- Children collecting the floating oil-grease from the discharge pool (spot-2).



Photograph 14- Larger portion of the oil-grease pool showing absence of floating hydrophytes (spot-2).

CHEMICAL CONDITIONS

HYDROGEN-ION CONCENTRATION (pH)

The value of pH was determined by a digital pH meter (Model - HANNA instruments).

DISSOLVED OXYGEN (DO)

Winkler's method (unmodified) was followed for the estimation of dissolved oxygen. The water samples collected for dissolved oxygen estimation were treated with manganous sulphate solution, alkaline iodide solution and acidified with concentrated sulphuric acid on the spot. The treated sample were transferred to the laboratory and the remaining steps of analysis were done. No noticeable change occurred in the treated samples within 24 hours. The quantity of dissolved oxygen, thus estimated, was expressed in milligram of oxygen per liter of water (mg/l). DO content of sample water was also determined by DO Meter (Model - JENWAY - 9015 DO Meter)

OXIDATION REDUCTION POTENTIAL (Eh)

It was estimated by a Digital pH Redox Meter- CORNING MODEL-3, AND HANNA INSTRUEMENT. It was also estimated by following deduction methods (Gautam 1990). The result was expressed in m volt.

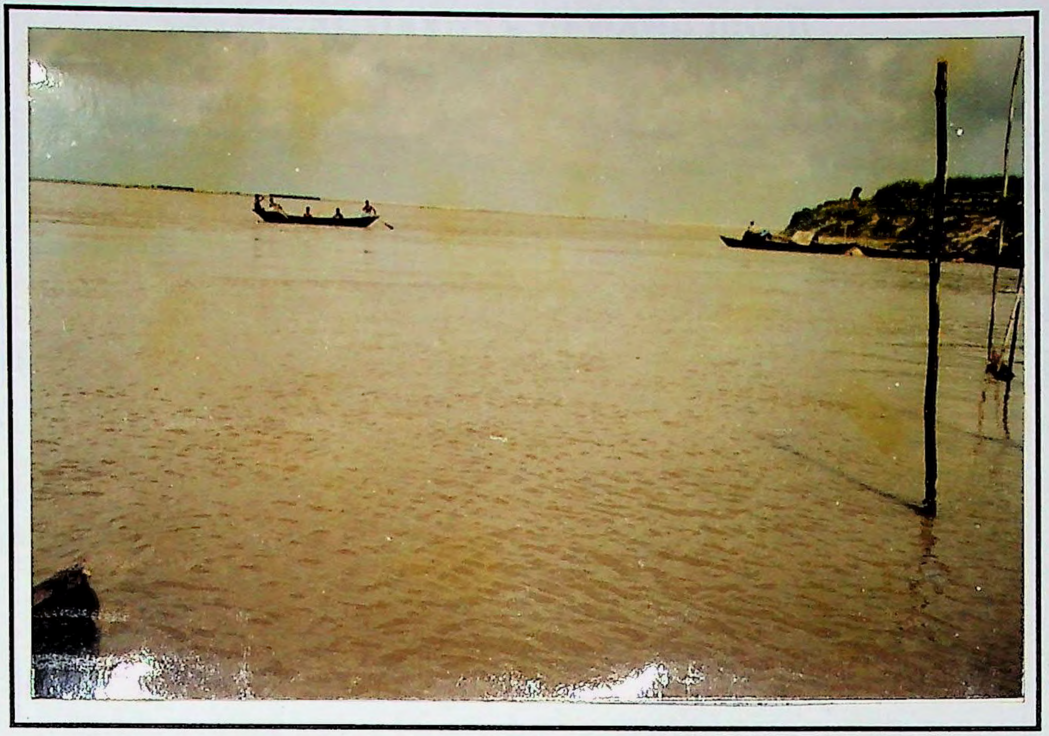
OXIDATION REDUCTION INDEX (rH_2)

Oxidation Reduction Index (rH_2) was estimated by deduction of data of Eh by following Gautam (1990).

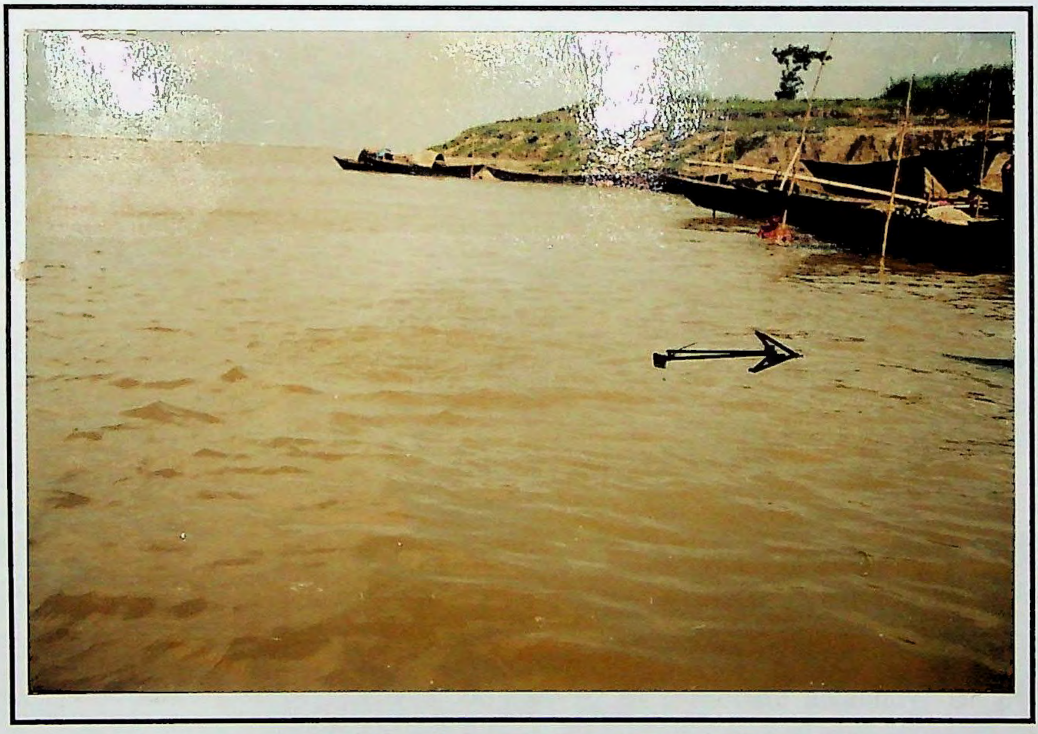
BIOCHEMICAL OXYGEN DEMAND (BOD_5)

The sample of BOD bottles were filled with water and immediately transported to the laboratory and left for incubation in 20°C for five days. Dissolved oxygen (DO) content of BOD bottle water sample was determined after five days by following the Winkler method (unmodified). The value of BOD_5 was obtained by subtracting final dissolve oxygen (FDO) from initial dissolve oxygen (IDO).

When the DO content was almost negligible or showing a condition of total anoxia, the BOD_5 was determined by dilution method (APHA 1989).



Photograph 15- Discharge point of Padma river with effluent mixed polluted water.



Photograph 16- Sampling site – 3 (Arrow head).

TOTAL HARDNESS

50 ml. sample of water pretreated with 1 ml. ammonia buffer solution was titrated against EDTA using Eriocrome Black - T as an indicator (Mishra *et al.*1992). The result was expressed in mg/l.

CALCIUM HARDNESS

50 ml. of sample pretreated with 1 ml. of 8% sodium hydroxide solution was titrated against EDTA solution (0.01M)using Murexide indicator (Mishra *et.al.*1992). The result was expressed in mg/l.

MAGNESIUM HARDNESS

Magnesium hardness was estimated by following Mishra *et. al.* (1992) method. The resultant data were expressed in mg/l.

AMMONIUM , AMMONIA AND AMMONIUM NITROGEN

For qualitative determination in the field, to 20 ml. of the water sample was added 10 drops of the sodium potassium tartrate solution plus 2-3 drops of Nesslers reagent and mixed vigorously. If no clearly detectable yellow colouration appears, less than 0.1 mg/l of ammonium ion is present; when more than this quantity of Ammonia is present; a more or less yellow colouration is seen (0.1-5 mg/l). When more than 5 mg/l is present, yellowish to reddish-brown precipitate forms. For quantitative determination, 2 ml. each of the Sodium potassium tartrate solution and Nessler's reagent with 100 ml. of the water sample was taken into an Erlenmeyer flask and shaken vigorously and left for 5 minutes. Ammonia free 100 ml. of distilled water was filled in a second flask and mixed it with the same reagents. Then with a burette graduated in 0.1 ml. scales, standard ammonia solution was added drop by drop and was compared the resulting yellowish colour with the colour of the water sample. When the colours were matched the amount of standard ammonium solution added can be read off and the ammonia content can be calculated. The values are given to an accuracy of a decimal point in mg/l. (APHA 1989 and Schwoerbel 1972).

TOTAL PHOSPHATE (PO_4)

50 mg. of sample was treated by 2 ml. acid ammonium molybdate solution and added 4-5 drops of stenus chloride solution. A blue colour appeared. The same procedure was run with a blank sample for comparison. Both the flasks were then kept on white paper for clear

view, followed by the addition of standard phosphate solution to the blank drop by drop with the help of a graduated pipette until the colour of blank exactly matched with the sample. (Gautam 1990). The result was expressed in mg/l.

SILICATE

50 ml. of sample was treated by 2 ml. of ammonium molybdate solution and added 0.5 ml. of 5% H_2SO_4. A yellow colour appeared. A blank was run following the same procedure. Then the colour was compared with colour of the sample, by adding drop by drop of K_2CrO_4 solution (Gautam 1990). The resultant data were expressed in mg/l.

TOTAL AND DISSOLVED SULPHIDE

It was determined by titrimetric method (Mishra *et al.*1992). 110 ml. of the water sample was taken in a glass stoppered bottle and added 1 ml. $CdCl_2$ solution (2%). This sample was allowed to stand for 24 to 48 hours. The supernatant was decanted and dissolved the precipitate in an exactly known small volume of iodine solution and 5 ml. HCL. The excess iodine was titrated with standarized $Na_2S_2O_3$ solution using starch indicator. A change from dark blue colour to colourless solution is the end point. A blank was run with distilled water in similar manner.

OIL AND GREASE

In natural waters oil and grease have been not of autochthonous origin. However, they enter in the system because of pollution. Being immiscible in water and low in density they float and form a film on the water surface. Content of oil and grease were determined by sulphuric acid and Petroleum ether method (Mishra *et al.*1992). A wide mouth bottle was filled with 250 ml. of sample. To this was added 100 ml. sulphuric acid (50 ml. con. H_2SO_4 + 100 ml. distilled water), about 50 ml. of Petroleum ether and little amount of ethyl alcohol. It was shaken and the whole suspension was transferred to a separatory funnel. It was kept for some time so that the two layers - upper one of Petroleum ether and lower one of water, were separated. Lower layer of water was rejected from the separatory funnel. The remaining Petroleum ether was drained out from the separatory funnel, through a filter paper soaked in Petroleum ether in a pre weighted (W_i) glass beaker. Now some more Petroleum ether was passed through the filter paper so that no oil and grease could remain stuck to the paper. Now, the beaker with contents was passed in a hot water bath so as to evaporate the Petroleum ether. The weight of beaker was found out with residue in it (W_f). The results were expressed in mg/l.

BIOLOGICAL CONDITIONS

PLANKTON STUDY

The collection of plankton was made by a plankton net of No. 20 silk bolting cloth. 75 litters of water collected from below the surface, were passed through the net. Water was poured round the inner side of the net to wash down the adhering plankter from the meshes. The plankton concentrate was immediately preserved either in 5% formalin or in Transeau's solution in vials. The concentrate in vials were made to 70 ml. in each by adding more preservative. These were regarded as original concentrate and stored for analysis and enumeration. The quantitative enumeration of the phyto- and zooplankton organisms were carried out with the help of Sedwick Rafter Counting Cell and Ocular whiple micrometer (Welch 1948). The counting cell was filled with water to test for any leakage and it was emptied and dried properly. The vials containing the concentrate were shaken properly and 1 ml. of concentrate was taken into the Sedwick Rafter counting cell. Numerical counts of all members of phyto- and zooplankton were made using the whiple micrometer. To achieve a random sampling, each time 3 fields were examined for each sample and an average of the counts had been recorded. The organisms thus counted were expressed as units per liter (units/l) of the sample, irrespective of whether they were solitary cells, colonies or filaments or part thereof. The average value as units/l of the water sample were computed on tables and was used in plotting the pie chart for both phyto- and zooplankton organisms. Monthly mean abundance of the phyto and zooplankton were calculated. Seasonal variation and abundance of the dominant algal genera, zooplankton genera and the groups of both phytoplankton and zooplankton were noted. All plankton were identified with the help of relevant literature.

The abundance of plankton groups were calculated according to the following formulae (Welch 1948).

$$N = \frac{(a \times 1000)\,C}{L}$$

Where,

N= Number of plankton per liter of original water.

a = Average number of plankton in all counts in the counting cell.

C = Volume of original concentrate in ml.

L = Volume of water passed through the net.

VEGETATION STUDY

Collection and preservation of all types of hydrophytes, prevailing at the sampling spots were done and identified with the help of relevant literature e.g. Khan and Halim (1987), Fasset (1960), Arber (1972), Monocot weeds - vol. 2, 3 (Ciba-geigy 1982), Subramanyan (1962) and Biswas and Calder (1954).

CHAPTER - FOUR

OBSERVATIONS AND RESULTS

OBSERVATIONS AND RESULTS

PHYSICAL CONDITIONS

AIR TEMPERATURE

Spot-1

During the period of study the air temperature varied from 19.75 to 33°C. The highest temperature was recorded in the month of May `97 and the lowest in the month of January``97. The temperature started to rise from the month of January till it reached the highest.

Spot-2

The range of air temperature was found to vary from 18 to 35.8°C during the period of study. The highest was recorded in May`97 and the lowest in the month of February`97. From the highest value, temperature decreased gradually.

Spot-3

At this spot the air temperature varied from 23.25 to 37°C. The maximum value was recorded in May`97 and the minimum in January`97. The temperature fluctuations were noted throughout the study period at this spot.

The data were presented in Table - I, II & III.

WATER TEMPERATURE

Spot-1

During the period of study the temperature of effluent mixed water varied from 25 to 37.3°C. The maximum value was recorded in sugar production period in November`96 and minimum in April`97 when production was stopped. Similar (29°C) values were recorded in the month of June and July`97.

Spot-2

At this spot the temperature of effluent mixed water varied from 18 to 32°C during the period of study. The minimum were recorded in January and February`97 and the maximum in May`97. Similar values were recorded in the month of June and July`97.

Spot-3

The water temperature at this spot in the river Padma varied from 18 to 32°C during the study period. The minimum and the maximum temperature were recorded in February`97 and May`97 respectively.

The data were presented in Table - I, II & III.

TRANSPARENCY

Spot-1

Range of transparency of the effluent mixed water was found to vary from 6.5 to 20 cm. The minimum was recorded in March`97 and the maximum in August and September`97.

Spot-2

Transparency of the effluent mixed water varied from 5 to 17.5 cm. during the period of study. The highest value was recorded in August`97. The minimum was recorded in January`97. Similar values of transparency were recorded in February and October`97.

Spot-3

Transparency of water at this spot in the Padma river varied from 6 to 58 cm. during the period of study. The minimum value was recorded in August `97 while the maximum was recorded in April`97. The transparency was found to increase gradually from November `96 and rose to the highest value in April`97. The water was a bit turbid in May`97 but the transparency value again rose to a maximum in July`97. During August to October 1997, the water was extremely turbid with a transparency value of 6-10cm .

The data were presented in Table - I, II & III.

TABLE : I : **MONTHLY MEAN ($\bar{X}$) OF PHYSICO-CHEMICAL CONDITIONS, PLANKTON ABUNDANCE AND THEIR YEARLY MEAN AND STANDARD DEVIATION OF SUGAR MILLS SPOT (Spot-1).**

PARAMETER	1996		1997										Yearly	
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	Mean ($\bar{X}$)	SD (σ) ±
Air Temp. ^{0}C	27.5	22.75	19.75	20.5	29	29.8	33	31.5	31.5	29.9	29	28.5	27.73	4.18
Water Temp. ^{0}C	37.3	32.15	32.5	33	27	25	30.5	29	29	28.5	28	31	30.25	3.11
Transparency cm	9.5	13.75	6.75	12.5	6.5	10	7	12	14.5	20	20	18	12.54	4.68
TSS mg/l	195	190	215	130	390	430	410	295	280	120	130	190	247.92	107.09
TDS mg/l	3780	2140	2960	2440	4040	6160	4520	3610	1210	640	790	3148	2953.17	1556.34
pH	7.35	6.1	7.05	7.3	6.8	7.7	7.2	7.2	7.1	8.2	7.3	6.8	7.18	0.49
DO mg/l	Anoxia	Anoxia	Anoxia	Anoxia	Anoxia	Anoxia	Anoxia	Anoxia	Anoxia	1.15	Anoxia	Anoxia	0.095	0.32
Eh m Volt	0.094	0.116	0.096	0.092	0.145	0.137	0.142	0.142	0.144	0.228	0.181	0.107	0.135	0.038
rH_2	8.28	8.85	8.79	8.10	9.31	8.28	8.96	8.96	9.31	10.21	9.97	8.30	8.94	0.64
BOD mg/l	10.4	10.4	16.36	11.2	12.67	15	13.2	9.65	7.1	5.2	6.39	9.8	10.62	3.2
COD mg/l	2471	1736	1912	1894	1340	1442	1510	1293	1140	892	964	2076	1555.83	454.27
Conductivity µ ohms / cm	1325.34	1077.59	1039.73	647.75	1420.86	838.59	1558.17	1048.35	721.77	261.89	547.31	837.30	943.72	361.73
Chloride mg/l	61.06	63.19	47.57	46.92	137.74	51.12	142.06	59.02	48.28	26.98	41.42	52.54	64.83	34.81
CO_2 mg/l	58.5	109	95	45	52	35	72	66	53	9	33	46	56.13	26.01
CO_3 alk. mg/l	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HCO_3 Alk. mg/l	148.5	293.5	194	233	442	290	556	516	489	76	197	229	305.33	150.66
Total Hardness mg/l	550	604	498	464	600	516	372	287	254	230	310	452	428.08	127.93
Ca. Hardness mg/l	405.3	459.9	478	457.8	411.6	319.2	319.2	261.5	72	138.6	203	184	309.18	131.59
Mg. Hardness mg/l	35.32	35.16	8.79	1.55	45.97	48.02	13.88	6.23	44.41	22.31	26.11	65.39	29.43	18.82
NH_4 mg/l	0.318	0.583	0.583	0.636	0.74	0.424	0.53	0.53	0.636	0.212	0.318	0.53	0.503	0.149
NH_3 mg/l	0.30	0.55	0.55	0.60	0.70	0.40	0.50	0.50	0.60	0.20	0.30	0.50	0.475	0.141
NH_4. Nmg/l	0.247	0.453	0.453	0.49	0.58	0.33	0.412	0.412	0.49	0.165	0.247	0.412	0.391	0.116
PO_4 mg/l	0.01	0.012	0.011	0.012	0.012	0.014	0.013	0.012	0.009	0.008	0.009	0.009	0.011	0.0018
Silicate mg/l	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Total sulphide M mol l^{-1}	4.89	5.03	3.81	2.96	2.18	1.86	1.65	1.49	1.24	0.92	1.89	3.92	2.65	1.38
Oil-grease mg/l	2.46	2.92	7.12	7.13	4.2	3.92	2.96	1.85	1.26	1.04	1.64	2.18	3.22	1.97
Phytoplankton Units/l	48834	42196	39678	34052	31748	27354	29986	38662	56822	64982	59212	52764	43858	11934.38
Zooplankton Units/l	64565	60884	56396	48178	42704	29169	33646	41881	52366	65547	75935	67681	53246	13848.81

TABLE : II : MONTHLY MEAN ($\overline{X}$) OF PHYSICO-CHEMICAL CONDITIONS, PLANKTON ABUNDANCE AND THEIR YEARLY MEAN AND STANDARD DEVIATION OF POWER HOUSE SPOT (Spot-2).

PARAMETER	1996		1997										Yearly	
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	Mean ($\overline{X}$)	SD (σ) ±
Air Temp. ^{0}C	27.75	22.25	19.5	18	29.5	33	35.8	34.5	33.5	31.5	31	30.5	28.9	5.66
Water Temp. ^{0}C	23	20.65	18	18	24.8	26.5	32	30	30	29	28	27	25.58	4.54
Transparency cm	9.5	8.25	5	10	7	9	11	12.5	14	17.5	12	10	10.48	3.15
TSS mg/l	170	140	235	185	310	370	160	150	130	120	130	155	187.92	75.01
TDS mg/l	1540	2160	2440	1650	1800	1860	520	480	420	400	680	1230	1265	708.44
pH	7.4	6.1	7.05	7.7	8.7	8.8	7.3	7.1	6.9	7.9	6.95	6.4	7.36	0.78
DO mg/l	Anoxia	Anoxia	Anoxia	Anoxia	Anoxia	0.026	0.19	0.56	1.05	1.68	0.89	Anoxia	0.366	0.537
Eh m Volt	0.099	0.114	0.091	0.085	0.127	0.125	0.142	0.148	0.151	0.233	0.249	0.115	0.140	0.049
rH_2	8.28	8.69	8.66	8.58	8.91	8.55	8.97	9.69	10.03	10.24	10.73	8.66	9.17	0.762
BOD mg/l	5.6	7.95	9.72	8.6	7.8	9.38	6.4	5.2	4.9	3.72	4.16	5.38	6.57	1.97
COD mg/l	626	704	738	810	896	872	808	736	564	512	574	609	704.08	121.72
Conductivity µ ohms / cm	1368.49	920.38	817.15	753.32	2113.78	1558.17	779.09	652.27	370.14	224.74	672.93	1012.51	936.91	501.27
Chloride mg/l	73.13	61.77	52.54	51.18	147.68	62.48	56.56	47.18	40.64	25.56	33.42	69.58	60.14	29.63
CO_2 mg/l	35	65	26.5	30	5	NIL	21	19	17	13	21	28	23.38	15.83
CO_3 alk. mg/l	NIL	NIL	NIL	NIL	NIL	29	NIL	NIL	NIL	NIL	NIL	NIL	2.42	8.02
HCO_3 alk. mg/l	200.5	338	329	247	198	120	228	197	168	71	154	163	201.13	74.29
Total Hardness mg/l	312	534	344	384	288	264	156	143	112	72	193	328	260.83	126.45
Ca. Hardness mg/l	231	296.1	308.7	315	247.8	174.4	138.6	117	96.5	58.8	146	276	200.49	85.72
Mg. Hardness mg/l	19.77	58.05	8.62	16.84	9.81	21.38	4.25	6.34	3.78	3.23	11.47	12.69	14.69	14.32
NH_4 mg/l	0.424	0.424	0.53	0.636	0.318	0.212	0.318	0.318	0.212	0.016	0.016	0.318	0.312	0.176
NH_3 mg/l	0.40	0.40	0.50	0.60	0.30	0.20	0.30	0.30	0.20	0.01	0.01	0.30	0.293	0.168
NH_4.N mg/l	0.329	0.329	0.412	0.494	0.25	0.165	0.247	0.247	0.165	0.08	0.08	0.25	0.254	0.119
PO_4 mg/l	0.011	0.037	0.014	0.08	0.01	0.013	0.012	0.011	0.01	0.008	0.008	0.016	0.019	0.02
Silicate mg/l	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Total sulphide M mol l^{-1}	3.67	4.09	4.18	3.85	2.64	1.26	1.00	0.83	0.64	0.38	0.25	1.89	2.06	1.48
Oil-grease mg/l	43.6	52.14	101.18	89.06	175.68	141.92	39.68	28.4	23.8	22.36	36.22	41.58	66.30	47.9
Phytoplankton Units/l	56766	65328	72874	79234	67446	58978	45758	36726	27462	33190	37944	49986	52683	11046.60
Zooplankton Units/l	93759	97825	94338	89146	82275	73408	70962	52524	33637	47458	69983	90641	74663	19920.24

TABLE : III : MONTHLY MEAN ($\overline{X}$) OF PHYSICO-CHEMICAL CONDITIONS, PLANKTON ABUNDANCE AND THEIR YEARLY MEAN AND STANDARD DEVIATION OF PADMA RIVER SPOT (Sopt-3).

PARAMETER	1996		1997										Yearly	
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	Mean ($\overline{X}$)	SD (σ) ±
Air Temp. ^{0}C	26.5	24.9	23.25	25	32	30.5	3.7	33	32	28.9	27.5	27	28.96	3.86
Water Temp. ^{0}C	23.85	20.25	18.75	18	26	28	32	31	30	28	26	25.5	25.61	4.45
Transparency cm	11	20.5	22	41	39	58	40.5	47	56	6	8	10	29.92	18.34
TSS mg/l	65	90	132.5	95	280	70	60	80	120	340	110	80	126.88	85.41
TDS mg/l	840	1100	1380	1140	1040	440	280	295	310	520	630	710	723.75	358.46
pH	7.75	7.3	7.55	8.4	8.1	8.3	8.6	8.2	7.5	7.8	7.5	6	7.75	0.66
DO mg/l	3.88	3.84	3.37	2.34	3.68	5.1	8.52	4.08	3.77	3.7	3.00	3.4	4.06	1.48
Eh m Volt	0.139	0.125	0.119	0.116	0.118	0.189	0.275	0.292	0.393	0.367	0.282	0.158	0.214	0.098
rH_2	11.26	11.25	10.89	10.05	10.83	11.56	12.68	13.51	14.56	14.22	13.41	12.22	12.20	1.40
BOD mg/l	2.33	2.46	4.22	2.08	2.45	2.01	1.95	1.8	1.7	1.7	2.01	2.19	2.24	0.646
COD mg/l	320	388	455	266	158	148	138	136	132	280	306	314	253.42	105.10
Conductivity μ ohms / cm	286.96	479.72	303.67	340.33	364.77	383.47	311.63	265.27	185.07	187.06	194.72	283.58	298.85	83.62
Chloride mg/l	66.03	58.93	44.73	35.5	49.1	58.22	46.62	41.8	39.58	41.18	44.32	47.91	47.83	8.6
CO_2 mg/l	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	7	0.58	1.94
CO_3 alk. mg/l	5	4.5	6.5	5	8	10	11	12	14	6	9	NIL	7.58	3.7
HCO_3 alk. mg/l	68	122.5	125.5	99	101	93	78	99	123	59	68	81	93.08	21.87
Total Hardness mg/l	116	124	120	124	188	200	96	87	84	75	163	88	130.42	42.06
Ca. Hardness mg/l	98.7	48.6	65.1	54.6	121.8	37.8	58.8	52.3	29.4	50.4	107	130.2	71.23	32.54
Mg. Hardness mg/l	4.22	18.4	13.35	16.93	16.15	39.58	9.08	8.47	13.33	5.27	13.67	14.11	14.38	8.72
NH_4 mg/l	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
NH_3 mg/l	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
NH_4.N mg/l	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
PO_4 mg/l	0.004	0.0052	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	0.0008	0.002
Silicate mg/l	0.03	0.0012	0.004	0.006	0.006	0.008	0.136	0.141	0.148	0.158	0.152	0.112	0.075	0.067
Total sulphide M mol l^{-1}	0.44	0.62	1.01	0.85	0.46	0.31	0.28	0.22	0.16	0.14	0.08	0.39	0.413	0.275
Oil-grease mg/l	0.28	0.83	1.83	1.38	1.08	0.72	0.28	NIL	NIL	NIL	NIL	0.64	0.586	0.582
Phytoplankton Units/l	65384	71262	88798	91656	86287	69659	53316	40242	22998	34860	47132	53974	60464	21227.12
Zooplankton Units/l	39762	56198	63684	55357	48464	36228	25109	10335	7667	3990	17856	24534	32432	19645.24

TOTAL SUSPENDED SOLIDS (TSS)

Spot-1

At this spot the TSS value varied from 120 to 430 mg/l during the period of study. The highest value was recorded in April`97 and the lowest in August `97. The values were found to be similar in the month of December `96 and October`97. The TSS value was found to fluctuate considerably during the study time.

Spot-2

The TSS value was found to vary from 120 to 370 mg/l. The maximum value was recorded in April`97 and the minimum was recorded in August `97. The TSS values were found to be similar in July and September`97.

Spot-3

During the period of study total suspended solids varied from 60 to 340 mg/l. The highest value was recorded in August `97 and the lowest in May`97. The TSS values were similar in the month of June and October`97.

The data were presented in Table - I, II & III.

TOTAL DISSOLVED SOLIDS (TDS)

Spot-1

The TDS values varied from 640 to 6160 mg/l during the study period. The maximum value was recorded in the month of April`97 and the minimum in August`97. The TDS value was found to be higher during the sugar productions period (November - February). During the off-production period, the values were yet higher than those of the production period, which could be due to the cleaning and washing of the mills.

Spot-2

At this spot the TDS values varied from 400 to 2440 mg/l. The maximum value was recorded in the month of January`97 and the minimum in the month of August`97. At this spot the TDS values were comparatively lower than these in the spot-1.

Spot-3

In the Padma river water TDS values varied form 280 to 1380 mg/l. The maximum value was recorded in the month of January`97 and the minimum in the month of May`97.

The data were presented in Table - I, II & III.

CHEMICAL CONDITIONS

HYDROGEN ION CONCENTRATION (pH)

Spot-1

The pH value of effluent mixed water varied from 6.1 to 8.2 during the period of study. The maximum value was recorded in August`97 and the minimum in the month of December`96. The values were almost similar (7.3 and 7.2) in the month of February, September`97 and May, June`97 respectively. Slightly acidic values were obtained in the months of December, 1996, March and October, 1997 (6.1 - 6.8)

Spot-2

During the period of study the pH of effluent mixed water varied from 6.1 to 8.8. The maximum value was recorded in the month of April`97 and the minimum in the month of December`96. Acidic values were obtained in December`96 (6.1), July (6.9), September (6.95) and October (6.4) in 1997.

Spot-3

The pH value of Padma river water varied from 6 to 8.6. The maximum value was recorded in May`97 and the minimum value was recorded in the month of October`97. The rise of pH values did not show a gradual and regular pattern

The data were presented in Table - I, II & III.

DISSOLVED OXYGEN

Spot-1

At this spot the dissolved oxygen content varied from anoxia to 1.15 mg/l during the period of study. During the study period DO was traced only once in August, 1997, and the rest of the period total anoxia prevailed.

Spot-2

The dissolved oxygen value varied from total anoxia to 1.68 mg/l. The maximum value was recorded in the month of August`97. The total anoxia were recorded from November`96 to March`97 and October`97.

Spot-3

During the period of study the DO content of Padma river varied from 2.34 to 8.52 mg/l. The maximum value was recorded in the month of May`97 and the minimum was recorded in the month of February`97. At this discharge point, the DO content varied from 2.43 - 3.88 mg/l during the production period. During the off-production period the highest value (8.52 mg/l) was obtained in May`97, when Padma water was comparatively clear. Since then the DO content fell to lower values (3.0 - 4.08 mg/l) as the Padma was in spat with muddy water (June-October`97)

The data were presented in Table - I, II & III.

OXIDATION-REDUCTION POTENTIAL (Eh)

Spot-1

During the period of study Oxidation-Reduction Potential value varied from 0.092 to 0.228 m volt. The maximum value was recorded in the month of August`97 and the minimum value was recorded in the month of February`97.

Spot-2

At this spot, Oxidation-Reduction Potential value varied from 0.085 to 0.249 m volt, during the period of study. The maximum value was recorded in the month of September`97 and the minimum was recorded in the month of February`97.

Spot-3

The value of Oxidation-Reduction Potential varied from 0.116 to 0.393 m volt during the period of study. The maximum was recorded in the month of July and the minimum in the month of February`97.

The data were presented in Table - I, II & III.

OXIDATION-REDUCTION INDEX (rH_2)

Spot-1

Oxidation-Reduction Index was found to vary from 8.10 to 10.21 during the period of study. The maximum rH_2 was recorded in the month of August`97 and the minimum in the month of February`97.

Spot-2

At this spot, Oxidation-Reduction Index was found to vary from 8.28 to 10.73 during the period of study. The highest rH_2 value was recorded in the month of September`97 and the lowest was recorded in the month of November`96.

Spot-3

During the period of study the Oxidation-Reduction Index was found to vary from 10.05 to 14.56 of this spot. The maximum rH_2 was recorded in the month of July`97 and the minimum was recorded in the month of February`97.

The data were presented in Table - I, II & III.

BIOLOGICAL OXYGEN DEMAND (BOD)

Spot-1

The BOD value was found to vary from 5.2 to 16.36 mg/l. The highest value was recorded in the month of January`97 and the lowest in August`97.

Spot-2

During the period of study the BOD value varied from 3.72 to 9.72 mg/l. The maximum value was recorded in the month of January`97 and the minimum was recorded in August`97.

Spot-3

The BOD value of the Padma river water varied from 1.7 to 4.22 mg/l during the period of study. The maximum value was recorded in the month of January`97. The minimum values were recorded in the month of July and August`97.

The data were presented in Table - I, II & III.

CHEMICAL OXYGEN DEMAND (COD)

Spot-1

The COD value of sugar mills effluent mixed water varied from 892 to 2471 mg/l during the period of study. The maximum COD value was recorded in the month of November`96 and the minimum was recorded in August`97.

Table IV.

(a) **BOD : COD IN SPOT - 1**

1996		1997										Yearly	SD(σ)
NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	Mean ($\bar{X}$)	±
0.0042	0.006	0.009	0.006	0.009	0.01	0.009	0.008	0.006	0.006	0.007	0.005	0.007	0.0018

(b) **BOD : COD IN SPOT - 2**

1996		1997										Yearly	SD(σ)
NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	Mean ($\bar{X}$)	±
0.009	0.011	0.013	0.011	0.009	0.011	0.008	0.007	0.009	0.007	0.007	0.009	0.009	0.0018

(c) **BOD : COD IN SPOT - 3**

1996		1997										Yearly	SD (σ)
NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	Mean ($\bar{X}$)	±
0.007	0.006	0.009	0.008	0.016	0.014	0.014	0.013	0.013	0.006	0.007	0.007	0.01	0.0035

Spot-2

During the period of study the COD value of effluent mixed water was found to vary from 512 to 896 mg/l. The maximum value was recorded in the month of March`97 and the minimum in August`97.

Spot-3

At this spot the Padma water COD value varied from 132 to 455 mg/l during the period of study. The maximum value was recorded in the month of January`97 and the minimum was recorded in the month of July`97.

The data were presented in Table - I, II & III.

ELECTRIC CONDUCTIVITY

Spot-1

The electric conductivity value of effluent mixed water was found to vary from 261.89 to 1558.17 μ ohms/cm during the study period. The maximum value was recorded in the month of May`97 while the minimum was in August`97. Higher values were also obtained in November, December`96, January, March and June, 1997. In the rest of the study period, the electric conductivity values were also moderately high.

