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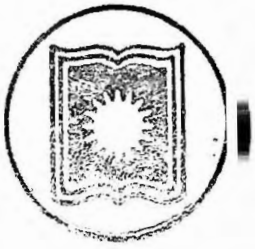
A Study on Aquatic Fungi in Diferent Water Bodies in and Around Rajshahi City

Das, Tapoti

University of Rajshahi

A STUDY ON AQUATIC FUNGI IN DIFERENT WATER BODIES IN AND AROUND RAJSHAHI CITY



Thesis Submited to the Faclty of Life and Earth Science Uniersity of Rajshahi Fulfillment of Requirements for The Degree of Master of Philosophy Of Botany.

By

Tapoti Das

September, 2000
Rajshahi

Plant Pathology Laboratory
Department of Botany
University of Rajshahi
Bangladesh

SEMINAR COPY

Dedicated to my

Beloved Parents

And

Husband

whose instant inspiration led

me to achieve the goal

DECLARATION

I 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.

Candidate

Tapoti Das

2.9.2000

Tapoti Das

CERTIFICATE

This is to certify that the research work entitled "A STUDY ON AQUATIC FUNGI IN DIFFERENT WATER BODIES IN AND AROUND RAJSHAHI CITY" presented by Tapoti Das as a thesis towards the fulfilment of the Degree of Master of Philosophy in Botany of the University of Rajshahi is suitable for submission as to its style and content.

Supervisor

M.S. Alam.
1.9.2000.

Dr. M. Shah Alam
Professor
Department of Botany
University of Rajshahi
Bangladesh

CERTIFICATE

I hereby certify that the work embodied in the thesis has not already been submitted in substance for any degree and has not been concurrently submitted in candidature for any degree.

Candidate

Tapoti Das

2.9.2000

Tapoti Das

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The Author

Tapoti Das

ABSTRACT

The physico-chemical and biological conditions of three different sampling spots have been studied fortnightly from the month of November, 1998 to December 1999. Sampling spot one (SP-1) was situated on the northern side of the Rajshahi University Campus, behind the 3rd science building. Sampling spot two (SP-2) was polluted canal receiving effluent from the Horian sugar mills at Rajshahi. On the other hand sampling spot three (SP-3) was two kilometres away from SP-2 in the same canal receiving effluent from Katakhali Power Station at Rajshahi. These mixed effluent were discharged into the river Padma five kilometre from Katakhali Power station. The monthly mean value of different variables of three sampling spots were treated for each sampling spot.

Sampling Spot - 1 (SP-1)

Air temperature varied from 22.4°C to 33°C, while the water temperature varied from 22°C-36°C. Transparency from 12.5 to 39.37cm, pH from 7.4 to 10.3 while the DO value ranged from 4.47 to 11.67 mg/l, with a percentage of saturation of O_2 ranging from 59.22 to 157.86%. Conductivity, CO_2, CO_3, HCO_3 alkalinities values ranged from 296.112 to 739 µS/cm, 0 to 6.6 mg/l, 0 to 44 mg/l, 116 to 289 mg/l respectively. Total hardness, Calcium hardness, magnesium hardness, Chloride and Phosphate values ranged from 90 to 410 mg/l, 80 to 214.2 mg/l, 10 to 304 mg/l, 17.04 to 46.86 mg/l and 0 to 0.066 mg/l respectively. NH_4, NH_3 and NH_4-N ranged from 0 to 1.0696 mg/l, 0 to 1.00970 mg/l and 0 to 0.83098 mg/l respectively. Oxidation-Reduction Potential (Eh), Oxidation-Reduction index (rH_2) and BOD values varied from 0.00910 to 0.34522 mv, 20.914 to 27.656 and 1.535 to 9.6324 mg/l respectively.

All the 13 fungal species belonging to 10 genera were recorded from this spot.

Sampling Spot - 2 (SP-2)

In the effluent mixed black water at SP-2, the monthly mean of the air temperature varied from 22 to 33°C. Water temperature from 23 to 34°C, Transparency from 3.25 to 30.2 cm. The pH value varied from 5.3 to 8.4, while the DO value ranged from total anoxia to 6.212 mg/l, with a percentage of saturation of O_2 ranging from 6.536 - 81.632%. The conductivity values were found to vary from 271.24 to 1193.01 µS/cm. CO_2, CO_3 and HCO_3 alkalinities values ranged from 2.0 to 11.2 mg/l, always nil, and 79 to 391 mg/l respectively. Total hardness, Ca-hardness, Mg-hardness, Chloride and Phosphate values varied from 142.8 to 790 mg/l, 70 to 378 mg/l, 9.0 to 439.3 mg/l, 5.68 to 39.76 mg/l and 0 to 0.08 mg/l respectively. NH_4, NH_3 and NH_4-N values ranged from 0 to 1.1119 mg/l, 0 to 1.04968 mg/l and 0 to 0.86389 mg/l respectively. Eh, rH_2 and BOD values varied from 0.23330 to 0.61985 mv, 24.845 to 31.974 and 0.2792 to 4.537 mg/l respectively.

A total of 13 fungal species belonging to 10 genera were recorded from Sampling spot-2.

Sampling Spot –3 (SP-3)

The range of monthly mean value of different variables were: Air temperature from 21 to 36°C, water temperature from 19 to 33°C, Transparency from 1.65 to 41 cm, pH from 7.1 to 9.0, DO from 2.513 to 16.612 mg/l, percentage of saturation of O_2 from 32.174 to 184.377%. Again conductivity value varied from 193.53 to 1072.61 µS/cm. CO_2, CO_3 and HCO_3, alkalinities values ranged from 0 to 6.6 mg/l, 0 to 30 mg/l and 99 to 332 mg/l respectively. Total hardness, Ca-hardness and Mg-hardness values ranged from 105 to 441 mg/l, 56 to 268 mg/l and 4.35 to 224.3 mg/l respectively. The chloronity values were found to vary from 15.62 to 171.82 mg/l. Phosphate, NH_4, NH_3, NH_4-N ranged from 0 to 0.09 mg/l, 0 to 3.1875 mg/l, 0 to 3.00908 mg/l and 0 to 2.47647 mg/l respectively, Eh, rH_2 and BOD values varied from 0.15905 to 0.41128 mv, 23.484 to 28.382 and 0.0698 to 12.494 mg/l respectively.

A total of 15 fungal species belonging to 10 genera were recorded from this spot.

From the three spots, a total of 22 fungal species belonging to 14 genera were reported throughout the period of study. Monthly abundance of species were recorded from each spot. Maximum species diversity was presented by the Order Eurotiales. A total of 6 species belonging to 2 genera were recorded from the three sampling spots throughout the period of study. Saprolegniales population of the three sampling spots were recorded by 5 species belonging to 3 genera. Order Moniliales were represented by 3 species belonging to 3 genera from the three sampling spots. The Mucorales population consisted of 2 fungal genera. On the other hand, order Blastocladiales were represented by 2 fungal species belonging to 1 genera. Three (3) species of the order Peronosporales belonging to 2 genera were recorded. A single genera was the representative of the order Chytridiales and was recorded from SP-2 and SP-3.

SP-1 and SP-2 exhibited similar number of fungal species, although they differed in population structure. Structural similarity was evident between SP-2 and SP-3, indicating their same nature of pollution (e.g. industrial pollution). Considering the BOD values SP-1 was found to be polluted organically, while the other two showed a comparatively lesser degree of pollution of organic origin which further predicts about their pollution of chemical origin. *Achlya imperfecta, Aphanomyces laevis, Aspergillus terreus, Alternaria alternata, Fusarium oxysporum, Mucor saturinus* and *Allomyces javanicus* can be considered as indicators of organic pollution, hence indicators of chemically unpolluted aquatic body, as they were only recorded from SP-1. Further, *Saprolegnia luxurians, Aspergillus flavus, Penicillium chrysogenum, Nigrospora* sp., *Rhizopus stolonifer, Allomyces arbuscula, Phytophthora parasitica, Pythium debaryanum* and *Chytridium olla* can be considered as indicators of chemical pollution as they were recorded from SP-2 and SP-3. All the three spots under study were of highly eutrophic nature, degrading at a faster rate leading to hypertrophication.

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LIST OF ABBREVIATION

µS/cm	=	Micro Siemens per centimeter.
BOD	=	Biochemical Oxygen Demand.
Cl^-	=	Chloride content.
cm	=	Centimeter.
CO_2	=	Carbon di Oxide.
CO_3	=	Carbonate Content.
DO	=	Dissolved Oxygen.
e.g	=	Example.
HCO_3	=	Bicarbonate Content.
mg/l	=	Milligram per liter.
NH_3	=	Ammonia.
NH_4	=	Ammonium.
NH_4-N	=	Ammonium nitrogen.
O_2	=	Oxygen.
°C	=	Degree centigrade.
pH	=	Hydrogen ion concentration.
sp.	=	Species.
SP-1/SP_1	=	Sampling Spot One.
SP-2/SP_2	=	Sampling Spot Two.
SP-3/SP_3	=	Sampling Spot Three.

CHAPTER – 1

INTRODUCTION

CHAPTER - 1

Bangladesh is a small (147570 sq. km. Source: Statistical bulletin, Bangladesh, 1999) densely populated (755 per sq. km. Source: Statistical Bulletin, Bangladesh, 1999) country. Its large area of open water resources includes river, canal, beel, jheel, haor, lake, pond, swamps, ditches etc. Total freshwater area of Bangladesh is about 36.663 km^2 (Ameen, 1987, Rahman, 1998, Khondker, 1994, 1995). Bangladesh is a country characterized by virtual stagnation in real income. Its national income continues to grow at around 4 to 5 per cent per annum which had been the experience for the last 35 years, it would require nearly 35 to 40 years to double the present level of per capita income of only US$ 256 per annum. Whereas, our population rate is increasing at a rate of 2.17 per cent. From that viewpoint our actual per capita income is increasing only at 1.6 % rate (Statistical Bulletin, Bangladesh 1999). Such growth prospects are not acceptable and would not take much dents on the present widespread poverty. The effort must, therefore, be made to identify different development constraints and aim to set the stage for overcoming them and further expand the dynamics of the economy so that the growth rate could be raised to at least 8 per annum by the turn of the century.

Rapid economic development will put even increasing pressure on renewable and non-renewable natural resources such as land, water, energy etc. and tend to increase the discharge of pollutants to the environment in varying degrees depending on the chosen path of development. It is therefore essential to choose the future pattern of development in such a way that environmental degradation is minimized through judicious use of resources on an inter-temporal basis to achieve sustainable development. Pollution of waters have been going on in Bangladesh for quite a long time and has become widespread in the recent years. The chief sources of water pollution in aquatic environment of Bangladesh may be

classified as (1) Industrial pollution (2) Agricultural wastes (3) Sewage system (4) Domestic pollution (5) Natural pollution. Bangladesh has more than 10,000 small industries in different areas. Among these, the major chemical and organic waste producing industries are paper and pulp mills, rayon mills, tanneries, fertilizer factories, pharmaceutical and chemical industries, jute mills, textile mills, rubber processing industries, fish processing, oil refineries, machine tools factories, soap factories, cement industries, sugar mills, power stations etc. These industries discharge large quantities of their untreated liquid and solid wastes directly into natural water systems. Beside these, domestic wastes are also thrown directly into lentic and lotic water bodies too. As a result, rapid alternation and deterioration of chemical and biological characteristics are observed in the aquatic habitats.

During the last two decades, environmental pollution has gained a lot of attention of the mass people, administrative and scientists. Research has been carried out to make base line data, as well as to assess the impact of various sorts of pollution in different parts of the country. Unfortunately, the northern region of the country still remained unexplored apart a few sporadic attempts (See: Chap.: 2). Now it is essential to evaluate the physical, chemical and biological conditions of natural water bodies for future pollution abatement program. Monitoring of environmental-quality is an essential step in environmental protection or environment management program. It is the essential first step to know whether there is any need for concern or action, and if so the desirable direction and the likely magnitude of the effort needed. Meaningful goals, targets or schedules of action cannot be set without knowing the starting point and only field monitoring data of specified type may also be necessary in appropriate choice of technology and design and also for evaluating the performance of the policies/processes/devices adopted in respect of environment protection and pollution control at various stages of time of their implementation. The present

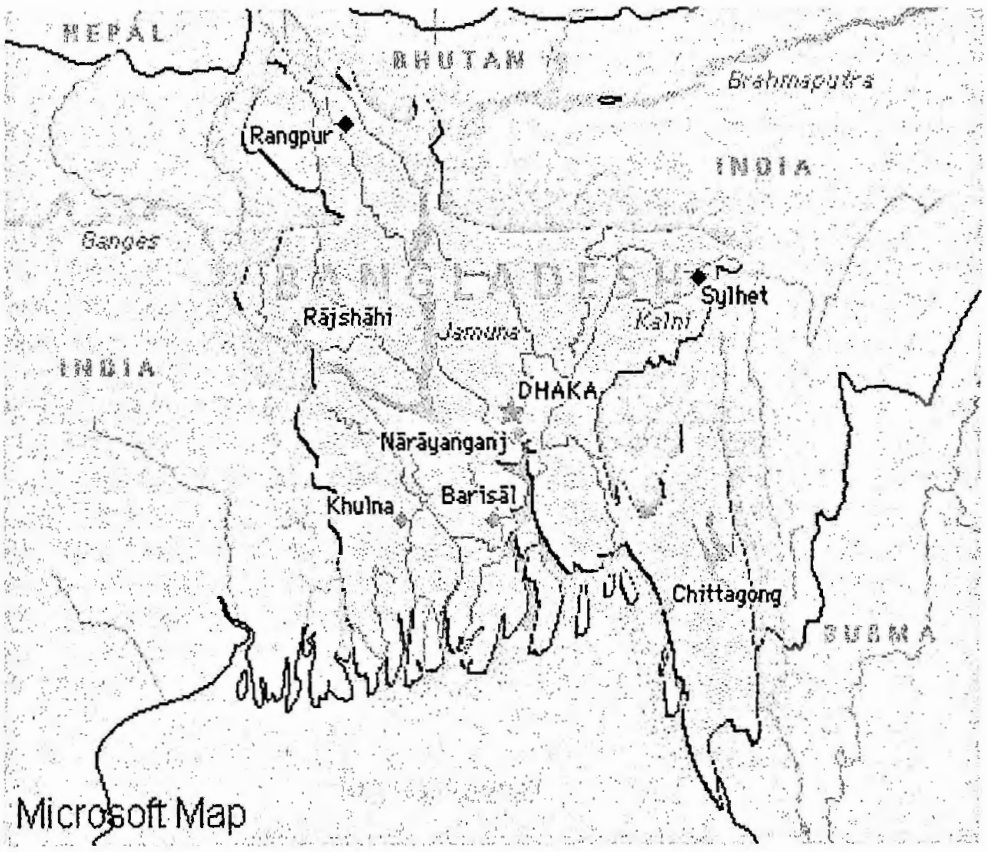
study was conducted to study the physico-chemical and fungal communities of the canal which receives the entire effluent from the Harian sugar mills and Khatakhali power station at Rajshahi, which open into the river Padma. Another pond was selected as sampling site, which receives a huge amount of domestic waste from an adjacent student Hall, which is also under extensive pisciculture. It may be mentioned that, study of the fungal community of the concerned habitats has been taken into consideration as fungi is considered as one of the major biotic component of aquatic environment, for its role as a decomposer and pathogen. But unfortunately till now no published document has been reported in our country; Hence present work can be considered as pioneer one in the field of aquatic mycology of our country.

AIM AND OBJECTIVE

The present investigation has been undertaken to conduct a fourteen months study to achieve the following objectives:

1. To know the physico-chemical conditions of Sugar mill effluent during sugar production period.
2. To know the physico-chemical conditions of the water body when sugar mill is in function (beyond the production period).
3. To know the physico-chemical conditions of the mixed effluent (i.e. effluent of sugar mill and power station).
4. To know the physico-chemical conditions of the effluent of power station when sugar mill is closed after production period.
5. To know the physico-chemical characteristics of the water body which receives a huge load of domestic waste round the year.
6. Identification of the fungal flora of the concerned water body, if possible to identify certain indicator species for specific environment.

7. Above all, to make a base line of the concerned habitats for future environmental management program.



Map of Bangladesh showing Rajshahi.

GEOGRAPHICAL LOCATION AND CLIMATE OF RAJSHAHI

Bangladesh lie between 24.35° to 24.70° North latitude and 89.10° to 89.35° East longitudes. Rajshahi is situated in the northern part of the country flanked by the fringe of the greater Barind tract on the north and Bhar (VOR) basin on the south and east. Rajshahi 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 15-20 m.

The climate of Rajshahi division, on the smaller aspect the Rajshahi district where the concerned habitats are situated, is characterized by great extreme 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 the east and Himalayas to the north.

The hot season commences early in the March with the ceasation of the northerly wind. Southwesterly 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. Atmospheric temperature continues to rise till early June. Southerly wind prevails in May and southeasterly wind in the monsoon from June to the middle of October, when cool nights begin to give indications of the approach of winter. Winter persists till early February.

Seasonal range of atmospheric temperature of Rajshahi has been recorded as a maximum of 43.3°C and a minimum of 4.7°C during the period of study. Frequent rainfall started to take place from the end of April and persists up to mid October. The frequency and amount of rainfall increases as the months proceed till the end of the monsoon period. Heavy rainfall (200-400 mm) is recorded in this season. Other seasons are marked by scanty or no rainfall. To get a general view of the

climatic pattern of Rajshahi, Tables (1-3) present data collected from meteorological department of Rajshahi.

Table 1:Monthly Mean ($\overline{X}$) Rainfall (in mm) Data of Rajshahi from 1995 to 1999.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	A.R*
1995	017	031	009	008	091	291	287	270	370	013	044	001	1432
1996	000	021	004	073	095	284	106	270	298	118	000	000	1269
1997	008	035	019	057	049	259	674	503	339	004	044	015	2006
1998	015	005	052	034	136	085	402	273	253	200	031	-	1486
1999	-	-	-	009	144	381	312	365	505	145	001	000	1862

* A.R – Annual rainfall.

Table 2: Yearly Mean ($\overline{X}$) Data of Relative Humidity (expressed in percentage).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1995	63.6	75.3	62.6	59.1	71.8	86	89.7	88.8	89.2	84	83	80
1996	79	76	64	62	72	86	88	88	86	85	79	75
1997	74	68	58	67	64	79	89	87	87	79	81	85
1998	85	73	61	68	71	79	84	87	85	84	83	80
1999	76	65	49	86	76	81	88	88	87	85	79	78

Table 3: Monthly Mean of Atmospheric Temperature Variation Data of Rajshahi from 1995 to 1999.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1995 Max	24.3	27.7	31.5	36.9	37.7	33.7	32.2	31.3	31.0	32.1	28.6	25.1	31.0
Min	9.2	12.8	17.2	22.9	25.6	25.6	26.0	26.0	25.4	23.7	16.1	12.4	20.24
1996 Max	24.4	27.9	33.9	36.6	36.7	32.9	32.9	32.5	33.3	31.1	29.5	26.1	31.5
Min	10.6	13.0	19.3	22.4	25.3	24.3	26.3	26.0	26.2	22.8	17.0	12.0	20.4
1997 Max	23.9	27.0	31.7	32.0	36.4	34.5	31.8	32.6	31.8	32.0	29.3	21.2	30.6
Min	9.8	12.5	19.6	20.5	24.4	25.3	26.0	26.5	25.1	22.1	18.6	10.8	20.1
1998 Max	21.2	27.5	30.7	34.3	35.0	35.7	32.8	32.7	32.6	32.7	30.0	26.8	31.0
Min	10.3	14.2	16.2	22.1	24.9	27.3	26.5	26.7	26.2	25.0	20.4	14.1	21.16
1999 Max	24.8	30.2	35.2	37.7	34.6	33.8	32.3	32.0	31.3	31.5	29.7	26.8	31.66
Min	11.2	14.3	17.6	25.7	24.8	26.3	26.1	26.1	25.7	24.3	18.2	14.2	21.21

CHAPTER – 2

REVIEW OF LITERATURE

CHAPTER - 2

Bangladesh is commonly termed as a land of water, as waterbodies play an important role in the socio-economic life of the populace. The available scientific literature in the country bears the testimony that majority of these water bodies still remained uncared and unexplored from environmental view point. In the recent years there has been a growing awareness amongst the researchers to institute hydrobiological, limnological and other environmental investigations with a view to exploring the overall biological and physico-chemical conditions prevailing in the water bodies of the country, with their faunalogical and floristic composition. Balanced management of the water systems with the ecosystem therein and the economic productivity, have also received considerable attention. The practical implication of these studies comprising of detection and evaluation of the fresh water resources with respect to quality and quantity of aquatic lives with their influencing environmental components have been receiving due consideration.

As mentioned earlier, studies on the hydrobiological and limnological aspects of the inland waters are not sufficient. A recent limnological review mentioned that around 200 research works have been done on openwater, ponds, groundwater and flood plain situations in Bangladesh (FAP 17, 1993) and not a single document has been reported regarding aquatic fungi. Thus our discussion about the concerned literature will be dealt with a broader perspective. Ecology of freshwater fungi has not attained the degree of prominence as the ecology of soil fungi, because of latter's significance in phyto pathological studies and agriculture. There are two spheres of aquatic environments, the benthic at the bottom and planktonic, the floating. Both are connected with physical and chemical nature of aquatic

environment. Water molds have been observed growing on dead as well as living aquatic animals and fishes by Bennett (1842), Clinton (1894), Tiffney & Wolf (1937) and Tiffney (1939a & b). Heterotrophic organisms are usually present in natural water in direct proportion to the amount of organic matter available. Where oxygen is in abundance, a wide variety of aquatic fungi, such as Chytridiomygcetes, Saprolegniales and Peronosporales are found. Till 1942 whatever information was available, it was mainly in relation to "Oosporic Phycomycetes", which till then were regarded as true water fungal flora. In 1942 Ingold reported a distinctive and abundant flora of conidial fungi with distinct shape and structure and were well adapted to habitat on submerged and decaying leaves of *Alms Ilutinosa* in the bed of a stream in England as aquatic hyphomycetes. Shanore and Saslow (1944) identified aphanomyces as fish pathogen. Glen-Blott (1951) recognized another assemblage of aquatic hyphomycetes as aeroaquatic fungi with the mycellium in submerged decaying leaves including those in stagnant water and sporulate when brought above water surface. Vishniac and Nigrelli (1957) worked out the ability of Saprolegniaceae to parasitize platyfish. Cooke (1961; 1963) divided the fungi encoutered in fresh water into two principal groups, the hydrofungi, which required presence of water to complete their life cycle and geofungi or typical soil fungi which were not specifically adapted to an aquatic existence but nevertheless might be found in water because of an adequate supply of nutrients. These were regarded as "facultative aquatic fungi". Apart from these, noteworthy addition was done by Scott & O'Bier (1962), Scott (1964), Scott & O'Warren (1964), Unestam (1965), Stuart & Fuller (1968), Wilbughby (1968, 1969, 1970, 1971, 1977, 1978), Noland-Tintigner (1970-1973), O'Brien (1976), Richards (1977) and Neish (1976 & 1977).

As per above discussion, there are at least four groups of fungi, which are active in aquatic systems in different ways, these are the true water molds comprising:

1. Chytridiomycetes, Oomycetes compiled as Mastigomycetes and some Zygomycetes.
2. Aquatic Hyphomycetes found on decaying leaves of deciduous trees in well aerated waters which are taxonomically unrelated forms, though most of them resemble one another in the production of conidia with projecting arms or consisting of a curved or branched row of cells. Their shape is well adapted to their habitat and readily becomes entangled in submerged leaves which they colonize after germination.
3. Aeroaquatic Hyphomycetes is an assemblage of aquatic hyphomycetes with the mycellium in submerged decaying leaves, especially in stagnant water. They do not sporulate below water, but when leaves are brought above water they sporulate. Many of these fungi have a terrestrial potential and apparently limited terrestrial occurrence.
4. Terrestrial or Geofungi are typical soil fungi belonging to Moniliales, Sphaeropsidales and yeasts which are metabolically active in aquatic conditions and appear to be sufficiently versatile to operate facultatively in environment.

The distribution, biology, ecology and the role of fungi of four groups in the decomposition and simplification of organic matter, forms the basis of this review:

Mastigomycotina : Emerson, 1958, Sparrow, 1960, Fuller and Ponynton 1964, Miller, 1967 and Fuller, 1978 worked on the collection method of this group from aquatic habitat. The Chytridiomycetes parasitize and destroy algae that form a link in the food chain of aquatic animals. Many species of Coeiomomyces parasitize mosquito larvae. Comprehensive and fundamental monographs of this group were

compiled by Sparrow (1943, 1960), Karling (1935, 1966-1968), Canter (1960, 1966, 1968) and Willoughby (1962).

Das Gupta (1982) adequately summarized the works done in India in his "Discourse of Aquatic Phycomycetes in India", presenting the list of genera and species. In the post war era along with European researchers emerged important workers in the United Kingdom (Cook, 1926, Blackwell, 1937, Canter and Land, 1948, Water house, 1940, Goldie Smith, 1956) each with many contributions. In the United States these studies flourished with the studies of Coker (1923, 1937), Johnson (1956), Scymour (1956). Japanese works has been compiled by Kobayashi and others (1934, 1971), significantly the life history, cytology and host parasite relationships of the members of Woroninaceae, Olpidiaceae, Lagenidiaceae, Monoblepharis, Allomyces etc.

In India studies on water molds started with the arrival of E.J. Butler with his special interest in the genus *Pythium*. In 1907, he distinguished 18 species of Pythium of which five were from India. Further he identified eleven chytrids four (*Nowokowskiella ramosa, Pseudolpidium aphanomyces, Olpidiopsis minor* and *O. schenkiana*) were from India. Butler (1911) established a genus *Allomyces* to accomodate *A. abrusculus* in family Blastocladiaceae. The studies of Chaudhury and co-workers (1931-47) resulted in the discovery of seven more genera (*Pythiopsis, Isoachlya, Protoachlya, Achlya, Alpanes, Thraustotheca* and Hamidia) in addition to Saprolegina. Iyengar (1935) described two species of Coelomomyces. There was simultaneous development in taxonomic studies of aquatic phycomycetes in Lucknow and Patna (1949-1958) under the able guidance of Prof. Das Gupta. After a gap of few years these studies were continued by his student Rai and coworkers (studied the occurence of aquatic phycomycetes in alkaline saline soils). The other centres were Gorakhpur (Bhargava, Srivastava and Srivastava, Singh, Prabhujyi, 1963-1977); Varnasi (Singh and Pargi, Dayal,

Thakurji, Ushakiran and others from 1970 and onwards). Bilgrami *et al.*, (1979) compiled all of these data in "Fungi of India." From time to time many workers added to the knowledge of aquatic phycomycetes from various centres Khulbe and Bhargava, 1971, Dayal and UshaKiran 1978, 1979, 1980a,b; Ushakiran and Dayal, 1982; Hasija and Khan 1982; Chawdhary and Agarwal, 1981, Khulbe and Sati, 1979, Manoharachary, 1985, Prabhuji *et al.*, 1984; Prabhuji and Srivastava, 1978. Srivastava (1980) and Srivastava *et al.*, (1983) reported that malnutrition and over crowding usually lead to debility and enhance the susceptibility of fish to fungal attack. Gopal Krishnan (1963, 1964), Bhargava *et al.*, (1971) found species of Aphanomyces along with *Achlya* and *Dictyuchus* as fish pathogens.

Srivastava (1980) during his investigation for the host range of *Achlya diffusa* reported ten fresh water fish (*Puntinus sophere, P. ticto, P. conchonius, Colisa latia, Labeo rohita, L. bata,* L. *Calbasu, Cirrhinus mrigala, Anabas testudineus* and C*hanna punctatus*) as its hosts. Mer *et al.*, (1981) isolated a Saprolegnial, *Leptolegnia candata* from the infected eggs of *Cyprinus carpia* as a parasite in Bhimtal., Nainital. In pathogenisity test they observed that in controlled inoculation about 70 per cent infected eggs did not hatch. Sati (1986) reported two species of *Achlya, A. flagellata* and *A. orion* pathogenic on two new hosts *Tor tor* and *Barlius dendelisis* respectively.

For the last few decades considerable attention has been paid to the various aspects of saprolegniales, especially for their fine structure, life cycle, relationship to environmental factors with respect to fish disease; especially the zoospore behaviour, the nutritional physiology (Bhargava, 1943; Beakes, 1980; Beakes *et al.*, 1980; Dayal, 1960; Pickering *et al.*, 1979; Reischer, 1951; Smith *et al.*, 1984; Willoughby, 1962, 1977, 1978, 1983, 1984. *Achlya, Aphanomyces* and *Saprolegnia* do have the ability to utilize ammonia N (Cantino, 1966). The possible chemical substances which stimulated growth of zoospores of

Saprolegnia isolate 847 were, ammonia, bound phosphorous and organic acids at lakewater at over turn (Willoughby *et al.*, 1983). He further added the numbers zoospores produced and behaviour of pathogenic strain of *Saprolegnia diclina* were markedly affected by temperature, pH, oxygen tension and presence of biocides, the use of the nutrients, such as, aspartic and glutamic acids at equivalent concentration occuring in fresh tissue encouraged the colonization of fresh sites. Van Der Plaats-Niterink (1981) presented a condensed data about geographic distribution and pathogenicity of each species of *Pythium* acknowledging the work of Rangaswami (1962) and Tomkins (1975).

Trichomycetes are a group of primitive fungi in zygomycotina, which live attached by a hold fast to the gut living, mostly, on aquatic arthropods. As they obtain their nutrition from the contents of gut lumen, their association has usually been referred either obligate symbionts or commensals. Whisler (1960) isolated an ecto-commensal *Amoebidium parasitiocum* from cladocera on an axenic Tryptone agar medium. Tuzet *et al.*, (1961) were able to obtain some elongated hyphal filaments of *Ruinetella culius* but could not induce the conidia to germinate in axenic culture.

Entomophthora : Waterhouse and Brady (1982) revised the first key (Waterhouse, 1973) of the species of *Entomopthora*. They listed 106 species in a tabular form on the basis of hyphal bodies, pseudocystidia, nuclear content and description of secondary conidia along with hosts and field characters. Most of the species are pathogenic to terrestrial insects, but some have been reported from wet habitats on small diptera e.g. *E. papillata, E. lanceolata* (on a small diptera), *E. variabilis* incl. *Currispora* (minute gnats), *E. ovispora* (on small flies), *E. rhizospora* (Caddis and some small diptera), *E. conica* (gnats and caddis), *E. sepulchlaris* (tipulid flies), The majority of zoopagales are either predacious on

amoebae, rhizopods or nematodes or live parasitically in or on such animals (Duddington, 1973).

Leptomitales : Dick (1975) mentioned it as a group comprising of about 20 species recognizable from other oomycetes by a constricted thallus at regular intervals. *Leptomitus* is commonly called as sewage fungi which increase with the organic content of the water and is particularly common in water polluted by sewage or industrial effluents may be due to their ability to reduce sulphates and utilize sulpher in their metabolism (Gleason, 1968). In these habitats, leptomitales become a serious nuisanse by actual mechanisms blocking of channels and by exhaustion of the available oxygen supply. Cook (1970) reported their occurence on plant material submerged in clear, unpolluted water. Galeasons and Unestam (1968a,b) and Held (1970) pointed out a trend for fermentative metabolism within leptomitales. Under reduced oxygen tension *Sapromyces* and *Mindeniella* could produce acid, while *Leptomitus* and *Apodachlya* failed to do so. *Rhipidium* was strongly fermentative.

