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ZOOLOGICAL SURVEY OF INDIA

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INTRODUCTION

Hyderabad city, in Andhra Pradesh is located in the heart of Dakshinapatha or the Deccan Plateau of the Indian subcontinent at latitude 17° 20'N and longitude 78° 30'E (Fig. 1). The Hyderabad Development Area is a sprawling region spreading to over 1552 km and includes a good many major and minor man made wetlands (Parthasarthy, 1983), which constitute important lentic freshwater resources of the city. Among lotic resources, the main river Musi passes through the city. However, during recent past this river has literally run dry as a masonry dam was build to impound water into a reservoir (Osman sagar). Besides Musi, Saklavani (East), a tributary of Musi, and Pasupuleru (Haldi), a tributary of Manjira, are other notable streams in the area.

The climate of the region is hot and humid. Generally a *hot steppe* type climate or *semiarid* conditions prevail in Hyderabad and adjoining areas. Broadly, the climate of Hyderabad is characterised by a hot summer, a mild winter and a moderate monsoon season. Parthasarthy (1983) divided the annual cycle of the region into following four seasons.

Winter - December to mid February.

Summer - Mid February to May.

Monsoon - June to September.

Retreating season - October to November.

Strictly speaking, among lentic freshwater resources, there are no natural lakes in the entire State but many large and small man made lakes/reservoirs and tanks constitute the sizable portion of the State's freshwater resources. These man made lakes or impoundments, commonly termed as lake/sagar, were formed by throwing dams across the valley of small rivulet and streams for irrigation. The prominent major lakes of the drainage system in Hyderabad are Hussain sagar, Osman sagar, Himayat sagar, Mir Alam tank and once formed the major source of surface water in the region (Fig. 1).

There are more than 10 major lakes/irrigation tanks located in Hyderabad, besides some small tanks/ponds. The major man made lakes and ponds have been the focus of several scientific studies and by now limnology of some of these is known in some detail. Notable contributions include the works of Zafar (1964a, 1964 b, 1986), Munawar (1970a), Seenayya (1971a, 1972), Rao (1975, 1977), Satya Mohan (1981,1987) and Satya Mohan and Reddy (1986) on phytoplankton; Srinivasan *et al.* (1965), Zafar (1966), Munawar (1970b, 1974), Seenayya (1971b), Rao (1971 1972), Seenayya and Zafar (1979), Kumar *et al.* (1978), Kumar (1980), Schamamba (1984) and Narendra Reddy and Prasad (1988) on general physico-chemical and ecological characteristics; Zafar, (1975), Prahlad *et al.* (1985), Siddiqi and Rama Rao (1991) and Pandey, Siddiqi and Rama Rao (1993) on pollution aspects and Seenayya (1973) and Babu Rao, *et al.* (1981) on zooplankton.

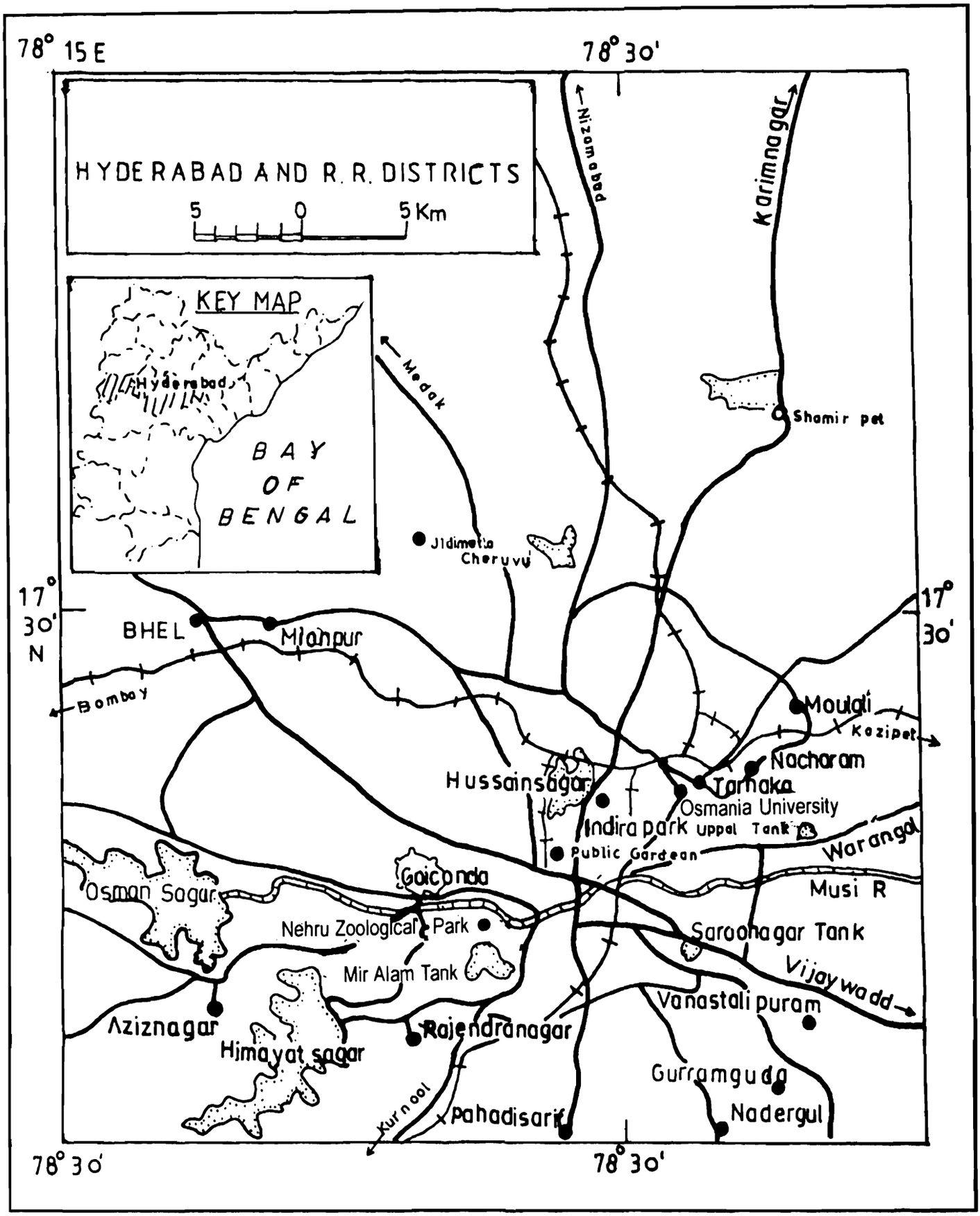


Fig. 1. Map of Hyderabad and adjoining Ranga Reddy Districts showing location of different lakes and tanks in the regionn. Inset. Location of Hyderabad district in the state of Andhra Pradesh.

A close scrutiny of the available literature revealed that while works on the phytoplankton and general limnological condition of these lakes/ponds were done in some details, the information on faunal groups *viz.* zooplankton, nekton and benthos, which play indispensable roles in the trophic dynamics of the aquatic ecosystem, is extremely meagre as no detailed systematic taxo-ecological studies on any of the faunal communities inhabiting littoral, limnetic or profundal zones or those associated with macrophytes, has been undertaken by any worker systematically save for few studies on an assortment of heterogeneous faunal groups, comprising zooplankton community. Infinite array of other freshwater invertebrates including insects, have almost been totally neglected. With the result there exists no document on the whole gamut of freshwater invertebrates as compared to similar studies from the adjoining regions- Sri Lanka (Fernando, 1963, 1964, 1969 and 1974). Further , excepting the work of Zafar (1986), comparative limnological studies on different lakes/ tanks of the region is also lacking.

Realising the importance of the subject and lacunae in knowledge, the present investigations were undertaken to have a comparative account of the physico-chemical and biological condition of five important man made lakes/tanks of Hyderabad which differed significantly in their limnological attributes (open/closed lake system) and trophy (nutrient status), with emphasis on the structure and composition of faunal communities of zooplankton, macrophytes associated macro-invertebrates and nekton (fishes). A list of the characteristic species from the varied ecological communities in Hussain sagar and Saroor Nagar tank was prepared. Some observations on the avifauna of these water-bodies were also made and commonly occurring species listed. Attempts have also been made to forge the indiscernible nexus between ecological succession and eutrophication and to evaluate the trophic status of the lakes based on some physico-chemical and biological characterstics. The lakes studied were Hussain sagar, Himayat sagar, Osman sagar, Mir Alam tank and Large tank Saroor Nagar.

DESCRIPTION OF THE STUDY AREA

The comparative morphometry of these five lakes/tanks, based on the data gathered from various sources is given in Table 1. The details of each lake/tank are described below.

1. Hussain Sagar

This man made lake was excavated between 1550-1580 AD by Sultan Ibrahim Kutub Shah, to make way for the construction of a new city and provision of water supply to Golkonda suburban of Khairatabad, Saifabad, north Chadarghata and Langer Hauz. It was built by constructing a dam on a tributary of the river Musi. The dam was originally fed by Balkapur river which branched off from River Musi, about 32 km away from Hyderabad.

The lake is located at about 51 cm above the sea level, between the twin cities of Hyderabad (Saifabad) in the south and Secunderabad in the north. Its maximum length and breadth are reported to be 3.02 km and 2.80 km respectively with a maximum depth (zm) of 12.50 m and mean depth of 2.50 m. The total catchment area is about 240.80 km^2. The original maximum water spread area (10.06 km^2) has been reduced considerably due to human abuse (reclamation

Table 1 Major morphometric attributes of different man made - lakes/reservoir/tanks of Hyderabad

Morphometric Features	Hussain Sagar	Himayat Sagar	Osman Sagar	Mir Alam Tank	Large Tank, Saroor Nagar
Surface area, km^2	4.40	22.00	23.00	1.70	0.40
Catchment area, km^2	240.80	1,315.72	740.72	15.24	41.13
Capacity at Storage, mcm	38.57	181.91	304.73	8.12	0.77
Max. water spread, km^2	10.06	29.27	37.81	1.69	–
Max. length, km	3.02	–	11.28	2.54	–
Max. width/breadth, km	2.80	–	5.11	1.63	–
Mean width, km	3.14	–	1.96	0.66	–
Max. depth, m	12.50	25.53	30.70	31.41	6.10
Mean depth, m	2.50	11.88	6.17	4.80	–
Total volume, acre-feet/mtm^3	7,652.00	–	–	8,12,136.00	–
Volume development/volume, V	0.52	–	–	–	–
Shore development, km	–	–	–	2,448.00	–
Abs. Shore development, DL, km	1.90	–	–	8.68	–
Max. run off in river cum/sec	–	4,531.10	2,973.60	–	–
Max. length of bundh, m	2,286.00	2,255.00	1,257.00	1,024.12	1,798.00

for human habitation) and currently it covers an area of 7.055 m^2. The dam (bundh) is 2286 m long and forms the main highway between Hyderabad and Secunderabad (Fig. 2). The flood gate lies in the centre of the bundh (locally known as tank bundh) and is operational only in emergency. However, the sluices at both ends, discharge water almost throughout the year. The lake is essentially a large depression and therefore is a single basin lake in a mildly undulating terrain. The lake is mainly rain fed as the original canal connecting to Osman sagar, situated at 19 km upstream, remains dry for most of the year. However, it receives flood water from adjacent area through the Begumpet nala (Fig. 2).

Untreated industrial effluents are discharged in the lake from nearly 200 industries through Kukatpally Main Sewer pipeline or the K-main, which comes from the industrial belt and is almost corroded by now. Besides, the level of organic pollution due to the entry of sullage and sewage into the lake is also alarming (Zafar, 1975). The increasing load of industrial and organic wastes, both from point and non point sources, had triggered nutrient enrichment and consequent eutrophication of the lake (Siddiqi, 1990). During present study, major portion of the water spread area of the lake was covered by the dense strands of nuisance, floating macrophyte *Eichhornia sp.* A permanent bloom of blue green algae contributed by the species *Microcystis aeroruginosa* and *Melosira granulata* was also evident. At places, the condition of the water was very bad, emiting nauseating foul smell. The lake water where the K-main leaks effluents into the lake, resembled India-ink suspension because of the presence of ferrous sulfide.

The lake has been increasingly used as recreational waters for various sports and other secondary needs of the city like watering of lawns and gardens *etc.* The earlier studies on this lake include the work of Zafar (1966a, 1975) and Siddiqi (1990) *etc.*

2. Osman Sagar

One of the biggest dam reservoir in the State, it was constructed across the river Musi, a tributary of river Krishna, during the period 1905 and 1920 AD. Essentially a flood control and water supply reservoir for the twin city of Hyderabad - Secunderabad until quite recent past, it supplied about 29.5 mld of water. Located upstream in the midst of hills and valleys in the granite country, nearly 19 km north west of the city, it has a combined catchment area measuring 740.72 km^2. The main lake is essentially a single basin structure but the country around is a vast expanse of widely undulating terrain and rocky knolls with scanty vegetation (Siddiqi 1990). The maximum length and breadth of the reservoir are 11.28 and 5.11 km respectively. Its maximum depth (zm) was recorded as 30.70 m and the mean depth as 6.17 m. The length of the bundh is 96.01 m. It has a total storage capacity of 4.04 TMC at FTL (Fig. 3).

In general, the raw water quality is good from aesthetic and chemical viewpoints. The reservoir water is primarily alkaline. And it generally does not witness algal blooms, although it does harbour good phytoplankton population.

Earlier studies on this reservoir include the works of Satya Mohan (1981) on general limnology, Satya Mohan and Reddy (1986) and Satya Mohan (1987) on the ecology of phytoplankton and Siddiqi (1990) on general fauna.

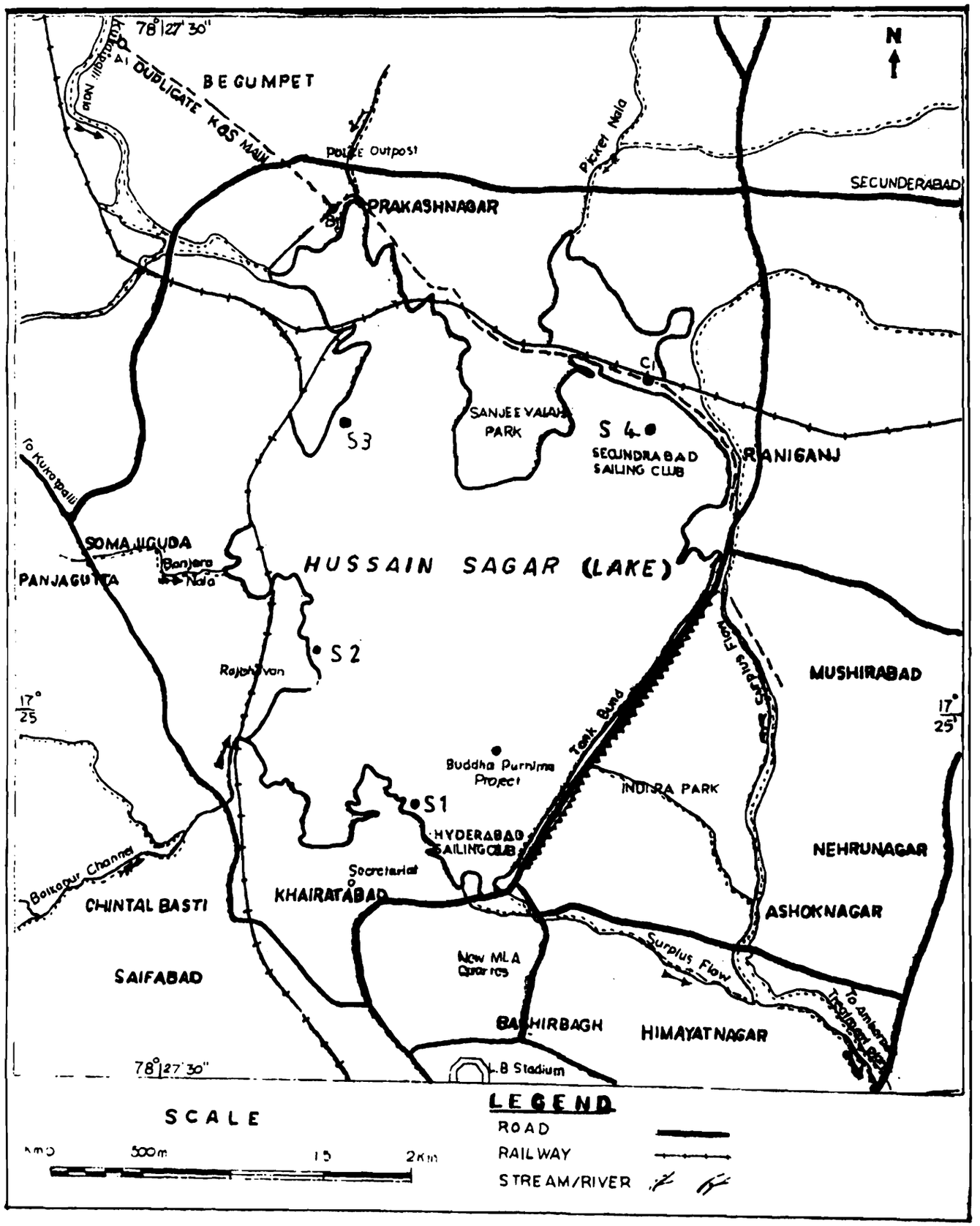


Fig. 2. Topographic map of Hussain Sagar (lake), Hyderabad showing various sampling sites, inflows (nalas), outflows as also the duplicate Kukatpally-Secunderabad (K-S) Main, (A1-B1-C1) the intercepter sewer, for divversion of industrial effluents / domestic sewage by passing lake for eventual discharge after treatment (Amber Treatment Plant).

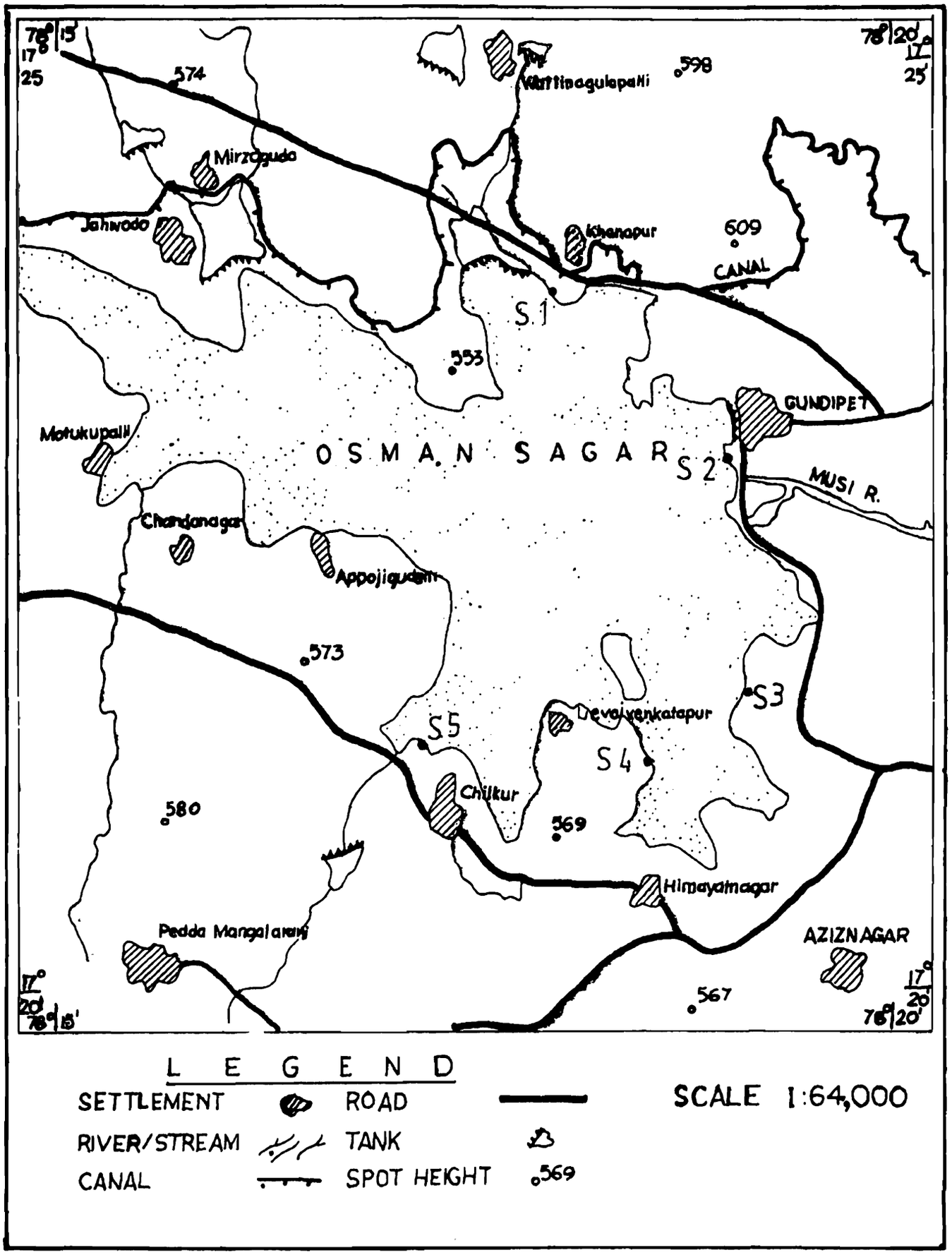


Fig. 3. Topographic map of Osman Sagar, Hyderabad, a raw water reservoir, showinng location of sampling sites, (S1-S5) in the lake

