

# RIVER HINDON : EVALUATION OF POLLUTION

A DISSERTATION

*Submitted in partial fulfilment of the  
requirements for the award of the degree*

*of*

MASTER OF ENGINEERING

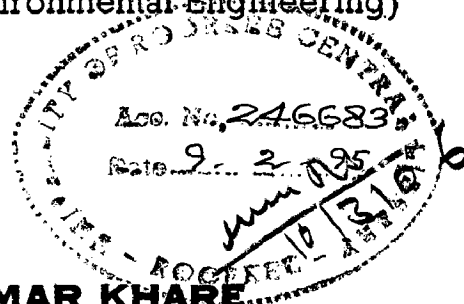
*in*

CIVIL ENGINEERING

(With Specialization in Environmental Engineering)

By

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MARCH, 1994

## CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in this dissertation entitled "RIVER HINDON : EVALUATION OF POLLUTION" in partial fulfillment of the requirement for the award of the degree of the Master of Engineering with specialisation in ENVIRONMENTAL ENGINEERING submitted in the department of Civil Engineering, University of Roorkee, Roorkee is a record of my own work carried out under the supervision of Dr. Pradeep Kumar.  
*This work has been done during Oct. 93 to March 94.*  
The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

skhare

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This is to be certified that the above statement made by the candidate is correct to the best of my knowledge.

*Pradeep Kumar*

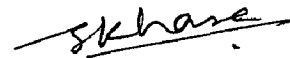
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(SANDEEP KUMAR KHARE)

## ABSTRACT

Without improvement in the quality of Hindon river the on going clean up of Yamuna river and subsequently the Ganga river would not produce commensurate results. For realization of the need it is important to study the Hindon river water quality in terms of various pollutional parameters.

The river Hindon is ephemeral upto about 130 km from extreme upstream. A lot of work has been done in the upper part of Hindon basin. A significant study was also carried out in regard to fish and fisheries by Verma et al. (1980) during 1971-73. In the present study in the perinneeal part of the river five sampling stations were selected. The period of study was Dec. 1993 to Feb. 1994. Sampling frequency was thrice a month 1st, 11th and 21st of each month.

In the stretch of study (about 200 kms) from Maheshpur (MH) to Barnawa (BA), the dissolved oxygen level is very low or almost zero, indicating higher pollutional loads. In the rest lower half stretch of the river the gradual decline in BOD and COD values from about 35 to 3.5 mg/l and 65 to 13 mg/l respectively were observed. DO was found sharply improving. It could be attributed to the dilution provided by Upper Ganga Canal water released through one or both the Jani Escape and Khatauli Escape.

From the comparison of BOD values taken from the results of YAP (1992) and the present study, it can be seen that the trend in the BOD values almost matching. The deoxygenation and reaeration rate coefficient were found in the range of 0.31 to 0.83 d<sup>-1</sup> and 0.048 to 3.758 d<sup>-1</sup>. Because of the non-existence of the applicability conditions of the Streeter Phelps Eq., a very good correlation between computed and observed values could not be obtained. The BOD of the river water being discharged at Tilwara into Yamuna could be extrapolated around 3 mg/l for non-monsoon period.

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## INTRODUCTION

For the formulation of any water control policy and programme, it is necessary to have adequate knowledge of existing nature, sources and magnitude of pollutional loads on the concerned body of water. Although pollution arising from industrial and urban wastewater discharge is often more serious in terms of the overall quantity yet the contribution by runoff waters originating from rural communities, cattle farming etc. should not be underestimated.

But the first thing to be kept in mind is the fast growing and rapidly changing nature of human activities. Broadly speaking, because of the day to day increasing population loads on the land and increasing demand of water per capita, the river and other natural water bodies have to play an important role in fulfilling the same. The rural population near the natural stream of water use it in their daily routine of works and other activities because of poverty, ignorance and lack of adequate socio-economic development dominating the community life in India. Also, because the natural water is most likely to be polluted easily by unpredictable human or natural activities, so a

consistant watch is needed on the quality parameters of the rivers and other natural water bodies.

According to a report (Choudhary,1981), ninety six percent of water pollution problems in India are due to the indiscriminate discharge of municipal wastes. These wastes being biodegradable in nature produce a series of directional but predictable changes in water bodies. Industrial effluents are responsible for pollution to a lesser extent but the effect produced by them may be more serious as nature is often unable to assimilate them. Sometimes the polluttional load due to organic wastes are so heavy that the dissolved oxygen is depleted to the extent of affecting the fish culture and other aquatic lives of water bodies.

