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HYDRO-CHEMICAL STUDIES OF HINDON RIVER

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ABSTRACT

A detailed survey of the river Hindon was carried out to understand the nature of waste effluents and their impact on the water quality of river Hindon. From the study conducted, it is found that the water of the river is subjected to varying degree of pollution, caused by numerous untreated waste outfalls of municipal and industrial effluents. The main sources, which create pollution in river Hindon include municipal waste of Saharanpur, Muzaffarnagar and Ghaziabad districts and industrial effluents of sugar, pulp and paper, distilleries and other miscellaneous industries through tributaries as well as direct outfalls. In non-monsoon months the river is completely dry from its origin upto Saharanpur town. The effluents of Nagdev nala and Star Paper Mill at Saharanpur generate the flow of water in the river.

The dissolved oxygen content in the upstream section of the river was found to be quite satisfactory, however, a critical situation was observed after the confluence of paper mill and distillery effluents. The efluent of pulp and paper mill and distillery added high concentration of organic matter to the river, which is responsible for the decrease in dissolved oxygen alongwith increase in BOD, COD and TDS alongwith other factors. In the middle section of the river, the dissolved oxygen level improves significantly due to the reaeration and photosynthesis. In the lower stretch, the dissolved oxygen shows a large variation depending on the flow of the water in the river and is controlled by the discharge of water from Upper Ganga Canal through Khatauli and Jani escapes. The maximum concentration of ammonia was found after the confluence of Dhamola nala, which is carrying the municipal waste of Saharanpur town and has significant flow throughout the year.

1.0 INTRODUCTION

The human activities combined with changes in land use pattern like urbanisation, deforestation, agricultural and mining practices greatly influence the quality of river water. The influence of urbanisation on the water quality depends mainly on the nature of generated industrial effluents, domestic sewage and surface runoff from urban areas.

Urban settlements and growing industrial development, combined with rapidly increasing demand for water, are causing water management problems. Ninety six percent of water pollution problems in India are due to indiscriminate discharge of municipal wastes (Chaudhary, 1981). These wastes being biodegradable produce a series of directional but predictable changes in water bodies. Industrial effluents are responsible for pollution to a lesser extent but the effects produced by them may be more serious as nature is often unable to assimilate them.

Agriculture is also responsible for degrading the river water quality by generating runoff from animal husbandry units, which contain predominantly organic compounds from the use of mineral fertilizers and chemical pesticides.

The sources of pollution may be classified into point sources and non-point sources. Generally, point sources of pollution are those sources emitted to a watershed at a specific point. They usually can be directly measured and their impact can be assessed. Common point sources include municipal and industrial pollutants discharged directly to a stream. The non-point (diffuse) sources are those sources discharged to a watershed in a way that they depend upon the vagaries of the hydrologic cycle to transport them to the stream system. Nutrients, pesticides, bacteria, heavy loads of organic matter, and sediments are considered non-point source pollutants.

In most cases the sources and concentrations of non-point source pollutants are the result of land use interactions with the transport system. It is a source transport problem in which the hydrologic cycle provides the transport processes to move pollutants from the source to ground water, a stream, or a reservoir. Non-point sources can be urban, industrial, or agricultural pollutants that are distributed over the surface. The mode of transport is the flow of water across the soil surface and in stream channels and reservoirs or the flow of water through the soil profile.

In western districts of Uttar Pradesh (U.P.), mainly Saharanpur, Muzaffarnagar, Meerut and Ghaziabad, large amount of water resources are present which are being used for irrigation, fishing, or to produce fish seeds and fingerlings. These water resources are also utilized for the disposal of industrial wastes of more than 20 different industries (Verma et al., 1974). The main water resources of this region are river Hindon, Kali, Krishni, Ganga, and Yamuna with their respective tributaries and canals. Verma et al. (1974) studied the characteristics and disposal problems of various industrial effluents with reference to Indian standards. They also studied the pollution of stream Khala by the sugar factory effluent near Laksar (Verma and Shukla, 1969) and pollution of Kalinadi by industrial effluents near Mansurpur (Verma and Dalela, 1975).

In western Uttar Pradesh rapid industrial and agricultural growth has taken place during last few decades. This is likely to become manifold in near future particularly in areas like Saharanpur, Muzaffarnagar, Meerut and Ghaziabad where necessary industrial nucleus already exits. A variety of industries have already been set up in this area such as paper and pulp, sugar, chemicals, rubber, plastics, food-processing, small scale industries and cottage industries etc. Most of these industries are discharging their wastes and effluents into the nearby water course without considering its consequences. In addition to this, the municipal waste of Saharanpur, Muzaffarnagar, Meerut and Ghaziabad districts are also being discharged to the nearby rivers. On account of these outfalls of municipal and industrial wastes into the rivers, the water is subjected to varying degree of pollution.

The river Hindon, an important tributary of river Yamuna, carries pollution load from industrial towns and agricultural areas of western Uttar Pradesh. The river originates from

Upper Shivaliks (Lower Himalayas) and flows through four major districts namely Saharanpur, Muzaffarnagar, Meerut and Ghaziabad in western Uttar Pradesh and finally joins river Yamuna downstream of Delhi.

Some preliminary studies have been conducted on some selected stretches of river Hindon dealing with the pollutional aspects of the river (Rao, 1965; Verma and Mathur, 1971; Handa, 1983a,b; Joshi, 1987; Kumar and Mathur, 1991; Seth and Singhal, 1994; Kumar, 1994; Khare, 1994; Report on Hindon Monitoring Project, 1996; Kumar, 1997).

Verma et al. (1980) conducted detailed limnological studies of Hindon river in relation to fish and fisheries and reported that quality of the river water is not suitable for propagation of fish culture and related aquatic life. Singhal et al. (1987) studied the influence of industrial effluents on water quality of river Hindon. Seth (1991) carried out studies on hydrological aspects of waste disposal in the Upper Hindon basin while Kumar (1993) have investigated the bioaccumulation and concentration of toxic metals (Cd, Pb and Zn) in aquatic flora and fauna alongwith the impact of physico-chemical conditions in the river. Lokesh (1996) studied the fate of heavy metals in water and sediments of the Hindon river.

Recently, detailed studies on water and sediments of river Kali, a tributary of river Hindon, have also been carried out in the Water Quality Laboratory of National Institute of Hydrology, Roorkee (Jain, 1996; Jain and Ram, 1997a,b; Jain et al., 1997, 1998). It is reported that the river is highly polluted due to the numerous untreated municipal and industrial effluents of Muzaffarnagar district. The discharge of municipal and industrial wastes at regular intervals does not allow any self purification to occur. The important characteristic associated with the pollution of the river is the depletion of oxygen over a stretch of about 25 km. The mass balance conducted for some water quality constituents shows that changes found in load along the river may be mainly due to the contribution of non-point sources of pollution.

In view of the above observations, it is of interest to study the detailed hydro-chemical characteristics of the waste effluents being discharged into river Hindon and their impact on the river water quality. For this purpose, 8 sampling stations in the waste effluents and 13 sampling stations in the river water were selected for water quality monitoring. The data was collected for a period of two years (April 1997 to February 1999) on alternate months and the results have been discussed in this report. The present investigations would be a step towards understanding the nature of pollutants and their impact on the quality of river water.

2.0 STUDY AREA

The study area is a part of Indogangetic Plains, composed of Pleistocene and subrecent alluvium and lies between latitude 28° 30' to 30° 15' N and longitude 77° 50' to 77° 20' E. The river Hindon originates from Upper Shivaliks (Lower Himalayas) and flows through four major districts, viz., Saharanpur, Muzaffarnagar, Meerut and Ghaziabad in western Uttar Pradesh and Joins river Yamuna downstream of Delhi. (Fig. 1).

2.1 Physiography

Physiographically the area is generally flat except Siwalik hills in the north and north east. The area is devoid of relief features of any prominence except from deep garges cut by nalas and rivers flowing through the area. River Ganga in the east and river Yamuna in west bound the river.

2.2 Drainage

Regarding the drainage of the area, the rivers generally flow from north to south. These rivers during most of the non-monsoon season carry water drained into them from ground water storage. Some of the important rivers of the area are the Ganga, Yamuna, Hindon, Krishni, and the Kali. Apart from these rivers, the Western Ganga Canal and Eastern Yamuna Canal also drain the area.

2.2 Climate

The climate of the region is moderate subtropical monsoon type. Significant diurnal variations in hydrometeorological parameters like precipitation, temperature and relative humidity exist. The temperature varies from 8°C in winter to 40°C in summer. The average annual rainfall is about 1000 mm, major part of which is received during monsoon period.

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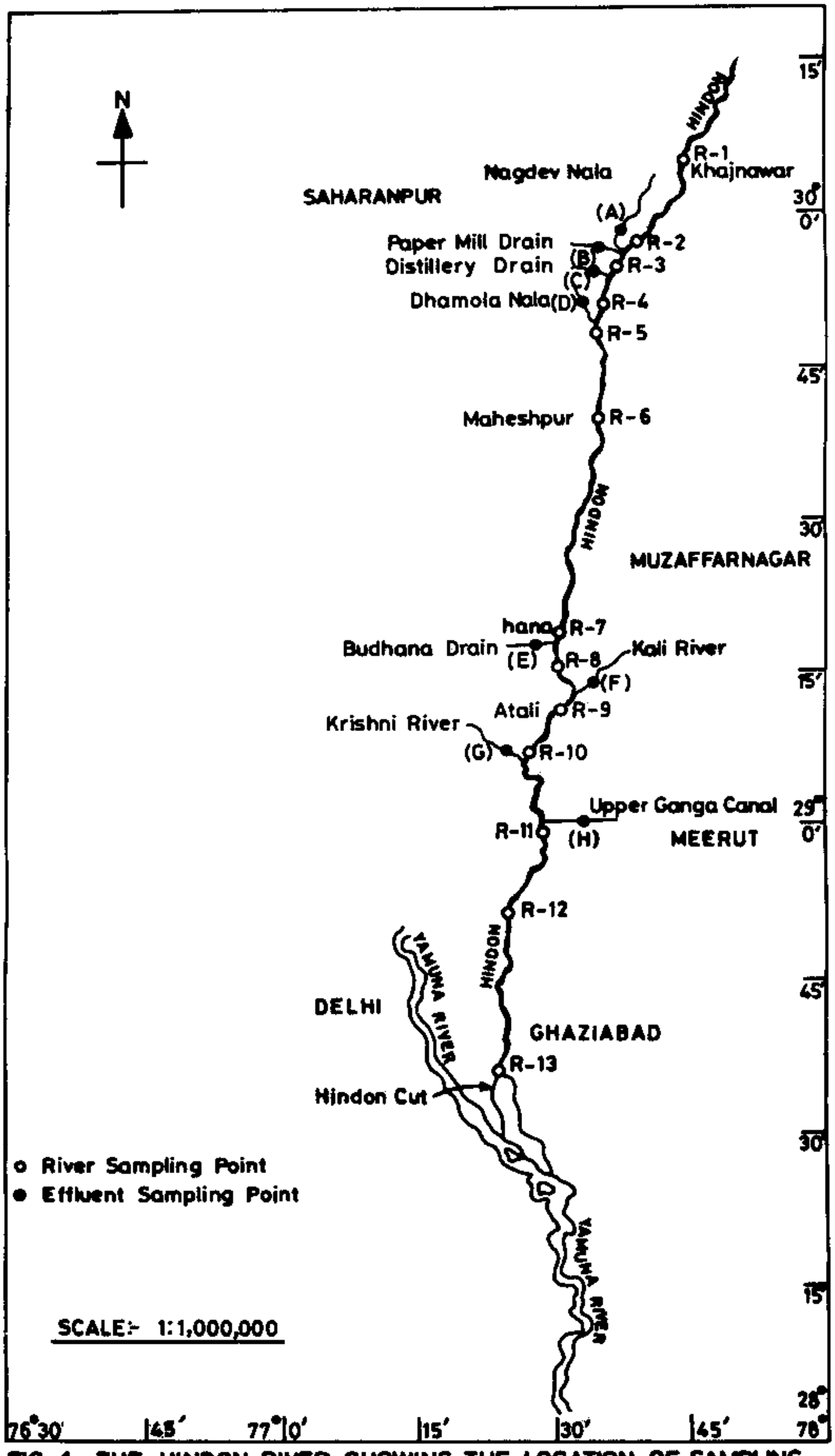


FIG. 1. THE HINDON RIVER SHOWING THE LOCATION OF SAMPLING POINTS

2.4 Geology

The area under study is a part of Indogangetic plain, which is mainly composed of pleistocene and subrecent alluvium brought down by river action from the Himalayan region. The soil type of the basin is alluvial. Lithologically, it mainly consists of clay, silt and fine to coarse sand. The deposits of sand beds of varying thickness are the main source of ground water in the area. The soils are very fertile for growing wheat, sugar cane and vegetables. However, along the sandy river coarse, fruit orchards are also common.

2.5 Landuse

The major landuse in the basin is agriculture. The basin is densely populated because of the rapid industrialization and agricultural growth during last few decades. Several industries related to paper, sugar, distillery and many small scale cottage industries related to electroplating, paper board, food processing, milk products, chemicals and rubber etc., existing in the western part of U.P., release their waste effluents into the river through various open drains. Due to the continuous pollution load, the river's environmental matrix has become very complex and need systematic study.

2.6 Source of Pollution

The main sources, which create pollution in river Hindon include municipal waste of Saharanpur, Muzaffarnagar and Ghaziabad districts and industrial effluents of sugar, pulp and paper, distilleries and other miscellaneous industries through tributaries as well as direct outfalls. In non-monsoon months the river is completely dry from its origin upto Saharanpur township. The effluents of Nagdev nala and Star Paper Mill at Saharanpur generate the flow of water in the river. The municipal wastewater generated from the Saharanpur city is discharged to the Hindon river through Dhamola nala. The industrial effluent from Cooperative Distillery also joins the river in this stretch.

The river Kali meets river Hindon on its left bank near the village of Atali, which is carrying municipal wastewater and effluents of industries located in the Muzaffarnagar city. Another tributary called Krishni meets Hindon on its right bank at village Binouli in Meerut district and carrying the waste water from sugar mill and distillery. In Ghaziabad district, downstream of Karhera village, majority of flow of river is diverted to Hindon cut canal at Mohan Nagar which outfalls into river Yamuna upstream of Okhla barrage. Thereafter river Hindon receives wastewater through Dhasna drain at village Bisrakh in Ghaziabad district. Dhasana drain is carrying the wastewater of municipal as well as industrial establishments in Ghaziabad. River Hindon further downstream flows through Kulesara and joins river Yamuna at village Tilwara.

2.7 Sampling Stations

A general plan of the sampling locations with respect to different outfalls of municipal and industrial effluents in river Hindon is shown in Fig. 1. The location of main sources of pollution has also been indicated in the same figure. In all, 8 stations in the waste effluents/tributaries and 13 stations in the river were selected for monitoring various water quality constituents. Each sampling station can be characterized as follows:

Waste effluents/tributaries:

Station A (Nagdev Nala), is located in the Nagdev nala at village Beherki, through which industrial effluents of some of the industries located in Saharanpur is discharged into the Hindon river.