Spot-2

During the study period the electric conductivity value of effluent mixed water ranged from 224.74 to 2113.78 μ ohms/cm. The maximum value was recorded in the month of March`97 and the minimum was recorded in August`97. Electric conductivity values were also found to be high in November`96, April and October`97. Moderately high values were noticed in other months with marked fluctuations.

Spot-3

The value of electric conductivity varied from 185.07 to 479.72 μ ohms/cm during the period of study. The maximum value was recorded in the month of December`96, while the minimum was in July`97. Moderate values were noticed in other months with noticeable changes.

The data were presented in Table - I, II & III.

CHLORIDE

Spot-1

During the period of study the chloride value was found to vary from 26.98 to 142.06 mg/l. The maximum value was recorded in the month of May`97 and the minimum was recorded in the month of August`97. High value was also obtained (137.74 mg/l) in March, 1997. Other than August `97, the chloride values of all other months were found to be uniform.

Spot-2

The chloride value varied from 25.56 to 147.68 mg/l, during the period of study. The maximum value was recorded in the month of March`97 and the minimum in August`97. Chloride values for all months other than August `97 were found to be almost similar.

Spot-3

During the period of study the chloride value varied from 35.5 to 66.03 mg/l. The maximum value was recorded in the month of November`96 and the minimum was recorded in the month of February`97. Fluctuation of chloride values at this spot was not prominent.

The data were presented in Table - I, II & III.

CARBON DIOXIDE (CO_2)

Spot-1

During the period of study the CO_2 value varied from 9 to 109 mg/l. The maximum value was recorded in the month of December`96 and the minimum in August`97.

Spot-2

The CO_2 value varied from zero to 65 mg/l during the period of study. The maximum value was recorded in the month of December`96 and the minimum was recorded in April`97.

Spot-3

In the river Padma CO_2 value was always recorded nil during the period of study except October`97 (7 mg/l).

The data were presented in Table - I, II & III.

CARBONATE ALKALINITY (CO_3)

Spot-1

During the period of study CO_3 alkalinity value was always found to be absent.

Spot-2

The CO_3 alkalinity value was always recorded nil during the period of study, except April`97 (29 mg/l).

Spot-3

The CO_3 alkalinity value of Padma river water was found to vary from zero to 14 mg/l, during the period of study. The maximum value was recorded in the month of July`97 and the minimum in October`97.

The data were presented in Table - I, II & III.

BICARBONATE ALKALINITY (HCO_3)

Spot-1

The HCO_3 alkalinity value of sugar mills effluent mixed water varied from 76 to 556 mg/l during the period of study. The maximum value was recorded in the month of May`97 and the minimum was recorded in the month of August`97. The fluctuation of the HCO_3 alkalinity values were noticeably irregular during the study period.

Spot-2

During the period of study the HCO_3 alkalinity value of effluent mixed water was found to vary from 71 to 338 mg/l. The maximum value was recorded in the month of December`96 and the minimum in August`97. The HCO_3 alkalinity curve showed irregular fluctuation during the study period.

Spot-3

The HCO_3 alkalinity value varied from 59 to 123 mg/l during the period of study. The maximum value was recorded in the month of July`97 and the minimum was recorded in the month of August`97. Similar values were recorded in the month of February and June`97. Moderate fluctuation of the HCO_3 alkalinity values at this spot was noticed.

The data were presented in Table - I, II & III.

TOTAL HARDNESS

Spot-1

The total hardness value of effluent mixed water was found to vary from 230 to 604 mg/l during the period of study. The maximum value was recorded in the month of December`96 and the minimum in August`97. Other higher values were also noted in November`96 (550 mg/l), March`97 (600 mg/l) and April`97 (516 mg/l). Fluctuation of total hardness values were noticed during the study period.

Spot -2

During the period of study the effluent mixed water hardness value was found to vary from 72 to 534 mg/l. The maximum value was recorded in the month of December`96 and the minimum was recorded in the month of August`97. The fluctuation of total hardness values was noticed during the study period.

Spot-3

The total hardness value varied from 75 to 200 mg/l during the period of study. The maximum value was recorded in the month of April`97 and the minimum in August`97. Noticeable fluctuation of total hardness values have been noted as the spot during the period of study.

The data were presented in Table - I, II & III.

CALCIUM HARDNESS

Spot -1

The calcium hardness value varied from 72 to 478 mg/l during the study period. The maximum value was recorded in the month of January`97 while the minimum was in July`97. Higher values were also obtained in November,December`96 and February,March`97. The value grdually declined and reached the lowest value in July`97; Since then, it started to rise steadily.

Spot -2

During the study period the calcium hardness was found to vary from 58.8 to 315 mg/l. The maximum value was recorded in the month of February`97 and the minimum in August`97. Another higher value (308.7 mg/l) was obtained in January `97. Calcium hardness values started to rise from November`96 and continued till highest value was reached in February`97. Since then, the value gradually fell to the lowest level in August`97 which again started rising steadily

Spot-3

At this spot the calcium hardness value ranged from 29.4 to 130.2 mg/l during the study period. The maximum value was recorded in the month of October`97 and the minimum was in July`97. No noticeable fluctuation was observed during the study period.

The data were presented in Table - I, II & III.

MAGNESIUM HARDNESS

Spot-1

The magnesium hardness value varied from 1.55 to 65.39 mg/l during the study period. The maximum value was recorded in the month of October`97 and the minimum in February`97. Magnesium hardness values showed a uphill and downhill fluctuations during the study period.

Spot-2

During the study period the magnesium hardness value varied from 3.23 to 58.05 mg/l. The maximum value was recorded in the month of December`96 while the minimum was in August`97. At this spot the magnesium hardness values maintained a low level with no noticeable fluctuation.

Spot-3

At this spot the magnesium hardness value was found to vary from 4.22 to 39.58 mg/l during the study period. The maximum value was recorded in the month of April`97 and the minimum was recorded in November`96. The magnesium hardness values were found to be more or less uniform with negligible fluctuation.

The data were presented in Table - I, II & III.

AMMONIUM (NH_4)

Spot-1

During the period of study the ammonium content varied from 0.212 to 0.74 mg/l. The maximum value was recorded in the month of March`97 and the minimum in August`97. In the rest of the period NH_4 values were more or less uniform.

Spot-2

The ammonium content was found to vary from 0.016 to 0.636 mg/l during the study period. The maximum value was recorded in the month of February`97 and the minimum were recorded in the month of August and September`97. The values were almost uniform during other months.

Spot-3

At this spot the ammonium content of water was always found to be absent during the study period.

The data were presented in Table - I, II & III.

AMMONIA (NH_3)

Spot-1

The ammonia content varied from 0.20 to 0.70 mg/l during the period of study. The maximum value was recorded in the month of March`97 and the minimum was recorded in August`97.

Spot-2

During the study period the value of ammonia was found to vary from 0.01 to 0.6 mg/l. The maximum value was recorded in the month of February and the minimum were recorded in August and September`97.

Spot-3

During the study period the value of ammonia was always nil.

The data were presented in Table - I, II & III.

AMMONIUM NITROGEN (NH_4-N)

Spot-1

The ammonium nitrogen content varied from 0.165 to 0.58 mg/l during the study period. The maximum value was recorded in March`97 and the minimum in August`97.

Spot-2

At this spot the ammonium nitrogen content was found to vary from 0.08 to 0.494 mg/l. The maximum value was recorded in the month of February`97 and the minimum values were recorded in August and September`97.

Spot-3

At this spot the value of ammonium nitrogen was always found to be nil during the period of study.

The data were presented in Table - I, II & III.

TOTAL PHOSPHATE (PO_4)

Spot-1

Average phosphate value varied from 0.008 to 0.014 mg/l during the study period. The maximum was recorded in April'97 and the minimum in August`97. Exactly similar values (0.012 mg/l) were recorded in December`96, February, March and June`97. In July, September and October`97 similar values (0.009 mg/l) were recorded.

Spot-2

The phosphate value varied from 0.008 to 0.08 mg/l during the period of study. The maximum value was recorded in February`97 and the minimum were recorded in August and September`97.

Spot-3

At this spot the phosphate value was always found to be nil during the period of study except in November, December`96, with extremely low values.

The data were presented in Table - I, II & III.

SILICATE

Spot-1

At this spot the value of silicate was always found to be absent during the study period.

Spot-2

During the study period the value of silicate was always zero.

Spot-3

The value of silicate was found to vary from 0.004 to 0.158 mg/l during the period of study. The maximum value was recorded in the month of August`97 while the minimum was in January`97.

The data were presented in Table - I, II & III.

TOTAL SULPHIDE

Spot-1

The sulphide value varied from 0.92 to 5.03 M mol l^{-1} during the period of study. The maximum value was recorded in December`96 while the minimum was in August`97.

Spot-2

During the study period the value of sulphide was found to vary from 0.25 to 4.18 M mol l^{-1} .The maximum value was recorded in January`97 and the minimum in September`97.

Spot-3

At this spot the value of sulphide varied from 0.08 to 1.01 M mol l^{-1} during the period of study. The maximum value was recorded in January`97 while the minimum in September`97.

The data were presented in Table - I, II & III.

Table V. Comparative account of physico-chemical conditions in different countries.

(a) Characteristics of effluents from seven Mauritius sugar factories.

Factory stream	BOD_5 (mg/l)	COD (mg/l)	TSS (mg/l)	T (°C)	pH
A	62	119	23	38	6.7
B	104	158	23	38	6.2
C	52	240	53	38	5.8
D	519	1510	252	34	6.1
E	28	90	10	43	6.4
F	128	230	29	31	6.4
G	168	290	42	-	-

(b) Comparable norms for sugar factory effluents discharged into surface waters.

Parameter	Taiwan	Australia	South Africa	India	China	Mauritius	Bangladesh (Present study)
BOD_5 mg/l	80	20	-	30	100	20	10.62±3.2
COD mg/l	300	-	75	-	160	30	1556±455
Suspended solids mg/l	200	30	25	30	150	30	248±107

(c) Water quality criteria in river water used for public supply
(adapted from WHO, 1988)

Water quality Criteria	High quality water/ minimum treatment[1]			Low quality water / advanced treatment[2]		
	India	Japan	UK	India	Japan	UK
Dissolved oxygen (DO) mg/l	> 6	> 7.5	-	> 4	> 5	-
% Saturation	-	-	> 80%	-	-	> 40%
Biochemical oxygen demand (BOD) mg/l	< 2	< 1	< 3	< 3	< 3	< 9

1. Disinfection and filtration
2. Full treatment and disinfection

OIL-GREASE

Spot-1

During the period of study the oil-grease content varied from 1.04 to 7.13 mg/l. The maximum value was recorded in the month of February'97 and the minimum in August'97. Higher values were also obtained in January, 1997 and during the rest of the study period the oil-grease values were found to be farely uniform with negligible variation.

Spot-2

In the study period the oil-grease content was found to vary from 22.36 to 175.68 mg/l. The maximum value was recorded in the month of March'97 while the minimum was in August'97. Next higher values were recorded in January and April, 1997, while the rest of the months the effluent mixed water maintained a moderately high values of oil-grease.

Spot-3

The oil-grease content of Padma river water varied from zero to 1.83 mg/l during the study period. The maximum value was recorded in January'97. The oil-grease was absent during June to September'97, period.

The data were presented in Table - I, II & III.

BIOLOGICAL CONDITIONS

PHYTOPLANKTON

During the period of investigation, phytoplankton population of three sampling spots were studied. From three sampling spots, 42 genera of euplanktonic and tychoplanktonic members were recorded. 29 genera were recorded from spot-1 (sugar mill), 31 genera from spot-2 (power house) and 26 genera from Spot-3 (Padma river).

Spot-1

The monthly phytoplankton abundance of this spot was found to very from 27354 to 64982 units/l during the study period. Maximum abundance was recorded in August, 1997 and the minimum was recorded in April, 1997. During the period of study Chlorophyceae was

Table VI. **Monthly mean abundance (units/l) and percentage composition of phytoplankton in spot-1.**

PHYTOPLANKTON	1996		1997										TOTAL	%
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT		
CYANOPHYCEAE														
Oscillatoria sp.	12560	11870	11380	10520	10375	10090	10942	12078	17192	17610	16230	15190	156037	29.65
Arthrospira sp.	3488	3020	2940	2795	2670	2440	2670	3590	5310	5430	3670	3550	41573	7.90
Lyngbya sp.	5736	4940	4790	4210	4090	3980	4290	4530	5730	5890	5980	5860	60026	11.41
Spirulina sp.	815	766	695	540	330	-	-	710	1340	1570	1220	920	8906	1.69
Anabaena sp.	630	410	380	-	-	-	-	480	910	1360	870	710	5750	1.09
Chroococcus sp.	-	-	-	-	-	-	-	-	460	830	500	-	1790	0.34
CHLOROPHYCEAE														
Chlorococcum sp.	1345	1210	1173	1090	985	890	930	1220	1770	2580	1940	1530	16663	3.17
Myrmecia sp.	898	780	690	570	535	-	-	625	910	1440	1210	1040	8698	1.65
Coelastrum sp.	460	260	180	-	-	-	-	-	-	-	-	-	900	0.17
Chlorella sp.	1228	1110	1040	962	838	794	844	1109	2030	2870	2110	1480	16415	3.12
Closteridium sp.	-	-	-	-	-	-	-	410	860	1140	720	324	3454	0.66
Westella sp.	-	-	-	-	-	-	-	390	570	737	460	-	2157	0.41
Scenedesmus sp.	-	-	-	-	-	-	-	-	440	580	512	-	1532	0.29
Padiastrum sp.	680	350	280	-	-	-	-	410	760	975	750	710	4915	0.93
Docidium sp.	864	690	610	560	510	180	-	-	-	-	-	540	3954	0.75
Spirogyra sp.	1010	930	890	626	580	235	385	595	1150	1330	1260	1060	10051	1.91
EUGLENOPHYCEAE														
Euglena sp.	5310	4640	4530	4080	3920	3740	4170	4720	5290	5340	5750	5490	56980	10.83
Phacus sp.	2020	1810	1750	1440	1200	990	1110	1320	1630	1710	1860	2185	19025	3.62
Trachelomonas sp.	920	540	510	430	380	-	-	-	-	360	640	730	4510	0.86
Astasia sp.	710	530	420	290	185	-	-	430	710	830	960	795	5860	1.11
Rhabdomonas sp.	-	-	-	-	-	-	-	370	440	690	350		1850	0.35
XANTHOPHYCEAE														
Chlorobotrys sp.	1330	1190	980	660	540	510	560	880	1280	1610	1570	1410	12520	2.38
Botrydiopsis sp.	950	760	610	554	480	210	320	-	640	840	1200	1080	7644	1.45
Bumilleriopsis sp.	410	330	180	-	-	-	-	-	-	-	580	470	1970	0.37
Botryococcus sp.	1190	820	740	495	360	-	-	430	945	1300	1330	1220	8830	1.68
BACILLARIOPHYCEAE														
Fragilaria sp.	760	680	630	565	530	510	595	705	930	1390	1120	810	9225	1.75
Nitzschia sp.	2170	1630	1590	1360	1190	970	1140	1170	1820	2160	2470	2230	19900	3.78
Pinnlaria sp.	1610	1390	1260	1035	920	795	920	1250	1915	2480	2050	1640	17265	3.28
Navicula sp.	1740	1540	1430	1270	1130	1020	1110	1240	1790	1930	1900	1790	17890	3.40
TOTAL	48834	42196	39678	34052	31748	27354	29986	38662	56822	64982	59212	52764	526290	100%

- = Not detected

Table VII. **Monthly mean abundance (units/l) and percentage composition of phytoplankton in spot-2.**

PHYTOPLANKTON	1996		1997											
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	TOTAL	%
CYANOPHYCEAE														
Oscillatoria sp.	16940	21820	26150	30365	25780	25250	21360	18190	13810	14120	14580	15340	243705	38.58
Lyngbya sp.	3720	4340	5230	5370	4950	4240	3170	2530	890	1550	1610	3350	40950	6.48
Spirulina sp.	2110	2350	2415	2590	2395	2108	930	250	-	-	-	1460	16608	2.63
Arthrospira sp.	3030	3170	3339	4110	3240	2890	1750	1220	960	930	1160	2680	28479	4.51
Phoremedium sp.	690	890	1115	1340	1220	930	490	-	-	-	390	520	7585	1.20
Anabaena sp.	780	660	570	520	340	-	-	-	310	870	1030	910	5990	0.95
CHLOROPHYCEAE														
Chlorogonium sp.	1150	1690	2040	2280	2160	1830	1350	1110	780	730	810	1020	16950	2.68
Chlorococcum sp.	1856	1960	2210	2399	2270	1620	1260	940	610	1020	1370	1696	19211	3.04
Myrmecia sp.	970	830	745	660	250	-	-	-	-	-	330	750	4535	0.72
Coelastrum sp.	-	-	-	-	-	-	-	-	680	950	510	370	2510	0.40
Chlorella sp.	1770	2348	2370	2430	2206	2040	1660	1050	640	520	840	1590	19464	3.08
Closteridium sp.	630	510	460	350	-	-	-	-	-	-	470	550	2970	0.47
Westella sp.	-	-	-	-	-	-	-	660	730	950	620	-	2960	0.47
Scenedesmus sp.	-	-	-	-	-	-	-	780	860	1130	510	-	3280	0.52
Netrium sp.	790	445	280	170	-	-	-	-	-	980	940	-	3605	0.57
Docidium sp.	930	670	590	510	230	-	-	-	-	-	-	750	3680	0.58
Spirogyra sp.	1250	1560	2150	2470	1660	1470	1340	970	850	970	1090	1170	16950	2.68
Stigeoclonium sp.	810	1055	1210	1450	1140	1035	710	520	200	-	410	680	9220	1.46
EUGLENOPHYCEAE														
Euglena sp.	5180	5960	6190	6380	5980	4690	3930	2210	850	610	960	3930	46870	7.42
Phacus sp.	1930	2210	2330	2490	2170	1520	1180	720	450	270	480	1620	17370	2.75
Trachelomonas sp.	1010	1240	1270	1360	1210	560	190	-	-	-	440	850	8130	1.29
Astasia sp.	970	1170	1420	1470	1250	1030	678	180	-	-	220	830	9218	1.46
Rhabdomonas sp.	-	-	-	-	-	-	-	590	630	1290	754	430	3694	0.59
XANTHOPHYCEAE														
Chlorobotrys sp.	1360	1460	1390	1260	1185	1015	920	676	590	830	960	1150	12796	2.03
Botrydiopsis sp.	980	910	860	795	660	280	-	-	-	-	540	780	5805	0.92
Bumilleriopsis sp.	540	460	325	280	-	-	-	-	-	-	310	450	2365	0.37
Botryococcus sp.	1230	1310	1250	1130	1010	910	750	560	442	590	820	1090	11092	1.75
BACILLARIOPHYCEAE														
Fragilaria sp.	910	820	740	680	640	610	570	510	890	1280	1130	1040	9820	1.56
Nitzschia sp.	1750	1940	2365	2490	2030	1840	1320	1150	920	910	1170	1470	19355	3.06
Pinnularia sp.	1860	1680	1610	1565	1440	1280	990	770	530	1680	2150	1940	17495	2.77
Navicula sp.	1620	1870	2250	2320	2030	1830	1210	1140	840	1010	1340	1570	19030	3.01
TOTAL	56766	65328	72874	79234	67446	58978	45758	36726	27462	33190	37944	49986	631692	100

- = Not detected

Table VIII. **Monthly mean abundance (units/l) and percentage composition of phytoplankton in spot-3.**

PHYTOPLANKTON	1996		1997										TOTAL	%
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT		
CYANOPHYCEAE														
Oscillatoria sp.	690	1080	2130	3410	2840	995	430	-	-	-	405	540	12520	1.73
Lyngbya sp.	310	362	670	790	570	310	-	-	-	-	-	-	3012	0.42
Arthrospira sp.	-	240	510	560	480	150	-	-	-	-	-	-	1940	0.27
CHLOROPHYCEAE														
Padiastrum sp.	730	715	680	540	460	380	-	-	-	-	-	-	3505	0.48
Chlorella sp.	560	680	1340	1470	1590	1645	1376	630	-	-	430	475	10196	1.41
Netrium sp.	710	740	690	630	585	420	380	-	-	-	-	-	4155	0.57
Spinoclosterium sp.	480	610	720	690	567	430	230	-	-	-	-	-	3727	0.51
Spirogyra sp.	1020	1090	1345	1480	1660	1750	1245	840	340	770	820	930	13290	1.83
EUGLENOPHYCEAE														
Euglena sp.	-	-	590	670	710	360	-	-	-	-	-	-	2330	0.32
Phacus sp.	-	-	180	210	285	165	-	-	-	-	-	-	840	0.12
XANTHOPHYCEAE														
Chlorobotrys sp.	550	615	1080	1165	1380	1415	1115	997	210	290	340	450	9607	1.32
Botrydiopsis sp.	414	460	660	730	855	920	480	190	-	-	-	220	4929	0.68
BACILLARIOPHYCEAE														
Fragilaria sp.	9150	9470	12338	11750	11520	10780	7960	5615	1450	2830	4970	5875	93708	12.92
Synedra sp.	1420	1550	1670	1560	1335	960	525	340	-	-	480	680	10520	1.44
Cocconeis sp.	1275	1300	1430	1516	1470	1210	790	470	180	-	465	590	10696	1.47
Hantzschia sp.	790	920	1010	980	930	820	570	390	-	-	560	630	7600	1.05
Nitzschia sp.	880	970	1480	1670	1780	1840	1555	1280	695	740	790	825	14505	2.00
Surirella sp.	1230	1565	1620	1490	1210	970	690	420	330	-	580	710	10815	1.49
Rhopalodina sp.	965	1040	1130	1190	1045	729	510	380	-	-	430	570	7989	1.10
Gyrosigma sp.	1740	1550	1480	1410	1350	1190	780	430	-	-	650	820	11400	1.57
Pinnularia sp.	6480	6730	8340	7790	7125	5480	3940	2390	935	2295	3770	4244	59519	8.20
Navicula sp.	7610	8990	10635	10840	10970	8150	6650	4480	1180	2380	4120	4985	80990	11.16
Gomphonema sp.	1970	2120	3970	4120	4330	4530	4110	2920	728	1350	1532	1660	33340	4.60
Cymbella sp.	1230	1340	1430	1260	1185	960	490	290	-	-	510	730	9425	1.30
Melosira sp.	23830	25750	30190	32420	28815	22120	18860	17770	16710	24205	25925	28570	295165	40.68
Stephanodiscus sp.	1350	1375	1480	1315	1240	980	630	410	240	-	355	470	9845	1.36
TOTAL	65384	71262	88798	91656	86287	69659	53316	40242	22998	34860	47132	53974	725568	100

- = Not detected

found to be the major dominant group constituting the phytoplankton population, represented by 10 genera. It was followed by Cyanophyceae by 6 genera, Euglenophyceae by 5 genera, Xanthophyceae and Bacillariophyceae both by 4 genera. Cyanophycean *Oscillatoria* sp. was the only genus which showed highest abundance throughout the period of study and constituted 29.65% of the phytoplankton population, whereas *Coelastrum* sp., was the least recorded genus constituting 0.17% of the phytoplankton population. Another dominant genus *Lyngbya* sp. and *Euglena* sp., constituted 11.41% and 10.83% respectively of the population. Its appeared that, although Chlorophyceae showed numerical dominance with respect to its number of genera, it did not contribute to the major bulk of the population abundance. *Chlorococcum* sp. belonging to Chlorophyceae showed maximum abundance constituting 3.17% of the phytoplankton population, whereas the diatom *Nitzschia* sp. with frequent occurrence, constituted 3.78% of the population.

The recorded phytoplankton genera of this spot were represented by Cyanophyceae (*Oscillatoria* sp. 29.65%, *Arthrospira* sp. 7.90%, *Lyngbya* sp. 11.41%, *Spirulina* sp. 1.69%, *Anabaena* sp. 1.09% and *Chroococcus* sp. 0.34%), Chlorophyceae (*Chlorococcum* sp. 3.17%, *Myrmecia* sp. 1.65%, *Coelastrum* sp. 0.17%, *Chlorella* sp. 3.12%, *Closteridium* sp. 0.66%, *Westella* sp. 0.41%, *Scenedesmus* sp. 0.29%, *Netrium* sp. 0.93%, *Docidium* sp. 0.75%, and *Spirogyra* sp. 1.91%), Euglenophyceae (*Euglena* sp. 10.83%, *Phacus* sp. 3.62%, *Trachelomonas* sp. 0.86%, *Astasia* sp. 1.11% and *Rhabdomonas* sp. 0.35%), Xanthophyceae (*Chlorobotrys* sp. 2.38% and *Botryococcus* sp. 1.68%) and Bacillariophyceae (*Fragilaria* sp. 1.75%, *Nitzschia* sp. 3.78%, *Pinnularia* sp. 3.28% and *Navicula* sp. 3.40%). The abundance gradually increased to its maximum and again started to decrease to its minimum.

The Data Were Presented In Table -VI.

Spot-2

At this spot monthly phytoplankton abundance was found to very from 27462 to 79234 units/l during the study period. The maximum abundance was recorded in the month of February, 1997, while the minimum was recorded in July, 1997. The abundance showed a gradual rise and fall pattern. During the investigation period, 31 phytoplankton genera were recorded at this spot and represented by Cyanophyceae (*Oscillatoria* sp. 38.58%, *Lyngbya* sp. 6.48%, *Spirulina* sp. 2.63%, *Arthrospira* sp. 4.51%, *Phormedium* sp. 1.20% and

Table IX. Monthly abundance (units/l) of different algal classes.

(a) **Spot - 1**

CLASS	1996		1997									
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
CYANOPHYCEAE	23229	20976	20185	18065	17465	16510	17902	21388	30942	32690	28470	26230
CHLOROPHYCEAE	6485	5360	4863	3808	3448	2099	2159	4759	8490	11652	8962	6684
EUGLENOPHYCEAE	8960	7520	7210	6240	5685	4730	5280	6840	8070	8930	9560	9200
XANTHOPHYCEAE	3880	3100	2510	1709	1380	720	880	1310	2865	3750	4680	4180
BACILLARIOPHYCEAE	6280	5240	4910	4230	3770	3295	3765	4365	6455	7960	7540	6470

(b) **Spot - 2**

CLASS	1996		1997									
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
CYANOPHYCEAE	27270	33230	38819	44295	37925	35388	27550	22190	15970	17470	18770	24260
CHLOROPHYCEAE	10156	11068	12055	13719	9916	8025	6420	6030	5350	7250	7900	8556
EUGLENOPHYCEAE	9090	10580	11210	11700	10610	7800	5978	3700	1930	2170	2854	7660
XANTHOPHYCEAE	4110	4140	3825	2465	2855	2205	1670	1236	1032	1420	2630	3490
BACILLARIOPHYCEAE	6140	6310	6965	7055	6140	5560	4140	3570	3180	4880	5790	6020

(c) **Spot - 3**

CLASS	1996		1997									
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
CYANOPHYCEAE	1000	1682	3310	4760	3890	1455	430	-	-	-	405	540
CHLOROPHYCEAE	3500	3835	4775	4810	4862	4625	3231	1470	340	790	1250	1405
EUGLENOPHYCEAE	-	-	770	880	995	525	-	-	-	-	-	-
XANTHOPHYCEAE	964	1075	1740	1895	2235	2335	1595	1187	210	290	340	670
BACILLARIOPHYCEAE	59920	64670	78203	79311	74305	60719	48060	37585	22448	33780	45137	51359

- = Not detected

Table X. **The percentage of similarity and dissimilarity co-efficient of different groups of phytoplankton found in three sampling spots.**

(a) **In Spot-1 and Spot-2**

GROUP OF ORGANISMS	SIMILARITY CO-EFFICIENT (%)	DISSIMILARITY CO-EFFICIENT (%)
CYANOPHYCEAE	83.33	16.67
CHLOROPHYCEAE	90.90	9.10
EUGLENOPHYCEAE	100	-
XANTHOPHYCEAE	100	-
BACILLARIOPHYCEAE	100	-

(b) **In Spot-1 and Spot-3**

GROUP OF ORGANISMS	SIMILARITY CO-EFFICIENT (%)	DISSIMILARITY CO-EFFICIENT (%)
CYANOPHYCEAE	66.67	33.33
CHLOROPHYCEAE	40	60
EUGLENOPHYCEAE	57.14	42.86
XANTHOPHYCEAE	66.67	33.33
BACILLARIOPHYCEAE	44.44	55.56

(c) **In Spot-2 and Spot-3**

GROUP OF ORGANISMS	SIMILARITY CO-EFFICIENT (%)	DISSIMILARITY CO-EFFICIENT (%)
CYANOPHYCEAE	66.67	33.33
CHLOROPHYCEAE	35.29	64.71
EUGLENOPHYCEAE	57.14	42.86
XANTHOPHYCEAE	66.67	33.33
BACILLARIOPHYCEAE	44.44	55.56

Anabaena sp. 0.95%), Chlorophyceae (*Chlorogonium* sp. 2.68%, *Chlorococcum* sp. 3.04%, *Myrmecia* sp. 0.72%, *Coelastrum* sp. 0.40%, *Chlorella* sp. 3.08%, *Closteridium* sp. 0.47%, *Westella* sp. 0.47%, *Scenedesmus* sp. 0.52%, *Netrium* sp. 0.57%, *Docidium* sp. 0.58%, *Spirogyra* sp. 2.68% and *Stigeoclonium* sp. 1.46%), Euglenophyceae (*Euglena* sp. 7.42%, *Phacus* sp. 2.75%, *Trachilomonas* sp. 1.29%, *Astasia* sp. 1.46% and *Rhabdomonas* sp. 0.59%), Xanthophyceae (*Chlorobotrys* sp. 2.03%, *Botrydiopsis* sp. 0.92%, *Bumilleriopsis* sp. 0.37% and *Botryococcus* sp. 1.75%) and Bacillariophyceae (*Fragilaria* sp. 1.56%, *Nitzschia* sp. 3.06%, *Pinnularia* sp. 2.77% and *Navicula* sp. 3.01%). The Chlorophycean genera were numerically dominant but did not constitute the major bulk of the phytoplankton population (16.67%). The Cyanophycean members were the dominant group which constituted the 54.35% of the whole population. Cyanophycean *Oscillatoria* sp. was the only genus which showed maximum abundance throughout the period of study and constituted 38.58% of the phytoplankton population, whereas *Bumilleriopsis* sp. was the least recorded genus constituting 0.37% of the phytoplankton population. Another dominant genus *Euglena* sp., *Lyngbya* sp. constituted 7.42% and 6.58% respectively of the total population. *Chlorella* sp., *Chlorobotrys* sp. and *Nitzschia* sp. were found to be the dominant genus of Chlorophyceae, Xanthophyceae and Bacillariophyceae groups respectively.

The Data Were Presented In Table -VII.

Spot-3

At this spot the monthly phytoplankton abundance varied from 3990 to 63684 units/l, during the study period. The maximum abundance was recorded in the month of February, 1997, while the minimum was recorded in the month of July, 1997. The plankton abundance showed a gradual increase and decrease during the study period. The Bacillariophyceae (diatoms) was found to be the major dominant group represented by 14 genera and constituted 90.34% of the total phytoplankton population. The 26 recorded genera were represented by Cyanophyceae - 2.42% (*Oscillatoria* sp., *Lyngbya* sp. and *Arthrospira* sp.), Chlorophyceae - 4.8% (*Padiastrum* sp. *Chlorella* sp. *Netrium* sp. *Spinoclosterium* sp. and *Spirogyra* sp.), Euglenophyceae - 0.44% (*Euglena* sp. and *Phacus* sp.), Xanthophyceae - 2% (*Chlorobotrys* sp. and *Botrydiopsis* sp.) and Bacillariophyceae - 90.34% (*Fragilaria* sp., *Synedra* sp., *Cocconeis* sp., *Hantzschia* sp., *Nitzschia* sp., *Surirella* sp., *Rhopalodina* sp., *Gyrosigma* sp.

Table XI. Palmer index (1969) for pollution rating.

(a) Pollution tolerant genera of algae. List of the most tolerant genera, in order of decreasing emphasis by 165 authorities.

No	Genus	Group	No. authors	Total points
1.	*Euglena* sp.	F	97	172
2.	*Oscillatoria* sp.	B	93	161
3.	*Scenedesmus* sp.	G	70	112
4.	*Chlorella* sp.	G	60	103
5.	*Nitzschia* sp.	D	58	98
6.	*Navicula* sp.	D	61	92
7.	*Stigeoclonium* sp.	G	50	69
8.	*Synedra* sp.	D	44	58
9.	*Phacus* sp.	F	39	57
10.	*Phormidium* sp.	B	37	52
11.	*Melosira* sp.	D	37	51
12.	*Gomphonema* sp.	D	35	48
13.	*Spirogyra* sp.	G	26	37
14.	*Anabaena* sp.	B	27	36
15.	*Arthrospira* sp.	B	18	34
16.	*Trachelomonas* sp.	F	26	34
17.	*Chlorogonium* sp.	F	23	33
18.	*Fragilaria* sp.	D	24	33
19.	*Surrirella* sp.	D	27	33
20.	*Stephanodiscus* sp.	D	22	32
21.	*Lyngbya* sp.	B	17	28
22.	*Spirulina* sp.	B	17	25
23.	*Cymbella* sp.	D	19	24
24.	*Hantzschia* sp.	D	18	23
25.	*Pinnularia* sp.	D	15	18
26.	*Chlorococcum* sp.	G	13	17

Group : B- Blue green; D- Diatom;
F - Flagellate; G - Green.

(b) algal genus pollution index

Genus	Pollution index
Chlorella sp.	3
Closterium sp.	1
Euglena sp.	5
Gomphonema sp.	1
Melosira sp.	1
Navicula sp.	3
Nitzschia sp.	3
Oscillatoria sp.	5
Phacus sp.	2
Phormidium sp.	1
Scenedesmus sp.	4
Stigeoclonium sp.	2
Synedra sp.	2

Pinnularia sp., *Navicula* sp., *Gomphonema* sp., *Cymbella* sp. *Melosira* sp. and *Stephanodiscus* sp.) during the investigation period. During the study period *Melosira* sp. was the major dominant genus of diatoms, which alone constituted 40.68% of the total phytoplankton population. Whereas *Hantzschia* sp. was the least recorded genus constituting 1.05% of the phytoplankton population. Another dominant diatom - *Fragilaria* sp. and *Navicula* sp. constituted 12.92% and 11.16% respectively of the total phytoplankton population. *Oscillatoria* sp., *Chlorella* sp., *Euglena* sp. and *Chlorobotrys* sp. were found to be dominant genera of Cyanophyceae, Chlorophyceae, Euglenophyceae and Xanthophyceae respectively.