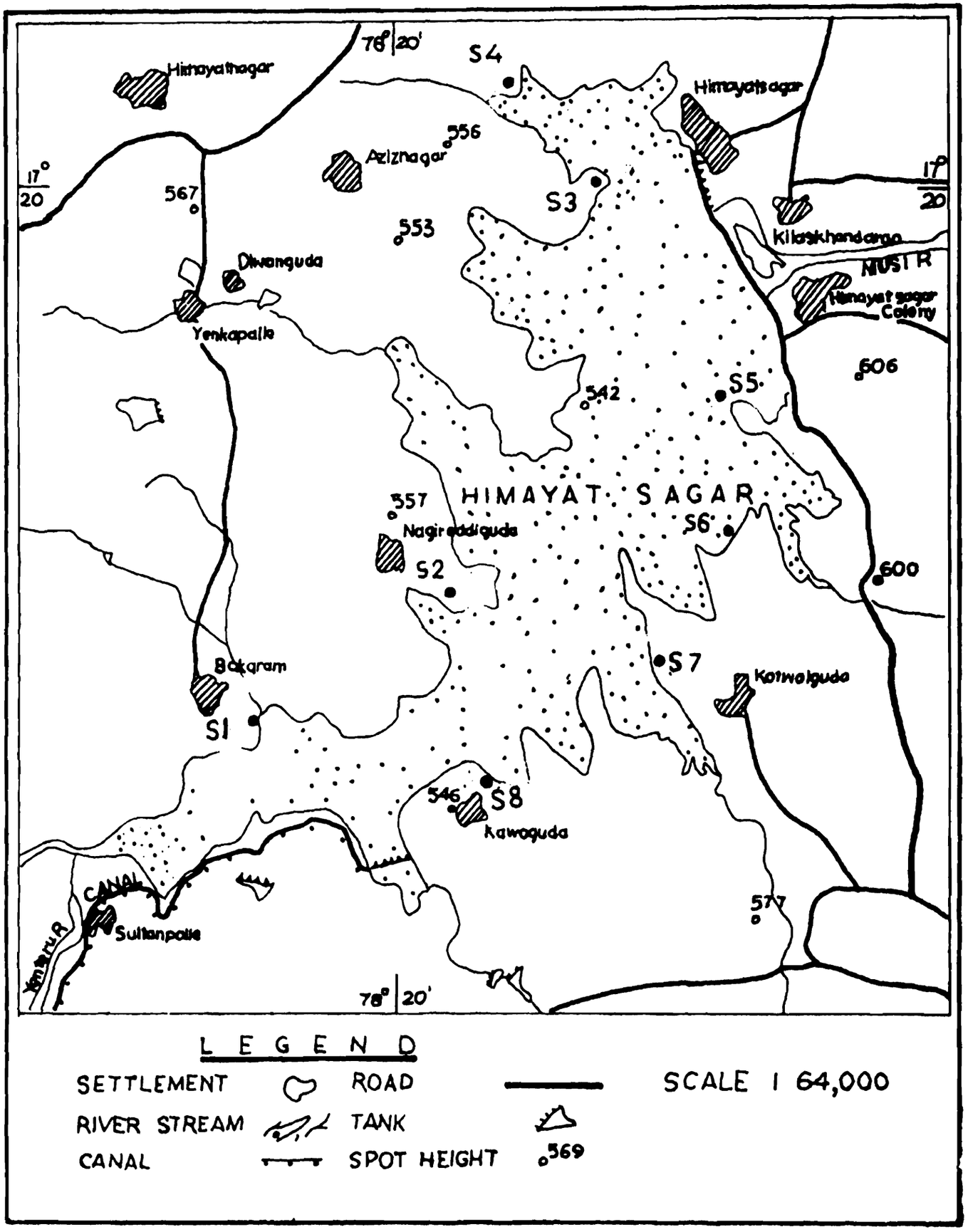


Fig. 4. Topographic map of Himayat Sagar (Lake), Hyderabad showing location of different sampling points (Si-S8) in the reservoir.

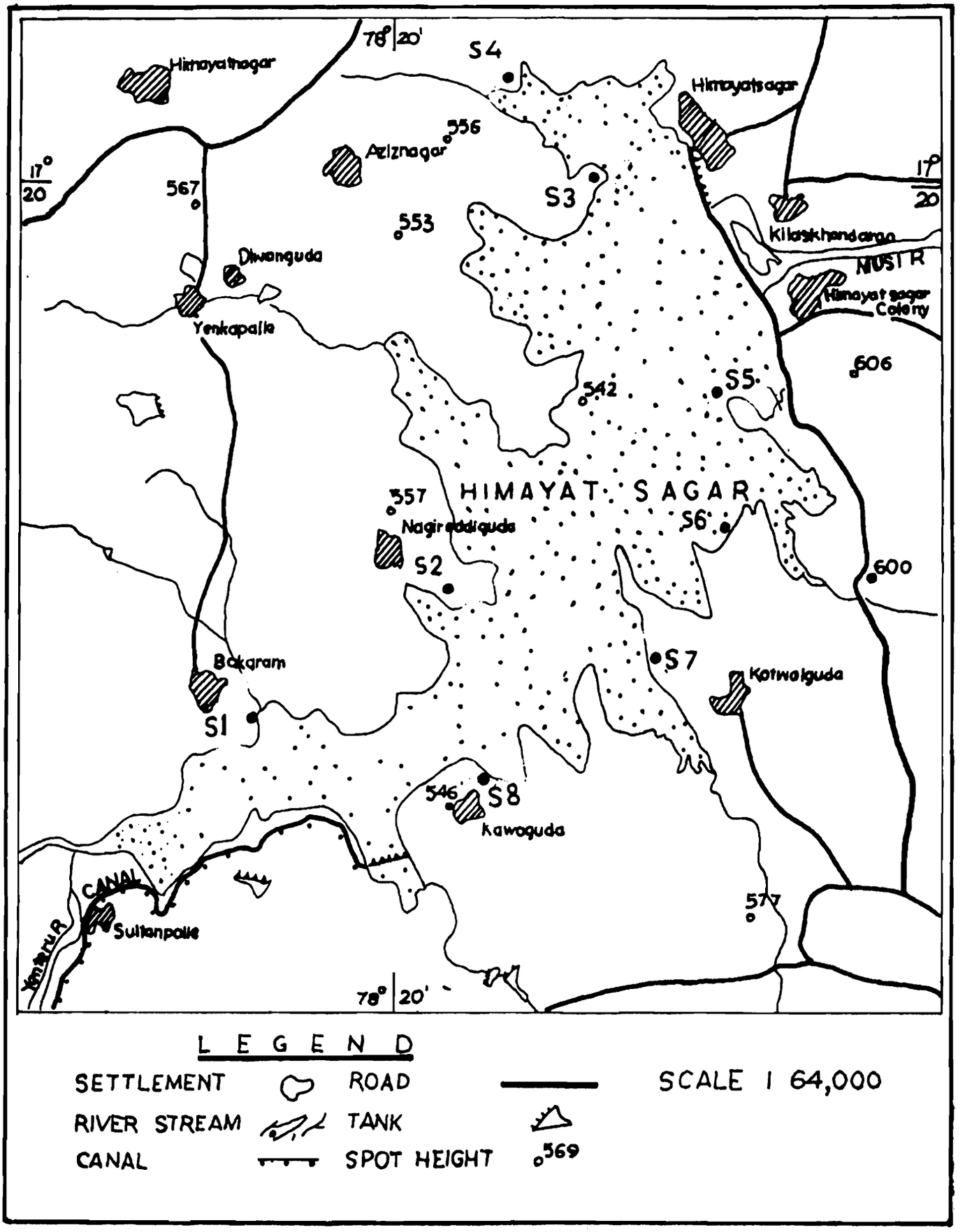


Fig. 5. Topographic map of Mir Alam Tank showing location of sampling points (S1-S5) in the lake.

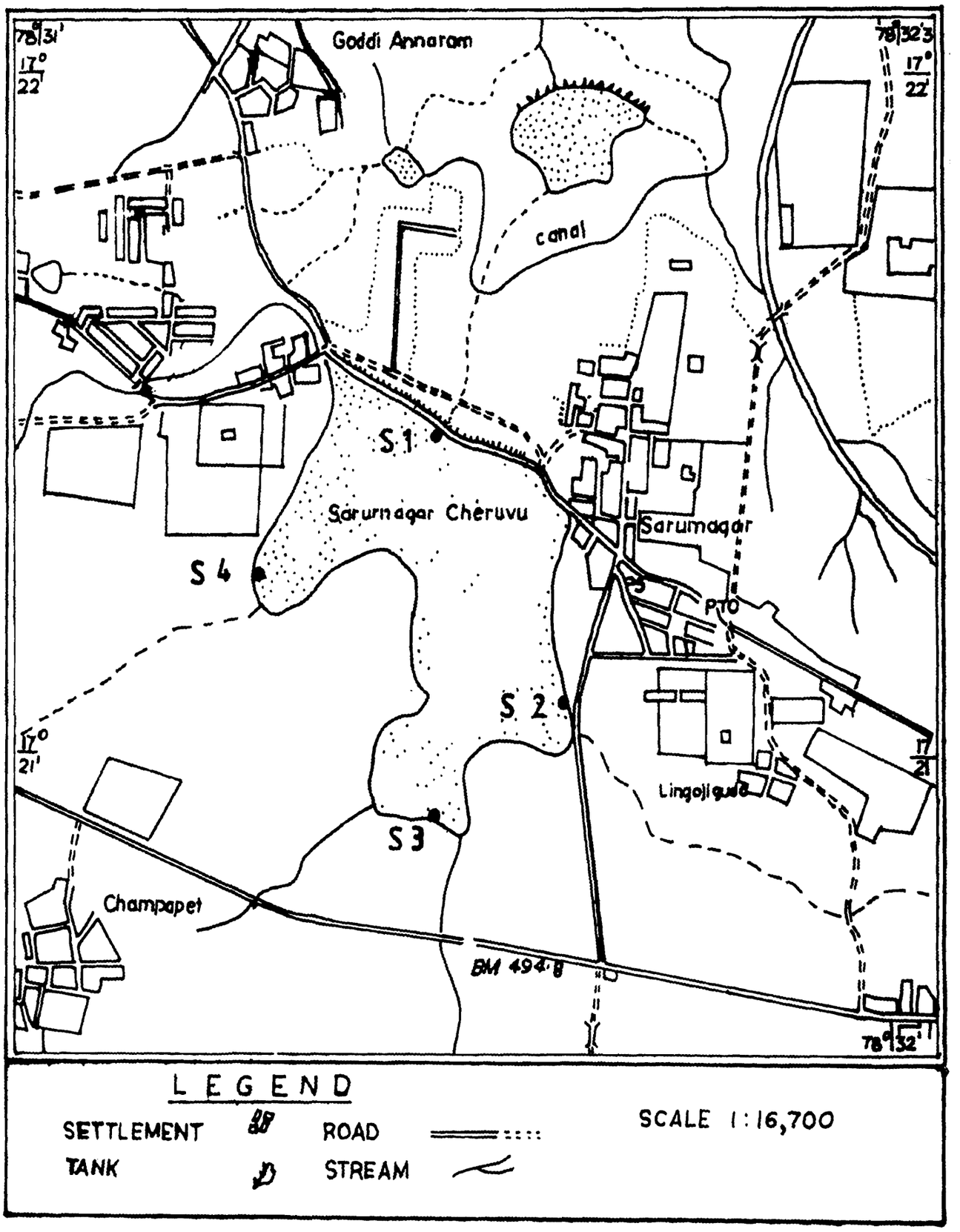


Fig. 6. Topographic map of Large tank, Saroornagar, Hyderabad Showing location of sampling sites (S1-S4) in the tank.

3. Himayat Sagar

Constructed across the Esi, a tributary of the Musi river, during the periods 1920 and 1927 AD. the reservoir is located south west of the city at a distance of 9.66 km from city centre. (Fig. 4). Its total catchment area is reported to be 1315 km sq. Its maximum length and breadth are 3.22 km and 2.80 km, with maximum depth of 12.5 m and mean depth of 2.5 m. It has a relatively smaller water spread area of 29.27 m^2 at full tank level. Two big nalas also open into the lake and its water were earlier taken into Mir Alam tank by means of a channel for supplies to the old part of the city. However, the practice has been discontinued for long now and the potable water is supplied directly to cater the needs of the twin cities.

The water quality is good, both from aesthetic and chemical point of views. The lake water is alkaline-bicarbonate type.

Excepting few isolated studies (Srinivasan *et al* 1965, Siddiqi, 1990), not much allention has been given to the limnology of this reservoir.

4. Mir Alam Tank

Located about 1 km south west of the old city of Hyderabad, this medium sized closed tank with 13 km circumference was once a wide sheet of water spread over an approximately flat basin, downstream in the granite country (Fig. 5). It is essentially a single basin lake with some rocky eminencies. Conceived primarily as a source of primary water supply, it was constructed in 1806. It is primarily rain fed, for the channels connecting to Himayat Sagar, located upstream, remain mainly dry. The lake has comparatively reduced water spread area of 1.69 km^2. Following abstraction /withdrawal for secondary use, human abuse and truant south west monsoon, the lake is now reduced to patchy sheet of water infested with macrophytes, predominately water hyacinth (*Eichhornia crassipes*).

The bundh is buttressed type and consists of a series of 21 small semi-circular arches and covers a total length of 1024 m. The lake also has a relatively smaller total catchment area of 15.24 km^2. The maximum length and breadth of the lake are 2.088 and 1.5 km^2 respectively, with maximum depth of 31.40 m and mean depth of 4.80 m (Table 1). Increasing encroachment and frequent failure of seasonal rains have lead to ecological degradation. Chemical enrichment from surface run-off and sewage have triggered eutrophication. The tank maintains a permanent bloom of blue green algae.

Some earlier works carried out on the ecology of this tank include the studies by Sreenivasan *et al.* (1965), Seenayya and Zafar (1979), Satya Mohan and Reddy (1986), Satya Mohan and Zafar (1986) and Siddiqi (1990).

Large Tank, Saroor Nagar

Yet another important component of water system in the drainage basin of river Musi, is the large tank in Saroor nagar, located on the eastern side of the city, nearly 5 km from Saidabad

(Fig. 6). Constructed in 1626 AD, it is essentially a storage tank. The northern edge of the lake has a 0.6 km long bundh. The total catchment area of the lake is 41.13 km^2. Its maximum depth is 6.19 m. It discharges surplus water into river Musi through a stream. As of now, it has a relatively reduced water area of just 0.35 km^2. The water is very turbid and dirty. The main lake basin, a simple depression, is devoid of prominent rocky eminences. Located in the gently plain region of the village Saroor nagar, it is surrounded by human settlements and receives untreated discharges. It maintains a permanent bloom of blue green algae. Like Hussain sagar, it is also a victim of high degree of organic pollution, resulting in hyper eutrophication.

The earlier studies on this tank includes the report of Khanam and Zafar (1983) and Siddiqi (1990).

MATERIAL AND METHODS

Sample collection

The studies were carried out during 1990-92. Water samples were collected from littoral zone at weekly interval from 4 fixed sampling stations in each reservoir/tank as indicated in Figs 2-5, early in the morning. For diurnal studies in Hussain sagar, samplings were done at 6 hourly intervals. Water for dissolved oxygen determination was collected in a 300 ml capacity BOD bottle from just below the surface slowly so as to avoid any air bubble entering into the bottle. Water samples for the determination of physico-chemical parameters to be carried out in the field were collected in a clean bottle of 500 ml capacity and for other parameters, to be determined in laboratory, in 1000 ml capacity PVC containers.

Qualitative zooplankton samples were collected with the help of a plankton net made of bolting cloth No 20 (mesh size, 75μ) from the littoral zone. Sweeps were made in all directions and also nets were thrown to some distance and towed. Samples were preserved in 4% formalin.

Macrophytes associated fauna were collected from littoral zones only, with the help of a quadrate sampler made of a iron frame fitted with a relatively coarser meshed nylon net. Net was swap in all directions, and all material including macrophytes were collected in a large polythene bag and brought to shore. The samples were washed thoroughly in a sieve of 0.5 mm mesh size (U.S. standard No. 30) and all fauna retained on the sieve were picked live with the help of a sable hair brush and blunt head soft forceps. All animals so collected were preserved in alcohol.

Fish fauna were collected from Hussain, Osman and Himayat sagars with the help of local fishermen. After slit opening the belly, the specimens were preserved in 8% formalin Avifauna were recorded by observing the bird through a field binocular at every visit.

Analyses

Physico-chemical parameters :

Temperature, pH, turbidity, conductivity, total hardness, dissolved oxygen (DO), alkalinity and chloride were measured in the field itself. Temperature was measured with a Hg glass thermometer and pH by a pH meter. Conductivity was determined with the help of a conductivity meter. Turbidity values were determined with the help of a turbidity meter. Transparency (Zsd) was recorded with the help of a Secchi disc.

Determination of chemical parameters followed primarily the Standard Methods (APHA 1989). DO was determined by modified Winkler's method, alkalinity and free CO_2 were determined by titrating samples with 0.02 N sulphuric acid using methyl orange and phenolpthaline indicators. Chloride was estimated argentimetrically. Total hardness was measured by EDTA titrimetic method.

For seasonal analyses, data were pooled and divided into 3 major seasons *viz* Summer (March-June), Monsoon (July-October) and Winter (November- February).

The faunae were identified to the lowest possible taxa (Family/genus/species)

RESULTS AND DISCUSSION

A PHYSICO-CHEMICAL CHARACTERISTICS

1. Hussain Sagar

a) Diurnal variations

Tables 2-4 provide a detailed synoptic view of the average station-wise values of different physicochemical parameters at 4 stations at 6 hourly interval during summer, monsoons and winter seasons respectively. In general, barring, temperature, dissolved oxygen, free carbon-di-oxide and alkalinity; diel fluctuations in most of the physico-chemical parameters were not pronounced and therefore exhibited only marginal variations. The diurnal fluctuation pattern in these factors (water temperature, DO, free CO_2, total alkalinity) at stations I and IV during different season are plotted in figs. 7 and 8. Wide diurnal fluctuations were recorded in the values of DO and free CO_2 which were obviously related to photosynthetic and respiratory activities. Generally, an increase from 06.00 hrs onwards till 18.00 hrs was observed whereafter a gradual fall was recorded culminating into minima around midnight (24.00 hrs) or early morning (06.00 hrs). The behavior of DO was different at the two stations. While lowest values at station I were observed in early morning, around 6.00 hrs, at Station-IV its minimum values were recorded at midnight (24.00 hrs.). However, the peak values at both stations were invariably recorded at 12.00 hrs (noon). In general DO concentrations at Station-IV were considerably lower than Station-I, due to highly polluted nature of the former, as it receives sewage and industrial effluents. The free CO_2 also fluctuated at the two stations during different periods of

Table 2. Station - wise mean diurnal values of some physico-chemical parameters of water quality in Hussain sagar during Summers

TIME	06.00 Hrs. Stations				12.00 Hrs. Stations				18.00 Hrs. Stations				24.00 Hrs. Stations			
FACTORS	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Temperature °C																
Ambient/	27.00	26.00	26.00	25.00	35.00	37.00	36.00	36.00	31.00	31.00	30.00	31.00	29.00	27.00	28.00	29.00
Water-Surface	25.00	25.00	25.00	25.00	32.00	31.00	30.00	29.00	27.00	27.00	27.00	27.00	26.00	26.00	26.00	26.00
pH	8.00	8.10	8.10	7.85	8.20	8.20	8.10	8.10	7.90	8.10	8.10	7.80	7.80	8.10	8.10	8.10
Transmittanse %	98.00	88.00	98.00	100.00	97.00	95.00	92.00	97.00	98.00	96.00	93.00	100.00	97.00	95.00	92.00	97.00
Turbidity-JTU	8.00	48.00	—	2.00	12.00	20.00	12.00	12.00	8.00	16.00	26.00	2.00	12.00	20.00	30.00	12.00
DO (mg/l)	1.10	2.00	1.10	1.00	3.10	8.00	1.00	3.50	3.00	4.90	1.50	1.80	1.60	2.10	1.70	0.80
Free CO_2 (mg/l)	21.00	20.00	26.00	35.00	15.00	26.00	30.00	21.00	26.00	21.00	23.00	31.00	34.00	20.00	26.00	33.00
Total Alkalinity (mg/l)	236.0	252.0	262.0	297.0	252.0	240.0	254.0	220.0	210.0	260.0	320.0	220.0	250.0	266.0	264.0	224.0
Total Alkalinity-meq/L	4.70	5.10	5.20	5.90	5.00	4.80	5.00	4.30	4.20	5.20	8.40	4.40	5.10	5.30	7.20	4.40
Bicorbonate (mg/l)	287.0	307.0	319.0	362.0	307.0	292.0	309.0	292.0	256.0	316.0	390.0	292	312.0	324	443.0	273.0
Carborate (mg/l)	141.0	150.0	156.0	177.0	150.0	143.0	152.0	143.0	125.0	155.0	191.0	143.0	153.0	159.0	218.0	134.0
Chloride (mg/l)	148.0	151.0	163.0	160.0	147.0	149.0	165.0	159.0	153.0	154.0	169.0	161.0	149.0	150.0	163	158.0
Hardness (mg/l)	316.0	336.0	342.0	324.0	312.0	314.0	318.0	300.0	336.0	340.0	344.0	340.0	316.0	346.0	304.0	304.0