Station B (Star Paper Mill), is located in the Star Paper Mill effluent drain at village Paragpur.

Station C ((Cooperative Distillery), is located in the Cooperative Distillery drain at village Yusufpur, through which distillery effluent is discharged into the river Hindon.

Station D (Dhamola Nala), is located in the Dhamola nala at village Nanandi, through which municipal waste of Saharanpur city is discharged into the Hindon river.

Station E (Budhana Drain), is located in the Budhana drain near Bus Stand, through which municipal waste of the Budhana town is discharged into the river Hindon.

Station F (Kali River), is located in the Kali river at village Ratanpuri downstream of the bridge over the Budhana-Khatouli road, through which municipal and industrial waste effluents of Muzaffarnagar city is discharged into the river Hindon.

Station G (Krishni River), is located in the Krishni river downstream of the bridge at village Barnawa, through which industrial effluent of sugar mill and distillery is discharged into the river Hindon.

Station H (Jani Escape), is located in the Upper Ganga Canal at village Jani.

River water:

Station R-1 (Khajnawar), is located in the unpolluted zone at village Khajnawar, where the water is shallow. The water at this point is very clean. The banks are high with sandy soil.

Station R-2 (Beherki), is located in the unpolluted zone above the confluence of Nagdev nala and Star Paper Mill. At this station water is only available in the monsoon months.

Station R-3 (Santagarh), is located downstream of Star Paper Mill at village Santagarh. The water is brown with oozing substratum. The pulp fibres are found lying in the bed and on the bank of the river.

Station R-4 (Nanandi), is located near village Nanandi before the confluence of Dhamola nala. The river banks are steepy with black muddy and oozing substratum which is full of pulp fibres.

Station R-5 (Sadhauli Hariya), is located near cremation ghat at village Sadhauli Hariya. The substratum is oozing and muddy. The colour of the water is brown black. The banks on both the sides are plain.

Station R-6 (Maheshpur), is located near the village of Maheshpur downstream of the bridge on Deoband road.

Station R-7 (Budhana), is located near the village of Budhana. The banks are high with sandy soil.

Station R-8 (Chandheri), is located downstream of Budhana drain at village Chandheri. The banks are high with sandy soil.

Station R-9 (Atali), is located near the village of Atali, just after the confluence of river Kali. The river is wide with high banks. The water is light brown in colour. The soil is sandy mixed with clay. A large quantity of water from Upper Ganga Canal is released into the river Kali through Khatauli escape.

Station R-10 (Barnawa), is located near the village of Barnawa downstream of bridge before the confluence of Krishni river. The water is light brown in colour. The soil is sandy mixed with clay.

Station R-11 (Daluhera), is located near the village of Daluhera downstream of the bridge after the confluence of Krishni river and Jani Escape of Upper Ganga Canal. The water is mostly clear with sandy and stony bed. This station assumes significance from the point of view of significant changes in water quality. Just upstream of this location, large quantity of water from Upper Ganga Canal is released into the river through Jani escape to supplement the discharge in Yamuna river.

Station R-12 (Surana), is located near the village of Surana. The water is mostly clear with deep pools.

Station R-13 (Mohan Nagar), is located just before Hindon cut canal, upstream of Hindon bridge at Mohan Nagar. Lot of human activities (washing and dying of cloths, disposing of ash of burnt bodies alongwith flowers and other offerings) can be seen at this point. The river is quite wide at this place. The station is important since the water regulatory works (barrage and canal diversion point) are situated here. Because of barrage across the river, the water is stagnant for long periods. A major portion of the Hindon river water is diverted into Hindon cut canal, which empties water into Agra canal at Okhla.

3.0 EXPERIMENTAL METHODOLOGY

For the pollution survey of the river, twelve sets of samples were collected from various locations on alternate months for a period of two years (April 1997 to February 1999) by dip (or grab) sampling method.

The water and wastewater samples were collected from mid stream at about 15 cm depth using standard water sampler (Hydro Bios, Germany) and subjected to various physico-chemical tests. The samples thus collected were stored in clean narrow mouth polyethylene bottles fitted with screw caps. Some parameters like temperature, pH and electrical conductance were measured on the spot by means of portable meters (HACH, USA). For other parameters, samples were preserved by adding an appropriate reagent. The samples thus preserved were stored at 4°C in sampling kits and brought to the laboratory for detailed chemical analysis. Physico-chemical analysis was conducted following standard methods (APHA, 1992; Jain and Bhatia, 1987).

All chemicals used in the study were obtained from Merck, India and were of analytical grade. Double distilled water was used throughout the study. All glass wares and other containers were thoroughly cleaned and finally rinsed with double distilled water several times prior to use.

4.0 RESULTS AND DISCUSSION

The river Hindon is flowing through Saharanpur, Muzaffarnagar, Meerut and Ghaziabad districts before outfalling in river Yamuna and receive wastewater from municipal areas of Saharanpur, Muzaffarnagar and Ghaziabad and industrial effluents of sugar, pulp and paper, distillaries and other miscellaneous industries through tributaries as well as direct outfalls.

The upper part of the river basin in Saharanpur district has a large number of industries related to paper, milk products, distillery and many small scale cottage industries related to electroplating, paper board, chemicals, and rubber, etc. The waste effluents generated from these industries are being released on lowlands and tributaries of the Hindon river system passing through the area. Much of these wastes apparently contaminate the receiving water as can be felt from the foul smell and anaesthetic colour especially in the stretches to the downstream of the outfalls of waste effluents.

The main effluent discharge in the upper part of the river system is from Star Paper Mill, Saharanpur, which is reported to be about 37,950 KLPD. The chemical analysis of the waste effluent shows that the effluent is rich in organic substances as reflected by high BOD and COD values. Beside this, the river has two drains in its upper portion, viz., Nagdev nala and Dhamola nala, which join the river Hindon near the village of Ghogreki and Sadhauli Haria, respectively. The municipal wastewater generated from the Saharanpur city is discharged to the Hindon river through Dhamola nala. There is no wastewater collection and treatment system in the city. In addition, the wastes from several small units such as textile factory, sugar factory, cigarette factory, card board factory and laundries etc. also transfer their wastes to the Hindon river through Dhamola nala. The industrial effluent from Cooperative distillery also joins the river in this stretch.

In the mid portion of the basin, Kali river carrying the municipal and industrial effluents of Muzaffarnagar district join the Hindon river near the village of Atali. River Krishni receiving wastes from sugar mill and distillery joins river Hindon near the village of Barnawa.

Besides these, some local drains from villages and towns also join the river. The characteristics of the various waste effluents/tributaries have been discussed in the following pages.

4.1 Physico-chemical Characteristics of the Wastes/Tributaries

The physico-chemical characteristics of the various waste effluents/tributaries discharged into river Hindon are given in Tables 1-8 to assess the deterioration of river water quality.

4.1.1 Characteristics of Wastewater of Nagdev Nala, Saharanpur

The Nagdev nala receive municipal wastewater of the adjoining villages and industrial wastes from some industrial units, viz., Foremost Dairies Ltd., Kailashpur, Jamuna Rubber Industries, Kailashpur, Anand Drinks (P) Ltd., Kailashpur, Gambhir Paper and Board Mill, Saharanpur, Kristan Engineering (P) Ltd., Saharanpur, Saharanpur Leather Board and Tannery (P) Ltd., Saharanpur, Rana Steel Rolling Mills, Saharanpur, Dainy Dairy and Food Engineers (P) Ltd., Saharanpur, Sidh Solvent Extraction (P) Ltd., Saharanpur, and Kamdhenu Paper and Board Mill (P) Ltd., Saharanpur. The physico-chemical characteristics of the composite waste effluent of Nagdev nala have been studied and are given in Table 1.

The pH of the waste effluent of the Nagdev nala varies from 7.4 to 8.4 indicating alkaline nature of the wastewater. The maximum value of dissolved oxygen was found to be 4.1 mg/L. However, in summer months the dissolved oxygen content was less than 1.0 mg/L. The BOD of the wastewater ranges from 12 to 35 mg/L with higher values in summer months. The COD values vary from 18 to 54 mg/L. High values of BOD and COD indicates organic contamination in the wastewater.

Table 1. Physico-chemical characteristics of wastewater of Nagdev nala

Characteristic	Min	Max	Average
PH	7.4	8.4	7.8
Conductance, µS/cm	508	1180	850
TDS, mg/L	325	755	544
Dissolved Oxygen, mg/L	0.9	4.1	2.1
BOD, mg/L	12	35	23
COD, mg/L	18	54	35
Alkalinity, mg/L	142	390	294
Hardness, mg/L	128	385	276
Chloride, mg/L	15	44	30
Sulphate, mg/L	21	56	31
Nitrate, mg/L	3.4	5.3	4.3
Ammonia, mg/L	1.1	2.8	1.7
Phosphate, mg/L	0.06	1.11	0.32
Sodium, mg/L	43	85	60
Potassium, mg/L	15	40	20
Calcium, mg/L	33	90	72
Magnesium, mg/L	11	39	23

4.1.2 Characteristics of Star Paper Mill Effluent, Saharanpur

The Star Paper Mill is located on the north-east of the Saharanpur railway station and manufactures all varieties of writing, printing, craft wrapping and wall papers. The raw materials used in the factory include wood, bamboo, jute sticks, straw, hemp, sawai and sabal grass. The important chemicals used by most of the paper and pulp mills are sodium sulphate, sodium hydroxide, sodium sulphide, sodium carbonate, calcium hypochlorite and magnesium bisulphite. Obviously, wastewater containing various amounts of these chemicals may be hazardous to aquatic life. The description of the various processes and the characteristics of the waste effluents generated from different plant operations of the Star Paper Mill, Saharanpur, have been reported by Verma et al. (1980). The wastes from different units flow separately for some distance but finally join at one point and form the combined waste of pulp and paper mill.

The combined effluent from the factory is discharged into the river through an open channel. The channel is about 3 km in length and opens on the right bank of river Hindon near the village of Paragpur. The waste is discharged with a considerable force. Due to the presence of caustic soda and other alkaline mixtures, a soapy and fibrous froth is continuously generated at the point of discharge. A characteristics smell of sulfate mercaptan and sulphide was very strong in this area. Dirty black subsoil with foul smelling is seen in the region. The effluent imparts a dark brown colour to the river water. The physico-chemical characteristics of the combined waste effluent are given in Table 2.

The combined waste effluent coming from various plant operations is usually brownish and has pungent or irritating smell. It is highly alkaline in nature, the pH being 8.1 to 8.9. The dissolved solids vary from 1381 to 1550 mg/L. The content of organic matter is quite high, the BOD of the effluent vary from 190 to 310 mg/L and COD from 270 to 464 mg/L. The discharge of the composite effluents resulted in depletion of dissolved oxygen (0.4 to 1.2), objectionable odour and colour due to lignin, the formation of bottom deposits and formation of

Table 2. Physico-chemical characteristics of Star Paper Mill effluent

Characteristic	Min	Max	Average
PH	8.1	8.9	8.4
Conductance, µS/cm	2158	2422	2281
TDS, mg/L	1381	1550	1460
Dissolved Oxygen, mg/L	0.4	1.2	0.8
BOD, mg/L	190	310	233
COD, mg/L	270	464	339
Alkalinity, mg/L	250	310	268
Hardness, mg/L	460	564	498
Chloride, mg/L	330	367	349
Sulphate, mg/L	270	330	299
Nitrate, mg/L	3.7	6.1	4.5
Ammonia, mg/L	2.4	9.1	5.6
Phosphate, mg/L	0.49	2.80	1.52
Sodium, mg/L	299	339	317
Potassium, mg/L	36	48	42
Calcium, mg/L	137	157	146
Magnesium, mg/L	27	45	33

slime and foam. The concentration of sodium and sulphate are very high due the presence of these constituents (sodium sulphate, sodium sulphite, sodium carbonate, calcium hypochlorite and magnesium bisulphate etc.) in the raw materials used in the manufacture of pulp and paper. The concentration of sulphate varies from 270 to 330 mg/L and that of sodium from 299 to 339 mg/L. Rao and Rao (1985) also reported high concentration of sodium in the paper and pulp mill effluent of Bhadrachalam area of A.P. Dhaneshwar et al. (1970) studied the characteristics of the effluent from pulp and paper mill located on the Hooghly river in West Bengal and reported that the composite effluent being disposed from the mills contain high BOD, COD and lignin.

4.1.3 Characteristics of Effluent of Cooperative Distillery, Saharanpur

The physico-chemical characteristics of the waste effluent of Cooperative distillery are given in Table 3. The distillery effluent resulting from cane molasses based alcohol industry is one of the highly polluting industrial effluents. The pH of the distillery effluents vary from 5.1 to 5.8 indicating acidic nature of the effluent. The total dissolved solids vary from 812 to 975 mg/L. The BOD and COD of the distillery effluent was found to be very high indicating very high pollution potential of distillery effluent on the river water quality. High values of BOD and COD in the distillery effluents were also reported by many authors at other places (Berchmans and Vijayavalli, 1989; Chauhan, 1991; Rao and Viraraghavan, 1985; Shankar et al., 1986). Nemerow (1971) has also reported that the effluent from distilleries contain large amount of biologically decomposed dissolved organic matter.

4.1.4 Characteristics of Wastewater of Dhamola Nala, Saharanpur

Another sources of pollution in Hindon river are the city sewage of Saharanpur and several other wastes from textile mill, sugar mill, cigarette factory, card board factory,

Table 3. Physico-chemical characteristics of Cooperative Distillery effluent

Characteristic	Min	Max	Average
PH	5.1	5.8	5.5
Conductance, μS/cm	1269	1524	1401
TDS, mg/L	812	975	896
Dissolved Oxygen, mg/L	1.1	2.4	1.6
Alkalinity, mg/L	305	366	328
Hardness, mg/L	336	480	414
Chloride, mg/L	76	105	91
Sulphate, mg/L	148	180	162
Nitrate, mg/L	5.1	7.8	6.4
Ammonia, mg/L	2.2	7.8	4.8
Phosphate, mg/L	0.31	1.46	0.79
Sodium, mg/L	105	136	121
Potassium, mg/L	29	52	38
Calcium, mg/L	80	120	102
Magnesium, mg/L	26	61	39

laundary and other small industrial units which discharge their waste effluents in Dhamola nala which in turn opens into Hindon river. The water samples from the Dhamola nala were collected from the village of Nanandi. At this point domestic animals (cows and baffalos) take bath in the wastewater. The physico-chemical characteristics of the wastewater of Dhamola nala are given in Table 4.

It is clear from the results, that the wastewater of Dhamola nala contains large amount of solids, moderate BOD and COD. It also contains toxic substances like ammonia and suspended solids. The pH of the wastewater varies from 7.1 to 8.4 indicating alkaline character of the wastewater. The dissolved oxygen content in the wastewater is almost nil throughout the year. The BOD and COD of the wastewater ranges from 150 to 272 and 230 to 385 mg/L respectively. The ammonia content in the wastewater is also very high and varies from 10 to 17 mg/L.