The Data Were Presented In Table - VIII.

ZOOPLANKTON

Spot-1

The monthly zooplankton abundance was found to vary from 29169 to 75935 units/l during the period of study. The maximum abundance was recorded in the month of September,1997 while the minimum was recorded in the month of April, 1997. The abundance showed a gradual increase and decrease during the investigations period. The total recorded zooplankton (30 genera) were represented by Protozoa group - 87.14% (*Difflugia* sp., *Arcella* sp., *Urochaenia* sp., *Didinium* sp., *Loxophyllum* sp., *Paramecium* sp., *Frontoniella* sp., *Frontonia* sp., *Uronema* sp., *Balanonema* sp., *Loxocephalus* sp., *Cohnilembus* sp., *Pleuronema* sp., *Coleps* sp., *Perispira* sp., *Epalxis* sp., *Atopodinium* sp., *Amphisiella* sp. and *Ophryoglena* sp.), Porifera group - 2.14% (*Spongilla* sp.), Rotifera - 6.93% (*Notholca* sp., *Didymodactylus* sp., *Brachionus* sp., *Cephalodella* sp., *Tetrasiphon* sp. and *Philodina* sp.), Nematoda group - 2.1% (*Rhabdolaimus* sp. and *Rhabditis* sp.) and Crustacea group - 1.43% (*Cyclops* sp. and *Naupilus* sp.). Throughout the period of study Protozoans were the major dominant group represented by 19 genera. The Protozoans *Loxocephalus* sp. was the dominant genus constituting 34.55% of the total zooplankton population, whereas *Cohnilembus* sp. was the least recorded genus constituting 0.28% of the zooplankton population (Table - XII). Another dominant protozoans genus *Paramecium* sp. constituted 24.76% of the population.

Table XII. **Monthly mean abundance (units/l) and percentage composition of zooplankton in spot-1.**

ZOOPLANKTON	1996		1997										TOTAL	%
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT		
PROTOZOA														
Difflugia sp.	1920	1740	1315	1178	995	620	734	1265	1640	2180	2244	2134	17965	2.81
Arcella sp.	-	-	-	-	-	-	570	882	1064	1174	1210	645	5545	0.87
Urochaenia sp.	675	435	350	-	-	-	-	-	-	-	496	598	2554	0.40
Didinium sp.	4524	4690	4730	4310	4112	2738	2610	2530	1515	1220	2060	3260	38299	5.99
Loxophyllum sp.	690	460	280	-	-	-	-	570	688	738	770	712	4908	0.77
Paramecium sp.	14880	14410	13730	13318	12978	9165	10280	10460	13592	14820	15422	15138	158193	24.76
Frontoniella sp.	1410	1245	1060	935	766	416	-	-	-	-	536	945	7313	1.15
Frontonia sp.	3170	2870	2355	1980	1722	1240	1065	940	565	430	1214	1656	19207	3.01
Uronema sp.	1345	1360	1480	1072	948	510	384	-	-	-	670	865	8634	1.35
Balanonema sp.	1780	1450	1335	1250	1136	760	430	354	224	-	728	930	10377	1.62
Loxocephalus sp.	18456	18644	19176	16989	13930	11082	12445	15821	17110	24163	29512	23457	220785	34.55
Cohnilembus sp.	750	525	310	-	-	-	-	-	-	-	-	194	1779	0.28
Pleuronema sp.	930	770	445	-	-	-	-	-	-	-	-	210	2355	0.37
Coleps sp.	1710	1490	1250	1172	1026	598	310	-	-	-	634	994	9184	1.44
Perispira sp.	3850	3580	3325	2994	2644	1470	1655	2075	3360	3796	3970	3915	36634	5.73
Epalxis sp.	1590	1330	1190	1035	870	360	-	-	-	-	-	200	6575	1.03
Atopodinium sp.	865	615	480	-	-	-	-	-	-	-	192	750	2902	0.45
Amphisiella sp.	640	570	365	-	-	-	-	-	-	-	264	586	2425	0.38
Ophryoglena sp.	780	660	345	-	-	-	-	-	-	-	350	660	2795	0.44
PORIFERA														
Spongilla sp.	1630	1385	1110	825	730	-	590	748	1290	1770	1864	1744	13686	2.14
ROTIFERA														
Notholca sp.	1085	960	570	388	185	-	672	1190	1730	2162	1878	1425	12245	1.92
Didymodactylus sp.	535	395	-	-	-	-	416	915	1370	1756	1450	908	7745	1.21
Brachionus sp.	-	-	-	-	-	-	540	1084	1322	1988	2146	1184	8264	1.29
Cephalodella sp.	-	-	-	-	-	-	-	598	1050	1290	1170	536	4644	0.73
Tetrasiphon sp.	-	-	-	-	-	-	-	634	1180	1465	1240	678	5197	0.81
Philodina sp.	-	-	-	-	-	-	480	775	1310	1640	1280	735	6220	0.97
NEMATODA														
Rhabdolaimus sp.	740	720	675	410	392	210	465	730	1040	1075	995	935	8387	1.31
Rhabditis sp.	610	580	520	322	270	-	-	310	532	594	646	630	5014	0.79
CRUSTACEA														
Cyclops sp.	-	-	-	-	-	-	-	-	818	1534	1484	497	4333	0.68
Naupilus sp.	-	-	-	-	-	-	-	-	966	1752	1510	560	4788	0.75
TOTAL	64565	60884	56396	48178	42704	29169	33646	41881	52366	65547	75935	67681	638952	100

- = Not detected

Table XIII. **Monthly mean abundance (units/l) and percentage composition of zooplankton in spot-2.**

ZOOPLANKTON	1996		1997										TOTAL	%
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT		
PROTOZOA														
Nebela sp.	1180	1225	995	638	570	342	182	-	-	242	680	985	7039	0.79
Difflugia sp.	1216	1254	1028	740	610	415	256	-	-	330	725	1048	7622	0.85
Arcella sp.	722	310	-	-	-	-	280	435	518	876	932	795	4868	0.54
Urochaenia sp.	974	780	558	275	186	-	-	-	-	-	474	824	4071	0.45
Coleps sp.	2830	2992	2660	2082	1915	987	940	384	-	-	912	2376	18078	2.02
Didinium sp.	6755	7388	7024	6194	5982	4870	4725	2996	1408	1380	3460	4698	56880	6.35
Loxophyllum sp.	892	960	635	420	360	-	-	-	-	-	510	654	4431	0.50
Trachelius sp.	1638	1775	1440	1066	899	765	729	561	213	209	870	1394	11559	1.29
Paramecium sp.	17558	17730	19310	17090	16640	14864	14540	9780	3945	4645	9430	13928	159460	17.80
Frontoniella sp.	1640	1810	1783	1538	1260	895	834	438	-	364	684	1156	12402	1.38
Frontonia sp.	4825	5112	4660	4510	3985	3448	2995	1755	848	920	2362	2948	38368	4.28
Glaucoma sp.	950	620	425	-	-	-	-	-	-	-	672	760	3427	0.38
Tetrahymena sp.	1340	1250	1080	965	744	520	390	-	-	434	644	1155	8522	0.95
Uronema sp.	17892	18114	18253	17864	16152	15980	15156	10270	4960	5195	10910	14775	165521	18.47
Loxocephalus sp.	20164	24598	25990	29907	28878	27275	26545	21286	16007	20620	24641	31469	297380	33.19
Homalogastra sp.	1223	1360	1478	1220	1146	938	798	343	-	398	598	952	10454	1.17
Ophryoglena sp.	985	792	535	370	-	-	-	-	-	-	535	660	3877	0.43
Pleuronema sp.	1076	936	574	396	-	-	-	-	-	-	482	868	4332	0.48
Epalxis sp.	1866	1840	1662	1410	1170	910	744	315	-	185	892	1412	12406	1.38
Amphisiella sp.	854	790	510	245	-	-	-	-	-	328	510	748	3985	0.45
PORIFERA														
Spongilla sp.	1770	1635	1260	1040	924	665	610	406	227	305	940	1254	11036	1.23
ROTIFERA														
Notholca sp.	1310	1279	858	466	290	224	285	665	1270	2160	1814	1465	12086	1.35
Didymodactylus sp.	642	620	440	240	178	-	-	290	624	1225	1123	710	6092	0.68
Brachionus sp.	790	410	-	-	-	-	440	575	764	1784	1444	924	7131	0.80
Cephalodella sp.	530	484	210	-	-	-	238	380	492	1008	835	582	4759	0.53
Tetrasiphon sp.	372	256	-	-	-	-	-	272	428	910	716	428	3382	0.38
Philodina sp.	480	315	-	-	-	-	-	346	518	1070	818	573	4120	0.46
Enteroplea sp.	-	-	-	-	-	-	-	394	475	835	314	-	2018	0.23
NEMATODA														
Rhabdolaimus sp.	835	810	740	470	386	310	275	-	-	322	520	790	5458	0.61
Rhabditis sp.	450	380	230	-	-	-	-	-	-	-	184	310	1554	0.17
CRUSTACEA														
Cyclops sp.	-	-	-	-	-	-	-	345	530	965	190	-	2030	0.23
Naupilus sp.	-	-	-	-	-	-	-	288	410	748	162	-	1608	0.18
TOTAL	93759	97825	94338	89146	82275	73408	70962	52524	33637	47458	69983	90641	895956	100

- = Not detected

Table XIV. **Monthly mean abundance (units/l) and percentage composition of zooplankton in spot-3.**

ZOOPLANKTON	1996		1997										TOTAL	%
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT		
PROTOZOA														
Arcella sp.	722	1238	1480	916	434	180	-	-	-	-	256	519	5745	1.48
Paramecium sp.	2630	4510	4830	3164	2350	908	354	-	-	-	585	1564	20895	5.37
Frontonia sp.	1256	1370	1865	1278	706	340	-	-	-	-	-	382	7197	1.85
Uronema sp.	1110	1440	1735	1210	682	310	-	-	-	-	-	350	6837	1.76
Loxocephalus sp.	3970	4176	4560	3380	1210	535	298	-	-	-	344	1392	19865	5.10
Homalogastra sp.	985	1250	1514	1140	508	295	-	-	-	-	-	-	5692	1.46
ROTIFERA														
Nothalca sp.	3864	6784	7840	7618	7245	6514	4545	1608	1236	682	2360	3070	53366	13.71
Keratella sp.	3560	5446	6228	5972	5316	5088	3976	1549	1013	538	2195	2842	43723	11.23
Brachionus sp.	5620	6512	7810	7990	7264	6384	4492	1685	1154	595	3468	3721	56695	14.57
Lecane sp.	3152	4608	4987	4737	3665	1846	650	266	-	-	1724	1946	27581	7.09
Hexarthra sp.	986	1266	1620	1345	1150	762	410	-	-	-	374	532	8445	2.17
Enteroplea sp.	1374	2195	2756	1664	1418	838	384	-	-	-	765	890	12284	3.16
CLADOCERA														
Daphnia sp.	990	1487	1660	1216	1174	475	228	-	-	-	410	662	8302	2.13
Moina sp.	780	1025	1240	932	788	318	-	-	-	-	320	398	5801	1.49
Bosmina sp.	955	1140	1172	910	736	304	-	-	-	-	327	480	6024	1.55
Aloma sp.	934	1112	1250	960	697	284	-	-	-	-	455	575	6267	1.61
Dadaya sp.	1115	1430	1515	836	620	372	-	-	-	-	392	622	6902	1.77
COPEPODA														
Cyclops sp.	1785	3224	3360	3484	4166	3486	3267	1793	1310	646	1260	1410	29191	7.50
Mesocyclops sp.	944	1642	1678	1585	1310	1290	1135	975	872	327	625	795	13178	3.39
Diaptomus sp.	1630	2345	2454	2628	3709	2955	2718	1085	885	584	1018	1378	23389	6.01
Naupilus sp.	1400	1998	2130	2392	3316	2744	2652	1374	1197	618	978	1006	21805	5.60
TOTAL	39762	56198	63684	55357	48464	36228	25109	10335	7667	3990	17856	24534	389184	100

- = Not detected

Notholca sp. (1.92%), *Rhabdolaimus* sp. (1.31%), *Naupilus* sp. (0.75%) were the dominant genera of Rotifera, Nematoda and Crustacea groups.

The Data Were Presented In Table - XII.

Spot-2

During the study period, monthly zooplankton abundance varied from 33637 to 97825 units/l. The maximum abundance was recorded in the month of December, 1996, while the minimum was recorded in the month of July, 1997. The abundance showed a gradual increase and decrease pattern. During the investigation a total 32 genera were recorded, represented by Protozoa - 93.15% (*Nebela* sp. *Difflugia* sp., *Arcella* sp., *Urochaenia* sp., *Coleps* sp., *Didinium* sp., *Loxophyllum* sp., *Trachelius* sp., *Paramecium* sp., *Frontoniella* sp., *Frontonia* sp., *Glaucoma* sp., *Tetrahymena* sp. *Uronema* sp., *Loxocephalus* sp., *Homologastra* sp., *Ophryoglena* sp., *Pleuronema* sp., *Epalxis* sp. and *Amphisiella* sp.), Porifera - 1.23% (*Spongilla* sp.), Rotifera - 4.43% (*Notholca* sp., *Didymodactylus* sp., *Brachionus* sp., *Cephalodela* sp., *Tetrasiphon* sp., *Philodina* sp. and *Enteroplea* sp.), Nematoda - 0.78% (*Rhabdolaimus* sp. and *Rhabditis* sp.) and Crustacea - 0.41% (*Cyclops* sp. and *Naupilus* sp.). Throughout the period of study, Protozoans were the major dominant group represented by 20 genera. The Protozoan *Loxocephalus* sp. was the major dominant genus, which alone constituting 33.19% of the total zooplankton population whereas *Rhabditis* sp. of the Nematoda group constituting only 0.17% of the total population. The other dominant genera *Uronema* sp. and *Paramecium* sp. were found to constitute 18.47% and 17.80% respectively of total zooplankton abundance. *Notholca* sp. (1.35%), *Rhabdolaimus* sp. (0.61%) and *Cyclops* sp. were the dominant genera of Rotifera, Nematoda and Crustacea groups respectively.

The Data Were Presented In Table - XIII.

Spot-3

At this spot, the monthly zooplankton abundance was found to very from 3990 to 63684 units/l during the study period. The maximum abundance was recorded in the month of January, 1997, while the minimum was recorded in the month of August, 1997. The zooplankton abundance showed a gradual decrease and increase pattern during the investigation period. Throughout the period of study a total of 21 genera were recorded in this

Table XV. Monthly abundance (units/l) of different zooplankton classes.

(a) **Spot - 1**

CLASS	1996		1997									
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
PROTOZOA	59965	56844	53521	46233	41127	28959	31073	34897	39758	48521	60272	57849
PORIFERA	1630	1385	1110	825	730	-	590	748	1290	1770	1864	1744
ROTIFERA	1620	1355	570	388	185	-	2108	5196	7962	10301	9164	5466
NEMATODA	1350	1300	1195	732	662	210	465	1040	1572	1669	1641	1565
CRUSTACEA	-	-	-	-	-	-	-	-	1784	3286	2994	1057

(b) **Spot - 2**

CLASS	1996		1997									
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
PROTOZOA	86580	91636	90600	86930	80497	72209	69114	48563	27899	36126	63405	83605
PORIFERA	1770	1635	1260	1040	924	665	610	406	227	305	940	1254
ROTIFERA	4124	3364	1508	706	468	224	963	2922	4571	8992	4682	4682
NEMATODA	1285	1190	970	470	386	310	275	-	-	322	604	1100
CRUSTACEA	-	-	-	-	-	-	-	633	940	1713	352	-

(c) **Spot - 3**

CLASS	1996		1997									
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
PROTOZOA	10673	13984	15984	11088	5890	2568	652	-	-	-	1185	4207
ROTIFERA	18556	26811	31241	29326	26058	21432	14457	5108	3403	1815	17564	13001
CLADOCERA	4774	6194	6837	4854	4015	1753	228	-	-	-	1904	2737
COPEPODA	5759	9209	9622	10089	12501	10475	9772	5227	4264	2175	3881	4589

- = Not detected

spot, represented by 6 genera of Protozoa - 17.02% (*Arcella* sp., *Paramecium* sp., *Frontonia* sp., *Uronema* sp., *Loxocephalus* sp. and *Homalogastra* sp.), 6 genera of Rotifera - 51.93% (*Notholca* sp., *Keratella* sp., *Brachionus* sp., *Lecane* sp., *Hexarthra* sp.and *Enteroplea* sp.), 5 genera of Cladocera - 8.55% (*Daphnia* sp. *Moina* sp., *Bosmina* sp., *Aloma* sp. and *Dadaya* sp.) and 4 genera of Copepoda - 22.5% (*Cyclops* sp., *Mesocyclops* sp., *Diaptomus* sp. and *Naupilus* sp.). Rotifera was found to be the major dominant group at this spot. *Brachionus* sp. was the dominant genus constituting 14.57% of the total population whereas Protozoan *Homologastra* sp. was the least recorded genus with 1.46% of the total population. Rotifer's *Notholca* sp. and *Keratella* sp. were the dominant genera constituting 13.71% and 11.23% of the total population respectively. Copepodian *Cyclops* sp. (7.50%), *Mesocyclops* sp. (3.39%), *Diaptomus* sp. (6.01%) and *Naupilus* sp. (5.60%) were observed throughout the study period. *Daphnia* sp. was the dominant genus of the Cladocera group constituting 2.13% of the total population.

The Data Were Presented In Table - XIV.

MACRO VEGETATION

Spot-1

A few hydrophytes were found from this spot. *Marsilea* sp., *Jussiaea* sp., *Cyperus* sp. and *Eichhornia* sp. were the dominant genera observed throughout the period of study. Maximum number of 10 genera, were observed in the months of August and September`97 while only 6 genera were recorded from December`96 to May`97. *Ipomoea reptans* and *Colocasia* sp. were recorded twice. While *Eichhornia* sp. showed dense growth in July, August and September`97. *Marsilea* sp. and *Jussiaea* sp. have shown moderate growth in the month of August`97. During the period of study *Eichhornia* sp., *Spirodela* sp., *Lemna* sp., *Enhydra fluctuans*, *Marsilea* sp., *Jussiaea* sp., *Ipomoea reptans*, *Colocasia* sp., *Cyperus esculentus*, *Imperata cylendrica* and *Cyperus difformis* were recorded from this study location.

TABLE : XVI : AQUATIC VEGETATION AT SPOT - 1

VEGETATION	1996		1997									
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
Eichhornia sp.	+	+	+	+	+	+	++	++	+++	+++	+++	++
Spirodela sp.	+	—	—	—	—	—	—	+	+	+	+	+
Lemna sp.	+	—	—	—	—	—	—	+	+	+	+	+
Enhydra fluctuans	—	—	—	—	—	—	—	+	+	+	+	+
Marsilea sp.	+	+	+	+	+	+	+	+	+	++	+	+
Jussiaea sp.	+	+	+	+	+	+	+	+	+	++	+	+
Ipomoea reptans	—	—	—	—	—	—	—	—	+	+	—	—
Colocasia sp.	—	—	—	—	—	—	—	—	—	+	+	—
Grass												
Cyperus esculentus	+	+	+	+	+	+	+	+	+	+	+	+
Imperata cylendrica	+	+	+	+	+	+	+	—	—	—	+	+
Cypcrus difformis	+	+	+	+	+	+	+	+	+	+	+	+

TABLE : XVII : AQUATIC VEGETATION AT SPOT - 2

VEGETATION	1996		1997									
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
Eichhornia sp.	+	+	+	+	+	+	+	++	++	++	+++	++
Spirodela sp.	+	+	—	—	—	—	—	+	+	+	+	+
Lemna sp.	+	+	+	—	—	—	—	+	+	+	+	+
Enhydra fluctuans	—	—	—	—	—	—	—	+	+	+	+	—
Marsilea sp.	+	—	—	—	—	—	—	+	+	+	++	+
Jussiaea sp.	+	—	—	—	—	—	—	—	+	+	+	+
Ipomoea reptans	—	—	—	—	—	—	—	—	+	+	+	—
Colocasia sp.	—	—	—	—	—	—	—	—	+	+	+	—
Polygonum hydropiper	—	—	—	—	—	—	+	+	—	—	—	—
Grass												
Cyperus esculentus	+	+	+	+	+	+	+	—	—	—	+	+

+++ = Dense growth
++ = Medium growth
\+ = Little growth
— = Absent.

Spot-2

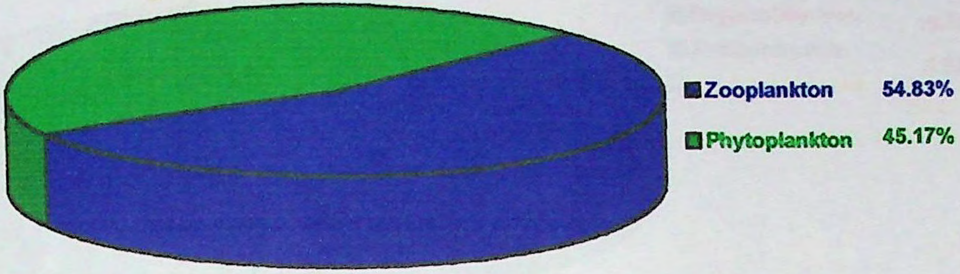
Only *Eichhornia* sp. was the major dominant genus at this spot and was observed throughout the period of study. In all 9 genera were recorded in the month of September`97 and only 2 genera were recorded from February`97 to April`97. *Marsilea* sp. appeared to be well adapted in this environment. *Ipomoea reptans*, *Colocasia* sp., *Polygonum hydropiper* were also found with sporadic appearance. *Cyperus esculentus* the only grass, was found during the period of study.

Spot-3

At this spot, no rooted emergent or free floating hydrophytes were recorded during the period of study. But occasionally *Vallisnaria* sp. and *Hydrila* sp. were found and collected from the running water. The hydrophytes were kept in the laboratory in preserved condition.

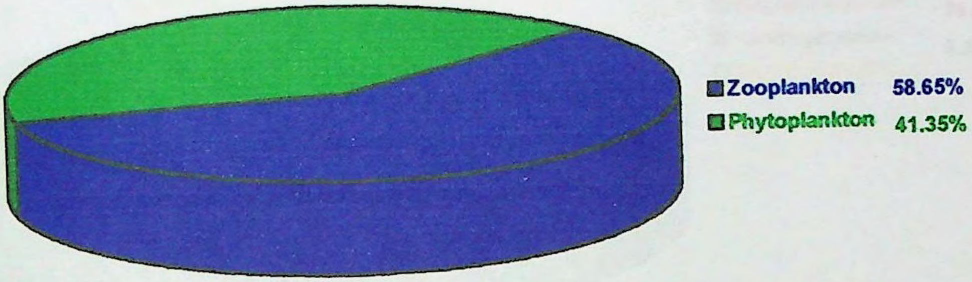
The data were presented in Table-XVI & XVII.

TOTAL ABUNDANCE OF PHYTOPLANKTON AND ZOOPLANKTON OF THREE SPOTS



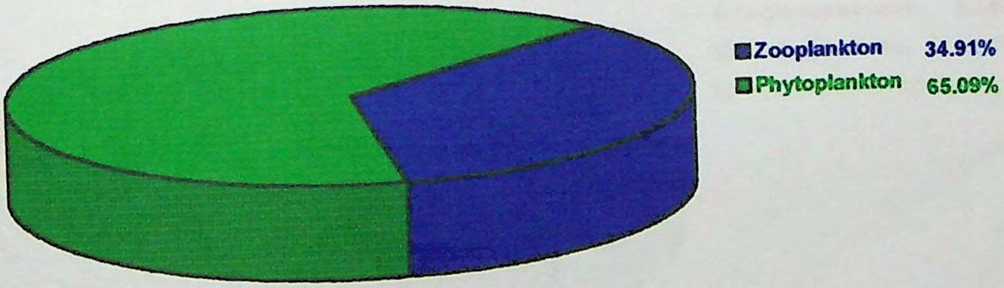
SPOT ONE

Figure : 1(a)



SPOT TWO

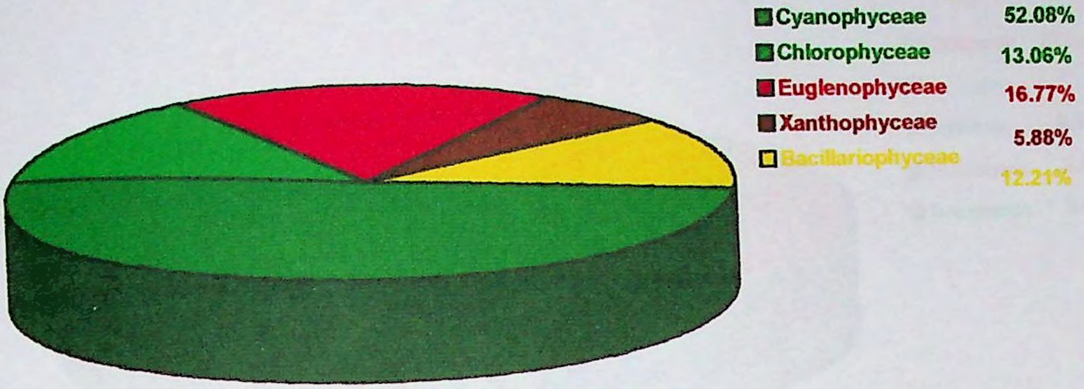
Figure: 1(b)



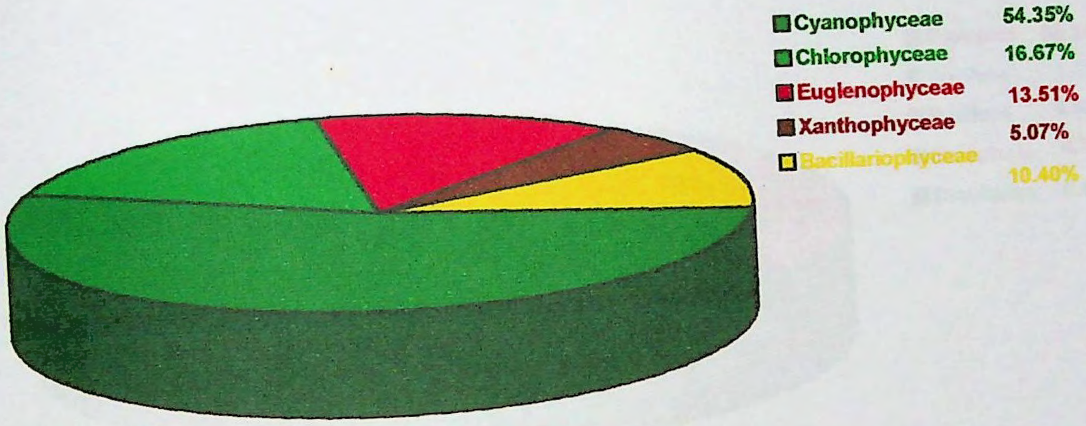
SPOT THREE

Figure: 1(c)

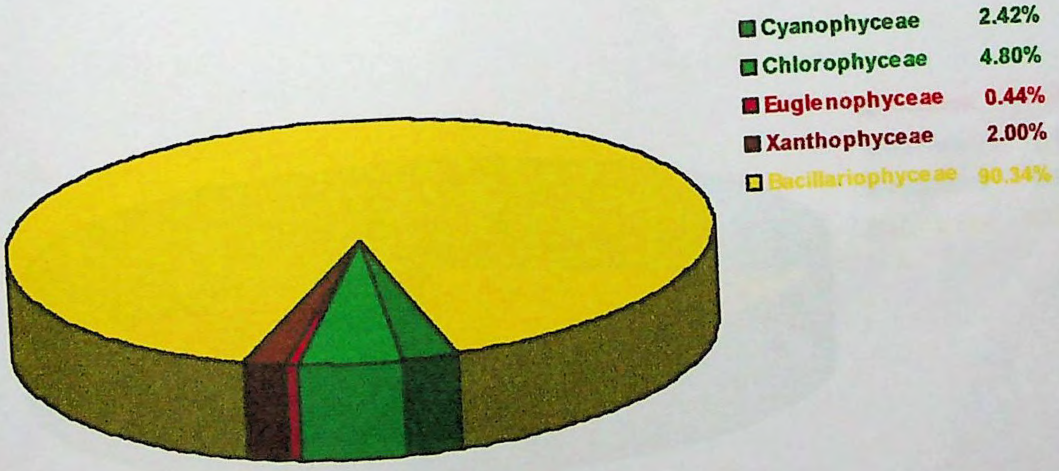
PERCENTAGE DISTRIBUTION OF DIFFERENT ALGAL CLASSES IN THE TOTAL POPULATION OF THE COMMUNITY AT THREE SPOTS



SPOT ONE

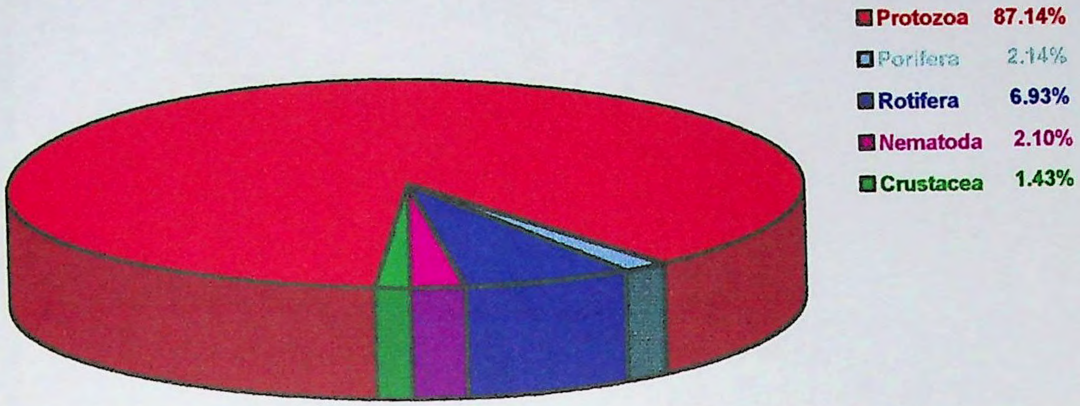


SPOT TWO

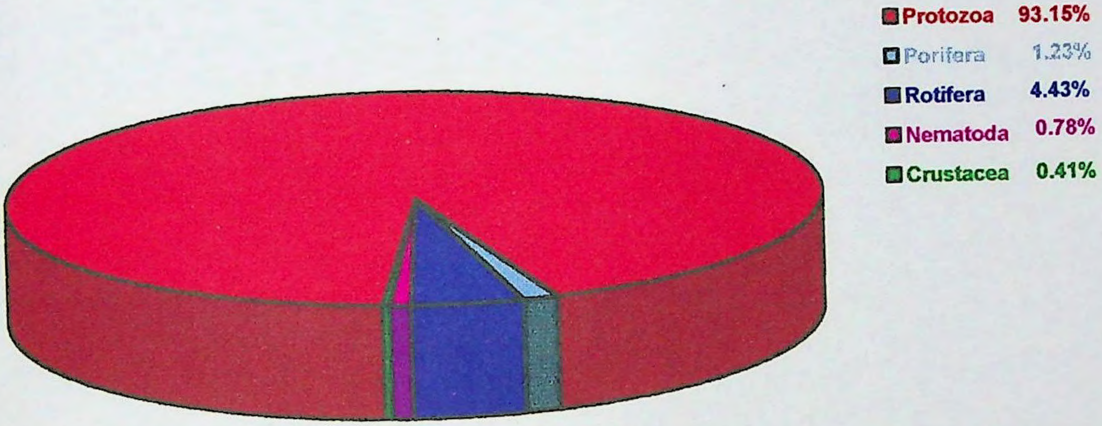


SPOT THREE

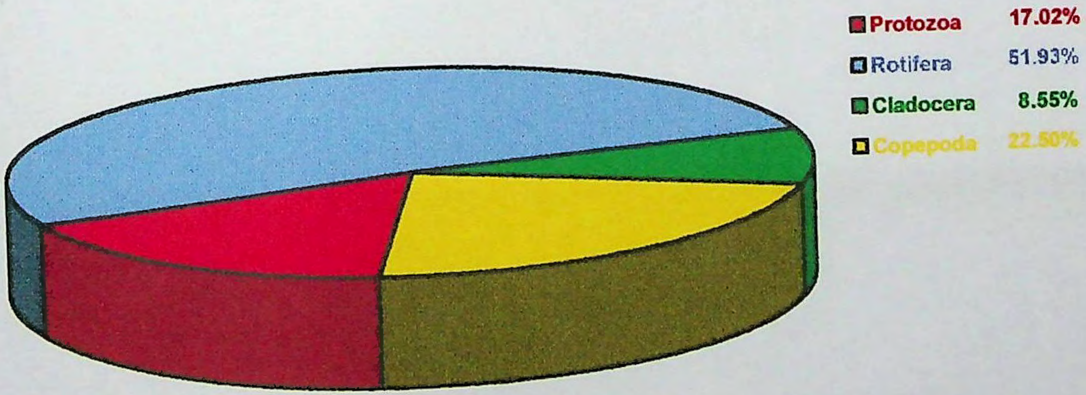
PERCENTAGE DISTRIBUTION OF DIFFERENT ZOOPLANKTON CLASSES IN THE TOTAL POPULATION OF THE COMMUNITY AT THREE SPOTS



SPOT ONE



SPOT TWO



SPOT THREE

TABLE : XVIII: CORRELATION CO-EFFICIENT (r) BETWEEN DIFFERENT PHYSICO-CHEMICAL FACTORS, PHYTO-AND ZOOPLANKTON ABUNDANCE IN SPOT-1