In the present context the focus is on the river Hindon, a tributary of the river Yamuna. The polluttional status of the river have been assessed by a continuous monitoring programme for a period of three months. The major contributor in the polluttional load is the urbanised block of western U.P., particularly Saharanpur, Muzaffarnagar, Meerut, and Ghaziabad districts.

Since the area is thickly populated in urban area and contains a number of large, medium, and small scale industries, so the major portion of the wastewaters from these industries and

towns comes in the Hindon river system passing through the area either directly or through tributaries.

The wastewater analysis and their impacts on the river water have been studied in details by Verma et al. (1980) for the period from 1971 to 1973. A need was felt to reexamine the pollutional loads in the River Hindon with particular reference to Yamuna Action Plan. Following objective was set:

To ascertain the chemical characteristics of the river water and impact of biodegradable organic matter on the water quality and DO-BOD relationship.

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## CATCHMENT CHARACTERISTICS AND LITERATURE REVIEW

### 2.1 CATCHMENT CHARACTERISTICS

#### 2.1.1.1 Physiography :

The area under study is a part of Indogangetic plain and lies in the region bound on Northern side by lower foot hills of Himalayas, on Eastern side by Upper Ganga Canal and on Western side by Eastern Yamuna Canal. Then finally it joins Yamuna near village Tilwara in Bulandshahar district. The irrigation to this area is provided both by Eastern Yamuna Canal and Upper Ganga Canal systems. Other water resources of the Hindon basin are rivers Kalinadi and Krishni with their respective tributaries in addition to the Hindon.

The river originates from lower Shivalik foothills in Dehradun district in the form of a number of small streams. Upto some distance upstream of Saharanpur, the river is monsoon fed only and remains dry in non-monsoon months. From Saharanpur district onwards, it is a perennial river mainly because of industrial and domestic wastewaters. The total length of the river is about 400 km, out of which approximately 270 km is perennial and 130 km is non-perennial. Total area contributing to Hindon is 7083 sq.km.

(YAP, 1992). The river exists between the latitude  $28^{\circ}4''$  to  $30^{\circ}5''$  N and longitude  $77^{\circ}8''$  to  $77^{\circ}4''$ E. Fig. 2.1 shows the overview of Hindon river alongwith rivers Ganga and Yamuna with all the sampling stations.

#### 2.1.2 Climate & Soil :

The climate is semi arid in nature due to marked dirunal differences of temperature and moderate rainfall. The temperature ranges from average of  $7^{\circ}\text{C}$  in winter to  $39^{\circ}\text{C}$  in summer.

The soil of the study area is of alluvial type deposited by Hindon river system. It mainly consists of clay, silt and fine to coarse sand. So, it is very fertile for growing wheat, sugar cane and vegetables. The average annual rainfall is around 1200 mm (Verma et al., 1980). Highest rainfall occurs in August and found to range from 410 to 499 mm.

#### 2.1.3 Hydrometric Data

It originates from hilly catchment and flows into the plain. The average rainfall received by it, is 1200 mm. Eighty per cent of this gets precipitated during southwest monsoon alone, i.e. during July to Sept.. River flows for different periods of year are given in Table 2.1 Figures given in Table 2.1 are approximate and are based on the records of canal division compiled