4.1.5 Characteristics of Wastewater of Budhana Drain, Budhana

The municipal wastewater of Budhana town is discharged into river Hindon near Budhana Bus Stand. The physico-chemical characteristics of the wastewater of Budhana drain are given in Table 5. The contents of dissolved solids are much higher in the Budhana drain (888-1326 mg/L) as compared to Dhamola nala (465-690 mg/L). The pH of the wastewater varies from 7.1 to 8.3 indicating alkaline character of the wastewater. The flow in the drain is negligible as compared to Dhamola nala but the organic load is higher than that of Dhamola nala. The BOD and COD of the wastewater ranges from 150 to 280 and 210 to 435 mg/L respectively. The ammonia content in the wastewater is also very high and varies from 30 to 44 mg/L. These observations indicate that the Budhana drain contain concentrated wastes and there is not much dilution of the wastewater.

Table 4. Physico-chemical characteristics of wastewater of Dhamola nala

Characteristic	Min	Max	Average
PH	7.1	8.4	7.6
Conductance, µS/cm	727	1078	916
TDS, mg/L	465	690	586
Dissolved Oxygen, mg/L	0.8	1.1	0.9
BOD, mg/L	150	272	192
COD, mg/L	230	385	274
Alkalinity, mg/L	234	380	309
Hardness, mg/L	210	331	290
Chloride, mg/L	21	56	41
Sulphate, mg/L	29	48	36
Nitrate, mg/L	2.2	4.4	3.2
Ammonia, mg/L	10	17	13
Phosphate, mg/L	0.86	3.56	2.07
Sodium, mg/L	52	88	74
Potassium, mg/L	8	25	18
Calcium, mg/L	56	88	72
Magnesium, mg/L	17	35	27

Table 5. Physico-chemical characteristics of wastewater of Budhana drain

Characteristic	Min	Max	Average
PH	7.1	8.3	7.4
Conductance, µS/cm	1388	2072	1865
TDS, mg/L	888	1326	1193
Dissolved Oxygen, mg/L	0.4	2.2	1.6
BOD, mg/L	150	280	217
COD, mg/L	210	433	320
Alkalinity, mg/L	470	630	576
Hardness, mg/L	316	482	417
Chloride, mg/L	60	156	127
Sulphate, mg/L	45	80	63
Nitrate, mg/L	3.1	7.5	4.8
Ammonia, mg/L	30	44	35
Phosphate, mg/L	1.41	5.90	4.45
Sodium, mg/L	138	248	208
Potassium, mg/L	43	72	56
Calcium, mg/L	80	122	100
Magnesium, mg/L	24	48	41

4.1.6 Characteristics of Kali and Krishni Rivers

The Muzaffarnagar portion of the catchment is not directly contributing municipal and/or industrial effluent to the river Hindon. Industries in Muzaffarnagar are discharging their waste effluent either in river Kali or river Krishni. The river Kali is subjected to varying degree of pollution caused by numerous untreated outfalls of municipal and industrial effluents. The main sources which create pollution in river Kali include municipal waste of Muzaffarnagar city, industrial waste from variety of industries (such as steel, rubber, ceramic, chemicals, plastic, dairy, pulp and paper and laundries) and Mansurpur sugar mill and distillery waste. The wastes of Shamli sugar factory and distillery pollute the river Krishni. The waste effluents stagnate in the river for a long time, because of which the biological action starts and obnoxious condition soon develop in the region. This septic condition results in the production of hydrogen sulphide gas imparting black colour to the river water. River Kali opens into river Hindon near the village of Atali and river Krishni near Shardhana. The water samples for analysis were taken just before the two rivers open into the Hindon river. The physico-chemical characteristics of the water of the two rivers are given in Tables 6 and 7, respectively.

The pH values of the two rivers indicate that there is not much variation in pH of the two rivers. The average value of conductivity of the two river indicate that water of river Krishni is having high mineral content as compared to Kali river water. The BOD and COD values were quite high ranging from 375 to 550 and 575 to 750 mg/L respectively in Krishni river. The same were found to be in the range 40 to 75 and 58 to 105 mg/L in the Kali river. Such high values of BOD and COD clearly indicate large scale disposal of untreated industrial effluent in the two rivers. The lower values of BOD and COD in the Kali river is due to the fact that a large quantity of water from Upper Ganga Canal is released into the river Kali through Khatauli escape. It can be observed from the results that the discharge of the two rivers in the Hindon river is hazardous due to the high values of BOD, COD and other constituents.

Table 6. Physico-chemical characteristics of Kali river

Characteristic	Min	Max	Average
PH	7.3	7.8	7.5
Conductance, µS/cm	727	973	855
TDS, mg/L	465	623	547
Dissolved Oxygen, mg/L	0.3	5.9	2.2
BOD, mg/L	40	75	52
COD, mg/L	58	105	72
Alkalinity, mg/L	260	340	296
Hardness, mg/L	201	258	237
Chloride, mg/L	23	55	38
Sulphate, mg/L	10	34	16
Nitrate, mg/L	3.5	7.0	5.4
Ammonia, mg/L	0.5	3.6	2.2
Phosphate, mg/L	0.36	1.40	0.65
Sodium, mg/L	60	95	77
Potassium, mg/L	20	38	25
Calcium, mg/L	54	65	60
Magnesium, mg/L	16	24	21

Table 7. Physico-chemical characteristics of Krishni river

Characteristic	Min	Max	Average
PH	7.3	8.4	7.6
Conductance, µS/cm	662	1387	1019
TDS, mg/L	424	888	652
Dissolved Oxygen, mg/L	2.3	2.4	2.35
BOD, mg/L	375	550	438
COD, mg/L	575	750	633
Alkalinity, mg/L	174	488	340
Hardness, mg/L	181	399	284
Chloride, mg/L	13	96	53
Sulphate, mg/L	20	44	34
Nitrate, mg/L	3.2	7.5	5.1
Ammonia, mg/L	1.2	3.6	2.6
Phosphate, mg/L	0.31	2.60	1.29
Sodium, mg/L	42	123	86
Potassium, mg/L	13	55	28
Calcium, mg/L	49	112	75
Magnesium, mg/L	13	34	24

4.1.7 Characteristics of Upper Ganga Canal at Jani Escape

The physico-chemical characteristics of the water of Upper Ganga Canal are given in Table 8. The pH of the canal water varies from 7.2 to 7.9 indicating alkaline nature of the canal water. The conductivity values are quite normal and vary from 395 to 488 μS/cm. The total dissolved solids vary from 253 to 312 mg/L. The dissolved oxygen content in the water is quite appreciable and varies from 7.0 to 9.0 mg/L. The BOD and COD content ranges from 4.5 to 7.3 and 6.2 to 9.3 mg/L respectively. The water of the Upper Ganga Canal is released into river Hindon through Jani escape to supplement the flow in the Yamuna river.

4.2 Effect of Waste Effluents on River Water Quality

For disposal of municipal and industrial wastes, a suitable source is essential. Natural rivers and streams by far serve as the most suitable source for this purpose. However, indiscriminate waste disposal results in serious pollution problem affecting the health of the river. The river Hindon is a major tributary of river Yamuna and flows in western districts of U.P. The local fishermen mainly use it for procuring fish, fish-seeds and fingerlings of several crops. The river is also utilized to flush the water of river Yamuna through Hindon cut canal in Delhi. Villagers, inhabiting on the banks of the river, also utilize the water of this river for agricultural purposes. However, the water of the river is highly polluted by the discharge of the indiscriminate wastes from different sources. The effluents of pulp and paper mill are directly discharged into the river while the wastewater of the textile factory, sugar factory and gatta factory alongwith city sewage of Saharanpur town is discharged into the river through Dhamola nala. The Muzaffarnagar portion of the catchment is not directly contributing municipal and industrial effluent to the river Hindon. Industries in Muzaffarnagar are discharging their industrial effluents either in river Kali or river Krishna, which in turn goes to the river Hindon. In addition, several other toxic chemical substances are also discharged into this river through

Table 8. Physico-chemical characteristics of Upper Ganga Canal

Characteristic	Min	Max	Average
PH	7.2	7.9	7.5
Conductance, µS/cm	395	488	438
TDS, mg/L	253	312	281
Dissolved Oxygen, mg/L	7.0	9.0	8.1
BOD, mg/L	4.5	7.3	5.8
COD, mg/L	6.2	9.3	7.7
Alkalinity, mg/L	110	145	125
Hardness, mg/L	80	117	96
Chloride, mg/L	19	35	26
Sulphate, mg/L	17	31	23
Nitrate, mg/L	1.9	3.9	2.5
Ammonia, mg/L	0.1	0.2	0.13
Phosphate, mg/L	0.06	0.52	0.19
Sodium, mg/L	38	63	49
Potassium, mg/L	11	15	13
Calcium, mg/L	20	32	25
Magnesium, mg/L	5	10	8

various industrial units. The city of Ghaziabad is discharging its wastewater to the river Hindon through Dhasna drain. All the three cities have no wastewater collection and treatment system.

The water quality of the river Hindon was monitored at 13 locations (R-1 to R-13) on the basis contribution of pollution load by point sources (Fig. 1). The variations of various constituents at different sampling locations are shown in Fig. 2 to 18.

The river Hindon arises in the Saharanpur district from Shivalik hills. In non-monsoon months the river is completely dry from its origin upto Saharanpur town. The flow of water in the river is generated by the effluents of Nagdev nala and Star Paper Mill. In the course of its flow, it receives the municipal wastewater from Saharanpur and Muzaffarnagar towns. The first tributary, i.e., western Kali meets river Hindon on its left bank near the village of Atali, which is carrying the municipal and industrial wastewater of Muzaffarnagar district. Another tributary, Krishna, meets river Hindon on its right bank near the village of Barnawa in Meerut district and carrying the wastewater from sugar industries. In Ghaziabad district, downstream of Karhera village, majority of flow of river is diverted to Hindon cut canal at Mohan Nagar which outfalls into river Yamuna upstream of Okhla barrage.

The water of Hindon has been put to the non-organized use only. The river has not been abstracted at any place in its course of flow for organized water supply.

The river water is clear and odourless at station R-1 and R-2 while that at station R-3 to R-6 has foul and pungent organic smell. The odour becomes much more pronounced in summer months. In addition to the floating froth and foam, the river water also becomes brown in colour owing to the discharge of effluent of pulp and paper factory. The water is dark brown at station R-3 and R-4, becoming light brown with black tinge at station R-5 and R-6. The brown colour of the water decreases the penetration of light and affects the spectrum of the wavelength, which penetrates into the river water. The change in the wavelength and its reduction in intensity limits the growth of phytoplankton and other aquatic plants which are of great importance, not only because they form an important link in the food-chain cycle of aquatic habitats, but also they produce oxygen by photosynthetic activity which plays an important role in reaeration of stream and in natural self-purification process.

The pH values at different sampling stations are shown in Fig. 2. The determination of pH serves as a valuable index which shows whether the waste is acidic or alkaline in nature. It also gives some idea about the extent of pollution. The pH of the river water was always found towards alkaline side except at station R-4, where the river water is acidic in nature. The pH at station R-1 and R-2 ranges between 7.7-8.3 and 7.4-8.3 respectively. At station R-4, the pH value gets reduced due to the mixing of distillery effluent and then slightly increased from station R-5 to R-7 after the discharge of wastewater from Dhamola nala. The values of pH show almost the same trend in the downstream section in between the stations R-9 to R-13. The variation in pH at different sampling station is well within the range of tolerance by the fish.

The contents of total dissolved solids vary between 210 to 263 mg/L in the upstream section at village Khajnawar. The same were found to vary from 654 to 1233 and 599 to 1667 mg/L at station R-3 and R-4 respectively, mainly due to the mixing of effluent from Star Paper Mill and Cooperative distillery. The excess dissolved solids create an imbalance and causes suffocation to fish even in the presence of high dissolved oxygen. The dissolved solids decreased considerably at station R-5, R-6 and R-7 due to the dilution effect of the Dhamola nala, which has significant flow throughout the year. A slight increase in dissolved solids was observed at station R-8 due to the discharge of wastewater from Budhana drain and then shows a slight decreasing trend in the downstream section of the river.

The dissolved oxygen content in the upstream section at Khajnawar was quite satisfactory (6.7 to 9.0 mg/L), but a critical situation was observed at station R-3 and R-4. The sudden fall in dissolved oxygen at station R-3 and R-4 is attributed to the discharge of untreated municipal and industrial wastes from Nagdev nala, Star Paper Mill and Cooperative distillery. However, the distribution of dissolved oxygen at all the station is not the same. The dissolved oxygen content gets reduced to nil at station R-3 and R-4 during summer months so that complete anaerobic condition is developed. This indicates that the wastewater generated from the industries is only flowing in the river. The DO values gradually improve from station R-5 to R-8 due to reaeration and photosynthesis.

The river Kali is another polluted stream carrying wastewater of municipal and industrial establishments of Mnuzaffarnagar district and meets river Hindon at village Atali (Station R-9) and accelerates the flow of the river Hindon. It was observed that quite a substantial amount of water is discharged in river Kali from the Upper Ganga Canal at Khatauli. The level of dissolved oxygen in river Hindon after confluence with river Kali deteriorates further and observed to be nil during summer months. At village Barnawa, the another tributary Krishna join river Hindon, which flow only during the sugar crushing season and remains stagnant for the rest of the year. In this stretch (Station R-9 to R-13), the dissolved oxygen shows a large variation depending on the flow in the river. During summer months the dissolved oxygen even gets reduced to nil at station R-9 and R-10. The quality of the river water in this stretch is controlled by the discharge of water from the Upper Ganga Canal through Khatauli and Jani escapes.

The BOD values vary from 0.7 to 1.6 mg/L in the upstream section at the village of Khajnawar and from 0.8 to 1.2 mg/L at the village of Beherki. However, sudden rise in BOD values were observed at stations R-3 and R-4 due to the discharge of paper mill and distillery effluents. The BOD values at the two stations vary from 44 to 172 and 164 to 294 mg/L respectively. The higher values of BOD observed at station R-3 and R-4 indicate high degree of organic pollution in this stretch of the river. The effluent of pulp and paper mill and distillery added high concentration of organic matter to the river, which was responsible for remarkable decrease in DO alongwith increase in BOD, COD and TDS alongwith other factors. From station R-4 to R-8, the oxygen condition improves significantly with the lowering of BOD values. At upstream of village Atali, the river Hindon ceases to flow due to significant abstraction for irrigation by the farmers in the course. At village Atali (Station R-9) the river Kali joins river Hindon and the water quality of river Hindon is controlled by the inputs of river Kali. The river Kali also receives significant amount of water from Upper Ganga Canal through Khatauli escape. At village Atali the values of BOD and COD rises while DO decreases due to the discharge of municipal wastes from Budhana drain and Kali river into the river Hindon. From station R-9 to

R-13, the BOD values shows a slight decreasing trend due to reaeration.