Table 3. Station - wise mean diurnal values of some physico-chemical parameters of water quality in Hussain sagar during Monsoons

TIME	06.00 Hrs. Stations				12.00 Hrs. Stations				18.00 Hrs. Stations				24.00 Hrs. Stations			
FACTORS	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Temperature °C																
Ambient/	24.00	25.00	26.00	25.00	29.00	29.00	26.00	30.00	28.00	28.00	27.00	25.00	26.00	25.00	25.00	–
Water-Surface	27.00	27.00	18.00	27.00	27.00	27.00	27.00	28.00	26.00	26.00	27.00	28.00	28.00	26.00	26.00	–
pH	8.00	8.00	7.90	7.90	7.90	7.90	7.90	7.90	8.00	8.00	7.90	8.10	7.90	8.10	8.00	7.80
Transmittanse %	95.00	92.00	88.00	94.00	95.00	93.00	87.00	93.00	95.00	96.00	91.00	95.00	95.00	92.00	88.00	94.00
Turbidity-JTU	16.00	30.00	42.00	20.00	16.00	26.00	44.00	26.00	16.00	12.00	30.00	20.00	16.00	25.00	42.00	22.00
Transparancy, Zsd (m)	0.60	–	0.26	0.44	0.40	0.40	0.20	0.40	–	–	–	–	–	–	–	–
Photic depth, Pd (m)	1.50	0.60	1.10	1.20	1.20	1.20	0.60	1.10	–	–	–	–	–	–	–	–
Ev	1.20	–	2.90	1.70	1.50	1.50	2.80	1.60	–	–	–	–	–	–	–	–
DO (mg/l)	1.40	1.10	2.40	2.20	6.60	5.00	4.30	2.90	2.70	3.4	Nil	1.70	1.50	1.30	Nil	.80
Free Co_2 (mg/l)	3.30	23.00	22.0	25.0	6.20	17.00	23.00	19.00	7.30	20.00	20.00	19.00	9.50	11.00	24.00	18.00
Total Alkalinity (mg/l)	210.0	199.0	203.0	213.0	252.0	230.0	240.0	220.0	183.0	189.0	172.0	230.0	173.0	184.0	175.0	181.0
Bicorbonate (mg/l)	256.0	242.0	247.0	260	307.0	280.0	292.0	268.0	223.0	231.0	210.0	280.0	210.0	224.0	213.0	221.0
Carborate (mg/l)	125.0	119.0	121.0	127.0	150.0	137.0	143.0	131.0	109.0	113.0	103.0	138.0	103.0	110.0	105.0	108.0
Chloride (mg/l)	136.0	126.0	149.0	142.0	133.0	127.0	133.0	134.0	128.0	118.0	133.0	129.0	136.0	123.0	160.0	154.0
Hardness (mg/l)	262.0	270.0	294.0	292.0	248.0	256.0	283.0	241.0	248.0	246.0	298.0	234.0	264.0	289.0	285.0	297.0

Table 4. Station - wise mean diurnal values of some physico-chemical parameters of water quality in Hussain sagar during Winters

TIME	06.00 Hrs: Stations				12.00 Hrs. Stations				18.00 Hrs. Stations				24.00 Hrs. Stations			
FACTORS	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Temperature °C Ambient/	20.00	19.00	21.00	21.00	30.00	29.00	32.00	32.00	24.00	22.00	25.00	24.00	17.00	18.00	18.00	18.00
Water-Surface	23.00	22.00	22.00	23.00	25.00	26.00	27.00	26.00	25.00	24.00	24.00	23.00	22.00	23.00	22.00	23.00
pH	7.50	7.50	8.00	7.70	7.60	7.60	7.90	7.70	7.70	7.80	8.20	7.70	7.60	7.60	7.80	7.60
Transmittanse %	93.00	94.00	90.00	92.00	93.00	94.00	88.00	95.00	93.00	93.00	91.00	90.00	92.00	96.00	92.00	91.00
Turbidity-JTU	26.00	22.00	36.00	26.00	26.00	20.00	42.00	16.00	22.00	26.00	32.00	36.00	26.00	12.00	26.00	30.00
Transparancy, Zsd (m)	.30	.41	–	.52	.34	.22	.58	–	–	–	–	–	–	–	–	–
Pd (m)	.75	1.02	–	1.3	.85	.55	1.45	–	–	–	–	–	–	–	–	–
DO (mg/l)	1.80	Nil	1.50	1.50	6.60	10.20	7.40	7.30	6.00	5.00	6.50	4.70	3.30	3.40	3.70	.40
Free CO_2 (mg/l)	17.00	27.00	20.00	32.00	14.00	36.00	32.00	11.00	12.00	25.00	27.00	12.00	20.00	20.00	Abst	12.00
Total Alkalinity (mg/l)	278	330	301	290	252	257	335	303	210	293	230	226	248	236	231	231
TA-meq/L	5.50	6.60	6.00	5.80	5.00	5.10	6.70	6.00	4.20	4.20	4.60	4.50	4.90	4.70	4.60	4.60
Bicorbonate (mg/l)	338.0	402.0	366.0	354.0	307.0	313.0	408.0	369.0	256.0	259.0	280.0	275	302.0	288.0	282.0	281.0
Carborate (mg/l)	166.0	197.0	180.0	174.0	150.0	153.0	200.0	181.0	125.0	127.0	137.0	135.0	148.0	141.0	138.0	138.0
Chloride (mg/l)	207.0	258.0	325.0	240.0	250.0	241.0	257.0	246.0	260.0	232.0	274.0	265.0	270.0	276.0	258.0	271.0
Hardness (mg/l)	312.0	356.0	366.0	332.0	345.0	365.0	380.0	350.0	313.0	336.0	342.0	310.0	312.0	284.0	304.0	308.0

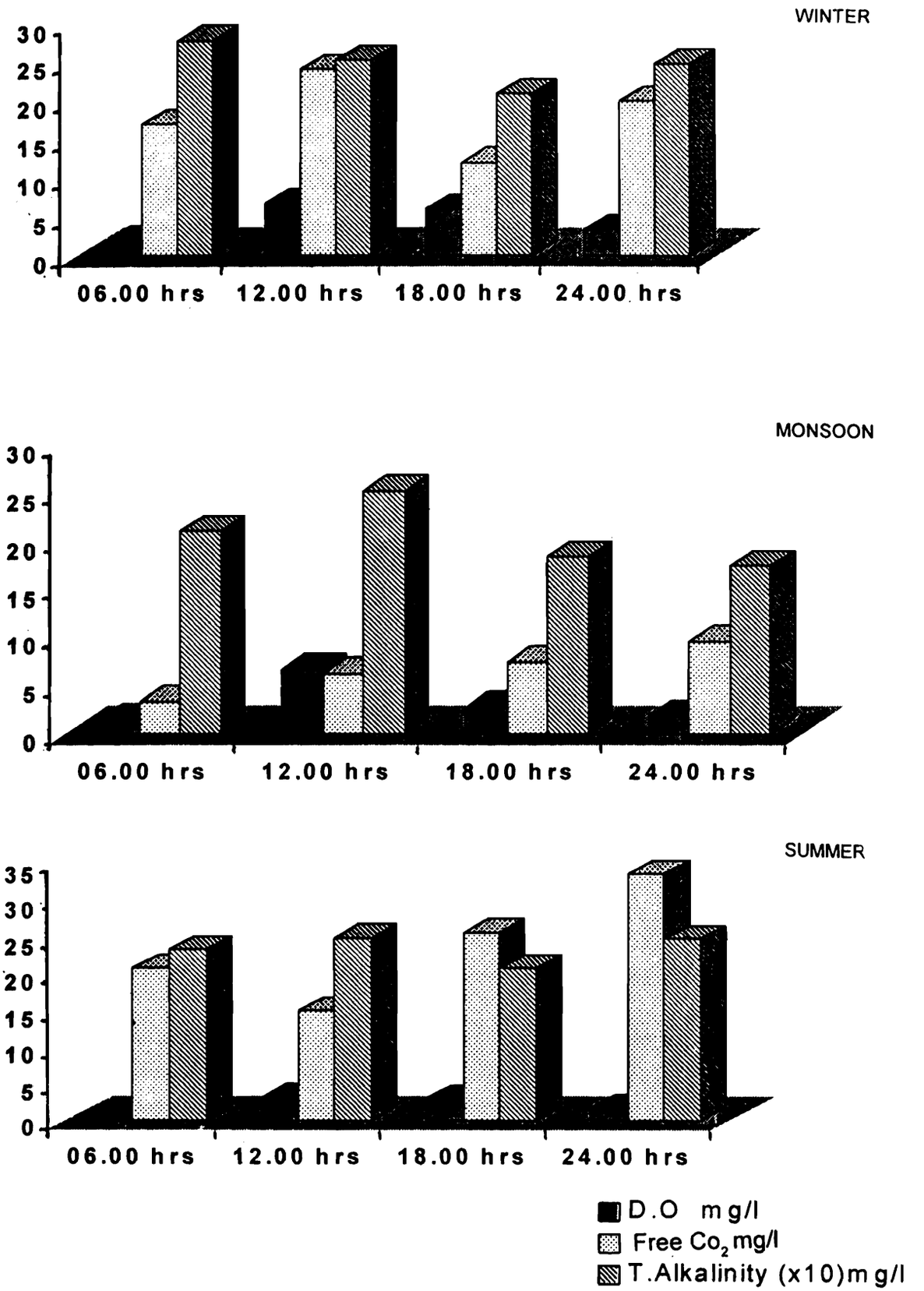


Fig. 7. Diurnal variations in dissolved oxygen, free Co_2 and total Alkalinity in subsurface waters of Hussain Sagar at Station-1.

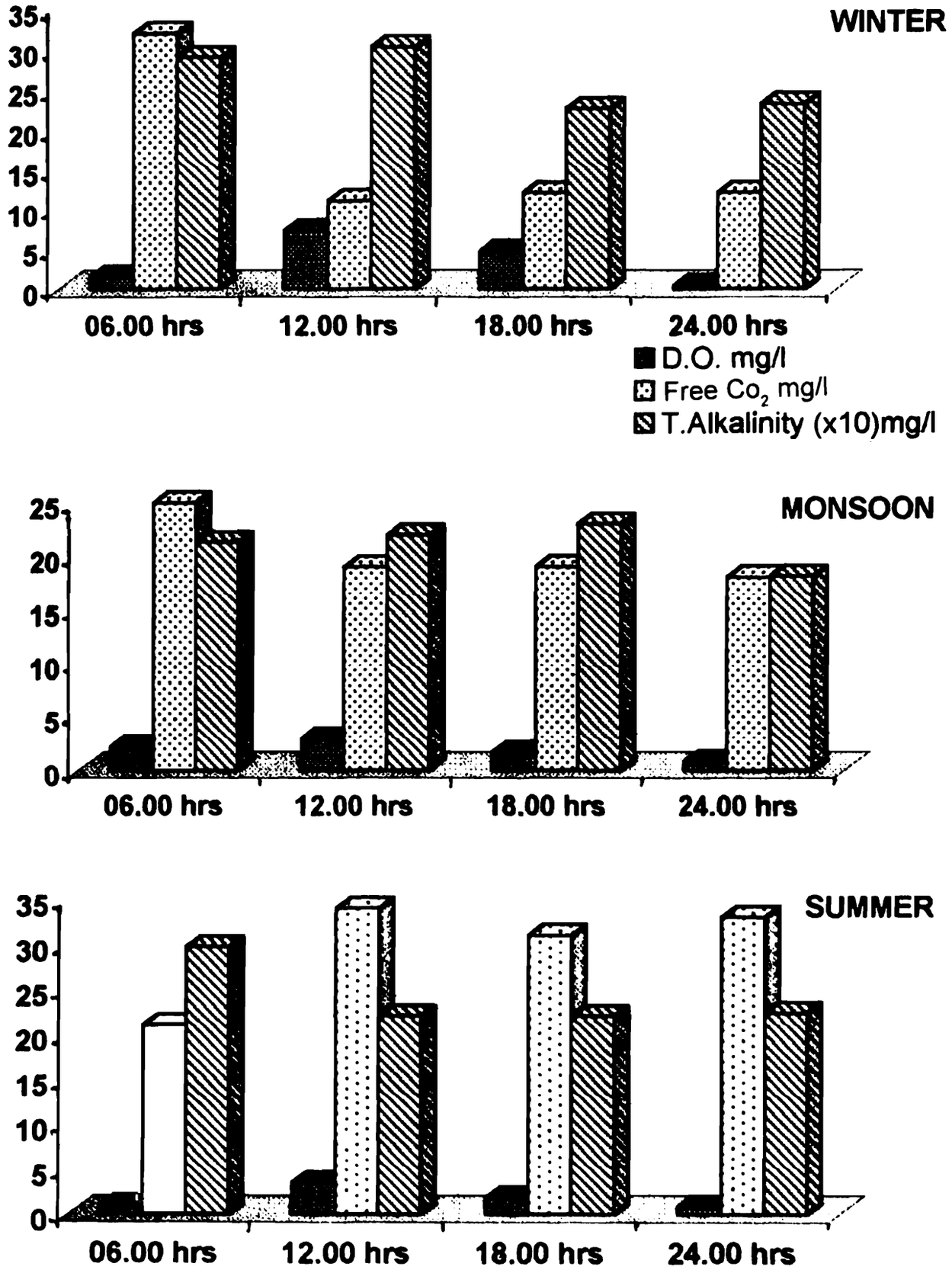


Fig. 8. Diurnal variations in dissolved oxygen, free CO_2 and total Alkalinity in subsurface waters of Hussain Sagar at Station-4.

the day and the pattern of fluctuation was again different. At Station-IV, highest values were observed in the morning (6.00 hrs) in all seasons. At Station-I, highest CO_2 contents were found at midnight (24.00 hrs). There was an inverse relationship between DO and free CO_2 at both stations. Although total alkalinity values were generally higher during the first part of the day, the overall pattern did not show much constancy. Diel fluctuations in alkalinity are usually negligible in natural waters (Cole, 1979). The increased contents around noon may be attributed to increased discharges from surrounding industries during day time.

b) Seasonal variations

The concentrations of different physico-chemical parameters exhibited pronounced seasonal variations in all lakes. However, the pattern was not clearly demarcated in some important factors like pH *etc.* The mean seasonal values of different parameters at different stations are given in Table 5. Mean values of some important factors are plotted in figs. 9a and 9b.

Water Temperature

Ambient atmospheric and surface water temperatures revealed a definite diurnal as well as seasonal pattern of fluctuations. The surface water temperature varied widely between a winter minima of 22.0 °C to a summer maxima of 32.8 °C. The highest range in the day/night temperature variation was recorded during summers (37.0/25.5 °C) and the amplitude of variations during the day (recorded around 06.00, 12.00 hrs and 16.00 hrs) was of the order of 11.5 °C. The minima in temperature variation was 1 °C, observed during south-west monsoons. In general, the average daily difference between ambient atmospheric and surface water temperature ranged between 1 - 6 °C.

pH

The pH of littoral water ranged between 7.5-8.2 and indicated the alkaline nature of the water. There was no marked seasonal or diurnal variations in pH during the period of study. Nevertheless, the pH values showed some seasonal patterns. The rise in pH during summer, and in particular during the day time, may be attributed to higher rate of photosynthesis. The pH values recorded from Station-III, the point receiving the inflow of effluents/sewage showed wide variations, pointing to poorly buffered nature of the water in this zone.

Turbidity (JTU)

Turbidity values from different stations during different seasons showed wide fluctuations. It varied between 2.0-44.0 units There appeared to be good seasonal constancy, values being low in summer and high during monsoon. Samples from Station-III recorded higher turbidity than samples from other stations, following higher *throughputs* of effluents/sewage into the lake at this point. The turbidity values showed negative correlation to transparency. Samples form Station-III were not only highly turbid but had poor visibility too. High turbidity is known to affect the primary productivity by restricting the light penetration and photosynthesis.

Table-5 Mean Seasonal values of different physio-chemical parameters at different stations in Hussain Sagar, Hyderabad
(All diurnal values combined)

STATIONS	I			II			III			IV			Seasonwise avarage		
SEASONS	Summer	Monsoon	Winter	Summer	Monsoon	Winter	Summer	Monsoon	Winter	Summer	Monsoon	Winter	Summer	Monsoon	Winter
Air Temperature °C	30.60	26.75	22.75	27.75	26.00	22.00	30.00	27.00	26.5	30.25	27.3	21.75	29.65	26.75	23.25
Water Temperature °C	27.50	27.00	23.75	27.25	26.5	23.75	27.00	27.00	23.77	21.75	27.6	21.75	27.76	27.02	23.25
pH	7.79	7.95	7.6	7.87	8.00	7.70	8.10	7.95	7.90	7.95	7.95	7.7	7.95	7.95	7.72
Transparency, %	98.25	96.00	93.00	9.15	93.25	94.00	94.60	88.26	90.00	98.05	94.00	92.00	75.01	92.87	92.25
Turbidity, JTU	10.00	16.00	25.00	15.70	93.00	20.00	17.00	158	34.00	7.00	88.00	26.50	12.42	88.75	26.75
Transparency, Zsd (m)	0.50	0.41	-	0.40	0.32		0.23	0.22		0.42	0.55	-	0.38	0.38	-
D.O.	2.20	3.05	4.42	4.25	2.70	4.90	2.65	1.67	4.77	1.77	1.90	4.55	2.71	2.33	4.46
CO_2 (mg/l)	24.00	6.55	18.00	21.70	17.75	27.00	26.20	24.75	19.75	29.70	20.25	16.70	25.40	17.35	20.36
TA (mg/l)	238.50	81.80	272.00	254.50	80.20	271.50	275.00	197.50	274.20	240.90	211.00	262.50	252.25	142.65	270.75
Chloride (mg/l)	149.20	133.20	246.70	161.00	123.50	251.70	165.00	143.70	278.50	159.50	139.70	230.50	158.65	135.02	251.85
Hardness (mg/l)	326.50	55.50	78.00	334.00	265.25	335.20	325.00	290.00	348.00	317.00	266.00	325.00	325.65	219.19	271.55

Secchi Disc Transparancy

The mean seasonal values of Secchi Disc Transparency (Zsd) during monsoon and winter seasons (0.425 and 0.396 m respectively) revealed no pronounced seasonal variations. As expected, Zsd readings at Station-III were low due to high turbidity, following inflow of effluents/sewage at this point. The relatively cleaner Stations-I and II showed higher visibility. The photic depth (pd) also revealed similar pattern. The attenuation coefficient (Ev) computed from Zsd and pd readings ranged between 1.26-2.82 m during winter seasons.

Conductivity and Total Dissolved Solids

The mean seasonal values of electrical conductivity for different sampling stations during different seasons varied widely between 1417.5-1755.0 µmhos/cm. Seasonal fluctuations were not pronounced and only marginal rise in the values were noticed during summer (1572.5-1755.0 µmhos/cm). The conductivity values were significantly higher at Station-III, the zone receiving effluents/sewage but lower at Stations I and II, located in the comparatively cleaner zone. Total dissolved solids (TDS) varied widely between 850.5-1053.0 mg/l. The values were higher during summer season. The highest TDS values were recorded from Station III.

Dissolved Oxygen and % saturation

Both diurnal and seasonal fluctuations in dissolved oxygen (DO) contents in littoral waters were very much pronounced and showed marked seasonal constancy, being higher during winter and lower during summer and monsoon seasons. The low DO concentration in these seasons may be attributed to decline in oxygen solubility with rise in water temperature. The DO profile revealed an interesting pattern. It was usually high at Stations I and II, often as high as 10.2 mg/l and invariably low to nil at Stations III and IV, the region receiving the leaked effluents and other waste-waters. Invariably, near anoxic and chemically reducing conditions prevailed in these zones and the water emitted a foul smell of sulphides. The high oxygen demanding organic discharges through leakage from corroded K-mains, were responsible for oxygen depletion and reducing chemical environment at Station III. The net samples from this site were devoid of plankton. The moderate to high DO at Stations I and II may be attributed to comparatively cleaner zones and increased photosynthetic activities by phytoplankton. The saturation values of DO ranged between 9.85-125.61% at different stations during different seasons. Conditions of *super* saturation prevailed for sometimes at Stations I and II due to abundance of phytoplankton.

Free CO_2

Free Co_2, which was present at all stations, althrough different seasons in varying amounts, revealed a pronounced seasonal pattern but the daily fluctuations were only minimal. The peak was witnessed during summer (15-34 mg/l), followed by slightly lower values during winter and

lowest during monsoon. The high free CO_2 content was invariably recorded at Stations III and IV, the highly polluted sites receiving effluent/sewage inflows.

Polluted waters are known to acquire CO_2 by biological oxidation of organic matter. Stations III and IV received high discharges of industrial effluents and sewage and their decay generated enough CO_2. Higher CO_2 values at these sites may also be due to the action of pollution acids on bicarbonates (Cole, 1979). The free CO_2 showed a negative correlation with pH, as low pH is generally associated with high free CO_2. Its inverse relationship with dissolved oxygen was also visible. High level of free CO_2 is known to be toxic to fishes and other aquatic life and therefore is an important factor. The dynamics of free CO_2 in lacustrine ecosystems appears to be biologically mediated (Wetzel, 1975).