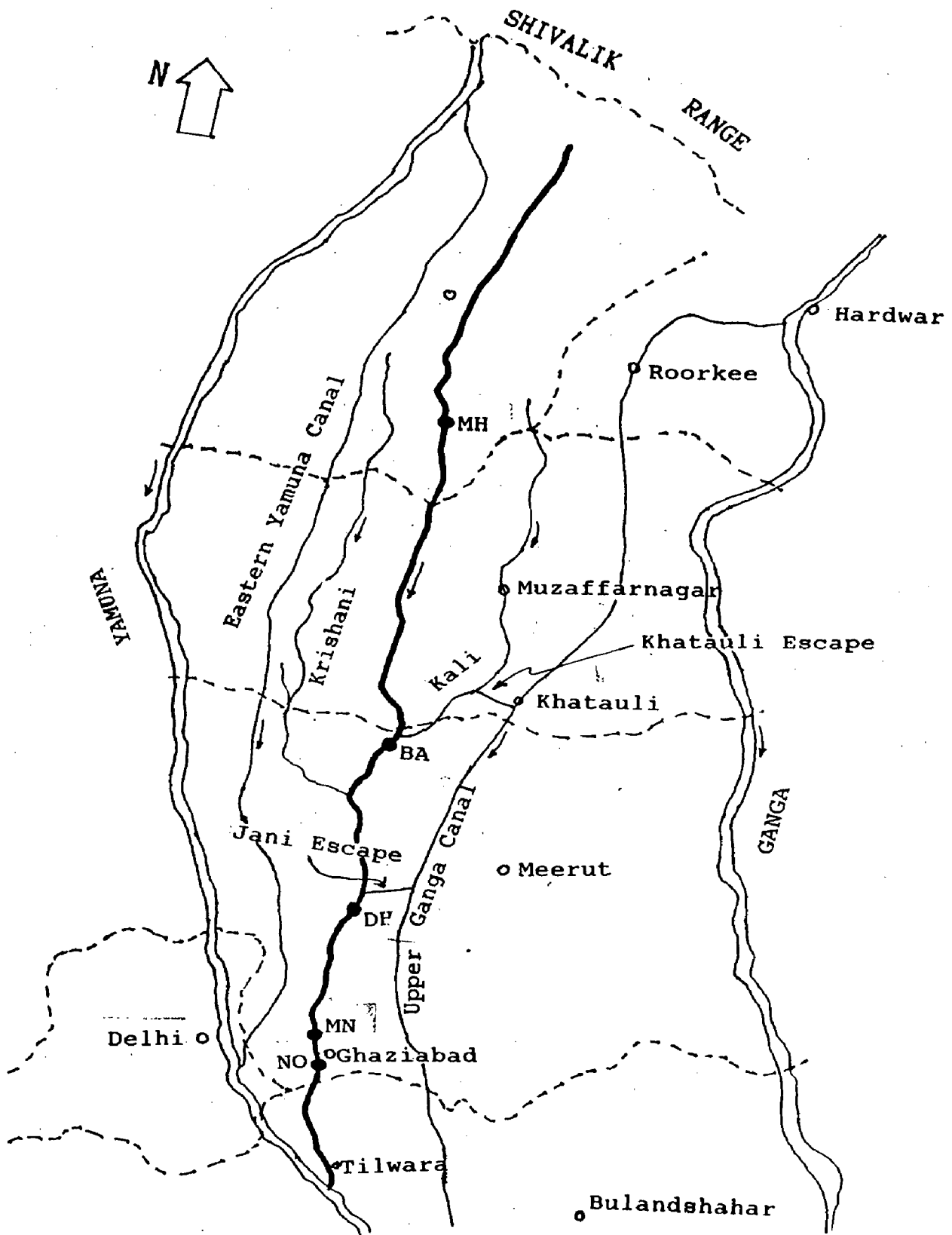


FIG.2.1 . HINDON RIVER BASIN ALONG WITH GANGA AND YAMUNA  
 (NATIONAL ATLAS OF INDIA - I, Plate - 25)

by Verma et al (1980). The depth of water in the river varies from 40 cm to 4 m in different stretches. The average velocity of flow is around 30 m/min. The river is sluggish except during rainy season and there is not high turbulence or fall in the river. It takes about 83 hours to travel from downstream of Kailashpur to Daruhera, a distance of 150 km (Verma et al., 1980).

**Table 2.1A Flows in River Hindon  
(Verma et al., 1980)**

Period	Flow (m <sup>3</sup> /s)
July - Sept	240
Oct. - Dec.	42 - 22
Jan. - March	14
April - June	10 - 7

**Table 2.1B Stream Runoff at Galata  
(Ganga Basin, 1977)**

Period	Flow (BCM)
Monsoon	0.7
Post monsoon	0.1
Winter	0.2
Summer	0.1

#### 2.1.4 Various Inputs and Outputs to the River :

A line diagram of Hindon basin is shown in Fig. 2.2. Just upstream of Saharanpur river is dry for most of the period in a year. During non-monsoon months flow in Hindon starts after joining of Nagdeo nala which apart from other wastes also brings wastewater from one of the milk product industries. Next noticeable discharge joining the river is from one of the major paper mills. Wastewater from Saharanpur town and other industries is discharged in Rives Dhamola and Paodhoi. This combined waste is discharged in Hindon near Tapri. Near Barnawa Kalinadi joins Hindon. Kalinadi brings domestic and industrial wastes of Muzaffarnagar and nearby areas. It also brings Ganges water discharged into it through Khatauli escape. After Barnawa River Krishni discharges its load of pollutants in Hindon upstream of Galata. Next to discharge is Jani escape which also brings relatively clean Ganges water from Upper Ganga Canal.