The COD values ranges from 1.4 to 2.8 mg/L in the upstream section at the village of Khajnawar and from 0.7 to 3.2 mg/L at the village of Beherki. However, sudden rise in COD values were observed at stations R-3 and R-4 due to the discharge of paper mill and distillery effluents. The COD values at the two stations vary from 78 to 274 and 230 to 404 mg/L respectively. The higher values of COD observed at station R-3 and R-4 indicate high degree of organic pollution in this stretch of the river. The effluent of pulp and paper mill and distillery added high concentration of organic matter to the river, which was responsible for remarkable decrease in DO alongwith increase in COD values. From station R-4 to R-8, the oxygen condition improves significantly due to reaeration with the lowering of COD values. At station R-9 again the values of COD rises while DO decreases due to the confluence of Budhana drain and river Kali into the river. From station R-9 to R-13, the COD values shows a slight decreasing trend due to the reaeration and dilution effect of water from Upper Ganga Canal.

The concentration of ammonia in the upstream section at village Khajnawar is quite low (< 1 mg/L). However the content of ammonia increases significantly at Station R-5 due to the confluence of Dhamola nala, which is carrying the municipal waste of Saharanpur town and has significant flow throughout the year. The maximum value of ammonia observed at Station R-5 was found to be 16 mg/L, which has reduced to about 1 mg/L at Station R-7. Again at Station R-8, the concentration of ammonia increases upto 7.8 mg/L due to the confluence of Budhana drain, which carries municipal waste of Budhana town.

The maximum concentration of sulphate was found to be 250 mg/L at Station R-3 after the confluence of paper mill waste. The highest concentration of sulphate at Station R-3 is due the discharge of paper mill waste, which uses sodium sulphate as raw material in the manufacture of pulp and paper.

The maximum concentration of phosphate was found to be 3.54 mg/L at Station R-8 after the confluence of wastewater from Budhana drain. This is due to the presence of soapy mixtures in the wastewater, which contain phosphate as one of the important constituents. The chemical characteristics in respect of other parameters like alkalinity, hardness, chloride, nitrate, sodium, potassium, calcium and magnesium are presented in the figures.

The river is sluggish except during high flow period. It is evident that during high flow period, there is no significant effect of pollution owing to very high dilution of the effluent, but once the water level falls, there is visible sign of pollution specifically during summer months.