Aquatic hyphomycetes on Ingoldian Fungi : Webster and Davey (1984) observed the flattening of the spiral curvature of the sigmoid conidia of *Flagellospora curvula* with increased current velocity or under increased velocity. A few of these fungi had been described earlier by Diwildeman (1893-1895), Huber Pestalozzi (1925) and Karling (1935). Much of this taxonomical literature has been summarized by Ingold (1975; 1979). In his later review (1979) recognizing the comprehensive treatment by Peterson (1962), Nilson (1964) and Dudka (1974) about 60 genera and 120 species with their perfect stages belonging to Ascomycetes (Webster and Descals, 1978) and to Basidiomycetes (Shaw, 1972; Nawami *et al.*, 1977a,b). Certain conidia e.g. *Chaetospermum chaetosporium* were pycnidial. These fungi have sometimes been erroneously identified as animal stages because of their unique morphology. Dyko (1978) described four new

hyphomycete taxa from North Carolina and Tennessee with two new genera *Fontanospora* and *Tetrabrunneospora*. He neotypified *Tricladium accentricum* as *F. accentrica.* Descals and Webster (1980) proposed neotypes for the *Dentrospora* aggregates including five new species *D. fusca, D. torulosa, D. tenella, D. nana* and *D. fastuosa.*

From India, the occurence and distribution of aquatic hyphomycetes has not been as widely explored as the aquatic phycomycetes mentioned earlier. The information about the distribution of these fungi comes from the work of Ingold and Webster (1973); Manoharachary (1977); Manoharachary and Rama Rao (1981); Rao and Manoharachary (1981-1989) from various streams and rivers of Andhra Pradesh, Sridhar and Kaveriappa (1985) and Subramanian and Bhat (1981) from western Ghats. Sridhar and Kaveriappa (1987) isolated a total of 19 and 17 species of aquatic hyphomycetes on ten leaf species collected from the banks of Neriya and Sampaje streams respectively. They reported highest species of aquatic hyphomycetes from dried leaves. These returned to aquatic system when the water level in rivers rose at the onset at monsoon. Sridhar and Kaveriappa (1989) reported a total of sixteen species belonging to thirteen genera of water borne hyphomycetes on five kinds of submerged leaves (*Ficus bengalensis, Coffea arabica, Mangifera indica* and *Hevea brasiliensis*) in the konaje stream Bangalore. These species were *Alataspora acuminata, Beltrania indica, B. rhombica, Dactylella oviparasitica, Dendrospora* sp., *Flagellospora penicillioides, Helicosporium* sp., *Infoldiella hamata, Lunulospora curvula, Phalangispora constricta, Pyramidospora casuarinae, P. constricta, Triscelophours acuminatus, T. Konajensis, T. monosporous* and *Wiesneriomyces laurinus.*

Aeroaquatic hyphomycetes : Glen-Bott (1951) first used the term aeroaquatic hyphomycetes to designate a group of fungi isolated from submerged decaying leaves, including those in stagnant water. These included a number of

helicosporous imperfect fungi (Linder 1925-1931) and also a large number of non-helicosporous types (Glen-Bott 1951 and 1955; Van Baverwijk 1953) the term was considered to be misleading as many terrestrial imperfect fungi also occurred in mycelial form in submerged litter and sporulate when brought on the surface of water and exposed in air. To avoid this confusion Park (1972) recognized only those types as aquatic which could maintain their biomass at a constant level throughout the year with available substrata and nutrients. Fisher (1977) redefined the term aeroaquatic for those indwelling fungi which formed conidia under certain moist atmospheric condition on exposure. Some of the species (*Helicoon pluriseptatum* and *Candelabrum spinulosum*) were recovered from moist leaf litter or land as well as from under water sources, which suggested their terrestrial occurrence also. Representative form genera of this unique group are *Aegerita, Beverniijkella, Candelabrum, Clathrosphaerina, Helicodendron, Helicoon, Helicosporium* and *Spirosphaera.* Fisher (1979) also provided evidence that aero-aquatic hyphomycetes could survive many a times in habitats deficient in oxygen. Fisher and Webster (1979) studied the effect of oxygen and carbondioxide on these fungi. Sanders and Webster (1978) determined the survival of these species in terrestrial environment and concuded that they have very little or insignificant role in ecosystem of temperate regions. Under severe conditions of desiccation the spores of six species of *Helicodendron* survive for 10 days. It was suggested that spore survival on land was limited.

Fisher and Webster (1981) provided evidence about the general ecology of aero-aquatic hyphomycetes in aquatic habitats under different conditions by conducting fieldwork carriedout with a eutrophic and oligotrophic habitat within the country of Devon, England. From results they concluded that many aero-aquatic fungi were well adapted to anaerobic or microaerobic situations, but the colonization was slow in comparison to well oxygenated environment. Fisher and Webster

(1981), Webster and Descals (1981), Field and Webster (1983) and Abdullah and Fisher (1984) were of the opinion that many of the aero-aquatic fungi were capable of growth at low levels of dissolved oxygen and can survive prolonged periods under strictly anaerobic conditions. Many of these habitats smell of hydrogen sulphide. This gas is a strong reducing agent and its presence is indicative of oxygen deficiencies, within the sediments and in the water immediately above. The toxicity of soluble sulphide within the range of 0.1-1.0 mg/l in animals (Oseid and Smith, 1974; Smith *et al.*, 1976) has been reported. Field and Webster (1985) studied the effect of sulphides on survival of aero-aquatic and aquatic hyphomycetes and concluded that they have greater tolerance of aero-aquatic fungi to anaerobic conditions and high sulphide concentrations made it probable that, the available oxygen become depleted in stagnant ponds and sulphide level in the litter tend to rise the aero-aquatic hyphomycetes will survive in preference to the other aquatic fungi. Gunasekara *et al.*, (1983) investigated the effect of enriching river water ecologically probable amounts of nitrate and phosphate on the decay of pine and oak work by aquatic and aero-aquatic hyphomycetes and observed that the effects were positive for all species, under study. The mycelial growth showed a greater response to nitrate in the presence of phosphate.

A very interesting finding is the production of an antibiotic quinaphthin by an aero-aquatic fungus *Helicoon richonic* (Fisher *et al.*, 1988), which has been reported to be active against a range of positive bacteria, two wall less bacteria and *Trichomonas vaginalis* (a human protozoan pathogen). They also reported its toxicity and considered its utility impracticable, in spite of the resemblance in its structure of Doxorubicin and related drugs used as anticancer agents.

Terrestrial Geofungi: Some terrestrial fungi have been shown to play an active role in aquatic environment. Aquatic species such as *Saprolegnia* and *Pythium* were

the first to colonize litter, followed by *Sphaeropsidales, Fusarium, Phialophora* (Cooke 1961, 1963). The leaf surface at the time of leaf fall in water, usually contains a residential population of common primary colonizers, such as, *Aspergillus, Alternaria, Fusarium* etc. Dickinson (1976) provided a tentative schematic classification of epiphytic fungi occuring on leaf surface. He stated that leaf surface acted as a trap for many fungal propagules which remained dormant. Repeated drying and wetting usually killed many fungi, only those species which could withstand such changes without loosing viability could survive. Fungal activity on freshly fallen leaves in aquatic habitats is most important during initial stage of decomposition (Triska, 1970, Kaushik and Hynes 1971; Barlocher and Kendrick 1974; 1976).

Manoharachary and Rama Rao (1983) isolated 47 fungal species representing 32 genera from two fresh water mud ponds in Hyderabad, but found no significant correlation with phoysico-chemical factors studied. The order of occurrence with reference to their dominance was fungi imperfecti followed by Aspergillia, Penicillia, Mucorales, Ascomycetes and *Pythium* sp. The present occurrence of zoosporic fungi was very meagre in relation to extra aquatic from semi-aquatic habitats. They regarded extra aquatic fungi as immigrants and versatile following Park (1972) and attributed their occurrence of surface running off soil particles, leaf litter, vegetable debris, dropping of aerospora or the perennating propagules that germinated at the approach of favorable conditions in favored substrata. The leaves and twigs present in the organic detritus of muds also contributed the non-aquatic fungi to aquatic habitats. From their results, they concluded that dominant extra aquatic fungal flora in semi aquatic habitats mainly comprised of fungi producing resting spores, pigmented spores, sclerotia, ascocarps or other perennating structures were the successful colonizers.

Rainwater removes large number of micro-organisms from air and collect them from surface of plants, buildingsor soil on which it falls. Large numbers are acquired from soil and pass out with drainage water into streams and rivers into fresh water lakes. The number and type of micro-organisms in surface water varies according to the source of water, its organic and inorganic contents and with geographical, biological and climatic factors. Singh and Wadhwani (1986) observed that six common geofungi *Aspergillus fumigatus, A. niger, A. terreus, Fusarium oxysporum, Helminthosporium spiciferum* and *Trichoderma viride* found associated with the blackened and submerged parts of four species of aquatic plants *Eichornia, Nymphaea, Pistia* and *Typha*, were also isolated in abundance from the air and water stagnant ponds and flowing waters with abundant aggregations of hydrophytes. Their adaptation to aquatic habitat was assigned to their capability to grow under a wide range of pH and to degrade cellulose.

Noteworthy works of nineties can be mentioned as works of Gupta and Mehrotra (1991), Sridhar and Deshmukh (1991), Manoharachary (1991) and Wadhwani *et al.*, (1992). These works mainly illustrates the interaction of aquatic fungi with its own environment.

CHAPTER – 3

MATERIALS AND METHODS

CHAPTER-3

3.1 MATERIALS :

Monthly sampling was carried out from the month of November 1998 to December 1999. at three sampling spots. An average of the collected data from the three spots were done. Detail description of the sampling spots are given as follows–

Sampling Spot 1 (SP-1) :

A pond situated on the northern side of the Rajshahi University Campus, behind the 3rd science building. Taposhi Rabeya Hall is situated on the western side of the pond and Botanical Garden is on the northern side of the pond. The pond has an area of $4000M^2$ and V shaped. Average depth of water of this pond is 2.0 meters, reaches its maxima (2.5M) during rainy season. Minimum depth is recorded 1.5M during summer months. The pond has no outlet, but receives huge amount of homestead waste water from Taposhi Rabeya Hall through a discharge drain. The pond overflows during monsoon months due to heavy rainfall. The pond is leased out for pisciculture and charged with inorganic fertilisers, cowdung and oilcakes at regular interval. The pond water is greenish in colour. The pond is not used for bathing and washing. The pond receives direct sunlight throughout the day. Shoreline vegetation is cleaned off at regular basis.

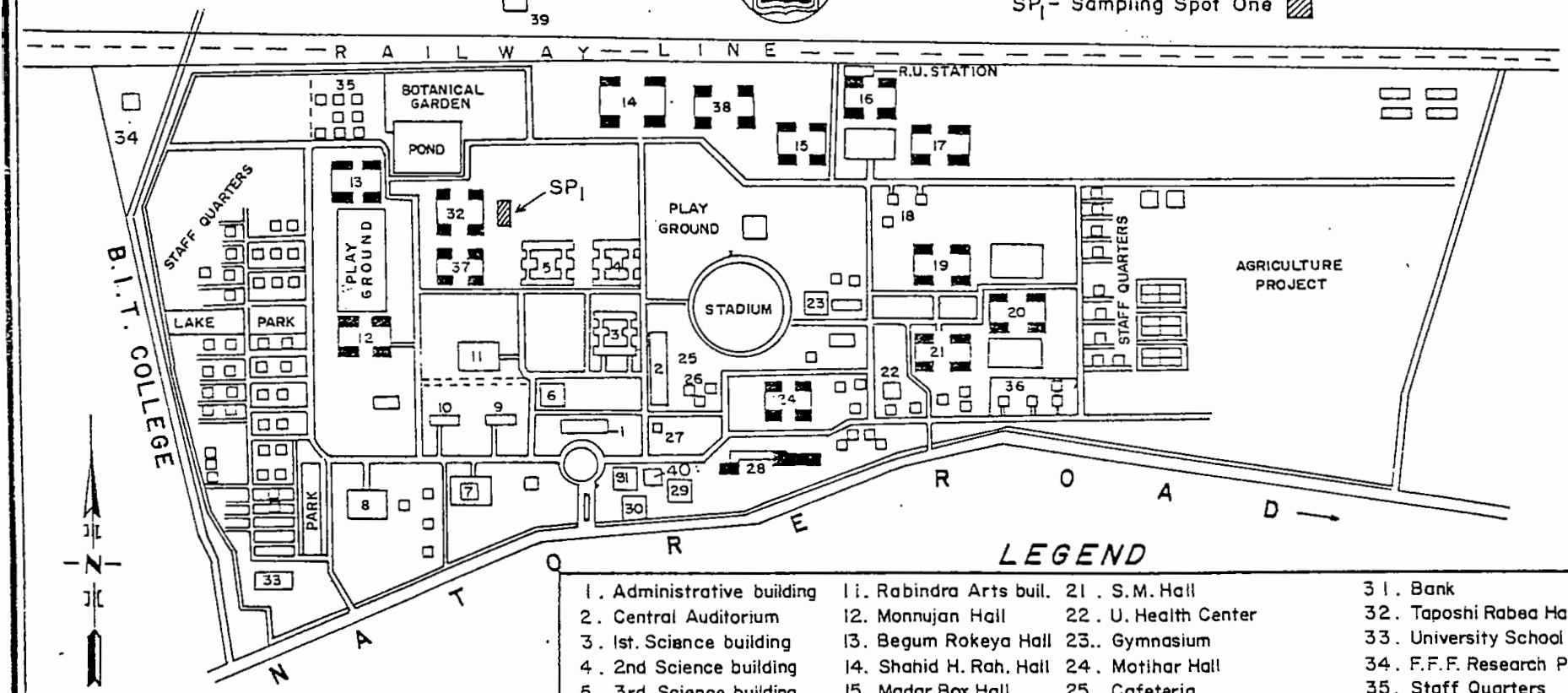
Sampling Spot 2 (SP-2) :

Rajshahi sugar mills is the second largest mill of "Bangladesh Food and Sugar Corporation" in terms of production capacity. The mill was established in 1963 and started its production from 1965-66 season. Annual production capacity is 20,000 metric tons. Sugarcane baggase is the only fuel source of this industry, with a crushing rate of 2000 metric tons of sugar cane per day.

Photographs of spot - 1

Photograph : 1

RAJSHAHI UNIVERSITY CAMPUS



LEGEND

1. Administrative building	11. Rabindra Arts buil.	21. S.M. Hall	31. Bank
2. Central Auditorium	12. Monnujan Hall	22. U. Health Center	32. Taposhi Rabea Hall
3. Ist. Science building	13. Begum Rokeya Hall	23.. Gymnasium	33. University School
4. 2nd Science building	14. Shahid H. Rah. Hall	24. Motihar Hall	34. F.F.F. Research Project
5. 3rd. Science building	15. Madar Box Hall	25. Cafeteria	35. Staff Quarters
6. Central Library	16. H.S. Sohrawrdi Hall	26. Rucsu building	36. I.B.S.
7. Residence af V.C.	17. S. Shamsuzzoha Hall	27. Shahid Minar	37. Khaleda Zia Hall
8. Zuberi House	18. Provost's Quarter	28. Sher-E-Bangla Hall	38. Ziaur Rahman Hall
9. Shahidullah Arts building	19. N.A. Latif Hall	29. Central Mosque	39. Art College
10. Momtazuddin Arts buil.	20. S.A. Ali Hall	30. B.N.C.C. & Military Sc. Dept.	40. 2nd Administrative buil.

This mills discharge 45 metric tons polluted and 360 metric tons of unpolluted effluents per hour during production period. Polluted effluents are clarified by washings of mill house, juice headers, various weighing scale, tanks, vacuum filter cleaning, centrifugal floor and other boiling house floor. Unpolluted effluents are clarified by mill bearing cooling water, power turbine oil cooling system, boiler blow down, otherwise cooling system, surplus condense overflow and surplus condenser water overflow. The mill has no facilities for effluent treatment. The effluent is collected in a canal by two pucca drain. (Source: Mill administration).

The sampling spot was selected 50 meters apart from sugar mill, situated within the mill campus. The spot is a part of a canal which receives effluent of the mill concerned. The canal is about 3-4 meter wide with an average depth of one meter. The entire canal within the campus is shaded with large trees, thus a huge amount of litter also accumulates the canal. Density of macro-aquatic vegetation also found to be rich. These mainly comprise of *Eichhornia* sp. *Marsilea* sp., *Jussiea* sp, *Spirodela* sp, *Enhydra* sp, *Colocasia* sp. and various sorts of grasses.

Sampling Spot 3 (SP-3)

Rajshahi Diesel Power Station has three power generating units of 1170 KVA, MKV with diesel engine. The diesel engines are driven by High Speed Diesel Oil (HSD). The engines are made from English Co. type of which is 8SRL 1794. BHP.

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 is selling electrical energy at 2.20 Taka per unit. The annual generation of this station is 40,50,000 units (Kilo watt per hour). This power generating station can supply power only for a small thana area.

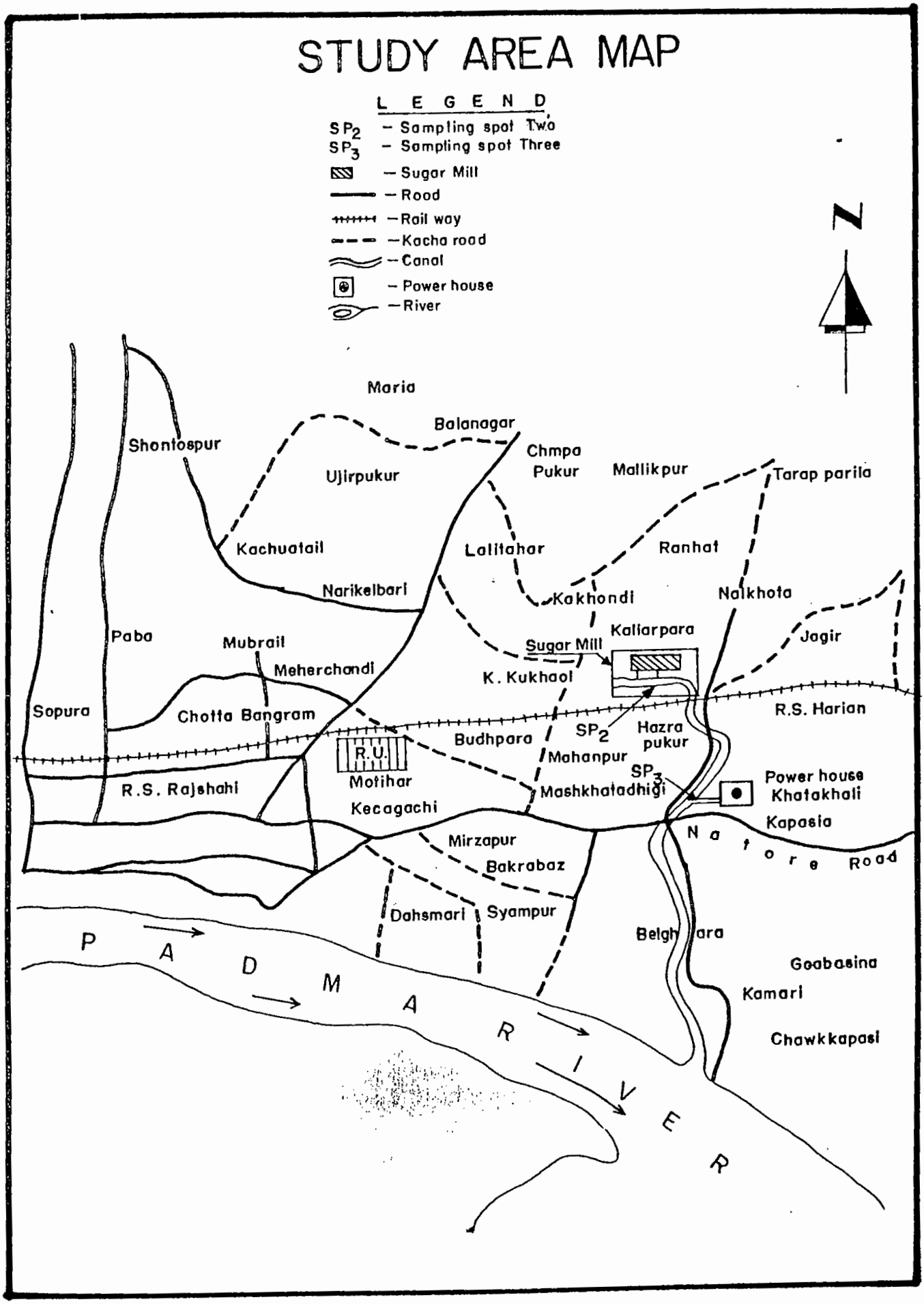
Photograph: 2

A. Rajshahi Sugar Mill

B. Canal Surface of Sampling Spot - 2

C. Canal Surface of Sampling Spot - 2

STUDY AREA MAP



The power house has no effluent treatment plant. The effluent of this power house is a mixture of cooling water, HSD oil and lubricating oil-CRB-40 are discharged by a steel pipe in a canal. A small percentage of high speed diesel oil and lubricating oil is mixed with drained cooling water is collected by pump and stored in earthen pot for sell by public. About 5 to 10 per cent of HSD and lubricating oil of the total mixture is expected to be wasted, where the proportion of the diesel oil and lubricating oil is estimated 1:5. The waste product is directly received by a canal -- a natural ecosystem.

This spot is located at Katakhali 50 meters away from power station, which is a part of a canal. At this point power house product is discharged through a steel pipe and the sugar mills effluent intermingles with it. The canal is of 2-3 meters wide, with its maximum depth of one meter during monsoon months. Macro-aquatic vegetation of this spot is noticeable, which mainly comprise of *Eichhornia* sp., *Lemna* sp., *Ipomoea* sp., *Colocasia* sp., *Marsilea* sp., *Polygonum* sp., and two species of *Cyperus.*

The mixed effluent flows to the river Padma at a distance of 6 Km. The latter two study locations are situated at a distance of 6 Km. from the Rajshahi University Campus. The sampling spots hereafter will be regarded as SP-1, SP-2 and SP-3 accordingly.

3.2 METHODS AND APPROACH OF STUDY :

Water samples were collected from a depth of 10-25 cm below the surface using a 250ml glass stoppered bottle as needed for the study of physico-chemical characteristics. Physical data of the sample water were recorded on the spot. Primary fixation required for chemical tests were also done in the spot. Fungal materials were collected by conventional methods from water, described in detail later.

Photograph : 3

A. Clear Effluent Discharged and Vegetation of Sampling Spot-3

B. Blackish Effluent Discharged and Vegetation of Sampling Spot-3

C. Highly Aquatic Vegetation of Sampling Spot - 3

3.3 PHYSICAL MEASURMENTS :

AIR TEMPERATURE AND WATER TEMPERATURE: A centigrade mercury thermometer with a range of 0°C to 120°C was used to note the air and water temperature at the time of sample collection.

TRANSPARENCY OF WATER: Measurement of limit of visibility i.e. penetration of light in water was done by "Secchidisk". Secchidisk is a circular metal plate of 20 cm in diameter. The upper surface of which is divided into four equal quadrants and so painted that two equal quadrants lie directly opposite each other are black and intervening ones are white. A staple fixed at the centre of the upper surface provides attachments of a graduated rope. Opposite the staple on the lower surface is a weight which facilitates the sinking of the disk in proper position. The lower side of the disk is painted black in order to eliminate reflection of light from that surface. The secchidisk was slowly lowered into the water on a graduated line and noted the depth at which it disappears, then the disk was gradually lifted up and noted the depth at which it reappears. The average of these two readings is considered to be the limit of visibility i.e. penetration of light in water. Penetration of light in water or transparency of water is expressed in centimetres (cm) [Welch-1948].

3.4 MEASUREMENT OF CHEMICAL FACTORS :

HYDROGEN-ION CONCENTRATION (pH) : The pH value of water was determined by digital pH meter (MODEL: HANNA INSTRUMENTS).

ELECTRIC CONDUCTIVITY : The value of electric conductivity was noted by using an electric conductivity meter (MODEL CM-1K) of range 0-10,000 µS/ cm.

FREE CO_2: Free carbon dioxide (CO_2) was determined by titration of water samples with N/44 sodium hydroxide solution (NaOH) using phenolphthalein as an indicator (Welch, 1948). The results were expressed in mg. of CO_2 per liter (mg/l) of water.

CARBONATE (CO_3) AND BICARBONATE (HCO_3) ALKALINITIES: Carbonate alkalinity or phenolphthalein alkalinity was determined by titration of 100 ml. of water sample with N/50 sulphuric acid using phenolphthalein as indicator (Welch, 1948). The resultant data was expressed in mg/l of $CaCO_3$. Bicarbonate alkalinity or methyl orange alkalinity was determined by titration of 100 ml. of water sample with N/50 Sulphuric acid using methyl orange as an indicator (Welch, 1948). The results were expressed in mg/l of $CaHCO_3$.

TOTAL HARDNESS : A 50 ml. sample pre treated with 1ml. ammonia buffer solution was titrated against EDTA using Eriochrome Black-T as an indicator (Mishra, *et al.,* 1992). The resultant data was expressed in mg/l.

CALCIUM HARDNESS : A 50 ml. of sample preteated by 1 ml. of 8% sodium hydroxide solution was titrated against EDTA solution (0.01M) using Mureoxide indicator (Mishra, *et al.,* 1992). The resultant data was expressed in mg/l.

MAGNESIUM HARDNESS : It was calculated by using formula [Mg hardness = Total hardness – Calcium hardness mg/l. (Source: Gautom, 1990)]

CHLORIDE : The most common method is known as Argentometric method ($AgNO_3$ method). Chloride ions reacts with $AgNO_3$ to produce white ppt. of silver chloride and at the end point the free silver ions react with chromate-ion to give reddish-brown colour of silver chromate. To 50 ml of sample water 2ml. of $K_2Cr_2O_7$ solution was added and titrated with 0.02N $AgNO_3$ solution. End point of titration is a red tinge colour (persistent). The resultant data was expressed in mg/l (APHA, 1989).

DISSOLVED OXYGEN (DO) : Winklers method (modified) was followed for the estimation of dissolved oxygen. To the sample collected in 250 ml glass stoppered bottle 1ml of $MnSO_4$ solution was added followed by 1 ml of alkaline-iodide-azide reagent and acidified with 1 ml of concentrated sulphuric acid (H_2SO_4) 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 per litre of water (mg/l).

BIO-CHEMICAL OXYGEN DEMAND (BOD) : 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 following the Winkler method (modified). The value of BOD_5 was obtained by subtracting final dissolved oxygen (FDO) from the initial dissolved oxygen (IDO) value (APHA, 1989).

When the DO content was almost negligible or shown condition of anoxia, the BOD_5 was determined by diluted method (APHA, 1989).

AMMONIUM : For qualitative determination in the field to 20 ml. of the water sample was added 10 drops of the sodium potassium tartarate solution plus 2-3 drops of Nesslers reagent and mixed thoroughly. If no clearly detectable yellow coloration appears, less than 0.1 mg/l of ammonium ion is present; when more than this is present a more or less yellow coloration is seen (0.1-5 mg/l). A yellowish to reddish-brown precipitate forms with 5 mg/l when more is present. For qualitative determination into an Erlenmeyer flask added 2 ml. each of the sodium potassium tartarate solution and Nessler's reagent with 100 ml. of the water sample was shaken vigorously and left for 5 minutes. Ammonia free 100 ml. of distilled water was filled by a second flask and mixed it with the same reagents.

Then with a burrette graduated in 0.1 ml. standard ammonia 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 one decimal point in mg/l. (Schwoerbel, 1972).

PHOSPHATE : 50 ml. of sample was taken in a flask followed by the addition of acid ammonium molybdate solution (2ml) and 4-5 drops of $SnCl_2$ solution. A blue colour appeared. The same procedure was run with a blank sample for comparison. Both (Sample and blank) were then kept on white paper, followed by the addition of standard phosphate solution to the blank drop by drop with the help of graduated pipette (1 ml) until the colour of the blank matched the sample colour at the end point the ml. of standard phosphate was calculated to get the amount of phosphate (Gautam, 1990).

PERCENTAGE OF SATURATION OF OXYGEN : The percentage of saturation of oxygen in water below the surface was calculated by dividing the titration value in ml. by the solubility value as determined by the temperature of the sample following the methods of Montogomary, Thom and Cockburn (1964) and Murray and Riley (1969). Rawson's nomogram (1944) was used for a quicker reference to the oxygen saturation values and was multiplied by correction factor as the percentage of saturation values vary with altitude, atmospheric pressure and temperature.

OXIDATION-REDUCTION POTENTIAL (Eh) : En was determined indirectly from the equation based on pH of water sample (Gautam, 1990).

i.e.

$$Eh = E_O - 0.058\ pH + 0.0145 \times \log PO_2$$

OXIDATION-REDUCTION INDEX (rH_2) : The oxidation-reduction conditions of freshwaters can be characterised by the oxidation reduction index (rH_2) and calculated as follows :

$$rH_2 = \frac{Eh}{0.029} + 2pH$$

(Source : Gautam, 1990).

3.5 BIOLOGICAL CHARACTERISTICS :

Fungal materials were collected from three sample spots on monthly basis. All the steps related to pre and post collection were done according to the methodology APHA (1989).

a) WASHING AND STERILIZATION :

All glassware were washed thoroughly with a suitable detergent (Jet powder) and hot water; later, rinsed with hot water to remove all traces of residual washing compound and finally rinsed with laboratory-pure water i.e. distil water.

For sterilization, glassware were sterilized in autoclave at 120°C for not less than 2h at $15/lb^2$ pressure. In some cases presterilized bags were used to collect samples which were sterilized in oven at 121°C for 15 min.

b) TYPES OF GLASSWARE USED AND SIZE OF THE SAMPLE :

Ground-glass stoppered bottles with wide mouth and of resistant glass (Pyrex) were used for sampling, 100 ml sample was were collected from each spot.

c) COLLECTION OF THE SAMPLE:

Sample bottles were kept closed until it was to be filled. Prior to sampling stopper and cap was removed as a unit. Care was taken to keep the inner surface of cap and neck of bottle contamination free. Holding the bottle near its base in the hand

and plunging it, neck downward, below the surface. The bottle was turned until the neck points slightly upward and mouth directed towards the current. As there ware no current in SP-2 and SP-3 an artificial current was created pushing the bottle forward horizontally in a direction away from the hand. In each case care was taken to avoid contact with bank or streambed; otherwise there was a chance of water fouling. The bottle was filled without rinsing and the stopper was replaced immediately after collection. At least 2.5 cm ample fair space was kept free in the bottle to facilitate shaking before examination. For aquatic hyphomycetes collection of foam, partially decayed, submerged leaves were also collected. Refrigeration was done immediately after reaching to laboratory. Samples were transferred into suitable media within 24hr. For aquatic hyphomycetes collected leaf samples were washed in sterile petridish about 1cm deep containing sterile water of the concerned spot. Incubated at room temperature. Within 1 to 2 days the mycellium and conidia developed.

Conidiophores and conidia were observed with a dissecting microscope on leaf surface. The conidia somtimes were transferred to suitable media to confirm identification. Search for conidia in foam samples were done in the same procedure and single conidium was isolated with the aid of micropippette and cultured in suitable medium for confirm identification. Medium used are Czapek agar, Dimalt agar and Neopeptone-glucose agar and Neopeptone-glucose rose bengal aureomycin agar.