Alkalinity

The total alkalinity values varied widely at different sampling stations. It fluctuated between a minimum of 172.5 mg/l and 335.3 mg/l or 3.79-6.70 meq/l during different seasons. The water of the reservoir was markedly alkaline, which is a characteristics of eutrophication (Phillipose, 1960). The bicarbonate and carbonate ions ranged between 231.0-408.7 mg/l and 113.0-200.8 mg/l respectively during different seasons and at different stations. The total alkalinity values in Hussain Sagar showed good seasonal constancy as well as marked diel changes. The peak was observed during winter, followed by summer. The bicarbonate ions also showed similar trend. Higher bicarbonate values were recorded althrough winter and summer, with a decline during monsoons. The carbonate ions too showed similar seasonal pattern and exhibited negative correlation with bicarbonate at all times and sites. Cynthia (1989) and Prasad *et al.* (1985) have reported similar observations.

The horizontal variations in the alkalinity and its forms are interesting too. Higher values were recorded from Stations III and IV, which were located in zones receiving industrial effluents/ sewage, through the corroded K-mains leakage. Highest values were recorded from Staion-III (353.3 mg/l carbonate and 408.7 mg/l bicarbonate alkalinities) during winter season. Some other workers (Goel *et al.* 1980) have also reported higher alkalinity values from polluted sites. The high bicarbonate content also probably emanates from high level of metabolic activities, typical of a highly eutrophic and sewage polluted water body.

Hardness

The range of total EDTA hardness values during different seasons indicated the hard nature of the reservoir water. In general, the total hardness values exceeded the sum total of bicarbonate and carbonate alkalinities, which indicated the presence of other hardness causing ions (non-carbonates) in significant amounts. Hardness values varied widely between a minimum of 241.0 mg/l to a maximum of 380.0 mg/l during different seasons. The non-carbonate hardness component computed ranged between 21.0-44.5 mg/l. Some seasonal constancy was observed in the hardness values, higher during summer and lower during monsoons. No diurnal pattern of variations was

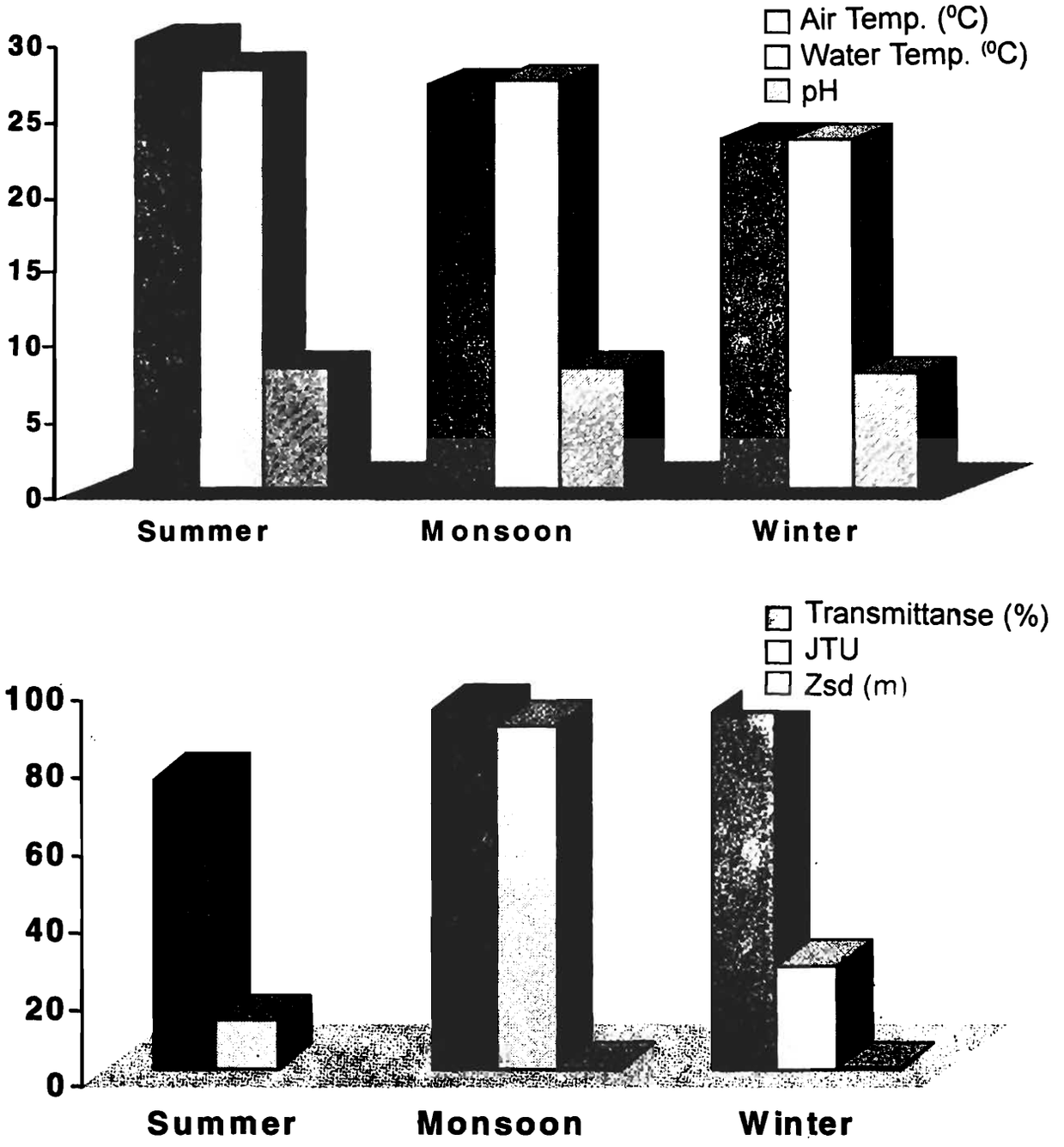


Fig. 9a. Seasonal variations in some physicochemical parameters in subsurface waters of Hussain Sagar (all diurnal and spatial values combinned) -Station

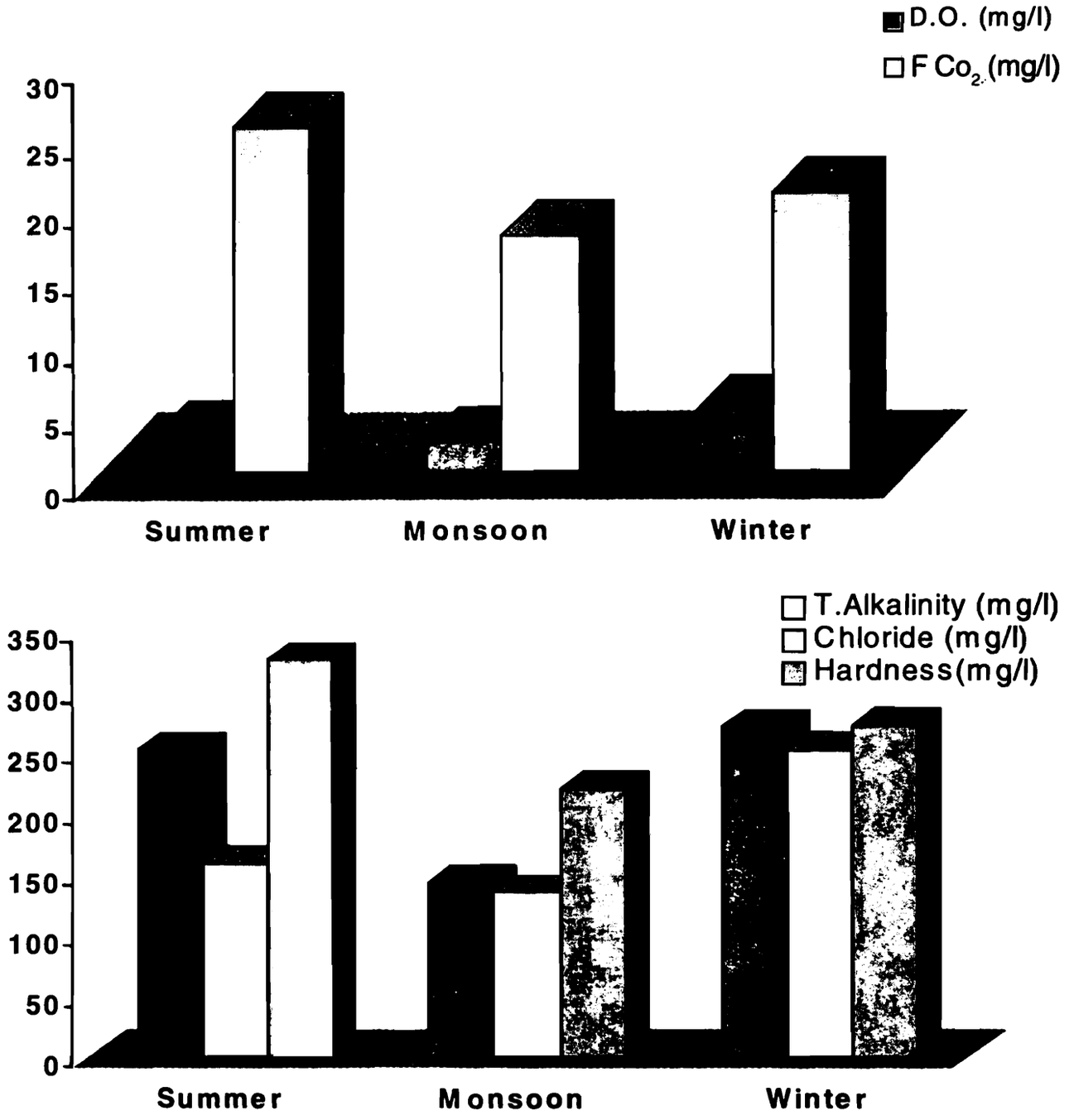


Fig. 9b. Seasonal variations in some physicochemical parameters in subsurface waters of Hussain Sagar (all diurnal and spatial values combinned) -Station

observed, however, a clear spatial variation was noticed. The hardness values were significantly higher at Stations III and IV than at Stations I and II, due to highly polluted nature of the inflow of effluents/sewage at these points.

Cations

Chemical data on the major cations - calcium and magnesium, could not be gathered for all the seasons. It was estimated during monsoon and winter seasons and is therefore patchy. Nonetheless, the data corroborated alkalinity findings. The calcium content ranged between 80.80-84.00 mg/l, or 4.03-4.19 meq/l and magnesium between 13.12-17.98 mg/l or 1.08-1.48 meq/l. Interastingly, considerably lower values were reported by Zafar (1975) in Hussain sagar ranging between 10.0-40.0 mg/l. The near four fold rise in the calcium content is definitely indicative of rapidly increasing level of eutophication of the reservoir. Munawar (1970) , Goel *et al.* (1980) and Prasad *et al.* (1985) also reported similar alarming rise in cataions in polluted waters. The rise in magnesium contents (*ca* 22.36-37.14% of calcium ion) is also indicative of rising level of pollution, as this is relatively a conservative element with extremely limited biological demand.

Chlorides

The chloride content at different stations ranged from 118.0-325.0 mg/l and showed clear seasonal constancy. Higher chloride values were observed during summer and lower during monsoon. Similar observations on the behavior of chlorides have been reported by several workers (Gonzalves and Joshi, 1946; Zafar, 1966 and Rao, 1971 & 1972). The peak in chloride values may be related to evotranspiration and high evaporation during hot season (Zafar, 1975). There was a marked spatial variation in the chloride concentrations, as values were considerably higher at Stations III and IV as compared to Stations I and II. The higher values at Stations III and IV were due to inflow of sewage and industrial effluents to these zones of the reservoir. The relatively low values at Stations I and II indicated lesser contamination.

Interestingly, Husain sagar has been the focus of extensive limnological studies for nearly three and a half decades (Zafar, 1966; Babu Rao *et al.*, 1981; Siddiqi and Rama Rao, 1991; Pandey, Siddiqi and Rama Rao, 1993; Siddiqi and Rama Rao, 1996). Therefore an analyses of chloride content, a relatively conservative anion and its accumulation over the decades reveals an interesting picture (Table 6a). The comparison has been made using studies by Srinivasan *et al.* (1965) as base. The values recorded by Zafar (1975) and observation made during present investigations (1990, the first year of the Study) were compared. The rate of accumulation of chloride ion for 10-year period between 1965-75 worked out to be 71.50 mg/l or 7.15 mg/l/year. When compared with present study, a gap of more than 25 years, the increase was found to be 129.63 mg/l or 5.19 mg/l/year. This shows constantly increasing trend of chlorides in Hussain sagar. The chloride contents further imply the presence of organic matter of animal origin and attendant rise in ammonia and nitrogen (Thresh, Suckling and Beadle, 1949). Ahsan (1982) reported rise in the value of ammonia due to industrial/domestic discharges. According to Zafar

Table 6a. Pattern in the increase of chloride and total dissolved soliids in Hussain sagar over a period of time taking Srinivasn *et al.* (1965) as base.

Factors	Srinivasan *et al.* (1965)	Zafar (1975)	Present Study (1990)
Approximate Time Lag (year)	–	10.00	25.00
Chloride contents (mg/l)	53.50	125.00	183.13
Accumulation of Chlorides (mg/l)	–	71.50	129.63
Rate of accumulation per year (mg/l)	–	7.15	5.19
Total Dissolves solids (mg/l)	373.33	950.00	983.62
Accumulation of TDS (mg/l)	–	576.67	610.29
Rate of accumulation per years (mg/l)	–	57.66	24.44

Table 6b. Pattern in the increase of chloride in Osman Sagar and Mir Alam Tank over a period of time taking Srinivasn et al (1965) as base.

Factors	Srinivasan et al (1965)	Zafar (1975)	Present Study (1990)
Approximate Time Lag (year)	–	15	25
Osman Sagar			
Chloride Contents (mg/l)	17.75	29.91	25.02
Accumulatiion of Chlorides (mg/l)	–	21.16	7.27
Rate of accumulation per year (mg/l)	–	0.85	0.29
Mir Alam tank			
Chloride contents (mg/l)	30.92	51.39	52.00
Accumulatiion of chlorides (mg/l)	–	20.47	21.07
Rate of accumulation per year (mg/l)	–	1.36	0.84

(1975), Hussain sagar is fast approaching 'Sulphato-chloride condition' (Hutchinson, 1957), where sulphates and chlorides dominate over carbonates and bicarbonates. Although hydrogen sulphide was not estimated, water samples at Station III appeared to be rich in sulphides as these emitted characteristic rotten egg pungent odour of hydrogen sulphide The water samples resembled dilute India Ink suspension because of the presence of ferrous sulphide (Cole, 1979). Goel *et al.* (1980) reported high sulphide contents from some polluted sites. Prahalad *et al.* (1985) recorded high hydrogen sulphide contents from Hussain sagar (90.52-1105.00 mg/l). The occurrence of hydrogen sulphide at Station III probably resulted from the decomposition of organic matter and reducing anaerobic conditions. As already indicated, the surface water samples from this station were characterized by greatly reduced dissolved oxygen contents. Similarly, an analyses of total dissolved solids pattern also revealed similar increasing trend. The analyses of the TDS contents over the period of time since 1965 (Srinivasan 1965) showed an alarming rise (Table 6). It rose by 610 mg/l lit during last 25 years, amounting to yearly rate of increase of 24.44 mg/l. The approximately two-fold increase may be attributed to indiscriminate discharge of industrial effluents as well as domestic sewage into the lake.

In conclusion, it can be said that the lake water was distinctly alkaline, hard to very hard, with low transparency, high turbidity, high bicarbonate, epilimnetic oxygen, super saturation and hypolimnetic oxygen deficiency, alarming chloride concentration and abundance of hydrogen sulphides. All indicative of chemical enrichment and consequent eutrophication of the lake.

2. Osman Sagar

The average seasonal physicochemical values for the three years (1990-92) in littoral surface water are furnished in Table 7 and patterns depicted in Fig 10.

Temperature

The range of ambient atmospheric temperature and water temperature observed was 22.00-33.35 °C and 24.00-32.37 °C respectively. Peaks in both ambient and water temperature were recorded during summer, closely followed by monsoons and lowest temperature was noted in winter.

Transparency, Conductivity and Total dissolved solids

The Secchi disc transparency (*Zsd* m) values were a little patchy but nevertheless revealed a clear seasonal pattern - low transparency (0.54 m) and photic depth (1.3 m) during rainy season and marginally higher values (*Zsd* 0.59 m and Pd 1.47 m) during summers/winters. The conductivity values, in littoral surface water, varied between 405 μmhos/ cm^{-1} and 530 μmhos/ cm^{-1}, and correspond well to the observed seasonal trends, showing marginal rise during monsoon over other seasons. The corresponding TDS values ranged between 202.50 mg/l and 265.00 mg/l. In an earlier study (Srinivasan, *et al.*, 1965) , the TDS values were found to fluctuate between 200.00 and 327.00 mg/l This shows an insignificant rise in TDS content of Osman sagar during the intervening period, indicating no appreciable deterioration in raw water quality of the reservior.

Table 7. Mean seasonal values of different physicco-chemical parameters in Osman sagar during 1990-92

YEAR	1990			1991			1992		
SEASONS	Winter	Summer	Monsoon	Winter	Summer	Monsoon	Winter	Summer	Monsoon
Air Temperature °C	26.00	32.00	29.75	22.00	31.00	27.00	23.00	33.35	26.50
Water Temperature °C	28.00	30.00	27.62	24.00	28.00	27.50	24.00	32.37	25.50
pH	7.60	7.80	7.70	7.80	7.90	8.10	8.10	8.20	8.20
Transparancy (m)	-	-	-	-	-	-	0.56	0.59	0.54
pd (m)	-	-	-	-	-	-	1.40	1.47	1.47
Condtivity (μmhos/cm²)	-	-	-	-	-	-	405.00	421.87	530.00
TDS (mg/l)	-	-	-	-			202.50	210.93	265.00
D.O (mg/l)	3.80	7.00	6.40	6.65	5.80	8.45	11.10	7.60	4.90
% Cs	48.46	92.47	82.56	79.16	73.97	107.78	132.15	100.39	60.34
CO_2 (mg/l)	7.5	3.41	4.25	12.25	0	0	0	0	0
T.Alkalinity (mg/l)	168.23	145.25	155.03	160.15	149.00	136.16	165.00	144.00	126.00
T.Alkalinity (meq/l)	3.36	2.90	3.10	3.20	2.98	2.72	3.30	2.88	2.52
Bicarbonate (mg/l)	203.55	175.75	187.58	193.78	181.63	163.79	198.00	175.53	104.00
Carbonate (mg/l)	100.76	87.00	92.86	95.920	89.25	68.08	82.50	86.25	75.50
Chloride (mg/l)	23.00	26.00	21.00	27.50	31.00	30.00	22.70	24.00	20.00
Hardness (mg/l)	123.00	-	127.00	128.50	125.00	129.00	127.00	123.00	122.12

pH

The pH values in littoral surface water varied between 7.6 to 8.3. The values were lower initially during the first year (7.6-7.8) but increased slightly during the second and third year. The higher pH may be attributed to increased photosynthetic activity following algal bloom during this period. No marked seosonality was observed.

Dissolve Oxygen and % Saturation

The dissolved oxygen content in littoral surface water ranged between 3.8 and 11.1 mg/l with corresponding % saturation values of 38.46 - 132.14 %. The DO values showed no seasonal constancy. Save during winter of 1990 (very low value) and summer of 1992 (very high value), the DO content of Osman sagar was always moderate Table 7, Fig. 10a), which may be related to increased solubility at lower temperatures during winter and increased photosynthetic activities, resulting from phytoplankton bloom, during summer.

Free Carbon-di-oxide

It was only occasionally recorded and was generally present at lower pH. It almost showed no fixed seasonal pattern. An inverse relationship of carbon-di-oxide with dissolved oxygen was observed (Fig. 10a).