Fig. 2. Monthly variation of pH at different sampling points

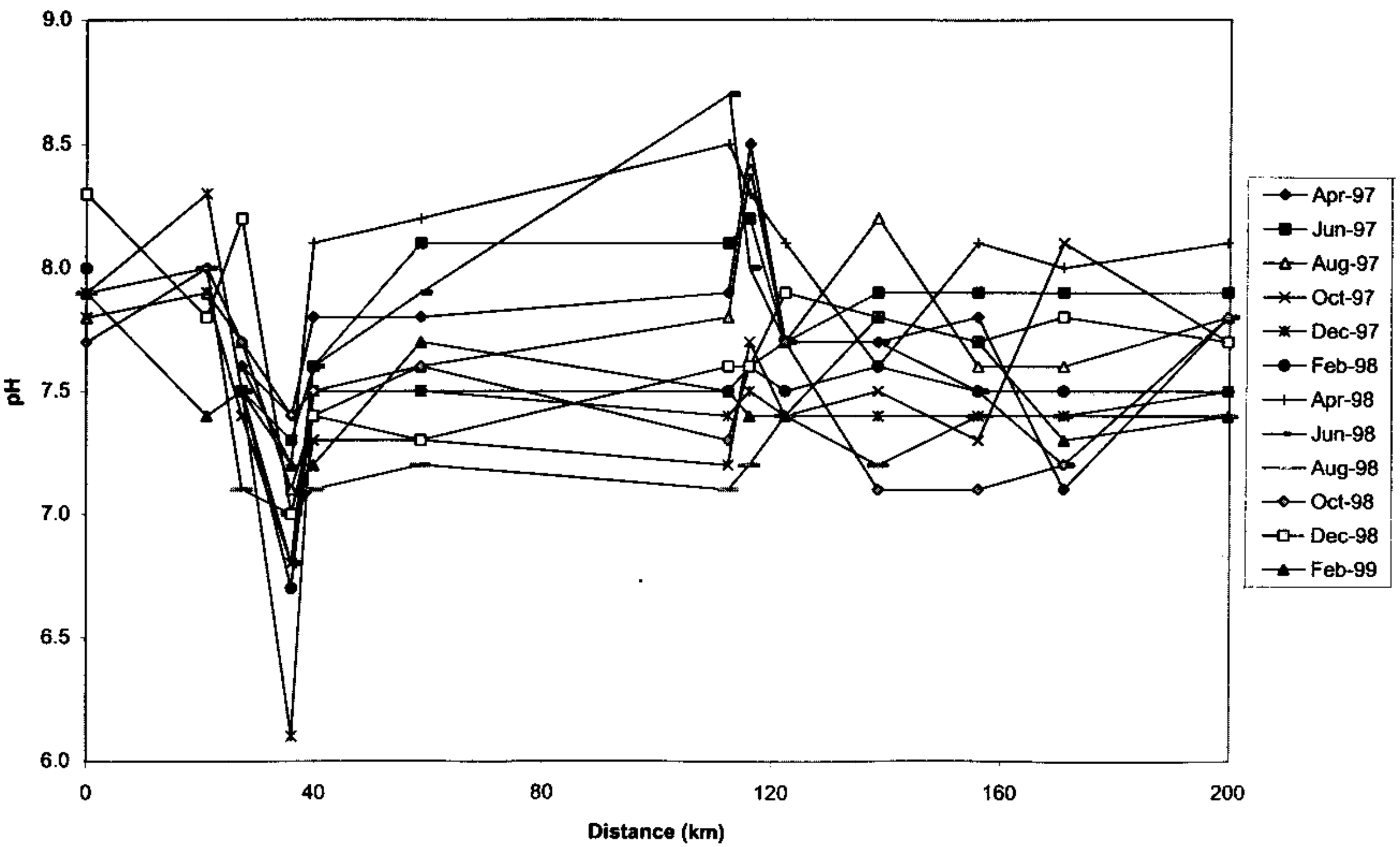


Fig. 3. Monthly variation of conductivity at different sampling points

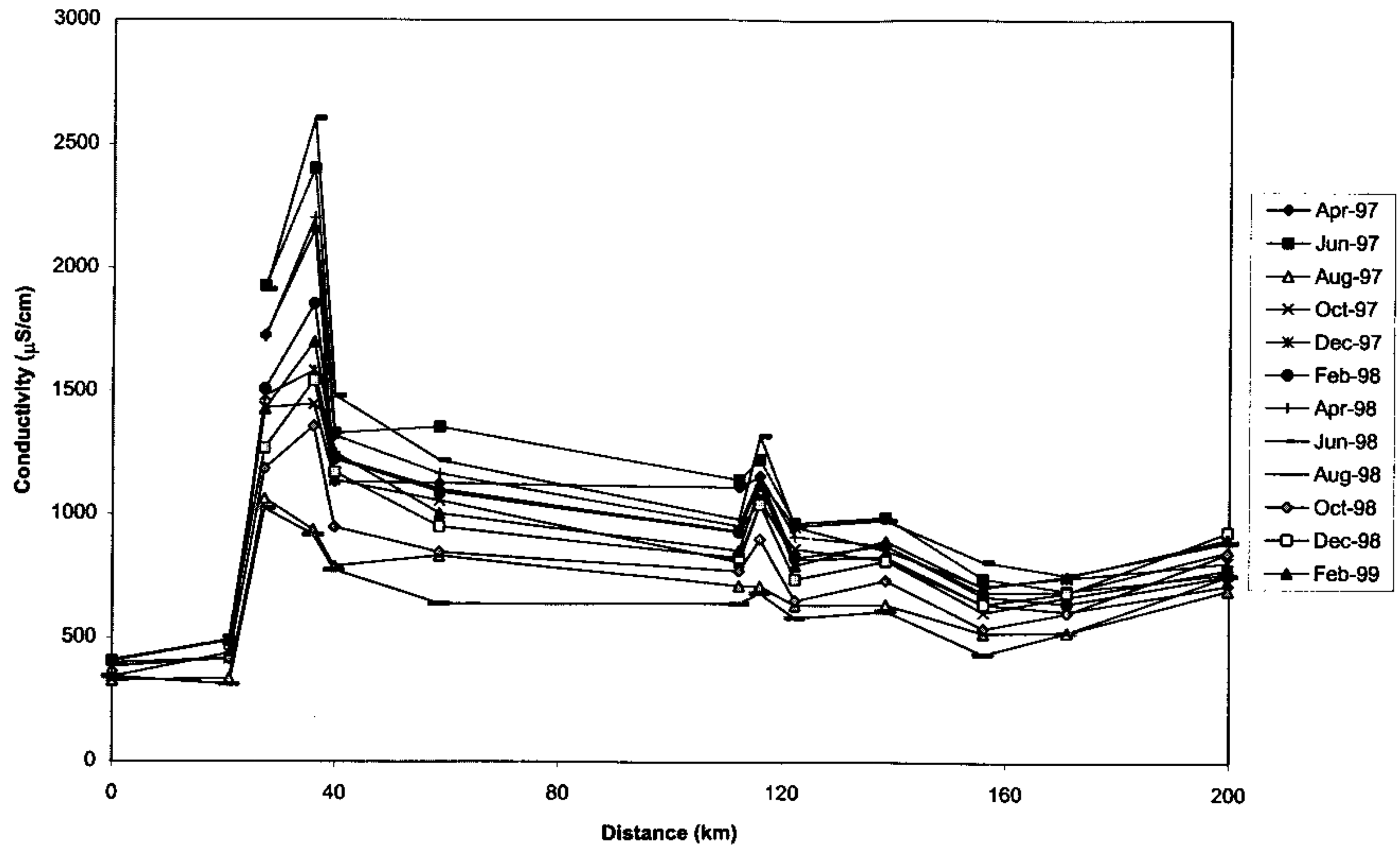


Fig.4. Monthly variation of TDS at different sampling points

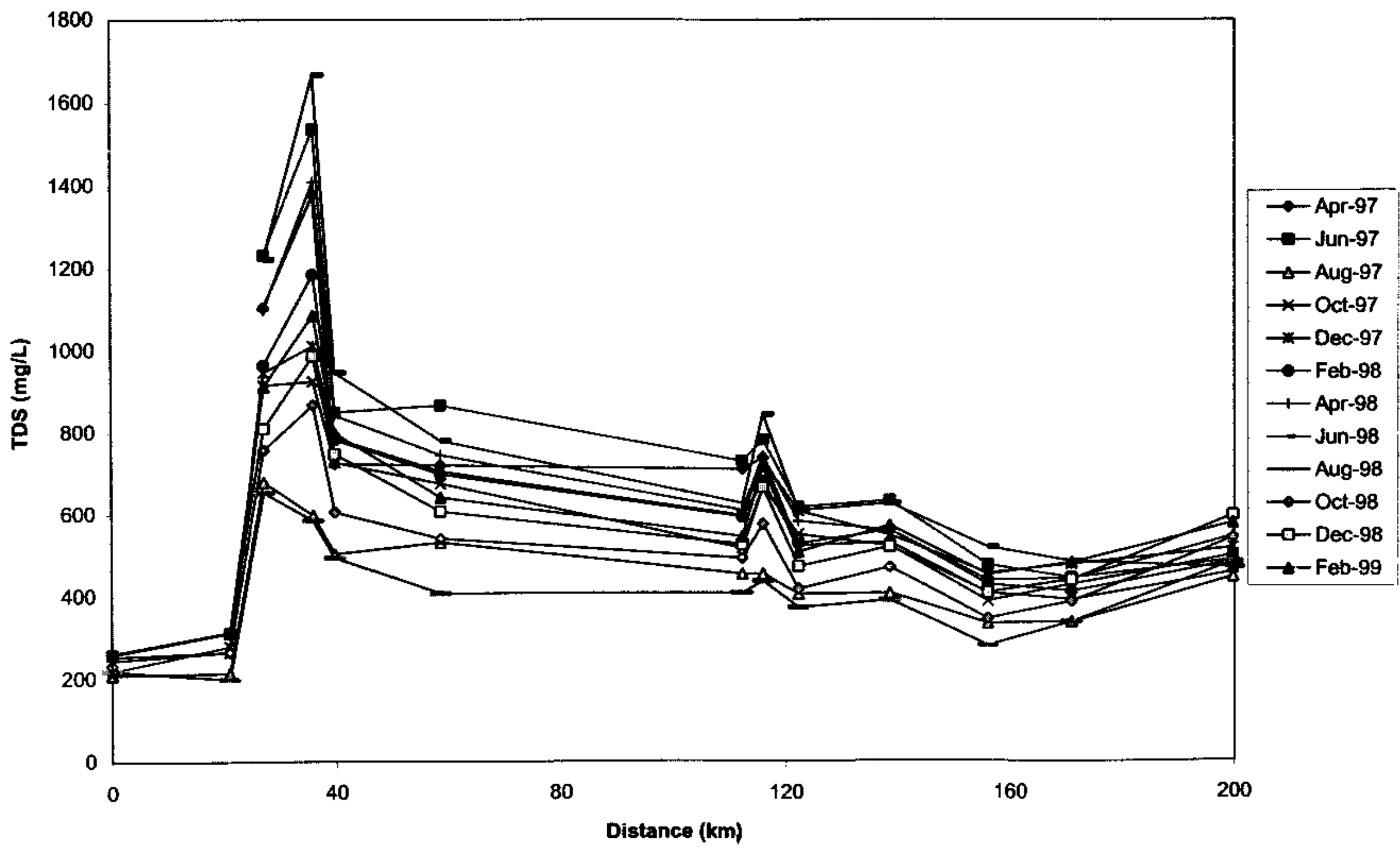


Fig. 5. Monthly variation of DO at different sampling points

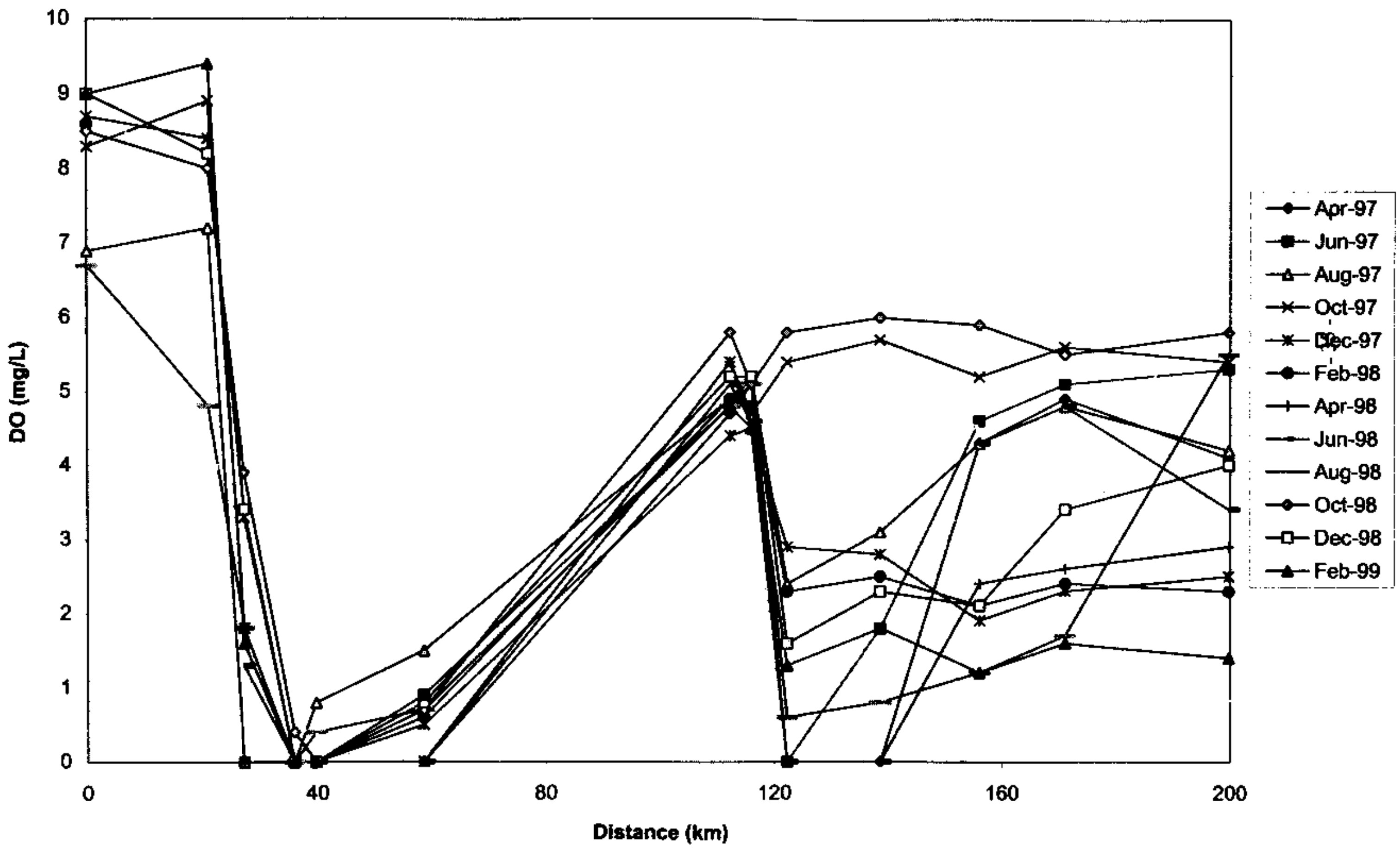


Fig. 6. Monthly variation of BOD at different sampling points

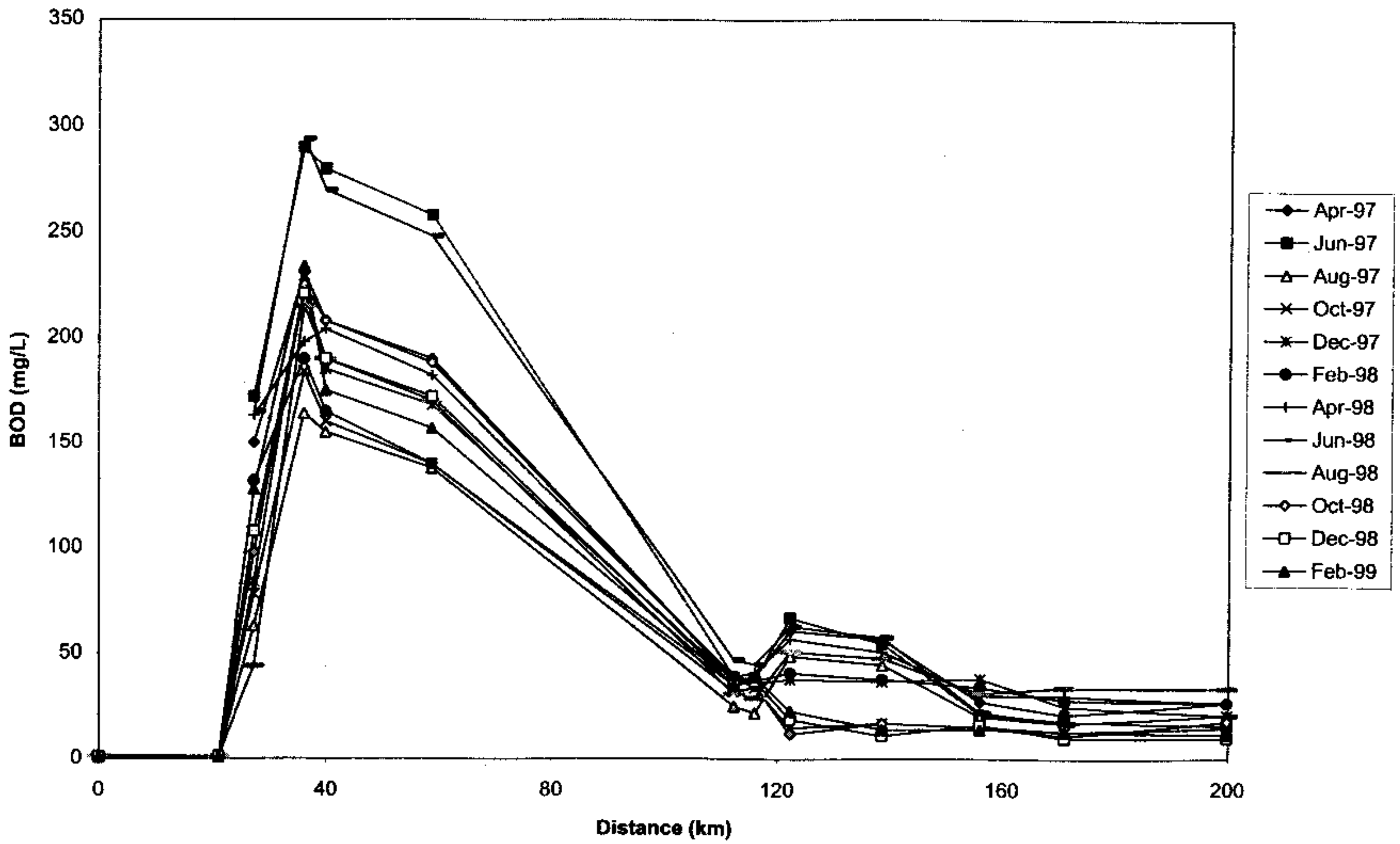


Fig. 7. Monthly variation of COD at different sampling points

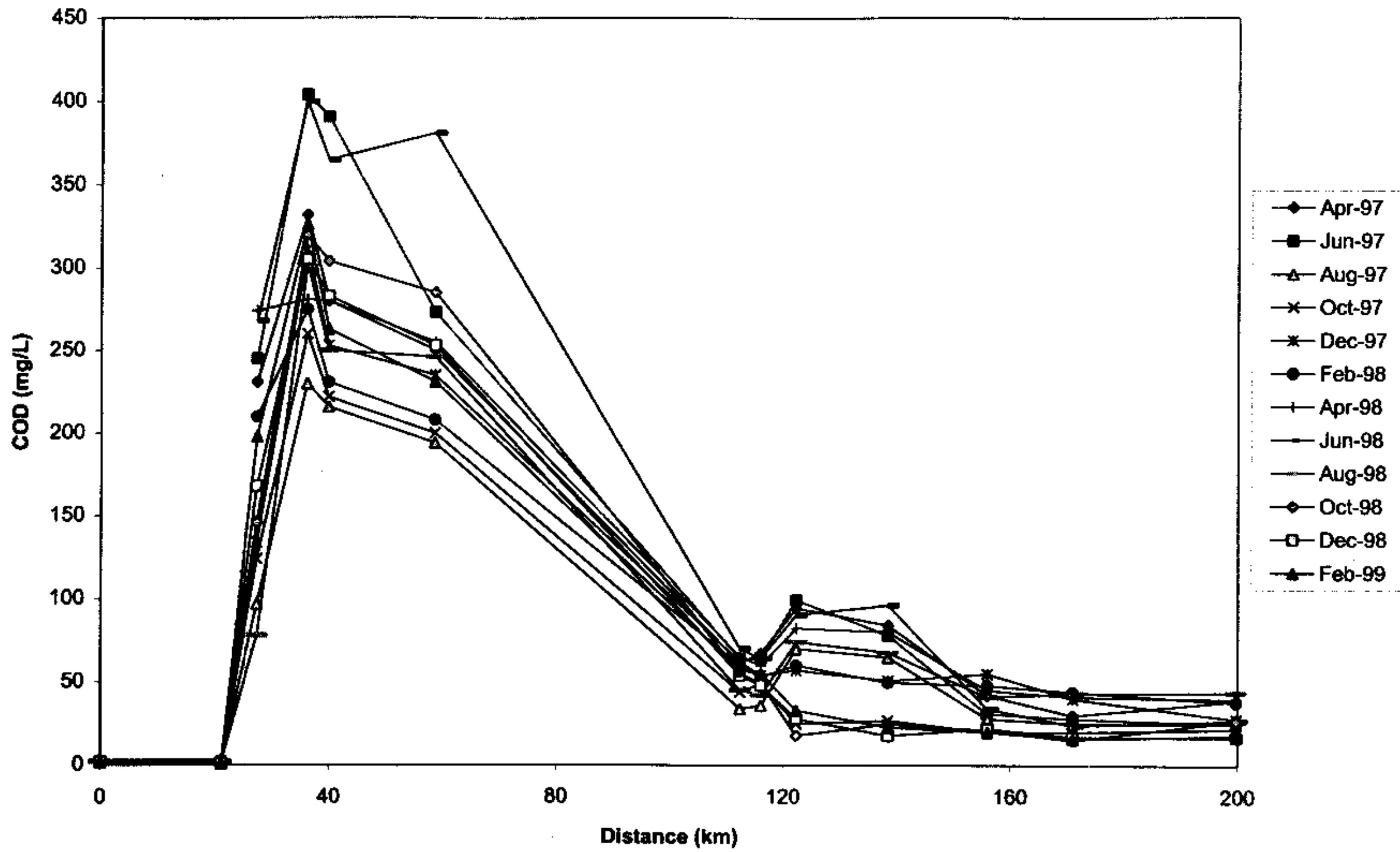


Fig. 8. Monthly variation of alkalinity at different sampling points

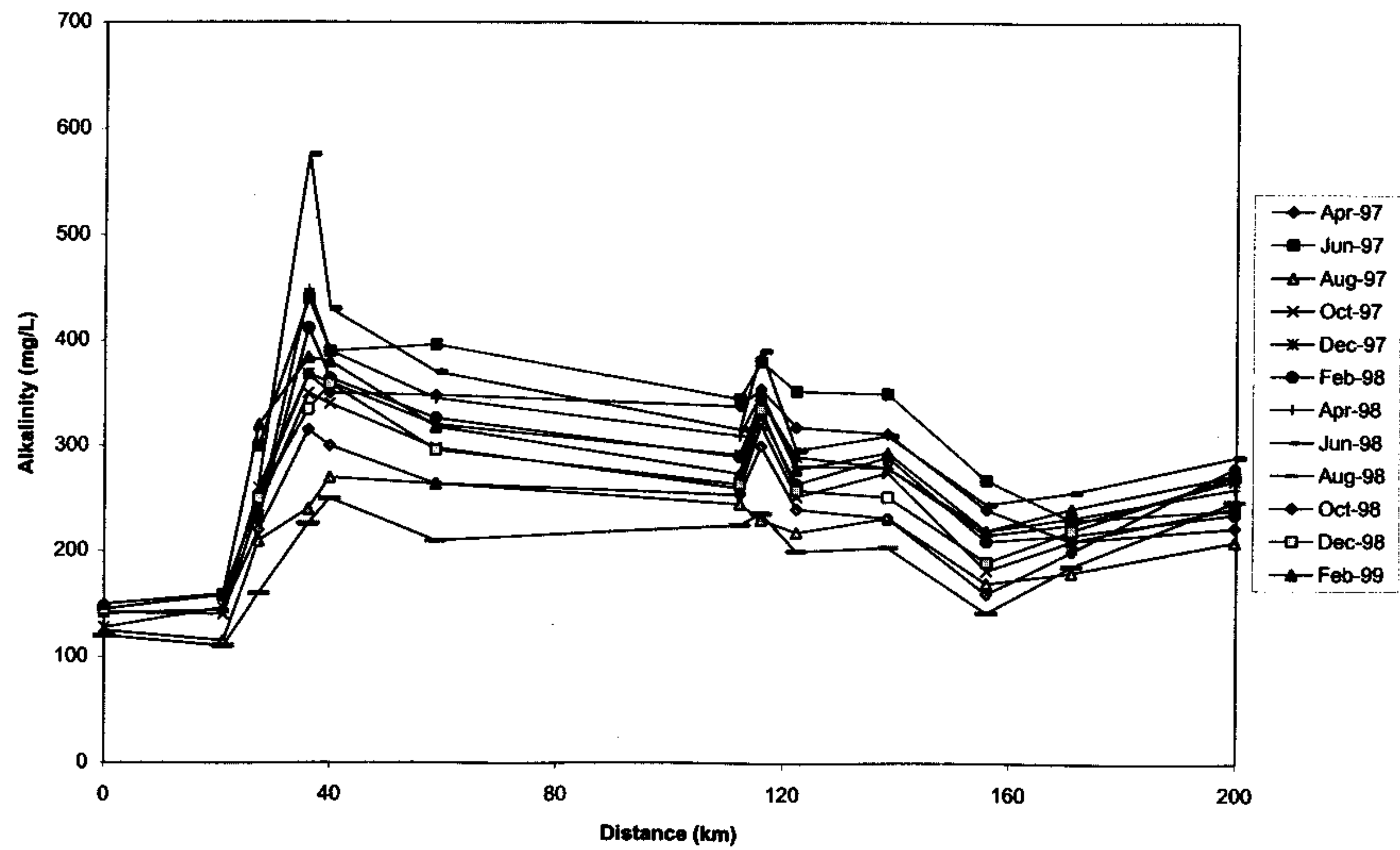


Fig. 9. Monthly variation of hardness at different sampling points

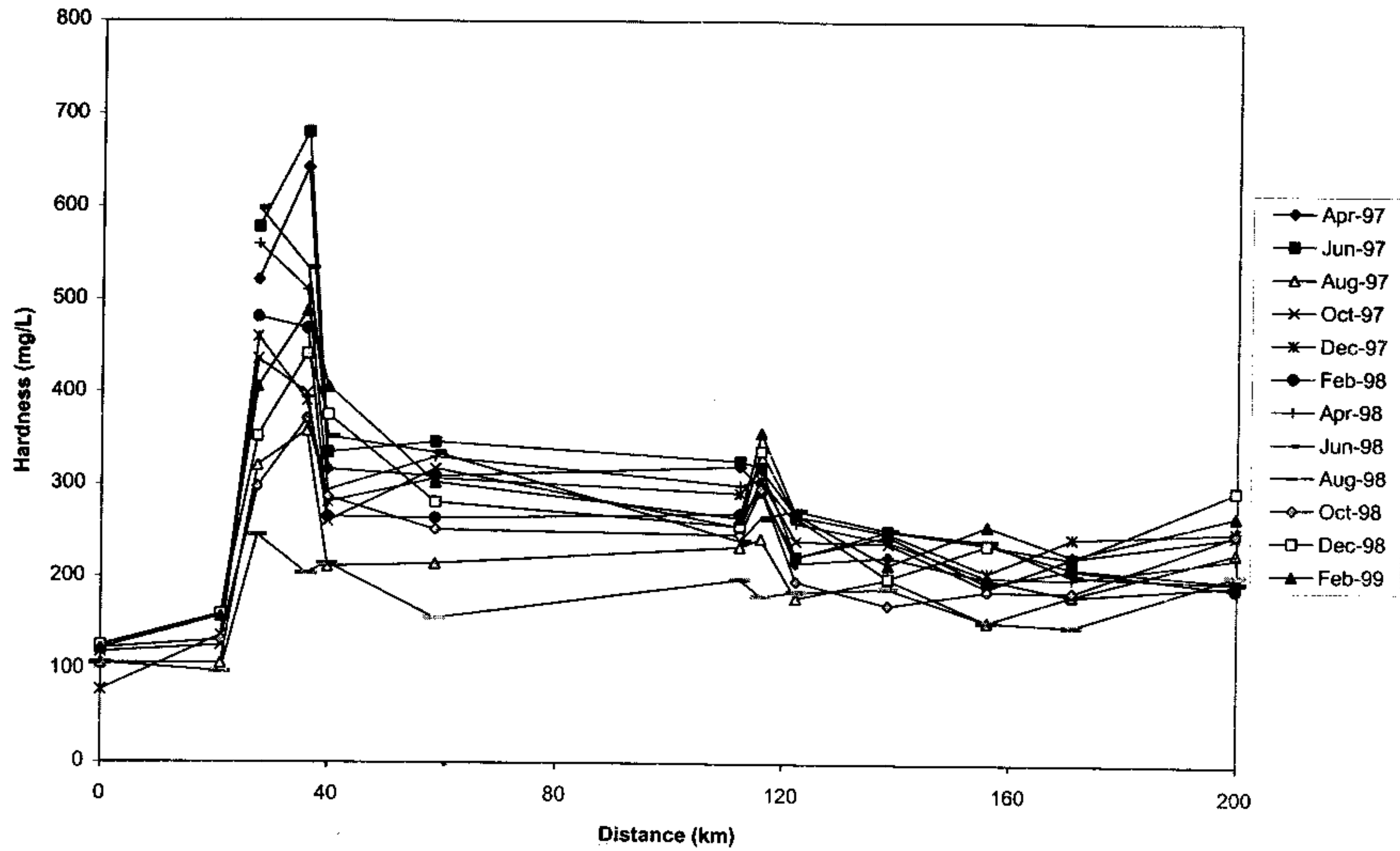


Fig. 10. Monthly variation of chloride at different sampling points

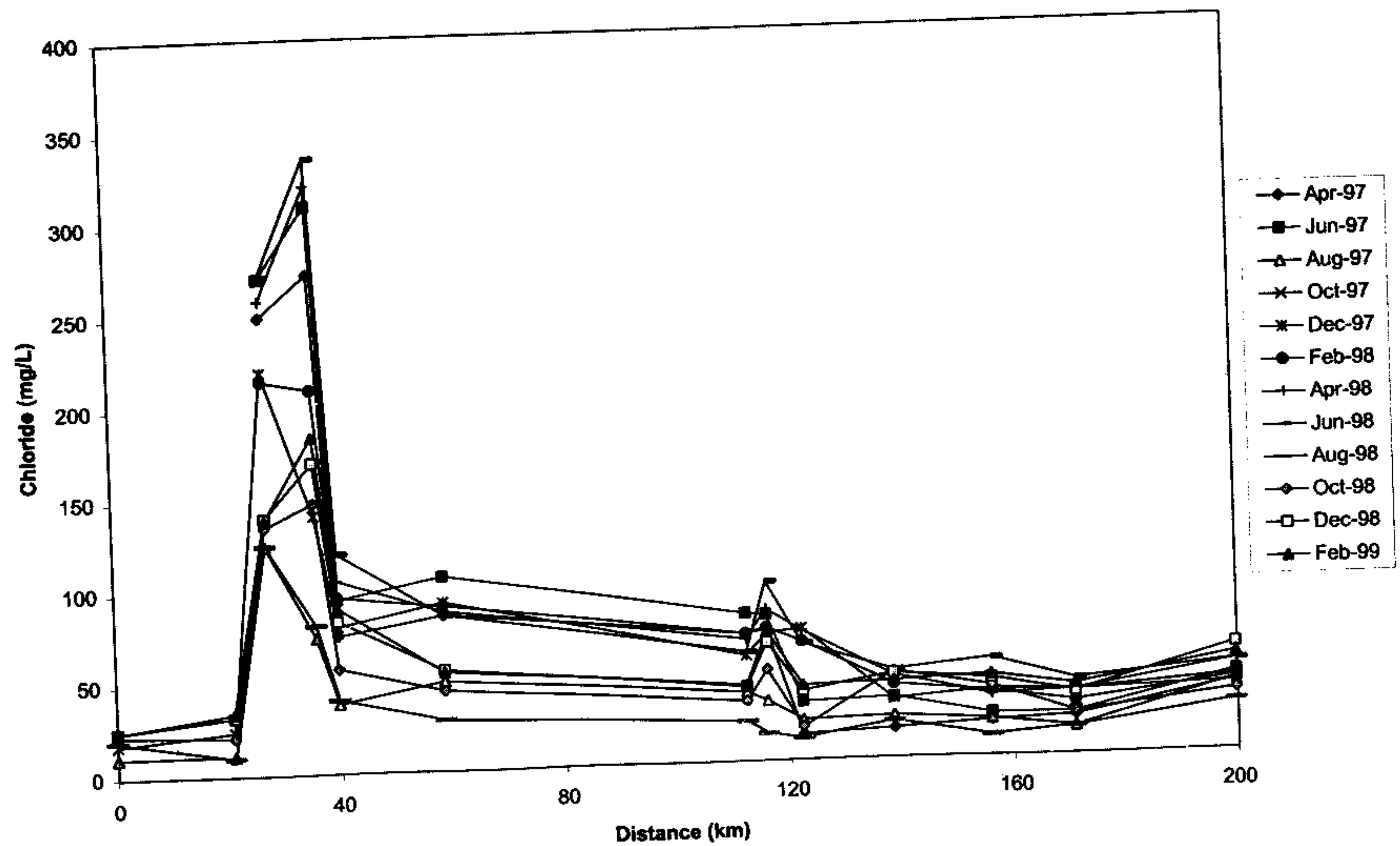


Fig. 11. Monthly variation of sulphate at different sampling points

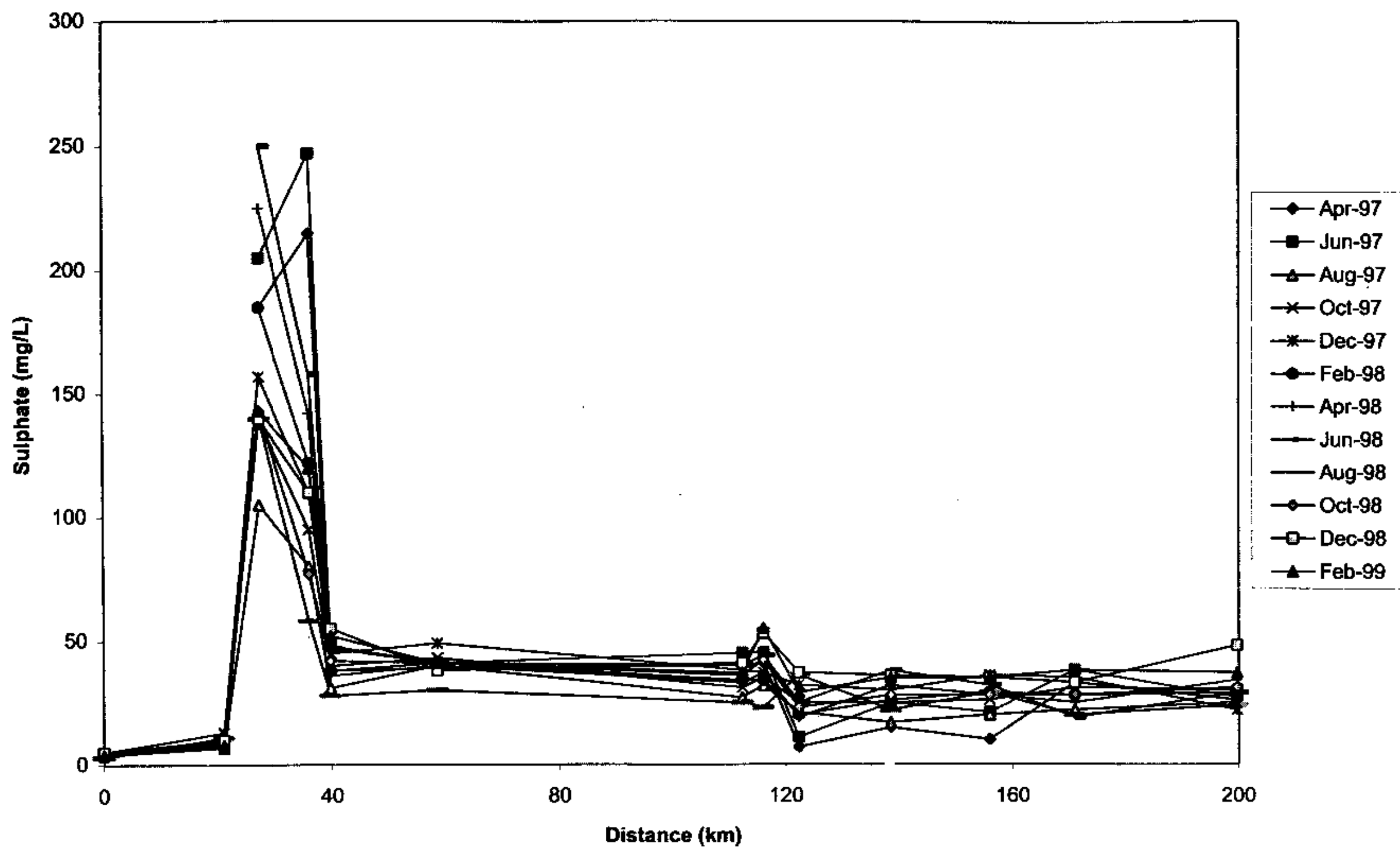


Fig. 12. Monthly variation of nitrate at different sampling points

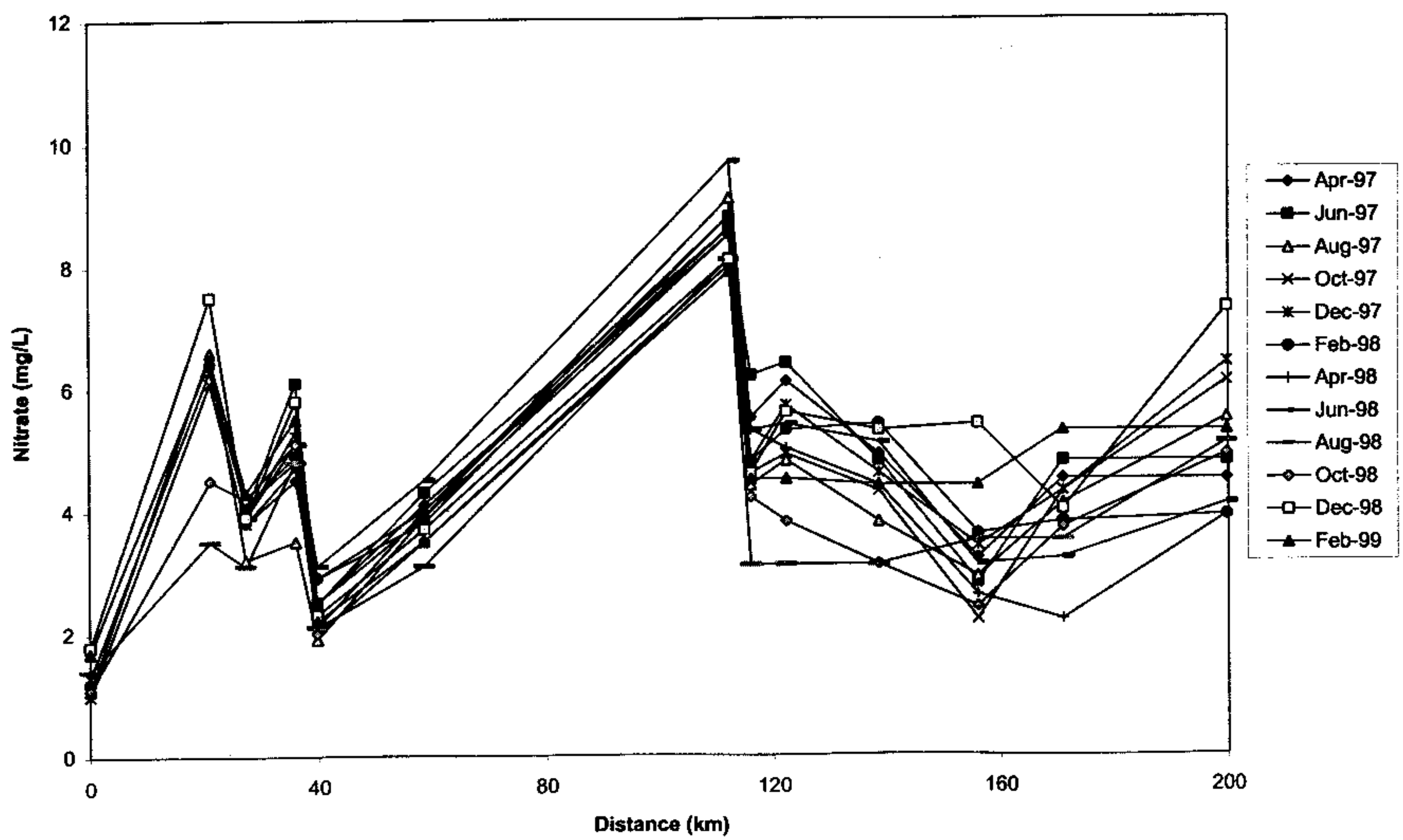


Fig. 13. Monthly variation of ammonia at different sampling points

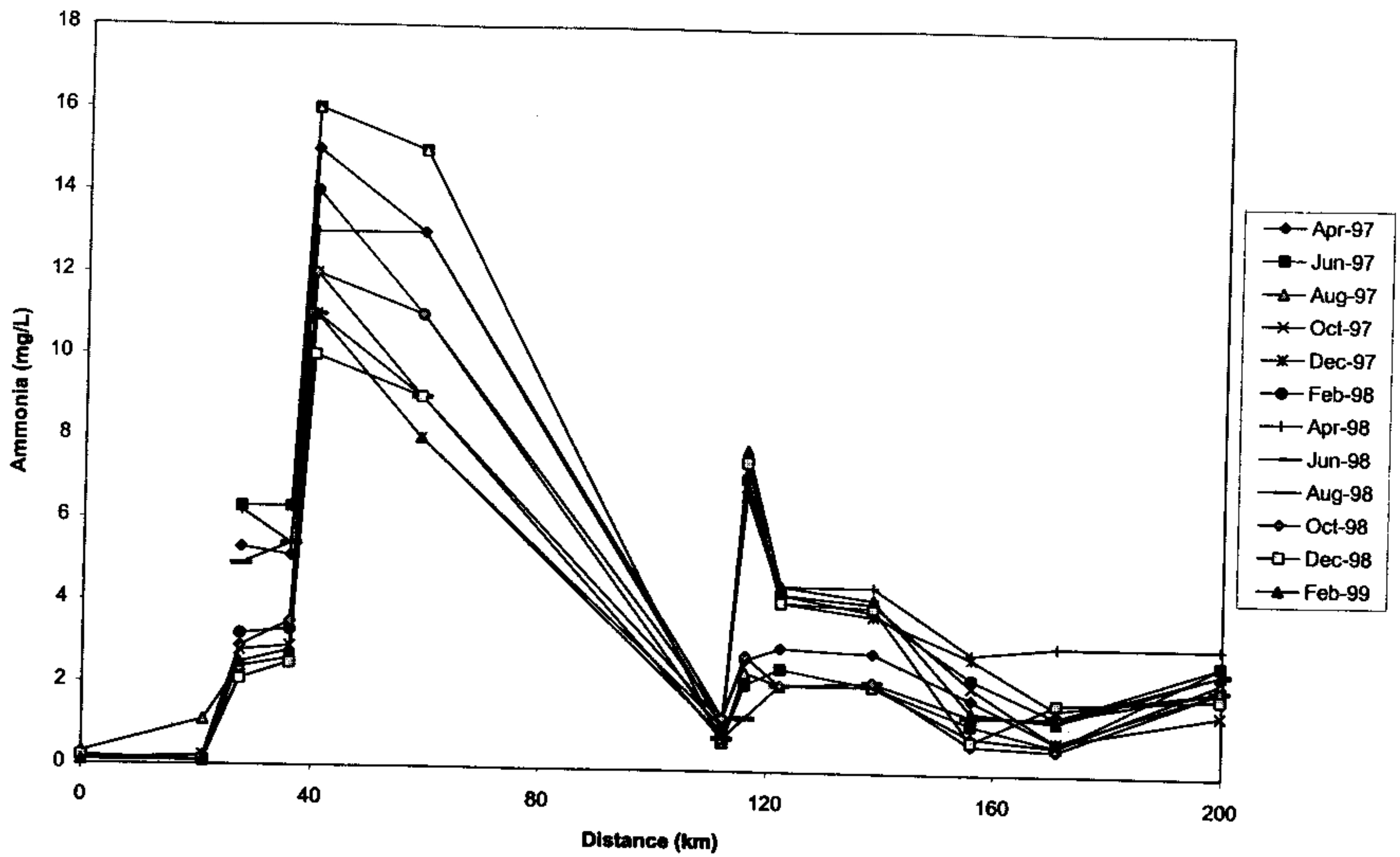


Fig. 14. Monthly variation of phosphate at different sampling points

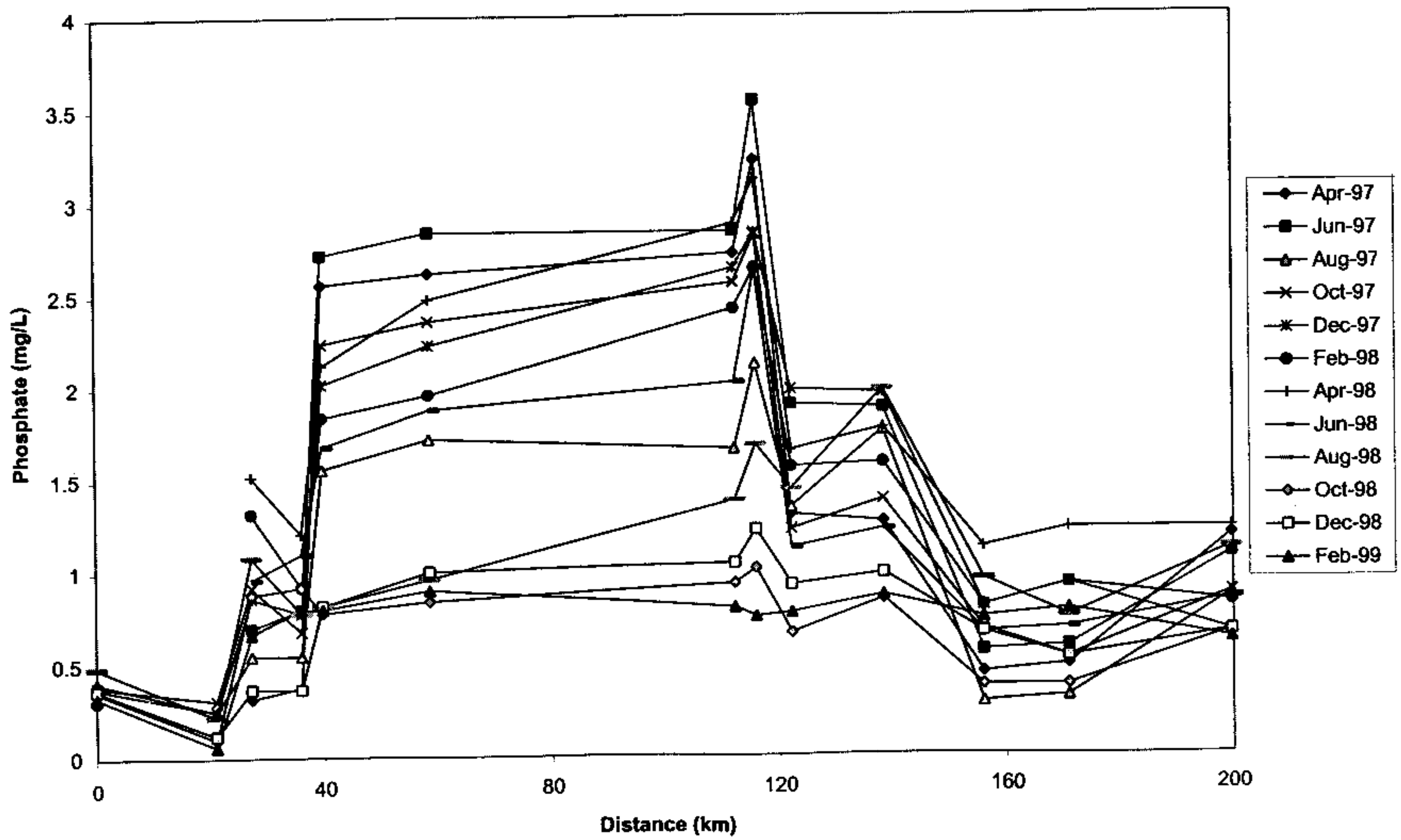


Fig. 15. Monthly variation of sodium at different sampling points

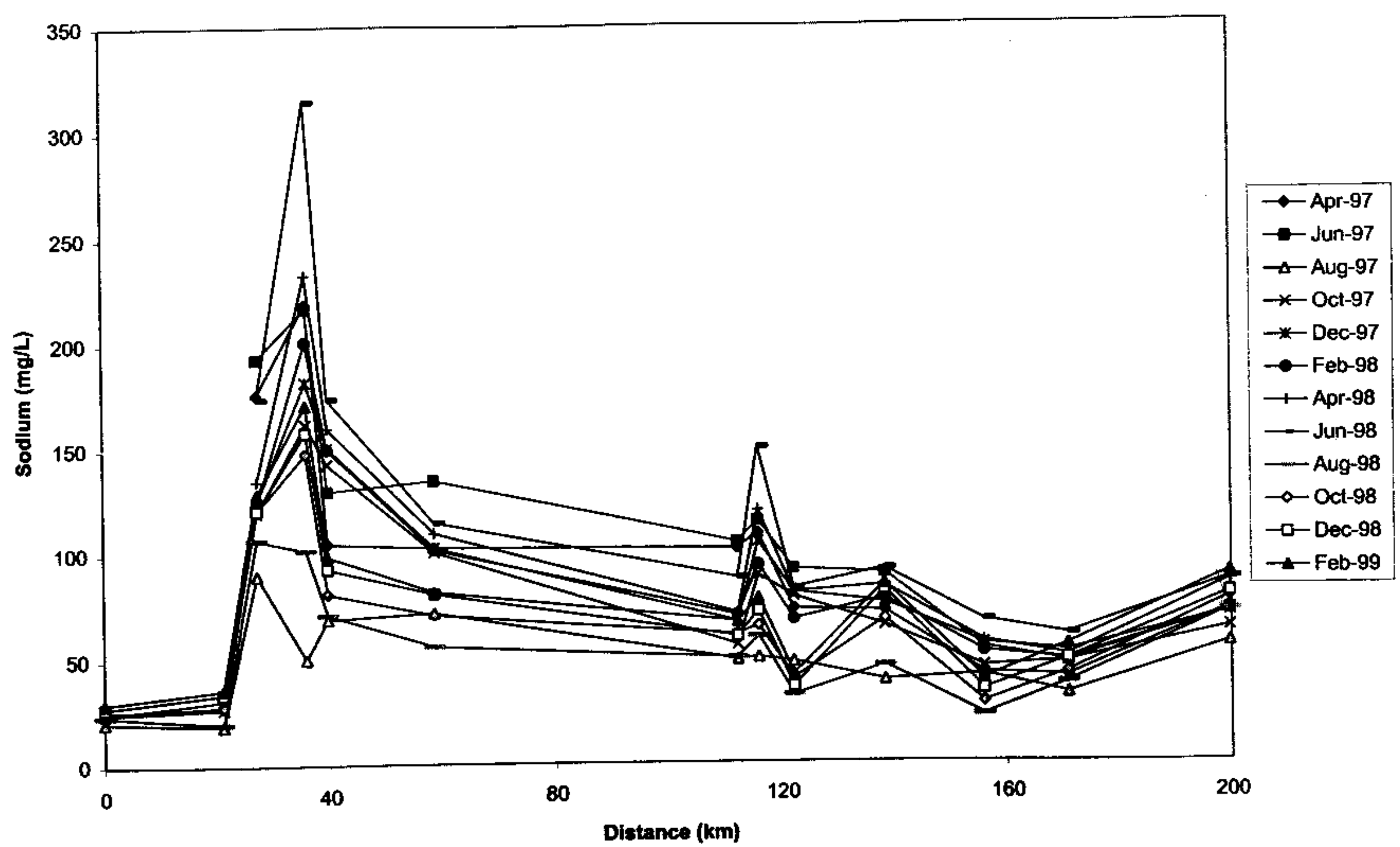


Fig. 16. Monthly variation of potassium at different sampling points

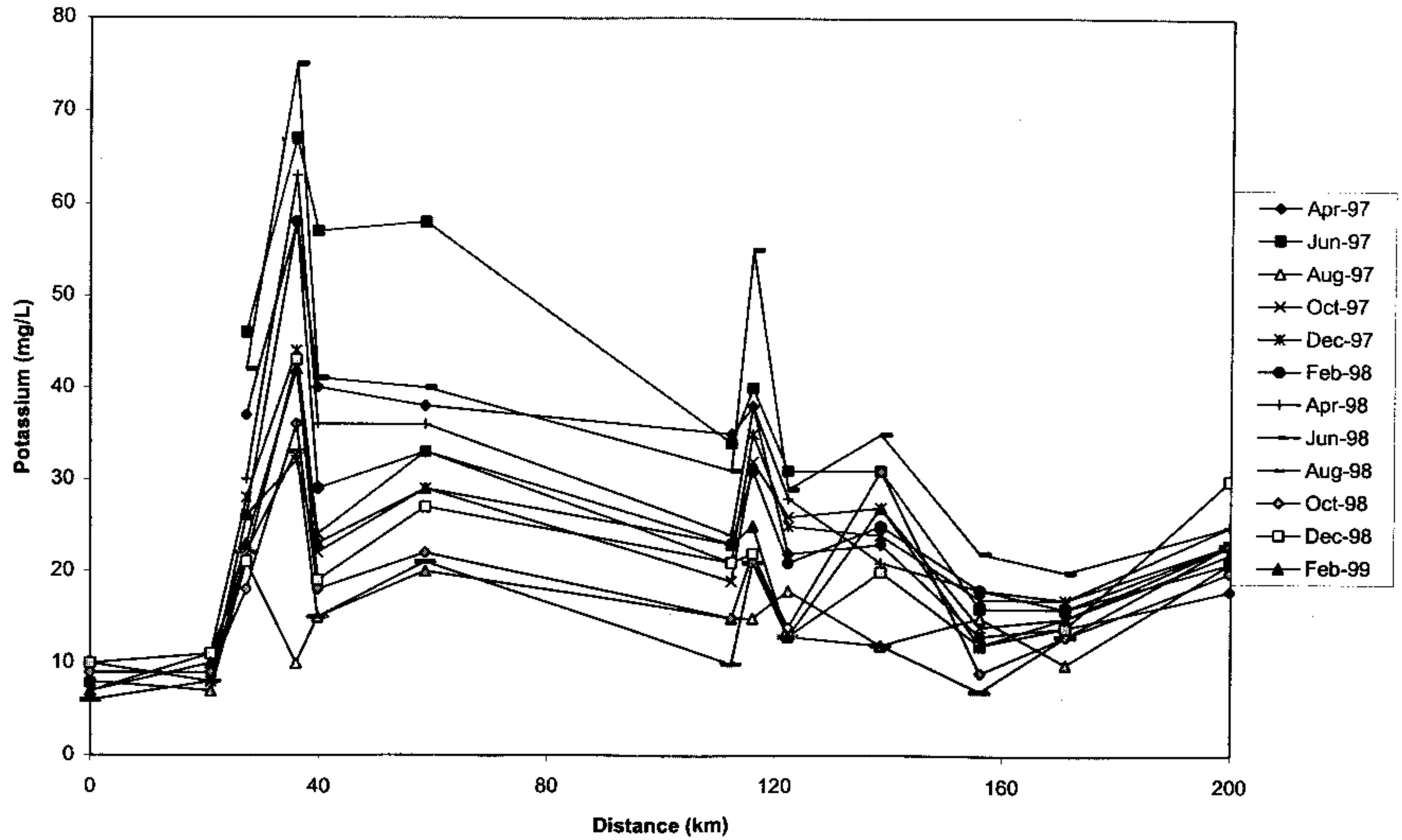


Fig. 17. Monthly variation of calcium at different sampling points

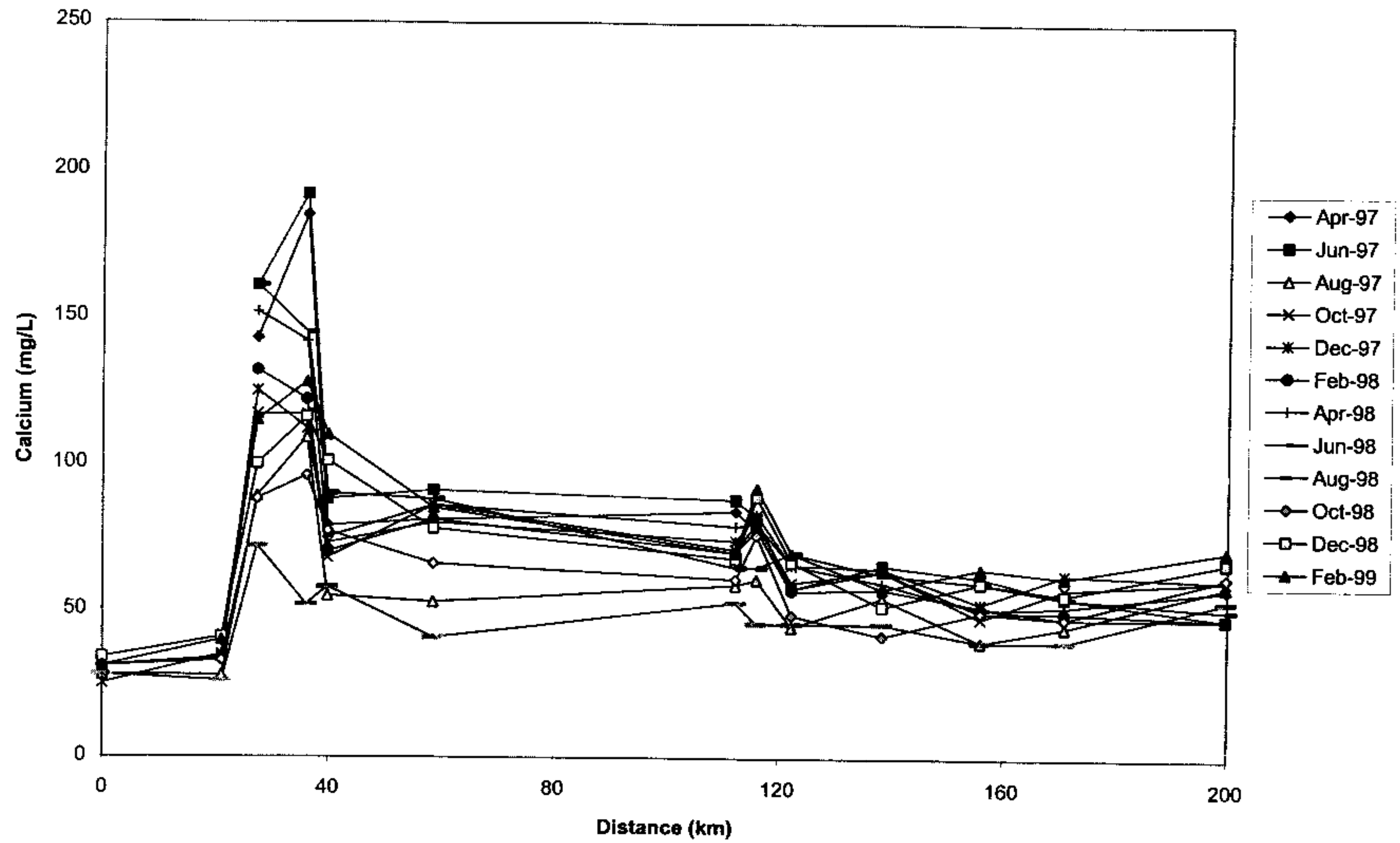
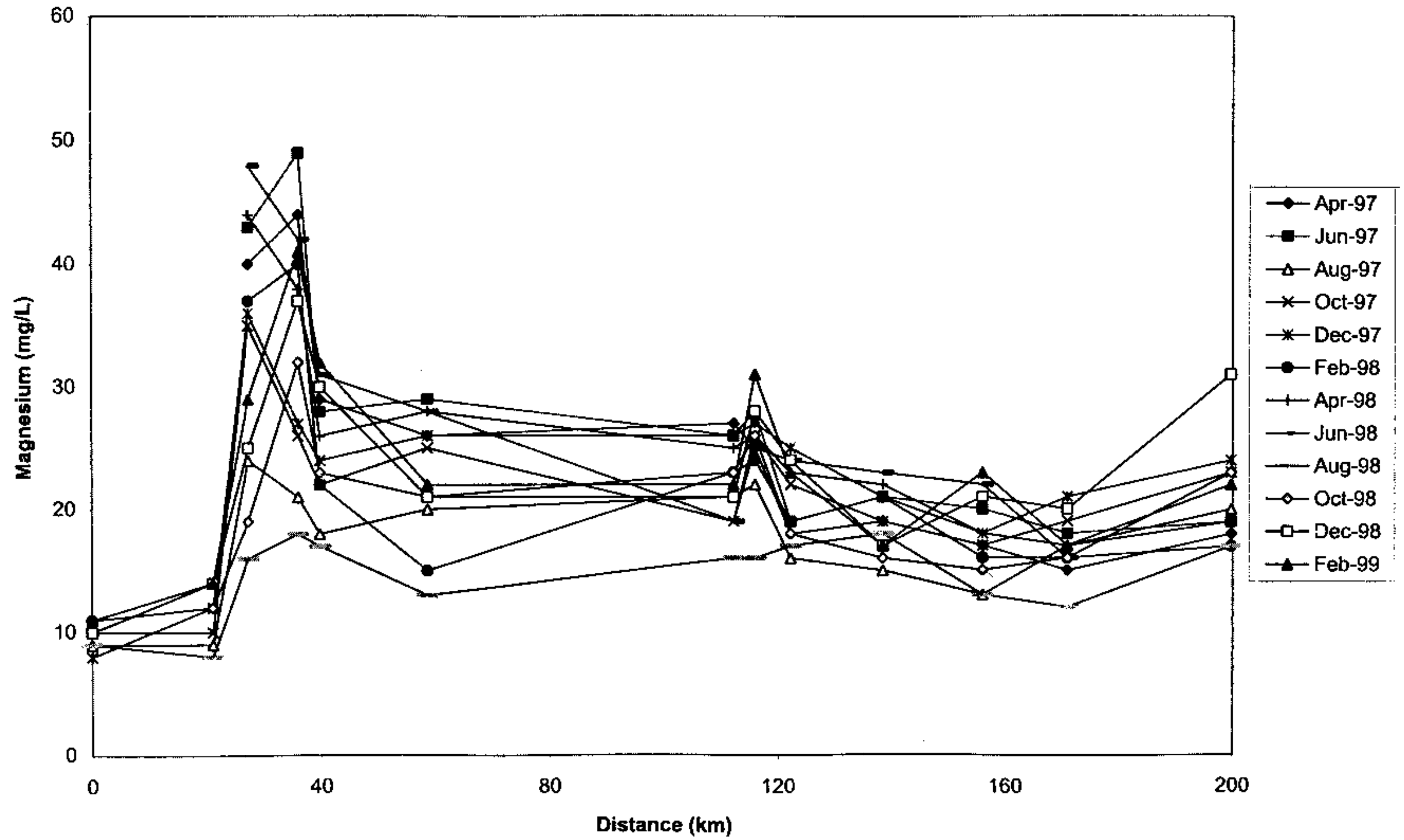


Fig. 18. Monthly variation of magnesium at different sampling points



5.0 CONCLUSION

The pollution load generated from Saharanpur town and industrial establishments of this region, viz. Star Paper Mill, Cooperative Distillery, Nagdev nala etc., is mainly responsible for the water quality degradation in the upper stretch of the Hindon river. In the intermediate stretches water quality shows a steady improvement due to reaeration and photosynthesis. Improvement in the river water quality in the downstream of the confluence of Dhamola nala indicate a