	WT	Tr	TSS	TDS	pH	DO	Eh	rH$_2$	BOD	COD	EC	Cl	CO$_2$	CO$_3$	HCO$_3$	TH	CaH	MgH	NH$_4$	NH$_3$	NH$_4$N	PO$_4$	Sil	TS	Oil	PP	ZP
AT	-0.091	0.151	0.49	0.155	0.33	0.157	0.567	0.376	-0.36	-0.504	0.096	0.31	-0.439	0	0.498	-0.525	*-0.707	0.308	-0.257	-0.256	-0.253	-0.092	0	*-0.652	*-0.773	0.151	-0.252
WT		-0.162	-0.479	-0.115	-0.252	-0.169	*-0.622	-0.446	0.063	*0.799	0.271	-0.097	0.434	0	-0.329	0.302	0.442	-0.24	-0.039	-0.039	-0.044	-0.17	0	*0.746	0.237	0.098	0.381
Tr			*-0.672	*-0.721	0.221	0.48	0527	0.457	*-0.847	-0.392	*-0.821	*-0.653	-0.526	0	-0.444	-0.558	*-0.674	0.198	-0.52	-0.52	-0.526	*-0.724	0	-0.183	*-0.576	*0.818	*0.687
TSS				*0.785	-0.059	-0.36	-0.052	-0.187	0.568	-0.121	*-0.624	*0.69	0.14	0	*0.727	0.206	0.076	0.213	0.384	0.385	0.392	*0.695	0	-0.322	0.036	*-0.698	*-0.857
TDS					-0.032	-0.448	-0.423	*-0.637	*0.782	0.382	*0.647	0.499	0.178	0	0.347	0.523	0.416	0.162	0.225	0.225	0.232	*0.794	0	0.107	0.307	*-0.824	*-0.751
pH						*0.634	0.547	0.28	-0.233	-0.354	-0.489	-0.332	*-0.781	0	-0.331	-0.547	-0.397	-0.234	*-0.669	*-0.669	*-0.671	-0.216	0	*-0.6	-0.151	0.338	-0.082
DO							*0.733	*0.594	-0.506	-0.441	-0.568	-0.328	-0.546	0	-0.459	-0.467	-0.391	-0.114	*-0.59	*-0.59	*-0.59	-0.488	0	-0.382	-0.334	0.534	0.268
Eh								*0.89	*-0.632	*-0.877	-0.488	-0.099	*-0.612	0	-0.056	*-0.656	*-0.641	-0.012	-0.522	-0.522	-0.517	-0.387	0	*-0.741	*-0.61	0.491	0.142
rH$_2$									*-0.615	*-0.829	-0.379	-0.047	-0.34	0	-0.029	*-0.596	-0.522	-0.012	-0.345	-0.345	-0.341	-0.514	0	*-0.581	-0.521	*0.581	0.341
BOD										0.474	*0.608	0.415	*0.594	0	0.194	*0.657	*0.715	0-.095	0.454	0.454	0.459	*0.766	0	0.311	*0.745	*-0.846	*-0.611
COD											0.449	0.039	0.443	0	-0.249	*0.658	*0.591	0.097	0.16	0.16	0.158	0.169	0	*0.856	0.437	-0.276	0.084
EC												*0.828	*0.612	0	0.549	0.554	0.529	0.028	0.447	0.447	0.455	0.569	0	0.332	0.191	*-0.642	-0.454
Cl													0.285	0	*0.655	0.333	0.302	0.046	0.481	0.481	0.491	0.509	0	-0.071	0.098	*-0.592	-0.53
CO$_2$														0	0.315	0.487	*0.601	-0.189	0.519	0.519	0.519	0.405	0	*0.596	0.341	-0.398	-0.118
CO$_3$															0	0	0	0	0	0	0	0	0	0	0	0	0
HCO$_3$																-0.125	-0.099	-0.044	*0.612	*0.612	*0.613	0.481	0	-0.386	-0.122	-0.481	*-0.67
TH																	*0.815	0.278	0.382	0.382	0.39	0.508	0	*0.743	0.542	-0.567	-0.145
CaH																		-0.332	0.359	0.359	0.363	*0.618	0	*0.628	*0.779	*-0.672	-0.232
MgH																			0.032	0.032	0.37	-0.206	0	0.174	-0.396	0.192	0.152
NH$_4$																				1	1	0.436	0	0.12	0.488	-0.553	-0.438
NH$_3$																					1	0.436	0	0.12	0.488	-0.553	-0.438
NH$_4$N																						0.44	0	0.121	0.468	-0.558	0.441
PO$_4$																							0	0.049	0.369	*-0.965	*-0.84
Sil																								0	0	0	0
TS																									0.326	-0.088	-0.367
Oil																										*-0.621	-0.308
PP																											*0.838
ZP																											1

☆ = Significant at 5% level

TABLE : XIX: CORRELATION CO-EFFICIENT (r) BETWEEN DIFFERENT PHYSICO-CHEMICAL FACTORS, PHYTO-AND ZOOPLANKTON ABUNDANCE IN SPOT-2

	WT	Tr	TSS	TDS	pH	DO	Eh	rH2	BOD	COD	EC	Cl	CO_2	CO_3	HCO_3	TH	CaH	MgH	NH_4	NH_3	NH_4.N	PO_4	Sil	TS	Oil	PP	ZP
AT	*0.969	0.544	-0.054	*-0.745	0.175	0.429	0.52	0.454	*-0.588	-0.152	-0.047	-0.056	-0.553	0.219	*-0.681	*-0.765	*-0.817	-0.485	*-0.721	*-0.721	*-0.789	*-0.707	0	*-0.867	-0.273	*-0.801	*-0.675
WT		*0.67	-0.245	*-0.861	0.049	0.556	*0.615	*0.581	*-0.689	-0.267	-0.25	-0.197	-0.48	0.061	*-0.659	*-0.817	*-0.864	-0.499	*-0.744	*-0.744	*-0.794	*-0.631	0	*-0.919	-0.425	*-0.876	*-0.75
Tr			*-0.589	*-0.879	-0.035	*0.889	*0.719	*0.727	*-0.816	*-0.642	*-0.673	*-0.592	-0.229	-0.142	*-0.703	*-0.743	*-0.833	-0.383	*-0.668	*-0.668	*-0.642	-0.185	0	*-0.751	*-0.676	*-0.823	*-0.806
TSS				*0.586	*0.749	-0.514	-0.388	-0.493	*0.724	*0.77	*0.784	*0.591	-0.511	*0.732	-0.025	0.211	0.283	0.034	0.17	0.17	0.119	-0.046	0	0.208	*0.927	0.531	0.281
TDS					0.10	*-0.751	*-0.687	*-0.743	*0.857	0.506	*0.582	0.458	0.325	0.253	*0.622	*0.853	*0.859	*0.581	*0.641	*0.641	*0.641	0.347	0	*0.856	*0.679	*0.899	*0.818
pH						-0.011	0.023	-0.113	0.291	0.536	0.527	0.411	*-0.767	0.556	-0.455	-0.268	-0.176	-0.327	-0.139	-0.139	-0.15	-0.072	0	-0.136	*0.714	0.20	-0.131
DO							*0.844	*0.885	*-0.743	*-0.693	*-0.681	*-0.578	-0.292	-0.191	*-0.616	*-0.761	*-0.824	-0.434	*-0.76	*-0.76	*-0.714	-0.349	0	*-0.717	-0.55	*-0.796	*-0.827
Eh								*0.914	*-0.725	-0.553	-0.441	-0.429	-0.312	-0.091	*-0.626	*-0.663	*-0.755	-0.325	*-0.911	*-0.911	*-0.856	-0.456	0	*-0.789	-0.414	*-0.733	*-0.616
rH_2									*-0.722	*-0.583	*-0.592	-0.493	-0.283	-0.244	-0.494	*-0.701	*-0.749	-0.415	*-0.782	*-0.782	*-0.737	-0.369	0	*-0.769	-0.483	*-0.78	*-0.76
BOD										*0.785	0.503	0.378	*0.62	0.432	*0.594	*0.648	*0.695	0.377	*0.769	*0.769	*0.655	0.432	0	*0.678	*0.762	*0.862	*0.596
COD											*0.67	*0.604	-0.224	0.416	0.342	0.338	0.405	0.134	0.493	0.493	0.443	0.287	0	0.341	*0.797	*0.652	0.376
EC												*0.899	-0.208	0.374	0.084	0.409	0.447	0.224	0.235	0.235	0.183	-0.081	0	0.366	*0.813	0.55	0.526
Cl													-0.155	0.024	0.166	0.346	0.433	0.113	0.278	0.278	0.228	-0.062	0	0.368	*0.732	0.483	0.422
CO_2														-0.445	*0.695	*0.692	0.51	*0.751	0.461	0.461	0.488	0.417	0	*0.598	-0.38	0.284	0.52
CO_3															-0.329	0.008	-0.092	0.141	-0.171	-0.171	-0.225	-0.082	0	-0.163	0.476	0.119	-0.19
HCO_3																*0.72	*0.712	0.514	*0.775	*0.775	*0.776	0.417	0	*0.78	0.141	*0.631	*0.615
TH																	*0.917	*0.815	*0.688	*0.688	*0.696	0.566	0	*0.867	0.36	*0.817	*0.879
CaH																		0.517	*0.804	*0.804	*0.818	0.571	0	*0.899	0.462	*0.899	*0.91
MgH																			0.311	0.311	0.307	0.386	0	0.557	0.096	0.446	0.565
NH_4																				1	1	*0.661	0	0.292	0.292	*0.791	*0.649
NH_3																					1	*0.661	0	0.292	0.292	*0.791	*0.649
NH_4.N																						*0.704	0	*0.88	0.267	*0.809	*0.673
PO_4																							0	0.544	0.129	*0.611	0.394
Sil																								0	0	0	0
TS																									0.377	*0.878	*0.826
Oil																										*0.689	0.403
PP																											*0.841
ZP																											1

☆ = Significant at 5% level

TABLE : XX: CORRELATION CO-EFFICIENT (r) BETWEEN DIFFERENT PHYSICO-CHEMICAL FACTORS, PHYTO-AND ZOOPLANKTON ABUNDANCE IN SPOT-3

	WT	Tr	TSS	TDS	pH	DO	Eh	rH2	BOD	COD	EC	Cl	CO_2	CO_3	HCO_3	TH	CaH	MgH	NH_4	NH_3	NH_4.N	PO_4	Sil	TS	Oil	PP	ZP
AT	*0.904	0.545	0.033	*-0.787	0.459	*0.735	0.551	0.485	-0.561	*-0.89	-0.195	-0.144	-0.154	*0.689	-0.184	-0.165	-0.161	-0.047	0	0	0	0.384	0.503	*-0.638	-0.542	-0.476	-0.565
WT		0.342	0.051	*-0.937	0.207	*0.603	*0.747	*0.747	*-0.641	*-0.79	-0.442	-0.098	-0.008	*0.635	-0.344	-0.185	-0.13	-0.102	0	0	0	-0.378	*0.722	*-0.856	*-0.777	*-0.751	*-0.821
Tr			-0.243	-0.343	0.559	0.314	0.137	-0.011	-0.221	*-0.744	0.205	-0.187	-0.327	*0.695	0.499	-0.003	-0.548	0.505	0	0	0	-0.327	-0.128	-0.03	0.062	0.012	-0.011
TSS				0.123	0.056	-0.245	0.223	0.196	-0.026	-0.009	-0.254	-0.283	-0.166	-0.055	-0.182	-0.099	0.104	-0.229	0	0	0	-0.248	0.109	-0.137	-0.01	-0.062	-0.169
TDS					-0.178	-0.529	*-0.807	*-0.79	*0.766	*0.748	0.48	0.13	-0.012	*-0.601	0.379	0.251	0.287	0.037	0	0	0	0.325	*-0.766	*0.872	*0.849	*0.829	*0.877
pH						0.412	0.102	-0.124	-0.165	-0.509	0.13	-0.11	*-0.801	*0.599	-0.029	-0.27	-0.474	0.114	0	0	0	-0.171	-0.141	0.002	0.011	0.187	0.076
DO							0.235	0.173	-0.187	-0.461	0.135	0.202	-0.134	0.398	-0.171	-0.161	-0.232	0.023	0	0	0	-0.06	0.222	-0.285	-0.259	-0.187	-0.185
Eh								*0.963	*-0.602	-0.48	*-0.75	-0.447	-0.174	*0.622	-0.253	-0.552	-0.409	-0.288	0	0	0	-0.377	*0.882	*-0.784	*-0.80	*-0.921	*-0.911
rH_2									-0.557	-0.375	*-0.755	-0.354	0.004	0.501	-0.269	-0.468	-0.248	-0.335	0	0	0	-0.30	*-0.923	*-0.825	*-0.843	*-0.973	*-0.941
BOD										*-0.685	0.289	0.145	-0.024	-0.30	0.469	0.145	0.162	0.028	0	0	0	0.111	*-0.575	*0.786	*0.786	*0.642	*0.728
COD											0.159	0.203	0.174	*-0.697	0.095	0.03	0.236	-0.182	0	0	0	0.442	-0.35	*0.59	0.469	0.389	0.516
EC												0.518	-0.055	-0.295	0.426	0.393	-0.052	0.519	0	0	0	0.514	*-0.799	0.549	*0.58	*0.704	*0.76
Cl													0.003	-0.26	-0.108	0.35	0.203	0.233	0	0	0	*0.73	-0.468	0.033	0.004	0.238	0.327
CO_2														*-0.618	-0.167	0.413	0.546	-0.009	0	0	0	-0.134	0.165	-0.026	0.028	-0.092	-0.121
CO_3															0.209	-0.339	-0.532	0.089	0	0	0	-0.343	0.36	-0.451	-0.408	-0.432	-0.42
HCO_3																-0.046	-0.39	0.311	0	0	0	0.116	-0.445	0.54	0.533	0.297	0.477
TH																	0.573	*0.664	0	0	0	-0.104	-0.432	0.09	0.348	0.463	0.349
CaH																		-0.232	0	0	0	-0.012	-0.041	-0.007	-0.086	0.23	0.121
MgH																			0	0	0	-0.109	-0.479	0.118	0.337	0.343	0.311
NH_4																				0	0	0	0	0	0	0	0
NH_3																					0	0	0	0	0	0	0
NH_4.N																						0	0	0	0	0	0
PO_4																							-0.405	0.207	0.003	0.172	0.375
Sil																								*-0.784	*-0.815	*-0.905	*-0.931
TS																									*0.935	*0.843	*0.901
Oil																										*0.901	*0.901
PP																											*0.948
ZP																											1

☆ = Significant at 5% level

PLATE - 1

Algae as high pollution indicators :

A,B - *Euglena* sp.

C - *Phacus* sp.

D - *Trachilomonas* sp.

E - *Chlorogonium* sp.

F - *Chlorococcum* sp.

G - *Chlorella* sp.

H - *Stigeoclonium* sp.

I - *Gomphonema* sp.

J - *Nitzschia* sp.

K - *Oscillatoria* sp.

L - *Lyngbya* sp.

M - *Arthrospira* sp.

N - *Spirulina* sp.

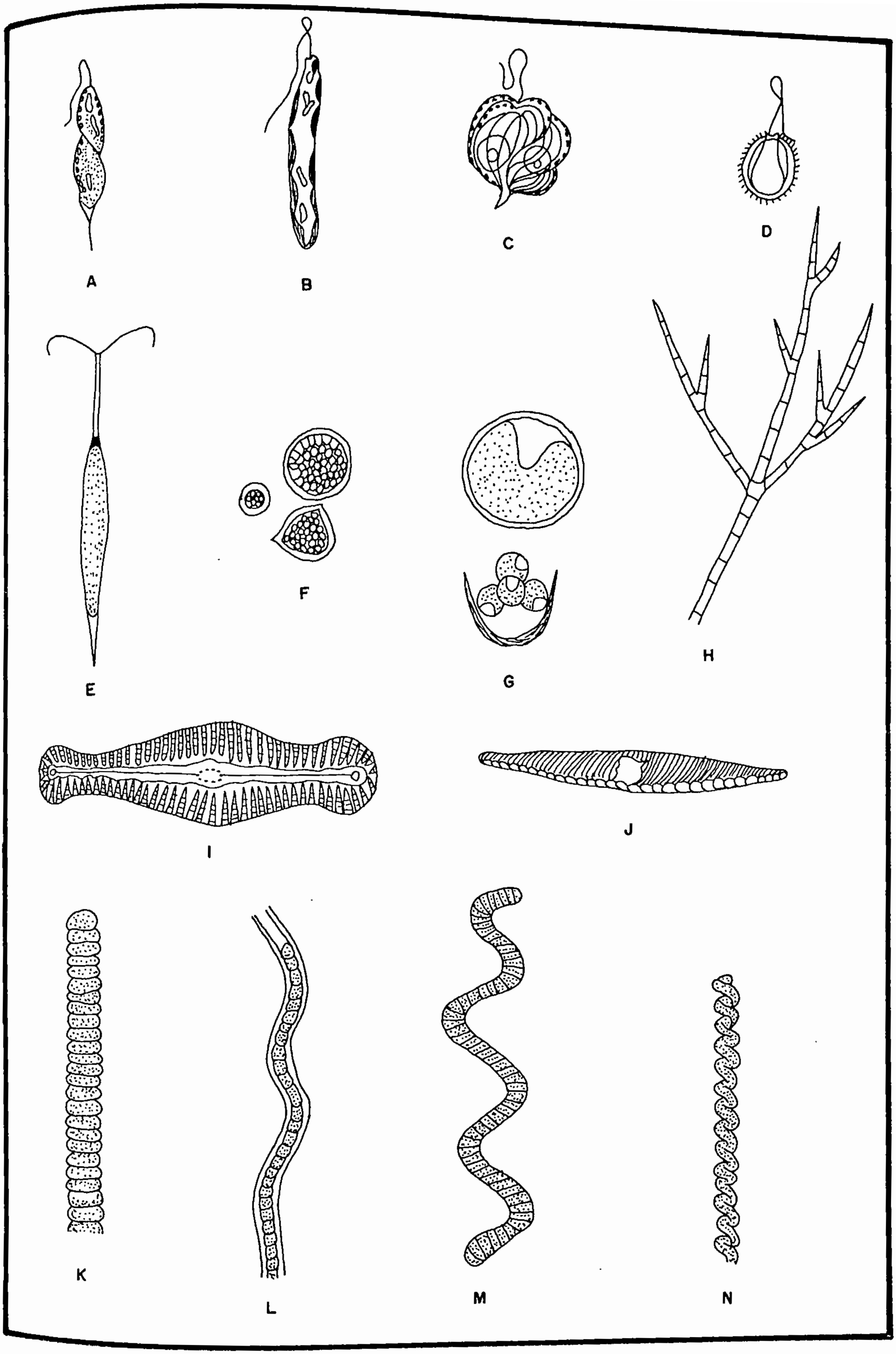


PLATE-1

PLATE - 2

Zooplankton as pollution indicators :

A - *Difflugia* sp.

B - *Didinium* sp.

C - *Loxophyllum* sp.

D - *Paramecium* sp.

E - *Frontonia* sp.

F - *Uronema* sp.

G - *Loxocephalus* sp.

H - *Epalxis* sp.

I - *Amphisiella* sp.

J - *Spongilla* sp.

K - *Arcella* sp.

L, M, N - *Brachionus* sp.

O - *Philodina* sp.

P, Q, R - *Notholca* sp.

S - *Keratella* sp.

T - *Cyclops* sp.

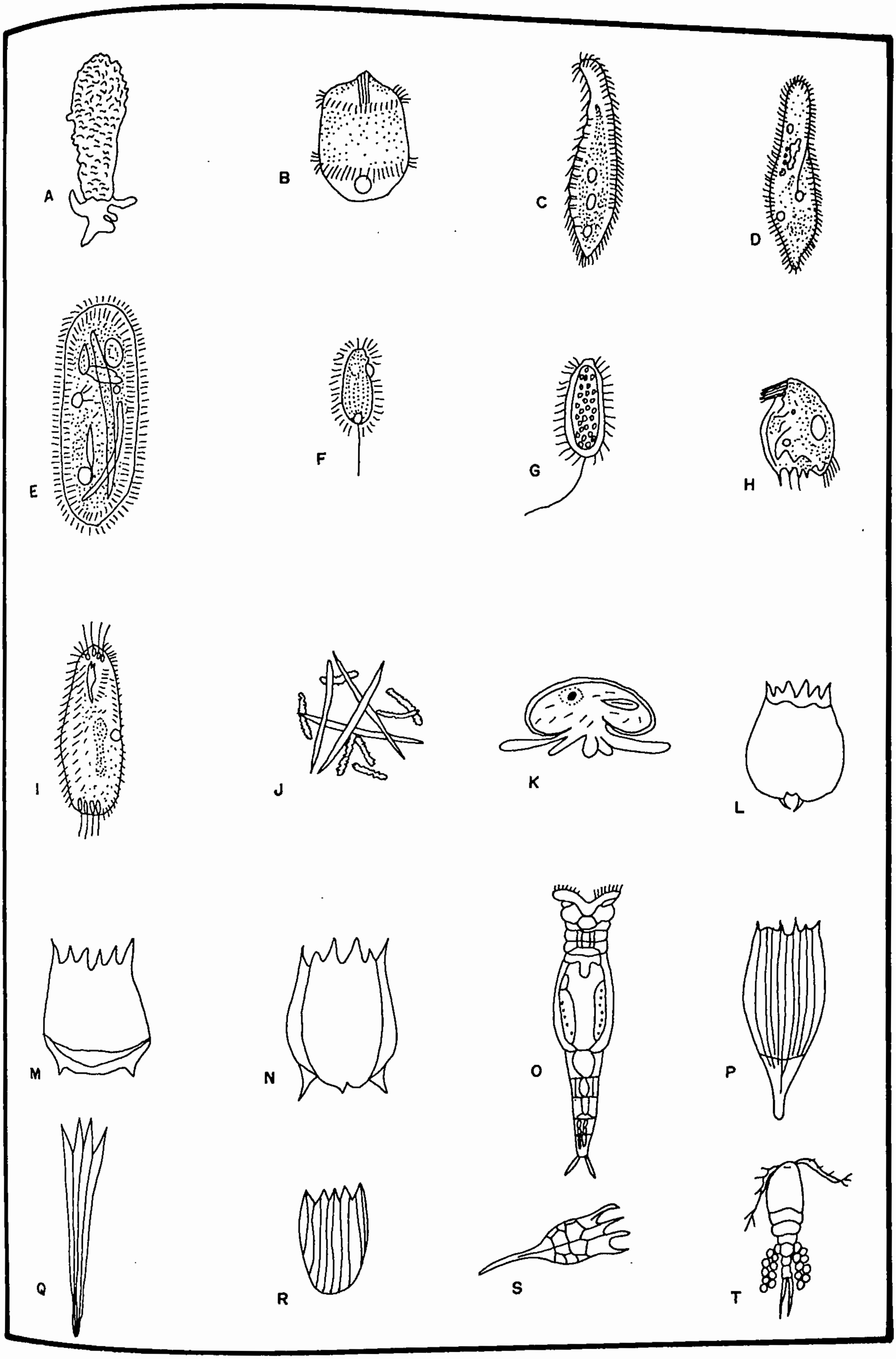


PLATE-2

Table XXI. Estimated multiple regression line in spot–1

$X_1=$	$31.702 - {*}0.0303X_{17} + 692.078X_{22} + 0.3463X_{23}$ (6.952) (0.0127 (734.085) (0.2847)	$R^2=0.42262$ I
$X_2=$	$48.9123 - {*}73.1843X_8 - 0.21545X_{11} - 593.1653X_{22}$ (6.2753) (23.6064) (0.3982) (609.141)	$R^2=0.59962$ II
$X_3=$	$-32.7742 - 0.0823X_4 + 0.0077X_5 - 0.2755X_{10} - 0.0191X_{12} + 0.00895X_{13}$ (57.8157) (0.0488) (0.0063) (1.2077) (0.0159) (0.01579) $+ 0.02468X_{17} + 38.5512X_{21} - 0.81031X_{23} + 1.53324X_{24} + 0.00093X_{25}$ (0.02574) (27.398) (0.79309) (3.53636) (0.00089)	$R^2=0.97916$ III
$X_4=$	$-272.5755 + {*}0.07946X_5 - {*}0.16681X_{12} + 0.12975X_{13} + 0.14566X_{15} + 266.2578X_{21}$ (399.2435) (0.032798) (0.05518) (0.0736) (0.74272) (172.5373) $+ 16.3298X_{24} + 0.00602X_{25}$ (19.0655) (0.0056)	$R^2=0.9378$ IV
$X_5=$	$17570.32 - 1001.762X_9 + 193.2718X_{10} - 0.30758X_{12} - 3053.777X_{21}$ (7155.081) (735.9894) (147.8492) (0.96214) (2091.469) $- {*}513.0295X_{24} - {*}0.10189X_{25}$ (153.8424) (0.040496)	$R^2=0.92542$ V
$X_6=$	$7.11159 + 0.5798X_7 - 0.00298X_{14} - 0.00124X_{18} - 156.7167X_{19} + 164.332X_{20}$ (1.08704) (0.5642) (0.00576) (0.0013) (351.788) (372.3287) $+ 129.0134X_{22}$ (110.0689)	$R^2=0.644799$ VI
$X_7=$	$-0.070715 + 7.8239X_8 - 0.091652X_9 + 0.000487X_{18} + 46.74364X_{19} - 50.00193X_{20}$ (2.005467) (6.18505) (0.285902) (0.000884) (203.4133) (215.0584)	$R^2=0.624523$ VII
$X_{10}=$	$4.853588 + 0.000338X_{12} - 0.000098X_{14} + 0.011999X_{16} + 0.011574X_{17}$ (19.72341) (0.002737) (0.050178) (0.027285) (0.019405) $- 12.569X_{21} - 0.049416X_{23} + 1.116615X_{24} - 0.0000424X_{25}$ (25.82342) (0.338466) (1.398474) (0.000249)	$R^2=0.846847$ VIII
$X_{11}=$	$-4.837954 - 0.001506X_{16} + 0.008235X_{17} + 1134.664X_{22}$ (3.97473) (0.005532) (0.00663) (532.9618)	$R^2=0.686653$ IX
$X_{12}=$	$733.0329 + {*}1.532486X_{13} - {*}13.06856X_{14} + 69.39468X_{24}$ (293.7418) (0.484286) (4.96396) (50.00776)	$R^2=0.640628$ X
$X_{13}=$	$567.9527 + 4.942468X_{15} + 22.86187X_{24}$ (306.1281) (4.171463) (56.72673)	$R^2=0.166484$ XI
$X_{14}=$	$-43.53685 + 0.029293X_{17} + 8777.593X_{22}$ (61.10365) (0.090112) (6401.219)	$R^2=0.267369$ XII
$X_{15}=$	$-56.88342 + 0.129624X_{18} + 16184.66X_{19} - 17072.85X_{20} + 0.000941X_{25}$ (88.28568) (0.083256) (16752.58) (17728.05) (0.001027)	$R^2=0.363966$ XIII
$X_{16}=$	$-113.5963 - 0.584603X_{17} + {*}61299.71X_{22}$ (236.483) (0.34875) (24773.96)	$R^2=0.414085$ XIV
$X_{17}=$	$142.9724 - 244.933X_{21} + 22523.15X_{22} + 14.63506X_{23} + 23.01879X_{24}$ (197.2842) (349.5356) (19956.26) (7.021258) (18.7009)	$R^2=0.613795$ XV
$X_{21}=$	$0.525752 + 0.013230X_{24} - 0.00000405X_{25}$ (0.196896) (0.020264) (0.00000335)	$R^2=0.343149$ XVI
$X_{23}=$	$2.211699 + 0.602369X_{24}$ (2.954024) (0.781601)	$R^2=0.056066$ XVII

*** = Significant at 5% level**

Where,

X_1 = Air temperature, X_2 = Water temperature, X_3 = Transparency, X_4 = TSS, X_5 = TDS, X_6 = pH, X_7 = DO, X_8 = Eh, X_9 = rH_2, X_{10} = BOD, X_{11} = COD, X_{12} = Electric conductivity, X_{13} = Chloride, X_{14} = CO_2, X_{15} = HCO_3 alkalinity, X_{16} = Total hardness X_{17} = Calcium hardness, X_{18} = NH_4, X_{19} = NH_3, X_{20} = $NH_4.N$, X_{21} = PO_4, X_{22} = Total sulphide, X_{23} = Oil–grease, X_{24}=Phytoplankton, X_{25}=Zooplankton.

Table XXII. Estimated multiple regression line in spot–2

X_1=	$36.06698 - 0.001912X_2 - *0.002548X_3 + 4.8856X_5 + 13.2898X_6$ (15.45791) (0.013821) (0.001087) (2.481596) (20.86986) $-2.781157X_7 + 0.0000626X_9 - 0.000226X_{10}$ (1.686918) (0.007843) (0.002036)	R^2= 0.949124 I
X_2=	$156.5475 - 0.034010X_3 - 8.88567X_4 + 10.49468X_8 - 0.05925X_9$ (209.3126) (0.041058) (27.29554) (16.82578) (0.173328) $+0.205453X_{11} + *3.667134X_{13} + 1.331358X_{23}$ (0.688287) (1.099412) (0.867577)	R^2 = 0.980521.........II
X_4=	$7.242997 - *0.048167X_{12} + *0.0000235\ X_{24}$ (0.46985) (0.009787) (0.00000888)	R^2 = 0.761575.........III
X_9=	$469.5911 + 0.134424X_{10} - 0.591243X_{11} + 0.49661X_{23} - 0.002331X_{24}$ (115.2389) (0.192841) (2.208318) (1.567521) (0.002497)	R^2 = 0.689441........IV
X_{10}=	$41.41239 + *8.871205X_{11} + *4.873765X_{23}$ (115.8402) (2.702949) (1.674807)	R^2 = 0.910907........V
X_{11}=	$26.53537 + *0.474324\ X_{23}$ (11.21801) (0.132895)	R^2 = 0.585997.......VI
X_{12}=	$-4.829379 + 0.113519X_{14} + 0.008632X_{15} + 0.652160X_{17} - 3.329646X_{22}$ (12.44134) (0.065198) (0.080712) (0.405792) (6.186645)	R^2 = 0.80192..........VII
X_{14}=	$185.5117 - 0.366151X_{15} + 0.195582X_{16} + 373260.5X_{18} - 371608.1X_{19}$ (125.2215) (0.597938) (1.413629) (404362.5) (403048.3) – 29333.78X20 + 74.0934X22 – 0.004393X24 + 0.003048X25 (31515.68) (50.84363) (0.003015) (0.003054)	R^2 = 0.899145.......VIII
X_{15}=	$0.059911 + 1.007957X_{16} + 4.095716X_{17} + 4606.46X_{18} - 4583.192X_{19}$ (1.184718) (0.010664) (0.0223173) (3808.629) (3796.294) $-372.0718X_{20} - 0.479134X_{22} + 0.000061X_{24} - 0.000017X_{25}$ (296.7705) (0.482418) (0.0000286) (0.0000289)	R^2 = 0.999997........IX
X_{16}=	$-33.57018 - 169790.8X_{18} + 169434.9X_{19} + 12966.05X_{20} + 23.69863X_{22}$ (50.11058) (108321.7) (107980.3) (8372.709) (16.63952) $-0.000339X_{24} + *0.002139X_{25}$ (0.001326) (0.000868)	R^2 = 0.96749.........X
X_{18}=	$-0.074427 + 2.888656X_{21} + 0.00000704X_{24} - 0.000000677X_{25}$ (0.146032) (2.405866) (0.00000512) (0.000000375)	R^2 = 699165 XI
X_{19}=	$-0.73643 + 2.717774X_{21} + 0.00000673X_{24} - 0.000000667X_{25}$ (0.139748) (2.302333) (0.0000049) (0.00000359)	R^2 = 0.695715.......XII
X_{20}=	$0.12659 + 1.789986X_{21} + 0.061599X_{22} + 0.000000542X_{24} - 0.00000091X_{25}$ (0.10603) (1.289347) (0.032370) (0.0000033 (0.000002)	R^2= 0.845386........XIII
X_{22}=	$-2.387402 + *0.0000688X_{24} + 0.00000964X_{25}$ (0.832336) (0.0000255) (0.00000214)	R^2 = 0.818599......XIV
X_{23}=	$-41.52052 + *0.002102X_{24}$ (38.19384) (0.000696)	R^2 = 0.503408........XV
X_{24}=	$-223.6361 + *0.719756X_{25}$ (10860.55) (0.143662)	R^2 = 0.736077......XVI

∗ = Significant at 5% level

Where,

X_1 = Transparency, X_2 = TSS, X_3 = TDS, X_4 = pH, X_5 = DO, X_6 = Eh, X_7 = rH_2, X_8 = BOD, X_9 = COD, X_{10} = Electric conductivity, X_{11} = Chloride, X_{12} = CO_2, X_{13} = CO_3 alkalinity, X_{14} = HCO_3 alkalinity, X_{15} = Total hardness, X_{16} = Calcium hardness, X_{17} = Magnesium hardness, X_{18} = NH_4, X_{19} = NH_3, X_{20} = $NH_4.N$, X_{21} = PO_4, X_{22} = Total sulphide, X_{23} = Oil-grease, X_{24} = Phytoplankton, X_{25} = Zooplankton

Table XXIII. **Estimated multiple regression line in spot–3.**

$X_1 =$	$11.03452 + 0.634281X_2 + 0.00459X_4 + 0.755282X_6 - {*}0.017772$ (8.623855) (0.319733) (0.002705) –(0.37331) (0.004852) $0.00563X_{14} - 0.273006X_{19}$ (0.220187) (3.554887)	$R^2 = 0.980645$ I
$X_3 =$	$55.65432 - 0.122364X_{10} + 0.623571X_{14}$ (33.64888) (0.062448) (2.40859)	$R^2 = 0.539248$ II
$X_5 =$	$8.041771 - {*}0.284962X_{13} - 0.005226X_{14}$ (0.50254) (0.067351) (0.052997)	$R^2 = 0.718947$ III
$X_7 =$	$-1.981731 + {*}0.170339X_8 - {*}0.073281X_9 + {*}0.000603X_{11} - {*}0.010141X_{14}$ (5.10 E–36) (295 E–37) (2.04E–37) (1.73E–39) (4.55E–38) $-{*}0.144767X_{18} + {*}0.169588X_{19} - 0.113108X_{20} - {*}0.00000107X_{21}$ (2.73E–36) (5.63E–37) (7.93E–37) (2.7E–41) $+ {*}0.00000894X_{22}$ (2.26E–41)	$R^2 = 1.00$ IV
$X_8 =$	$17.04998 - 0.004799X_{11} - 1.069246X_{18} - 0.798438X_{19} - 0.014246X_{20}$ 1.558975 (0.003576) (6.494053) (1.796712) (1.459822) $-0.0000552X_{21} + 0.0000122X_{22}$ (0.0000257) (0.0000411)	$R^2 = 0.981434$ V
$X_9 =$	$2.239788 + 0.002793X_{10} - 0.952215X_{19} + 0.691957X_{20}$ (0.990747) (0.001741) (1.83266) 1.507708 $-0.0000414X_{21} + 0.0000587X_{22}$ (0.0000278) (0.0000501)	$R^2 = 0.848502$ VI
$X_{10} =$	$375.276 - 19.62338X_{14} + 91.32217X_{19}$ (152.9159) (13.04407) (118.7218)	$R^2 = 0.484497$ VII
$X_{11} =$	$275.394 - 881.8012X_{18} - 81.44265X_{20} + 0.002419X_{21} - 0.000368X_{22}$ (150.0717) (598.9905) (103.9611) (0.00301) (0.005142)	$R^2 = 0.785877$ VIII
$X_{13} =$	$0.744472 - 0.004914X_{14}$ (2.624857) (0.278195)	$R^2 = 0.000039$ IX
$X_{15} =$	$79.50437 + {*}3.535163X_{16}$ (23.06955) (1.323817)	$R^2 = 0.471291$ X
$X_{18} =$	$0.169119 + 0.16855X_{19} - 0.131436X_{20} - 0.00000115X_{21}$ (0.058461) (0.120717) (0.096455) (0.00000184) $-0.0000000731X_{22}$ (0.00000326)	$R^2 = 0.908380$ XI
$X_{19} =$	$0.290896 + {*}0.592323X_{20} - 0.00000436X_{21} + 0.000000156X_{22}$ (0.158066) (0.218933) (0.00000598) (0.000011)	$R^2 = 0.933925$ XII
$X_{21} =$	$25934.68 + {*}1.123971X_{22}$ (3429.767) (0.096954)	$R^2 = 0.943818$ XIII

∗ = Significant at 5% level

Where,

X_1 = Air temperature, X_2 = Water temperature, X_3 = Transparency, X_4 = TDS, X_5 = pH, X_6 = DO, X_7 = Eh, X_8 = rH_2, X_9 = BOD, X_{10} = COD, X_{11} = Electric conductivity, X_{12} = Chloride, X_{13} = CO_2, X_{14} = CO_3, X_{15} = Total hardness, X_{16} = Magnesium hardness, X_{17} = PO_4, X_{18} = Silicate, X_{19} = Total Sulphide, X_{20} = oil–grease, X_{21} = Phytoplankton, X_{22} = Zooplankton

CHAPTER - FIVE

DISCUSSION

DISCUSSION

Environmental pollution is the unfavourable alternation of our surroundings, wholly or largely as byproducts by man's action through direct or indirect effects of changes in energy patterns, radiation levels, chemical and physical constitutions and abundance of organisms. Many human problems are also due to mismanagement of environment created by man himself. √/Pollution is defined as the addition of constituents to water, air or land which adversely affect the natural quality of the environment. In some cases, it may involve the removal rather than addition, of constituents from the environment. A pollutant is a substance which may alter environmental constituents or causes a pollution. A pollutant can also be defined as constituent in the wrong amount at the wrong place or at the wrong time. For example, nitrogen, phosphorus and potassium are extensively used in agriculture to increase crop yields but sometimes they cause pollution in ponds, lakes, canals and rivers by promoting algal growth.