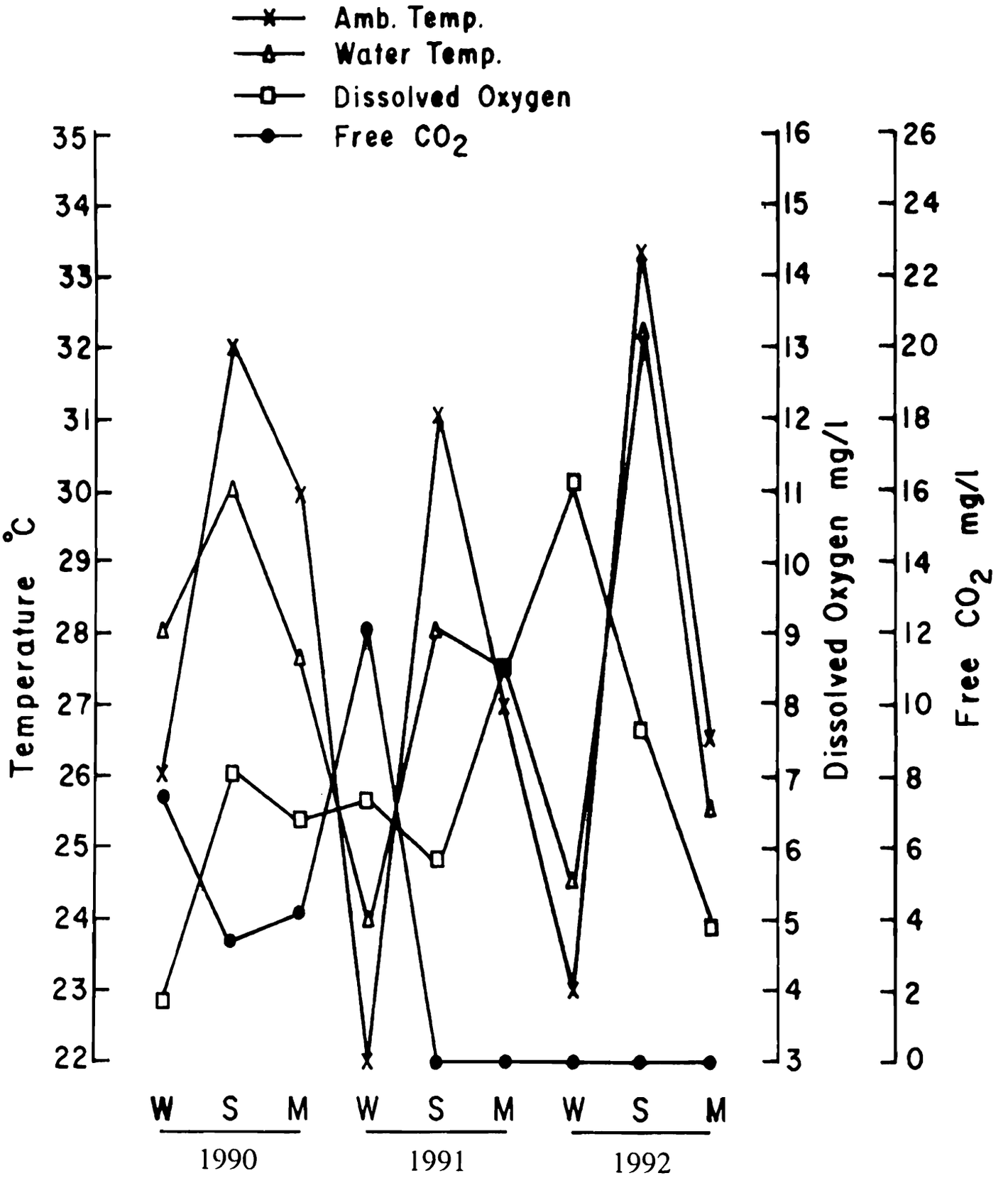
Alkalinity

The total alkalinity values varied between 126.00 - 168.23 $CaCO_3$ mg/l or 2.52-3.36 meq/l. The bicarbonate and carbonate ions varied between 104.00 - 203.55 mg/l and 68.08 - 95.92 mg/l respectively. The water was therefore distinctly alkaline (Phillipose, 1960). The relatively higher alkalinity in the reservoir indicated enrichment. The total alkalinity showed no synchronous relation to pH but nevertheless exhibited some seasonality. While higher values of total alkalinity were recorded during summer, bicarbonates were higher during winter with a gradual decline during monsoon. Similar observations were reported by several earlier workers (Munawar, 1970a, 1970b; Rao, 1972; Prasad, *et al.*, 1985). The range of inorganic carbon values varied between 30.24 - 42.05 mg/l which further corroborates the higher nutritional level.

Chloride

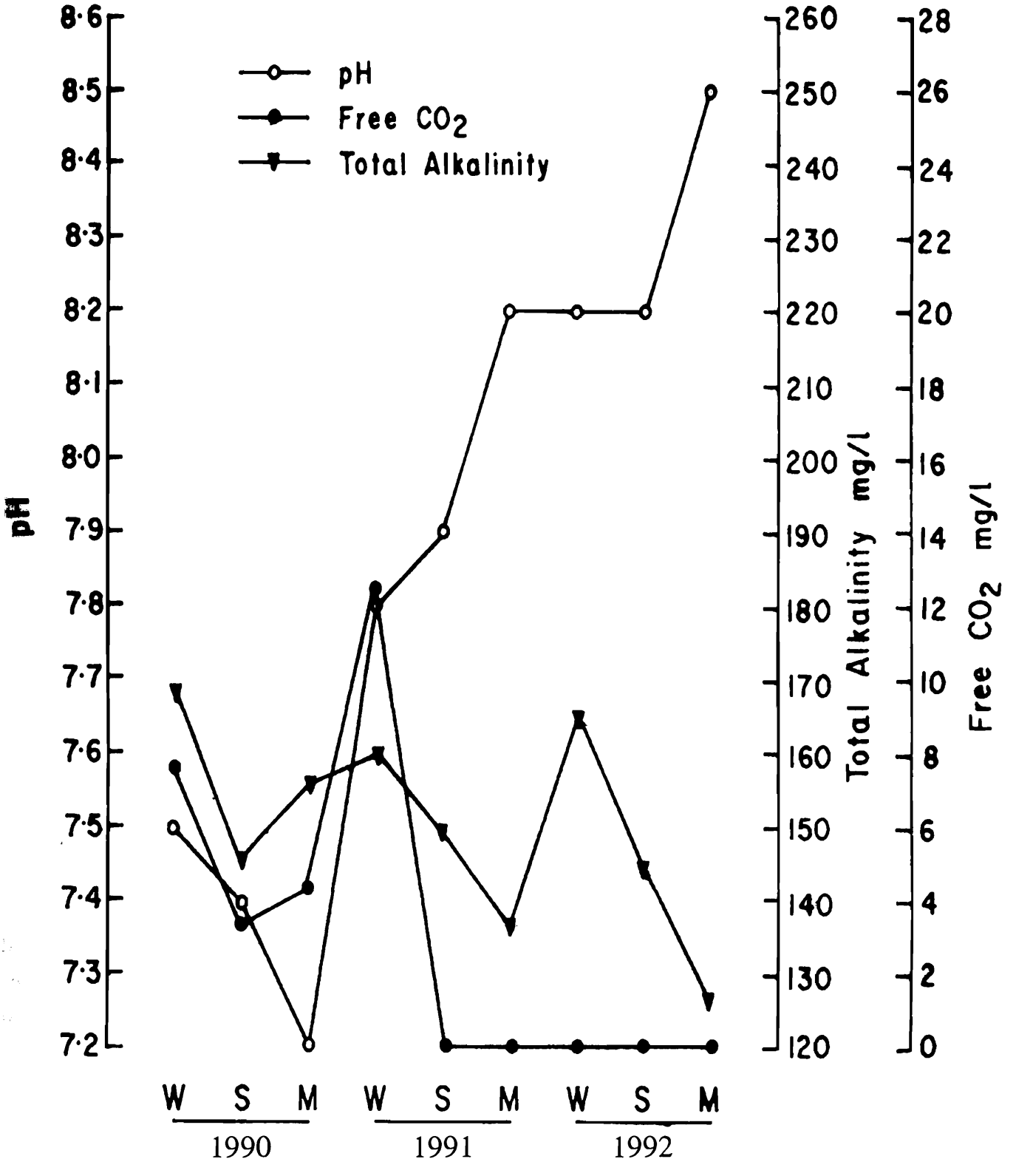
The chlorides in surface water ranged between 20.00 - 31.00 mg/l (0.56-0.87 meq/l). The maxima (31.00 mg/l) were recorded during summer and may be attributed to increased rates of evaporation during hot season. Zafar (1964a) and Rao (1971, 1972) reported similar seasonality in the behavior of chlorides. The range of chloride values observed is in agreement with the earlier reports (Srinivasan *et al.* 1965; Satya Mohan, 1981), save for natural marginal rise in the values over a period of time.

The rate of accumulation of chloride ion in Osman sagar over last several decades was computed taking into consideration the values reported by Srinivasan *et al.* (1965) as base. The water of the reservoir recorded a marginal rise during the intervening period of 25 years



Correlation betweenn Ambient temp./Water temp., Dissolved Oxygen and Free CO_2

Fig. 10a. Seasonnnal variations in some physicochemical parameters of water quality - ambient temperature, water temperature, dissolved oxygen and free CO_2 in Osman sagar, Hyderabad.



Correlation betweenn Free CO_2, pH and Total Alkalinity

Fig. 10b. Seasonal variations in some physicochemical parameters of water quality - pH, free CO_2, alkalinity in Osman sagar, Hyderabad.

(Table 6b). The rise in chloride content was not alarming and indicated little degradation of the water quality as far as chlorides were concerned. Similarly, the rate of accumulation of bicarbonates and carbonates (Table 11) was also found to be comparatively low. This worked out to be 70.15 mg/l in approximately 25 years, corresponding to 3.12 mg/l y^{r-1}

Total Hardness

The values of total hardness in littoral surface water varied narrowly between 122.12 and 129.00 $CaCO_3$ mg/l and 2.43-2.56 meq/l respectively. No seasonal pattern was visible. The total hardness of the reservoir was not alarming and indicated no degradation of water quality.

Cations

The values of calcium and magnesium ions were recorded only at few occasions. The values observed were 33.6 mg/l (1.67 meq/l) for Calcium and 2.18 mg/l (0.17 meq/l) for magnesium. The values recorded were well within the permissible range of raw water. However, the values, especially of magnesium, were substantially lower than those reported by Satya Mohan (1981).

It was inferred in general that the reservoir water was alkaline, bicarbonate rich, hard and mesotrophic.

3. Himayat Sagar

Table 9 and Fig 11 a and b provide the average seasonal physico-chemical values in littoral surface waters in Himayat sagar.

Temperature

The mean surface water temperature ranged between 25.0 - 30.0 °C, while the ambient atmospheric temperature varied widely between 24.0 - 33.0 °C. In general, on a seasonal/annual basis, the difference in surface water and ambient atmospheric temperature was 2-3 °C. The highest ambient atmospheric temperature (33.0 °C) was recorded during summer when the mean surface water temperature also recorded an all time high (30.0 °C). The minima in both temperatures were recorded during winters. The two temperature profiles, therefore, reveal clear seasonal constancy.

Transparency

The mean seasonal values for visibility, during the summer and winter in 1990 were 0.59 and 0.69 m. respectively and marginally lower during the southwest monsoon (0.4 m). The seasonal differences are not the least pronounced and may be attributed to failure of regular seasonal rains in the State. The photic depth (Pd) or the euphotic zone values for the reservoir waters ranged between 1.48 1.72 m during different seasons. The corresponding values of attenuation coefficient (Ev) varied between 2.76 3.05.

Conductivity

The average electrical conductivity values during different seasons ranged between 514.2 - 532.2 μmhos cm^{-1} and exhibited no seasonal pattern (following failure of monsoons). The total dissolved solids (TDS), estimated from values of conductivity for littoral waters, ranged between 256.5 - 273.0 mg/l and corroborate the values (250.0 - 445.0 mg/l) reported by Srinivasan *et al.* (1965). The annual mean, on analyses, worked out to 314.5 mg/l. The relatively lower range of TDS values observed, stems primarily to differences in sampling sites and methodology of estimation.

pH

The range of pH values fluctuated narrowly between 7.5 - 8.2 indicating the general alkaline nature of the water. Slightly higher pH values were generally recorded during winter but no marked seasonal pattern was evident.

Dissolved Oxygen and % Cs

The dissolved oxygen content values for littoral surface waters ranged between 4.9 - 8.9 mg/l. The corresponding values for percentage saturation of dissolved oxygen (% Cs) ranged between 59.32 to 107.74% during different seasons.

The DO values obtained showed no obvious correlation to any particular season and therefore, the graphs too revealed little seasonal pattern. A moderate level of supersaturation prevailed and the surface waters invariably were observed to have 50% Cs throughout the period of study. The observed range of values agrees well with previous studies (Srinivasan *et al.* 1965) and indicates no deterioration in the biological or aesthetic water quality of the reservoir over the decades. Ananda Rao (1982) recorded near similar values of DO (7.0 mg/l) from the reservoir.

Free CO_2

It was only recorded in littoral surface waters during first year of study, despite low pH.

Alkalinity

The total alkalinity values for surface waters in the littoral region varied between a minima of 152.0 mg/l to a maxima of 186.66 mg/l (or 2.34 - 3.72 $CaCO_3$ meq/l), indicating alkaline nature of the water (Phillipose, 1960). Comparatively higher values were recorded during winters. The computed mean seasonal values of bicarbonates (HCO_3) and carbonates (CO_3) ranged between 170.4 - 228.0 HCO_3 mg/l and 90.0-111.41 CO_3 mg/l during the period of study. Comparatively higher values were observed in winters. The bicarbonate and carbonate values fail to reveal any positive correlation to pH. The range of bicarbonate ions/fractions in the reservoir water does not indicate any adverse eutrophication trends and or contamination of reservoir water.

Table 8. Mean Seasonal values of different physico-chemical parameters in Himayat sagar, during 1991-1992.

YEAR	1990			1991			1992		
SEASONS	Winter	Summer	Monsoon	Winter	Summer	Monsoon	Winter	Summer	Monsoon
Air Temperature °C	28.00	31.82	28.92	24.00	33.00	27.00	28.50	32.25	25.00
Water Temperature °C	26.50	30.00	26.72	25.00	30.00	29.00	25.00	29.75	24.00
pH	7.80	7.70	7.50	7.90	7.90	7.9.00	80	7.90	8.00
Conductivity (μmhos/cm²)	-	-	-	-		-		514.50	523.50
TDS (mg/l)	-	-	-	-	-	-	-	257.00	266.25
D.O (mg/l)	4.90	6.50	6.20	6.70	7.9	5.60	8.90	7.30	6.90
% Cs	59.32	46.86	76.35	79.70	104.35	72.72	107.40	94.80	81.94
CO_2 (mg/l)	3.20	2.90	4.75	0	0	0	0	0	0
Total Alkalinity (mg/l)	180.00	180.00	160.00	186.66	172.00	152.00	180.00	163.50	172.00
Total Alkalinity(meq/l)	3,56	3.60	3.20	3,72	3,44	2,84	3,61	3,27	3.44
Bicarbonate (mg/l)	216.98	219.42	195.04	226.73	208.12	170.40	216.00	196.20	206.40
Carbonate (mg/l)	108.62	107.82	95.84	111.41	101.48	71.00	90.00	81.75	86.00
Chloride (mg/l)	27.00	29.50	29.00	28.00	31.00	29.50	26.00	32.00	28.50
Hardness (mg/l)	132.00	140.50	115.00	122.00	119.00	121.00	136.00	136.00	131.00

Total Hardness

The total hardness values during different seasons ranged between a minima of 115.00 to a maxima of 136.00 $CaCO_3$ mg/l or 2.28 - 2.70 $CaCO_3$ meq/l. The mean seasonal values recorded are in agreement with values reported by Ananda Rao. (1982) .The peaks were noticed in summers. The range of hardness values recorded were invariably lesser than the sum of bicarbonate and carbonate alkalinities, indicating presence of other ions and therefore all excess hardness can be termed as carbonate hardness. The lake waters may be classified as moderately hard to hard and indicate no physicochemical deterioration.

Cations

The values of major cations, *viz.* Ca and Mg were computed indirectly from calcium and magnesium hardness, occasionally, and ranged between 20.8 - 27.3 Ca mg/l and 14.25 - 21.56 Mg mg/l during the monsoons of 1992. Similar range of values of calcium (16-36.0 Ca mg/l) and magnesium ions (8 - 24.0 Mg mg/l) have been recorded from Upper Lake, Bhopal (Aboo & Manuel, 1967).

Chloride

The chloride concentration varied between 27.0 - 32.0 mg/l or 0.76 - 0.87 meq/l during different seasons. Save for minor variations, the chloride content is in agreement with the values reported by Ananda Rao (1982). Significantly lower chloride values in the reservoir are probably due to its distant location and natural elevation, which give protection from inflows of domestic wastes and cattle wading. Despite significant time lag, the range of chloride values observed during present study are not at much variance with the values reported by (Srinivasan *et al.* (1965), which varied between 14.0 and 29.0 mg/l with a mean of 22.5 mg/l for the year 1964.

4. Mir Alam Tank

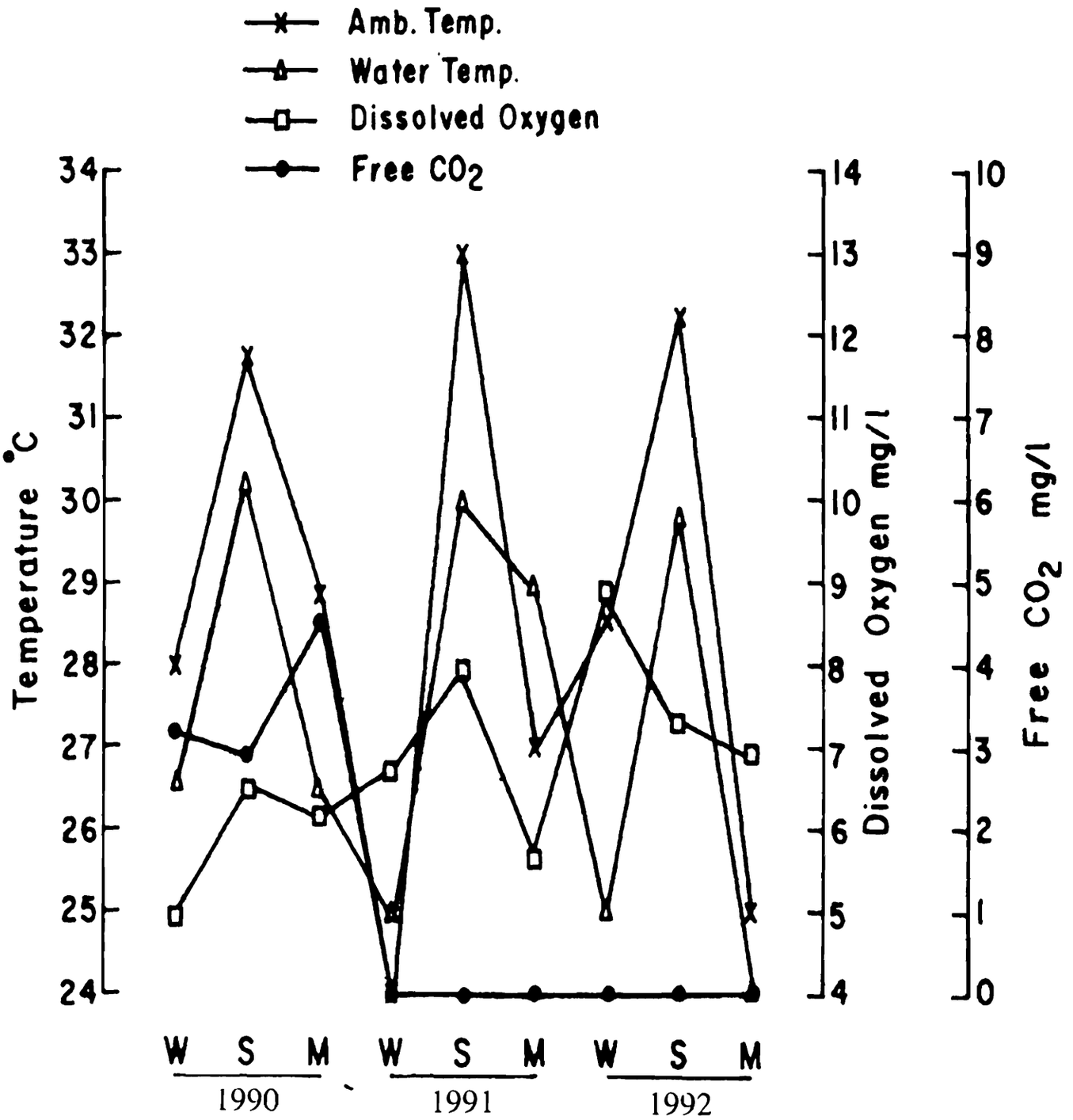
The mean seasonal values of various physico-chemical parameters of water quality in Mir Alam tank are shown in Table 9 and Figs. 12 a and b.

Temperature

The mean seasonal ambient atmqspheric temperature ranged between a low of 25.0 °C to a high of 33.5 °C and the sub-surface water temperature ranged between 23.5 °C - 32.0 °C. Like other reservoirs, the two temperature profiles in Mir Alam tank also followed each other closely and showed clear seasonal constancy. The corresponding minima were recorded during winters and maxima in summers.

Turbidity

The turbidity values observed during 1991 ranged between 26.0-31.0 JTU and were only marginally higher during the monsoon. Since the rains were grossly insufficient, there was not much marked difference from the summer values.



Correlation betweenn Ambient temp./Water temp., Dissolved Oxygen and Free CO_2

Fig. 11a. Showing correlation between different physiochemical complexes (a&b) during seasons in surface waters in Himayat sagar, Hyderabad.