relatively better quality of water in Dhamola nala compared to the river water. The river water before the confluence of Dhamola nala is mainly the mixture of wastewater of Nagdev nala and effluent from pulp and paper factory and distillery waste. A further improvement in the river water quality was noticed towards downstream of the river due to reaeration. In the lower stretch degradation of water quality is observed due to the discharge of wastewater from Budhana drain, Kali river and Krishni river. However, the water quality in this stretch is controlled by the discharge of water from Upper Ganga Canal through Khatauli and Jani escapes.

The wastewater generated by the municipal areas of Saharanpur, Muzaffarnagar and Ghaziabad should be treated and utilized for irrigation through an organized network. Effluent treatment plants should be installed by all the industries discharging their effluents directly into the river without any treatment.

REFERENCES

1. APHA (1992), Standard Methods for the Examination of Water and Wastewater, 18th edition, American Public Health Association, Washington, DC.

2. Berchmans, L. J. and Vijyavalli, R. (1989), Electrochemical oxidation as a tool for pollution control: Effect of anodic oxidation on the treatment of distillery effluent, Indian J. Environ. Hlth., 31(4), 309-313.

3. Chaudhary, N. (1981), The policy of water pollution control in India, Proc. International Symp. Water Resources Conservation, Pollution and Abatement, University of Roorkee, Roorkee, India, Vol. 2, pp. 27-40.

4. Chauhan, A. (1991), Effect of distillery effluent on river Wainganga, Indian J. Environ. Hlth., 33(2), 203-207.

5. Dhaneshwar, R. S., Rajgopalan, S.; Basu, A. K. and Rao, C. S. G. (1970), Characteristics of wastes from pulp and paper mills in the Hooghly estuary, Indian J. Environ. Hlth., 12, 9-23.

6. Handa, B. K. (1983a), Hydrogeochemical investigations in the alluvial formations of U.P. in the phreatic zone, Proc. Seminar on Assessment, Development and Management of Ground Water Resources, New Delhi, Vol. II, pp. 305-315.

7. Handa, B. K. (1983b), Pollution of natural waters by industrial waste effluents with special reference to pollution in some parts of north and NW India, Proc. Seminar on Assessment, Development and Management of Ground Water Resources, New Delhi, Vol. III, 355-365.