Man generated pollutants may be more important in urban and industrial areas where the adverse effects of pollution are most severe. There is accumulating evidence that many types of pollutants can be distributed over the whole earth in relatively short period of time. Comfort automobiles are polluting the atmosphere with oxides of C, N and other noxious gases. Coal, diesel oil and other fossil fuels are emitting suffocating SO_2, and choking our lives, synthetic chemicals like plastic are adding to the problem of solid waste disposal, while now-a-days, many detergents that cannot be decomposed by micro-organisms are making the natural ponds, lakes, rivers and streams polluted bubble box. Some other effects of environmental pollution are problem of health, economic, soil erosion, sanitation, water supply, energy crisis, destroying of ecosystem, population and depletion of natural resources. Some pollutants may harm living creatures exposed for long periods of time.

The pollution caused can be divided into following categories :

(A) Solid wastes, such as, garbage (waste from kitchen, slaughter houses cannings and freezing industry), rubbish (leaves, grasses, plants from the garden and non-combustible wastes such as bottles, crokeries and plastic materials), ashes, construction wastes (bricks, plastic, furniture etc.),dead animal wastes, settled solid components of sewage wastes, industrial solid wastes (Chemicals, paints and etc.), mining wastes (wastes from coal mine), agricultural wastes (from animal waste, manure, crop residue, pesticides insecticides etc.) etc.

(B) Liquid wastes, such as different types of industrial (sugarmills, powerhouse, soap factories, dyingmills, paper and pulp mills, rayon mills, tanneries, fertilizer factories, pharmaceutical and chemical industries, textile mills, oil refineries, cement industries etc.) untreated effluents, cooling water, petroleum wastes etc.

(C) Gaseous wastes, such as, carbon monoxide, SO_2, NO_2, ozone, H_2S etc. These gases are generally found in the industrial cities, which are most dangerous to people, animals and plants.

(D) Wastes without weight, such as, radioactive substance, heat, noise

(E) Biological pollutant, such as, population, micro-organisms.

Some major parameters (chemical, physical, biological and soil conditions) of above mentioned pollution caused are studied in respect of effluents discharged from sugar mills and power houses. The plankton composition and the macrovegetation existing therein have been considered as the indicator of pollution. The facts, consequences revealed during the study period are discussed in details in the proceeding pages.

PHYSICAL CONDITIONS

AIR TEMPERATURE

Air temperature is always governed by the sunlight, rainfall and humidity. The temperature of these three sampling spots depended upon the weather of Rajshahi district characterized by great extreme of heat, cold and moderate rainfall owing to its geographical situation.

At **Spot-1**, the highest air temperature (33°C) was recorded in summer in the month of May, 1997. From rainy season in the month of June, air temperature started to decrease, till it reached to minimum value (19.75°C) which was recorded in the month of January. From winter the air temperature started to increase till the summer (Table-I). Temperature of this spot was found to be dependant upon hot effluent discharged during the production period.

When the quantity of effluent discharge was high, the atmospheric temperature of this spot showed a value higher than other spots. Yearly mean value was found to be 27.73±4.18°C. It was found to have a negative correlation with calcium hardness, total sulphide and oil-grease content. The values were statistically significant (Table-XVIII).

At **Spot-2**, the highest temperature (35.8°C) was recorded in summer season in the month of May, 1997. From rainy season in the month of June, 1997 air temperature started to decrease gradually, till it reached the minimum value (18°C), recorded in the month of February, 1997. From winter the air temperature started to increase till the summer (Table-II). It appeared that the changes in air temperature of this spot was mainly governed by climatological factors (yearly mean value was observed 28.9±5.66°C). It was found that it had a positive correlation with water temperature and was statistically significant. It was also found to have a negative correlation with total dissolve solids, BOD, HCO_3 alkalinity, total hardness, calcium hardness, NH_4, NH_3, $NH_4.N$, PO_4, total sulphide, phytoplankton and zooplankton. The values were statistically significant (Table-XIX).

At **Spot-3**, the maximum (37°C) and the minimum (23.25°C) air temperature were recorded in May, 1997 and January, 1997. The temperature of this spot was always recorded after 10 AM, thus it showed a higher value than spot-2 as the sun was up above . From rainy season in the month of June, it started to decrease gradually till it reached the minimum value. From winter this value started to increase till summer, except April, 1997 (Table-III). It showed gradual seasonal change throughout the study period. Yearly mean value was found to be 28.96±3.86°C. It had a positive correlation with water temperature, DO and CO_3 alkalinity and statistically significant. It also was found to have a significant negative correlation with TDS, COD and total sulphide (Table-XX).

WATER TEMPERATURE

Temperature plays a vital part in chemical and biochemical reactions in a water body and is an important factor influencing self purification of streams. The thermal discharges are usually favourable to bacteria and pathogens. Temperature alone plays a significant role in determining the quality of water of an aquatic body because almost all the physical, biochemical and biological properties are governed by it. For example, as the temperature of water increases its viscosity decreases, the vapour pressure increases and solubility of gases in water decreases. Other biological and biochemical activities such as DO, BOD,electric conductivity, photosynthesis, growth and death of micro-macro organisms are all dependant on water temperature value. Rapid temperature changes produce thermal shocks and result in immediate death of fishes. The effect of temperature differs in different organisms (Mackenthun 1969). Temperature plays an important role in plankton productivity (Chakraborty *et al.* 1959, Tandon and Singh 1972, Chander 1940).

At **Spot-1**, the yearly mean value (30.25±3.11°C) of effluent temperature was higher than that of air (27.73±4.18°C). In sugar production period (October - February) effluent temperature was always recorded high (Table-I). From March to September,1997, when the mill was not in production and the monsoon rain mixed with the effluent, the temperature values recorded were lower than that of the air. The maximum value (37.3°C) was recorded in November, 1996 and the minimum (25°C) was in April, 1997. Effluent mixed water temperature had significant positive correlation with COD and total sulphide. It also was found to have a significant negative correlation with oxidation reduction potential (Table-XVIII). Resultant data obtained during the investigation, speak that the higher temperature value always created an anoxic condition. Similar observations were made by Mackenthun (1969) Bhouyain (1979). Higher evaporation rate caused by higher temperature resulted into decrease in density, viscosity and transparency. It is mentioned earlier that sulphur dioxide is used as a clearing agent in sugar manufacturing process. There was a higher amount of sulphide present in the effluent which formed a large amount of H_2S gas which produced a specific bad smell in the air. During the production period a huge amount of methane gas evolved as a product of anaerobic decomposition. Its presence was proved by testing the inflammable properties of methane gas. Another toxic gas- ammonia was quantified and found in higher amount. Its presence was also established by its specific fishy smell.

The disappearance of plant and animal life is an obvious results of the oxygen depletion of water, which is caused by increase in temperature of the water body. This occurs by a direct killing effect or by migration to other areas. A less obviously but important result has been a shift in water conditions from those favouring aerobic activity to those that support anaerobic activity. Similar views have been made by Mehra and Chhatwal (1990).

At **Spot-2**, the highest effluent mixed water temperature (32°C) was recorded in summer in the month of May, 1997. From rainy season in the month of June, temperature value started to decrease gradually and reached to the minimum value (18°C), in the month of January and February, 1997. From winter the temperature started to increase till summer. Except February, 1997, effluent mixed water temperature was always lower than that of the air (Table-II). Distinct feature of this spot was that the effluent contained a huge amount of oil-grease. The oil-grease content played a significant role in maintaining the temperature of this site. The resultant data can be explained from this stand point that due to presence of high oil-grease content throughout the period, heat absorption rate was minimized. Similar views were held by Bhouyain (1983) and Trivedi (1993). During the monsoon the influx of water removed the surface film layer of oil-grease and the heat absorption rate was enhanced. The temperature value was found to have a positive correlation with transparency, Eh, rH_2 and was statistically significant. It also was found to have a significant negative correlation with TDS, BOD, HCO_3 alkalinity, total hardness, calcium hardness, NH_4, NH_3, $NH_4.N$, PO_4, total sulphide, phytoplankton and zooplankton (Table-XIX).

At **Spot-3**, the water temperature was al0ways lower than that of air (Table-III). This spot is a lotic water system. All the parameters along with temperature appeared to have a moderate value. The maximum value (32°C) was recorded in summer in the month of May, 1997. From rainy season in the month of June, temperature started to decrease gradually and reached to the minimum value (18°C), recorded in the month of February, 1997. From winter the temperature started to increase till it reached the highest value in the summer. Water temperature was found to have a significant positive correlation with DO, Eh, rH_2, CO_3 alkalinity and silicate. It also had a significant negative correlation with TDS, BOD, COD, total sulphide, oil-grease, phytoplankton and zooplankton (Table-XX).

In these three spots upper limit of temperature range were 37.3°C, 32°C, 32°C which appeared to be higher than the IWQS (30°C), DWQS (25°C) values. Yearly mean value of these three spots are 30.25±3.11°C, 25.58±4.54°C and 25.61±4.45°C., which indicate all three sampling spots are thermally polluted. Zaman *et al.*(1993),Talukder *et al.*(1994) worked on the river Padma,–the temperature variation from their works showed a lower temperature (23.3°C). Effluent temperature might have contributed significantly in increasing the temperature value of the Padma at this site. It may be mentioned, in thermally polluted water, fish and other vertebrates need more oxygen for respiration. However the available oxygen in such water gets decreased. Thus thermal pollution affects fish and other vertebrates in many faced fashion. The life cycle and natural processes of many aquatic organisms including fish have been delicately affected due to water temperature (Trivedi and Raj 1992, Bhouyain 1983, Patrick 1953, Klein 1962). Thermal pollution may have been one of the causes that has created fish scarcity in Padma around this study zone. It may also be mentioned that, the water of Padma at this point is not healthy for domestic uses as per DWQS.

TRANSPARENCY

Transparency is an unique characteristic feature of any aquatic body. The ecosystem of a water body such as, the food and energy production of all the aquatic lives depend upon the transparency. Transparency i.e. amount of light penetration in a water body depends upon various factors such as, water color, abundance of plankton, total suspended and dissolved solids, electric conductivity, oil-grease, detergent, colloidal particles etc. (Mackenthun 1969).

At **Spot-1**, the effluent water was generally black in color, sometimes forming a white froth were found to from a layer upon it. During the period of sampling a lower value of transparency was recorded except in the month of August and September, 1997 (Table-1). These higher values of transparency were caused by increased depth of water due to monsoon rainfall. The lowest value (6.5 cm) was recorded in the next month following the closure of the mill in March, 1997. The lower value of transparency was a combined effect of TSS, TDS, electric conductivity, oil-grease, .solid press mud, effluent color etc. It is to be mentioned that this spot is shaded by big trees. Most of the leaves of these trees fall in this canal which is in turn is responsible in decreasing the transparency. In this spot the value of transparency was found to have a statistically significant positive correlation with phytoplankton and zooplankton. It also was found to have a negative correlation with TSS, TDS, BOD, electric conductivity, chloride, calcium hardness, PO_4 and oil-grease which were statistically significant (Table-XVIII).

At **Spot-2**, the effluent mixed water was almost blackish to brownish in color throughout the period of study. The highest value of transparency was recorded in rainy season in the month of August, 1997, when the water was green in color and the depth of water was maximum due to monsoon rainfall; maximum DO, lowest TSS, TDS, electric conductivity, chloride and oil-grease were recorded during this month. The lowest value (5 cm) of transparency was recorded in the month of January, 1997, when the sugar mills were running and the higher value of TSS, electric conductivity, oil-grease, highest value of TDS and total anoxia were recorded. Apart from this, TSS, TDS, oil-grease were the major factors which played a positive role in decreasing the transparency. Similar findings were made by Trivedi and Raj (1992), Mackenthun (1969), Bhouyain (1979), Klein (1962). Transparency was found to have a positive correlation with DO, Eh, rH_2, and were statistically significant. It was found to have a negative correlation with TSS, TDS, BOD, COD, electric conductivity, chloride, HCO_3 alkalinity, total hardness, calcium hardness, NH_4, NH_3, NH_4.N, total sulphide, oil-grease, phytoplankton and zooplankton which were statistically significant (Table-XIX).

At **Spot-3**, the transparency had a high value except in the month of August, September, October, 1997 and November, 1996. In August and September, flood water entered the river along with huge amount of silt and alluvium and detritus which resulted in the higher values of TSS and TDS. Similar observations were made by Hoak (1959), Tandon and Singh (1972), Welch (1952), Roy (1955), Chakroborty *et al.* (1959) and Berner (1951) in their works. In October and November, huge amount of effluent from sugar mills and power house mixed with the river water as a result of which transparency showed a lower value. A lower value of transparency during this time resulted into a lower DO content. The present investigation corroborates with the findings of Khan and Mahmood (1976), Bhouyain (1979) and Paul (1981). Transparency was found to have a statistically significant positive correlation with CO_3 alkalinity. It also was found to have a negative correlation with COD which was statistically significant (Table-XX).

TOTAL SUSPENDED SOLIDS (TSS)

TSS value is a very important factor to indicate the quality of water. TDS, pH, BOD, COD, electric conductivity, chloride, DO, alkalinity, Eh, rH_2 are directly or indirectly influenced by TSS value in a water body. TSS value also depends upon all types of suspended solids such as debries, silt, alluvium, dead parts of organisms, wastes and PO_4, oil-grease contents, etc. (Trivedi and Raj 1992, Andrews *et al.*1972 and APHA 1989).

At **Spot-1**, the highest value (430 mg/l) of TSS was recorded after production period in the month of April, 1997, caused by undiluted discharged sugar mills washing effluents. Whenever the discharged effluents had a higher dilution rate, the value of TSS had fallen which occured during the rainy season in the month of August and September, 1997. Due to monsoonal rainfall, the depth of water increased which eventually resulted into a lower value of TSS. According to Trivedi and Raj (1992), Rahman (1992), Ramjeawon and Baguant (1995), Pearson and Penridge (1987) TSS is a major pollutant substance of sugar mills effluent, which play a dominant role in decreasing DO, increasing CO_2 , BOD and other gaseous values. Our findings also match the above mentioned findings. TSS value was found to have a positive correlation with TDS, chloride, HCO_3 alkalinity, PO_4 and were statistically significant. It was also found to have a negative correlation with electric conductivity, phytoplankton, zooplankton which were statistically significant (Table-XVIII).

At **Spot-2**, the TSS values were always lower than that of spot-1, because as the effluents flowed through the canal it became more diluted than from its original source. The highest value (370 mg/l) was recorded in the month of April,1997, when the sugar mills washing effluents flowed through the canal and higher oil-grease and BOD values were recorded. The lower values (Table-II) were recorded in the rainy season (July, August and September, 1997) due to higher dilution rate. During these months, lower values of electric conductivity, TDS, BOD, COD, HCO_3 alkalinity, chloride, PO_4, oil-grease were recorded. Similar observations were made by Ramjeawon and Baguant (1995), Pearson and Penridge (1987) and Palhareya *et al.* (1993). TSS value was found to have a positive correlation with TDS, pH, BOD, COD, electric conductivity, chloride, CO_3 alkalinity, oil-grease and was statistically significant (Table-XIX).

At **Spot-3** the TSS values were much lower than that of the other two spots. Because, the effluent passed a long way to reach the river Padma, it became more and more diluted from the original source and this spot is a lotic water system. The highest value of TSS was observed in rainy season (August, 1997) when the run off water along with silt, alluvium and debris accumulated in water of Padma, which might have caused the increased value of TSS at this spot. The findings corroborate with those of Bhouyain (1979), Rahman (1992), Tandon and Singh (1972) and Mackenthun (1969). All the calculated correlation values regarding TSS were statistically non-significant (Table-XX).

TOTAL DISSOLVED SOLIDS (TDS)

The total dissolved solids in water consists of alkalies, some acids, sulphates, electric conductivity, chloride, total hardness, calcium hardness, magnesium hardness, oil-grease, ions, ammonium, ammonia, ammonium-nitrogen etc.(Andrews *et al.*1972, Gautam 1990)

At **Spot-1**, the highest value of TDS (6160 mg/l) was recorded in the month of April, 1997, probably caused by undiluted mills washing-effluent discharge. The highest and lowest value of TDS were directly depended upon the rate of dilution of effluent. When the rate was high, the TDS value was low and vice versa. TDS value was always high (Table-I) except in August, 1997, during this month rain water had mixed with the effluent and water depth was increased gradually. The effluent of present investigation also found to consist of large quantities of ammonium, ammonia, ammonium nitrogen, chloride, sulphide,COD, PO_4, total hardness, calcium hardness, magnesium hardness and high electric conductivity. This agrees well with the findings of Andrews *et al.*(1972), Ramjeawon and Baguant (1995), Pearson and Penridge (1987), Trivedi and Raj (1992), Palhareya *et al.*(1993) and Gautam (1990). At this spot TDS value was found to have a positive correlation with rH_2, BOD, electric conductivity, PO_4 and was statistically significant. It also was found to have a negative correlation with phytoplankton, zooplankton which were statistically significant (Table-XVIII). The yearly mean value of TDS was 2953.17±1556.34 mg/l. According to WHO (1982) standard, water having TDS value more than 1200 mg/l is unacceptable for any sort of domestic use. In this regard the effluent water in the present study zone is unfit for any use.

At **Spot-2**, the highest value of TDS (2440 mg/l) was recorded in the month of January, 1997, when the sugar mills were in production. The lowest value was recorded in the rainy season in the month of August, 1997, due to increased depth of the spot resulting from rainfall. TDS values of this spot were always lower than that of Spot-1 (Table-II), although the yearly mean value (1265±708.44 mg/l) was higher than that of normal water WHO (1982). TDS value was found to have a positive correlation with BOD, electric conductivity, HCO_3 alkalinity, total hardness, calcium hardness, magnesium hardness, NH_4, NH_3, $NH_4.N$, total sulphide, oil-grease, phytoplankton and zooplankton. These values were statistically significant. It also was found to have a negative correlation with DO, Eh, rH_2 and were statistically significant (Table-XIX).

At **Spot-3**, the highest value of TDS (1380 mg/l) was recorded in the month of Janurary, 1997, when the sugar mills were in production and effluent discharged that flowed through the canal in to the river Padma. TDS values of this spot were always lower than that of Spot-1 and Spot-2 (Table-III). But the highest TDS value of this spot was higher than that of normal water prescribed by WHO (1982). The lowest value was recorded in the month of April, 1997, when the effluent flow was stopped and consequently the TSS value marked a downhill approach.. It seems that whenever the effluent flow increased the value of TDS also increased. Similar findings were made by Palhareya *et al.* (1993) and Gautam (1990). TDS value was found to have a positive correlation with BOD, COD, total sulphide, oil-grease, phytoplankton and zooplankton which were statistically significant. It also was found to have a statistically significant negative correlation with Eh, rH_2, CO_3 alkalinity and silicate (Table-XX).

CHEMICAL CONDITIONS

HYDROGEN ION CONCENTRATION (pH)

The hydrogen ion concentration (pH) is an important factor as a measure of water quality. The waste water can alter the pH of natural waters (Motwani *et al.*1956, APHA 1989). The optimum range of pH for aquatic life are 6.8 to 9.0 (Gautam 1990, Palhareya *et al.*1993, Trivedi and Raj 1992, APHA 1989).

At **Spot-1**, the pH of effluent was found to range from 6.1 to 8.2. Whenever the effluent contained acidic material, the pH was marked by an acidic value, and when the effluent contained comparatively lesser acidic material then higher pH limit was achieved. The lowest pH (6.1) was recorded in sugar production period in the month of December, 1996 and the highest (8.2) was recorded in rainy season in the month of August, 1997, when sugar mills were not in operation. It seems that the sugar mills effluent produce acidic conditions. Similar findings have been made by Ramjeawon and Baguant (1995), Pearson and Penridge (1987), Baliarshingh *et al.* (1992), Rana (1977), Banerjea and Motwani (1960), who worked with sugar mills effluent. As is know earlier that usually the pH value of lentic and lotic water system of Rajshahi have a pH ranging from 7.0 to 8.0 (Fakhruzzaman and Zaman 1996, Zaman *et al.* 1993, Naz 1992, Chowdhury *et al.* 1996). According to Bhouyain (1979), Motwani *et al.* (1956), Sharma *et al.*(1982), Campbell(1979), Gautam (1990), Palhareya *et al.* (1993), Trivedi (1993), Vincent (1993), Ray (1990) also stated that the industrial waste materials had significant role in increasing or decreasing the pH of the adjacent water body, where the waste materials are dumped. pH was found to have a positive correlation with DO and was statistically significant. It also was found to have a negative correlation with CO_2, NH_4, NH_3, $NH_4.N$ and total sulphide which were statistically significant (Table-XVIII).

At **Spot-2**, the range of pH value was from 6.1 to 8.8 (Table-II) which was higher than that of spot-1. The highest pH value (8.8) was recorded in the month of April , 1997, when the sugar mills were not in function and zero value of CO_2 was recorded. The lowest pH value (6.1) was recorded in sugar production period in December, 1996, when the highest CO_2 value (65 mg/l) was recorded. The present investigation indicates that the sugar mills effluents are more acidic than the power house effluent. It was also noticed that when the acidity of the effluent gradually passes to alkaline condition, there was an increase in the bicarbonate and bicarbonate hardness. Trivedi and Raj (1992), Bhouyain (1983) expressed similar views. It may be mentioned that bicarbonate hardness was much more higher in this spot in comparison to spot-1. When the sugar mills effluent and power house effluent combines together, there is a further increases in the alkalinity of water. Similar information were given by Trivedi and Raj (1992). This might be the other reason for high pH and alkalinity of this spot. From May to June, 1997, the value of pH was found to decrease due to the increased biodegradation caused by the high water temperature (Trivedi and Raj 1992). The pH value was found to have a positive correlation with oil-grease and was statistically significant. It also was found to have a statistically significant negative correlation with CO_2 (Table-XIX).

At **Spot-3**, the pH value was always found to be alkaline except in October, 97 (Table-III). In October pH value was found to be acidic due to the mixture of the two effluents, increase of biodegradable organic substances, decrease of water depth, high amount of CO_2 gas and the absence of CO_3 alkalinity. The water of Padma was always alkaline in nature at this study zone. Similar investigations were made by Zaman *et al.* (1993), Talukder *et al.* (1994) and Naz *et al.* (1996). pH value was found to have a statistically significant positive correlation with CO_3 alkalinity and negative correlation with CO_2 (Table-XX).

The yearly pH mean value of spot-1, spot-2 and spot-3 are 7.18±0.49, 7.36±0.78 and 7.75±0.66 respectively. The pH standards of IWQS, DWQS and WHO are 6.0 - 8.5, 6.5 - 8.5 and 6.5 - 9.2 respectively. It therefore, appears that the effluents from both industrial sites have already polluted, the Padma water in the study zone.

DISSOLVED OXYGEN (DO)

In a body of water, dissolved oxygen (DO) is a fundamental requirement of life for the plant and animal population. Their survival is dependent upon the ability of water to maintain certain minimal concentrations of this vital substance (Trivedi and Raj 1992, APHA 1989, Ramjeawon and Baguant 1995, Thomas 1948).

At **Spot-1,** the effluent mixed water was always found to be in an anoxic condition except in August, 1997 (Table-I). DO (1.15 mg/l) was recorded in August, when rainfall increased the volume and level of the mobile effluent mixed water. The primary cause of water deoxygenation is due to the presence of substances easily broken down or decayed by bacteria in the presence of oxygen (Trivedi and Raj 1992). Verma and Shukla (1969) in a study observed that due to the addition of industrial wastes in a stream a sudden fall in dissolved oxygen and abrupt rise in BOD values occurred in polluted areas. High value of temperature, TSS, TDS, CO_2, BOD, NH_4, NH_3, NH_4.N, sulphide, oil-grease are responsible for anoxic condition of this spot. More or less similar observations were also made by Bhouyain (1979), Mahmood and Bhouyain (1988), Khan and Mahmood (1976), Paul (1981), Andrews *et al.* (1972), Balkrishnan (1984), Palhareya *et al.* (1993), Trivedi (1993), Gautam (1990), Vincent (1993), Wright and McDonnell (1979) while working with various industrial effluents. Pearson and Penridge (1987) in Australia, Ramjeawon and Baguant (1995) in Mauritius, Baliarsingh *et al.* (1992), Banerjea and Motwani (1960), Verma and Shukla (1969) in India, made similar findings, when working with the effluent of sugar factories. The DO range was much bellow the acceptable level of IWQS (5.0 mg/l) and DWQS (6.0 mg/l) standards. DO value was found to have a statistically significant positive correlation with Eh and rH_2. It also was found to have a negative correlation with NH_4, NH_3, NH_4.N and statistically significant (Table-XVIII).

At **Spot-2,** DO was recorded in the month of April to September, 1997 (Table-II) when the sugar mills were not in production. Except April to September, 1997, the DO value was always marked by an anoxic condition. The highest value (1.68mg/l) was recorded in the month of August, 1997, when the depth of water increased due to rainfall. During this period the content of oil-grease was also found to come down. Probably oil-grease was one of the factor which may have lowered the rate of photosynthesis in this spot. According to Trivedi and Raj (1992), Mishra *et al.* (1992), Bhouyain (1983) oil-grease inhabits the light penetration in water which decreases the rate of photosynthesis and due to floating layer of oil-grease on the surface of water, atmospheric oxygen (O_2) can not mix with water which may be the cause of lowering the DO content in the water body. The bacterial degradation of sunken oil needs huge amount of oxygen (Trivedi and Raj 1992, Bhouyain 1983). Almost similar observations were made by Mahmood and Bhouyain (1988) and Khan *et al.* (1986). DO was found to have a positive correlation with Eh, rH_2, and was statistically significant. It was also found to have a statistically significant negative correlation with BOD, COD, electric conductivity, chloride, HCO_3 alkalinity, total hardness, calcium hardness, NH_4, NH_3, NH_4.N, total sulphide, phytoplankton and zooplankton (Table-XIX).

At **Spot-3**, the DO values were always higher than that of other two spots during the period of study (Table-III). But in April and May, 1997, the DO content was always lower than IWQS (5 mg/l) and DWQS (6 mg/l) acceptable level. The highest DO (8.52 mg/l) was recorded in the month of May when the sugar mills effluent discharge was stopped. The lowest value (2.34 mg/l) was recorded in the month of February, 1997, when the sugar mills effluent was discharged in the river Padma. Water from upstream carried enough debries with the flowage of Padma which might have caused the depletion of DO in water. The TSS, TDS, CO_2, BOD, oil-grease values were lower than those of other two spots where effluents are discharged, due to which the DO was high in this spot. Khan and Mahmood (1976), Bhouyain (1979), Paul (1981) and Mahmood and Bhouyain (1988) observed that as the effluent approaches from its original source, the intensity of pollution becomes gradually lesser. All the calculated correlation values regarding DO were statistically nonsignificant (Table-XX).

The yearly mean value of spot-1, spot-2 and spot-3 are as follows, 0.095±0.32 mg/l, 0.366±0.537 mg/l and 4.06±1.48 mg/l respectively, which indicate that the study spots are already polluted and do not fit the DO value standards of IWQS (5 mg/l) and DWQS (6.0 mg/l).

OXIDATION REDUCTION POTENTIAL (Eh)

The oxidation reduction potential of any solution of water is the net of all these reactions and known as Redox Potential of that solution. The redox potential is an indication of the 'energy' state of water system governed by the presence of oxidized and reduced chemical substances or their biological activities (Gautam 1990). As the oxidation and reduction reactions are accompanied by the transference of electron, the redox potential is a valuable index to measure the conditions of water body. In any aquatic ecosystem undergoing biological metabolism, there is a continual change in the ratio between the materials in reduced form and the materials in oxidized form. If the ecosystem has organic material the concentration of reduced form is higher which results in lower Eh value. But after a short time when the materials degrade the system starts to attain its original form which means Eh value start increasing. But when a continuous addition of organic material takes place, a continuous decrease in Eh will occur. The low Eh value indicates the presence of higher amount of organic matter.

At **Spot-1**, the lowest Eh value (0.092 m volt) was recorded during the sugar production month of February, 1997 (Table-I), due to high content of organic matter in the sugar mills effluent along with high BOD, COD, TSS, TDS, electric conductivity values were recorded. The highest value of Eh (0.228 m volt) was recorded in rainy season in the month of August, 1997, due to increased water level, with low BOD, COD, TSS, TDS and electric conductivity values. The yearly mean value of Eh was 0.135±0.038 m volt. Eh was found to have a statistically significant positive correlation with rH_2. It also was found to have a statistically significant negative correlation with BOD, COD, CO_2 , total hardness, calcium hardness, total sulphide and oil-grease (Table-XVIII). Similar observation was also made by Gautam (1990) in his work on river systems.

At **Spot-2**, the lowest Eh value (0.085 m volt) was recorded during the sugar production period in the month of February, 1997, due to the same reasons as stated in case of spot-1. The highest Eh value (0.249 m volt) was recorded in the month of September, 1997, when water level was increased with low BOD, COD, TSS, TDS, oil-grease values at the same time. The yearly mean value of Eh was 0.140±0.49 m volt. Eh was found to have a statistically significant positive correlation with rH_2. It also was found to have a negative correlation with BOD, HCO_3 alkalinity, total hardness, calcium hardness, NH_4, NH_3, NH_4.N, total sulphide, phytoplankton and zooplankton which were statistically significant (Table-XIX).

At **Spot-3**, the lowest Eh value (0.116 m volt) was recorded in the month of February, 1997, when the mixed effluent from the sugar mill and power house was discharged in the Padma. The highest Eh value (0.393 m volt) was recorded in rainy season in the month of July, 1997, due to the rise of water level and degradation of organic materials. Yearly mean value of Eh was 0.214±0.098 m volt. Eh value was found to have positive correlation with rH_2, CO_3 alkalinity, total silicate and were statistically significant. It was also found to have a statistically significant negative correlation with BOD, electric conductivity, total sulphide, oil-grease, phytoplankton and zooplankton (Table-XX).

OXIDATION REDUCTION INDEX (rH_2)

The oxidation reduction index (rH_2) is a quick and efficient measurement for the oxidation reduction conditions of fresh water in open bodies (Voznaya 1981). It also showed the trend of Eh in its variation. Increasing and decreasing value of rH_2 is depended upon degradation and addition of organic material respectively similar to the Eh value. According to Voznaya (1981) rH_2 has its neutral point at 28. The lower rH_2 value from 28 indicates the organic pollution in water body (Gautam 1990).

At **Spot-1**, the lowest rH_2 value (10.05) was recorded during the sugar production period in the month of February, 1997, when the TSS, TDS, BOD, COD values were also found to be high. The highest rH_2 value (10.21) was recorded in rainy season when water depth have increased. Addition of organic materials decreased due to the closure of the sugar mills. At this time lowest BOD, COD, TSS, TDS values were recorded. Yearly mean value of rH_2 was 8.94±0.64. Oxidation reduction index was found to have a statistically significant positive correlation with phytoplankton. It also was found to have a negative correlation with BOD, COD, total hardness, total sulphide which were statistically significant (Table-XVIII). Similar findings were made by Gautam (1990).

At **Spot-2**, the lowest value of rH_2 (8.28) was recorded in November during the sugar production period with high TSS, TDS, BOD, COD, oil-grease, electric conductivity values. The highest rH_2 value (10.73) was recorded in the month of September, 1997, when sugar mills were not in function, lowest TSS, TDS, oil-grease values were recorded. Yearly mean value of rH_2 was 9.17±0.762. Oxidation reduction index was found to have a negative correlation with BOD, COD, electric conductivity, total hardness, calcium hardness, NH_4, NH_3, $NH_4.N$, total sulphide, phytoplankton, zooplankton and were statistically significant (Table-XIX). Similar observations made by Gautam (1990).

At **Spot-3**, the lowest rH_2 value of Padma river water (10.05) was recorded in the month of February, 1997, when industrial effluents were discharged into the Padma water. The highest rH_2 value (14.56) was recorded in the month of July followed by the rise of water level in the Padma due to monsoonal rainfall and lowest BOD, COD, electric conductivity were recorded. Yearly mean value of rH_2 was 12.20±1.40. Oxidation reduction index was found to have a negative correlation with electric conductivity, total silicate, total sulphide, oil-grease, phytoplankton and zooplankton which were statistically significant (Table-XX).

The yearly Eh mean value of spot-1, spot-2 and spot-3 (Table-I, II, III) were lesser than the Eh value (0.361±0.012 to 0.414±0.023 m volt) of Bhagirathi river water in India, investigated by Gautam (1990). The yearly rH_2 mean value of spot-1, spot-2 and spot-3 were also lesser than that of Bhagirathi river (27.69±0.337 to 28.74±0.56) in India (Gautam 1990). The lower Eh and rH_2 value of the present investigations showed that spot-1, spot-2 and spot-3 water are polluted by higher amount of organic materials. The findings of Voznaya (1981), Wright and McDonnell (1979) also corroborate with the present findings.