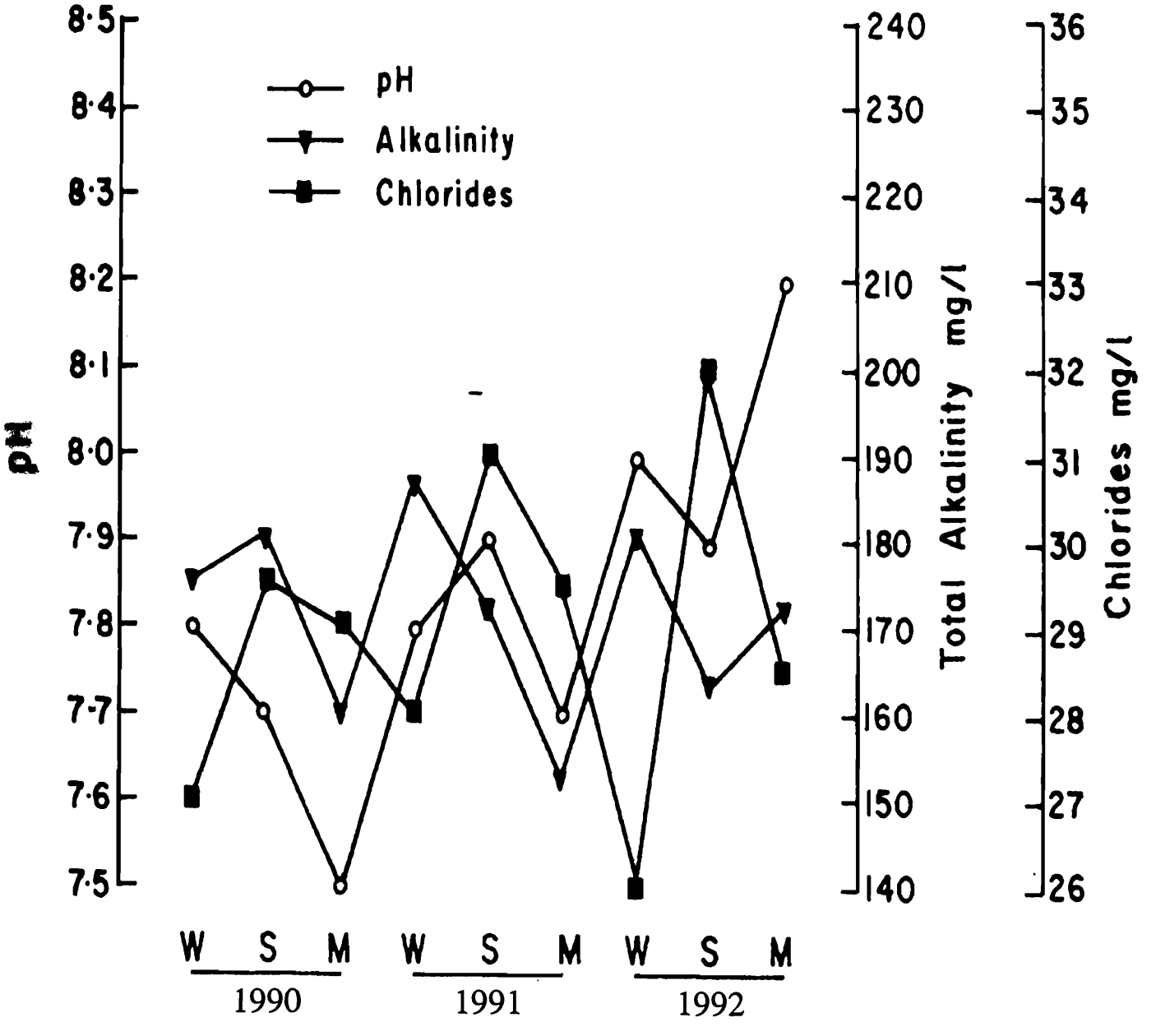


Fig. 11b. Line-graphs showing range of physicochemical values during different seasons and correlation between these (a&b) in surface waters in Mir Alam Tank, Hyderabad.

pH

The pH in littoral surface waters of this tank was always high and ranged between 8-2 -8.6. It was slightly lower in winter as compared to other seasons. The high pH may be due to increased bicarbonates.

Dissolved Oxygen and Saturations

The dissolved oxygen concentration in surface water varied between 5.1-7.8 mg/l with the corresponding percentage of saturation values as 66.23-101.29% Cs. The DO values showed no marked seasonal constancy as the peaks were recorded during the monsoon of first year and winters of the subsequent year of study. The high values during winter may be attributed to increased photosynthetic activities resulting from phytoplankton bloom (Goel *et al.*, 1980). Apparently the rise in surface water temperature did not markedly affect the oxygen solubility. The station-wise average value of DO and % saturation reported by Satya Mohan (1981) also ranged between 4.61-6.68 mg/l and 62.06-90.95 % respectively. However, Srinivasan *et al.* (1975) reported higher DO values ranging between 5.7 - 9.0 mg/l.

Free CO_2

It was absent in the littoral surface waters althrough the course of study, as the pH was always above 8.0. The absence of free CO_2 may be attributed to the presence of algal bloom, (Goel *et al.*, 1980). An inverse relationship between free CO_2 and dissolved oxygen content in the reservoir was visible.

Alkalinity

The range of total alkalinity varied between 224.0-261.0 $CaCO_3$ mg/l and was considerably higher than the corresponding values observed in Himayat sagar and Osman sagar. The corresponding total alkalinity values in terms of meq ranged between 4.48-5.22 $CaCO_3$ meq/l. The surface water was therefore alkaline and rich in carbonates.

In general, total alkalinity values showed some seasonal pattern and were higher during summer and winter and lower during monsoon. The maxima were also observed in summer by earlier workers (Zafar, 1966; Prasad, *et al.*, 1995). Higher alkalinity values were associated with higher pH and higher carbonates as stated earlier. The total alkalinity values were higher than total hardness, which indicated presence of appreciable quantities of sodium and potassium carbonates (Aboo and Manuel, 1967). Further higher alkalinity values indicated nutrient enrichment of this tank due to pollution. Polluted waters are known to have higher values of total alkalinity (Phillipose, 1960; Prasad *et al.*, 1985).

Table 10 provides a comparative synoptic view of relative rates of accumulation or enrichment of bicarbonates and carbonates as also yearly rise in the carbonic species in Osman sagar and Mir Alam tank over the last 25 years. Clearly, Mir Alam tank has accumulated higher amount

Table 9. Mean seasonal values of different physico-chemical parameters in Mir Alam tank.

YEAR	1991			1992		
SEASONS	Winter	Summer	Monsoon	Winter	Summer	Monsoon
Air Temperature °C	25.00	30.00	29.00	24.50	33.60	25.00
Water Temperature °C	24.00	29.00	28.00	23.50	32.00	24.00
pH	8.20	8.40	8.50	8.20	8.50	8.60
Turbidity(JTU)	26.00	30.00	31.00	-	-	-
D.O(mg/l)	5.20	5.10	7.80	7.60	7.00	6.40
% Cs	65.24	66.23	101.29	90.47	92.47	76.19
Free CO_2 (mg/l)	0	0	0	0	0	0
T.Alkalinity (mg/l)	227.00	235.42	224.00	241.04	261.00	230.00
T.Alkalinity (meq/l)	4.54	4.70	4.48	4.82	5.22	5.05
Bicarbonate (mg/l)	272.40	282.64	268.80	291.65	313.20	302.50
Carbonate (mg/l)	113.50	141.01	112.00	144.38	156.33	149.75
Chloride (mg/l)	46.00	51.00	50.00	54.00	58.00	53.00
Hardness (mg/l)	157.00	168.71	175.33	155.00	160.51	180

Table 10. Pattern in the increase of carbonate and bicarbonates in Osman sagar and Mir Alam Tank over a period of time taking Srinivasn *et al.* (1965) as base

Factors	Srinivasan *et al.* (1965)	Satya Mohan (1980)	Present Study (1990)
Approximate Time Lag (year)	–	15	25
Osman Sagar			
Carbonate and bicarbonate contents (mg/l)	1188.83	204.38	258.98
Accumulatiion of Chlorides (mg/l)	–	15.53	70.15
Rate of accumulation per year (mg/l)	–	1.03	2.81
Mir Alam tank			
Chloride contents (mg/l)	325.00	315.72	403.45
Accumulatiion of chlorides (mg/l)	–	9.28	77.55
Rate of accumulation per year (mg/l)	–	0.62	3.12

of bicarbonates and carbonates than Osman sagar. In Mir Alam tank, the relative rates of accumulation, works out to be 9.28 mg/l in 15 years (Satya Mohan, 1981) and 77.55 mg/l in 25 years (Present Study). The corresponding rise per year worked out to - 0.62 and 3.12 mg/l respectively. The values obtained during present investigations indicate a Significant temporal enrichment of the ions in the reservoirs due to external loading.

Total hardness

The total hardness ranged between 157.00-180.00 mg/l or 3.13-3.59 $CaCO_3$ meq/l. No marked seasonal constancy was observed. Higher values were recorded during monsoon (175.33- 180.00 mg/l). which was due to the failure of monsoon. The reservoir water was therefore hard to very hard. All hardness in the present case may be termed as carbonate hardness. The total hardness values in Mir Alam tank were substantially higher than those observed in Osman sagar and Himayat sagar over comparable period and may be attributed to relatively higher rate of chemical enrichment of Mir Alam tank from anthropogenic sources.

Chloride

The mean seasonal values of chloride ions observed in littoral surface water varied between 46.0-58.0 mg/l and showed some seasonal periodicity. The maxima were recorded during summers and minima in winters. Gonzalves and Joshi (1946), Goel *et al.* (1980) and Prasad *et al.,* (1985) also reported similar summer maxima in other tropical water-bodies. The higher values during warmer months may be attributed to high rate of evaporation, *etc.* Srinivasan *et al.* (1965) recorded a wide range of chloride values (17.0-40.0 mg/l) in lakes/reservoirs of this region. The range of value for different stations recorded by Satya Mohan (1981) from this tank was between 49.87-50.77 mg/l (mean 50.88 mg/l).

On a comparable scale, Mir Alam tank water showed relatively higher chloride content than in Himayat sagar and Osman sagar. The near two-fold rise in chloride values during 25 years may be attributed to domestic wastes and sewage run-off into the tank. The past average of chloride contents and relative rates of accumulation rise in chloride ions in Osman sagar and Mir Alam tank over last 25 years have been computed and shown in Table 6b (base Srinivasan, 1965). The rates of accumulation in Mir Alam tank worked out to be 20.47 mg/l / 15 years and 21.07 mg/l /25 years (present study). The corresponding yearly rise worked out to 1.36 mg/l and 0.84 mg/l respectively (Table 6b)

5. Large Tank Sarror Nagar

Limnological investigations were restricted to the random surveys/samplings during the three major seasons in 1991 and therefore the seasonal observations pertain to a single calendar year. Table 11 and Fig 13 shows the mean seasonal values of different physico-chemical parameters of water quality.

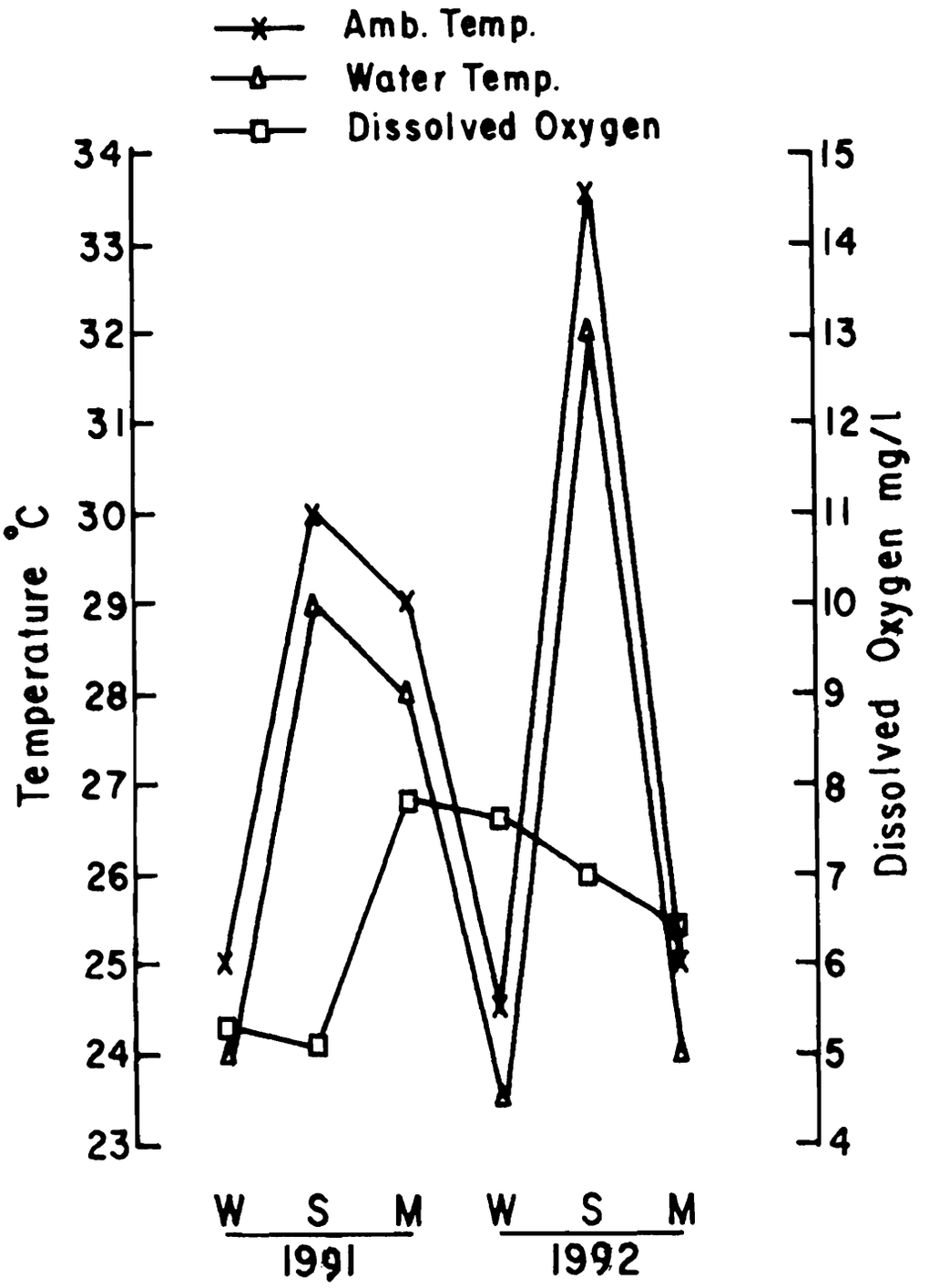


Fig. 12a. Seasonal variations in some physicochemical parameters of water quality in Mir Alam Tank - ambient temperature, water temperature and dissolved oxygen.

Temperature

The mean seasonal surface water temperature recorded were winter- 25.0°C, Summer- 28.2 °C and monsoons -26.0 °C. The corresponding ambient temperature values for different seasons were 25.0 °C (winter), 36.0 °C (summer) and 29.0 °C (monsoon). The air/water temperature gradient showed a positive correlation to different seasons.

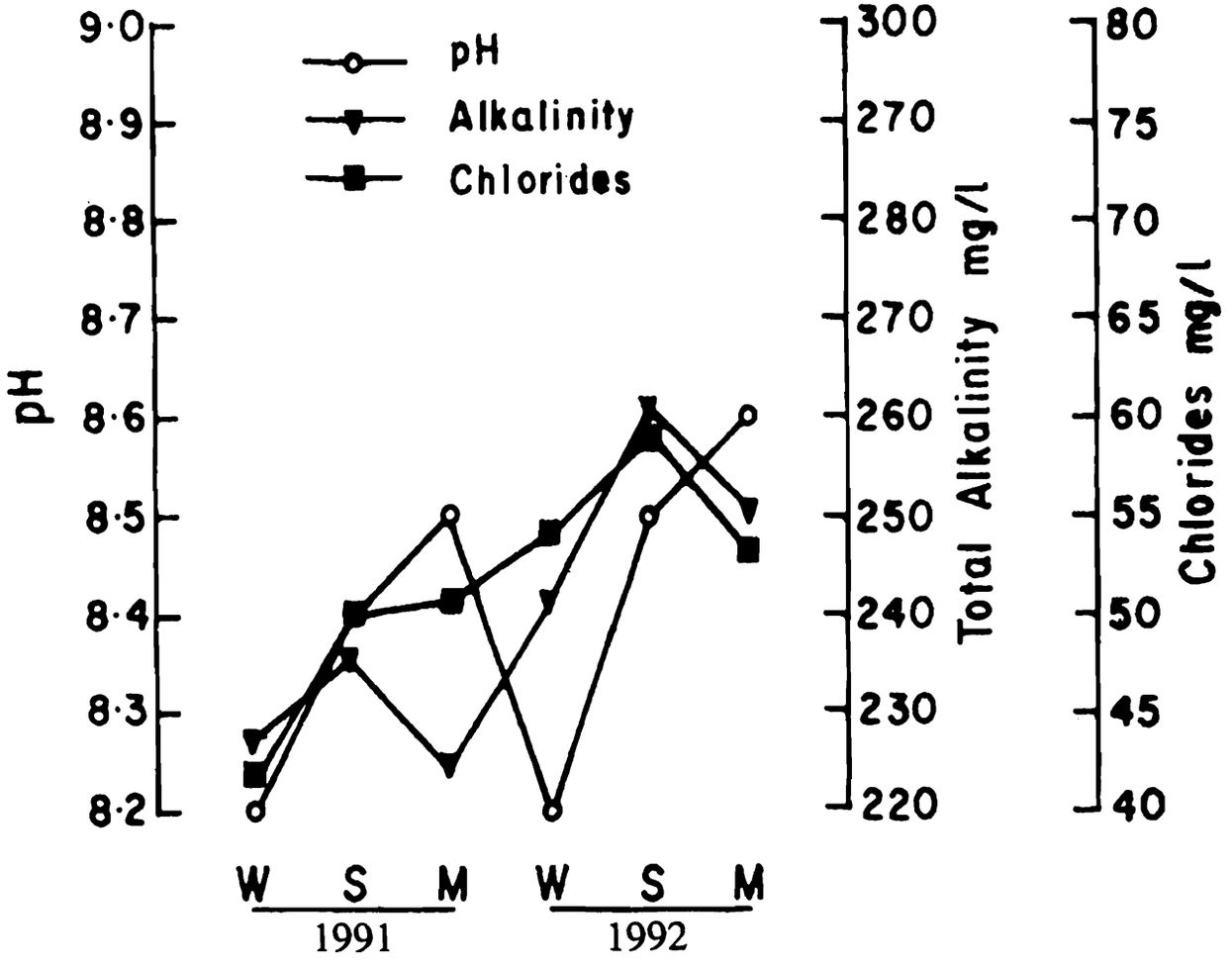


Fig. 12b. Seasonal variation in some physicochemical parameters of water quality in Mir, Alam Tank ph, alkalinity and chloride.

pH

The average pH values varied between 8.2-8.5 during different seasons. The pH values exhibited some seasonal constancy and were higher during winters and summers. The higher pH values may be attributed to carbonates and higher photosynthetic activities resulting from phytoplankton production. The pH values showed a correlation to free CO_2, which was invariably present at pH values around 8.0 but absent at 8.3. Contrary to widespread observations that pH and carbonates go hand in hand, the littoral waters revealed an inverse behavior of bicarbonates towards carbonates and pH (Ganapati, 1940).

Dissolved Oxygen and % saturation

The horizontal profile of DO content showed no seasonal pattern and ranged between 1.0-3.4 mg/l, the annual mean being a poor low of 2.3 mg/l. The corresponding range of % saturation for the tank water ranged between 12.75-41.46 %, the annual mean being 28.32%. The low DO content, the year round, may be attributed to very shallow nature of the tank. Near deoxygenating conditions prevailed near littoral region during summer.

Free CO_2

While free CO_2 was absent in winter, considerably higher values were recorded during monsoons (41.46 mg/l) and summer (20.0 mg/l). The higher rate of decomposition during summer due to rapidly receding water level and higher temperature followed by scanty rains during monsoon, were probably responsible for higher CO_2 values and reduced oxygen contents.

Alkalinity

The total alkalinity values ranged between 220.0 - 250.0 $CaCO_3$ mg/l (mean 236.0 mg/l) or 4.4 - 5.0 meq/l. The tank water was distinctly alkaline. The corresponding ranges of computed values for bicarbonates were 268.28-304.75 mg/l and for carbonate 131.78-304.75 mg/l respectively. The higher alkalinity may be attributed to organic polution as the lake basin receives domestic wastes and sewage.

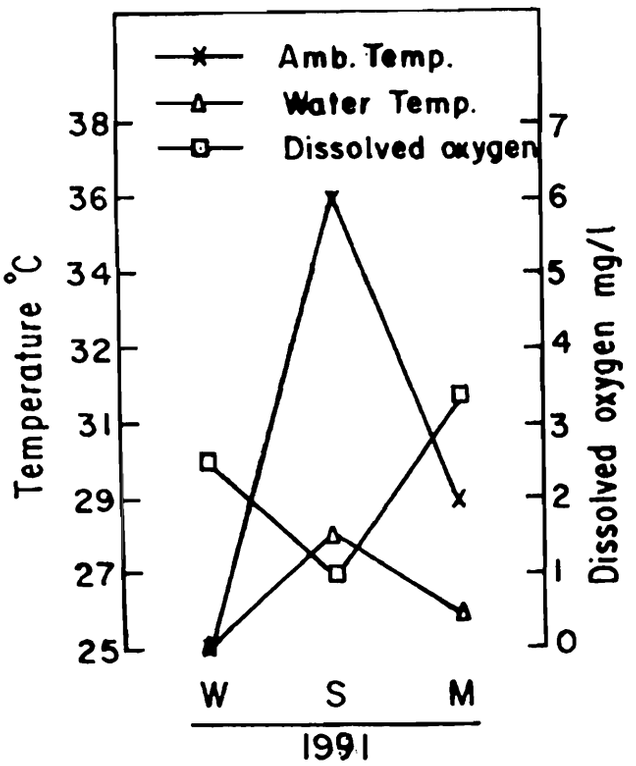
The total inorganic carbon estimated ranged between 55.0-62.5 mg/l, the annual mean being 59.0 mg/l. Substantially higher values of available carbon indicated the enrichment due to external loading. The range of values of carbonic species in this tank compares well with the values prevailing in littoral waters of Hussain sagar. Both receive heavy inflow of effluents, predominately industrial in case of Husssin sagar and domestic in case of Sarror Nagar tank.