Finally, after growth of 2-10 days the materials were identified with the aid of concerned literatures e.g.. Introduction to fungi (Webster, 1970), Peronosporales (Water house, 1973), Principles of fungal Taxonomy (Talbot, 1971), Studies on the Genus *Pythium* (Matthews, 1931), The Genus *Achlya*: Morphology and Taxonomy (Johnson, 1956), The lower Fungi-Phycomycetes (Fitzpatrick, 1930), Saprolegniales (Dick, 1973a), The Saprolegniaceae with notes on other water

molds (Coker, 1923), Morphology and Taxonomy of Fungi (Bessey, 1950), Introductory Mycology (Alexopoulos, 1962), The plasmodiophorales, (Karling, 1968), Morphogenesis in aquatic fungi (Cantino, 1966), Lower fungi in the Laboratory (Fuller, 1978), The Coelomycetes, fungi imperfecti with pycnidia Acervuli and stromata (Sutton, 1980), More Dematiaceous Hyphomycetes (Ellis, 1976), *Chytridiomycetarum iconographia* (Karling , 1977), Synchytrium (Karling , 1964) Aquatic Phycomycetes (Sparrow, 1960). Hyphomycetes. An account of Indian species, excepts Cercosporae. (Subramanian, 1971), Introductory Mycology (Alexopoulos and Mims, 1985).

CHAPTER – 4

OBSERVATION AND RESULTS

CHAPTER - 4

4.0 : Characteristics of an aquatic environment depend upon physical, chemical and biological interactions. Each aquatic ecosystem has its own dynamic state of change with respect to its geological age and geo-chemical characteristics. Human interference upset this dynamic state, resulting in deterioration of aquatic environment. So, the measurement of physico-chemical parameters along with its biological components is the best way to observe the water quality. As mentioned earlier, the present investigation was carried out for a period of fourteen months on three study spots. Observations and resultant data collected on monthly basis, are discussed elaborately with proper graphical presentation in this chapter.

4.1 AIR TEMPERATURE :

SP-1: During the period of study air temperature varied from 22.4°C to 33°C. The highest value was recorded in the month of May and August 1999, while the lowest in December 1998. Rise of temperature continued till May 1999. Temperature fluctuation was observed with the advent of rainy season. Highest air temperature was once recorded in August 1999. After that lower trend of temperature variation was observed till the end of study period. Yearly mean and SD of temperature of this spot is 28.05 ± 3.96.

SP-2 : The range of air temperature was found to vary from 22°C to 33°C during the period of study. The maximum value was recorded in May 1999 and the minimum in November 1999. An increased value of temperature was recorded in December and on the next two months the temperature maintained its usual lower trend. From March increased trend of temperature variation was observed, reached its maxima in May. At the beginning of rainy season temperature fluctuation was

observed with a cooling effect which continued to persist till the end of the study period. Yearly mean and SD of temperature of this spot is 27.043 ± 3.263.

SP-3 : Highest (36°C) air temperature of this spot was recorded in May 1999 while the minimum (21°C) in December 1998. Almost a similar trend of seasonal air temperature variation was observed from this spot. Yearly mean and SD of air temperature of this spot is 27.83 ± 4.288 accordingly.

Graphical representation of air temperature variation of three spots are shown in Fig. – 1. Data of three sampling spots are presented in table I – III (Appendix).

4.2 WATER TEMPERATURE :

SP-1: Water temperature of this spot varied from 22° - 36°C. The minimum value was recorded in December 1998 while the maximum was recorded in May 1999. Temperature of water changed with the season. Fluctuation of temperature was observed during monsoon. Mean and SD of water temperature of this spot is 27.91 ± 4.41. accordingly.

SP-2 : Minimum (23°C) and maximum (34°C) value of water temperature were recorded in September 1999 and January 1999 accordingly water temperature of this spot was found to be influenced by the production period of the mill. Mean and SD of this spot is 28.92 ± 2.85 accordingly.

SP-3 : The water temperature of this spot varied from 19°C to 33°C. The maximum and minimum values were recorded in April 1999 and December 1998. Mean and SD value of water temperature of this spot is 25.94 ± 4.38 accordingly.

Fluctuation pattern of water temperature of three sampling spot is depicted on Fig. - 2. Data of three sampling spots are presented in table I – III (Appendix).

FIGURE NO. 1 : MONTHLY VARIATION OF AIR TEMPERATURE OF THREE SAMPLING SPOTS.

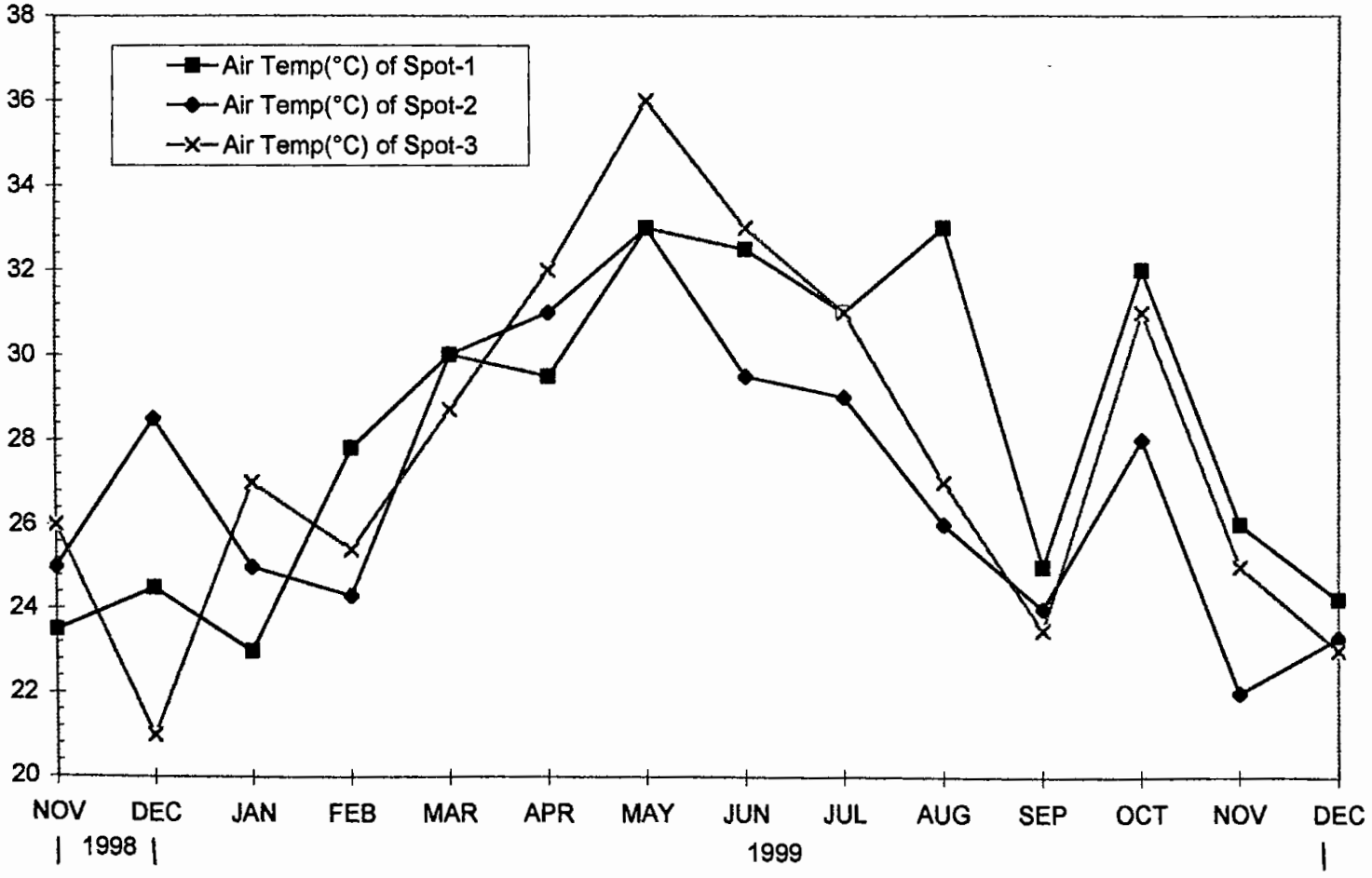
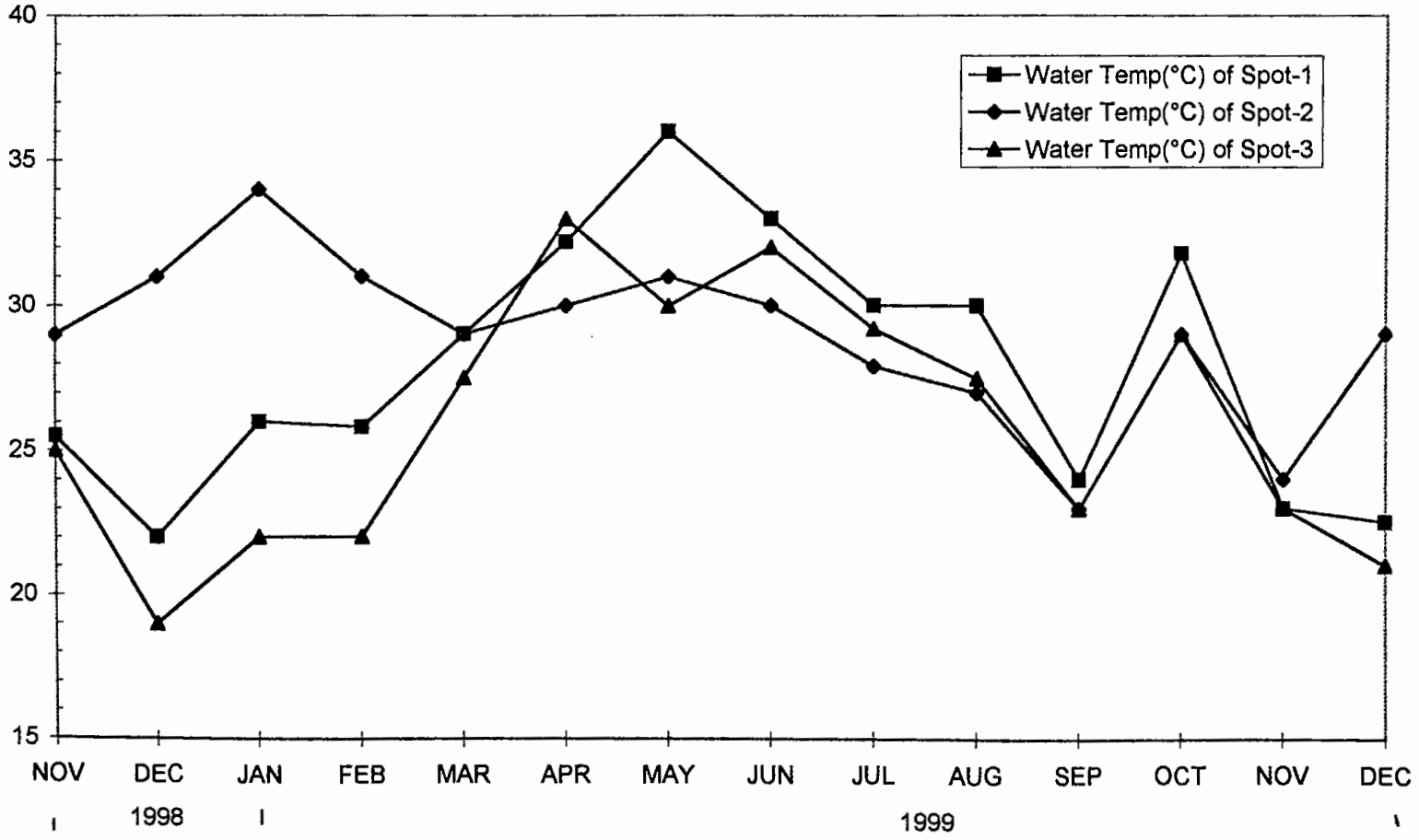


FIGURE NO. 2 : MONTHLY VARIATION OF WATER TEMPERATURE VALUE OF THREE SAMPLING SPOTS.



4.3 TRANSPARENCY :

SP-1: The range of transparency value was found to vary 12.5 cm to 39.37 cm. The maximum value was recorded in September 1999 and minimum in June 1999. Seasonal fluctuation was not clearly found in this spot. Mean and SD of transparency value of this spot is 28.06 ± 6.83 accordingly.

SP-2 : Transparency of water varied 3.25 cm to 30.2 cm during the period of study. The maximum transparency value was recorded in September 1999, while the minimum was recorded in May 1999. Mean and SD of this spot is 16.22 ± 8.62 accordingly.

SP-3 : During the period of study transparency of effluent mixed water varied from 1.65 cm to 41 cm. The maximum value was recorded in October 1999, while the minimum was recorded in May 1999. It may be mentioned, in May due to scorching heat of summer water level of this spot reached to minimum which has been considered as the transparency value (1.65 cm). Mean and SD value of transparency is 17.694±11.39.

Fluctuation pattern of transparency of three spots is depicted on Fig. 3. Monthly data of three sampling spots are presented in Table I-II (Appendix).

4.4 HYDROGEN ION CONCENTRATION (pH) :

SP-1: pH value varied from 7.4 to 10.3 during the period of study. Maximum value was recorded in June 1999 and the minimum was recorded in February 1999. Mean and SD value of pH is 8.493 ± 0.833402 accordingly.

SP-2 : pH value varied from 5.3 to 8.4 during the period of study. The maximum value was recorded in October 1999 and the minimum in February 1999. pH value of this spot was found to be influenced by the flow rate of effluent. Mean and SD value of pH of this spot is 7.064 ± 0.886 accordingly.

FIGURE NO. 3 : MONTHLY VARIATION OF TRANSPARENCY VALUE OF THREE SAMPLING SPOTS.

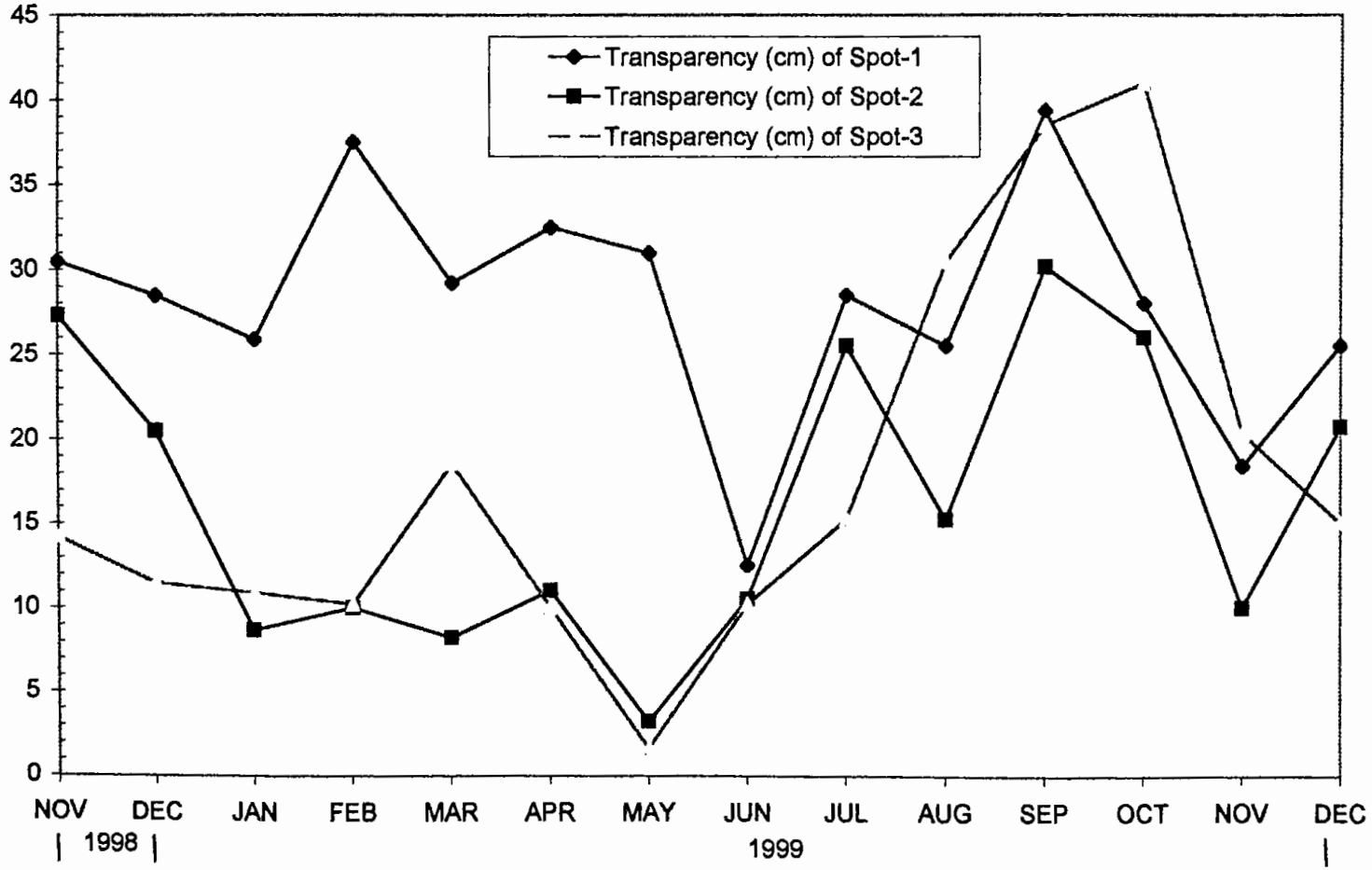
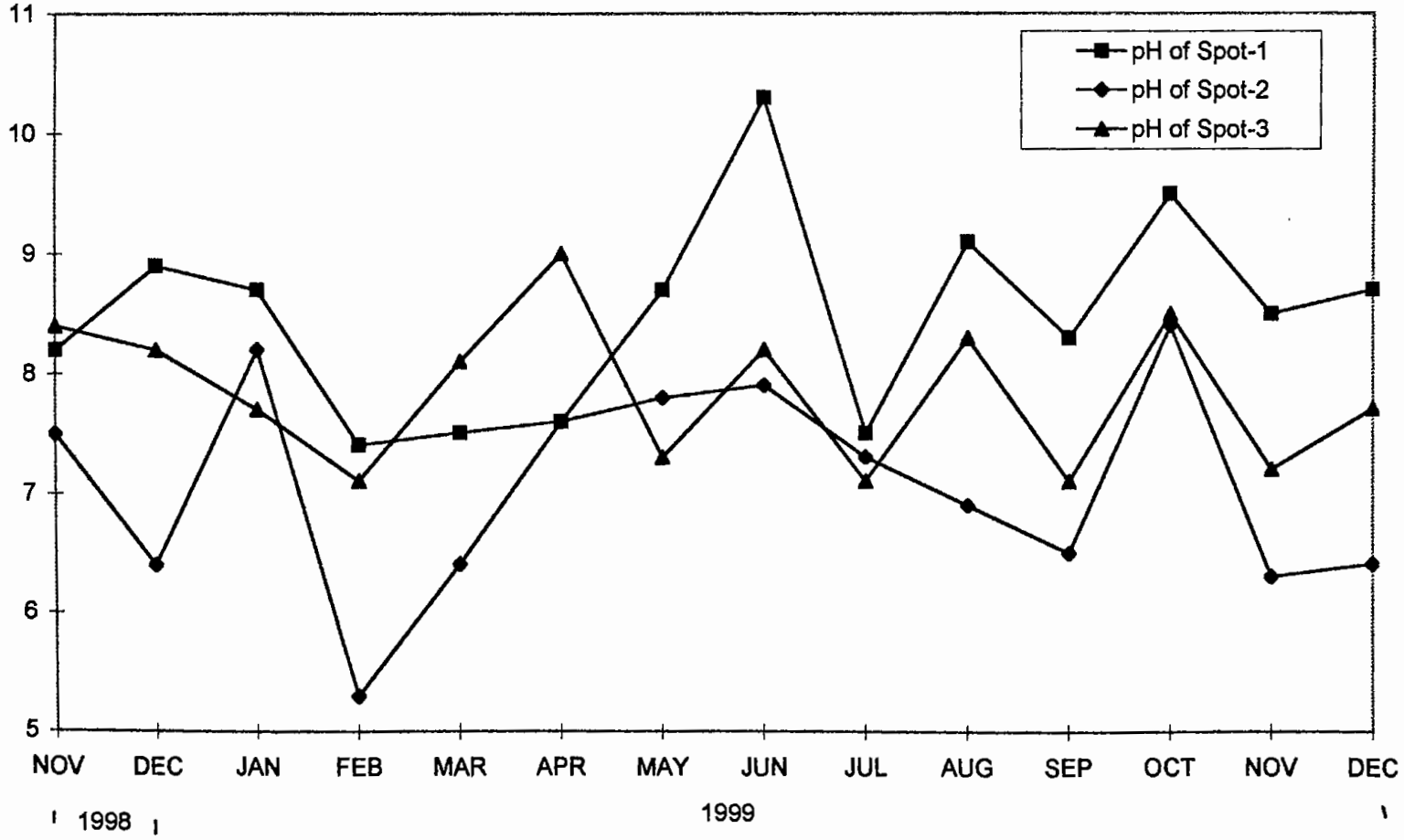


FIGURE NO. 4 : MONTHLY VARIATION OF pH VALUE OF THREE SAMPLING SPOTS.



SP-3 : During the period of study range of pH value varied found to be 7.1 – 9.0. The maximum value was recorded in April 1999 and the minimum was recorded thrice, in February, July and September 1999. Rise and fall of water level along with the flow rate of effluent influenced the pH value of this spot. Mean and SD value of pH of this spot is 7.85 ± 0.621 accordingly.

pH value fluctuation pattern of three sampling spots has been depicted on Fig-4. Monthly mean data of the same are presented in Tables (I-III) in the appendix.

4.5 DISSOLVED OXYGEN :

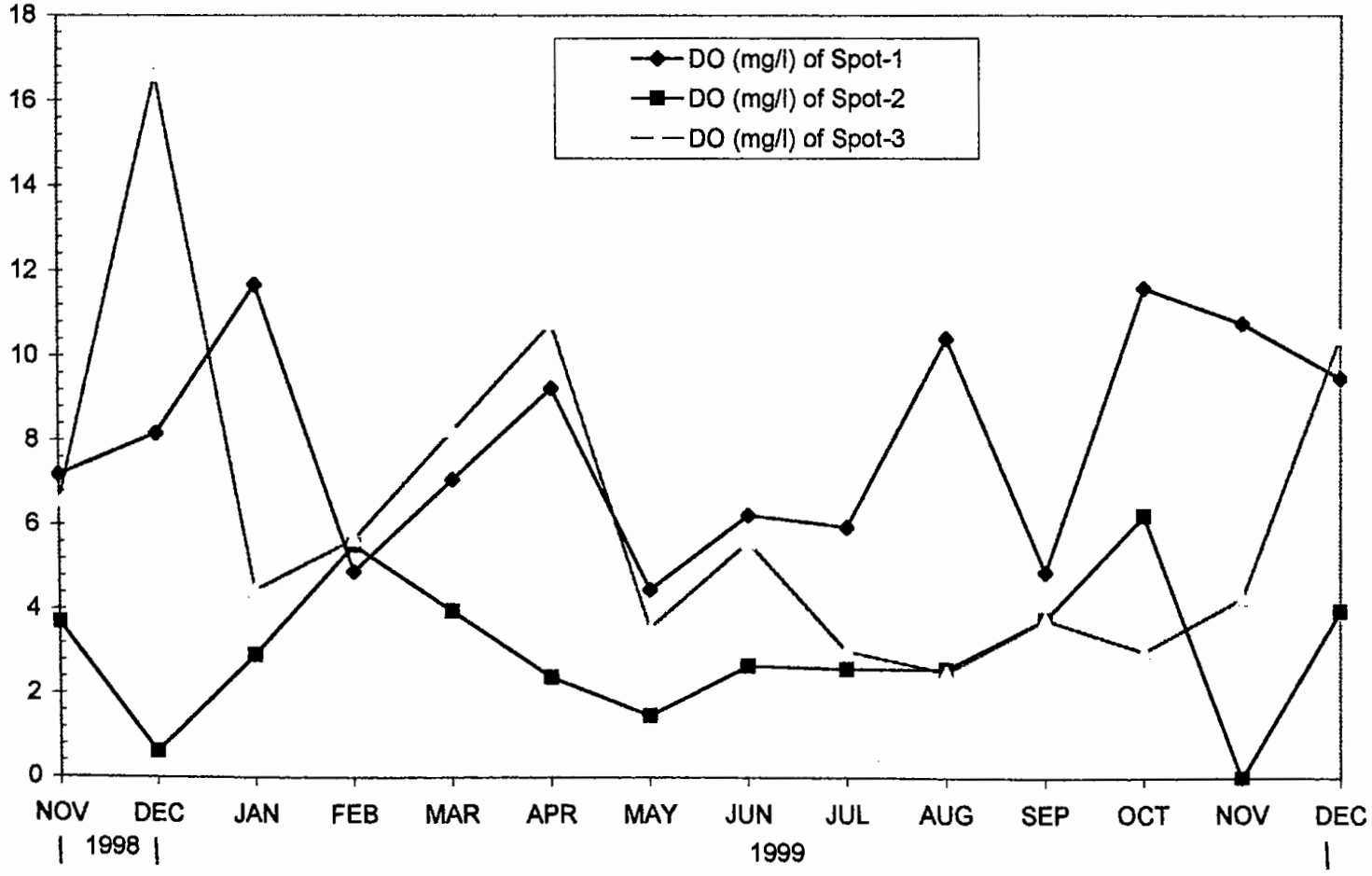
SP-1: A rich regime of DO concentration was observed throughout the period of study at this spot. Maximum value (11.67 mg/l) of DO was recorded in January 1999 and in minimum value (4.467 mg/l) was recorded in May 1999. Mean and SD value of DO of this spot is 7.99 ± 2.544 accordingly.

SP-2 : At this spot the dissolved oxygen value ranged from total anoxia to 6.212 mg/l was recorded in the month of November 1999 and in October accordingly. Fluctuation of DO value found to be related with the mill production period. Mean and SD value of DO of this spot is 3.0213 ± 1.695 accordingly.

SP-3 : At this spot the dissolved oxygen content varied from 2.513 mg/l to 16.612 mg/l during the period of study. The maximum value was recorded in the month of December 1998 and the minimum in August 1999. Mean and SD value of DO content 6.312 ± 3.975 mg/l.

Monthly data of DO values of three spots are shown in Tables (I-III). Fluctuation pattern of dissolved oxygen content of three sampling spots are plotted in Fig. 5.

FIGURE NO. 5 : MONTHLY VARIATION OF DO VALUE OF THREE SAMPLING SPOTS.



4.6 PERCENTAGE OF SATURATION OF OXYGEN :

SP-1: Percentage of saturation of oxygen varied from 59.22 to 157.86% during the period of study. The Maximum value was recorded in October 1999, while the minimum was recorded in September 1999. Super saturation of oxygen were recorded several times from this spot. Mean and SD value of this spot is 102.481 ± 32.484.

SP-2 : Maximum value of percentage of saturation of oxygen was obtained in October 1999. A very negligible DO value was recorded once in November 1999, so titration was not possible. Mean and SD value of percentage of sat. of 0_2 of this spot is 36.970 ± 22.863.

SP-3 : During the period of study, percentage of saturation of oxygen of water varied from 32.174 to 184.377%. The maximum value recorded in December 1998 and the minimum value was recorded in August 1999. Mean and SD value of percentage of sat. of 0_2 of this spot is 77.785 ± 46.022.

Monthly data of percentage sat of 0_2 is shown in Tables (I-III). Fluctuation pattern of the same are depicted in Fig. 6.

4.7 CONDUCTIVITY :

SP-1 : The electric conductivity was found to vary from 296.112µS/cm to 739 µS/cm during the period of study. The maximum value was recorded in October 1999 and the minimum was recorded in June 1999. Mean and SD value of conductivity of this spot is 540.29 ± 134.18.

SP-2 : The electric conductivity of effluent mixed water varied from 271.24 µS/cm to 1193.01µS/cm. conductivity value of this spot reached its maximum in

February 1999, while the minimum was recorded in October 1999. Mean and SD value of conductivity of this spot is 681.24 ± 286.57.

SP-3 : Electric conductivity ranged from 193.53 µS/cm to 1072.61 µS/cm , the minimum was recorded in the month of October 1999, while the maximum was recorded in May 1999. Mean and SD value of this spot is 609.20 ± 282.49.

Monthly fluctuation pattern of conductivity of three spots are shown in Fig. 7 and Tables I-III (Appendix).

4.8 FREE CARBONDIOXIDE (CO_2) :

SP-1: Free CO_2 were detected only thrice from this study spot during the period of study. These were in the months of November 1998, February 1999 and September 1999. In these three months maximum value (6.6 mg/l) of free CO_2 was obtained in February 1999. Mean and SD value of CO_2 of this spot is 0.8571 ± 1.92 accordingly.

SP-2 :. Free carbon dioxide was present in this spot throughout the period of study, with a maxima and minima of 11.2 mg/l and 2.0 mg/l accordingly. These two values were detected in February'99 and July'99 respectively. Mean and SD value of free CO_2 of this spot is 5.257 ± 3.133 accordingly.

SP-3 : . Except in the month April'99 free CO_2 was detected throughout the period of study from this spot. Maximum value (6.6 mg/l) was obtained in the month of September'99. Mean and SD value of free CO_2 of this spot is 3.328 ± 2.08 accordingly.

Monthly fluctuation pattern of free CO_2 of three spots are plotted in Fig. 8 and shown in tabular form in Tables: I-III (Appendix).

FIGURE NO. 6 : MONTHLY VARIATION OF PERCENTAGE OF SATURATION OFOXYGEN VALUE OF THREE SAMPLING SPOTS.