At Mohannagar a barrage is constructed across Hindon to feed water into Hindon Cut canal. This canal joins Yamuna upstream of Okhla barrage from where this water is fed into Agra canal system consisting of Agra Canal (length 163 km, discharge  $63.5 \text{ m}^3/\text{sec}$ , irrigation area 138000 ha in districts of Agra and Mathura) and Gurgaon canal (takes off from Agra canal 8 km from its off take at Okhla, discharge  $14.15 \text{ m}^3/\text{sec}$ , irrigation area 4000 ha). The discharge in Hindon from UGC through Khatauli and Jani escapes

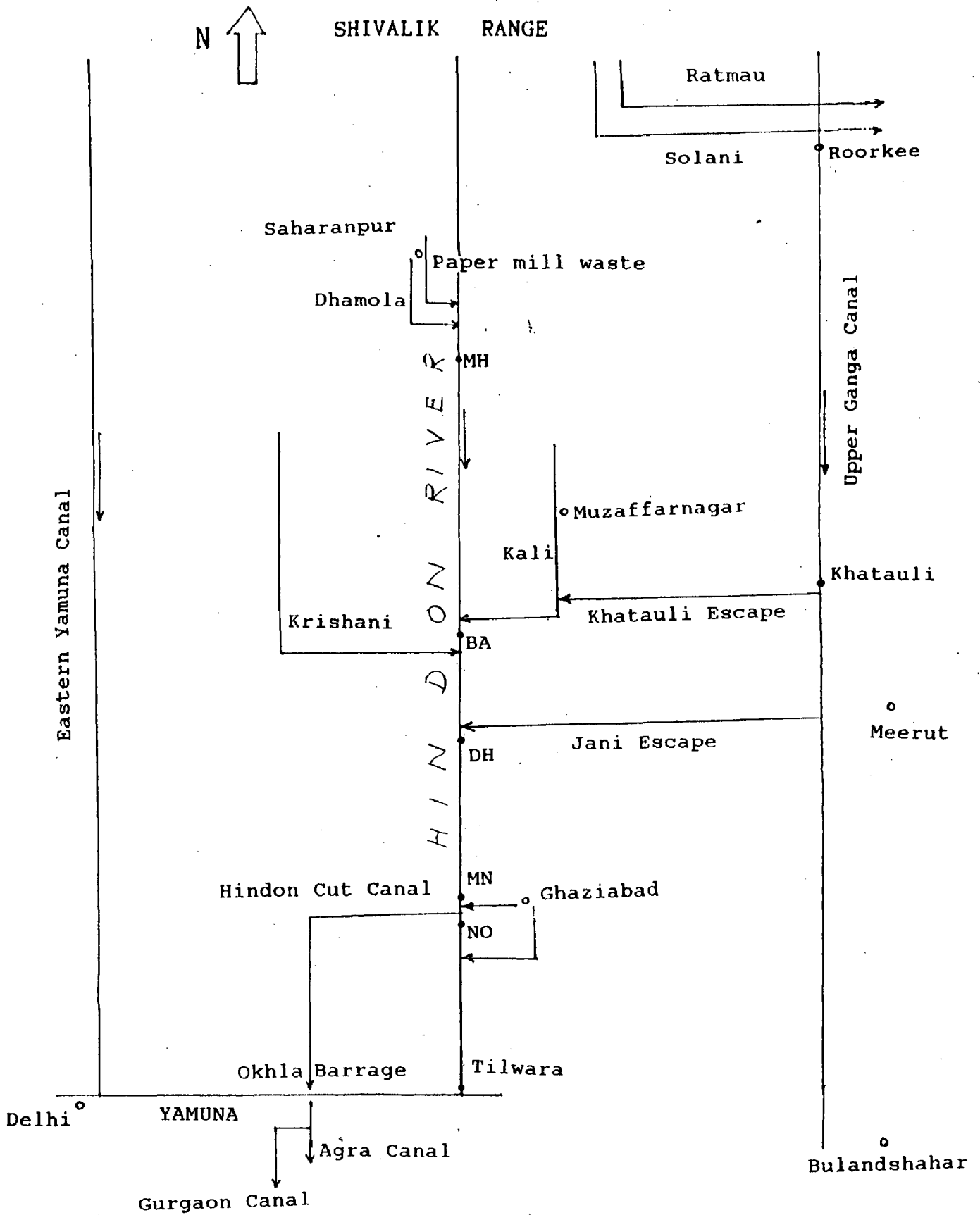


FIG.2.2 . INPUTS AND OUTPUTS TO HINDON RIVER SYSTEM

depends on requirement of water in Agra canal system. Depending upon requirement, water is discharged through both or one of the escapes. There are water, regulating devices at both places and if there is no demand of water downstream gates at both the escapes are closed. Quality of Hindon water depends on rate of flow of canal water into Hindon. Hindon carries only wastewaters in non-monsoon period while UGC water is of good quality.

Before barrage of Mohannagar part of that combined wastewater from Ghaziabad meets Hindon. After barrage flows in Hindon are very less. Dasna drain further discharges domestic wastewater into Hindon. Then Hindon bifurcates and finally joins Yamuna near village Tilwara.

Rivers Ratmau and Solani start from foothills of Shivalik and flow towards east crossing Hindon river basin upstream of Roorkee.

#### **2.1.5 List of Main Industries in the Catchment**

There are a number of large, medium and small scale industries in the Hindon river basin contributing pollutional loads to the river. Major industries include the sugar mills, pulp and paper mills, distilleries, dairies etc.

Table 2.2 shows the number of large, medium and small scale industries in the area. All of these may not be contributing waste load to the Hindon river.


**Table 2.2 Number of Industries (YAP, 1992)**

District	Large	Medium	Small