Hardness

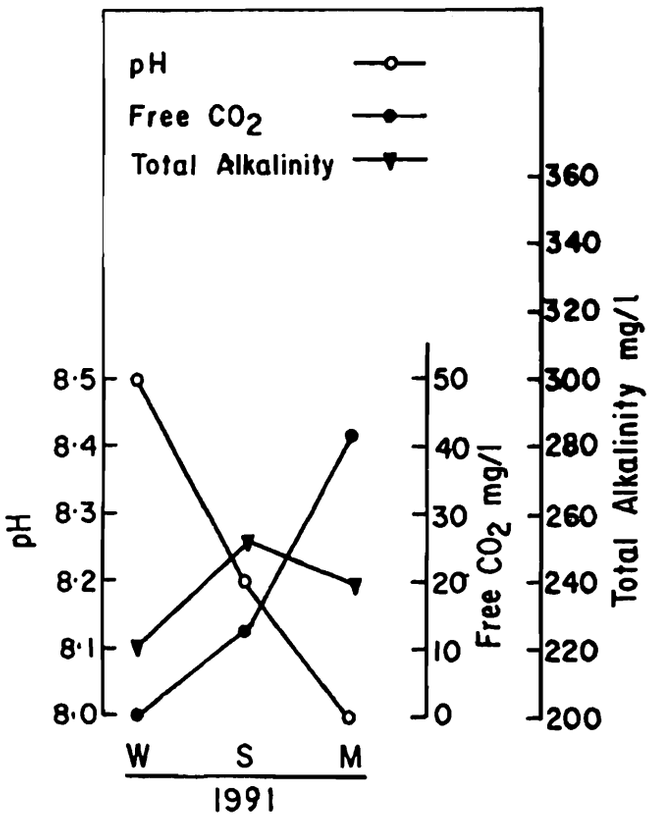
The total hardness for littoral surface water ranged between 253.00-289.00 mg/l and 5.03-5.75 meq/l during different seasons. A marked seasonality was noticed with peaks during summer.

Table 11. Mean sesonal values of different physico-chemical parameters in large Saroor nagar tank during 1991.

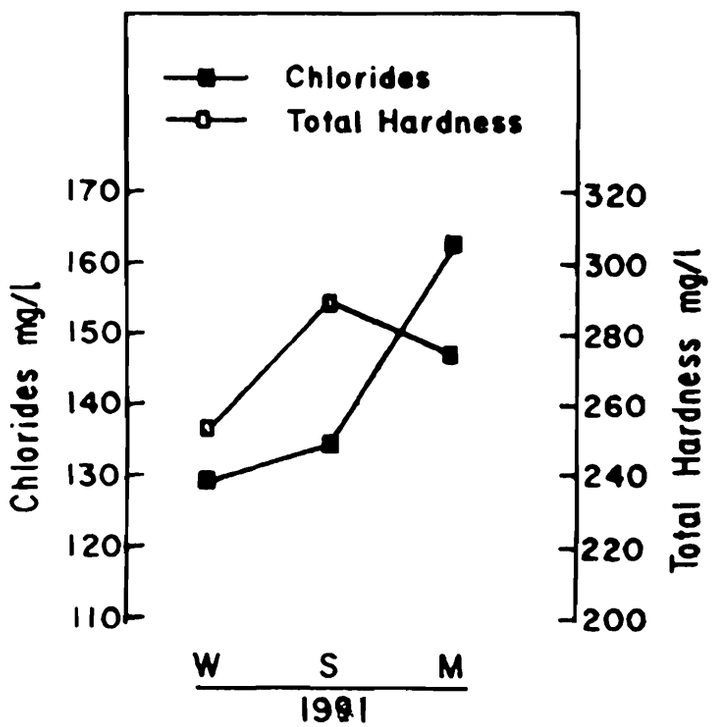
YEAR	1991		
SEASONS	Winter	Summer	Monsoon
Air Temperature °C	25.00	36.00	29.00
Water Temperature °C	25.00	28.00	26.00
pH	8.50	8.2.00	8.00
D.O(mg/l)	2.50	1.00	3.40
% Cs	30.26	12.75	41.87
Free CO_2 (mg/l)	0	20.00	41.46
Total Alkalinity (mg/l)	220.00	256.00	238.00
Total Alkalinity (meq)	4.40	5.00	4.77
Chloride (mg/l)	130.00	135.00	163.00
Hardness (mg/l)	253.00	289.00	276.00



(a) Correlation between Ambient temp, Water temp. and Dissolved oxygen.



(b) Correlation between Free CO_2, pH and Total Alkalinity



(c) Seasonal range of values of Chloride and Total Hardness

Fig. 13. Seasonal variation in some physicochemical parameters of water quality in Large tank, Saroor Nagar.

Chlorides

Chloride contents of the tank water varied between 163.0 mg/l or 4.59 meq/l and 130.0 mg/l or 3.80 meq/l. The peak was observed during summer. The chloride values during winter and summer were almost similar. The higher values of chloride in this tank were again related to high degree of pollution caused by anthropogenic activities.

From the foregoing accounts of the chemical conditions prevailing in Saroor Nagar tank, it can be concluded that the water quality of the tank is rapidly deteriorating, probably due to organic pollution resulting from excessive, undesirable discharge of domestic sewage.

BIOTIC PROFILE

Phytoplankton diversity

The phytoplankton flora of Osman sagar and Mir Alam tank as reported by Satya Mohan and Reddy (1986) and Satya Mohan (1987) are listed in Tables 12 and 13 respectively. The phytoplankton comprised of 3 major groups of algae *viz.* Cyanophyceae (Blue green algae), Chlorophycea (Green algae) and Desmids. Strangely, no diatoms were recorded from Osman sagar or Mir Alam tank. In Osman sagar, the phytoplankton flora comprised of 54 species. The Cyanophyceae (blue green algae) were represented by 22 species, Chlorophyceae (green algae) by 24 species and desmids by 8 species. Out of these, three species of blue green algae, *Merismopedia punctata, Phormidium faveolarum* and *Anabaenopsis raciborskii*, one species of green algae, *Ankistrodesmes falcatus* and one species of desmids, *Cosmarium staurastrum* were classified as dominant and two species of blue green algae, *Lyngbya limnetica* and *Anabaena sp.* were classified as common. The rest of the species occurred in comparatively smaller numbers. Quantitatively, blue green algae as a whole dominated the composition by contributing nearly 65% of the total phytoplankton numerical density. The chlorophyceae contributed around 25-28% and the rest by desmids. In Mir Alam tank, the phytoplankton was comprised of 58 species, which included 25 species of blue green algae, 28 of green algae and 5 of desmids. Out of these, 6 species of blue green algae (*Chroococcus minutus, Coelosphaerium kutzingianum, Spirulina* sp., *Phormidium favaeolarum, Lyngbya limnetica* and *Anabaenopsis raciborski*) and 3 species of green algae (*Schroederia setigera, Ankistrodesmus falcatus* and *Monoraphidium convulutum*) were designated as dominant. Beside these, 6 species of blue green algae and one species of desmids were designated as common. Like Osman sagar, blue green algae also dominated the phytoplankton composition in Mir Alam tank, contributing nearly 93% of the total phytoplankton numbers.

Faunal diversity

Detailed studies were carried out on the diverse faunal assemblage belonging to major communities of plankton and macrophytes-associated littoral benthic macro-invertebrates in Hussain sagar and Saroor Nagar tank only. Studies on fish fauna were carried out in Hussain sagar, Osman sagar and Himayat sagar. The occurrence of the fish species in these lakes were compared

Table 12. List of Phytoplankton taxa recorded from Osman Sagar. The dominant and commonly occurring species have been indicatyed by * and + signs respectively

(After Satya Mohan and Reddy, 1986 and Satya Mohan, 1987)

CYANOPHYCEAE

1. *Chrooccus minutus*
2. *C. turgidus*
3. *Gloeocapsa sp.*
4. *Synechocystis pevalekii*
5. *Aphanocapsa sp.*
6. *Synechococcus sp.*
7. *Aphanothece sp.*
8. *Merismopedia punctata* *
9. *Coelosphaerium kutzingianum*
10. *Gonephosphaeria apopina* +
11. *Spiirulina sp.*
12. *Oscillatoria angusa*
13. *O. germinata*
14. *O. limnetica*
15. *O. princeps*
16. *Phormidium laminorum*
17. *P. faveolarum* *
18. *Lyngbya limnetica*
19. *L. perelegons* +
20. *Anabaena sp.* +
21. *Anabaenopsis raciborskii* *
22. *Raphidiopsis mediterranea* +

CHLOROPHYCEAE

23. *Chlamydomonas sp.*
24. *Phacotus lenticularis*
25. *Schroederia setigera*
26. *Pediastrum boryanum*
27. *P. simplex var. duodenarium*
28. *Coelastrum sp.*
29. *Chlorella vulgaris*
30. *Oocystis sp.*
31. *Ankistrodesmus falcatus* *
32. *Monoraphidium convulutum*
33. *Tetraesuon limneticum*
34. *T. minimum*
35. *T. regulare*
36. *T. trigonum*
37. *Senedesmus acutiformis*
38. *S. armatus*
39. *S. bijuga*
40. *S. bijuga var. alternans*
41. *S. dimorphus*
42. *S. obliguus*
43. *S. opolicusis*
44. *S. quadricauda*
45. *Cruugenia tetrapedia*
46. *Actinastriam hantzschii*

DESMIDS

47. *Closterium sp.*
48. *Cosmarium botrytis*
49. *C. laeve*
50. *C. meneghini*
51. *C. portianum*
52. *C. subexcdvatum*
53. *C. subtumidum*
54. *C. staurastrum*

Table 13. List of Phytoplankton Taxa recorded from Mir Alan tank. The dominant and commonly occurring species have been indicated by * and + signs respectively

(After Satya Mohan and Reddy, 1986 and Satya Mohan, 1987)

CYANOPHYCEAE

1. *Chrooccus minor*
2. *C. minutus* *
3. *C. turgidus*
4. *Gloeocapsa* sp.
5. *Synechocystis aquatilis* +
6. *S. pevalgkil* +
7. *Aphanocapsa* sp. +
8. *Microcystis* sp.
9. *Synechoccus* sp.
10. *Meresmopedia minima*
11. *M. punctata* +
12. *Coelosphaerium kutzingianum* +
13. *Gomphosphaeria apopina*
14. *Spirulina* sp. *
15. *Oscillatoria amphigranulata*
16. *O. chalybea*
17. *O. princeps*
18. *Phormidium faveolarum* *
19. *Lyngbya limnetica*
20. *L. perelegans* *
21. *Anabaena* sp. +
22. *Anabaenopsis circularis* +
23. *A. raciborskii* *
24. *Nostoc* sp.
25. *Raphidiopsis mediterranea*

CHLOROPHYCEAE

26. *Chlamydomonas* sp.
27. *Phacotus lenticularis*
28. *Schroederia setigera* *
29. *Pediastrum duplex*
30. *P. simplex*
31. *P. tetras*
32. *Caelastrum* sp.
33. *Chlorella vulgaris*
34 *Ankistrodesmas falcatus* *
35. *A. spiraliis*
36. *Monoraphidium convulutum* *
37. *Tetraedron caudatum*
38. *T. limneticum*
39. *T. minimum*
40. *T. muticum*
41. *T. regulare*
42. *T. trigonum*
43. *T. victoriae*
44. *Scenedesmus acutiformis*
45. *S. armatus*
46. *S. bijuga*
47. *S. bijuga Var. alternas*
48. *S. dimorphus*
49. *S. obliques*
50. *Scenedesmus opoliensiis*
51. *S. quadricauda*
52. *S. quadricauda Var. longispina*
53. *Crucigenia rectangularis*

DESMIDS

54. *Closterium* Sp
55. *C. meneghinii*
56. *C. portianum*
57. *Euastrum* sp.
58. *Straurastrum tetracerum* +

with the earlier records of Rahimullah (1943a, 1943b) to find out any changes in faunal profile during the intervening period due to altered environmental conditions.

The taxa belonging to zooplankton community are listed in Table 14 and those belonging to macrophytes associated/littoral benthic macro-invertebrates in Table 15. The lists are by no mean complete as many important invertebrate groups communities could not be studied for want of taxonomie expertise.

Zooplankton

The zooplankton community in these water-bodies mainly comprised of three major groups *viz.* Rotifera, Cladocera and Copepoda. Beside, the Ostracoda also contributed significantly to zooplankton community but only few taxa could be identified. In Hussain sagar, altogether 41 species were recorded which comprised 19 species of Rotifera, 11 of Cladocera, 7 of Copepoda and 4 of Ostracoda. The rotifers were represented by families Brachionidae (8 species), Lecanidae (3 speceis)), Hexarthidae (3 species), Asplanchnidae (2 species) and Trichocercidae, Notomatidae, Concochilidae by one species each. Cladocerans were represented by families Sididae (3 species), Chydoridae (3 species), Daphnidae (2 species), Moinidae (2 species) and Macrothricidae by one species. The Copepods, which were represented by lowest number of taxa, included 5 species of Diaptomidae and 2 species of Cyclopoidae. The zooplankton diversity in Saroor Nagar tank was relatively poor and represented by only 21 species - 9 of rotifers, 6 of cladocerans, 4 of copepods and 2 of ostracodes (Table 14).

Macro-invertebrates

Several groups constituted macrophyte associated/ littoral benthic macro-invertebrate communities viz. Annelida : Oligochaeta, Arachnida; Hydracrina; Insecta : Odonata, Ephemeroptera, Hemiptera, Coleoptera and Diptera and Mollucsa: Gastropoda. Altogether 35 taxa were recorded form Hussain sagar and 18 from Saroor Nagar tank (Table 15). Among insects, the most important and dominant group was Hemiptera, followed by Coleoptera. In Hussain sagar, the Oligochaeta was represented by 2 taxa, Hydracrina by 3, Odonata by I, Ephemeroptera by 2, Hemiptera by 10, Coleoptera by 6, Diptera by 5 and Mollusca by 7 taxa. The macro-invertebrate communities in Saroor Nagar tank was comprised of 1 taxa of Oligochaeta. 2 of Hydracrina, 1 of Odonata, 4 of Hemiptera, 4 of Diptera and 6 of Mollusca. Like zooplankton, macro-invertebrate species diversity of Saroor Nagar tank was relatively poor, exhibiting monotony.

Nekton (Fishes)

The fish species recorded from Hussain sagar, Osman sagar and Himayat sagar are listed in Table 16. A total of 43 species were recorded from all the wetlands studied and belonged mainly to Cyprinidae, Gerridae, Cobitidae, Bagaridae, Siluridae, Claridae, Heteropneustidae, Poecilidae, Channidae, Cicilidae, Gobiidae and Ospheronemidae. Highest number of species (29) was recorded from Hussain sagar. From Osman sagar and Himayat sagar considerably lower number of species were recorded - 18 and 16 respectively.

Table 14. List of Zooplankton Species occurring in Hussain sagar and Saroor nagar tank

Zooplankton Species	Hussain Sagar	Saroor Nagar Tank
ROTIFERA		
Subclass EUROTATORIA		
Superorder MONOGONATHA		
Order : PLOIMIDA		
Family : BRACHIONIDAE		
1. *Brachionus angularis* Gosse	+	+
2. *Brachionus caudatus* (Barrois & Daddy)	+	–
3. *Brachionus cayiflorus* (Gosse)	+	–
4. *Brachionus diversicornis* (Daddy)	+	+
5. *Brachionus forficula* Wierzejski	+	–
6. *Brachinus rubens* Ehrenberg	+	+
7. *Keratekla tropica* (Apstein)	+	+
8. *Keratella quadrata* (Muller)	+	+
Family LECANIDAE		
9. *Lecane (L) aculeata* (Jakubski)	+	–
10. *L.(L.) ungulata* (Gosse)	+	+
11. *L.(Monostyla) bulla* (Gosse)	+	–
Family : TRICHOCERCIDAE		
12. *Trichocerca longiseta* (Schrank)	+	–
Family : ASPLANCHNIDAE		
13. *Asplanchna brightwelli* Gosse	+	+
14. *Asplanchnopus sp*	+	+
FAMILY NOTOMMATIDAE		
15. *Scaridium longicaudum* (Muller)	+	–
ORDER GNESIOTROCHA		
FAMILY : CONOCHILIDAE		
16. *Conochilus arboreus* (Rajendran)	+	–
FAMILY HEXARTHIDAE		
17. *Hexartha mira* (Hudson)	+	+
FAMILY FILINIDAE		
18. *Filinia longiseta* (Ehrenbers)	+	–
19. *Filinia terminalis* (Plate)	+	–
CLADOCERA		
Family SIDIDAE		
20. *Pseudosida bidentata* Herrick	+	+

Tabel 14 Contd.

Zooplankton Species	Hussain Sagar	Saroor Nagar Tank
21. *Diaphanosoma sarsi* Richard	+	+
22. *D. excisum* Sars	+	–
FAMILY : DAPHNIDAE		
23. *Ceriodaphnia cornuta* Sars	+	+
24. *Simocephalus vetulus* (O.F.Muller)	+	–
Family MONIDAE		
25. *Moina brachiata* (Jurine)	+	+
26. *Moinodaphnia macleayi* (King)	+	–
FAMILY MACROTHRICIDAE		
27. *Macrothrix spinosa* King	+	–
FAMILY CHYDORIDAE		
Subfamily CHYDORINAE		
28. *Chydorus sphaericus* (O.F.Muller)	+	+
Subfamily ALONINAE		
29. *Alona rectangula* Sars	+	+
30. *Alona davidi* Richard	+	–
Suborder CALANOIDA		
Family DIPTOMIDAE		
31. *Heliodiaptomus viduus* (Gurney)	+	+
32. *Phyllodiaptomus annae* (Apstein)	+	–
33. *Phyllodiaptomus blanci* (Gueme &Richard)	+	–
34. *Neodiaptomus diaphorus* Kiefer	+	–
35. *Neodiaptomus* sp.	+	+
Suborder CYCLOPOIDA		
Family CYCLOPOIDAE		
36. *Mesocyclops leuckarti* (Claus)	+	+
37. *Eucyclops* sp.	+	+
CLASS OSTRACODA		
38. *Chrissia sp.*	+	–
39. *Cyprinotus sp.*	+	+
40 *Stenocypris Sp.*	+	–
41. *Heterocypris sp.*	+	+
Number of species	41	21

Table 15. List of Macrophyte-associated/littoral benthic macroinvertebrates taxa in Hussain Sagar and Saroor nagar tank

Macrobenthic Taxa	Hussain Sagar	Saroor Sagar
CLASS OLIGOCHAETA		
Limnodrilus hoffmeisteri Claparede	+	-
Tubifix tubifix. (Muller)	+	+
CLASS :ARACHNIDA		
ORDER HYDROACARINA		
Argyronecta sp.	+	-
Arrenurus sp.	+	+
Hydrachna sp.	+	-
CLASS INSECTA		
ORDER ODONATA (nymph)		
Zygoptera/Anisoptera	+	+
ORDER EPHEMEROPTERA		
FAMILY CAENIDAE	+	-
FAMILY BAETIDAE	+	-
ORDER HEMIPTERA :		
FAMILY HYDROMETRIDAE		
Hydrometra vittata Stall	+	-
FAMILY GERRIDAE		
Limnometra fluviorum (Fabricius)	+	+
Gerris sp.	+	-
FAMILY VELLIDAE		
Microvelia diluta Distant	+	-
FAMILY NOTONECTIDAE		
Notonecta sp.	+	+
Anisops sp.	+	-
FAMILY NAPIDAE		
Laccotrephus maculatus (Fabricius)	+	-
Ranatra filiformis Fabricius	+	+
FAMILY BELOSTOMATIDAE		
Diplonychus rusticus (Fabricius)	+	-
FAMILY CORIXIDAE		
Corixa sp.	+	+

Tabel 15 Contd.