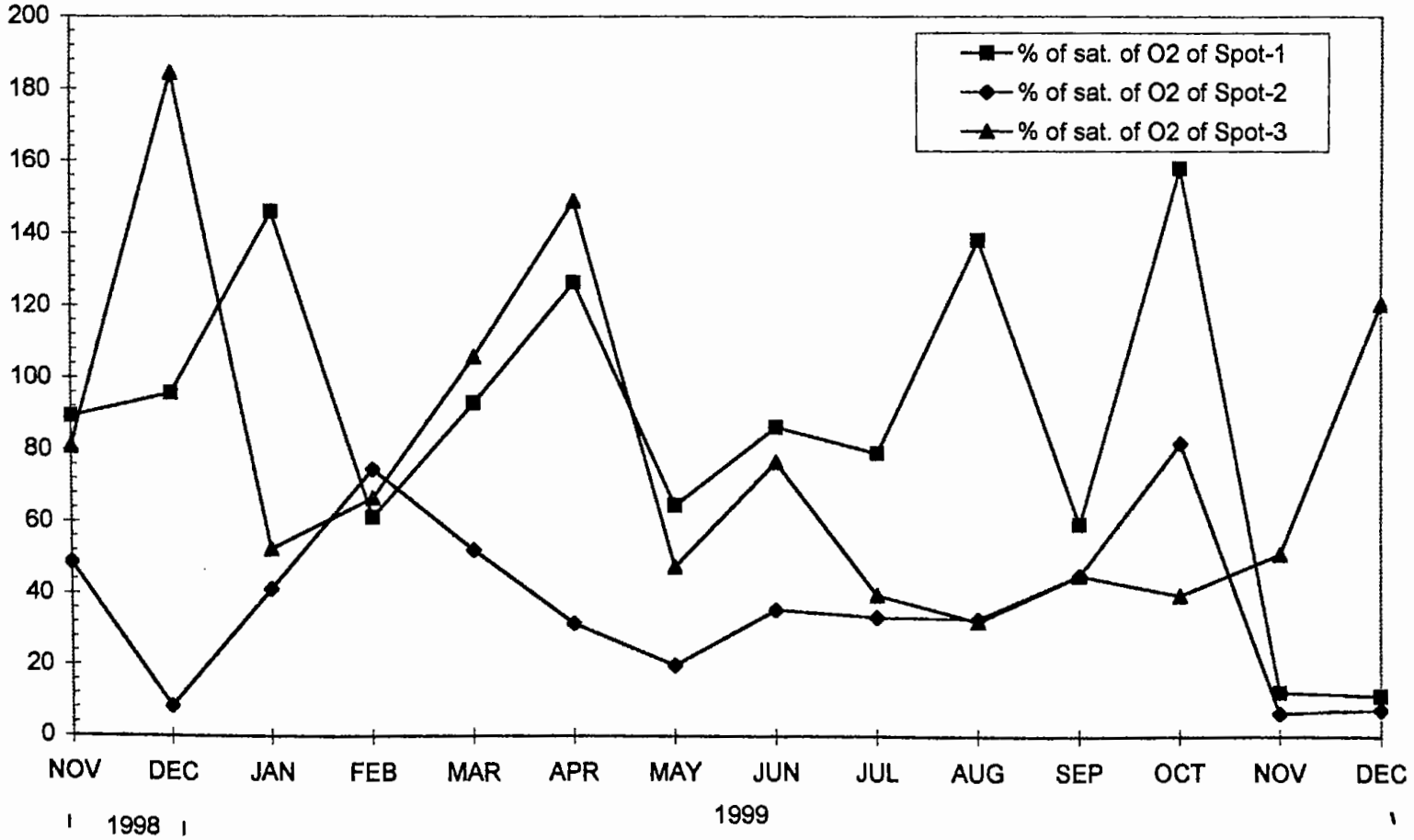


FIGURE NO. 7 : MONTHLY VARIATION OF CONDUCTIVITY VALUE OF THREE SAMPLING SPOTS.

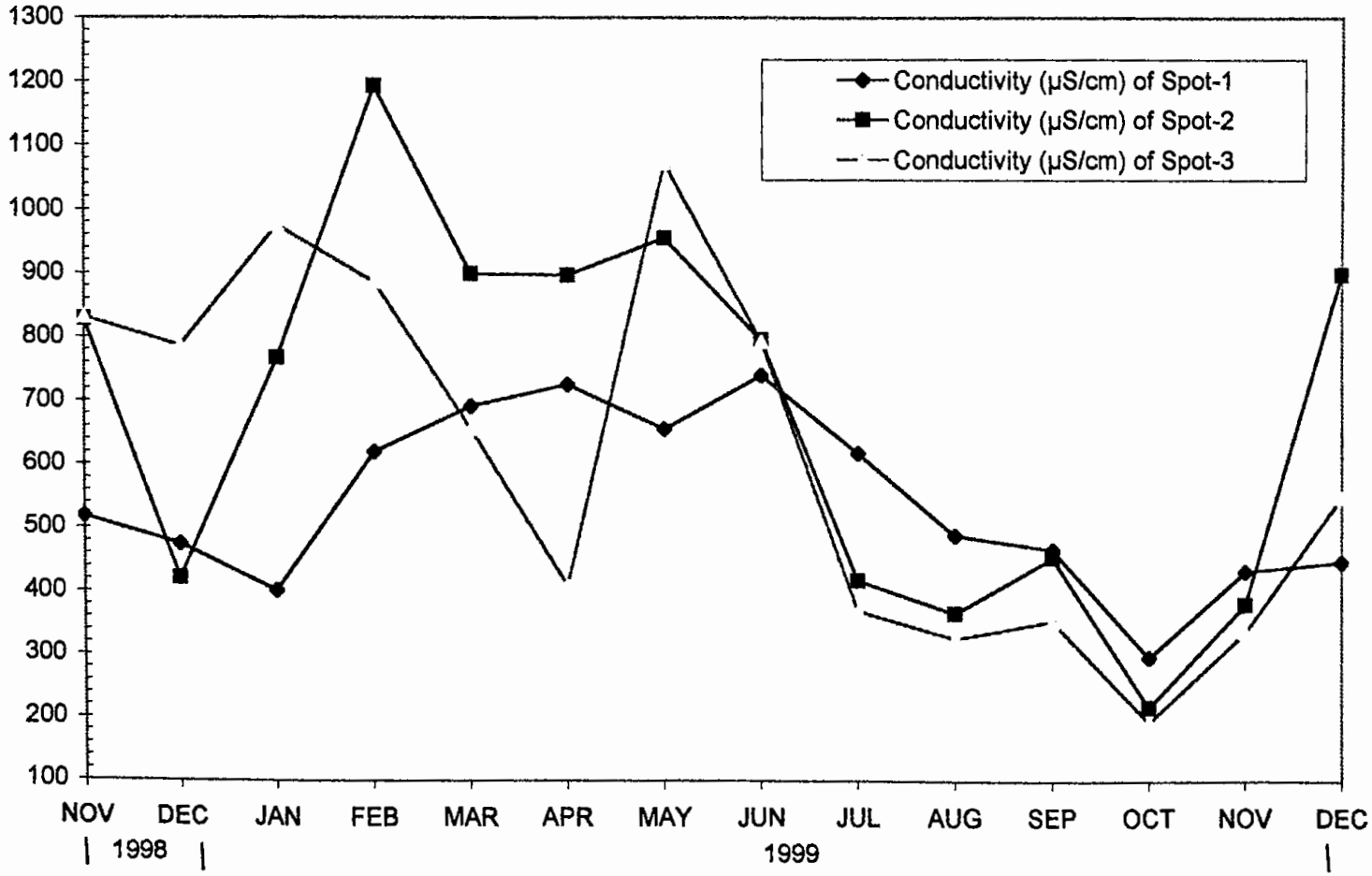
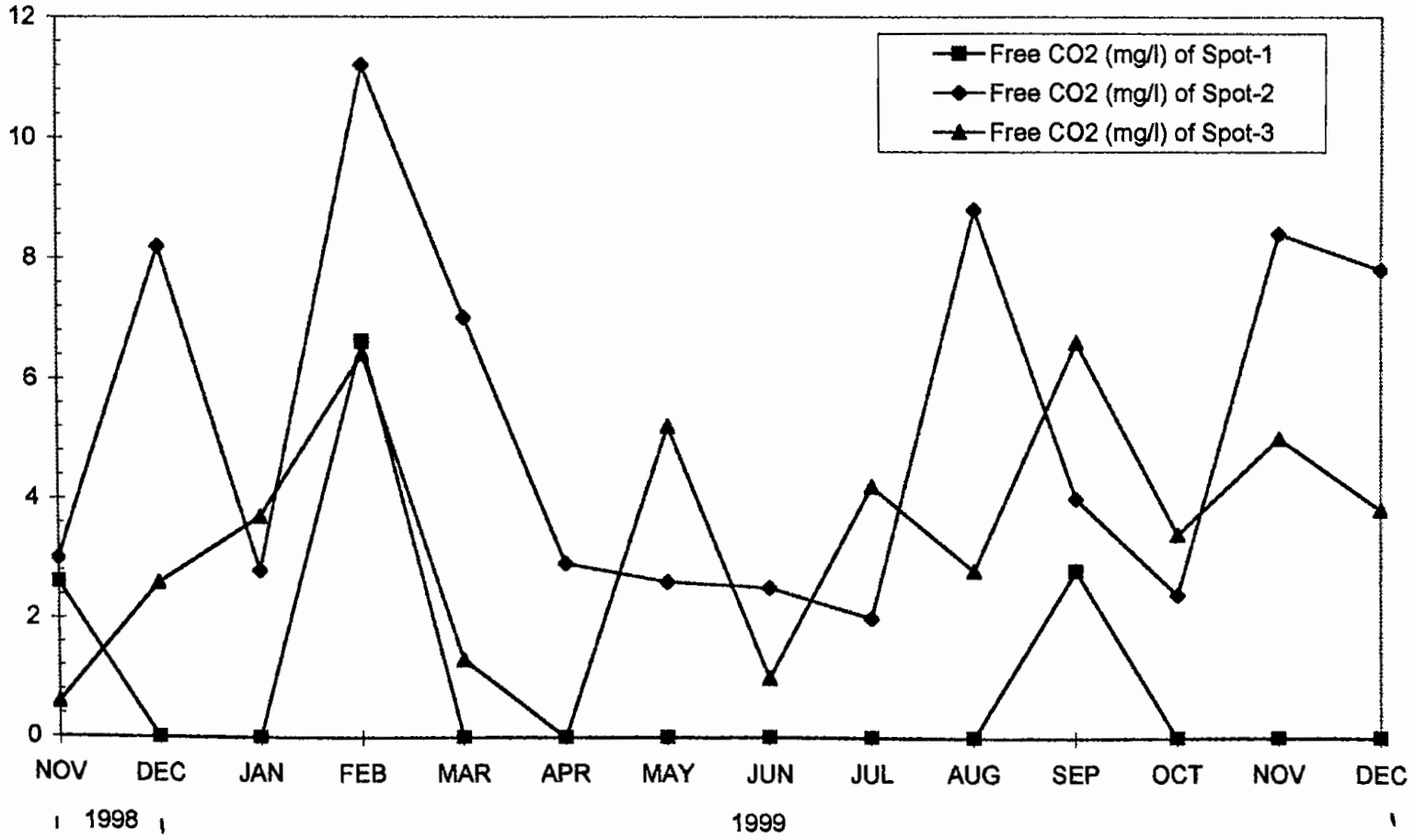


FIGURE NO. 8 : MONTHLY VARIATION OF FREE CARBON DI OXIDE VALUE OF THREE SAMPLING SPOTS.



4.9 CARBONATE ALKALINITY :

SP-1: Except three occasions (November 1998, February 1999 and September 1999) carbonate content of water of this spot showed a more or less rich presence. Maximum value (44 mg/l) was obtained in the month of October 1999. Mean and SD value of carbonate of this spot is 26.07 ± 16.33 accordingly.

SP-2 :. Throughout the period of study carbonate content of water was undetectable from this spot.

SP-3 : . Absence of carbonate content evident from this spot with an exception in the month of April 1999 (30 mg/l). Mean and SD value of carbonate content of this spot is 2.1428 ± 8.0178 accordingly.

Monthly fluctuation of carbonate content of three spots are shown in Fig. 9 and data of the same are presented in Tables I-III respectively.

4.10 BICARBONATE ALKALINITY :

SP-1: Maximum value (289 mg/l) of bicarbonate alkalinity was obtained in December 1998, while the minimum (116 mg/l) in August 1999. Mean and SD value of the same at this spot is 220.143 ± 55.284 accordingly.

SP-2:. Bicarbonate content of water of this spot ranged from 79 to 391 mg/l during the period of study. The minimum value (79 mg/l) was recorded in the month October 1999 while the maximum (391 mg/l) was obtained in April 1999. Mean and SD value of bicarbonate content at this spot is 248.357 ± 110.829 respectively.

SP-3: . Bicarbonate content of water at this spot varied from 99 to 332 mg/l throughout the period of study. Mean and SD value of bicarbonate content at this spot is 215.51 ± 88.04 accordingly.

FIGURE NO. 9 : MONTHLY VARIATION OF CARBONATE VALUE OF THREE SAMPLING SPOTS.

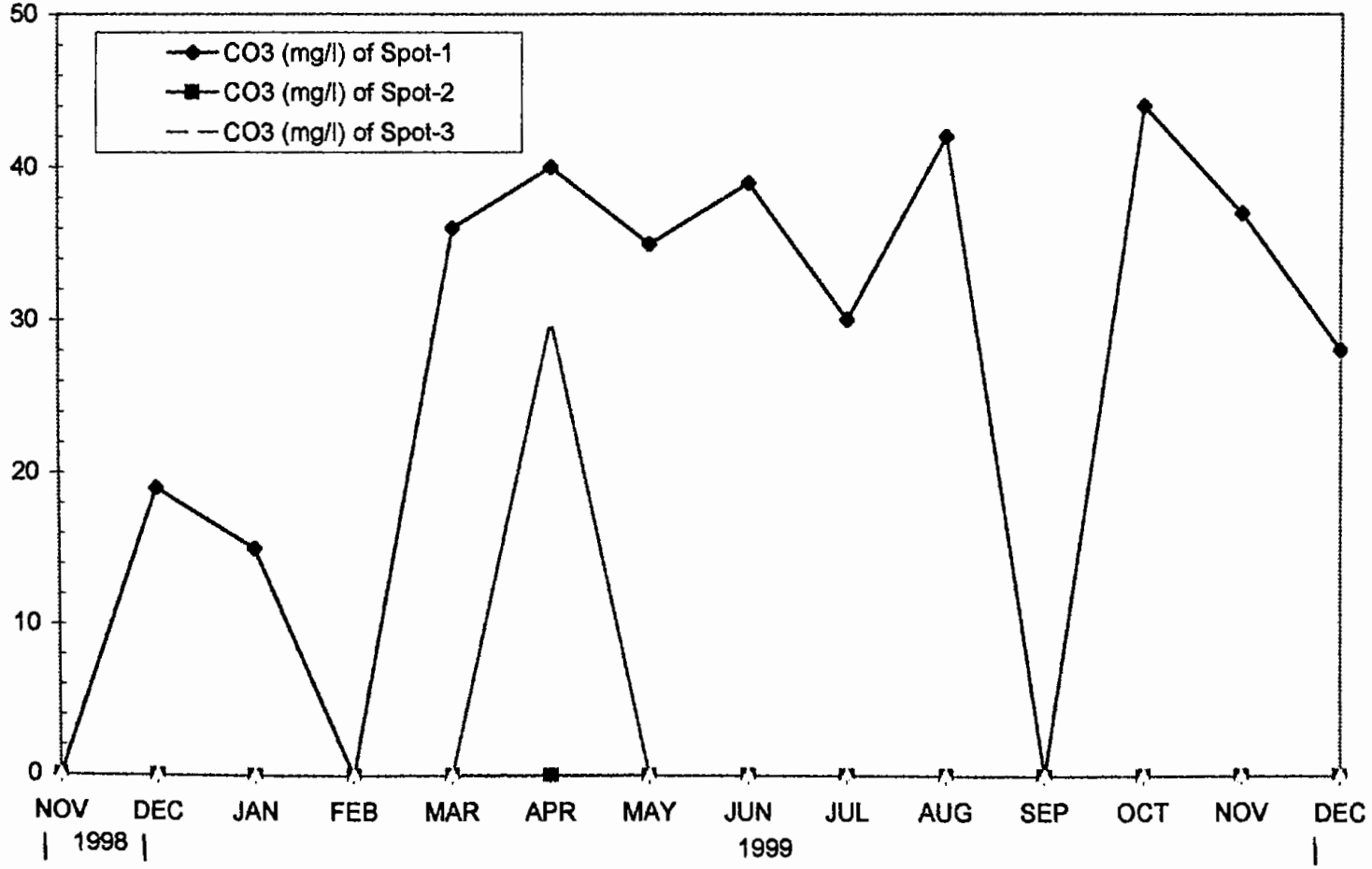
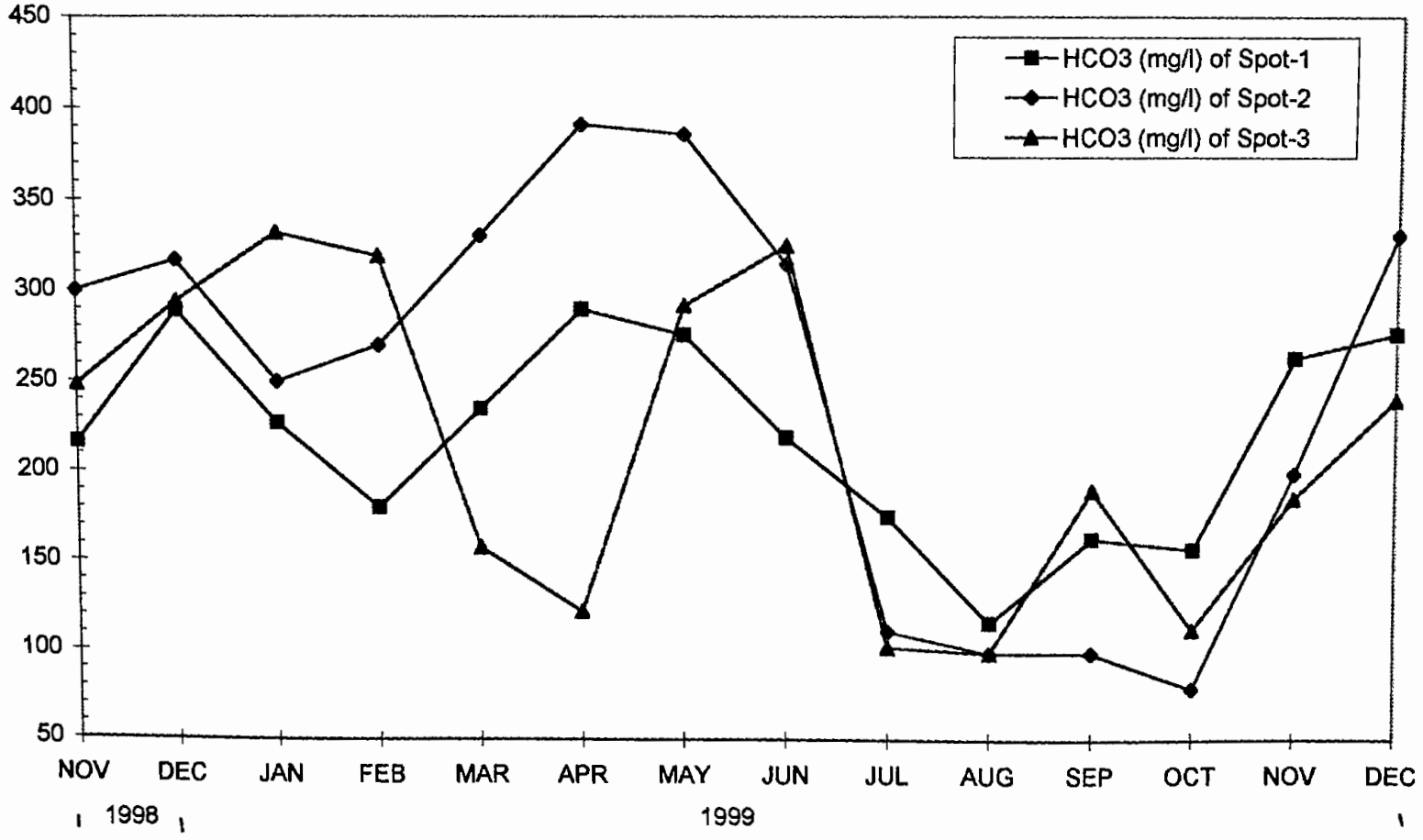


FIGURE NO. 10 : MONTHLY VARIATION OF BI-CARBONATE VALUE OF THREE SAMPLING SPOTS.



Fluctuation pattern of bicarbonate content of three spots are plotted in Fig. 10 and data of the same are presented in Tables I-III respectively in (Appendix).

4.11 TOTAL HARDNESS :

SP-1 :Total hardness value was found to vary from 90 to 410 mg/l during the period of study. The maximum value was recorded in September 1999 and the minimum in October 1999. Mean and SD value of hardness of this spot is 246.04 ± 81.95 accordingly.

SP-2 :. Total hardness value ranged from 142.8 to 790 mg/l during the period of study. The maximum value was recorded in February 1999, while the minimum was recorded in October 1999. Mean and SD value of the same is 357.42 ± 175.88 accordingly.

SP-3 : . Total hardness value ranged from 105 to 441 mg/l during the period of study. The maximum value was recorded in January 1999 and the minimum was recorded in October 1999. Mean and SD value of the same is 226.81 ± 85.61 accordingly.

Fluctuation pattern of total hardness of three spots during the period of study is depicted on Fig. 11 and data of the same are presented Tables I-III appendix.

4.12 CALCIUM HARDNESS :

SP-1:Hardness due to calcium ranged from 80-214.2 mg/l during the period of study. Minimum value recorded in October 1999, while the maximum was obtained in June 1999. Mean and SD value of calcium hardness content at water of this spot is 140.66 ± 43.40 accordingly.

SP-2:. At this study point calcium hardness value varied from 70 to 378 mg/l during the period of study. Maximum value was recorded in January 1999, while

the minimum was recorded in October 1999. Mean and SD value of calcium hardness at this spot is 224.69 ± 101.32 accordingly.

SP-3: . Range of calcium hardness content varied from 56 to 268 mg/l. Maximum value was recorded in January 1999 while the minimum was recorded in September 1999. Mean and SD value of calcium hardness at this spot is 142.66 ± 63.62.

Monthly fluctuation pattern of calcium hardness of water is depicted in Fig. 12 and data are shown in Tables I-III in appendix.

4.13. MAGNESIUM HARDNESS :

SP-1 : Magnesium hardness varied from 10 to 304 mg/l throughout the period of study. Maximum value was obtained in September 1999 and the minimum October 1999. Mean and SD value of the same at this spot is 105.361 ± 84.52 accordingly.

SP-2 :. The magnesium hardness value ranged from 9.0 to 439.3 mg/l during the period of study. Maximum value was obtained in February 1999 and the minimum was recorded in April 1999. Mean and SD value at the same of this spot is 132.736 ± 113.019 accordingly.

SP-3 : .Magnesium hardness varied from 4.35 to 224.3 mg/l during the presence of study. Maximum value was obtained in the month of June 1999 and the minimum in December 1999. Mean and SD value of the same is 84.15 ± 62.53 accordingly.

Monthly fluctuation pattern of magnesium hardness at this spot is depicted in Fig. 13 and the data of the same are presented in Tables I-III in appendix.

FIGURE NO. 11 : MONTHLY VARIATION OF TOTAL HARDNESS VALUE OF THREE SAMPLING SPOTS.

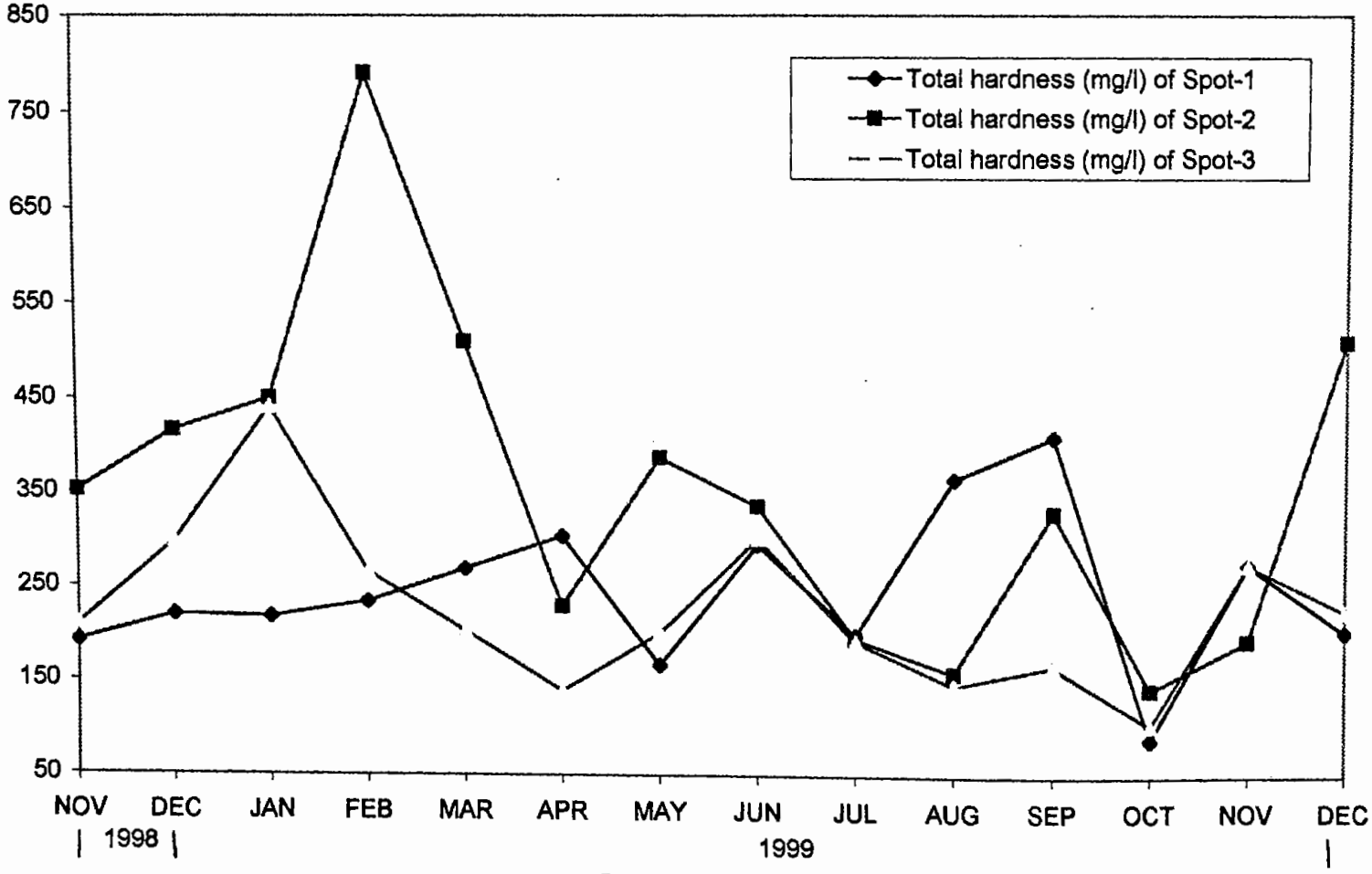


FIGURE NO. 12 : MONTHLY VARIATION OF CALCIUM HARDNESS VALUE OF THREE SAMPLING SPOTS.

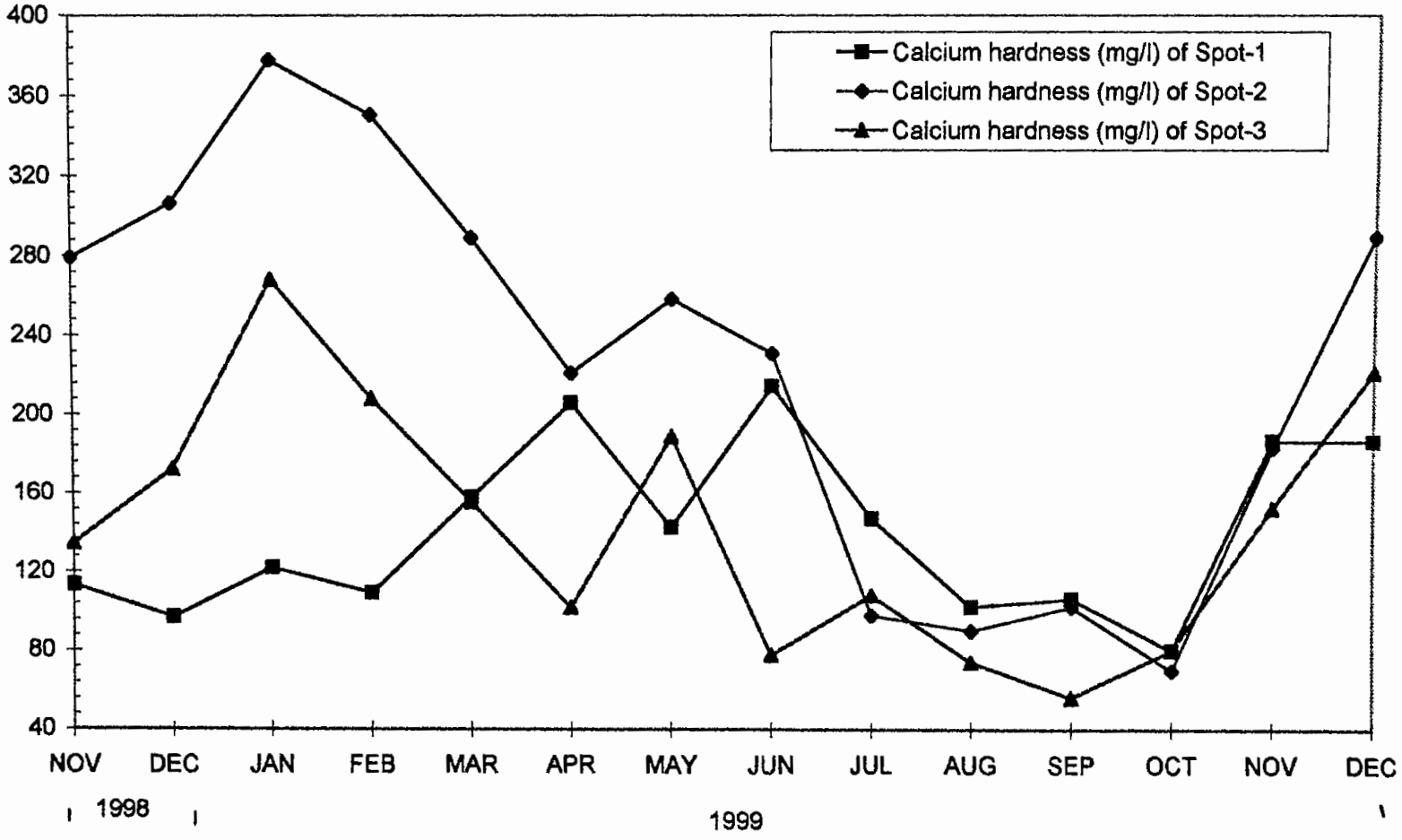
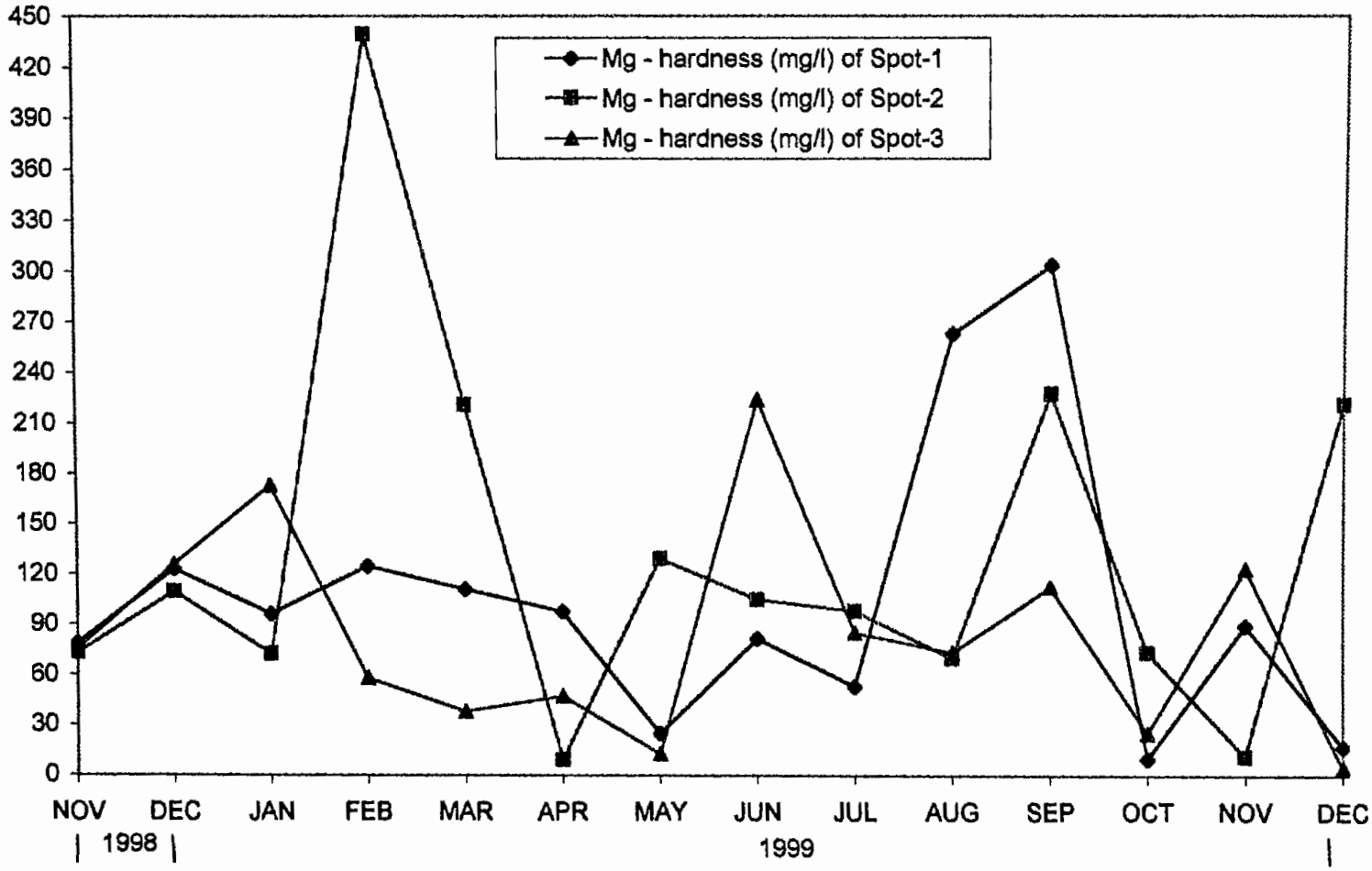


FIGURE NO. 13 : MONTHLY VARIATION OF MAGNESIUM HARDNESS VALUE OF THREE SAMPLING SPOTS.