8. Jain, C. K. and Bhatia, K. K. S. (1997), Physico-chemical Analysis of Water and Wastewater, Users Manual, UM-26, National Institute of Hydrology, Roorkee, India.

9. Jain, C. K. (1996), Application of chemical mass balance to upstream/downstream river monitoring data, J. of Hydrology, 182, 105-115.

10. Jain, C. K. and Ram, D. (1997), Adsorption of lead and zinc on bed sediments of the river Kali, Water Research, 31(1), 154-162.

11. Jain, C. K. and Ram, D. (1997), Adsorption of metal ions on bed sediments, Hydrological Sciences Journal, 42(5), 713-723.

12. Jain, C. K., Bhatia, K. K. S. and Seth, S. M. (1997), Seth, Characterization of waste disposals and their impact on water quality of river Kali, Uttar Pradesh, Indian J. Environ. Prot., 17(4), 287-295.

13. Jain, C. K., Bhatia, K. K. S. and Seth, S. M. (1998), Assessment of point and non-point sources of pollution using a chemical mass balance approach, Hydrological Sciences Journal, 43(3), 379-390.

14. Joshi, S. B. (1987), Hydrochemical Studies of Upper Hindon Basin, U.P., M.E. Thesis, Department of Hydrology, University of Roorkee, Roorkee, India.

15. Khare, S. K. (1994), River Hindon: Evaluation of Pollution, M.E. Thesis, Department of Civil Engineering, University of Roorkee, Roorkee, India.

16. Kumar, A. and Mathur, R. P. (1991), Bioaccumulation kinetics and organ distribution of lead in a fresh water Teleost, Colisa Fasciatus, Env. Tech., 12, 731-735.

17. Kumar, A. (1993), Bioaccumulation of Selected Heavy Metals in an Ecosystem, Ph.D. Thesis, Department of Bioscience and Biotechnology, University of Roorkee, Roorkee, India.

18. Kumar, B. (1997), River Hindon and Tributaries: Assessment of Water Quality, M.E. Thesis, Department of Civil Engineering, University of Roorkee, Roorkee, India.

19. Kumar, U. (1994), Assessment of Hindon River Water Quality, M.E. Thesis, Department of Civil Engineering, University of Roorkee, Roorkee, India.

20. Lokesh, K. S. (1996), Studies of Heavy Metals in Water and Sediment of Hindon River, Ph.D. Thesis, Department of Civil Engineering, University of Roorkee, Roorkee, India.

21. Rao, K. V. R. (1965), Hydrological Studies of Alluvial Areas in the Parts of Saharanpur District, U.P., Ph.D. Thesis, University of Roorkee, Roorkee, India.