Macrobenthic Taxa	Hussain Sagar	Saroor Sagar
ORDER COLEOPTERA		
FAMILY DYTISCIDAE		
Cybister sp.	+	-
Hydaticus sp.	+	+
Laccophilus sp.	+	-
Eretes sp.	+	-
FAMILY GYRINIDAE		
Dineutus sp.	+	-
FAMILY HYDROPHILIDAE		
Hydrophilus sp.	+	-
ORDER : DIPTERA (Larvae)		
Chironomus sp.	+	+
Anopheles sp.	+	+
Culex sp.	+	+
Chaoborus sp.	+	-
Eristalis sp.	+	+
Phylum MOLLUSCA		
CLASS GASTROPODA		
Bellamya bengalensis (Lamarck)	+	+
Indoplanorbis exustus (Deshayes)	+	+
Gyraulus convexiusculus (Hutton)	+	+
Lymnaea luteola Lamarck	-	+
Lymnaea accuminata Lamarck	-	+
Lymnaea sp.	+	-
Thiara (Melanoides) tuberculata (Muller)	+	-
Pila sp.	-	+
Total No. Taxa	34	18

Avifauna

General observations on birds were made in and around Hussain sagar during the course of study. The bulk of resident avifauna comprised of the marsh birds belonging to families Podicipitidae, Phalacrocoracidae and Ardeidae (little Grebes, cormorants, Pond herons, cattle egrets, large, medium and little egrets, night herons, grey herons, *etc*) and kingfishers (Family Alcedinidae). Besides resident species, several migratory species were also recorded, which have recently resumed their visits after a long gap. The migratory species recorded mainly belonged to family Anatidae (spot-billed ducks, pin-tailed ducks, whistling teals, cotton teals, etc. (Table 17).

GENERAL ECOLOGICAL OBSERVATIONS

Zooplankton

The shallow littoral vegetated region and also nearby limnetic zone play a host to a wide variaety of zooplankton communities. In Hussain sagar, the copepods dominated the quantitative composition followed by cladocerans. Rotifers ranked third in order of abundance. The ostracod representation in term of number was also least. Among copepods, the calanoid, *Heliodiatomus viduus* and cyclopoid, *Mesocyclops leuckarti* dominated the numerical composition throughout the year. Copepodites of these species were invariably present in almost all the samples. Among cladocera, Chydorids dominated the numerical abundance. This group is well known to occupy littoral vegetated zone of lentic freshwaters in general. Beside Chydorids, the species of the genra *Sida, Pseudosida, Moina* and *Macrothrix* also occurred abundantly in this region. These species, in general, are the characterstics of the littoral vegetation rich zones. However, several open water species like *Diaphanosoma sarsi, Diaphanosoma excisum* and *Ceriodaphnia cornuta* also occurred in fair numbers showing their wider adaptability. Among rotifers, Brachionids dominated both the content and numbers. Two genera, *Brachionus* and *Keratella* mainly represented this family. While the genus *Brachionus* was constituted by a large number of species and subspecies, genus *Keratella* was represented by only two species. The other important group was Lecanid, represented by few species of the genus *Lecane*. In fact, the rotifer community of most of the tropical alkaline waters are dominated by several species of *Brachionus*. With its large number of species, subspecies and polymorphs, the genus has fully adapted to the varied conditions in tropical alkaline water-bodies. Further, most of these species are well known to be associated with the degree of eutrophy and their abundance indicated the highly eutrophic nature of Hussain sagar. In fact they are good indicators of *saprobiety* i.e. of the content of putrescible organic matter as expressed by BOD (Sladecek, 1983).

Macro-invertebrates

The fauna associated with macrophytes or the weed bed fauna along with the fauna of littoral bottom comprised the major macroinvertebrate component of Hussain sagar and Saroor Nagar tank. Hemipterans, coleopterans and dipteran insects, mollucs and oligochaetes markedly dominated the macroinvertebrate community. This was due to the abundance of macrophyte, *Eichhornia*

Table 16. List of Fish species occurring in Hussain Sagar, Osman Sagar and Himayat Sagar, Hyderabad

Species	Hussain Sagar	Osman Sagar	Himayat Sagar
ORDER OSTEGLOSSIFORMES			
Family Notopteridae			
1. *Notopterus notopterus* (Pallas)	+	+	+
ORDER CYPRINIFORMES			
Family Cyprinidae			
2. *Salmostoma bacaila* (Hamilton)	+	–	–
3. *Rasbora daniconius* (Hamilton)	+	+	–
4. *Puntius amphibius* (Valenciennes)	+	+	–
5. *P. arenatus* (Day)	+	–	–
6. *P. chola* (Hamilton)	+	+	–
7. *P. conchonius* (Hamilton)	+	–	+
8. *P. dorsalis* (Jerdon)	–	–	+
9. *P. filamentosus* (Valenciennes)	+	+	+
10. *P. guganio* (Hamilton)	–	–	+
11. *P. kolus* (Sykes)	–	+	+
12. *P. parrah* Day	–	–	+
13. *P. sarana* (Hamilton)	+	+	+
14. *P. Subnastus* (Valenciennes)	+	–	–
15. *P. sophore* (Hamilton)	+	–	–
16. *P. titco* (Hamiton)	+	+	+
17. *P. vittatus* Day	+	–	–
18. *P. Jerdoni* (Day)	–	+	–
19. *Cirrhina fulungea* (Sykes)	–	+	–
20. *C. mrigala* (Hamilton)	–	+	+
21. *Labeo rohita* (Hamilton)	–	+	–
22. *Cyprinus carpio communis* Linnaeus	–	+	–
23. *Crossocheilus latius* (Hamilton)	–	+	–
24. *Garra lamta* (Hamilton)	–	+	–
25. *G. mullya* (Sykes)	+	+	–
Family: Cobitidae			
26. *Lepidocephalus guntea* (Hamilton)	+	–	–

Table 16 Contd.

Species	Hussain Sagar	Osman Sagar	Himayat Sagar
27. *Oreonectes evezardi* (Day)	–	+	–
Fmily Bagaridae			
28. *Mystus vittatus* (Bloch)	+	–	+
29. *M. bleekeri* (Day)	+	–	–
30. *M. cavasius* (Hamilton)	–	–	+
Family Siluridae			
31. *Ompok bimaculatus* (Bleeker)	+	+	+
32. *Wallago attu* (Schneider)	–	–	+
Family Clariidae			
33. *Clarius batrachus* (Linnaeus)	+	–	–
Family Heteropneustidae			
34. *Heteropneustes fossilis* (Bloch).	+	–	–
ORDER ATHERINIFORMES			
Family Poecilidae			
35. *Gambusia affinis* (Baird & Garird)	+	–	–
ORDER CHANNIFORMES			
Family : Channidae			
36. *Channa punctatus* (Bloch)	+	–	+
37. *C. orientalis* ((Schneider)	+	–	–
38. *C. marulia* (Hamiton)	+	–	–
39. *C. straitus* (Bloch)	+	–	–
40. *C. gachua* (Hamilton)	+	–	–
ORDER PERCIFORMES			
Family : Cichlidae			
41. *Etroplus maculatus* (Bloch)	+	–	–
Family Gobiidae			
42. *Glossogobius giuris* (Hamiton)	+	–	+
Family : Osphronemidae			
43. *Osphronemus goramy* Lecepede.	+	–	–
Total number of species	29	18	16

Table 17. List of Avifauna recorded from Hussain sagar, Hyderabad

Species	Common name
Family Phalacrocoracidae	
Phalacrocorax niger (Viellot)	Little Cormorant
Ahinga ruga melanogaster Pennant	Darter
Family Ardeidae	
Ardea grayii grayii (Sykes)	Indian Pond Heron
Bubalis ibis coromandus (Boddaert)	Cattle Egret
Egretta alba modesta (J. E .Gray)	Large Egret
Egretta garzetta garzetta (Linnaeus)	Little Egret
Nycticorax nycticorax nycticorax	(Linnaeus) Night Heron
Family Anatidae	
Dendrocygna javanica (Horsfield)	- Lesser Whistling Teal
Anas acuta (Linnaeus)	- Pintail
Anas crecca (Linnaeus)	- Common Teal
Anas platyrhynchos Linnaeus	- Mallard
Aythya ferina (Linnaeus)	- Common Pochard
Nettapus coromandelianus (Gmelin)	- Cotton Teal
Family : Alcedinidae	
Ceryle rudis leucomelanura (Reichenbach)	- Lesser Pied Kingfisher
Alcedo atthis bengalensis Gmelin	—
Halcyon smyrnemsis fusca (Boddaert)	—

crassipes, that flourished in both the water-bodies and provided shelter to a large number of species. The whole gamut of aquatic insect groups find adequate representation, having successfully exploited the various ecological niches of the most productive littoral zone. The aquatic coleopteran, predominately the predaceous diving beetles- *Cybister* sp. and Whirling beetles-*Dineutes* sp. and hemiptertan, Giant water bug, *Diplonychus* sp. were found in plenty amidst aquatic vegetation and detritus in littoral region. Thus, while the habitat of different species the shallow macrophytes choked substrate-environment, was similar, they have different trophic niches. For example, *Notonecta* sp. is an active predator while *Corixa* sp feed on decaying organic vegetation.

Generally the hemipterans and coleopterans enjoy numerical abundance, contributing substantially towards the macrophyte associated insect biomass and therefore are dominants. Together with malacofauna, these go to form major communities. Going by the mode of occurrence and abundance, most species of the insect communities are classified as 'characteristics' for while they do naturally occur in comparatively cleaner waters (Hussain sagar station I and II), they were also found in small but significant numbers at other stations, despite deteriorating changes in water chemistry. The water mites *Arrenurus* sp, and *Hydrachna* sp. occur abundantly in relatively polluted stretch of Hussian sagar around Kairatabad infested with water hyacinth. Dipteran larvae (Chironomids, Culicids and Syrphids) were observed in huge numbers around Kukatpally Nullah- Hussain sagar junction. While chironomid larvae were frequently encountered, the larvae of *Eristalis* sp. (rat-tailed maggots) were only recorded on two occasions at Station IV (Secunderabad sailing club). These larvae are known to occur in filthy organic situations and therefore serve a good indicator of water polluted with rich organic wastes. In Saroor Nagar tank, which is also highly organically polluted, larvae of *Eristalis* sp. alongwith chronomids and tubificids, were found in abundance, thriving in anoxic condition in lettoral region.

Among molluscs, *Indoplanorbis exustus* was of common occurrence in the littoral regions of all stations of Hussain sagar and along with *Gyraulus convexiusculus* and *Thiara (M) tuberculata,* formed the dominant component of malacofauna. The planorbids, in general are good indicator of the environment and their occurrence in large numbers around Station III indicates the poor water quality of the area.

It may be noticed that inspite of very high pollution load of Hussain sagar, its zooplankton and macro-invertebrate fauna were an admixture of polluted as well as few cleaner water species. Although there was a definite dominance of polluted water species, the occurrence of comparatively cleaner water species is remarkable. The occurrence of such species indicates both, the existance of some comparatively less/polluted/ cleaner areas in the reservoir and adaptability of these species to prevailing conditions of the lake.

Nekton (Fishes)

The higher species diversity of fishes in highly eutrophic Hussain sagar, as compared to comparatively cleaner Osman sagar and Himayat sagar, is again significant. In all 28 species were recorded from Hussain sagar, 25 from Osman sagar and 15 from Himayat sagar. Rahimulla (1934) reported the occurrence of only 23 species of fishes in Hussain sagar, which is quite less

as compared to present record of 28 species. However, a thorough analyses revealed a replacement of several species. During early 1940's, there was a predominance of commercially important and sensitive major carps. During present investigations, there was a predominance of catfishes; particularly air breathing ones, which are well known to survive in highly polluted and near deoxygenated conditions. The replacement of sensitive species by more tolerant species or hardy ones in an ecosystem is a biological adaptation to ecological stress or to deteriorating quality of the physico-chemical and biological conditions (Siddiqi, 1990). In contrast, the fish fauna of raw water reservers of Osman sagar and Himayat sagar, were characterised by predominance of important clean water food fishes belonging to major carps, which are relatively sensitive to changes in ecological conditions.

Presumably, for Hussain sagar, the fish communities of early 1940's represented a climax of sorts in ecological succession. Temporal changes and accelerated eutrophication trends, over the last few decades, have given rise to final or stable community. The ecological succession in species structure and community process within Hussain sagar, possibly represents the externally generated succession (Siddiqi, 1990). On the other hand, the fish communities in Himayat sagar and Osman sagar, are seral or developmental stages. For various natural (autogenic) and other external reasons, climax communities are a distant possibility, because the two lakes are primarily raw water reservoirs, located upstream amidst valley, and their catchment relatively free form influence of anthropogenic activities.

CLASSIFICATION OF LAKES

Based on the present studies as well as on the data gathered by earlier workers, different lakes have been classified using 'typology' scheme in vogue, for reliable evaluation of the lakes trophy (Table 18). From limnological viewpoint, Hussain sagar and Saroor Nagar tank are categorized as highly eutrophic, Mir Alam tank in the intervening mesotrophic category and the two raw water storage reservoirs, Himayat sagar and Osman sagar as oligotrophic.

CONCLUSIONS

From the foregoing account, it is clear that the five large to medium sized impoundments differed significantly in their limnological attributes. These lakes/tanks vary from the oligo-mesotrophic categories to highly eutrophic categories. In general, littoral surface waters of these lakes/tanks showed some seasonality in most of physico-chemical factors which mainly depended on the behavior of monsoon. The insufficient rains during monsoon sometimes resulted in vague or irregular seasonal variation pattern. In Hussain Sagar while diurnal fluctuations in most of the physico-chemical parameters were not very much demarcated, some parameters like water temperature, dissolved oxygen and free carbon-di-oxide exhibited very pronounced patterns, in line with the general diurnal variation studies.

Based on the physico-chemical and biological conditions, Hussain sagar and Saroor Nagar tank were found to be highly organically polluted, chiefly due to anthropogenic activities. The other three water bodies were comparatively cleaner. Hussain sagar is receiving domestic sewage

Table 18. General typology of various lakes/tanks investigated, according to different schemes.

Lake Classification Scheme	Criteria (on)	Lakes / Tanks				
		Hussain Sagar	Saroor Nagar Cheruvu/Tank	Mir Alam Tank	Osman Sagar	Himayat Sagar
1. Weber, 1907.	Nutrients	Highly Eutrophic	Highly Eutrophic	Mesotrophic	Oligotrophic	Oligotrophic
Naumann, 1919.	-do-	Eutrophic	Eutrophic			
2. Thienemann, 1927.	Oxygen supply & Benthos	Highly Eutrophic	Eutrophic	—	—	—
3. Zafar, 1975.	DOM, Ionic composition	Eutrophic	—	—	Oligotrophic	Oligotrophic
4. Zafar, 1986.	N & P	Eutrophic	Mesotrophic	Mesotrophic	Oligotrophic	Oligotrophic
5. Likens, 1972.	Nutrients	Hyper eutrophic	Hyper eutorphic	Mesotrophic	Oligotrophic	Oligotrophic
6. Wetzel, 1975.	Phytoplankton communities	Eutrophic	Eutrophic	—	—	—
7. Strom, 1980.	Ca, N., P. & Humus	Highly Eutrophic	Highly Eutrophic	Mesotrophic	Oligotrophic	Oligotrophic
8. Uttormork Peterwell, 1975.	Lake condition index	Highly Eutrophic	Highly Eutrophic	Mesotrophic	Oligotrophic	Oligotrophic
9. Present study	Limnochemical Biological characteritics	Eutrophic	Hyper eutrophic	Mesotrophic	Oligotrophic	Oligotrophic

and untreated wastes from several industries and this has drastically altered its ecology. Similarly, Saroor Nagar tank, located amidst dense human settlements, is used for a variety of undesirable purpose by surrounding population. Because of its distant location, Osman sagar is not affected much by the human activities and, therefore, still maintains good ecological conditions.

The detailed faunal investigations in Hussain sagar revealed the dominance of pollution tolerant species of zooplankton, macro-invertebrates and fishes. An apparent replacement of important food fishes (major carps) by pollution tolerant hardy species (catfishes, specially the air breathing ones) over last 50 years was observed. Like zooplankton and macro-invertebrates, the availability of some cleaner water species in Hussain sagar again pointed towards the adaptability of these species to changing conditions and also towards the availability of certain comparatively unpolluted stretches. A detailed investigations on the physiochemical as well as biological conditions of open water zones of this lake is urgently desired for adequate understanding of the structure and function of the lake in totality.

SUMMARY

Studies on the physico-chemical and biological characteristics of some important man-made lakes/reservoirs/tanks of Hyderabad district (Andhra Pradesh, India, latitude 17° 20' N, longitude 78° 30' E) were carried out during 1990-92. These were Hussain sagar, Himayat sagar, Osman sagar, Mir Alam tank and Saroor Nagar tank. Physicochemical parameters studied were temperature, transparency, turbidity, pH, electrical conductivity, total dissolved solids, dissolved oxygen, free carbon-di-oxide, total Alkalinity, chloride and hardness. While studies were conducted on seasonal basis in Osman sagar, Himayat sagar, Mir Alam tank and Saror Nagar tank, Hussain sagar was subjected to intensive studies, which included diurnal samplings from four different stations during all seasons. The annual cycle was divided into three main seasons, *viz.* summer (March-June), Monsoon (July-October) and winter (November-February). The biological studies included the analysis of faunal diversity of zooplankton and macrophytes associated macro-invertebrates in Hussain sagar and Saroor Nagar tank. Studies on fish fauna were conducted in Hussain sagar, Osman sagar and Himayat sagar and currently available species were compared with the earlier records (Rahimullah, 1943). Due to the discharge of effluents from several industries as well as domestic sector, Hussain sagar is highly polluted in the regions of outfall. While diel fluctuation in different physico-chemical parameters excepting water temperature, dissolved oxygen, free CO_2 and alkalinity were not significant, season-wise the different parameters exhibited considerable variations. Similarly the physicochemical condition of water at different stations were also different. The water quality at polluted stations III and IV, located in the regions of inflows was considerably deteriorated as compared to Stations I and II located in comparatively cleaner zones.

In general, Hussain sagar water was characterized as highly alkaline, hard to very hard, with low transparency, dissolved oxygen deficient, high free CO_2 at polluted stations, alarming chloride concentration and occurrence of Hydrogen sulphides, all indicative of chemical enrichment and

consequent eutrophication. The chloride content of the lake increased several folds during last 25 years. The zooplankton community was comprised of 41 species belonging to Rotifera, Cladocera, Copepoda and Ostracoda. Most of the species are known to be associated with eutrophy. Macrophytes associated / littoral benthic macro-invertebrate communities were constituted by several species of Annelida-Oligochaeta, Hydracrina, Insecta- Odonata, Hemiptera, Coleoptera and Diptera and Mollusa-gastropoda. Altogether, 34 taxa were recorded. The fish fauna was comprised of 29 species. Inspite of highly deteriorating conditions of the lake at several points, it harbored a good number of species, which was probably due to availability of several comparatively less polluted stretches in the lake and adaptability of the species to changed environmental conditions. Many of the species available are known to be related to degraded water quality.

Osman sagar was constructed across river Musi, as a flood control and water supply reservoir. Located upstream in the midst of hills and valleys in the granite country, nearly 19-km northwest of the city, it has a surface area of 32.0 km^2. The reservoir does not face any pollution problem and it general raw water quality was good from aesthetic and chemical viewpoints. The water was alkaline, bicarbonate rich, hard and moderately nutrient rich. The reservoir water recorded a very insignificant increase of chlorides during last 25 years indicating little degradation of its water quality. The fish fauna of the reservoir was mainly constituted by 18 Species, most of which was commercially important food fishes.

Himayat sagar, constructed across the river Esi, also a tributary of river Musi, is located in southwest area of the city, at a distance of 9.6 km from city centre. It covers a surface area of about 22.0 km^2. The lake too does not face any serious threat of pollution and therefore the water quality in general was good, both from aesthetic as well as chemical point of views. The water may be regarded as alkaline, hard and moderately nutrient rich. Despite significant time lag of nearly 25 years, the increase in chloride content is very insignificant which was due to its distant location and natural elevation, which gave protection from inflows of domestic wastes and cattle wading. The fish fauna were represented by 16 species.

Mir Alam tank, located about 7 km south of the old city of Hyderabad, is a medium sized tank with 13 km circumference. It was once a wide sheet of water spread over an approximately flat basin. It is primarily rain-fed. Following abstraction/ withdrawal of water for secondary use, it has now a considerably reduced surface area of 1.7 km^2. The tank is now reduced to a patchy sheet of water, infested with macrophytes, predominately water hyacinth. Increasing encroachment, frequent failure of seasonal rains, surface run off and inflow of sewage have resulted in considerable degradation of water quality. The tank maintains a permanent bloom of blue green algae. On a comparable scale, this tank showed relatively higher chloride contents than Himayat sagar and Osman sagar. The near two-fold rises in 25 years may be attributed to the factors cited above.

Saroor Nagar tank, located on the eastern side of the city nearly 5 km from Saifabad, is essentially a storage tank with a surface area of 0.4 km^2. It is the shallowest amongst the reservoirs/ tanks studied, with a mean depth of 6.1 m. It is surrounded by a dense human

settlement of the village Saroor Nagar and receives waste discharges and, therefore, is highly polluted. Because of its small area and considerable load from the surrounding population, the water quality of the tank was very much deteriorated. The studies on the faunal diversity of zooplankton and macrophytes associated macro-invertebrates revealed a very dismal picture. The zooplankton community was comprised of only 21 species. Similarly considerably reduced number of taxon (18) also represented macro-invertebrates.

Based on the present observations and earlier reports, these water bodies were classified according to their trophic status using typology schemes in vogue. From limnological viewpoints, Hussain sagar and Saroor Nagar tank are categorized as highly eutrophic, Mir Alam tank in the intervening mesotrophic category and the two raw water reservoirs, Osman Sagar and Himayt Sagar as oligotrophic.

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