4.14 CHLORIDE CONTENT :

SP-1 : Chloride content was found to vary from 17.04 to 46.86 mg/l during the period of study. Maximum value was recorded in December 1998 and the minimum was recorded in August 1999. Mean and SD value of the same is 35.66 ± 10.48 mg/l.

SP-2 :. Chloride value ranged from 5.68 to 39.76 mg/l during the study period. Maximum value was obtained in November 1998 and February 1999 while the minimum was recorded in May 1999. Mean and SD value of the same is 23.994 ± 11.124.

SP-3 : . The chloride value varied from 15.62 to 171.82 mg/l during the period of study. Maximum value recorded in November 1998 and the minimum value recorded in June 1999. Mean and SD value of the same is 81.95 ± 61.14 accordingly.

Monthly fluctuation values of chloride content at the three spots is depicted in Fig. 14 and data of the same are shown in appendix Tables I-III.

4.15 PHOSPHATE CONTENT :

SP-1 : Phosphate content of this spot found to vary from 0-0.066 mg/l. Maximum value was obtained in November 1999. Absence of phosphate content was observed thrice (February 1999, September 1999 and October 1999) during the period of study. Mean and SD value of phosphate content at this spot is 0.02214 ± 0.02278 accordingly.

SP-2:. At this study point the phosphate value varied from zero to 0.08 mg/l the highest value was recorded in December 1998 and the lowest value was obtained six times (March 1999, April 1999, June 1999, July 1999, October 1999 and

FIGURE NO. 14 : MONTHLY VARIATION OF CHLORIDE VALUE OF THREE SAMPLING SPOTS.

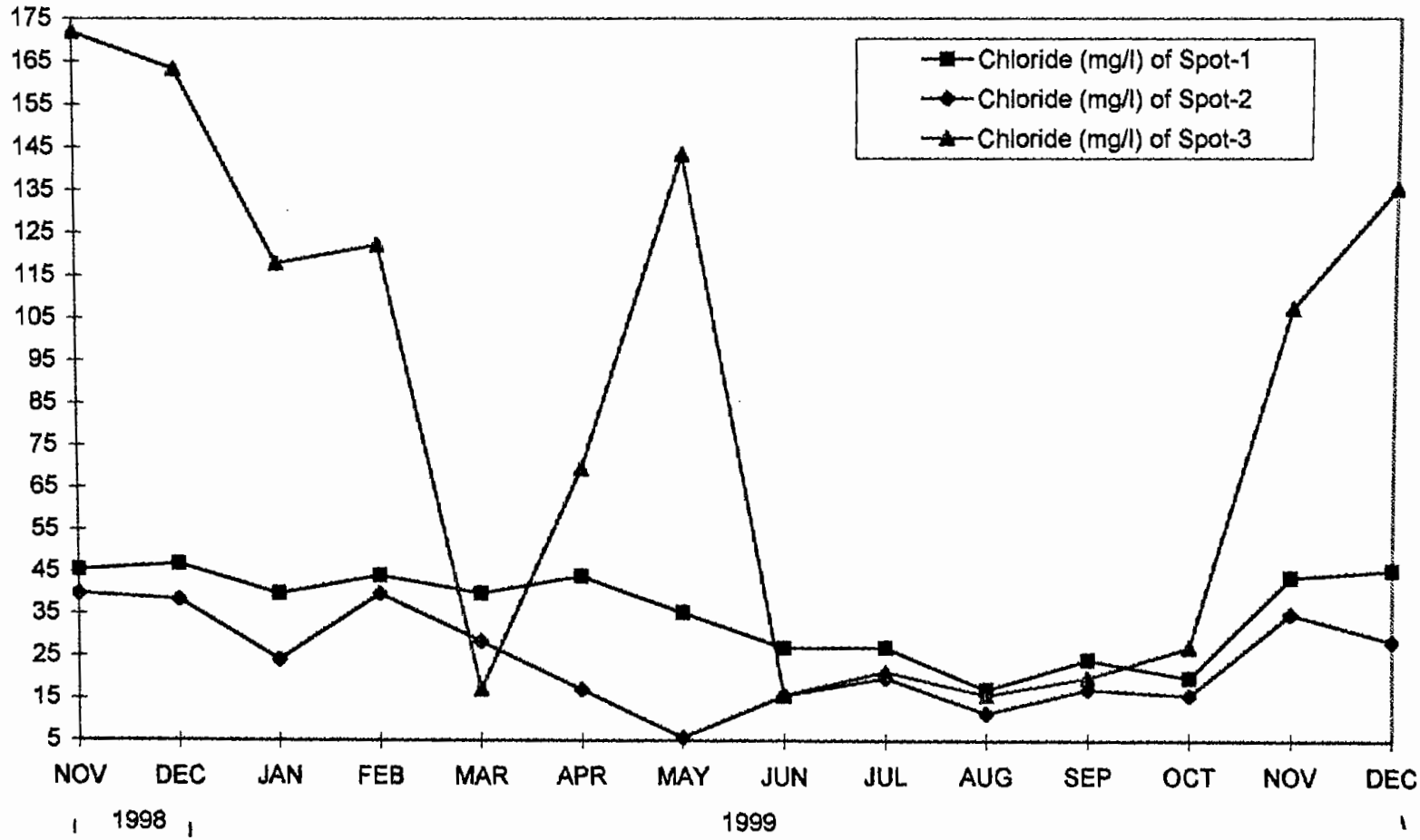
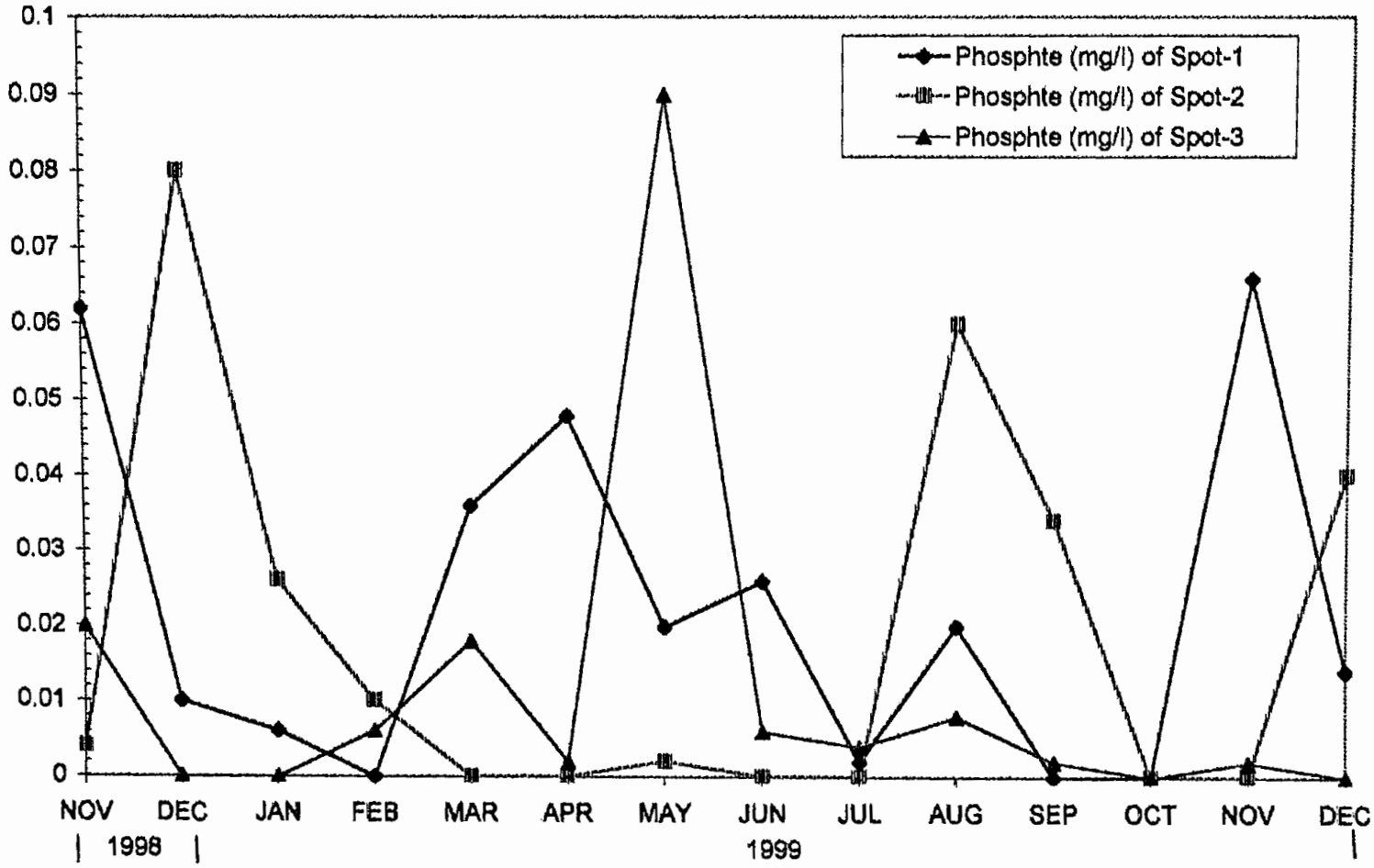


FIGURE NO. 15 : MONTHLY VARIATION OF PHOSPHATE VALUE OF THREE SAMPLING SPOTS.



November 1999). Mean and SD value of the phosphate content is 0.01828 ± 0.02612 accordingly.

SP-3: . Phosphate content at this spot varied from zero to 0.09 mg/l during the period of study. The maximum value was observed in May 1999. The minimum value was obtained four times (December 1998, January 1999, October 1999 and December 1999). Mean and SD value of phosphate content is 0.01129 ± 0.02354 accordingly.

Monthly fluctuation pattern of phosphate content at the three spots are plotted in Fig. 15 and data of the same are shown in Tables I-III is appendix.

4.16 AMMONIUM (NH_4) :

SP-1 : Ammonium content of water varied from zero to 1.0696 mg/l during the period of study. Absence of ammonium content was detected thrice (January 1999, February 1999 and June 1999) during the period of study, while the maximum value was obtained in December 1999. Mean and SD value of the same at this spot is 0.23525 ± 0.35918 accordingly.

SP-2:. The NH_4 value varied from zero to 1.11195 mg/l during the period of study. Maximum value was recorded in the month of November 1999 and the minimum values were obtained twice, once in September 1999 and October 1999. Mean and SD of the same of this spot is 0.19743 ± 0.281401 accordingly.

SP-3: . At this spot, ammonium value varied from zero to 3.1875 mg/l during the period of study. Ammonium content of water was undectable thrice during the period of study (June 1999, September 1999 and October 1999) and the maximum value was obtained in November 1999. Mean and SD value of ammonium content is as follows 053782 ± 0.88727.

Monthly fluctuation pattern of ammonium content at the three spots are depicted in Fig. 16 and data of the same are shown in Tables I-III in appendix.

4.17 AMMONIA (NH_3) :

SP-1 : The value of ammonia of water varied from zero to 1.0097 mg/l during the study period. the maximum value was recorded in December 1999, while the minimum value was obtained thrice (January 1999, February 1999 and June 1999). Mean and SD value of the same of this spot is 0.22208 ± 0.33906 accordingly.

SP-2: At this spot ammonia value varied from zero to 1.04968 mg/l during the period of study. The minimum values were obtained twice, once in September 1999, the other in October 1999 and the maximum value was obtained in November 1999. Mean and SD value of the same at this spot is 0.250636 ± 0.341217 accordingly.

SP-3: Ammonia value of water was found to vary from zero to 3.00908 mg/l during the study period. The maximum value was recorded in November 1999 while in the months June 1999, September 1999 and October 1999 ammonia was found to be absent. Mean and SD value of the same of this spot is 0.50770 ± 0.83757 accordingly.

Monthly fluctuation pattern of ammonia content of the three spots are plotted in Fig. 17 and data at the same are shown in Tables I-III in appendix.

4.18 AMMONIUM NITROGEN (NH_4-N) :

SP-1 : The content of ammonium nitrogen varied from zero to 0.83098 mg/l during the study period. The maximum value was recorded in December 1999, while the

minimum values were obtained thrice (January 1999, February 1999 and June 1999). Mean and SD value of the same is as follows 0.18277 ± 0.27905.

SP-2 :. Ammonium nitrogen values of water at this spot varied from zero to 0.86389 mg/l during the study period. Minimum values were obtained twice (September 1999 and October 1999) while the maximum was recorded in November 1999. Mean and SD value of the same is 0.15338 ± 0.21862 accordingly.

SP-3 : . At this spot ammonium nitrogen content varied from zero to 2.47647 mg/l during the period of study. The maximum value was recorded in November 1999, while the minimum values were recorded thrice (June 1999, September 1999 and October 1999). Mean and SD value of the same of this spot is 0.41783 ± 0.68932 accordingly.

Monthly fluctuation pattern of ammonium-nitrogen content of three spots are plotted in Fig. 18 and the data of the same are shown in Tables I-III (Appendix).

4.19 OXIDATION-REDUCTION POTENTIAL (Eh) :

SP-1 : Oxidation-reduction potential of water varied from 0.00910 to 0.37281 mv, found to be recorded in the month of June 1999 and February 1999 accordingly. Mean and SD value of the same is as follows 0.22679 ± 0.10647.

SP-2 :. Eh value ranged from 0.23330 to 0.61985 mv. Maximum value was obtained in February 1999 and the minimum in October 1999. Mean and SD value of the same is as follows 0.408814 ± 0.111138.

SP-3 : . Eh value varied from 0.41128 to 0.15905 mv throughout the study period. The maximum value was obtained in July 1999, while the minimum in April 1999 respectively. Mean and SD value of the same is 0.306214 ± 0.08341 accordingly.

FIGURE NO. 16 : MONTHLY VARIATION OF AMMONIUM VALUE OF THREE SAMPLING SPOTS.

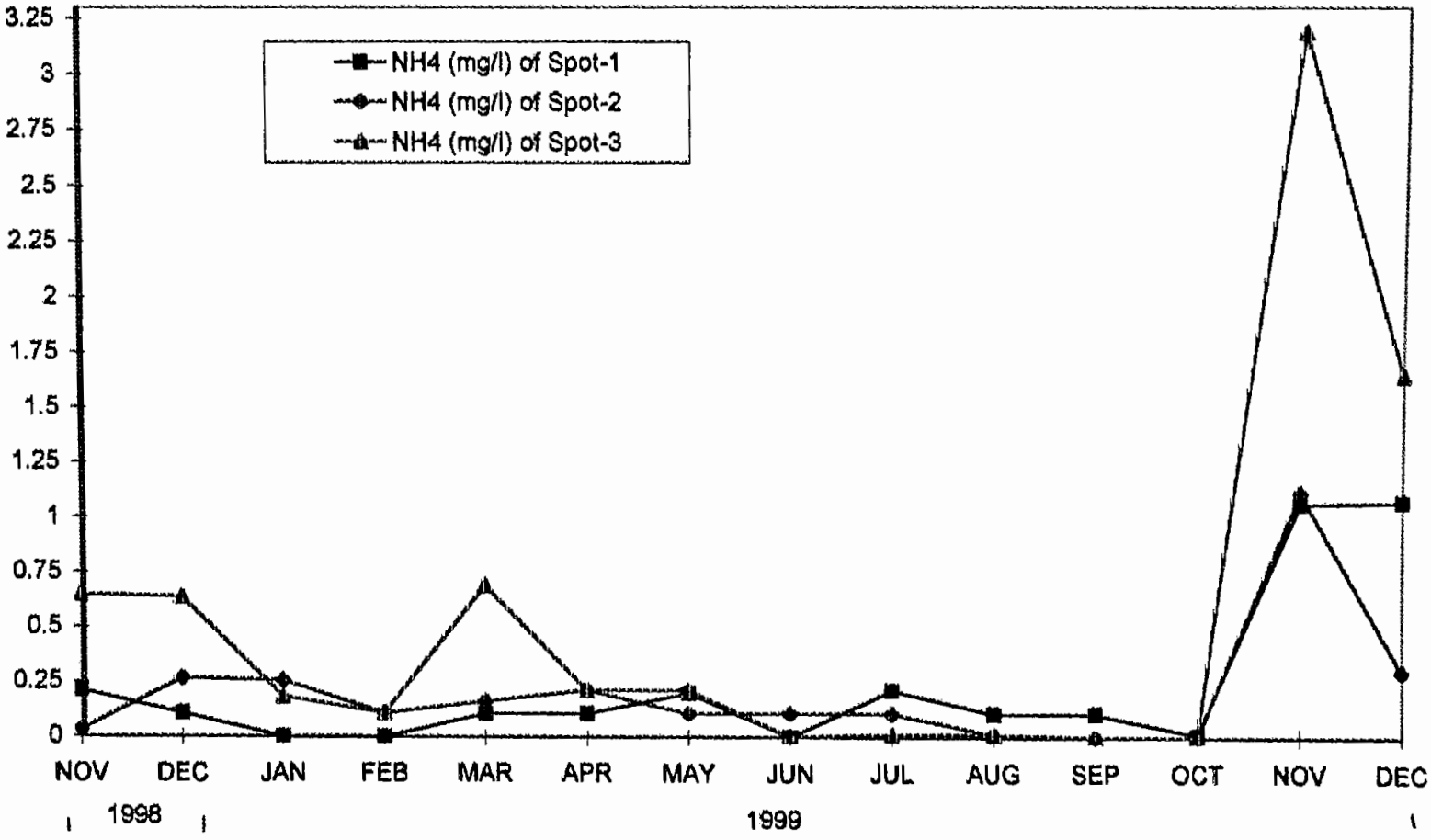


FIGURE NO. 17 : MONTHLY VARIATION OF AMMONIA VALUE OF THREE SAMPLING SPOTS.

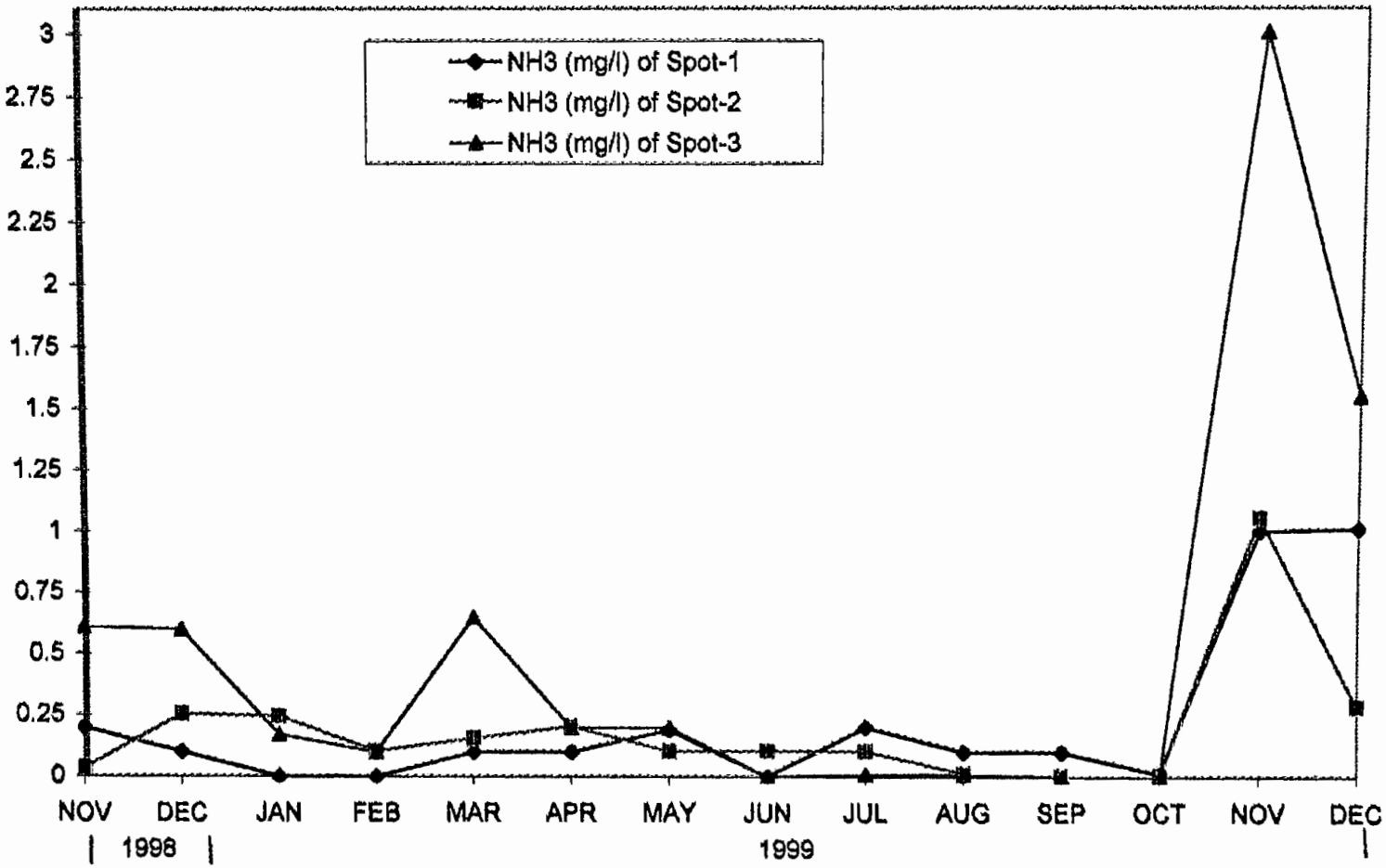


FIGURE NO. 18 : MONTHLY VARIATION OF AMMONIUM-NITROGEN VALUE OF THREE SAMPLING SPOTS.

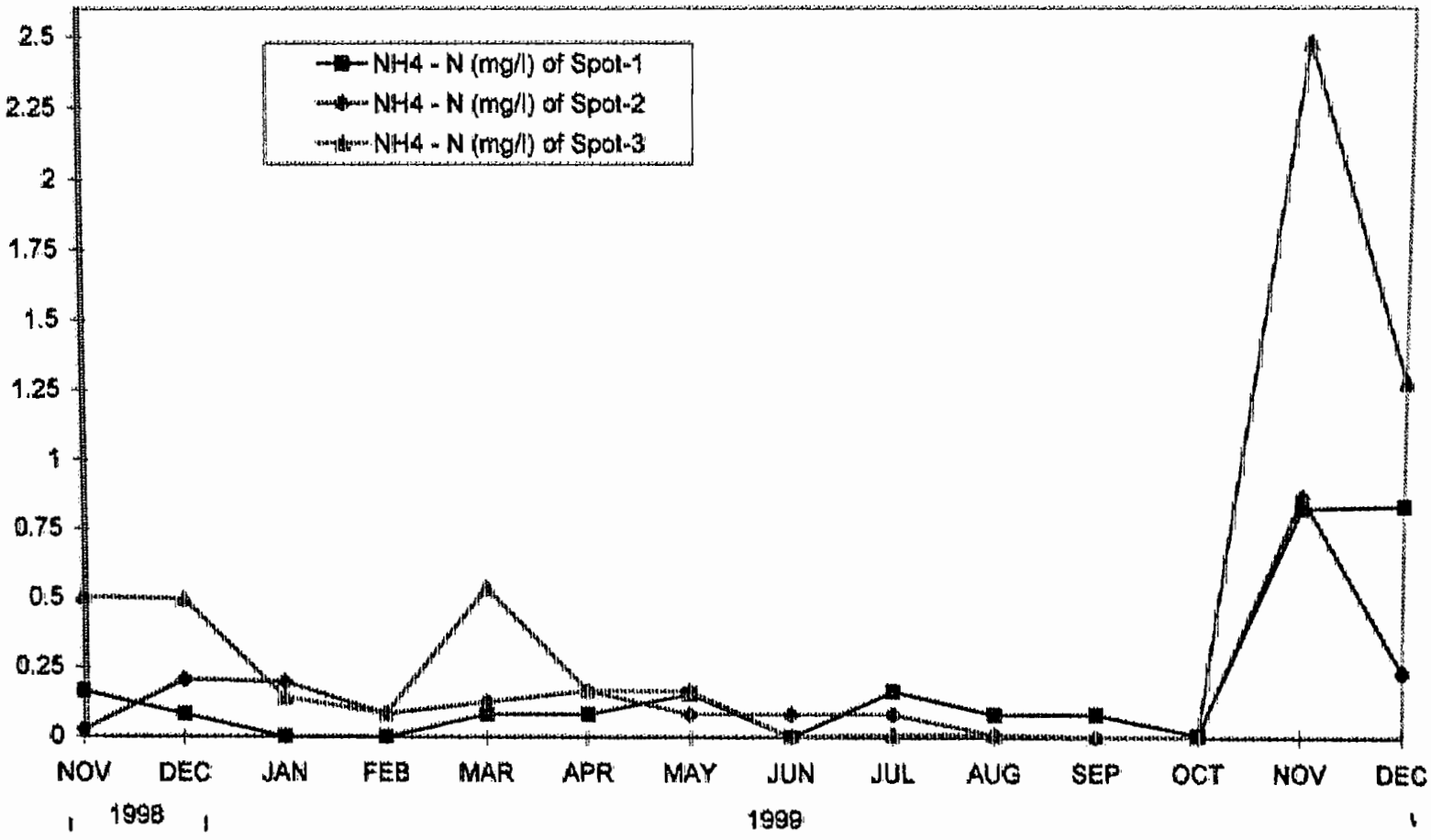
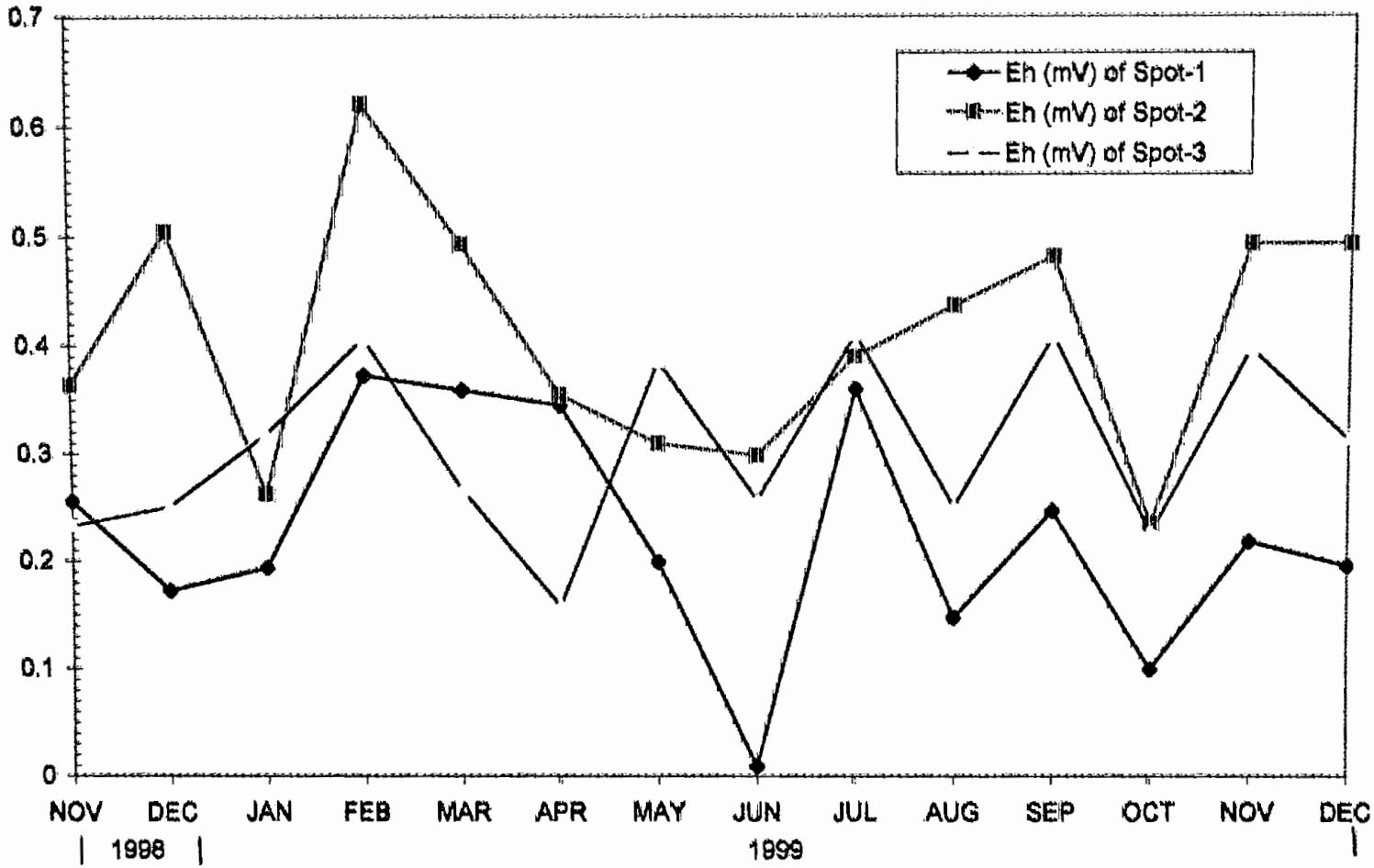


FIGURE NO. 19 : MONTHLY VARIATION OF Eh VALUE OF THREE SAMPLING SPOTS.



Monthly fluctuation pattern of oxidation-reduction potential of the three spots are plotted in Fig. 19 and data of same are shown in appendix tables I-III.

4.20 OXIDATION-REDUCTION INDEX (rH_2) :

SP-1 : Oxidation-reduction index varied 20.914 to 27.656, was found to be recorded in the month of April June and February 1999 accordingly. Mean and SD value of the same of this spot is 24.806 ± 2.01006 accordingly.