BIOCHEMICAL OXYGEN DEMAND (BOD_5)

BOD is an important measure to determine the amount of biodegradable organic mater. It may be defined as the rate of dissolved oxygen used by the micro-organisms in aerobic decomposing of the dissolved or even particulate organic matter in water. BOD in general provides a quantitative index of the organic matter which is easily degradable in a short span of time. So it is to be mentioned that the more the oxidizable organic matter present in water, the more the amount of oxygen required to degrade it biologically, hence more BOD value as a consequent is achieved (Gautam 1990, Pearson and Penridge 1987, Ramjeawon and Baguant 1995, Khanna 1993).

At **Spot-1**, the maximum BOD value (16.36 mg/l) of this spot was recorded in the month of January, 1997, during the sugar production period when TSS, COD values were higher, transparency was low, DO value was in the state of anoxia, oil-grease content was high and water temperature was high (Table-1). The minimum BOD value (5.2 mg/l) was recorded in August, 1997, during the rainy season followed by highest transparency, low DO (1.15 mg/l) higher phytoplankton abundance and lowest COD, TSS, TDS, CO_2, HCO_3 alkalinity, total hardness, chloride, PO_4 and oil-grease values. The yearly mean value of BOD (10.62±3.2 mg/l) is lesser than that observed in the sugar mills effluents of Taiwan (80 mg/l), Australia (20 mg/l), India (30 mg/l) and Mauritius (20 mg/l), which exceeds the acceptable BOD value of water approved by WHO (1988) for domestic usage (India = < 3 mg/l, Japan < 3 mg/l and UK < 9 mg/l BOD values). Pearson and Penridge (1987), Ramjeawon and Baguant (1995), Butcher (1931 In Klein 1962), Baliarsingh *et al.* (1992) and Motwani *et al.* (1956) also recorded high BOD values in sugar mills effluents in their studies. It is to be noted that the Rajshahi Sugar Mills do not discharge the pressmud along with the liquid effluent. As a result of which the BOD value in the effluent shows a lower value compared to those in Taiwan, Australia, India, Mauritius and Chaina where the pressmud in released with liquid effluent. BOD value was found to have a positive correlation with electric conductivity, free CO_2, total hardness, calcium hardness, PO_4 and oil-grease which were statistically significant. It was also found to have a statistically significant negative correlation with phytoplankton and zooplankton (Table-XVIII).

At **Spot-2**, the BOD value was found to be less than that of spot-1 (Table-I, II). The maximum value of BOD (9.72 mg/l) was recorded in the month of January, 1997, when sugar mills were in function, high TSS, TDS, COD, CO_2, oil-grease, electric conductivity, total sulphide, high abundance of plankton were recorded with lower values of transparency, Eh and rH_2. DO value was in the state of anoxia. The minimum BOD value (3.72 mg/l) was recorded in rainy season in the month of August, with increased water depth, highest transparency with a DO value of 1.68 mg/l were recorded. It was followed by lowest TSS, TDS, oil-grease, COD, electric conductivity, PO_4 .values with low abundance of plankton. According to Trivedi (1993), APHA (1989), Ramjeawon and Baguant (1995), Pearson and Penridge (1987), Wright and McDonnell (1979) and Gautam (1990), nature, amount and dilution of effluent increases the amount of BOD. The same can be attributed to the lesser value of BOD at this spot. Paul (1981) Bhouyain (1979) found higher BOD value in the oil polluted zone of Karnafully river estuary than that in the controlled zone. Andrews *et al.* (1972) reported that the Biochemical Oxygen Demand of the lake Eria with untreated sewage had a high BOD value causing pollution in the water body. BOD value did not maintain any relation with the changes of the seasons or any other natural factors to its increased or decreased values. The results of the above authors closely support the present investigation. BOD value was found to have a statistically significant positive correlation with COD, CO_2, HCO_3 alkalinity, total hardness, calcium hardness, NH_4, NH_3, NH_4.N, total sulphide, oil-grease, phytoplankton and zooplankton (Table-XIX).

At **Spot-3**, the maximum BOD value (4.22 mg/l) was recorded in the month of January, 1997, when effluent was discharged in the river Padma. The minimum value (1.7 mg/l) were recorded in rainy season in the July and August, 1997 and then water level increased and the mills were not in operation. Yearly mean value was 2.24±0.646 mg/l. Works carried out in four polluted stations of Bhagirathi river in India showed an annual mean value of BOD 2.2±0.259, 2.21±0.318 and 2.14±0.163 mg/l (Gautam, 1990) which indicates that the BOD value of Padma study point is higher than that of Bhagirathi. At this spot BOD value was found to have a statistically significant positive correlation with total sulphide, oil-grease, phytoplankton and zooplankton. It was also found to have a statistically significant negative correlation with COD (Table-XX).

CHEMICAL OXYGEN DEMAND (COD)

The chemical oxygen demand (COD) is an indication of total organic matter (biodegradable + nonbiodegradable) present in water whereas the BOD is only a measure of biodegradable organic matter. COD test is designed to measure the oxygen required for the oxidation of organic matter in the sample by using a strong oxidant ($K_2Cr_2O_7$, strong acid and high temperature), where BOD test fails, COD succeed (APHA 1989, Mishra *et al.* 1992, Gautam 1990). COD value is always influenced by TSS, TDS, electric conductivity, BOD, Eh, rH_2, total hardness, calcium hardness, NH_4, NH_3, NH_4.N, total sulphide and oil-grease content (Trivedi and Raj 1992).

At **Spot-1**, the maximum COD value (2471 mg/l) was recorded in the month of November, 1996, during the sugar production period when high COD, TSS, TDS, electric conductivity, total hardness calcium hardness, NH_4, NH_3, NH_4.N, total sulphide and low Eh, rH_2 values were recorded. The minimum COD value (892 mg/l) was recorded in rainy season in the month of August, 1997. At this time the water level was increased due to rainfall, when TSS, TDS, BOD, electric conductivity, total hardness, NH_4, NH_3, NH_4.N, total sulphide, oil-grease values were found to be lowest, with hgih Eh, rH_2 values (Table-I). Talukder *et al.* (1994) recorded a COD value of 52 mg/l of Nandakuja river in north western region of

Bangladesh, where sugar mills effluent of Natore is dumped off. Ramjeawon and Baguant (1995) recorded COD values of seven Mauritian sugar factories as 119, 158, 240, 1510, 90, 233 and 290 mg/l. The normal COD value of sugar factory effluents in Taiwan, Australia, South Africa, China and Mauritius were reported to be 300, 30, 75, 160 and 30 mg/l respectively (Ramjeawon and Baguant 1995, Pearson and Penridge 1987). The yearly mean value (1555.83±454.27 mg/l) of the present investigation is much higher than that of above mention findings. According to Pearson and Penridge (1987), Ramjeawon and Baguant (1995), Baliarsingh *et al.* (1992), Pandey (1980) sugar mills effluents largely increase the COD value of natural waters indicating a higher load of biodegradable and nonbiodegradable organic matter. The higher COD value in the present study may be due to the same reasons.The COD value was found to have a statistically significant positive correlation with total hardness, calcium hardness and total sulphide (Table-XVIII).

At **Spot-2**, the maximum COD value (896 mg/l) was recorded in the month of March, 1997, when sugar mills were in function. At this time maximum oil-grease (175.68 mg/l) and electric conductivity (2113.78 μ ohms/cm) were also recorded. The minimum COD value (512 mg/l) was recorded in the month of August during the rainy season . At this time the water level rose due to rainfall when, minimum values of TSS, TDS, BOD, total hardness, calcium hardness, electric conductivity, NH_4, NH_3, $NH_4.N$ and oil-grease were recorded. The maximum and minimum values of this spot have probably been influence by sugar mills effluent, and oil-grease content played as a major factor to increase COD value (Trivedi and Raj 1992, Bhouyain 1983). The yearly mean value of this spot (704.08±121.72 mg/l) is more higher than that of WHO (1988) water quality standards, used for public supply and pisciculture, Chowdhury *et al.* (1996) recorded COD value of 893±65.22 mg/l of a canal where power house effluent is dumped off. The present investigation corroborates with the above mentioned findings. COD value was found to have a statistically significant positive correlation with electric conductivity, chloride, oil-grease and phytoplankton (Table-XIX).

At **Spot-3**, the maximum COD value (455 mg/l) was recorded in the month of January, 1997, when sugar mills and power house effluents were discharged in the Padma water, with higher TDS (1380 mg/l) values. The minimum value (32 mg/l) was recorded in July at the time of monsoon, when low hardness, electric conductivity and BOD values were recorded.

Talukder *et al.* (1994) recorded a COD value of 40 mg/l from Padma of north western region of Bangladesh. In 1986 and 1987, the maximum COD value of the Bhagirathi river in India were reported as 13.23±1.379 mg/l and 13.38±1.19 mg/l by Gautam (1990). The yearly mean value (253.42±105.10 mg/l) of this spot reveals that the water of Padma at study site has become highly polluted, although it is a running water system. The value of COD was found to have a statistically significant positive correlation with total sulphide. It was also found to have a statistically significant negative correlation with CO_3 alkalinity (Table-XX).

The value of COD was positively correlated with those of ammonia, nitrite, nitrate, total suspended and dissolved solids. Higher amount of suspended-dissolved solids with higher organic and inorganic load consume more dissolved oxygen from the water body. Ammonia and nitrite also take up a huge amount of dissolved oxygen for their chemical process (Ramjeawon and Baguant 1995, Pearson and Penridge 1987, Gautam 1990). The present findings at this site fit well with the above correlation.

BOD AND COD RATIO

The ratio of BOD-COD shows the types of treatment required for the particular waste water sample (Trivedi and Raj 1992). Accordingly when BOD and COD ratio is 0.6, it mean that the waste is rich putreascible matter. Therefore the best treatment for such type of waste is biological one; when BOD and COD is between 0.3 to 0.6, it means that the waste water require acclimatization, prior to subjecting it for the biological treatment, and if and when BOD and COD ratio is 0.3, the chemical treatment is the best for such waste.

The BOD and COD ratio of three spots of the present investigation is far below [Table - IV, (a,b,c)] the range of chemical treatment and it indicates a greater degree of pollution by biodegradable and non-biodegradable organic matter.

ELECTRIC CONDUCTIVITY (EC)

The capacity of water to conduct electric current is known as electric conductivity. This is a good measure of ionic concentration and dissolved inorganic substances (APHA 1989, Ambasht 1990, Mishra *et al.* 1992). Dissolved salts are ionized in the aquous medium. The ability of conductance is dependent upon the concentration, mobility and valency of ions. Temperature of the medium also regulates this inorganic substances show better conductance while organic compounds are poor current conductors as they do not disasociate. Electric conductivity are normally influenced by TSS, TDS, chloride, NH_4, NH_3, $NH_4.N$, total hardness values (APHA 1989, Paul 1981).

At **Spot-1,** the maximum value of electric conductivity (1558.17 μ ohms/cm) was recorded in May, 1997, immediately after the production period resumed. Due to the discharge of sugar mills washing effluent, high TSS, TDS, HCO_3 alkalinity, chloride, total hardness, calcium hardness, BOD, COD, NH_4, NH_3, $NH_4.N$ were recorded. The minimum electric conductivity value (261.89 μ ohms/cm) was recorded in August, 1997, during the nonproduction period.The water level was high due to rainfall and dilution of the effluent resulted in the lower values of TSS, TDS, hardness, chloride, BOD, COD, NH_4, NH_3, $NH_4.N$. Similar findings were made by Pearson and Penridge (1987), Andrews *et al.*. (1972), APHA (1976), Trivedi (1993), Bhouyain (1979) and Paul (1981). Electric conductivity was found to have a statistically significant positive correlation with chloride and CO_2. It also was found to have a statistically significant negative correlation with phytoplankton (Table-XVIII).

At **Spot-2**, the maximum electric conductivity value (2113.78 μ ohms/cm) was recorded in the month of March, 1997, when sugar mills effluent intermixed with the power house effluent resulting in high TSS, TDS, chloride, hardness, COD, BOD and oil-grease values. The minimum electric conductivity value (224.74 μ ohms/cm) was observed in August, 1997, when the water level was maximum due to monsoonal rains. At this time the sugar production period was over and the effluent mixed water showed lowest TSS, TDS, chloride, total hardness, oil-grease NH_4, NH_3, $NH_4.N$ values. Similar results were reported by Chowdhuary *et al.* (1996). Electric conductivity was found to have a statistically significant positive correlation with chloride and oil-grease (Table-XIX).

At **Spot-3,** the maximum electric conductivity (479.72 μ ohms/cm) was recorded in December, 1996, during the sugar production period, when effluent was being discharged in the Padma water. The minimum value was recorded in the month of July, 1997, during high monsoon. Electric conductivity value of this spot was always found to be lower than that of other two spots. As we know as the dumped effluent moves away along the canal, its various anions and cations are absorbed by various plants and micro flora and fauna. A lower value of electric conductivity in Padma might be this cause working behind it. The yearly mean value of electric conductivity (298.85±83.62 μ ohms/cm) in the Padma is more higher than that of Bhagirathi river (62.8 to 157.8 μ ohms/cm) as observed by Gautam (1990). Electric conductivity value was found to have a statistically significant positive correlation with oil-grease, phytoplankton and zooplankton. It also was found to have a statistically significant negative correlation with silicate (Table-XX).

The yearly electric conductivity mean value of spot-1 (943.72±361.73 μ ohms/cm), spot-2 (936.91 ±501.27 μ ohms/cm) and spot0-3 (298.85±83.62 μ ohms/cm) are more higher than that of WHO (1985), ISI (1974) and ICMR (1975) water quality standards (300 μ ohms/cm). The present investigation also indicates that the river water has become more polluted by industrial effluents at the study site.

CHLORIDE

Natural water generally contains low concentration of chloride. Chloride and salinity is positively correlated with each other. At high concentration it is harmful and produces salty taste (Gautam 1990). The sudden increase in the concentration of chloride in surface water bodies at abnormally high concentrated was previously used as index of pollution through contamination by fecal matters. Since chloride ions are non-biodegradable these are not removed from the waste even after subjecting it to the secondary treatment process (Trivedi and Raj 1992). In natural water when chlorine appeared to be free, it reacts with nitrogenous organic material and form chloramines which are toxic to fish (Venkateswarlu and Jayanti 1968). Total hardness, calcium hardness, electric conductivity values are influence by chloride.

At **Spot-1,** the maximum value of chloride (142.06 mg/l) was recorded in May, 1997, immediately after ceasation of the sugar production period was over. Due to the discharge of sugar mills washing effluent high TSS and TDS content were recorded. The minimum value (26.98 mg/l) was observed in August, 1997, during the rainy season when there was no effluent discharge and the remaining effluent was more diluted due to rain water. Chloride content of Ghorashal Urea Fertilizer Factory (UFFG) effluent has been reported to vary from 17 to 19 mg/l (Rahman 1992). Sugar mills effluent seems to have a much more higher concentration of chloride than that of UFFG effluent. Similar observations were made by Ramjeawon and Baguant (1995), Pearson and Penridge (1987) in sugar mills effluent. APHA (1976), Venkateswarlu and Jayanti (1968), Gautam (1990), Trivedi and Raj (1992), Bhouyain (1979) and Paul (1981) studied that whenever the industrial effluent contained high concentration of chloride it increased the chloride value of the water body where the effluent was being dumped. The present investigation also corroborates with the above scientists. Chloride value was found to have a statistically significant positive and negative correlation with HCO_3 alkalinity and phytoplankton respectively (Table-XVIII).

At **Spot-2,** the maximum value (147.68 mg/l) of chloride was observed in the month of March, 1997, when sugar production period was continuing and high TSS, TDS values were also recorded. The minimum value of chloride (25.56 mg/l) was observed in August, 1997, during the rainy season when the mill was not in production and low TSS, TDS and electric conductivity values were recorded. Andrews *et al.* (1972), Trivedi and Raj (1992) observed that, whenever the industrial effluent contained high chloride, the chloride content of water also increased. Bhouyain (1983), Paul (1981) and Chowdhuary *et al.* (1996) worked on the high oil-grease content effluent. They observed that oil-grease is a major organic factor to increase the chloride value. The present findings fit well with those value above works. Chloride value showed a statistically significant positive correlation with oil-grease content (Table-XIX).

At **Spot-3,** the maximum chloride value (66.03 mg/l) was recorded in November, 1996, and the minimum (35.5 mg/l) in February, 1997. Chloride content of this spot was lesser than that of the other two spots. At this spot the water is always used for domestic purposes. Human and domestic animal excreta contains chloride equal to the chloride consumed with food and water (Gautam 1990, Venkateswarlu and Jayanti 1968). Normal human body discharges from 8 to 15 g (average 9g of chloride) a day (Trivedi and Raj 1992). In Bhagirathi river in India, chloride value was found to vary from 2.03 to 5.38 mg/l and 2.35 to 3.88 mg/l in 1986 and 1987 respectively (Gautam 1990). It seems that although the spot is far away from original spot of effluent discharge, its chloride contain is still noticeably high probably due to discharge of effluent in stream in addition to its organic load from domestic and municipal sources. Chloride value showed statistically significant positive correlation with PO_4 (Table-XX).

In natural waters when chlorine appeared to be free, it reacts with nitrogenous organic material and forms chloramines which is harmful to a pregnant mother. It is also toxic to fish population (Venkateswarlu and Jayanti 1968, Gautam 1990, Trivedi and Raj 1992). Tsai (1973) observed in his studies that the total number of fish species was drastically reduced below down streams from the place of discharging chlorinated effluent. During the present study fishes were almost absent at the discharge point followed by their limited appearance down streams which may probably be due to the above reason.

CARBON DIOXIDE (CO_2)

Carbon dioxide plays a major role in the production biology of aquatic bodies. It is essential for photosynthesis for the aquatic green plants including the phytoplankton. As a water quality constituent it may be derived from different sources, such as the atmosphere, inflowing ground water, decomposed organic matter and respiration of animals and plants. When it is dissolved in water body, causes increase in acidity (Ellis 1937).

At **Spot-1**, the CO_2 values were always higher than that of other two spots (Table-I, II, III). The highest value (109 mg/l) was recorded in sugar production period in the month of December, 1996, when the BOD value was high, zooplankton abundance was higher than that of phytoplankton, lowest pH (6.1) was recorded, DO value was in the state of anoxia, TSS value was high and carbonate was absent. Study of Ramjeawon and Baguant (1995), Pearson and Penridge (1987), Vincent (1993), Trivedi and Raj (1992), Palhareya *et al.*(1993), Gautam (1990), Bhouyain (1979), Pandey (1980) and Trivedi (1993) are also in agreement with the present findings. The minimum value of free CO_2 (9 mg/l) was recorded in rainy season in the month of August, 1997, when the water level increased due to rainfall; highest pH (8.2), lowest BOD (5.2), highest DO value (1.15 mg/l), lowest TSS value (120 mg/l) were recorded during this time. CO_2 value was found to have a statistically significant positive correlation with calcium hardness and total sulphide(Table-XVIII).

At **Spot-2**, the highest value of carbon dioxide (65 mg/l) was recorded during sugar production in the month of December, 1996, when BOD, TSS values were high, highest zooplankton abundance was recorded, DO value was in the state of anoxia, lowest pH (6.1) was recorded and CO_3 alkalinity was absent. Carbon dioxide was absent in April, 1997, when the high CO_3 alkalinity (29mg/l) with high pH value (8.8) were recorded. Similar findings were also made by Palhareya *et al.* (1993), Bhouyain (1983), Pearson and Penridge (1987), Thomas (1948), Trivedi (1990), Paul (1981) and Khanna (1993), while working with lentic and lotic water systems. CO_2 value was found to have a statistically significant positive correlation with HCO_3 alkalinity, total hardness, magnesium hardness and total sulphide (Table-XIX).

At **Spot-3**, the free CO_2 content was found to be almost nil during the period of study except in the month of October, 1997. At this time the CO_2 registered a value of 7 mg/l, the cause of which may be attributed to the high discharge of the mills effluent when the CO_3

alkalinity was nil with a low pH value of 6. As the water at this spot was highly mobile, the content of free CO_2 is likely to be very low or almost absent. Consequently the spot showed low oil-grease content and poor BOD with moderately higher plankton abundance. Similar relationships were made by Chowdhury *et al.* (1996) and Palhareya *et al.* (1993). Carbon dioxide value showed statistically significant negative correlation with CO_3 alkalinity (Table-XX).

Ellis (1937) considered that the concentration of free CO_2 should not exceed 6 mg/l and that any higher value usually indicates pollution. Verma and Shukla (1969) reported that due to the addition of a sugar factory effluent, the CO_2 concentration of the stream becomes vary high (30.2 mg/l). which is lethal to fish. Yearly mean value of CO_2 of spot-1 and spot-2 are 56.13±26.01 mg/l and 23.38 ±15.83 mg/l respectively which showed that the spot-1 and spot-2 polluted.

CARBONATE ALKALINITY (CO_3)

Carbonate alkalinity is positively related with pH and DO values and negatively related with CO_2.

At **Spot-1,** the CO_3 alkalinity value was found to be nil (Table-I) during the period of study. At this time high values of carbon dioxide were recorded whenever the pH value was less than 8.0 except in August, 1997. Similar observations were made by Hutchinson (1957), Pearson and Penridge (1987) and Chowdhury *et al.* (1994).

At **Spot-2,** the CO_3 alkalinity was found to be present in April, 1997 (Table-II), during the period of study, when the pH value was high (8.8) and CO_2 was not traced. All the calculated correlation values regarding CO_3 alkalinity were statistically non-significant (Table-XIX).

At **Spot-3,** carbonate alkalinity value was recorded high during the period of study, except in October, 1997 (Table-III). The maximum value of carbonate alkalinity was obtained in August, 1997, when CO_2 value was nil (Table-III). In October, 1997, carbonate value was found to be nil when CO_2 was present, pH value was on the acidic side (6.0). Similar observation was made by Chowdhury *et al.* (1996). All the calculated correlation values regarding CO_3 alkalinity were statistically non-significant (Table-XX).

BICARBONATE ALKALINITY (HCO_3)

The capacity of water to neutralize a strong acid is known as alkalinity. This is an anionic phenomenon. All anions such as CO_3^{-2} (Carbonate) HCO_3 (bicarbonate), OH^- (hydroxyl), PO_4^{-3} (Phosphate), SiO_4^- (silicate) etc. contribute to alkalinity of water (Andrews 1972). Here the bicarbonate alkalinity is considered.

At **Spot -1,** the maximum value of bicarbonate alkalinity (556 mg/l) was recorded in May, 1997, immediately of the closure of the sugar production period, when the washing effluent of the sugar mills was discharged and the highest electric conductivity was recorded (Table-I). The bicarbonate alkalinity varied from 76 to 556 mg/l. Similar observations were made by Pearson and Penridge (1987), Ramjeawon and Baguant (1995) and Chowdhury *et al.* (1994), in sugar mills effluent. Seth and Bhaskaran (1950) found that alkalinity ranged between 76 to 400 mg/l in Hoogly river due to disposal of industrial wastes. In Bangladesh, the effluent of Ghorashal Urea Fertilizer Factory (UFFG) the HCO_3 alkalinity ranged from 240 to 270 mg/l when pH was 8.0 to 8.1 (Rahman 1992). The minimum alkalinity value (76 mg/l) was observed in rainy season in the month of August, 1997, when the rain water had mixed with the effluent. Welch (1952) and Yaron (1964) held that the alkalinity of aquatic habitat partly depends on the amount of water present in it. The dilution of bicarbonate concentration may occur during the rains in comparatively shallow bodies of water. Further, Welch (1952), Hutchinson (1957), Andrews (1972) held that a decrease in the alkalinity may be caused by the breakdown of bicarbonate due to the photosynthetic activity of plants. Bicarbonate alkalinity was found to have a positive correlation with NH_4, NH_3 and $NH_4.N$ which were statistically significant. It also showed statistically significant negative correlation with zooplankton (Table-XVIII).

At **Spot-2,** the maximum HCO_3 alkalinity (338 mg/l) was observed in sugar production period in the month of December, 1996, and the minimum (71 mg/l) was observed in the rainy month of August, 1997 (Table-II), when the water level was high due to rainfall. Paul (1981) studied the oil pollution of the Karnafully river and Chowdhuary *et al.* (1996) studied the oil pollution of a canal which receiving power house effluent. They found oil-grease were directly responsible for the increase in alkalinity. A similar phenomenon was observed in the present investigation. Bicarbonate alkalinity showed a statistically significant positive correlation with total hardness, calcium hardness, NH_4, NH_3, $NH_4.N$, total sulphide, phytoplankton and zooplankton (Table-XIX).

At **Spot-3,** the HCO_3 alkalinity values varied from 59 to 123 mg/l. The mean alkalinity value of this spot was found to be much lower than that of the other two spots (spot-1=305.33±150.66 mg/l, spot-2=201.13±74.29 mg/l, spot-3=93.08±21.87 mg/l). A similar observation was made by Chowdhury *et al.* (1996). The bicarbonate alkalinity value in 1986 (28.10 to 51.0 mg/l) and 1987 (30.47 to 54.50 mg/l) of Bhagirathi river in India were recorded by Gautam (1990). Skakalskiy (1966), also showed lower values of HCO_3 alkalinity in the river Pyalitsa of USSR. The findings of the present investigation was higher than that of Gautam (1990) and Skakalskiy (1966). Casey (1969) observed inverse relationships between HCO_3 alkalinity and run off. All the calculated correlation values regarding HCO_3 alkalinity were statistically non-significant (Table-XX).

TOTAL HARDNESS

Total hardness of the natural water is mainly caused by the bi-valent cations such as Ca^{++}, Mg^{++} etc. Many other cations and anions which can cause it are iron, stronium, chloride, manganese, sulphate etc. (Gautam 1990). Higher cations also contributes to hardness to lesser degree but monovalent cations never produce hardness (Trivedi and Raj 1992). The higher hardness value occur due to the presence of different types of salts in the industrial effluent which is loaded with high concentration of chlorides and sulphates. Its economic significance is enormous and as such the hardness tests are among the most commonly performed to test the quality of water (Gautam 1990, APHA 1989, Mishra *et al.* 1992 and Andrews *et al.* 1972).

At **Spot-1,** the maximum total hardness value (604 mg/l) was recorded in December, 1996, during the sugar production period and the minimum (230 mg/l) was recorded in the rainy month of August, 1997, when sugar mills were not in function. The water level of the effluent canal was high due to rainfall. The minimum hardness value was much more higher than that of the drinking water standards as set by the Ministry of works housing (Sinha *et al.* 1992) and WHO (1985). During the period of study, hardness showed a higher deviation (±127.93 mg/l) value which indicates that the discharged effluent have caused the increase in hardness and the present investigation also indicates that the nature of the sugar mills effluent is marked by high hardness. Similar observations have been made by Ramjeawon and Baguant (1995), Pearson and Penridge (1987) and Chowdhury *et al.* (1994). Total hardness value was found to have a statistically significant positive correlation with calcium hardness and total sulphide (Table-XVIII).

At **Spot-2,** the total hardness value was lower than that of spot-1. But still the hardness value was not within the acceptable range. The maximum value (534 mg/l) was recorded in December, 1996, when the sugar mills effluent was discharged and oil-grease content was high. The minimum total hardness (72 mg/l) was recorded in the rainy month of August, 1997, when the sugar mills were not in function. At this time the water level was high, having lower value of oil and grease in it. Bhouyain (1983), Paul (1981), Trivedi and Raj (1992) and Chowdhury *et al.* (1996) observed that the high oil-grease and NH_3 content of effluent are responsible for increasing the total hardness. Throughout the period of study a higher deviation (± 126.45 mg/l) of total hardness value showed fits well with the above mentioned works. Total hardness value was found to have a positive correlation with calcium hardness, magnesium hardness, NH_4, NH_3, $NH_4.N$, total sulphide, phytoplankton and zooplankton which were statistically significant (Table-XIX).

At **Spot-3,** the total hardness value always appeared to be lower than that of spot-1 and spot-2. The hardness value ranged from 75 to 200 mg/l, which indicates that the water of Padma has almost crossed the limit of acceptable range of hardness. The total hardness value of the Bhagirathi river water in India was found to range from 33.68 to 66 mg/l and 43.83 to 66.58 mg/l in 1986 and 1987 respectively (Gautam 1990) which is much lower than that of Padma river water. Naz *et al.* (1996) observed that the total hardness value of Padma water varied from 84 to 208 mg/l near Rajshahi. The present investigation also corroborates with them. Total hardness showed statistically significant positive correlation with the magnesium hardness (Table-XX).

In the three sampling spots the alkalinity values were always less than the hardness value.

WHO (1982) classified drinking water on the basis of degree of hardness as follows :

Soft	0 - 60 mg/l
Medium hard	60 - 120 mg/l
Hard	120 - 180 mg/l
Very hard	180 mg/l and above

Based on this rating, it can be said that the water at spot 1 & 2 is very hard and the Padma water passed from medium hard to a very hard level which renders it unfit for domestic use. Gautam (1990), Trivedi (1993), Palhareya *et al.* (1993), Vincent (1993), Ray (1990), Pearson and Penridge (1987), Paul (1981), Andrews *et al.* (1972), APHA (1976) stated that many industrial effluents very often increase the hardness of the fresh water rivers, lakes etc. This supports the findings of the present investigation also.

CALCIUM HARDNESS

The calcium hardness value of any water depends on the amount of various calcium salts such as $CaCO_3$, $CaHCO_3$, $CaSO_4$, $Ca(PO_4)_3$ dissolved in it (APHA 1989, Andrews 1972). Calcium carbonate and bicarbonate salts cause the temporary hardness, which can be removed by simple boiling and permanent hardness is caused by the chloride and sulphate salts of the calcium. Vincent (1993), Ray (1990), Pearson and Penridge (1987), Paul (1981), Gautam (1990), Trivedi (1993), Palhareya *et al.* (1993), Andrews *et al.* (1972), APHA (1976) started that many industries were also responsible for increasing the calcium hardness of the water body where the effluents are discharged, thus changing the quality of natural water. The calcium hardness always superseded magnesium hardness in the degree of volumetric presence.

At **Spot-1,** the highest calcium hardness value (478 mg/l) was recorded in january, 1997, during the sugar production period, which is caused by Calcium oxide (CaO) used as sugar juice clearing agent. The lowest value (72 mg/l) was recorded in the rainy month of July, 1997, when water level was maximum high and effluent was more diluted due to rain water. Similar observations were made by Pearson and Penridge (1987) in Mauritius, Verma and Shukla (1969) in India and Chowdhury *et al.* (1994) in Bangladesh. In the present investigation, the high value of chloride (64.83±34.81 mg/l) and total sulphide (2.65±1.38 m mol l^{-1}) indicate that the sugar mills effluent always tend to make permanent hardness. This result is also supported by the findings of Ramjeawon and Baguant (1995), Pearson and Penridge (1987). Calcium hardness was found to have a statistically significant positive correlation with PO_4, total sulphide and oil-grease. It also showed statistically significant negative correlation with phytoplankton (Table-XVIII).

At **Spot-2,** the maximum calcium hardness value (315 mg/l) was recorded in February, 1997, when sugar mills were in function and the minimum value (58.8 mg/l) was recorded in rainy month of August, 1997, when water level was high due to monsoonal rains. The sugar mills were closed during this period. During the period of study the high value of chloride (60.14±29.63 mg/l) and total sulphide (2.06±1.48 M mol l^{-1}) indicate that the high value of calcium hardness was a permanent nature of this spot. It also indicates that the power house effluent also contribute to permanent hardness. The present findings are supported by the works of Trivedi and Raj (1992), Chowdhury *et al.* (1996). Calcium hardness values of this spot showed statistically significant positive correlation with NH_4, NH_3, $NH_4.N$, total sulphide, phytoplankton and zooplankton (Table-XIX).

At **Spot-3,** the calcium hardness value of Padma river water varied from 29.4 to 130.2 mg/l during the period of study. It is always lower than that of other two spots (Table-I, II, III). The maximum value was recorded in the month of October, 1997, when sugar mills and power house effluent mixed together and discharged in the river. The minimum value was recorded in the rainy month of August, 1997. The calcium hardness values (26.26 to 51.75 in 1986 and 35.68 to 59.42 mg/l in 1987) of Bhagirathi river in India (Gautam 1990) indicate that the water of Padma has a higher value of calcium hardness. All the calculated correlation values regarding calcium hardness were found to be statistically non-significant (Table-XX).

MAGNESIUM HARDNESS

The magnesium hardness is caused by the carbonates, bicarbonates, chlorides and sulphates salt of magnesium. It makes temporary and permanent hardness. The magnesium and calcium hardness shows an inverse relationship (Gautam 1990, APHA 1989), but the calcium always dominated over magnesium quantitatively.

At **Spot-1,** the maximum magnesium hardness value (65.39 mg/l) was observed in the month of October, 1997, during the sugar production period, when the calcium hardness value rose to 184 mg/l. The minimum value (1.55 mg/l) was also recorded in the month of February, 1997, when calcium hardness value was found to be 478 mg/l. The yearly mean value of magnesium hardness in the present investigation (29.43±18.82 mg/l) is higher than that of Bhagirathi river (13.04±6.85 mg/l) in India observed by Gautam (1990). The findings of Pearson and Penridge (1987), Ramjeawon and Baguant (1995) are in agreement with the present findings. All the calculated correlation values regarding magnesium hardness were found to be statistically non significant (Table-XVIII).

At **Spot-2,** the highest value of magnesium (58.05 mg/l) was recorded in the month of December, 1996, when sugar mills were in function. The lowest value (3.23 mg/l) was recorded in rainy season in the month of August, 1997. The yearly mean value (14.69±14.32

mg/l) of this spot appears to be higher than that of the observed values made by Gautam (1990) in India. All the calculated correlation values regarding magnesium hardness were found to be statistically non-significant (Table-XIX).

At **Spot-3,** the maximum magnesium hardness value (39.58 mg/l) was recorded in the month of April, 1997, and the minimum (4.22 mg/l) was recorded in the month of November, 1996. The yearly mean value (14.38±8.72 mg/l) of Padma river was similar to that in Bhagirathi river in India observed by Gautam (1990). All the calculated correlation values regarding magnesium hardness were found to be statistically non-significant (Table-XX).

The yearly mean value of magnesium hardness at spot-1, spot-2 and spot-3 (29.43±18.82, 14.69±14.32 and 14.38±8.72 respectively) indicate that the WHO (1988) water quality standard does not fit with the observed values and the Padma water at the site of study has registered an alarming state of pollution level.

AMMONIUM (NH_4)

Ammonium is a source of nitrogen. It takes up a huge amount of dissolve oxygen for chemical processes as in nature through microbial activities, thereby liberating ammonia (NH_3) (APHA 1989, Vincent 1993, Pearson and Penridge 1987, Trivedi and Raj 1992). Total suspended solids, electrict conductivity, biological oxygen demand (BOD) and chemical oxygen demand (COD) are influenced by ammonium concentration. In industrial water it comes from variety of sources (Shukla and Chandel 1980, Vincent 1993).