22. Rao, R. C. and Rao, T. V. N. (1985), Studies on pollution of river waters (Godavari and Tungabhadra) by effluents from paper mills, Proc. Seminar on Water Quality and its Managements, CBIP, New Delhi, pp. 103-110.

23. Rao, T. D. and Veeraraghavan, T. (1985), Treatment of an Indian distillery wastewater, J. Effluent and Water Treatment, 394-396.

24. Report on Water Qality Monitoring of River Hindon, Ganga Action Plan Phase II, (1996), Department of Civil Engineering, University of Roorkee, Rookee, India.

25. Seth, A. K. (1991), Hydrological Aspects of Waste Disposal of Upper Hindon Basin, U.P., Ph.D. Thesis, Department of Earth Science, University of Roorkee, Roorkee, India.

26. Seth, A. K. and Singhal, D. C. (1994), Status of ground water quality in upper Hindon Basin, Saharanpur area (U.P.), Proc. Regional Workshop on Environmental Aspects of

Groundwater Development, Krukshetra, India, pp. I-114-I-122.

27. Shankar, V., Sangu, R. P. S. and Joshi, G. C. (1986), Impact of distillery effluent on the water quality and ecosystem of river Reh in Don valley, Poll. Res., 5(3&4), 137-142.

28. Singhal, B. B. S., Mathur, R. P., Singhal, D. C., Mathur, B. S., Minocha, V. K., Seth, A. K. and Sinha, S. K. (1987), Effects of industrial effluents on the water quality of river Hindon, District Sharanpur, U.P., J. Geological Survey of India, 30(5), 356-368.

29. Verma, S. R., Dalela, R. C., Tyagi, M. P. and Gupta, S. P. (1974), Studies on the characteristics and disposal problems of industrial effluents with reference to ISI standards: Part I, Indian J. Environ. Hlth., 16, 289-299.

30. Verma, S. R. and Dalela, R. C. (1975), Studies on the pollution of the Kalinadi by industrial wastes near Mansurpur, Part I & II, Acta Hydrochim. et Hydrobiol., 3(3), 239-274.

31. Verma, S. R. and Mathur, R. P. (1971), characteristics and pollutional effect of paper mill wastes on Hindon river, Proc. Seminar on Water Supply and Sanitary Problems in Urban Areas, Institution of Engineers (India), Roorkee, Vol. 2, E-4, pp. 1-11.

32. Verma. S. R. and Shukla, G. R. (1969), Pollution in a perennial stream Khala by the sugar factory effluent near Laksar (District Saharanpur), U.P., India, Environ. Hlth., 11, 145-162.

33. Verma, S. R., Shukla, G. R. and Dalela, R. C. (1980), Studies on the pollution of Hindon river in relation to fish and fisheries, Limnologica (Berlin), 12(1), 33-75.

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