SP-2:. rH_2 value ranged from 24.845 to 31.974 during the study period. Maximum value was obtained in February 1999, while minimum was recorded in October 1999. Mean and SD value of the same is as follows 28.226 ± 2.0692.

SP-3 : Range of rH_2 value was found to be 23.484 ± 28.382 during the study period. The maximum value was obtained in July 1999 and the minimum was recorded in April 1999. Mean and SD value of the same of this spot is 26.259 ± 1.6407 accordingly.

Monthly fluctuation pattern of oxidation-reduction index of the three spots are plotted in Fig. 20 and data of the same is shown Tables I-III in appendix.

4.21 BIOLOGICAL OXYGEN DEMAND [BOD] :

SP-1 : BOD values varied from 1.535 to 9.6324 mg/l during the period of study. Maximum and minimum value of the same was found to be recorded in August 1999 and May 1999 accordingly. Mean and SD value of BOD at this spot is 4.7694 ±2.3344 accordingly.

SP-2 : BOD values varied from 0.2792 to 4.537 mg/l during the period of study. Maximum and minimum values of BOD were detected in October 1999 and April 1999 accordingly. Increased final dissolve oxygen values were obtained four times

FIGURE NO. 20 : MONTHLY VARIATION OF rH_2 VALUE OF THREE SAMPLING SPOTS.

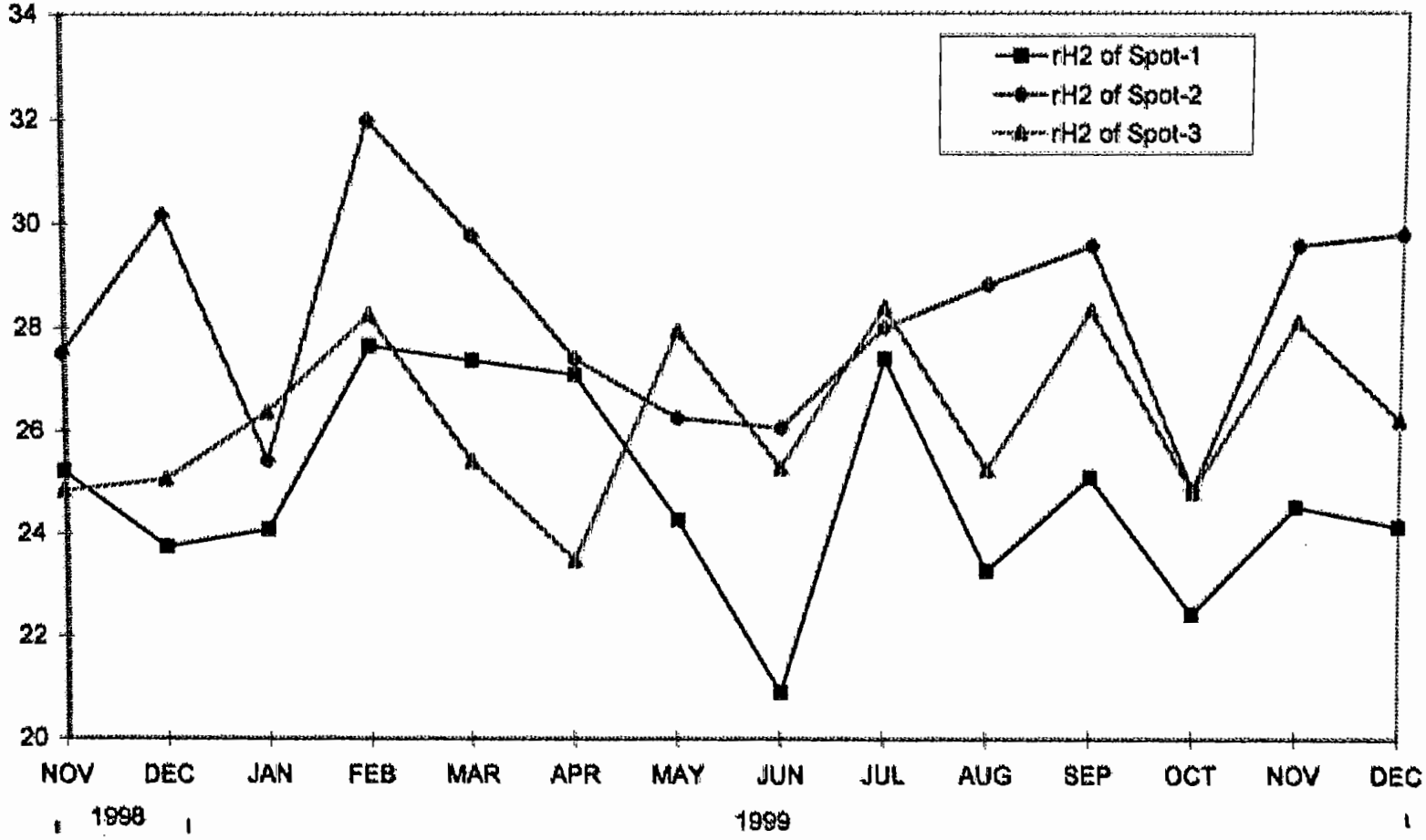
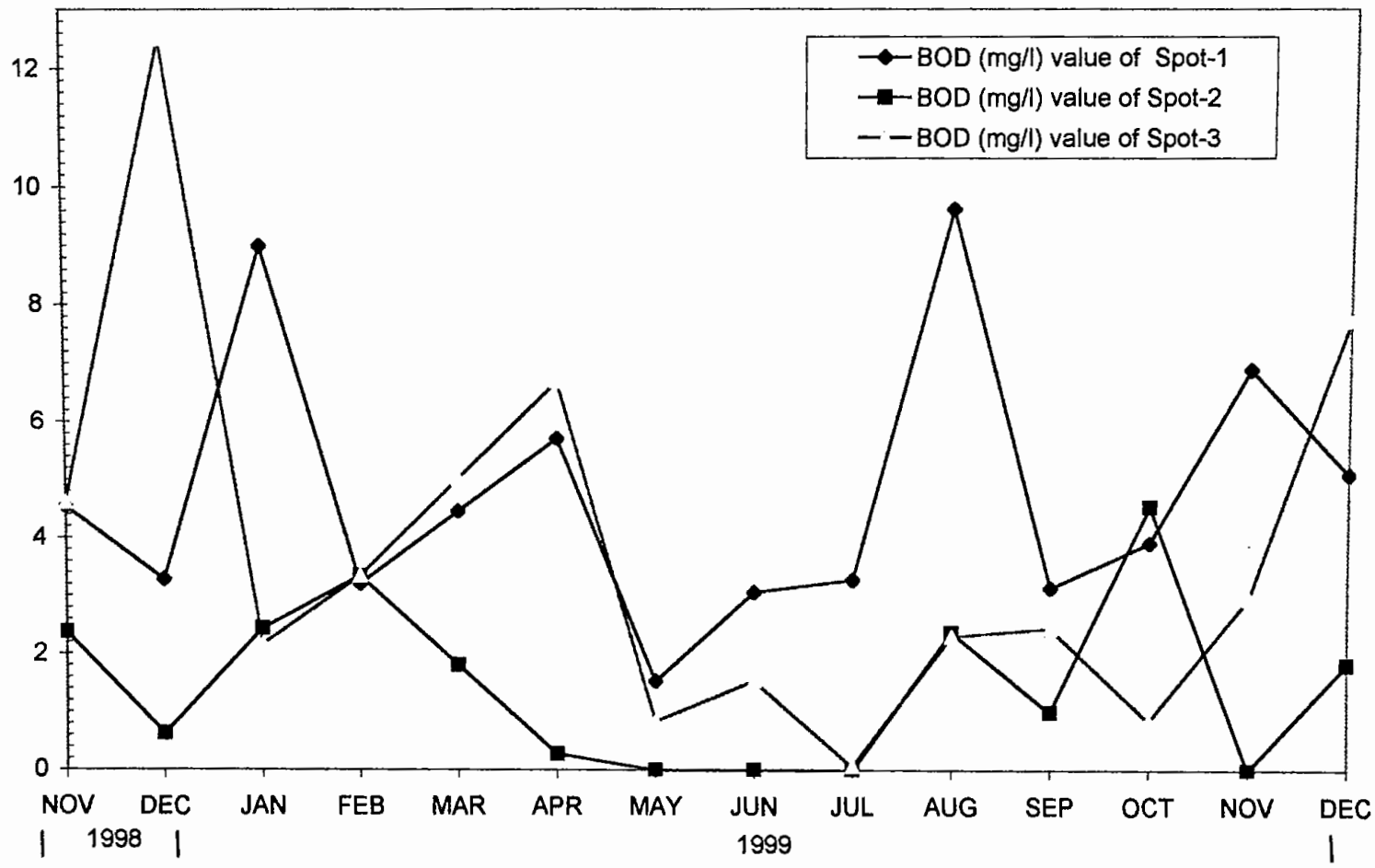


FIGURE NO. 21 : MONTHLY VARIATION OF BOD VALUE OF THREE SAMPLING SPOTS.



from this spot, thus it was not possible to calculate BOD_5 results. Mean and SD value of the same is as follows 1.4723 ± 1.4345.

SP-3 : BOD_5 values varied from 0.0698 to 12.4942 mg/l during the study period. The maximum value was recorded in December 1998 while the minimum in July 1999. Mean and SD value at the same of this spot is 3.789 ± 3.349 accordingly.

Monthly fluctuation pattern of BOD_5 values of the three spots are depicted in Fig. 21 and data of the same are shown in Tables I-III of appendix.

4.22 BIOLOGICAL CONDITIONS :

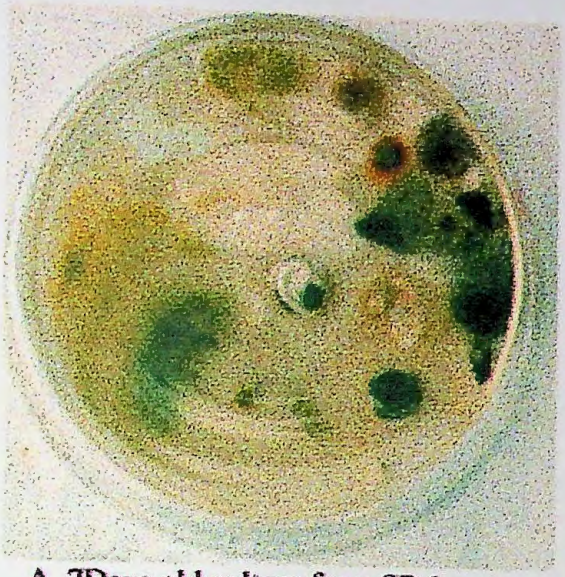
A total of 22 fungal species belonging to 14 genera were reported from three spots (Table : 4) throughout the period of study. Monthly abundance of species were recorded from each spot and presented in Tables 5-7 accordingly.

4.23 SEASONAL ABUNDANCE :

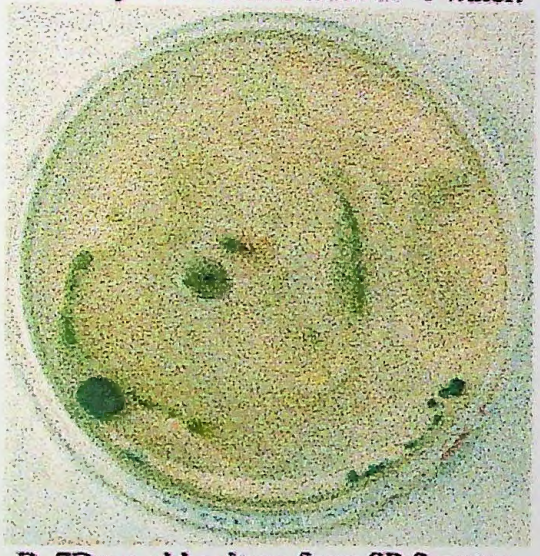
Seasonal abundance of fungal population reveal the fact that their abundance was high during summer and monsoon while lower abundance was recorded during winter [Tables : 5-7]. Further it was also evident from the three of spots that members of Eurotiales, Moniliales, Mucorales, Blastocladiales and Peronosporales were well flourished during summer and monsoon. Only members of Saprolegniales were found to be well adapted during winter months [Tables : 5-7].

Table – 4 : List of fungal genera and species under study spots (In each order genera arranged alphabetically)

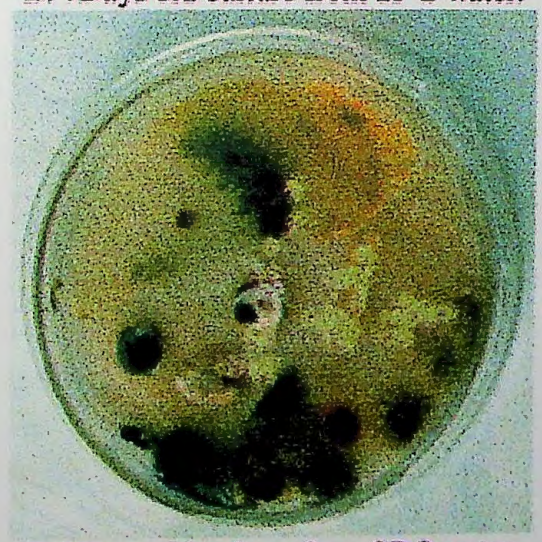
Name	Spot-1	Spot-2	Spot-3
SAPROLEGNIALES			
1 Achlya americana	+	+	+
2 Achlya imperfecta	+		
3 Aphanomyces laevis	+		
4 Saprolegnia Luxurians		+	+
5 Saprolegnia parasitica	+		+
EUROTIALES			
6 Aspergillus niger	+	+	+
7 Aspergillus fumigatus	+	+	+
8 Aspergillus terreus	+		
9 Aspergillus flavus		+	+
10 Penicillium chrysogenum		+	+
11 Penicillium italicum	+	+	+
MONILIALES			
12 Alternaria alternata	+		
13 Fusarium oxysporum	+		
14 Nigrospora sp.		+	+
MUCORALES			
15 Mucor saturinus	+		
16 Rhizopus stolonifer		+	+
BLASTOCLADIALES			
17 Allomyces arbuscula		+	+
18 Allomyces javanicus	+		
PERONOSPORALES			
19 Phytophthora parasitica		+	+
20 Pythium aphanodermatum	+		+
21 Pythium debaryanum		+	+
CHYTRIDIALES			
22 Chytridium olla		+	+



A. 7Days old culture from SP-1 water.



B. 7Days old culture from SP-2 water.



C. 7Days old culture from SP-3 water.

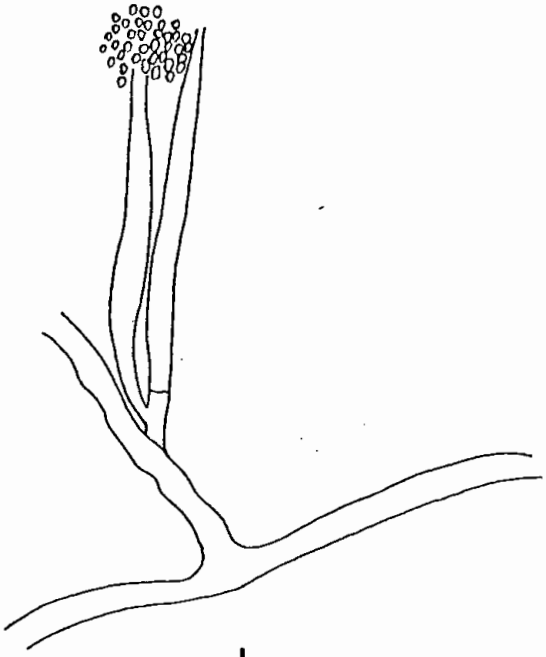
PLATE – 1

Figures :

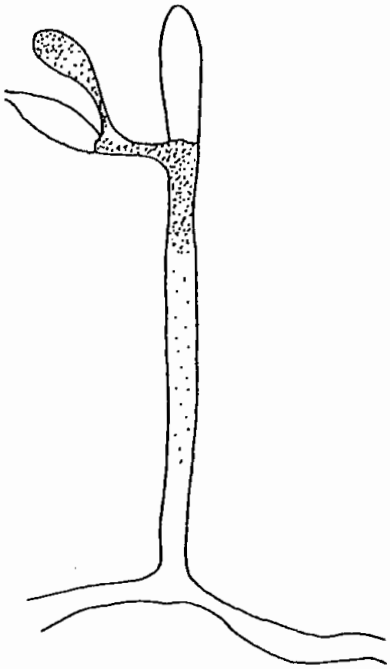
1. *Achlya americana.* (400x)
2. *Achlya imperfecta.* (400x)
3. *Aphanomyces laevis.* (400x)

* The above numbers of these figures are taken from Table : 4.

PLATE – I



1



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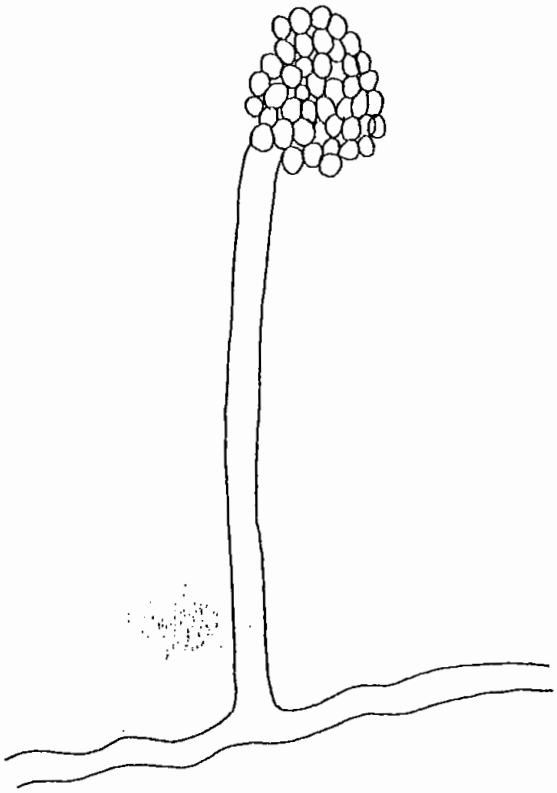


3

PLATE – 2

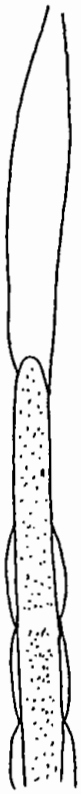
Figures :

4. *Saprolegnia luxurians* (400x)
5. *Saprolegnia parasitica* (400x)
6. *Aspergillus niger* (400x)

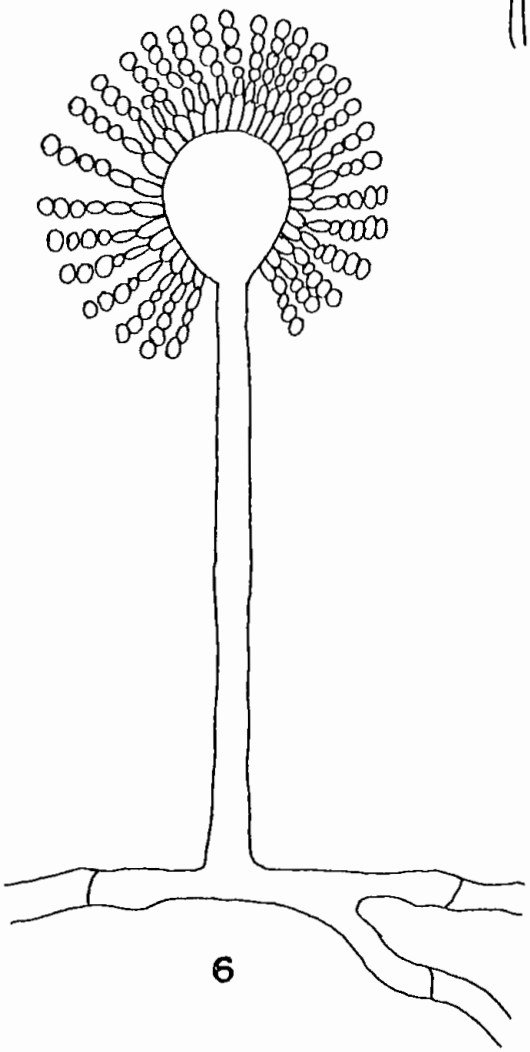
* The above numbers of these figures are taken from Table : 4.

PLATE – 2

4



5



6

PLATE – 3

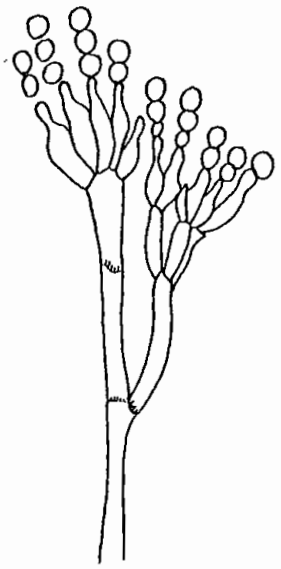
Figures :

10. *Penicillium chrysogenum* (400x)

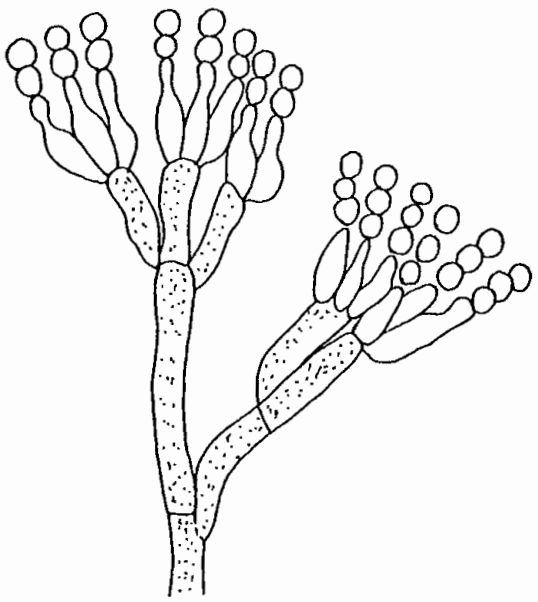
11. *Penicillium italicum* (400x)

* The above numbers of these figures are taken from Table : 4.

PLATE – 3



10



11

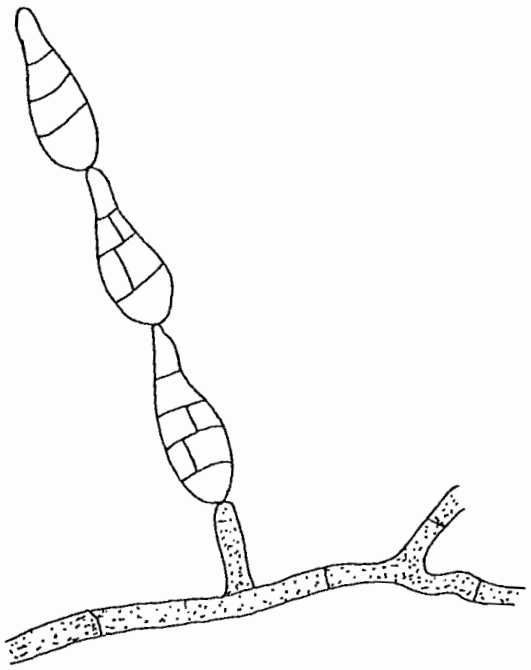
PLATE – 4

Figures :

12. *Alternaria alternata* (400x)
13. *Fusarium oxysporum* (400x)

* The above numbers of these figures are taken from Table : 4.

PLATE – 4



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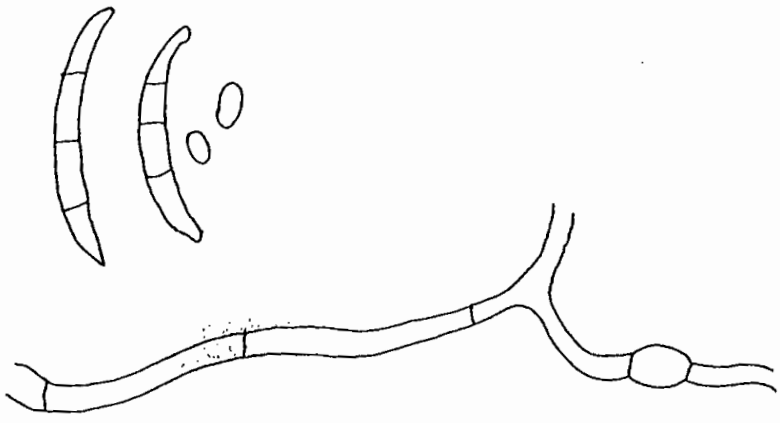


13

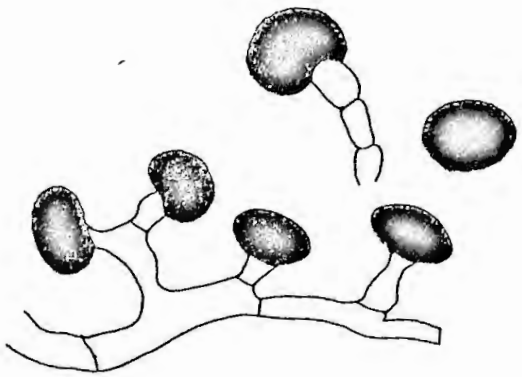
PLATE – 5

Figures :

14. *Nigrospora sp.* (400x)
15. *Mucor saturinus.* (400x)

* The above numbers of these figures are taken from Table : 4.

PLATE – 5



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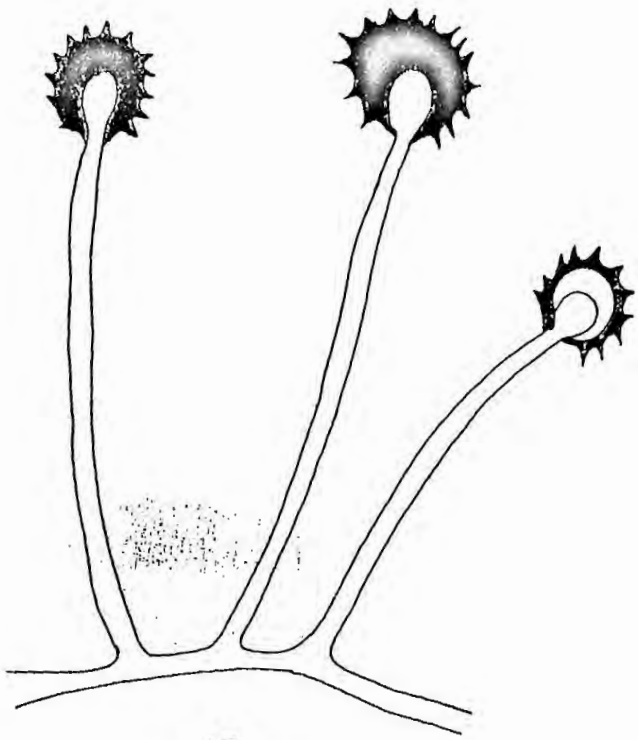


15

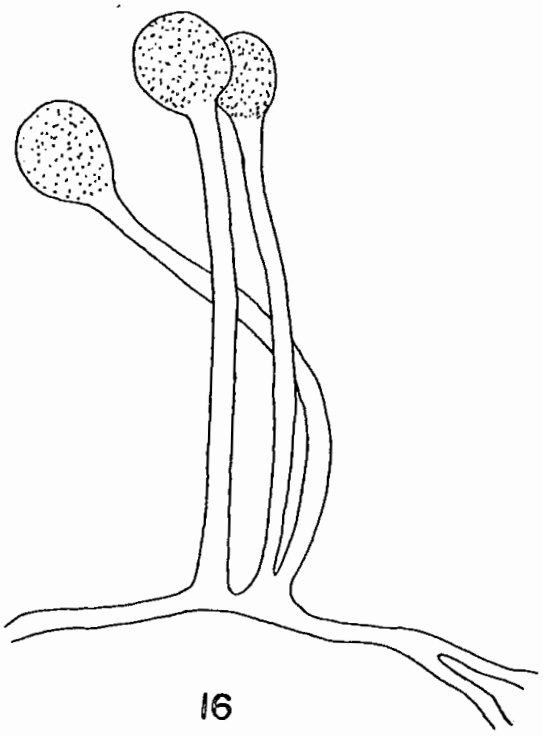
PLATE – 6

Figures :

16. *Rhizopus stolonifer.* (400x)
17. *Allomyces arbuscula.* (400x)

* The above numbers of these figures are taken from Table : 4.

PLATE – 6



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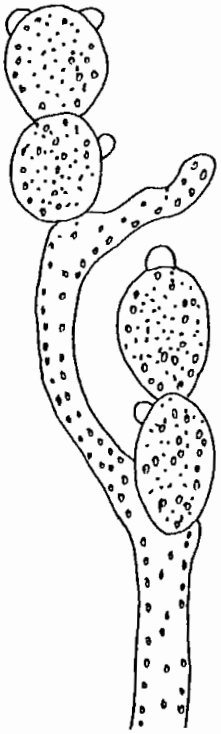


17

PLATE – 7

Figures :

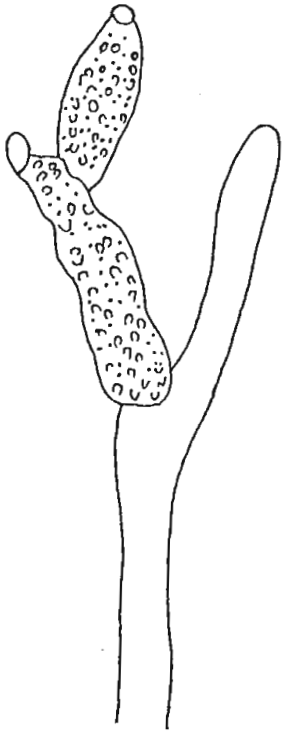
18. *Allomyces javanicus.* (400x)

19. *Phytophthora parasitica.* (400x)

20. Pythium aphanodermatum (400x)

* The above numbers of these figures are taken from Table : 4.

PLATE – 7



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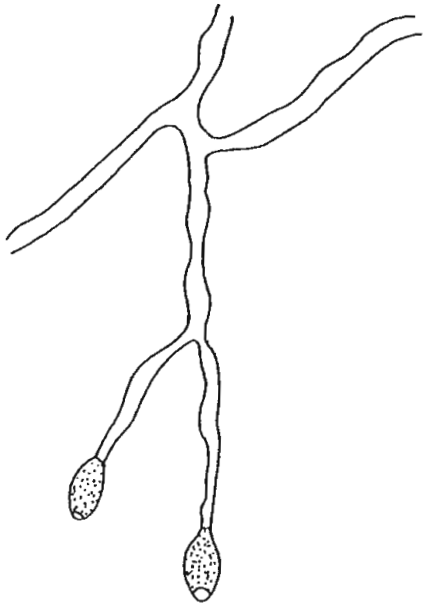
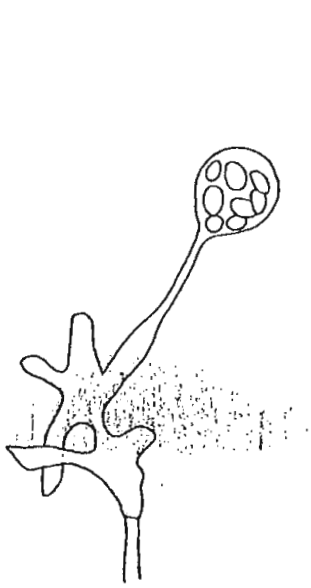


19



20

PLATE – 8

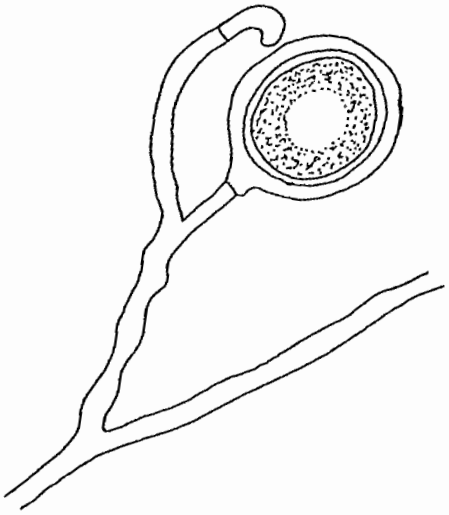
Figures :

21. *Pythium debaryanum.* (400x)

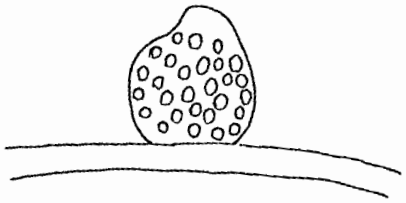
22. *Chytridium olla.* (400x)

* The above numbers of these figures are taken from Table : 4.