At **Spot-1,** the maximum value (0.74 mg/l) of ammonium was recorded in March, 1997, in the sugar production period, during which high values of TDS, BOD, COD, NH_3 and electric conductivity were recorded. The minimum value (0.212 mg/l) was recorded in the rainy month of August, when TDS, BOD, COD, NH_3 and electric conductivity values also were found to be lowest. All the calculated correlation values regarding ammonium were found to be statistically non-significant (Table-XVIII).

At **Spot-2,** the maximum value (0.636 mg/l) of ammonium was recorded in February, 1997, when large amount of sugar mills effluent mixed with power house effluent and the oil-grease, BOD, COD, TDS, electric conductivity values were also high. The minimum value (0.016 mg/l) was recorded in rainy season in the month of August and September, 1997, when sugar mills were not in function and lower values of oil-grease, TDS, BOD, COD and electric conductivity were recorded (Table-II). The present investigation indicates that the value of ammonia was influenced by oil-grease content of this spot. Similar observations were also made by Tsai (1973), Vincent (1993), Trivedi and Raj (1992), Chowdhury *et al.* (1996) and Bhouyain (1983). Ammonium (NH_4) value of this spot was found to have a statistically significant positive correlation with PO_4, phytoplankton and zooplankton (Table-XIX).

At **Spot-3,** the ammonium, which is modified in to ammonia may be removed from the water, due to continuous air stripping of the mobile water. During the period of investigation ammonium was observed nil (Table-III). Absence of ammonium might have been caused by the wave action of the river.

Ammonium (NH_4) mean value of sugar mills (0.503±0.149 mg/l) and power house (0.312±0.176 mg/l) effluent were more high than that of WHO (1988) standard (0.19 mg/l), which also indicates the higher pollution level of study sites.

AMMONIA (NH_3)

In effluent loaded water, ammonia comes from a variety of sources. Ammonia is naturally present in surface and ground water and in industrial and other waste water (APHA 1976, Vincent 1993). The desirable limit of ammonia is less than 0.10 mg/l (WHO 1988). Chemical oxygen demand (COD), biological oxygen demand (BOD), hardness, TDS, electric conductivity are influenced by ammonia content (Trivedi and Raj 1992, Andrews *et al.* 1972).

At **Spot-1,** the maximum content of ammonia (0.70 mg/l) was recorded in March, 1997, in the sugar production period. At this time the BOD, COD, hardness, electric conductivity and TDS values were also high. The minimum content (0.20 mg/l) was obtained in non-sugar production period in the month of August, 1997, when the effluent was more diluted due to rain water. At this spot ammonia content was always more high than the desirable level of WHO. According to WHO (1988), Ray (1990), Trivedi and Raj (1992), a higher concentration of ammonia is toxic to fish and aquatic lives. Absence of fishes, other vertebrates and invertebrates (eg. *Unio* sp, *Pilla* sp.) in this canal water might have been caused by the presence of higher amount of ammonia. All the calculated correlation values regarding ammonia were found to be statistically non-significant (Table-XVIII).

At **Spot-2,** the highest content of ammonia (0.60 mg/l) was observed in February, 1997, when high amount of sugar mills effluent was mixed with the power house effluents. At this time the oil-grease, COD, BOD, TDS, electric conductivity and hardness values were also found to be high (Table-II). The amount of ammonia was found to be higher than the WHO level throughout the period of study except in the rainy months of August and September, 1997. At this spot few species of fishes and Molluscs (*Pilla* sp. and *Unio* sp.) were present. But whenever the ammonia content crossed its desirable level (0.10 mg/l) death of fishes, Molluscs etc. immediately occurred. The content of ammonia was influenced by the oil-grease content of this spot. Similar findings were also made by Bhouyain (1983), Chowdhury *et al.* (1996), Trivedi and Raj (1992) in their studies. Ammonia value showed a statistically significant positive correlation with PO_4, phytoplankton and zooplankton (Table-XIX).

At **Spot-3,** the ammonia was found to be absent in the Padma river water throughout the period of study. Wave action might have stripped away ammonia from this zone, although Talukder *et al.* (1994) recorded 0.2 mg/l of ammonia from the Padma in March, 1992 and Chowdhury *et al.* (1996) recorded 0.0823 mg/l of ammonia from the Padma in April, 1995.

The mean value of ammonia of spot-1 (0.475±0.141 mg/l) and spot-2 (0.293±0.168 mg/l) indicate that the sugar mills and power house effluent always raise the content of ammonia and these study sites could be leveled as polluted.

AMMONIUM NITROGEN (NH_4.N)

Ammonium nitrogen (NH_4.N) is a state of ammonia. Its concentration is depended upon the concentration of ammonia. Ammonium nitrogen has similar kind of effect like ammonia in the aquatic environment (APHA 1989).

Ammonium nitrogen content was maximum in spot-1, minimum in spot-2, and nil in spot-3 (Table-I, II, III). Its availability depended upon the amount of effluent discharged. Nitrogen, which is an essential factor for the growth of phytoplankton was observed in its oxidized form i.e. nitrate, but some times excess nitrate create toxic water bloom (Saha *et al.*1971) and form chloramines which are toxic to fish (Tsai 1973). Amount of ammonium-nitrogen was found to cross the WHO (1988) levels in study spot-1 and spot-2.

All the calculated correlation values regarding ammonium-nitrogen in spot-1 were found to be statistically non-significant (Table-XVIII).

The ammonium-nitrogen values of the spot-2 were found have a statistically significant positive correlation with PO_4, total sulphide, phytoplankton and zooplankton (Table-XIX).

TOTAL PHOSPHATE (PO_4)

In natural water phosphorus is present in the form of phosphate (i.e. $H_2PO_4^-$, HPO_4^- and PO_4^{3-}). The prominent sources of phosphorus in natural water are industrial effluent, sewage, agricultural runoff, detergents etc. (Gautam 1990, APHA 1989). The higher concentration of phosphate causes eutrophication in natural water which indicates pollution of water. It also often implicate algal blooms in water ways.

At **Spot-1,** the highest value of phosphate (0.014 mg/l) was recorded in the month of April, 1997, immediately after the end of sugar production period. The lowest value (0.008 mg/l) was recorded in August, 1997, when water level was high due to monsoonal rains. The yearly mean value was found to be 0.011±0.0018 mg/l. Similar observations were made by Pearson and Penridge (1987), Ramjeawon and Baguant (1995) and according to them the sugar mills effluent is not a cause of phosphate increasing. Such informations are not available from the existing literature in Bangladesh. The total phosphate value was found to have a statistically significant negative correlation with phytoplankton and zooplankton (Table-XVIII).

At **Spot-2,** the maximum value of phosphate (0.08 mg/l) was observed in February, 1997, and the minimum (0.008 mg/l) was recorded in August and September, 1997. The phosphate value of this spot was lower than that of the spot-1 (Table-I,II). The present investigation indicates that the power house effluent did not contribute to increase the phosphate value. All the calculated correlation values regarding total phosphate were found to be statistically non significant (Table-XIX).

At **Spot-3,** the phosphate content was found to be nil during the period of study except in November, December, 1996. The phosphate value of Padma was dependent on the river flow dynamics and quantity and quality of the run off. In Bhagirathi river in India the phosphate value was found to vary from 0.0215 to 0.1815 mg/l in 1986 and 0.024 to 0.19017 mg/l in 1987 (Gautam 1990). The phosphate value of Padma is much lesser than that of river Bhagirathi as shown by Gautam (1990). All the calculated correlation values regarding the total phosphate were found to be statistically non significant (Table-XX).

SILICATE

The silicate is a most important constituent of the cell wall of diatoms. Mostly, it is a less soluble constituent of river water (Gautam 1990, APHA 1989), but in natural water, lower concentration of silicates is always present. An increase in its concentration enhances the growth of diatoms.

At **Spot-1,** the silicate content was always found to be nil during the period of investigation. The low abundance of diatoms also supported the present findings. Similar observations were made by Saha *et al.* (1971) and Vincent (1993).

At **Spot-2,** the silicate content was always found to be nil throughout the period of investigation. The poor abundance of diatoms at this spot supported the present investigation. Similar observations were made by Saha *et al.* (1971) and Vincent (1993).

At **Spot-3,** the silicate value in Padma water was found to vary from 0.004 to 0.158 mg/l throughout the period of study. The maximum value was recorded in the rainy month of August, 1997, when water level was maximum as Padma water rose to highest level due to monsoonal exodus of flowing water. The minimum value (0.004 mg/l) was record in winter month of January, 1997. The changing pattern of silicate was probably due to the difference in the river flow dynamics and quantity and quality of the run-off (APHA 1989, Vincent 1993, Saha *et al.* 1971). The high abundance of diatoms (*Melosira* sp. *Navicula* sp. *Pinnularia* sp. *Fragilaria* sp. etc.) also supported the present investigation. Similar observations were made by Gautam (1990) in the Bhagirathi river, in India. No such information is available from the existing literature in the Bangladesh. Silicate value was found to have a statistically significant negative correlation with total sulphide, oil-grease, phytoplankton and zooplankton (Table-XX).

TOTAL SULPHIDE

Sulphides are compounds of various industrial and sewage wastes and many natural waters get it from the anaerobic decomposition of organic matter. Discharge of industrial effluent also contribute to the concentration of sulphides. The sulphate undergoes the transformation and forms sulphide, which mainly depends on the redox conditions of water system (APHA 1989, Gautam 1990). It causes objectionable taste and colour of water at higher concentration. Different forms of sulphide are SO_4, H_2S, SO_2 etc. When sufficient organic matter and constant supply of sulphide from the wastes are insured, this stimulate the activation for sulphur reducing bacteria capable of producing hydrogen sulphide, a gas highly toxic to fish and other biota as well (Smith and Oseid 1973). Biologically produced H_2S, when oxidized, produces sulpher dioxide (SO_2). SO_2 can damage materials and properties mainly through their conversion into the highly reactive H_2SO_4 . SO_2 and H_2SO_4 are both capable of causing irritation in respiratory tracts of animals and humans and high concentrations of SO_2 cause severe heart and lung diseases (APHA 1989, Gautam 1990 etc.).

At **Spot-1,** the maximum total sulphide value (5.03 M mol l^{-1}) was recorded in December, 1996, during the sugar production period. The minimum value (0.92 M mol l^{-1}) was recorded in the rainy month of August, 1997, when sugar mills were not in function and water level rose to maximum due to rain water influx. Throughout the period of sugar production, sulphide value was always recorded high (Table-I), because the sugarcane juice is treated with sulphur dioxide gas (0.05% sulphur on sugar cane). White fumes of H_2S was also visible whenever the amount of liberated gas was high. A large number of different fish species were found dead at this spot probably due to the presence of high concentration of H_2S, when sugar mills started functioning in the month of October. Similar observations were made by Ramjeawon and Baguant (1995) in Mauritius, Pearson and Penridge (1987) in Australia, Verma and Shukla (1969) in India, Chowdhury *et al.* (1994) in Bangladesh, while working with sugar mills effluent. Except Chowdhuary *et al.* (1994), adequate information is not available in Bangladesh as yet. The villagers around the sugar mills area complained that many people suffer from pulmonary ailment when the odour of SO_2 gas is high in the sugar production period. Consequently the concentration of SO_2 was high during this period. The yearly mean value was 2.65±1.38 M mol l^{-1} which higher than the WHO (1988) standard. All the calculated correlation values regarding total sulphide were found to be statistically non significant (Table-XVIII).

At **Spot-2,** the maximum value (4.18 M mol l^{-1}) of sulphide was recorded in the month of January, 1997, when the flow of sugar mills effluent was high which mixed with the power house effluent. In December, 1996, January and February, 1997, a large number of different species of fishes and some invertebrates (*Unio* sp., *Pila* sp.) were found dead and floating, probably caused by higher concentration of H_2S. The sulphide value of this spot was always lower than that spot-1, but higher than that of Padma river (spot-3) (Table-I,II,III). The minimum value was recorded in the month of September, 1997, when the water level was high due to rain water. The mean value was higher than that of WHO (1988) standards. Total sulphide value was found to have a statistically significant positive correlation with phytoplankton and zooplankton (Table-XIX).

The **Spot-3,** is a large lotic water system, the pollution due to sulphide was observed to be a lesser degree (Table-III). Sulphide was found to be present throughout the period of study. The maximum sulphide (1.01 M mol l^{-1}) was recorded in the month of January, 1997, when the sugar mills and power house effluents mixed together and discharged into the Padma water. The minimum sulphide (0.08 M mol l^{-1}) was recorded in September, 1997, when effluent discharge ceased and the water level of Padma was maximum. The yearly mean value of this spot was 0.413±0.275 M mol l^{-1}. Similar observations were made by Gautam (1990) in the Bhagirathi river in India. The sulphide value was found to have a statistically significant positive correlation with oil-grease, phytoplankton and zooplankton (Table-XX).

OIL-GREASE

Oil-grease is a highly volatile substance, composed of hydrogen, carbon, nickel, ferrous, calcium, sodium and copper. Approximately 75% of the constituents of oil are hydrogen (Bhouyain 1983, Mishra *et al.* 1992). Temperature, transparency, pH, CO_2, CO_3 alkalinity, HCO_3 alkalinity, hardness, DO, BOD, COD values of oil polluted water are influenced by oil content (Bhouyain 1983, Trivedi and Raj 1992, Mishra *et al.* 1992, Vincent 1993). Phytoplankton and zooplankton may be coated with oil grease and get destroyed. Birds, fishes, worms, carbs and other aquatic biota are severely affected by oil pollution (Mironov 1969).

At **Spot-1,** the maximum oil-grease value (7.13 mg/l) was recorded in February, 1997, during the sugar production period, while the minimum (1.04 mg/l) was recorded in August during the off period, when water level rose to maximum due to rainfall. The yearly mean value (3.22±1.97 mg/l) reveals that a little amount of oil-grease was present in the sugar mills effluent. According to APHA (1989), Vincent (1993), Trivedi and Raj (1992), oil-grease tolerance level in any aquatic body is 10 mg/l. The canal water at this spot was below the tolerance level. Oil-grease was found to have a statistically significant negative correlation with phytoplankton (Table-XVIII).

At **Spot-2,** the maximum oil-grease value (175.68 mg/l) was recorded in the month of March, 1997, while the minimum (22.36 mg/l) was recorded in the rainy month of August, 1997, when water level was recorded high due to rainfall. The yearly mean value (66.30±47.9 mg/l) of oil-grease of this spot was far above the tolerance level (10 mg/l), creating fatal pollution. According to power house sources, the power house effluent contained about 10 to 15% High Speed Diesel (HSD) and lubricating waste oil in the mixture and the proportion of the diesel oil and lubricating oil is estimated to be about 1:5. For this reason water of this spot contained a high amount oil-grease discharged by the power house. The blackish color of water, lower value of transparency, poor DO, higher carbon dioxide, BOD, COD, hardness and poor abundance of different aquatic biota were caused by the oil spill in this spot. Similar observations were made by Trivedi and Raj (1992), Vincent (1993), Bhouyain (1983), WHO (1988). Mironov (1969) found that planktonic organisms are sensitive to the presence of oil in sea water which accelerated their death at the concentration of 0.001 mg/l. At this spot oil-grease was found to have as statistically significant positive correlation with phytoplankton (Table-X1X).

At **Spot-3,** presence of very small amount of oil-grease were recorded throughout the investigation period (Table-III). It was not traced in the month of June, July, August and September, 1997. Oil-grease showed a statistically significant positive correlation with phytoplankton and zooplankton (Table-XX).

From the present investigation of the three spots, it could be established that the power house effluent is causing a fatal oil-grease pollution in the discharging area. Adequate sludge and effluent management, treatment methods and impact assessment studies should be undertaken for the protection of the environment.

BIOLOGICAL CONDITIONS

Hussainy and Abdul (1967) stressed the importance of using biological indicators for the assessment of degree of pollution in any water body. They carried out some investigation in hydrobiology taking plankton, hydrophytes, micro and macro - invertebrates as indicator organisms to evaluate the water quality and obtained results. According to Gautam (1990), Trivedi and Raj (1992), Sarkar and Krishnamoorthi (1977), Whitton (1975), Venkateshwarlu (1986), APHA (1989), Palmer (1969), Kohler (1977) and Melzer (1981), chemical data provides quantitative data of the important pollution, whereas biological analysis may be useful in monitoring assessment and control of pollution studies. Destruction of aquatic organisms and the extent of destruction are direct reflections of the character and quantity of wastes entering a water body (Cairns and Dickson 1971). Therefore, the presence or absence of animal and plant communities provide significant information on the nature and quantity of inflowing wastes. Assessing the importance of biological parameters, investigation were carried out throughout the study period, will be discussed in the proceeding pages.

PHYTOPLANKTON

Many scientists used phytoplankton as a pollution index in different countries.

At **Spot-1**, the highest abundance of phytoplankton (64982 units / l) was recorded in August, 1997, during the rainy season, when effluent was more diluted due to rains and water level rose to its highest maximum where as the lowest abundance (27354 units/l) was recorded in April, 1997, when production period ceased. The sugar mills discharged enormous quantity of dirt and effluent when washing of the mills starts after its closure of sugar production. Bhouyain *et al.* (1978), McCauly (1966) stated that during the period of phytoplankton activities, increase in the photosynthesis rates causes a fall in CO_2 concentration and consequently increases pH values. Similar observation was also made in the present investigation (Table-I). Throughout the study period a total 29 algal genera were recorded. Maximum number of genera (27) were recorded in September, 1997, before the resumption of the production period and minimum number of genera (14) were recorded in May, 1997, immediately after the closure of the production period.The algal plankton consisted of Cyanophyceae (BGA) 52.8 %, Euglenophyceae (16.77%), Chlorophyceae (13.06%), Bacillariophyceae (Diatom) (12.21%) and Xanthophyceae (5.88%). It appears that the members of Cyanophyceae constituted the major dominant group at this spot. Similar observation was made by Rana (1977) while studying the effluent of Bhopal sugar factory in India. He recorded two species each of *Oscillatoria*, *Phormidium* and one species each of *Arthrospira* and *Euglena* including other Euglenoids. During the present investigation a total of 29 genera were recorded of which 6 belonged to Cyanophyceae, 10 to Chlorophyceae, 5 to Euglenophyceae, 4 each to Xanthophyceae and Bacillariophyceae (Table-VI). Baliarsingh *et al.* (1992) recorded 25 algal genera while working with the plankton community of sugar mills effluent at Orrisa in India, Out of which 9 belonged to Cyanophyceae, 7 to Chlorophyceae, 1 to Euglenophyceae and 7 to Bacillariophyceae. The Cyanophycean *Oscillatoria* sp. *Lyngbya* sp., *Arthrospira* sp., Chlorophycean *Chlorococcum* sp. *Spirogyra* sp., Euglenophycean *Euglena* sp., *Phacus* sp., Xanthophycean *Chlorobotrys* sp. and all detected Bacillariophycean genera were recorded throughout the investigation period. But *Chroococcus* sp., *Westella* sp., *Scenedesmus* sp., *Rhabdomonas* sp. were only recorded in the non production period (Table-VI). The Cyanophycean *Oscillatoria* sps. was the major dominant genus constituting 29.65% of the total phytoplankton population. Amongst Chlorophycean *Chlorococcum* sp. was the dominant genus (3.17%), and of the Euglenoids *Euglena* sps. constituted 10.83% of the total population. Whereas amongst the members of Xanthophyceae and Bacillariophycean *Chlorobotrys* sp. and *Nitzschia* sp. constituted 2.38% and 3.78% of the phytoplankton population respectively. The phytoplankton of the present investigation registered a lower abundance when the BOD, COD, electric conductivity, TSS, TDS, CO_2 and hardness values were high and the transparency,.pH, DO, Eh, rH_2 values were found to be low. When the BOD, COD, electric conductivity, TSS, TDS, CO_2 and hardness content were low and the transparency, pH, DO, Eh, rH_2 content were high, the phytoplankton showed higher abundance (Table-I). Similar findings were made by Pearson and Penridge (1987), Ramjeawon and Baguant (1995) while working on the sugar mills effluent in Australia and Mauritius.The phytoplankton abundance of this spot was found to have a statistically significant positive correlation with the zooplankton abundance (Table-XVIII).

Based on the Palmer (1969) index for pollution ratting (Table-XI), the present findings reveal that this spot in highly polluted with pollution tolerant genera of algae.

At **Spot -2,** the maximum phytoplankton abundance of this spot (79234 units/l) was recorded in the month of February, 1997, when the PO_4 and $NH_4.N$ values were high (Table-I). The minimum abundance (27462 units/l) was recorded in the rainy month of July, 1997. Throughout the study period 31 genera were recorded. Maximum number of genera (29) were recorded in September, 1997, before the resumption of the sugar production period, while the minimum number of genera (20) were recorded in May, 1997, when the production period ceased. Similar findings were recorded in Spot-1. No previous informations are available regarding the impact of effluent of power house, except Chowdhury *et al.* (1996).At this spot the planktonic algae comprised of Cyanophyceae (54.35%), Chlorophyceae (16.67%), Euglenophyceae (13.51%), Xanthophyceae (5.07%) and Bacillariophyceae (10.4%). It appears that the member of Cyanophyceae constituted the major dominant group at this spot. Bhouyain (1979) and Chowdhury *et al.* (1996), reported similar findings while working on the oil polluted water. Palhareya *et al.* (1993), Rana (1977), Baliarsingh *et al.* (1992), Begum and Zahangir (1993), Chowdhuary *et al.* (1996) reported that the Cyanophyceae is the most dominant group of pollution tolerant algae. During the study period a total of 31 genera were recorded of which 6 belonged to Cyanophyceae, 12 to Chlorophyceae, 5 to Euglenophyceae, 4 each to Xanthophyceae and Bacillariophyceae (Table-VII). The Cyanophycean *Oscillatoria* sp., *Lyngbya* sp., *Arthrospira* sp., Chlorophycean *Chlorogonium* sp., *Chlorococcum* sp., *Chlorella* sp., *Spirogyra* sp., Euglenophycean *Euglena* sp., *Phacus* sp., Xanthophycean *Chlorobotrys* sp. *Botryococcus* sp. and all detected Bacillariophycean genera were recorded throughout the investigation period (Table-VII). *Oscillatoria* sps. was the major dominant genera of the total phytoplankton population. *Chlorella* sp. was the dominant genera constituting 3.08% of total population. *Euglena* sp. (7.42 %), *Chlorobotrys* sp. (2.03 %) and *Nitzschia* sp. (3.06 %) were the dominant genera of Eulenophyceae, Xanthophyceae and Bacillariophyceae respectively.At spot-1, highest phytoplankton abundance was recorded in the rainy season but at spot-2 lower abundance was recorded in the rainy season (Table-I, II). Chakraborty *et al.*(1959) and Bhouyain (1979) observed that the sudden influx of water acts as a controlling factor or even lethal factor as instanced by depletion of plankton. The present investigation also corroborates with their observations. The physico-chemical conditions and high oil-grease content throughout the period of investigation at this spot reveal that the water has been polluted by the oily effluent. The tolerance level of oil-grease for the growth of phytoplankton is said to be 10 mg/l (Trivedi and Raj 1992, Bhouyain 1983). They held that a level above it, retards the phytoplankton growth and calls upon their population abundance. But the present study do not agree with them and higher values of oil-grease content and higher phytoplankton abundance have been recorded here (Table-II). The present investigation reveals that the recorded phytoplankton genera were highly tolerant to oil-grease and other pollutants. The Palmer (1969) index (Table-XI) for pollution ratting also fit well with the present findings. Accordingly, the presence of the phytoplankton genera indicate the high pollution level of this spot-2. The phytoplankton abundance was found to have a statistically significant positive correlation with zooplankton abundance (Table-XIX).

The percentage of similarity and dissimilarity co-efficient of different groups of phytoplankton in spot one and spot two [Table-IX (a)] is indicated by Cyanophyceae 83.33 %, Chlorophyceae 90.90 %, Euglenophyceae 100 %, Xanthophyceae 100% and Bacillariophyceae 100% similarity.

The Spot-3, is a running water system. The maximum phytoplankton abundance (91656 units/l) was recorded in the month of February, 1997, when the water level was high. The minimum abundance (22998 units/l) was recorded in the month of July, 1997, when Padma water was flowing very high. Throughout the study period 26 genera of algal plankton were recorded of which 3 belonged to Cyanophyceae, 5 to Chlorophyceae , 2 to Euglenophyceae, 2 to Xanthophyceae and 14 to Bacillariophyceae (Table-VIII). During the period from January to April, 1997, a total of 26 genera were recorded while only 8 and 11 genera were recorded in the rainy months of July and August, 1997, respectively. No Cyanophyceae and Euglenophyceae genera were recorded in June and August, 1997, during the rainy season when the water current of the river was very rapid. Berner (1951) found paucity of plankton and benthos in the Missouri river and concluded that swift current is perhaps the most important factor, limiting aquatic life in this river. Chakraborty *et al.* (1959) in a study on the plankton and the physico-chemical conditions of the river Januma, observed that current, turbidity and sudden influx of the river water act as a controlling factor or even lethal factor as instanced by depletion of plankton. They referred to Allen (1920), who stated that water current above a very moderate speed is distinctly determental to plankton development. The present findings also support the above mentioned findings (Table-III, VIII). At this spot algal plankton consisted of Cyanophyceae (2.42%), Chlorophyceae (4.8%), Euglenophyceae (0.44%), Xanthophyceae (2%) and Bacillariophyceae (90.24%). It appears that the members of Bacillariophyceae constituted the major dominant group at this spot. Similar observations were made by Palhareya *et al.* (1993), Bhouyain (1979), Jolly and Chapman (1966). The silicate values of this spot (Table-III) also supported the present findings. The *Melosira* sp. of diatom was the major dominant genera which constituted 40.68% of the total phytoplankton population. *Fragilaria* sp., *Navicula* sp., *Pinnularia* sp. and *Gomphonema* sp. were constituting 12.92%, 11.16%, 8.20% and 4.60% respectively of the total phytoplankton population. Throughout the period of investigation Chlorophycean *Spirogyra* sp., Xanthophycean *Chlorobotrys* sp., Bacillariophycean *Fragilaria* sp., *Nitzschia* sp., *Pinnularia* sp., *Navicula* sp. and *Gomphonema* sp. were always recorded. 2 genera of Euglenophyceae were recorded from January to April, 1997, when mixed sugar mills and power house effluent was discharged in Padma river. The dominant genera of Cyanophyceae, Chlorophyceae and Xanthophyceae were *Oscillatoria* sp. (1.73%), *Spirogyra* sp. (1.83%) and *Chlorobotrys* sp. (1.32%) respectively occurring at this spot. According to Palmer (1969) index (Table-XI) for pollution ratting, the recorded phytoplankton genera of this spot are pollution tolerant indicating the pollution status of Padma water. The phytoplankton abundance of this spot was found to have a statistically significant positive correlation with zooplankton abundance (Table-XX).

Similarity and dissimilarity co-efficient of different groups of phytoplankton in spot-1 and spot -3 [Table-IX (b)] reveal that, Cyanophyceae, Chlorophyceae, Euglenophyceae, Xanthophyceae and Bacillariophyceae have shown 66.67, 40, 57.14, 66.67 and 44.44 percent similarity respectively. In spot-2 and spot-3 [Table-IX(c)], Cyanophyceae, Chlorophyceae, Euglenophyceae, Xanthophyceae and Bacillariophyceae have shown 66.67,35.29, 57.14, 66.67 and 44.44 percent similarity respectively.

ZOOPLANKTON

Berner (1951), Tandon and Singh (1972), Ruttner (1963), Arora (1966), Lackey (1957), Sampath *et al.* (1979), Rao (1977) reported that the zooplankton are the indicators of pollution and also the trophic nature of the aquatic environment. In the present investigation, zooplankton from the study sites were collected regularly and their identification and quantitative analysis have been made.

At **Spot-1,** the maximum zooplankton abundance (75935 units/l) was recorded in September, 1997, before the resumption of the sugar production period. The minimum abundance (29169 units/l) was recorded in April immediately after the ceasation of the production period, when sugar mills washing effluent was being discharged regularly and the BOD, COD, TSS, TDS, electric conductivity and total hardness values were high. A total of 30 genera were recorded throughout the study period.Of the total population, 19 genera of Protozoa constituted 87.14%, followed by 6 genera of Rotifera (6.93%), 2 genera of Nematoda (2.1%), 2 genera of Crustaceans (1.43%) and a single genus of the Porifera (1%). It appears that the members of Protozoa constituted the major dominant group at this spot. Protozoan *Loxocephalus* sp. was the major dominant genera, which alone constituting 34.55% of the total zooplankton population, whereas Protozoan *Cohnilembus* sp. constituted only 0.28% during the study period. The second dominant genus was Protozoan's *Paramecium* sp. which constituted 24.76% of the total population. The highest number of genera (30 genera) were recorded in October, 1997 and only 12 genera were recorded in April, 1997. Maximum number of Rotifer genera and their high abundance were recorded in non production period (Table-XII). According to Arora (1966) and APHA (1989), Rotifers indicate the degree of pollution. Tandon and Singh (1972), Ruttner (1963), Calaway and Lackey (1962) observed that the high abundance of Protozoa indicate the high rate of pollution. The present study also corroborates with the above findings. Baliarsingh *et al.* (1992) while studying the impact of sugar mills effluent on zooplankton population in India, recorded 21 genera of zooplankton of which 6 belonged to Protozoa, 4 to Diptera, 4 to Cladocera, 3 to Rotifera and 3 to Ostracoda which is similar to the present findings. *Notholca* sp. (1.92%) *Rhabdolaimus* sp. (1.31%) and *Naupilus* sp. (0.75%) were the dominant genera of Rotifera, Nematoda and Crustacea groups respectively. The zooplankton status of this spot indicate that spot-1 was highly polluted by sugar mills effluent.

At **Spot-2,** the maximum zooplankton abundance (97825 units/l) was recorded in the month of December, 1996, when sugar mills was in production. The minimum abundance (33637 units/l) was record in the rainy month of July, 1997, when water level attained maximum highest due to rainfall.' Throughout the period of study a total of 32 genera of zooplankton were recorded of which 20 genera belonged to Protozoa, 7 to Rotifera, 2 to Nematoda, 2 to Crustacea and 1 to Porifera. The Protozoa consisted of 93.15%, Rotifera, 4.43%, Nematoda 0.78%, Crustacean 0.41% and Porifera 1.23% of the total zooplankton population (Table-XIII). The highest number of genera (32) were recorded in the month of September, 1997, and the lowest number of genera (16) were recorded in April, 1997, during the sugar production period. It appears that in the month of April, 1997, this spot was highly polluted by the sugar mills and power house effluents. Except Chowdhury *et al.* (1994), this type of report is not available in the country. The members of Protozoa constituted the major dominant group of this spot. Protozoan *Loxocephalus* sp. was the major dominant genera, throughout the period of study which alone constituted 33.19% of the total population whereas Crustacean *Cyclops* sp. was the least recorded genus constituting 0.23% of the total zooplankton population. Protozoan *Uronema* sp. and *Paramecium* sp. constituted 18.47% and 17.80% of the total population respectively. During the study period the highest abundance of Protozoan members and lowest abundance of Crustacean members (only recorded in the rainy season when effluent was more diluted due to rainfall) (Table-XIII), indicate high level of pollution at this spot.Throughout the study period Rotiferas members *Notholca* sp. and *Brachionus* sp. constituted only 1.35% and 0.80% abundance respectively which also indicate the pollution level. Chowdhury *et al.* (1996), Bhouyain (1979), APHA (1989), Jolly and Chapman (1966), Cairns and Dickson (1971) also made similar observations. Lackey (1957) reported that high abundance of Protozoa indicate a polluted conditions of a water body. The maximum abundance of Protozoa were recorded in sugar production period whereas the minimum was recorded in non-production month of July, 1997 (Table-XIII). High oil-grease content (66.30±47.9 mg/l) at this spot indicate that the zooplankton genera were also tolerant to oil-grease pollution. Similar observations were made by Chowdhury *et al.* (1996).*Notholca* sp. (1.35%), *Rhabdolaimus* sp. (0.61%) and *Cyclops* sp. were the dominant genera of Rotifera, Nematoda and Crustacea respectively. The only Poriferan *Spongilla* sp. was recorded throughout the study period. It is apparent that the prevailing effluent load with the existing physico-chemical conditions have provided congenial conditions for the occurrence of the Protozoans in particular at spot-1 and spot-2.

At **Spot-3,** the maximum zooplankton abundance (63684 units/l) was recorded in January, 1997 and the minimum (3990 units/l) was recorded in the rainy month of August, 1997, when transparency value was only 6 cm, with higher value of TSS (340 mg/l) and the river current was very swift with highest water level. Tandon and Singh (1972) found that during the monsoon high turbidity and TSS values result in the death of plankton. Similar views were also expressed by Welch (1952), Roy (1955) and Chakraborty *et al.* (1959). Berner (1951) and Chander (1940) stated that large quantities of suspended materials could injure plankters through mechanical action or by carrying them to the bottom during settling. Chakraborty *et al.* (1959) in a study on the plankton and the physico-chemical conditions of the river Jamuna, observed that rapid current, turbidity and sudden influx of the river water act as a controlling factor or even lethal factor resulting in the depletion of plankton population. Similar conclusion may also be made in connection with the present findings, as only 4 genera were recorded in the rainy season (Table-XIV). During the study period, a total number of 21 genera were recorded, of which 6 genera belonged to Rotifera (51.93%), 6 genera to Protozoa (17.02%), 5 genera to Cladocera (8.55%) and 4 genera to Copepoda (22.5%). It appears that Rotifera was the major dominant group of this spot, with *Brachionus* sp. as the major dominant genus which constituted 14.57% of the total population. Other major dominant genera of Rotifera were *Notholca* sp. (13.71%), *Keratella* sp. (11.23%) and *Lecane* sp. (7.09%). Copepodan *Cyclops* sp., *Mesocyclops* sp. *Diaptomus* sp., and *Naupilus* sp., were recorded throughout the whole study period. *Cyclops* sp., was the dominant genus of Copepods constituting 7.50% of the total zooplankton population. The dominant genus of Cladocera was *Daphnia* sp. which constituted 2.13% of the total population. A lesser number of genera and low abundance of Protozoa indicate a lesser degree of pollution in this spot in comparison to spot-1 and spot-2.Similar results were also obtained by Bhouyain (1979), Naz *et al.* (1996), Tandon and Singh (1972) findings, while working on the different polluted habitats.

It was clear from the composition and abundance of the phyto-and zooplankton in three study spots that spot-1 and spot-2 were dominated by zooplankton with 54.83% and 58.65% respectively while spot-3 was dominated by phytoplankton with an abundance of 65.09% (Figure-1).