Saharanpur	7	6	2,323
Muzaffarnagar	7	9	1,524
Meerut	4	9	1,681
Ghaziabad	7	12	1,694

Table 2.3 gives the partial list of major industries in the area.

**TABLE 2.3 PARTIAL LIST OF MAJOR INDUSTRIES (DISCHARGE > 100 KLPD) IN CATCHMENT OF RIVER HINDON**

Sl. No.	Name of Industry	Discharge	BOD	S.S.
1.	Foremost Dairies Ltd., Kailashpur Saharanpur	2000 KLPD (83333 lit/hr)	350 mg/l	400 mg/l
2.	CO-operative Co. Ltd., Distilleries, Nawabaganj, Saharanpur	140 KLPD (5833 lit/hr)	40000 mg/l	-

3.	Star Paper Mills, Saharanpur	37950 KLPD (1581250 lit/hr)	100-300 mg/l	-
4.	The Bagpat Cooperative Sagar Mills Ltd, Bagpat, Meerut	300 to 500 m <sup>3</sup> /day	1000-1500 mg/l	250-300 mg/l
5.	Ganeshwer Ltd., Deoband, Saharanpur	2000 to 2500 m <sup>3</sup> /day	1000-1500 mg/l	250-300 mg/l
6.	The Mahalakshmi Sugar Mills Co. Ltd., Iqbalpur, Saharanpur	800-1200 m <sup>3</sup> /day	1000-1500 mg/l	200-300 mg/l
7.	Sir Shadilal Sugar & General Mills, Mansurpur, Muzaffarnagar	800-1200 m <sup>3</sup> /day	"	"
8.	Mohan Meakin Breweries Ltd., Mohan Nagar, Ghaziabad		-	-
9.	The Shamli, Distillery and Chemical works, Shamli, Muzaffarnagar		-	-
10.	Sir Shadilal Distillery and Chemical works, Mansurpar, Muzaffarnagar		-	-
11.	Titawi Sugar Industry, Titawi, Muzaffarnagar		-	-

## 2.2 LITERATURE REVIEW

### 2.2.1 General

Geohydrological studies of the Hindon basin in the Saharanpur area were carried out by Raghav Rao (1965). Effects of paper mill wastes on the Hindon river have been studied by Verma and Mathur (1971). A considerable amount of work was done by Verma et al., (1980) on the pollution of Hindon river in relation to fish and fisheries. It was found that the water of Hindon river is not suitable for propagation of the fish culture, phytoplankton and other related aquatic lives. They also pointed that due to a high variation in temperature in summer and winter, the D.O. and oxidation rates of the organic matter also changes rapidly. Also, D.O. in summer may go below the desired level.