PLATE – 8.

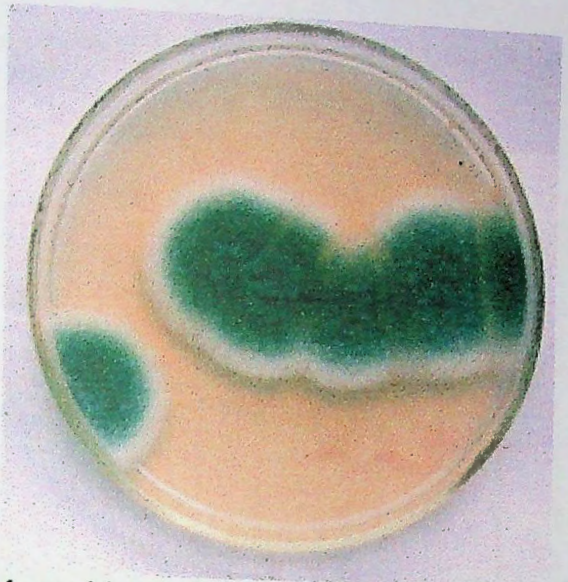


21

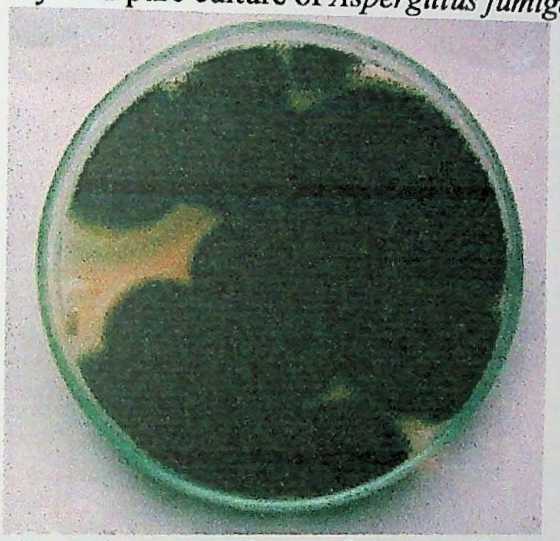


22

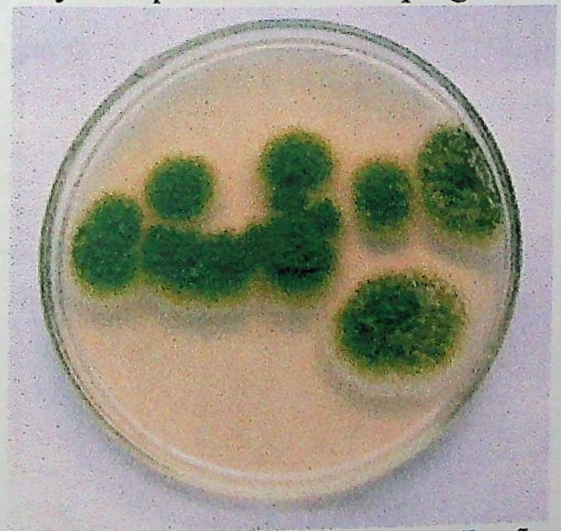
Photograph : 5



A. 5 days old pure culture of *Aspergillus fumigatus.*



B. 5 days old pure culture of *Aspergillus niger*



C. 5 days old pure culture of *Aspergillus flavus*

Table – 5 : Monthly occurrence of fungal population of SP-1.

YEAR	1998		1999											
Name	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SAPROLEGNIALES														
1 *Achlya americana*	+	+	+	+								+	+	+
2 *Achlya imperfecta*	+	+	+	+								+	+	+
3 *Aphanomyces laevis*					+	+	+	+	+	+	+	+		
4 *Saprolegnia parasitica*	+	+	+	+								+	+	+
EUROTIALES														
1 *Aspergillus niger*						+	+	+	+	+	+	+		
2 *Aspergillus fumigatus*						+	+	+	+	+	+	+		
3 *Aspergillus terreus*						+	+	+	+	+	+	+		
4 *Penicillium italicum*				+	+	+	+	+	+	+	+	+		
MONILIALES														
1 *Alternaria alternata*				+	+	+	+	+	+	+	+	+		
2 *Fusarium oxysporum*						+	+	+	+	+	+	+		
MUCORALES														
1 *Mucor saturinus*				+	+	+	+	+	+	+	+	+		
BLASTOCLADIALES														
1 *Allomyces javanicus*				+	+	+						+	+	+
PERONOSPORALES														
1 *Pythium aphanodermatum*					+	+	+	+	+	+	+	+		

Table – 6 : Monthly occurrence of fungal population of SP-2.

YEAR	1998		1999											
Name	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SAPROLEGNIALES														
1. Achlya americana	+	+	+	+								+	+	+
2. Saprolegnia luxurians	+	+	+	+									+	+
EUROTIALES														
1. Aspergillus niger						+	+	+	+	+	+	+		
2. Aspergillus fumigatus						+	+	+	+	+	+	+		
3. Aspergillus flavus						+	+	+	+	+	+	+		
4. Penicillium chrysogenum				+	+	+	+	+	+	+	+	+		
5. Penicillium italicum					+	+	+	+	+	+	+			
MONILIALES														
1 Nigrospora sp.					+	+	+	+	+	+	+	+		
MUCORALES														
1 Rhizopus stolonifer						+	+	+	+	+	+	+		
BLASTOCLADIALES														
1 Allomyces arbuscula					+	+	+	+	+	+	+	+		
PERONOSPORALES														
1 Pythium debaryanum					+	+	+	+	+	+	+			
2 Phytophthora parasitica					+	+	+				+			
CHYTRIDIALES														
1 Chytridium olla						+	+	+	+	+	+	+		

Table – 7 : Monthly occurrence of fungal population of SP-3.

YEAR	1998		1999											
Name	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SAPROLEGNIALES														
1. Achlya americana	+	+	+	+								+	+	+
2. Saprolegnia parasitica	+	+	+	+								+	+	+
3. Saprolegnia luxurians	+	+	+	+									+	+
EUROTIALES														
1. Aspergillus niger						+	+	+	+	+	+	+		
2. Aspergillus fumigatus						+	+	+	+	+	+	+		
3. Aspergillus flavus						+	+	+	+	+	+	+		
4. Penicillium chrysogenum				+	+	+	+	+	+	+	+	+		
5. Penicillium italicum						+	+	+	+	+	+	+		
MONILIALES														
1. Nigrospora sp.					+	+	+	+	+	+	+	+		
MUCORALES														
1. Rhizopus stolonifer						+	+	+	+	+	+	+		
BLASTOCLADIALES														
1. Allomyces arbuscula					+	+	+	+	+	+	+	+		
PERONOSPORALES														
1. Pythium aphanodermatum					+	+	+	+	+	+	+	+		
2. Pythium debaryanum					+	+	+	+	+	+	+	+		
3. Phytophthora parasitica						+	+	+	+	+	+	+		
CHYTRIDIALES														
1. Chytridium olla						+	+	+	+	+	+	+		

4.24 DOMINANCE OF ORDER :

A) Eurotiales : Maximum species diversity was presented by Order Eurotials. The population of Eurotiales found to be well adapted in SP-2. and SP-3. *Aspergillus niger, A. famigatus* and *Penicillium italicum* were found to be present in all three spots. Whereas *Aspergillus terreus* was only reported from

SP-1. On the other hand *Aspergillus flavus, Penicillium chrysogenum* were recorded from SP-2 and SP-3.

B) **Saprolegniales :** A total of 5 species belonging to 3 genus were reported from the sampling spots throughout the period of study. Saprolegniales population of SP-1 (Table 4) were represented by 4 species belonging to 3 genera. Of which *Achlya imperfecta* and *Aphanomyces laevis* were found to be only recorded from this spot. In SP-2 only two genera were recorded. These are *Achlya americana* and *Saprolegnia luxurians.* Saprolegniales population of SP-3 constituted of 3 fungal specimen belonging to 2 genera. It is evident that members of Saprolegniales are found to be well adapted in SP-1.

C) **Moniliales :** Only single genera e.g. *Nigrospora* sp., of Order Moniliales was recorded from SP-2 and SP-3. Whereas 2 genera (Table : 4) belonging to Moniliales were recorded from SP-1. Thus it can be concluded that recorded members of Moniliales are well adapted in SP-1.

D) **Mucorales :** Order Mucorales were represented by two genera e.g. *Mucor saturinus.* and *Rhizopus stolonifer.* The former was recorded from SP-1 only, while the later was reported from both SP-2 and SP-3.

E) **Blastocladiales :** The Blastocladiales population consisted of two fungal specimen [Table : 4]. Of which *Allomyces arbuscula* was only reported in SP-1, while *Allomyces javanicus* was recorded from SP-2 and SP-3.

F) **Peronosporales :** Three species of this order belonging to two genera were recorded [Table : 4] from SP-3. Whereas, a single member *Pythium aphanodermatum* was reported from SP-1, while from SP-2 two genera e.g.

Phytophthora parasitica and *Pythium debaryanum* were recorded. It seems that members of Peronosporales are well adapted in SP-3.

G) **Chytridiales :** A single genera e.g. *chytridium olla* was the representative of this order and was recorded from SP-2 and SP-3.

It is evident from Table : 4 that fungal biodiversity was maximum in SP-3 and rest of the two spots showed same number of fungal species. Although SP-I and SP-2 differed in population structure.

CHAPTER – 5

DISCUSSION

CHAPTER - 5

5.0 : The quality of water is of vital concern for mankind since it is directly linked with human welfare. It is a matter of history that faecal pollution of drinking water caused waterborne diseases which wiped out entire populations of a place. At present, the menace of water-borne diseases and epidemics still looms large on the horizons of developing countries. Polluted water is the culprit in all such cases. Virtually water quality characteristics of aquatic environments arise from a multitude of physical, chemical and biological interactions. The waterbodies are continuously subjected to a dynamic state of change with respect to the geological age and geochemical characteristics. Any shift in the naturally dynamic equilibrium of aquatic environment gives rise to the state of pollution. The dynamic balance in the aquatic ecosystem is upset by human activities, resulting in pollution which is manifested dramatically as:

(a) fish kill or decrease in number of faunal diversity;

(b) offensive taste and odour of water;

(c) rich source of pathogens;

(d) unchecked growth of aquatic weeds and blooms in water;

(e) oil and grease floating on water surface.

The major sources of water pollution are domestic waste from urban and rural areas and industrial wastes which are discharged into natural waterbodies. Bangladesh is a small developing country of the third world, with its burgeoning population. Along with the increasing rate of industrialization and urbanization environmental degradation specially of aquatic environment is becoming a threat. Present government has undertaken a massive program to built a base line data of the existing environment for future abatement program. As mentioned earlier the present effort is a pioneer in the field, data complied throughout the period of study will be discussed in this chapter and prediction will be made on concluding lines for future scope of work in this aspect.

5.1 RAINFALL AND RELATIVE HUMIDITY :

Geographical characteristics of Rajshahi are great extreme of heat, cold and moderate rainfall as evident from Table 1,2 and 3. No rainfall or minimum rainfall were recorded in the month of December in the consecutive years (98"and 99") of sampling. Similar findings were also made by Khondker *et al.*, (1990) and Naz (1999) while making limnological study in Dhaka and Rajshahi accordingly. As evident from Table: 1, June to September are the months which documented the maximum rainfall, during the study period, while from October, the rainfall started decreasing till December. In January sporadic rains were observed and in February the rainfall was a bit increased with the cessation of winter. March, April and May are the months of hot scorching summer with hail which are frequent in these months. June is the beginning of monsoon. The monthly and seasonal fluctuation of atmospheric humidity (Table: 2) was found to be in conformity with the extent of rainfall (Table: 1). This is supported by similar observations made by Islam and Mendes (1976) and Naz (1997). Humidity was normally high during the monsoonal months from June-September with a range of 79-89.7 per cent. The winter months were comparatively dry with a range of 65-83 percent. A similar pattern of humidity was also found by Naz (1999), while working in some fishponds of Rajshahi. A characteristics feature of the rainfall in this area is that about 80 per cent of precipitation occurs from June to September and the remaining 20 per cent occurs during the rest of the year.

5.2 TEMPERATURE (AIR AND WATER) :

Large number of environmental factors operate at a site, which have a profound effect on the development of a community. Out of these factors, temperature seems to be of most importance. It directly acts upon many processes such as germination of over-wintering structures for vegetative growth, induction of a

sexual reproduction by means of zoospores and formation of sexual organs. Earlier researchers also confirmed that the temperature plays an important role in the occurrence of fungi (Bock, 1956, Schmitt, 1967, Srivastava, 1967, Rattan *et al.*, 1980). On the other hand, Lund and Talling (1957) stated, temperature measurement occupy a central position in Limnology, as temperature changes, it affects not only many physiological processes but also the density of water the fundamental stratification of a water body.

Ahmed (1964) and Rashid (1991) divided Bangladesh into three regions on the basis of climatological factors. These are as follows: **(i)** Tropical wet region **(ii)** Subtropical wet region and **(iii)** Subtropical moderately wet region. The Rajshahi district where the study areas are located is within the subtropical moderately wet region of Bangladesh, which is characterized by hotter summer, moderate monsoon and cooler winter. Details of air temperature measured during the period of study showed (Table: 3) a hotter summer leading to scorching summer followed by moderately hot monsoon and a cold winter, which corroborates the findings of Ahmed (1964), Rashid (1991) and Naz (1999). The moderately hot summer commences from March by the cessation of the northerly wind, while south westerly wind prevails throughout the month of April with higher values of atmospheric temperature and occasional gusty wind and dust storms. The month of May was found to be the hottest month during the years of study when southerly hot wind prevailed, while the monsoon period (June to September) experiences a south easterly heavy monsoonal wind. The month of October has cooler nights indicating the advent of winter with moderately low air temperature. Throughout the study period the daily air temperature varied from 10.3-37.7. Minimum value of temperature was recorded in January, while the maximum was recorded in June. As evident from Table: 3, maximum air temperature started declining after November and continued upto to February. After a peak in March, April and May

it remained more or less uniform. The difference between maximum and minimum air temperature gradually narrowed down with the advent of the rainy season. Almost similar patterns of temperature fluctuation were reported by Khondker and Rahim (1991) and Naz (1999) while working in Dhaka and Rajshahi accordingly - subtropical moderately wet region of Bangladesh (Ahmed, 1964). Rainfall had a cooling effect on air temperature, which is also supported by the findings of Islam *et al.*,(1974).

The recorded air temperature fluctuation values of the study spots fit well data obtained from the meteorological department. The air temperature values of the three spots were almost (Appendix Tables I-III and Fig. 1), same observed deviation were due to time of the sampling and sometimes by sudden rainfall. Minimum values of water temperature were observed in winter and monsoon season, while maximum in summer, corresponding with atmospheric temperature (Fig. 2 and Table: 3). Similar findings were made by Rice (1938), Vijayaraghavan (1971), Islam *et al.*, (1974). Islam and Mendes (1976), Begum *et al.*, (1989) and Naser *et al.*, (1990) in their studies.

SP-1 : Water temperature was always lower than the air temperature except in the months of January, May and June 1999. In summer months sunray falls directly on water, thus absorption of heat becomes maximum in these days, which ultimately resulted the above mentioned phenomenon. Further, Vyas (1968) stated that in summer water temperature appears to be higher due low water level, clear atmosphere and greater solar radiation, which also corroborates with the present findings. But higher temperature of water than air in January 1999 needs further investigation.

SP-2 : Except in the months of March, April, May, July and September 1999 throughout the period of study the effluent water temperature value was always

higher than that of air [Fig 1 and 2). It may be mentioned that in these months the mill was not in production. Higher temperature value of discharged effluent caused the higher value of water than air in this spot.

SP-3 : With an exception in April water temperature of this spot [Fig: 1 and 2] was always found to be lower than that of air. Maximum variation (6°C) of air and water was recorded from this spot in May 1999, during hot scorching summer.

Heat is not ordinarily thought as a pollutant by many people, at least in the sense as a corrosive chemical. However, the addition of excess heat to a body of water brings about adverse effects as rates of chemical reactions decrease in decreasing temperature. 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 density, viscosity, surface tension, vapour pressure of water and biochemical activities such as DO, BOD, rate of photosynthesis are all depended on water temperature value. Upper limit of temperature range of these three spots were 36°C, 34°C and 33°C accordingly which appeared to be higher than the IWQS, DWQS (30°C) values, this indicates all three sampling spots are thermally polluted.

5.3 TRANSPARENCY :

Food and energy production of aquatic body is light dependent. Transparency i.e. the quantity and intensity of light that can penetrate into a waterbody depend on the surroundings, especially condition of the embankment, season, length of the day, aquatic vegetation, geographical position and turbidity. Prescott (1969) held that water with lower colour indices had lower absorbance and the harder the water of a lake the greater is the absorbance.

SP-1 : Transparency of water was found to vary throughout the period of study. Minimum value of DO corresponded with the minimum value of transparency

(Fig: 3). This might have been caused by runoff accumulation along with rain water. Similar findings were also made by Khan and Mahmood (1976), Bhouyain (1979) and Paul (1981).

As seen from (Fig 2 and 3 or Appendix Tables I-III) water temperature was found to be positively related with the transparency of water. Begum *et al.*, (1994) also found significant positive relationship with transparency and water temperature while working in a semi intensively managed pond.

SP-2 : Effluent mixed water was black in colour, sometimes a white froth was found to form a layer upon it. Throughout the period of sampling a lower value of transparency was recorded except in the months of September, October 1999 and November 1998. Higher values of transparency due to monsoon rainfall and rise of water level of Padma. It may be mentioned that the canal has its outlet in river Padma during late monsoon when the river flows fall to its brim then water flows to an opposite direction i.e. from river towards the canal. Lower value of transparency was a combined effect of TSS, TDS received as effluent from the mill. Further it is to be added that as mentioned earlier that this spot is shaded by bigtrees. Most of the litter of these trees fall in this canal which in turn is responsible in decreasing the transparency.

SP-3 : During the period of investigation the water color of this spot was found almost blackish to brownish in color. Higher values of transparency were recorded in late monsoon (August, September and October 1999) [Fig. 3], when the water was green in color and the depth of water was maximum due to monsoonal rainfall and in surge of water from Padma, Apart from these months TSS, TDS along with oil-grease the were the key factors which played a positive role in decreasing the transparency of water. Similar findings are supported by Trivedi and Raj (1992).

5.4 HYDROGEN ION CONCENTRATION (pH) :

Natural waters exhibit wide variations in relative actidity and alkalinity, not only in actual pH values, but also in the amount of dissolved material producing the acidity or alkalinity. The concentration of these compounds and ratio of one to another determine the actual pH and the buffering capacity of a given water. Since lethal effects of most acids begin to appear near pH 4.5 and at most alkalis near pH 9.5 that buffering can be of major importance in the maintenance of life (Wetzel, 1983). The waste water can alter the pH of natural water.

SP-1 : Higher values of pH were recorded in the late monsoon and winter months, while lower values were recorded during summer months [Fig.: 4]. This could be interpreted as:- in low water temperature solubility of oxygen is increased and pH is positively relatively with DO content of the water. Again Ernst *et al.*, (1980), Hickman (1979), Nasar and Sharma (1980), Henson *et.al.*, (1961)observed that pH peaks may result due to rapid utilization of free CO_2 in by water by the phytoplankton and other photosynthetic organisms, which also corroborates with present findings. (Fig.: 8 and Appendix Table: I). An inverse relation between air, water temperature and pH were also observed (Fig. 1, 2, 4 and Appendix Table : I), similar findings were also made by Kumar (1992) while working in Bhagalpur, India.

SP-2 : The effluent pH range was observed 5.3 to 8.4, whenever the effluent contains high acidic material then pH was acidic and when the effluent contained comparatively lesser acidic material then its maximum limit was achieved. Similar findings have been achieved by workers (Chowdhury *et al.* Baliarsingh *et al.* 1992, Rana 1977, Banerjea and Motwani 1960) who earlier worked with different sugar mills effluent. As is known earlier that usually the pH value of lotic and lentic water system have a pH ranging from 7.0-8.5 (Naz, 1992, Zaman *et al.*1993 and Naz, 1999). Moor (1972), Motwani *et al.* (1956), Mahmood and Bhouyain

(1988), Sharma *et al.*, (1982) and Campbell (1979) also stated that the industrial waste materials had significant role in increasing or decreasing the pH of the adjacent water, where the materials are dumped.

SP-3 : pH value ranged from 7.1 – 9.0 throughout the period of study. With two exceptions values pH of this spot were always higher than that of SP_2. This might have been caused by the acidic effluent which in turn reacts with natural alkalinity of the water and increase the carbonate and bicarbonate hardness. Trivedi and Raj (1992) expressed similar views. Monthly fluctuation pattern of pH was similar to that of alkalinity and hardness in this spot (Fig . 4).

pH, indicative of hydrogen ion concentration express the intensity of an acid/ alkali depending upon its dissociation as well as the total amount that is present. The alteration of pH of water is also accompanied by changes in other physico-chemical aspects of the medium. According to the standards of WHO (1971) highest desirable level of drinking water pH is 7.0 – 8.5, while maximum permissible range is 6.5 – 9.2. On the other hand Trivedi and Raj (1992) stated optimum range of pH for aquatic life is 6.8 to 9.0. As evident from both stand point of view pH range of the study spots (6.7 – 10.3, 5.3 – 8.4 and 7.1 – 9.0) are polluted.

5.5 DISSOLVED OXYGEN CONTENT AND PERCENTAGE OF SATURATION OF OXYGEN :

Dissolved oxygen content of the water is probably the most common measurement of biological significance. Oxygen is essential to almost all lives. So deficiency or absence commonly delimits the distribution of plants and animals. Disturbance in oxygen level in any aquatic ecosystem can be caused through four major methods : (1) decreasing the photosynthetic rate of the plants, (2) decreasing the solubility of the oxygen within the water column, (3) interfering with the diffusion of

atmospheric oxygen at the air-water interface, and (4) increasing the oxygen consumption of the aerobic bacterial component of the system [increasing the BOD] Chhatwal *et al.*, (1995). DO content of the sample sites were measured throughout the period of study showed a wide range of variation. Results are presented in Fig. 5 and Appendix Tables I-III.

SP-1 : DO content of this spot exhibited distinct seasonal variation as evident from Fig. : 5. Winter and post monsoon months-recorded higher values of DO content, while during summer months lower values were recorded. Oxygen levels have been decreased as the temperature of this spot is increased. Similar findings were also found by Chhatwal *et al.*, (1995). They stated, increasing temperatures tend to increase the molecular motion of the water and any dissolved gases, which decrease the solubility of the dissolved oxygen. Lakes have been especially sensitive to increased water temperatures, since this reinforces the temperature density barrier and prevents efficient mixing of the surface euphotic zone and the hypolimnion. Thus, if the temperature input has been great enough to prevent or delay the normal fall overturn, severe and prolonged anaerobic conditions will take place in the hypolimnion. Super saturation of oxygen were recorded from this spot several times. Super saturation by oxygen is a characteristic of eutrophicated water and due to the photosynthetic activity of algal biomass. Similar explanation were also given by Khond ker and Rahim (1991), while working in Dhanmondi lake of Dhaka.

SP-2 : The effluent mixed water at this spot was always found to be low, an anoxia was reported in November 1999 (Fig. 5 and Appendix Table: II). Percentage of saturation of oxygen values were found to be related with DO content and water temperature. Similar findings were made by Chowdhury (1995). The highest DO value and percentage of saturation of oxygen value were reported in October 1999, when back flow of river water mixed with the effluent and

increased the water level, which also corroborates the findings of Chowdhury (1995). Chhattwal *et al.*, (1995) expressed the view that higher temperatures favourable to increased bacterial growth and also increase the metabolic process of bacteria. This has the net effect of increasing the decomposition rate in the regeneration zone. As bacterial decomposition (aerobic) needs oxygen, an increase in the rate will also tend to increase the depletion of oxygen levels. Similar views are also expressed by Trivedi and Raj (1992). High values of temperature, suspended materials, CO_2 and BOD were responsible for lower DO content of this spot. More or less similar observations were made by Khan and Mahmood (1976), Bhouyain (1979), Paul (1981), Balakrishnon (1984), Andrews *et al.*, (1972), while working with various industrial effluents.

SP-3 : During the period of study dissolved oxygen fluctuation exhibited a more or less similar pattern of variation than that of SP-2 [Fig.: 5]. Probably oil-grease was one of the major factor which may have lowered the rate of photosynthesis on this spot, whenever its amount was observed to be negligible the DO content was found to be increased. According to Trivedi and Raj (1992) oil-grease inhibits the light penetration in water which decreases the rate of photosynthesis. They further added that due to floating of oil-grease on the surface of water atmospheric O_2 cannot mix with water which also in turn lowers the DO content in the waterbody. The bacterial degradation of sunken oil needs huge amount of oxygen (Trivedi and Raj, 1992). Almost similar observations was also made by Khan and Mahmood (1976). As evident Mean and SD values of DO content (Appendix Table I-III) of three spots indicate SP-2 was under minimum acceptable level of IWQS (5.0 mg/l) and DWQS standards (6.0 mg/l), while the state of SP-3 was also found to be alarming and SP-1 was showed quite normal regime, though its super saturation values indicated threshold of eutrophication.

5.6 ELECTRIC CONDUCTIVITY :

Most of the salts dissolved in water are in ionic forms by which water is capable to conduct electricity. The capacity of waters to conduct electric current is known as conductivity. Generally, natural water posses low conductivity but contamination increases its level. Any increase or decrease in the concentration of dissolved substances, such as sulfates chlorides and carbonates is reflected in corresponding increase or decrease in conductivity. The pollution by inorganic or organic wastes containing excessive amount of dissolved solids increase the concentration of salts in water. Mean and SD values of the study spots reveals the fact that (SP_1-540.29 ± 134.18, SP_2-681.24 ± 286.57 and SP_3 – 609.20 ± 282.49) SP_2 had the highest concentration of dissolved substances, followed by SP_3 and SP_1 accordingly.

SP-1 : Conductivity values of this spot showed a seasonal mode of variation. With increase of water temperature and decreasing trend of waterlevel higher values of conductivity were recorded. Similar findings were also made by Naz (1999) while working in some pisciculture ponds of Rajshahi.

SP-2 : Lowest electric conductivity value was recorded in non-production period and when the water level was maximum, dilution of effluent and lower values of hardness and bicarbonate might have caused this. Higher values were obtained during production period which might have been caused by the discharged effluents. Similar observations were made by Andrews *et al.*, (1972), APHA (1976), Bhouyain (1979) and Chowdhury *et al.*, (1998).

SP-3 : Except for three occasions (Appendix Tables: II and III, Fig. 7) conductivity value was always higher than that of SP_2. Higher values of conductivity were recorded when sugar mill was in production and effluent discharge intermixed the power house effluent. Lowest value of conductivity was

obtained in October 1999 when the water level was maximum and sugar production was closed.

In some strongly polluted habitats in and around Dhaka City, the conductivity ranged from 225-900 µS cm $^{-1}$ (Islam and Khondker 1991). Gopal *et al.*, (1981) reported on average conductivity of 182µS cm $^{-1}$ in oligomesotrophic Jamwa Ramgarh Reservoir, Rajasthani, India. Higher conductivity (565.42 µS cm^{-1}) was recorded from Dhanmondi lake by Khondker and Rahim (1991). Again average conductivity of Mirpur jheel for 0.5m was 444.88 µS cm^{-1} and for bottom was 473.87 µS cm^{-1}. The range was some what higher than mesotrophic Shahidullah Hall pond (341.33 µS cm^{-1}), Khondker and Kabir (1994). A much lower conductivity (78.77 µS cm^{-1}) has been reported by Islam *et al.*, (1992) in a pond near Uttra shopping center of Dhaka. Higher conductivity for natural fresh water habitats is usually a feature of water where the rate of mineralization is very high, which may be applicable in case of SP_1 and is eutrophic from, trophic point of view. The other two habitats are over loaded with nutrients and have reached a state of hypertrophication.

5.7 CO_2, CO_3, HCO_3, TOTAL HARDNESS, Ca-HARDNESS AND Mg-HARDNESS :

A review of literature on the free carbon dioxide shows that carbon dioxide combines chemically with water to form carbonic acid, which affects the pH of the water, carbonic acid (H_2CO_3) dissociates partly to produce (H+), and bicarbonate (HCO_3) ions. The bicarbonate ions may decompose further forming more hydrogen and carbonate ion; mostly carbon dioxide is always present in the form of bicarbonates and carbonates, when the pH is low. Then the combined carbon dioxide is converted into the free form and when increase in the bicarbonate and carbonate occurs, water become alkaline and resist hydrogen ions. The carbon

dioxide, pH and alkalinity are thus directly related with each other, (Michael, 1984).

SP-1: Free carbon dioxide content of this spot was found to be inversely related with pH, carbonate and bicarbonate content. Hutchinson (1957) also made similar findings, Kern (1960), Stumn and Morgan (1970) and Golterman (1975). They explained the higher growth of phytoplankton and macrophytes causes the enhanced uptake of carbondioxide, bicarbonates and carbonates formed, which increases the pH of water. Except for three occasions carbonate content was found to be present throughout the period of study from this spot [Fig. 9 and Appendix Table: I]. According to Sharma (1973) and Palharya *et al.,* (1993) presence of carbonate alkalinity is an indication of higher rate of carbon assimilation, which might also be the reason interacting in case of spot SP-1.

SP-2 : Presence of free CO_2 was detected throughout the period of study, while on the other hand carbonate content totally absent [Appendix Table : II]. Bicarbonate content, pH and DO content exhibited a clear cut inverse relationship free carbon dioxide. Similar findings were also made by Tamot *et al.,* (1997) and Sarker *et al.,* (1980).

SP-3 : With an exception in April, 1999 carbon dioxide was found to be present throughout the period of study. More or less similar fluctuation trend of carbon dioxide were observed from SP-2 and SP-3 [Fig. 8]. As usual an inverse relation existed between CO_2 and pH, temperature, DO and carbonate content of water (Appendix Table : III).

In an ordinary hard water quantity of HCO_3 is in excess, and free CO_2 will also be present and in the soft water but in excessively alkaline lakes most of CO_2 will be present as CO_3^- (Ruttner, 1948), which seems to be applicable in case of SP-1. Moyle (1945) designated the lakes with alkalinity values of 40 mg/l as 'soft', those

with values of 40-90 mg/l as 'medium hard' and those with values 90 mg/l 'hard' types. Accordingly, the study spots are all of 'hard' types.