MACRO VEGETATION

Kohler (1977), Melzer (1976, 1981), suggest that aquatic macrophytes can also be used as biological indicators and for monitoring water pollution. Tourbier and Pearson (1976), Godfrey *et al.* (1985), Athie and Cerri (1986), Reddy and Smith (1987) held that some macrophytes, especially water hyacinth, lemnids and cattails, have a potential to absorb and accumulate nutrients and toxic pollutants from waste water effluents. So aquatic macrophytes also make an important contribution to the ecological balance of any water body. Pollution or eutrophication of water occurs due to an increase in plant nutrients with consequent changes in the physical, chemical and biological characteristics (Vollenwider 1979).

At **Spot-1,** a total of 11 genera of macrophytes were recorded (Table-XVI) during the study period. They were *Eichhornia* sp., *Spirodela* sp., *Lemna* sp., *Enhydra fluctuans*, *Marsilea* sp., *Jussiaea* sp., *Ipomoea reptans*, *Colocasia* sp. and the aquatic weeds were represented by *Cyperus esculentus*, *Imperata cylendrica* and *Cyperus difformis*. Dense growth of hydrophytes and macrophytes were observed in August, 1997, during the rainy season and lowest were recorded in December, 1996, during the sugar production period extending upto April, 1997 (Table-XVI). *Eichhornia* sp., *Marsilea* sp., *Jussiaea* sp., *Cyperus esculentus* and *Cyperus difformis* were recorded throughout the study period. *Ipomoea reptans* and *Colocasia* sp. were recorded twice only (Table-XVI). *Eichhornia* sp. were found to be in higher abundance in this spot followed by *Marsilea* sp. and *Jussiaea* sp. Trivedi and Raj (1992) considered *Eichhornia* sp. as a pollution tolerant hydrophytes as it is capable of absorbing different kinds of heavy metals for its growth. Many workers including Baily and Litterick (1993) and Trivedi (1993) held that *Eichhornia* sp. and *Lemna* sp., probably act as waste water treatment agents. According to Harly (1993) there is no doubt that plants that grow fast on water are capable of removing pollutants and wastes from water used by people. The sugar mills effluent consisted of solid and semisolid matter which formed a thick surface scum and grasses were found to grew abundantly over it. Keya (1996) reported 20 genera of hydrophytes while working on the aquatic plants in Rajshahi University campus which is about two kilometers away from the present study spot. Similar hydrophytes *Eichhornia* sp., *Marsilea* sp. *Lemna* sp. and *Ipomoea* sp. were recorded in this spot. So the findings of the present study indicate that the recorded hydrophytes are tolerant to polluted conditions caused by effluents from the sugar mills.

At **Spot-2,** a total of ten genera were recorded. These are *Eichhornia* sp., *Spirodella* sp., *Lemna* sp., *Enhydra fluctuans, Marsilea* sp., *Jussiaea* sp., *Ipomoea reptans, Colocasia* sp., *Polygonum hydropiper,* and *Cyperus esculentus* (Table-XVII). *Eichhornia* sp. was the dominant member followed by *Lemna* sp. Both the *Eichhornia* sp. and *Lemna* sp. were the distinctive features of this aquatic body which probably acted as agents for recovering the water from pollution as emphasized by Bailey and Litterick (1993), Trivedi (1993), Kohler and Labus (1983), Best (1982) and Godfrey *et al.* (1985). The maximum abundance of hydrophytes were recorded in September, 1997 and minimum were during the period from February to April, 1997 (Table-XVII). A scanty growth of *Cyperus esculentus* (Aquatic weeds) was recorded throughout the study period except from June to August, 1997. The recorded hydrophytes of this spot indicate that they are tolerant to similar polluted conditions caused by effluents from the power generating station and the sugar mills, as well.

The **Spot-3,** is a lotic water system. So no rooted emergent or free floating hydrophytes were recorded in this spot. Occasionally various hydrophytes such as *Vallisnaria* sp. was found in the running water in floating condition. Sporadic floating formations of *Eichhornia* sp. were also found to pass down with the strong current.

All aquatic plants and animals manifest different degrees of sensitivity to the prevailing physical and chemical conditions of their surrounding environment, as is evidenced from the present study. Recently Goodnight (1973) dealt in length about such sensitivities in his studies.

THE MULTIPLE REGRESSION

SAMPLING SPOT-1 (Table-XXI)

Equation -I

The regression equation-I indicates that 42.26% variation of air temperature is explained by calcium hardness (X_{17}), total sulphide (X_{22}) and oil-grease (X_{23}). The co-efficient of calcium hardness (X_{17}) indicates that if calcium hardness increases by one unit then air temperature (X_1) will decrease by 0.0303 unit. The co-efficient of total sulphide (X_{22}) and oil-grease (X_{23}) indicate that if total sulphide and oil-grease increase by one unit then the air temperature (X_1) will increase by 692.078 and 0.3463 units respectively. The co-efficient of calcium hardness is significant but total sulphide and oil-grease are nonsignificant.

Equation - II

The regression equation-II indicates that 59.96% variation of water temperature (X_2) is explained by Eh (X_8), COD (X_{11}) and total sulphide (X_{22}). The co-efficient of Eh (X_8), COD (X_{11}) and total sulphide (X_{22}) indicate that if Eh, COD and total sulphide increase by one unit then water temperature (X_2) will decrease by 73.1843, 0.21545 and 593.1653 units respectively. The co-efficient of Eh is significant but COD and total sulphide are nonsignificant.

Equation - III

The regression equation-III indicates that 97.92% variation of transparency (X_3) is explained by TSS (X_4), TDS (X_5), BOD (X_{10}), electric conductivity (X_{12}), chloride (X_{13}), calcium hardness (X_{17}), total phosphate (X_{21}), oil-grease (X_{23}), phytoplankton (X_{24}) and zooplankton (X_{25}). The co-efficient of TSS (X_4), BOD (X_{10}), electric conductivity (X_{12}) and oil-grease (X_{23}) indicate that if TSS, BOD, electric conductivity and oil-grease increase by one unit then transparency (X_3) will decrease by 0.0823, 0.2755, 0.0191 and 0.81031 units respectively. The co-efficient of TDS (X_5), chloride (X_{13}), Calcium hardness (X_{17}), total phosphate (X_{21}), phytoplankton (X_{24}) and zooplankton (X_{25}) indicate that if TDS, chloride, calcium hardness, total phosphate, phytoplankton, and zooplankton increase by one unit then transparency (X_3) will increase by 0.0077, 0.00895, 0.02468, 38.5512, 1.53324 and 0.00093 units respectively. None of the co-efficient is statistically significant.

Equation - IV

The regression equation-IV indicates that 93.78% variation of TSS (X_4) is explained by TDS (X_5), electric conductivity (X_{12}), chloride (X_{13}), HCO_3 alkalinity (X_{15}), total phosphate (X_{21}), phytoplankton (X_{24}) and zooplankton (X_{25}). The co-efficient of electric conductivity (X_{12}) indicates that if electric conductivity increases by one unit then TSS (X_4) will decrease by 0.16681 unit. The co-efficient of TDS (X_5), chloride (X_{13}), HCO_3 alkalinity (X_{15}), total phosphate (X_{21}), phytoplankton (X_{24}) and zooplankton (X_{25}) indicate that if TDS, chloride, HCO_3 alkalinity, total phosphate, phytoplankton and zooplankton increase by one unit then TSS (X_4) will increase by 0.07946, 0.12975, 0.14566, 266.2578, 16.3298 and 0.00602 units respectively. The co-efficient of chloride, HCO_3 alkalinity, total phosphate, phytoplankton and zooplankton are statistically nonsignificant but TDS and electric conductivity are significant.

Equation - V

The regression equation-V indicates that 92.54% variation of TDS (X_5) is explained by rH_2 (X_9), BOD (X_{10}), electric conductivity (X_{12}), total phosphate (X_{21}), phytoplankton (X_{24}) and zooplankton (X_{25}). The co-efficient of rH_2 (X_9), electric conductivity (X_{12}), total phosphate (X_{21}), phytoplankton (X_{24}) and zooplankton (X_{25}) indicate that if rH_2, electric conductivity, total phosphate, phytoplankton and zooplankton increase by one unit then TDS (X_5) will decrease by 1001.762, 0.30758, 3053.777, 513.0295 and 0.10189 units respectively. The co-efficient of BOD (X_{10}) indicates that if BOD increases by one unit then TDS (X_5) will decrease by 193.2718 unit.The co-efficient of rH_2, BOD, electric conductivity and total phosphate are statistically nonsignificant but phytoplankton and zooplankton are significant.

Equation - VI

The regression equation-VI indicates that 64.48% variation of pH (X_6) is explained by DO (X_7), CO_2 (X_{14}), NH_4 (X_{18}), NH_3 (X_{19}) $NH_4.N$ (X_{20}) and total sulphide (X_{22}). The co-efficient of CO_2 (X_{14}), NH_4 (X_{18}) and NH_3 (X_{19}) indicate that if CO_2, NH_4 and NH_3 increase by one unit then pH (X_6) will decrease by 0.00298, 0.00124 and 156.7167 units respectively. The co-efficient of DO (X_7), $NH_4.N$ (X_{20}) and total sulphide (X_{22}) indicate that if DO, $NH_4.N$ and total sulphide increase by one unit then pH (X_6) will increase by 0.5798, 164.332 and 129.0134 units respectively. None of the co-efficient is statistically significant.

Equation - VII

The regression equation-VII indicates that 62.45% variation of DO (X_7) is explained by Eh (X_8), rH_2 (X_9), NH_4 (X_{18}), NH_3 (X_{19}) and $NH_4.N$ (X_{20}). The co-efficient of rH_2 (X_9) and $NH_4.N$ (X_{20}), indicate that if rH_2 and $NH_4.N$ increase by one unit then DO (X_7) will decrease by 0.091652 and 50.00193 units respectively. The co-efficient of Eh (X_8), NH_4 (X_{18}) and NH_3 (X_{19}) indicate that if Eh, NH_4 and NH_3 increase by one unit then DO (X_7) will increase by 7.8239, 0.000487 and 46.74364 units respectively. None of the co-efficient is statistically significant.

Equation - VIII

The regression equation-VIII indicates that 84.69% variation of BOD (X_{10}) is explained by electric conductivity (X_{12}), CO_2 (X_{14}), total hardness (X_{16}), calcium hardness (X_{17}), total phosphate (X_{21}), oil-grease (X_{23}), phytoplankton (X_{24}) and zooplankton (X_{25}). The co-efficient of CO_2 (X_{14}), total phosphate (X_{21}), oil-grease (X_{23}) and zooplankton (X_{25}) indicate that if CO_2, total phosphate, oil-grease and zooplankton increase by one unit then BOD (X_{10}) will decrease by 0.000098, 12.569, 0.049416, and 0.0000424 units respectively. The co-efficient of electric conductivity (X_{12}), total hardness (X_{16}), calcium hardness (X_{17}) and phytoplankton (X_{24}) indicate that if electric conductivity, total hardness, calcium hardness and phytoplankton increase by one unit then BOD (X_{10}) will increase by 0.000338, 0.011999, 0.011574 and 1.116615 units respectively. None of the co-efficient is statistically significant.

Equation - IX

The regression equation-IX indicates that 68.67% variation of COD (X_{11}) is explained by total hardness (X_{16}), calcium hardness (X_{17}) and total sulphide (X_{22}). The co-efficient of total hardness (X_{16}) indicates that if total hardness increase by one unit then COD (X_{11}) will decrease by 0.001506 unit. The co-efficient of calcium hardness (X_{17}) and total sulphide (X_{22}) indicate that if calcium hardness and total sulphide increase by one unit then COD (X_{11}) will increase by 0.008235 and 1134.664 units respectively. None of the co-efficient is statistically significant.

Equation - X

The regression equation-X indicates that 64.06% variation of electric conductivity (X_{12}) is explained by chloride (X_{13}), CO_2 (X_{14}) and phytoplankton (X_{24}). The co-efficient of CO_2 (X_{14}) indicates that if CO_2 increases by one unit then electric conductivity (X_{12}) will decrease by 13.06856 unit. The co-efficient of chloride (X_{13}) and phytoplankton (X_{24}) indicate that if chloride and phytoplankton increase by one unit then electric conductivity (X_{12}) will increase by 1.532486 and 69.39468 unit respectively. The co-efficient of chloride and CO_2 are statistically significant but phytoplankton is nonsignificant.

Equation - XI

The regression equation-XI indicates that 16.65% variation of chloride (X_{13}) is explained by HCO_3 alkalinity (X_{15}) and phytoplankton (X_{24}). The co-efficient of HCO_3 alkalinity(X_{15}) and phytoplankton (X_{24}) indicate that if HCO_3 alkalinity and phytoplankton increase by one unit then chloride (X_{13}) will increase by 4.942468 and 22.86187 units respectively. None of the co-efficient is statistically significant.

Equation - XII

The regression equation-XII indicates that 26.74% variation of CO_2 (X_{14}) is explained by calcium hardness (X_{17}) and total sulphide (X_{22}). The co-efficient of calcium hardness (X_{17}) and total sulphide (X_{22}) indicate that if calcium hardness and total sulphide increase by one unit then CO_2 (X_{14}) will increase by 0.029293 and 8777.593 unit respectively. None of the co-efficient is statistically significant.

Equation - XIII

The regression equation-XIII indicates that 36.40% variation of HCO_3 alkalinity (X_{15}) is explained by NH_4 (X_{18}), NH_3 (X_{19}), $NH_4.N$ (X_{20}) and zooplankton (X_{25}). The co-efficient of $NH_4.N$ (X_{20}) indicates that if $NH_4.N$ increases by one unit then HCO_3 alkalinity (X_{15}) will decrease by 17072.85 unit. The co-efficient of NH_4 (X_{18}), NH_3 (X_{19}) and zooplankton (X_{25}) indicate that if NH_4, NH_3 and zooplankton increase by one unit then HCO_3 alkalinity (X_{15}) will increase by 0.129624, 16184.66 and 0.000941 units respectively. None of the co-efficient is statistically significant.

Equation - XIV

The regression equation-XIV indicates that 41.41% variation of total hardness (X_{16}) is explained by calcium hardness (X_{17}) and total sulphide (X_{22}). The co-efficient of calcium hardness (X_{17}) indicates that if calcium hardness increases by one unit then total hardness will decrease by 0.584603 unit. The co-efficient of total sulphide (X_{22}) indicates that if total sulphide increases by one unit then total hardness (X_{16}) will increase by 61299.71 unit. The co-efficient of calcium hardness is statistically non significant but total sulphide is significant.

Equation - XV

The regression equation-XV indicates that 61.38% variation of calcium hardness (X_{17}) is explained by total phosphate (X_{21}), total sulphide (X_{22}), oil-grease (X_{23}) and phytoplankton (X_{24}). The co-efficient of total phosphate (X_{21}) indicates that if total phosphate increases by one unit then calcium hardness (X_{17}) will decrease by 244.933 unit. The co-efficient of total sulphide (X_{22}), oil-grease (X_{23}) and phytoplankton (X_{24}) indicate that if total sulphide, oil-grease and phytoplankton increase by one unit then calcium hardness (X_{17}) will increase by 22523.15, 14.63506 and 23.01879 units respectively. None of the co-efficient is statistically significant.

Equation - XVI

The regression equation-XVI indicates that 34.32% variation of total phosphate (X_{21}) is explained by phytoplankton (X_{24}) and zooplankton (X_{25}). The co-efficient of zooplankton (X_{25}) indicates that if zooplankton increases by one unit then total phosphate (X_{21}) will decrease by 0.00000405 unit. The co-efficient of phytoplankton (X_{24}) indicates that if phytoplankton increases by one unit then total phosphate (X_{21}) will increase by 0.01323 unit. None of the co-efficient is statistically significant.

Equation - XVII

The regression equation-XVII indicates that 5.61% variation of oil-grease (X_{23}) is explained by phytoplankton (X_{24}). The co-efficient of phytoplankton (X_{24}) indicates that if phytoplankton increases by one unit then oil-grease (X_{23}) will increase by 0.602369 unit. The co-efficient is statistically non significant.

SAMPLING SPOT-2 (TABLE-XXII)

Equation - I

The regression equation-I indicates that 94.91% variation of transparency (X_1), is explained by TSS (X_2) TDS (X_3), DO (X_5), Eh (X_6), rH_2 (X_7) COD (X_9) and electric conductivity (X_{10}). The co-efficient of TSS (X_2), TDS (X_3), rH_2 (X_7) and electric conductivity (X_{10}) indicate that if TSS, TDS, rH_2 and electric conductivity increase by one unit then transparency (X_1) will decrease by 0.001912, 0.002548, 2.781157 and 0.000226 units respectively. The co-efficient of DO (X_5), Eh (X_6) and COD (X_9) indicate that if DO, Eh and COD increase by one unit then transparency (X_1) will increase by 4.8856, 13.2898 and 0.0000626 units respectively. The co-efficient of TSS, DO, Eh, rH_2, COD and electric conductivity are statistically non significant but TDS is significant.

Equation - II

The regression Equation-II indicates that 98.05% variation of, TSS (X_2) is explained by TDS (X_3), pH (X_4), BOD (X_8), COD (X_9), chloride (X_{11}), CO_3 alkalinity (X_{13}) and oil-grease (X_{23}). The co-efficient of TDS (X_3), pH (X_4) and COD (X_9) indicate that if TDS, pH and COD increase by one unit then TSS (X_2) will decrease by 0.03401, 8.88567 and 0.05925 units respectively. The co-efficient of BOD (X_8), chloride (X_{11}), CO_3 alkalinity (X_{13}) and oil-grease (X_{23}) indicate that if BOD, chloride, CO_3 alkalinity and oil-grease increase by one unit then TSS (X_2) will increase by 10.49468, 0.205453, 3.667134 and 1.331358 units respectively. The co-efficient of TDS, pH, BOD, COD, cloride and oil-grease are statistically nonsignificant but CO_3 alkalinity is significant.

Equation - III

The regression equation-III indicates that 76.16% variation of pH (X_4) is explained by CO_2 (X_{12}) and phytoplankton (X_{24}). The co-efficient of CO_2 (X_{12}) indicates that if CO_2 increases by one unit then pH (X_6) will decrease by 0.048167 unit. The co-efficient of phytoplankton (X_{24}) indicates that if phytoplankton increases by one unit then pH (X_4) will increase by 0.0000235 unit.All the co-efficient are statistically significant.

Equation - IV

The regression equation-IV indicates that 68.94% variation of COD (X_9) is explained by electric conductivity (X_{10}), chloride (X_{11}), oil-grease (X_{23}) and phytoplankton (X_{24}). The co-efficient of chloride (X_{11}) indicates that if chloride increases by one unit then COD (X_9) will decrease by 0.591243 unit. The co-efficient of electric conductivity (X_{10}), oil-grease (X_{23}) and phytoplankton (X_{24}), indicate that if electric conductivity, oil-grease and phytoplankton increase by one unit then COD (X_9) will increase by 0.134424, 0.49661 and 0.002331 units respectively. None of the co-efficient is statistically significant.

Equation - V

The regression equation-V indicates that 91.09% variation of electric conductivity (X_{10}) is explained by chloride (X_{11}) and oil-grease (X_{23}). The co-efficient of chloride (X_{11}) and oil-grease (X_{23}) indicate that if chloride and oil-grease increase by one unit then electric conductivity (X_{10}) will increase by 8.871205 and 4.873765 units respectively. All the co-efficient are statistically significant.

Equation - VI

The regression equation-VI indicates that 58.60% variation of chloride (X_{11}) is explained by oil-grease (X_{23}). The co-efficient of oil-grease (X_{23}) indicates that if oil-grease increases by one unit then chloride will increase by 0.474324 unit.The co-efficient is statistically significant.

Equation - VII

The regression equation-VII indicates that 80.19% variation of CO_2 (X_{12}) is explained by HCO_3 alkalinity (X_{14}), total hardness (X_{15}), magnesium hardness (X_{17}) and total sulphide (X_{22}). The co-efficient of total sulphide (X_{22}) indicates that if total sulphide increases by one unit then CO_2 (X_{12}) will decrease by 3.329646 unit. The co-efficient of HCO_3 alkalinity (X_{14}), total hardness (X_{15}) and magnesium hardness (X_{17}) indicate that if HCO_3 alkalinity, total hardness and magnesium hardness increase by one unit then CO_2 (X_{12}) will increase by 0.113519, 0.008632 and 0.65216 units respectively. None of the co-efficient is statistically significant.

Equation - VIII

The regression equation-VIII indicates that 89.92% variation of HCO_3 alkalinity (X_{14}) is explained by total hardness (X_{15}), calcium hardness (X_{16}), NH_4 (X_{18}), NH_3 (X_{19}), NH_4.N (X_{20}), total sulphide (X_{22}), phytoplankton (X_{24}) and zooplankton (X_{25}). The co-efficient of total hardness (X_{15}), NH_3 (X_{19}), NH_4.N (X_{20}) and phytoplankton (X_{24}) indicate that if total hardness, NH_3, NH_4.N and phytoplankton increase by one unit then HCO_3 alkalinity (X_{14}) will decrease by 0.366151, 371608.1, 29333.78 and 0.004393 units respectively. The co-efficient of calcium hardness (X_{16}), NH_4 (X_{18}), total sulphide (X_{22}) and zooplankton (X_{25}) indicate that if calcium hardness, NH_4, total sulphide and zooplankton increase by one unit then HCO_3 alkalinity (X_{14}) will increase by 0.195582, 373260.5, 74.0934 and 0.003048 units respectively. None of the co-efficient is statistically significant.

Equation - IX

The regression equation-IX indicates that 100% variation of total hardness (X_{15}) is explained by calcium hardness (X_{16}), magnesium hardness (X_{17}), NH_4 (X_{18}), NH_3 (X_{19}), NH_4.N (X_{20}), total sulphide (X_{22}), phytoplankton (X_{24}) and zooplankton (X_{25}). The co-efficient of NH_3 (X_{19}), NH_4.N (X_{20}), total sulphide (X_{22}) and zooplankton (X_{25}) indicate that if NH_3, NH_4.N, total sulphide and zooplankton increase by one unit then total hardness (X_{15}) will decrease by 4583.192, 372.0718, 0.479134 and 0.000017 units respectively. The co-efficient of calcium hardness (X_{16}), magnesium hardness (X_{17}), NH_4 (X_{18}) and phytoplankton (X_{24}) indicate that if calcium hardness, magnesium hardness, NH_4 and phytoplankton increase by one unit then total hardness (X_{15}) will increase by 1.007957 , 4.095716, 4606.46 and 0.000061 units respectively. The co-efficient of magnesium hardness, NH_4, NH_3, NH_4.N, total sulphide, phytoplankton and zooplankton are statistically nonsignificant but calcium hardness is significant.

Equation - X

The regression equation-X indicate that 96.75% variation of calcium hardness (X_{16}) is explained by NH_4 (X_{18}), NH_3 (X_{19}), NH_4.N (X_{20}), total sulphide (X_{22}), phytoplankton (X_{24}) and zooplankton (X_{25}). The co-efficient of NH_4 (X_{18}) and phytoplankton (X_{24}) indicate that if NH_4 and phytoplankton increase by one unit then calcium hardness (X_{16}) will decrease by 169790.8 and 0.000339 units respectively. The co-efficient of NH_3 (X_{19}), NH_4.N (X_{20}), total sulphide

(X_{22}) and zooplankton (X_{25}) indicate that if NH_3, $NH_4.N$, total sulphide and zooplankton increase by one unit then calcium hardness (X_{16}) will increase by 169434.9, 12966.05, 23.69863 and 0.002139 units respectively.The co-efficient of NH_4 ,NH_3,$NH_4.H$, total sulphide and phytoplankton are statistically nonsignificant but zooplankton is significant.

Equation - XI

The regression equation-XI indicates that 69.92% variation of NH_4 (X_{18}) is explained by total phosphate (X_{21}), phytoplankton (X_{24}) and zooplankton (X_{25}). The co-efficient of zooplankton (X_{25}) indicates that if zooplankton increases by one unit then NH_4 (X_{18}) will decrease by 0.00000068 unit. The co-efficient of total phosphate (X_{21}) and phytoplankton (X_{24}) indicate that if total phosphate and phytoplankton increase by one unit then NH_4 (X_{18}) will increase by 2.888656 and 0.00000704 units respectively.None of the co-efficient is statistically significant.

Equation - XII

The regression equation-XII indicates that 69.57% variation of NH_3 (X_{19}) is explained by total phosphate (X_{21}), phytoplankton (X_{24}) and zooplankton (X_{25}). The co-efficient of zooplankton (X_{25}) indicates that if zooplankton increases by one unit then NH_3 (X_{19}) will decrease by 0.000000667 unit. The co-efficient of total phosphate (X_{21}) and phytoplankton (X_{24}) indicate that if total phosphate and phytoplankton increase by one unit then NH_3 (X_{19}) will increase by 2.717774 and 0.00000673 units respectively. None of the co-efficient is statistically significant.

Equation - XIII

The regression equation-XIII indicates that 84.54% variation of $NH_4.N$ (X_{20}) is explained by total phosphate (X_{21}), total sulphide (X_{22}), phytoplankton (X_{24}) and zooplankton (X_{25}). The co-efficient of zooplankton (X_{25}) indicates that if zooplankton inecreases by one unit then $NH_4.N$ (X_{20}) will decrease by 0.00000091 unit. The co-efficient of total phosphate (X_{21}), total sulphide (X_{22}) and phytoplankton (X_{24}), indicate that if total phosphate, total sulphide and phytoplankton increase by one unit then $NH_4.N$ (X_{20}) will increase by 1.78999, 0.061599, 0.000000642 units respectively. None of the co-efficient is statistically significant.

Equation - XIV

The regression equation-XIV indicates that 81.86% variation of total sulphide (X_{22}) is explained by phytoplankton (X_{24}) and zooplankton (X_{25}). The co-efficient of phytoplankton (X_{24}) and zooplankton (X_{25}) indicate that if phytoplankton and zooplankton increase by one unit then total sulphide (X_{22}) will increase by 0.0000688 and 0.00000964 units respectively. The co-efficient of phytoplankton is statistically significant but zooplankton is statistically nonsignificant.

Equation - XV

The regression equation-XV indicates that 50.34% variation of oil-grease (X_{23}) is explained by phytoplankton (X_{24}). The co-efficient of phytoplankton (X_{24}) indicates that if phytoplankton increases by one unit then oil-grease (X_{23}) will increase by 0.002102 unit. The co-efficient is statistically significant.

Equation - XVI

The regression equation-XVI indicates that 73.61% variation of phytoplankton (X_{24}) is explained by zooplankton (X_{25}). The co-efficient of zooplankton (X_{25}) indicates that if zooplankton increases by one unit then phytoplankton (X_{24}) will increase by 0.719756 unit. The co-efficient is statistically significant.

SAMPLING SPOT-3 (TABLE: XXIII)

Equation - I

The regression equation-I indicates that 98.07% variation of air temperature (X_1) is explained by water temperature (X_2), TDS (X_4), DO (X_6), COD (X_{10}), CO_3 alkalinity (X_{14}) and total sulphide (X_{19}). The co-efficient of COD (X_{10}), CO_3 alkalinity (X_{14}) and total sulphide (X_{19}) indicate that if COD, CO_3 alkalinity and total sulphide increase by one unit then air temperature (X_1) will decrease by 0.017772, 0.00563 and 0.273006 units respectively. The co-efficient of water temperature (X_2), TDS (X_4) and DO (X_6) indicate that if water temperature, TDS and DO increase by one unit then air temperature (X_1) will increase by 0.634281, 0.00459 and 0.755282 units respectively. The co-efficient of water temperature, TDS, DO, CO_3 alkalinity and total sulphide are statistically nonsignificant but COD is significant.

Equation - II

The regression equation-II indicates that 53.93% variation of transparency (X_3) is explained by COD (X_{10}) and CO_3 alkalinity (X_{14}). The co-efficient of COD (X_{10}) indicates that if COD increases by one unit then transparency (X_3) will decrease by 0.122364 unit. The co-efficient of CO_3 alkalinity (X_{14}) indicates that if CO_3 alkalinity increases by one unit then transparency (X_3) will increase by 0.623571 unit. None of the co-efficient is statistically significant.

Equation - III

The regression equation-III indicates that 71.90% variation of pH (X_5) is explained by CO_2 (X_{13}) and CO_3 alkalinity (X_{14}). The co-efficient of CO_2 (X_{13}), and CO_3 alkalinity (X_{14}) indicate that if CO_2 and CO_3 alkalinity increase by one unit then pH (X_5) will decrease by 0.284962 and 0.005226 unit respectively. The co-efficient of CO_2 is statistically significant but CO_3 alkalinity is nonsignificant.

Equation - IV

The regression equation-IV indicates that 100% variation of Eh (X_7) is explained by rH_2 (X_8), BOD (X_9), electric conductivity (X_{11}), CO_3 alkalinity (X_{14}), silicate (X_{18}), total sulphide (X_{19}), oil-grease (X_{20}), phytoplankton (X_{21}) and zooplankton (X_{22}). The co-efficient of BOD (X_9), CO_3 alkalinity (X_{14}), silicate (X_{18}), oil-grease (X_{20}) and phytoplankton (X_{21}) indicate that if BOD, CO_3 alkalinity, silicate, oil-grease and phytoplankton increase by one unit then Eh (X_7) will decrease by 0.073281, 0.010141, 0.144767, 0.113108 and 0.00000107 units respectively. The co-efficient of rH_2 (X_8), electric conductivity (X_{11}), total sulphide (X_{19}) and zooplankton (X_{22}) indicate that if rH_2, electric conductivity, total sulphide and zooplankton increases by one unit then Eh (X_7) will increase by 0.170339, 0.000603, 0.169588 and 0.00000894 units respectively. All the co-efficient are statistically significant except oil-grease.

Equation - V

The regression equation-V indicates that 98.14% variation of rH_2 (X_8) is explained by electric conductivity (X_{11}), silicate (X_{18}), total sulphide (X_{19}), oil-grease (X_{20}), phytoplankton (X_{21}) and zooplankton (X_{22}). The co-efficient of electric conductivity (X_{11}), silicate (X_{18}), total sulphide (X_{19}), oil-grease (X_{20}) and phytoplankton (X_{21}) indicate that if electric conductivity, silicate, total sulphide, oil-grease and phytoplankton increase by one unit then

$rH_2(X_8)$ will decrease by 0.004799, 1.069246, 0.798438, 0.014246 and 0.000552 units respectively. The co-efficient of zooplankton (X_{22}) indicates that if zooplankton increases by one unit then rH_2 (X_8) will increase by 0.0000122 unit. None of the co-efficient is statistically significant.

Equation - VI

The regression equation-VI indicates that 84.85% variation of BOD (X_9) is explained by COD (X_{10}), total sulphide (X_{19}), oil-grease (X_{20}), phytoplankton (X_{21}) and zooplankton (X_{22}). The co-efficient of total sulphide (X_{19}) and phytoplankton (X_{21}) indicate that if total sulphide and phytoplankton increase by one unit then BOD (X_9) will decrease by 0.952215 and 0.0000414 units respectively. The co-efficient of COD (X_{10}), oil-grease (X_{20}) and zooplankton (X_{22}) indicate that if COD, oil-grease and zooplankton increase by one unit then BOD (X_9) will increase by 0.002793, 0.691957 and 0.0000587 units respectively. None of the co-efficient is statistically significant.

Equation - VII

The regression equation-VII indicates that 48.45% variation of COD (X_{10}) is explained by CO_3 alkalinity (X_{14}) and total sulphide (X_{19}). The co-efficient of CO_3 alkalinity (X_{14}) indicates that if CO_3 alkalinity increases by one unit then COD (X_{10}) will decrease by 19.62338 unit. The co-efficient of total sulphide (X_{19}) indicates that if total sulphide increases by one unit then COD (X_{10}) will increase by 91.32217 unit. None of the co-efficient is statistically significant.

Equation - VIII

The regression equation-VIII indicates that 78.59% variation of electric conductivity (X_{11}) is explained by silicate (X_{18}), oil-grease (X_{20}), phytoplankton (X_{21}) and zooplankton (X_{22}). The co-efficient of silicate (X_{18}), oil-grease (X_{20}) and zooplankton (X_{22}) indicate that if silicate, oil-grease and zooplankton increase by one unit then electric conductivity (X_{11})will decrease by 881.8012, 81.44265 and 0.000368 units respectively. The co-efficient of phytoplankton (X_{21}) indicates that if phytoplankton increases by one unit then electric conductivity (X_{11}) will increase by 0.002419 unit. None of the co-efficient is statistically significant.

Equation - IX

The regression equation-IX indicates that 0.0004% variation of CO_2 (X_{13}) is explained by CO_3 alkalinity (X_{14}). The co-efficient of CO_3 alkalinity (X_{14}) indicates that if CO_3 alkalinity increases by one unit then CO_2 (X_{13}) will decrease by 0.004914 unit. The co-efficient is statistically nonsignificant.

Equation - X

The regression equation-X indicates that 47.13% variation of total hardness (X_{15}) is explained by magnesium hardness (X_{16}). The co-efficient of magnesium hardness (X_{16}) indicates that if magnesium hardness increases by one unit then total hardness (X_{16}) will increase by 3.535163 unit. The co-efficient is statistically significant.

Equation - XI

The regression equation-XI indicates that 90.84% variation of silicate (X_{18}) is explained by total sulphide (X_{19}), oil-grease (X_{20}), phytoplankton (X_{21}) and zooplankton (X_{22}). The co-efficient of oil-grease (X_{20}), phytoplankton (X_{21}) and zooplankton (X_{22}) indicate that if oil-grease, phytoplankton and zooplankton increase by one unit then silicate (X_{18}) will decrease by 0.131436, 0.00000115 and 0.0000000731 units respectively. The co-efficient of total sulphide (X_{19}) indicates that if total sulphide increases by one unit then silicate (X_{18}) will increase by 0.16855 unit. None of the co-efficient is statistically significant.

Equation - XII

The regression equation-XII indicates that 93.39% variation of total sulphide (X_{19}) is explained by oil-grease (X_{20}), phytoplankton (X_{21}) and zooplankton (X_{22}). The co-efficient of phytoplankton (X_{21}) indicates that if phytoplankton increases by one unit then total sulphide (X_{19}) will decrease by 0.00000436 unit. The co-efficient of oil-grease (X_{20}) and zooplankton (X_{22}) indicate that if oil-grease and zooplankton increase by one unit then total sulphide (X_{19}) will increase by 0.592323 and 0.000000156 units respectively. The co-efficient of phytoplankton and zooplankton are statistically nonsignificant but oil-grease is significant.

Equation - XIII

The regression equation-XIII indicates that 94.38% variation of phytoplankton (X_{21}) is explained by zooplankton (X_{22}). The co-efficient of zooplankton (X_{22}) indicates that if zooplankton increases by one unit then phytoplankton (X_{21}) will increase by 1.123971 unit. The co-efficient is statistically significant.

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