Hardness of water is governed by the content of calcium and magnesium, largely combined with bicarbonate and carbonate (temporary) and with sulfates, chlorides and other mineral acids (permanent hardness). If and when the total hardness is higher than the total alkalinity (i.e. alkalinity due carbonate and bicarbonate), then the value for total alkalinity is for carbonate hardness and the difference of the two shows the value for non carbonate hardness. As evident from (Appendix Tables I-III). SP_1 and SP_2 showed richness due to non-carbonate hardness, while in SP_2 hardness due carbonate was a bit higher than the former.

According to Klein (1956), Sawyer (1960) and Sinha (1988) water less than 50-150 ppm hardness is moderately hard, 150 to 300 ppm is hard and over 300 ppm is considered very hard. As evident from mean and SD values of study spots (SP-1 246.036 ± 81.946, SP-2 357.421 ± 175.88 and SP-3 226.807 ± 85.605) SP-1 and SP-3 are of hard type and SP-2 is of very hard type. Fluctuation patterns of SP-2 and SP-3 were found to be more or less same, effluent discharge and along with seasonal changes governed its pattern of fluctuation. In case of SP-1 its fluctuation pattern was mainly governed by seasonal change and water level.

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

The above discussion based on the obtained data clearly indicate that the water of three study spots is highly polluted and unfit for any sort of domestic use.

The value of calcium and magnesium hardness of a water depends on the amounts of various salts Viz. $CaCO_3$, $MgCO_3$, $MgHCO_3$, $CaHCO_3$, $CaSO_4$, $MgSO_4$, $Ca(PO_4)$ dissolved in it. These salts cause temporary hardness while permanent hardness is caused by the chloride and other salts of the same. Andrews *et al.*, (1972) and APHA (1976) stated that many industries were also responsible for increasing the calcium and magnesium hardness of the water body where the effluent were discharged, thus pollution was caused in fresh water, which corroborates with the present findings in case of SP-2 and SP-3.

SP-1 : Higher values of Ca-hardness were obtained during summer months, while the lowest value was obtained in October 1999 when the water level was maximum [Fig. 12]. More or less similar trend of magnesium hardness variation was also observed [Fig. 13].

SP-2 : Higher values of calcium hardness was obtained during sugar production period which is probably caused by CaO used as clearing agent and the lowest was observed in October, 1999 when the water level was maximum. Similar relationship between water level and calcium hardness was also found by Chowdhury (1995).

SP-3 : Calcium and magnesium hardness variation of this spot were found to be similar than that of SP-2. Chowdhury and Mazumder (1981) stated, hardness, alkalinity of water are, as yet poorly understood factors and hardly anything is known about their general limnological significance. It is, however, quite understandable that these two factors will affect (i) the solubility of different nutrients and (ii) formation of various chemical complexes thereby affecting uptake and utilization of dissolved substances by organisms.

5.8 CHLORIDE :

Chloride in the form of chloride ions are one of the major inorganic anions present in natural water. Only the water containing 250 mg/l chloride and above may have a detectable salty taste if the action is sodium, on the other hand, the typical salty taste may be absent in water as much as 100 mg/l chlorides, when the predominant anions are calcium and magnesium APHA (1976). According to Trivedi and Raj (1992) chloride in fresh water is harmless up to 1500ppm concentration. Although chlorides are not harmful, concentrations beyond 250 mg/l impart a peculiar taste to water rendering it unacceptable from aesthetic point of view for drinking purpose. Presence of chlorides above the usual concentration in a water source is also used as an indicator of pollution by domestic sewage (Course Mannal NEERI 1979). Chloride concentration is not only an index of eutrophication but also of pollution caused by cattle, sewage and other wastes (Misra and Yadav, 1978). Thresh *et al.*, (1944) suggested high chloride concentrations indicated the presence of organic matter, presumably of animal origin, which has been further supported by Bhatnagar and Sharma (1973), Adoni (1985). As evident from Appendix Tables I-III and Fig. 14 higher values of chloride content were obtained from SP-3 all throughout the period of study. Mean and SD of the study spots shows that (SP-1 35.66± 10.48, SP-2 23.99±11.12 and SP-3 81.95 ± 61.14) all the spots under study are polluted in respect of chloride content as Sreenivasan (1965) stated that chloride content between 4 and 10ppm indicates purity of water. Dhakar (1979) reported that a polluted water having a chloride content between 45 and 122 ppm, indicate medium pollution and its content between 60 and 200 ppm is an indicator of heavy pollution. Among the study spots SP-3 appeared to be the most pollutant followed by SP-1 and SP-2 accordingly.

Higher values of chlorides were obtained during winter months from all three spots [Fig. 14] which can be attributed to highly soluble chloride salts through run-off from the catchment area during monsoon and high rates of evaporation. Similar findings were also made by Zafar (1964), Rao (1971, 1972), Yadav and Misra (1978) and Khanna *et al.*, (1992).

5.9 AMMONIUM, AMMONIA AND AMMONIAM NITROGEN :

Ammonium is a source of nitrogen in organically polluted waters, have higher concentration of ammonia which is a product of ammonification of organic matter (Ellis *et al.*, 1946, Rybak and Sikorska, 1976). It takes up a huge amount of dissolved oxygen for chemical process in nature with the help of bacteria and ammonia is liberated (Trivedi and Raj, 1992). Chemical oxygen demand is influenced by ammonium concentration. In industrial water it comes from variety of sources.

Ammonium content of SP-2 and SP-3 showed a similar mode of variation [Fig.: 16], while SP-1 exhibited a different trend [Fig. 16]. As evident from mean and SD values of ammonium of three spots (SP-1: 0.23525 ± 0.35918, SP-2: 0.19745 ± 0.281401 and SP-3: 0.53782 ± 0.88727) pollution due to ammonium was maximum in SP-3. The value of NH_4 was influenced by oil-grease of this spot. Similar observations were also made by Trivedi and Raj (1992) and Chowdhury (1995).

Ammonia is naturally present in surface and ground water and in industrial and other waste water (APHA 1976). The desirable criteria of ammonia is less than 0.01 mg/l. As evident from Fig. : 17 apart a few exceptions all the spots exhibited higher values than the desirable criteria throughout the period of study. Further it is also evident from mean and SD values of ammonia (SP-1 0.22208 ± 0.33906,

SP-2 0.250636 ± 0.341217 and SP-3 0.50770 ± 0.83757) all the three spots are polluted by the presence of higher content of ammonium.

Ammonium nitrogen (NH_4-N) is a state of ammonia. Its concentration is depended upon the concentration of ammonia. Ammonium nitrogen has a similar kind of effect like ammonia in the aquatic environment. Ammonium nitrogen was maximum in SP_3 and followed by SP_2 and SP_1 accordingly.

5.10 PHOSPHATE :

Palharya *et al.*, (1995) pointed out that phosphorus is essential [i.e. to plant]. for it forms a constituent of many proteids and nuclein contains as much as 6%. Ecological interest in phosphorous is because of its major role in biological metabolisim and relatively small amount of phosphorus is present in the hydrosphere (Juday *et al.*, 1928). The importance of phosphate in natural waters has been stressed by several authors (Ohle, 1934). Total phosphate concentration is considered to be a nutrient of major importance in production process (Hutchinson, 1957 and Vollenwider, 1968). Schindler (1971) proposed that phosphate is the limiting nutrient in ponds and lakes. Gonapati (1960) is of opinion that in tropical waters, phosphates are always present in sufficient quantities and they do not seem to constitute a limiting factor, which also confirms the present findings. With few exceptions [Fig. 15] phosphate seems to be present throughout the period of study. Concentrations in SP1 (fertilized at regular interval) appeared to be higher than that of unfertilized ones (SP-2 and SP-3). Similar findings were also made by Boyd (1973). He stated both feed and treatments resulted in higher phosphorus levels than were in controls. Concentrations of phosphate ranged from 0-0.66 mg/l in SP-1, 0-0.08 mg/l in SP-2 and 0-0.09 mg/l in SP-3 and in 70 per cent cases either concentrations were higher in SP-2 or SP-3. Boyd (1973) stated that though phosphorous levels were higher in

ponds receiving fertilizers and feeds than in controls, concentrations were relatively low when contrasted to amounts of phosphorous added to the ponds, which also corroborates with present findings. Hall *et al.*, (1970) also reported higher concentrations of PO_4-P in ponds receiving high nutrients addition than in control ponds, which also corroborates with the present findings.

5.11 Eh and rH_2 :

Redox potential may be defined as the measure of oxidating or reducing power of the water. During process of oxidation a substance looses electrons while during reduction it gains electrons. Both the processes always occur simultaneously. When any solution contains chemical substance in more than one state of oxidation or reduction a particular potential is associated with each state. But the potential of any solution is the net of all these reactions and known as oxidation reduction potential of that solutions (or water). Redox potential is proportional to the equivalent free energy change per mole of electrons associated with a given reduction (Stumm 1966, Morris and Stumm 1967). Although aqueous solutions do not contain free protons and electron it is possible to define proton activity [$pH = -\log (H^+)$] and electron activity [$pt = -\log(e^-)$]. pE is large and positive in strongly oxidizing solution [low electron activity], just as pH is high in strongly alkaline solutions (low proton activity). Thus pH and pE are intensity factors of free energy levels and are not related to capacity or condition e.g. alkalinity, acidity (Wetzel, 1983). Eh value of the three spots were detected throughout the period of study (Fig. 19 and Appendix Tables I-III) reveal the fact that higher values of Eh were reported from SP-1, followed by SP-3 and SP-1. Higher nutrient loads carried along with the water might have caused this phenomenon. Further a distinct relationship between DO content, pH and redox potential were observed in all three spots, which can be explained by the statement of Wetzel (1983). He stated, redox potential of water is dependent upon the oxygen concentration and

extent of saturation in water. The activity of the hydroxyl ions, however, influences the activity of the hydrogen ions, therefore the redox potential is significantly changed by a alterations of H^+ and is reflected in the pH. As evident from Fig. 19 lower values of Eh were obtained during June from three spots and three spots exhibited trend of minimum values during winter months [Fig. : 19]. Low Eh values during winter months were also obtained by Werner (1966) and Gautom (1990). Werner (1966) stated that decomposition of organic matter takes place through a complex sequence of redox reactions resulting in heterotrophic activity (respiration, succeeded by NO_3 reduction etc) which is accompanied by a microbial ecological succession and by a corresponding lowering of pH (Eh).

Few elements [C, O, N,S.Fe, Mn] are predominant reactants in redox processes in natural waters. By conversion of energy into chemical bonds, photosynthesis produces reduced states (negative Eh) of free energy and results in non-equilibrium concentrations of C,N and S compounds [Stumm, 1966]. Respiratory, fermentative and other non photosynthetic reactions of organisms tend to restore equilibrium by catalytically decomposing through energy-yielding redox reactions, the thermodynamically unstable products of photosynthesis. It is through such reactions that non photosynthetic organisms obtain a source of free energy for their metabolic demands. The mean Eh is increased by these combined process. Further, it may be mentioned that organisms act as redox catalysts by mediating the reactions and transfer of electrons, the organisms themselves do not oxidize substrates or reduce compounds. Kjensmo (1970) added that, lower redox potentials are generally observed in lake systems containing relatively high concentrations of dissolved humic compounds which also corroborates with the present findings, as SP-1 receives feed and treatment of both organic and inorganic source it appeared to be richer in humic substances in comparison to other two spots.

Oxidation reduction index (rH_2) is a quick and efficient measurement for the oxidation reduction conditions of fresh water in open waterbodies (Voznaya 1981). Throughout the period of study rH_2 value of the sample ponds showed a distinct variation [Fig. 20 and Appendix Tables : I-III] also found to show a similar variation pattern to that of Eh [Fig. 19]. rH_2 values of three spots exhibited a distinct inverse relationship with pH and DO content. As Gautam (1992) stated, 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 rH_2 values. But after a short time when the materials degrade, the system starts to attain its original form which means Eh and rH_2 values starts increasing. But when a continuous addition of organic material takes place, a continuous decrease in Eh and rH_2 is observed, this also seems to be true in case of SP_1, an intensively managed pond.

Voznaya (1981) stated, a neutral point in the sense of the oxidation reduction conditions in fresh water is assumed to be rH_2=28. Values above 28 indicate the presence of strong oxidants in the waters, while values below 28 represent that reduction processes prevail over oxidation. Mean and SD values of rH_2 show that (SP-1 24.81 ± 2.01, SP-2 28.23 ± 2.07 and SP-3 26.26± 1.64) all the spots under study except SP-2 were below the neutral point which explains that the reduction process was higher than the oxidation rate. And in SP-2 the opposite phenomenon was present.

5.12 BIOLOGICAL OXYGEN DEMAND [BOD_5] :

Biochemical or biological oxygen demand is of great important in water quality assessment. Seasonal variation in the values of BOD appears to be a function of changes in the degree of dilution, quantity of organic matter and the activities of

micro-organisms carrying out decomposition of carbonaceous and nitrogenous matters (Palharya *et al.*, 1993). The biological oxygen demand of a system can be increased to the addition of both organic and some inorganic substance to the environment. It is to be noted that the more the amount of oxygen required to degrade it biologically the more is the BOD. SP-2 and SP-3 exhibited a more or less similar trend of BOD_5 variation. Exceptions were observed in the months of May, June, July and November 1999, in these months increased DO in the dark bottle was found after 5 days of incubation in SP-2. This has no explanation except the work of Dogdale and Wallace (1960) who concluded that the dissolved oxygen increased during summer months in dark bottles was due to some photosynthetic organisms. Similar Findings were also made by Bhouyain and Himangshu (1995) and Naz (1999).

As it is evident from Fig. 21 higher values of BOD_5 were recorded from SP-1, indicating a presence of higher degree of pollution of biological organic origin in comparison with latter two spots. As these two receives huge amount pollutants of chemical origin. Higher degree of chemical pollution can be expected at SP-2 and SP-3.

5.13 BIOTIC COMPONENTS :

In all systems certain materials have been taken in by plants, converted to complex molecules, and incorporated into plant tissues. These materials then pass into various animals because of the animals grazing on the plants. When the plants die and the animals excrete waste materials or die, these materials get reconverted by a large group of organisms called microorganisms, into a form where they can again be used by plants. Thus materials tend to cycle from plant to animal to microorganism and back to plants in what is called food chain.

Microorganisms usually exhibit mixed population in natural condition. Microbial communities have been constantly changing in response to both environmental and the interactions of other organisms within the microbial, plant and animal community.

The interaction among organisms of different species is called symbiosis. The symbiotic relationship may result in one of three direct effects that may get exerted on the participating organisms: commensalisms, mutalism or parasitism. There has been an indirect relationship, called saphrotism. Saphrophytes are involved in the break down of various materials such as macrophytes into smaller particles termed detritus. The detritus is then used as a food source by the animals present in these system [e.g. Zooplankton, fishes]. Thus in the saprophyte chain, material cycles from plant to microorganisms to animals, rather than from plant to animal to microorganism. Microorganisms involved in the decay of litter are an important link between primary and secondary production in detritus-based food webs of wetland ecosystems (Fenchel and Jorgenson 1977, Odum and de la Cruz 1969). As most of the lignocellulosic matter enters into detritus food chain in the wetlands, it is important to know the relative contribution of different groups of microorganisms to decay, their interactions and succession on detritus.

There is a paucity of studies on the relative contributions of different microorganisms in decay of lignocellulosic matter in aquatic ecosystem. Fungi are considered to be important during the initial phase of the decay process and the bacteria during the later phase of decay (Suberkropp and Klug 1976, Lee *et al.*, 1980, Rublee and Roman 1982, Chamier *et al.*, 1984). In other studies the bacteria were found to be the primary colonizers of plant detritus (Morrison *et al.*, (1977), Newell 1981, Brock 1984, Benner *et al*, 1983, Benner *et al.*, 1986a). Experiments with antibiotic suppressions of either fungal or bacterial activity also indicate that fungi are important initially and the bacteria during latter stages of decay (Kaushik

and Hynes 1971, Mason 1976). As mentioned earlier, considering the importance of fungal flora in aquatic ecosystem the present study was undertaken, discussion will be made on the basis of floristic composition of fungi and interaction with physico-chemical parameters has also been brought under consideration.

A large number of environmental factors interact, which have a profound effect on the development of a community, in any ecosystem. Importance of temperature upon the occurrence and growth of fungal population has been emphasized by many workers (Bock 1956, Paterson, 1960, Perott, 1960, Dick and Newby, 1961, Dayal and Tandon, 1962, 1963, Roberts, 1963, Alabi, 1971 a,b; Khulbe and Bhargava 1977, Hasija and Batra, 1978, Rattan *et al.*, 1980 Misra, 1983). During the period of study monthly variation of fungal flora [Table: 5-7] revealed the fact that the fungal occurence was temperature dependent and it fluctuated with the variation of temperature. It shows that there is a marked variation in temperature from season to season. Higher abundance of the members of saprolegniales were observed during winter months, while the rest were abundant during summer and monsoon months. Similar observations were made by Dayal and Tandon (1962), Rattan *et al.*, (1980), Khan (1981). Roberts (1963) classified species of Saprolegniaceae into constant species occurring throughout the year, summer species occurring during January to March and winter species occurring during January to March. Chowdhury and Agarwal (1980b) classified the group of fungi as per their appearance into winter season species (November to February), temperature ranging between 10°C and 25°C), summer season species (March to June, temperature ranging between 30° to 45°C), rainy season species (July to October, temperature, ranging between 20° and 30°C) and all season species (January to December, temperature ranging between 10°C and 45°C]. After having a general observation on the results of present investigation, it is noted that members of Saprolegniales were recorded during low to moderate temperatures.

Members of Blastocladiales and Pernosporales occured as moderate to high temperature species. These observations fully agree with those of Suzuki (1960a), Haskins (1963) and Schmitt (1967). pH is an important factor in the chemical and biological systems of the natural water as the toxicity of many compounds is greatly affected with change in pH. The importance of this factor in connection with occurrence of water molds has been studied by Lund (1934), Roberts (1963). From Fig. 4 and Tables : 5-7 reveal no definite pattern, although alkaline values of pH were recorded throughout the period of study. Thus it may be concluded that fungal flora are well flourished in alkaline condition. Findings of Alabi (1971b) also confirms the present findings.

DO content of water has proved to be a major factor in determining the occurrence of water molds in water (Sparrow, 1968). DO content showed a positive relation with members of saprolegniales and inverse with the others [Fig: 5 and Tables: 5-7]. This result also agrees with findings of Suzuki (1961b). Chlorides are not utilized for plant growth and their presence in large amounts is regarded as suggestive of pollution by organic matter. A more or less inverse relationship was observed with fungal flora during the period of study [Fig. 14 and Tables: 5-7]. Pagon (1970) considered Chloride as fungi toxic. Khan (1981) and Khulbe (1981) also found that chloride had an adverse effect on the fungal occurrence. Rao and Manoharachary (1983) reported that the chloride has little or influence on the occurrence of water molds.

Misra (1982) reported that calcium plays a positive and significant role in affecting the frequency percentage of water molds. Calcium hardness values as well as fungal occurrence were low during post monsoon and with a richer presence calcium hardness different fungal flora flourished [Fig.12 and Tables: 5-7]. Similar findings were also made by Gupta and Mehrotra (1991). Manoharachary (1979c), Rao and Manoharachary (1983) opinioned that free carbon dioxide has

little or no influence on the fungal number, which also corroborates with the present findings. Although Roberts (1963), Manoharachary (1978) considered phosphate content of water as an important factor for the occurrence of water molds, but present study could not reveal such sort of facts.

As evident from Tables : 4 highest number of fungal species were recorded from SP-3 while in SP-2 and SP-1 number of species occurrence were same. But if population structure is considered then a close similarity was observed in SP-2 and SP-3, probably as the physico-chemical scenario of these spots were more or less similar. Monthly abundance of fungal flora exhibit the fact that each member had specific mode of appearance and disappearance (Tables : 5-7).

CONCLUSION

Fungi as a detrivores has a major importance in aquatic ecosystem. Fungi through its role, supply the nutrient, by which maintenance of high production status of waterbodies are achieved. On the other hand, occurrence, abundance and growth of fungi are also influenced by various physico-chemical factors of the system, together a net work is built. So, it is our foremost task to explore and evaluate each and every biotic and a biotic components of aquatic ecosystem for future conservation and abatement program.

CHAPTER – 6

APPENDIX

TABLE NO.I : MONTHLY MEAN AND SD VALUES OF VARIOUS PHYSICO-CHEMICAL PARAMETERS OF SPOT-1.

YEAR	1998		1999													
PARAMETERS / MONTHS	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	$\bar{X}$	SD
Air Temp. (° C)	23.5	22.4	23	27.8	30	29.5	33	32.3	31	33	25	32	26	24.2	28.05	3.959381
Water Temp. (° C)	25.5	22	26	25.8	29	32.2	36	33	30	30	24	31.8	23	22.5	27.914	4.405566
Transparency (cm)	30.5	28.5	25.9	37.5	29.2	32.5	31	12.5	28.5	25.5	39.37	28	18.41	25.5	28.062	6.827347
pH	8.2	8.9	8.7	7.4	7.5	7.6	8.7	10.3	7.5	9.1	8.3	9.5	8.5	8.7	8.493	0.833402
DO (mg/l)	7.19	8.17	11.67	4.89	7.049	9.213	4.467	6.212	5.933	10.4002	4.886	11.586	10.749	9.457	7.9905	2.544214
% of sat. of O_2	89.309	95.74	145.89	60.999	92.639	126.214	64.369	86.042	78.792	138.117	59.225	157.858	128.272	111.269	102.481	32.484
Conductivity (µS/cm)	518	475	401	618.2	690.132	724.36	655.307	739	617	488	466	296.112	431	445	540.294	134.183
CO_2 (mg/l)	2.6	0	0	6.6	0	0	0	0	0	0	2.8	0	0	0	0.8571	1.92
CO_3 (mg/l)	0	19	15	0	36	40	35	39	30	42	0	44	37	28	26.0714	16.326
HCO_3 (mg/l)	216	289	227	180	235	290	276	219	175	116	163	157	263	276	220.143	55.284
Total hardness (mg/l)	192	220	218	234	269	304	168	296	200	365.4	410	90	275.1	203	246.036	81.946
Calcium hardness (mg/l)	113.4	97	122	109.2	158	206	142.8	214.2	147	102	106	80	186	185.85	140.675	43.398
Magnesium hardness (mg/l)	78.6	123	96	124.8	111	98	25.2	81.8	53	263.4	304	10	89.1	17.15	105.361	84.52
Chloride (mg/l)	45.44	46.86	39.76	44.02	39.88	44.02	35.5	26.98	26.98	17.04	24.14	19.88	43.57	45.23	35.664	10.484
Phosphate (mg/l)	0.062	0.01	0.006	0	0.036	0.048	0.02	0.026	0.002	0.02	0	0	0.066	0.014	0.02214	0.02278
NH_4 (mg/l)	0.2118	0.1059	0	0	0.1059	0.1059	0.20121	0	0.2118	0.1059	0.1059	0.01059	1.059	1.0696	0.23525	0.35918
NH_3 (mg/l)	0.18994	0.09997	0	0	0.09997	0.09997	0.18994	0	0.19994	0.09997	0.09997	0.009997	0.9997	1.0097	0.22208	0.33906
NH_4-N (mg/l)	0.16455	0.08227	0	0	0.08227	0.08227	0.15632	0	0.16455	0.08227	0.08227	0.008227	0.82275	0.83098	0.18277	0.27905
Eh (mv)	0.25598	0.17257	0.19393	0.37281	0.3587	0.34522	0.19997	0.0091	0.35979	0.14745	0.24661	0.09957	0.21805	0.19525	0.22679	0.10647
rH_2	25.227	23.751	24.087	27.656	27.361	27.104	24.296	20.914	27.407	23.284	25.104	22.433	24.519	24.133	24.806	2.01006
BOD (mg/l)	4.537	3.281	9.004	3.211	4.467	5.723	1.535	3.0712	3.2806	9.6324	3.141	3.9088	6.8932	5.0889	4.7694	2.3344

TABLE NO.II : MONTHLY MEAN AND SD VALUES OF VARIOUS PHYSICO-CHEMICAL PARAMETERS OF SPOT-2.

YEAR	1998		1999													
PARAMETERS / MONTHS	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	$\overline{X}$	SD
Air Temp. (° C)	25	28.5	25	24.3	30	31	33	29.5	29	26	24	28	22	23.3	27.043	3.26
Water Temp. (° C)	29	31	34	31	29	30	31	30	27.9	27	23	29	24	29	28.921	2.844
Transparency (cm)	27.3	20.5	8.7	10	8.2	11	3.25	10.5	25.5	15.25	30.2	26	10	20.7	16.221	8.619
pH	7.5	6.4	8.2	5.3	6.4	7.6	7.8	7.9	7.3	6.9	6.5	8.4	6.3	6.4	7.064	0.886
DO (mg/l)	3.699	0.628	2.932	5.514	3.944	2.373	1.466	2.652	2.583	2.583	3.769	6.212	ANOXIA	3.944	3.0213	1.695
% of sat. of O_2	48.612	8.468	41.116	74.315	51.823	31.517	19.755	35.224	33.281	32.858	44.979	81.632	6.536	7.474	38.97	22.863
Conductivity (µS/cm)	828.039	421.88	766.946	1193.005	897.888	896.396	955.2	795.005	416.109	365.364	452.825	271.24	379.593	897.888	681.241	286.567
CO_2 (mg/l)	3	8.2	2.8	11.2	7	2.9	2.6	2.5	2	8.8	4	2.4	8.4	7.8	5.257	3.133
CO_3 (mg/l)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HCO_3 (mg/l)	300	317	250	270	330.5	391	386	315	111	99	99	79	199	330.5	248.357	110.829
Total hardness (mg/l)	352	416	450	790	510	230	388	336	195.8	159.6	329.7	142.8	194	510	357.421	175.88
Calcium hardness (mg/l)	279.3	306.6	378	350.7	289	221	258.3	231	98	90	102	70	182.7	289	224.686	101.324
Magnesium hardness (mg/l)	72.7	109.4	72	439.3	221	9	129.7	105	97.8	69.6	227.7	72.8	11.3	221	132.736	113.019
Chloride (mg/l)	39.76	38.34	24.14	39.76	28.41	17.04	5.68	15.62	19.88	11.36	17.04	15.62	34.85	28.41	23.994	11.124
Phosphate (mg/l)	0.004	0.08	0.026	0.01	0	0	0.002	0	0	0.06	0.034	0	0	0.04	0.01828	0.02612
NH_4 (mg/l)	0.03177	0.26475	0.25416	0.1059	0.15885	0.2118	0.1059	0.1059	0.1059	0.01059	0	0	1.1195	0.29652	0.19743	0.281401
NH_3 (mg/l)	0.02999	0.24992	0.23992	0.09997	0.14995	0.19994	0.09997	0.09997	0.09997	0.009997	0	0	1.04968	0.27991	0.250636	0.341217
NH_4-N (mg/l)	0.02468	0.20588	0.19745	0.08227	0.12341	0.16455	0.08227	0.08227	0.08227	0.008227	0	0	0.86388	0.23036	0.15338	0.218623
Eh (mv)	0.36276	0.50373	0.26163	0.61985	0.49216	0.35376	0.30919	0.29766	0.38863	0.43583	0.48064	0.2333	0.4921	0.49216	0.408814	0.111138
rH_2	27.509	30.17	25.422	31.974	29.771	27.399	26.262	26.064	28.001	28.829	29.574	24.845	29.569	29.771	28.226	2.0692
BOD (mg/l)	2.3732	0.6282	2.443	3.3504	1.8148	0.2792	*	*	*	2.3732	0.998	4.537	0	1.8148	1.4723	1.4345

* = BOD_5 can not be determined.

TABLE NO.III : MONTHLY MEAN AND SD VALUES OF VARIOUS PHYSICO-CHEMICAL PARAMETERS OF SPOT-3.

YEAR	1998		1999													
PARAMETERS / MONTHS	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	$\bar{X}$	SD
Air Temp. (° C)	26	21	27	25.4	28.7	32	36	33	31	27	23.5	31	25	23	27.828	4.288
Water Temp. (° C)	25	19	22	22	27.5	33	30	32	29.2	27.5	23	29	23	21	25.943	4.383
Transparency (cm)	14.2	11.5	10.9	10.2	18.5	10	1.65	10.2	15.25	30.5	38.5	41	20.32	15	17.694	11.39
pH	8.4	8.2	7.7	7.1	8.1	9	7.3	8.2	7.1	8.3	7.1	8.5	7.2	7.7	7.85	0.6211
DO (mg/l)	6.561	16.612	4.467	5.654	8.202	10.749	3.56	5.584	3.001	2.513	3.769	3.001	4.258	10.435	6.312	3.975
% of sat. of O_2	80.903	184.377	52.37	66.281	105.553	148.881	47.275	76.284	39.44	32.174	44.978	39.44	50.809	120.22	77.785	46.022
Conductivity (µS/cm)	831.024	786.448	975.1	885.55	653.317	407.453	1072.61	792.816	368.15	324.77	353.424	193.53	336.211	548.44	609.203	282.49
CO_2 (mg/l)	0.6	2.6	3.7	6.4	1.3	0	5.2	1	4.2	2.8	6.6	3.4	5	3.8	3.328	2.08
CO_3 (mg/l)	0	0	0	0	0	30	0	0	0	0	0	0	0	0	2.1428	8.0178
HCO_3 (mg/l)	248	294	332	319	122	157.6	292	325	102	99	190	112	185	239.5	215.51	88.04
Total hardness (mg/l)	210	298	441	266	203	140	202	302	193.2	147	168	105	275.1	225	226.807	85.605
Calcium hardness (mg/l)	134.4	172.2	268	207.9	155.4	102	189	77.7	108	74	56	80	152	220.65	142.881	63.616
Magnesium hardness (mg/l)	75.6	125.8	173	58.1	47.6	38	13	224.3	85.2	73	112	25	123.1	4.35	84.146	62.534
Chloride (mg/l)	171.82	163.3	117.86	122.12	69.58	17.04	143.42	15.62	21.3	15.62	19.88	26.98	107.98	135.34	81.947	61.138
Phosphate (mg/l)	0.02	0	0	0.006	0.018	0.002	0.09	0.006	0.004	0.008	0.002	0	0.002	0	0.01129	0.02354
NH_4 (mg/l)	0.64599	0.6354	0.18003	0.1059	0.68835	0.2118	0.2118	0	0.01059	0.01059	0	0	3.18759	1.6415	0.53782	0.88727
NH_3 (mg/l)	0.60981	0.59981	0.16994	0.09996	0.6498	0.19993	0.19993	0	0.009997	0.009997	0	0	3.00908	1.54952	0.5077	0.837572
NH_4-N (mg/l)	0.50187	0.49364	0.13986	0.08227	0.53478	0.16454	0.16454	0	0.008227	0.008227	0	0	2.47647	1.27526	0.417834	0.689322
Eh (mv)	0.23295	0.250703	0.31797	0.40729	0.26695	0.15905	0.386604	0.25757	0.41128	0.2508	0.40984	0.22608	0.39728	0.312631	0.306214	0.08341
rH_2	24.833	25.045	26.364	28.244	25.405	23.484	27.931	25.282	28.382	25.248	28.332	24.796	26.099	26.1803	26.259	1.6407
BOD (mg/l)	4.607	12.494	2.164	3.35	5.026	8.7008	0.8376	1.536	0.0698	2.303	2.443	0.8376	2.953	7.724	3.789	3.349

CHAPTER – 7

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** = Original document not seen.