Handa (1983) has studied pollution of natural waters by industrial waste effluents in some parts close to Hindon river. Patel et al., (1985) have carried out hydrochemical studies of natural waters with reference to the waste effluent disposal in the upper part of Hindon basin in Saharanpur area. Seth (1991) has studied the chemical characteristics of surface water of the Hindon river system and the ground water with the objective to assess the synoptic quality of the water for various specified uses. The field of study was the upper Hindon basin lying in the Saharanpur district. It was concluded that both from inorganic and organic

considerations the natural waters of the area are unsuitable for drinking, outdoor bathing and fish culture.

## **2.2.2 SOURCES, VOLUMES AND CHARACTERISTICS**

As mentioned in section 2.1.4 following major streams discharge wastewaters either domestic or industrial into river Hindon :

- (1) Channel from Pulp and paper mill
- (2) Dhamola
- (3) Kalinadi
- (4) Krishna
- (5) Channel from Ghaziabad upstream of Mohannagar barrage
- (6) Dasna drain

The wastewater for first four streams was analysed by Verma et al.,(1980).Their characteristics are shown in Fig. 2.3 alongwith daily amount of pollution load thrown in Hindon.

## **2.2.3 General Characteristics of Main Wastewaters being Generated in the Hindon Basin**

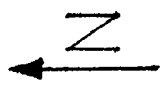
As mentioned in section 2.1.5 there are four major industries in Hindon River basin. General characteristics of these four industries are given in the following sections.

Physico-chemical characteristics of the combined waste of pulp and paper

Characteristics	Values		
	Minimum	Maximum	Average
Colour	Light brown	Brown	Brown
Specific conductivity ( $\mu$ mhos)	1880	2190	1975
Temperature	70 °C	78 °C	75.5 °C
pH	9.4	10.2	9.5
Turbidity	1700	2300	1960
Total solid	2550	3139	2850
Dissolved solid	1330	1631	1578
Suspended solid	1082	1221	1125
Total alkalinity	1210	2125	1610
B.O.D. (5 days at 37 °C)	410	810	640
C.O.D. (dichromate value at 37 °C)	415	960	720
O.A. (KMnO <sub>4</sub> value of 37 °C)	390	480	450
Dissolved oxygen	3.8	4.4	4.0
Lignin	50.2	162.6	132.5
Mercurials	1.8	3.5	3.2
Resin acid	0.8	25.8	19.6
H <sub>2</sub> S	14.6	25.8	19.6
Chlorine	7.0	10.0	8.5

Amount of the pollution load thrown in Hindan river per day

Waste substance	Amounts Kgs/day
Total solids	25576.236
Dissolved solids	16439.825
Suspended solids	12843.684
Lignin	4213.944
B.O.D.	8015.112
C.O.D.	10991.635
Nitrogen	147.42
Sulphide Chloride	204.12



Physico-chemical characteristics of the waste-water of river Damola

Characteristics	Values		
	Minimum	Maximum	Average
Appearance	Black	Black	Black
pH	7.9	8.7	8.6
D.O.	2.3	3.2	2.5
Dissolved CO <sub>2</sub>	20	40	35
Alkalinity as -CO <sub>3</sub>	105	510	395
Total solid	720	795	735
Suspended solids	120	390	310
B.O.D. (5 days at 37 °C)	190	410	325
C.O.D.	295	480	375
Free NH <sub>3</sub> (as nitrogen)	3.5	16.3	12.8
Albuminoid NH <sub>3</sub> (as nitrogen)	1.2	12.2	8.1
Nitrite nitrogen	0.01	0.28	0.12
Nitrate nitrogen	0.12	10.2	6.5
Phosphate	0.25	6.2	4.6
H <sub>2</sub> S			

Physico-chemical characteristics of water of Krishna river before its confluence in Hindan

Characteristics	Values		
	Minimum	Maximum	Average
Appearance	Blackish	Blackish	Blackish
pH	5.8	6.9	6.6
Total solids	720	960	920
Suspended solids	340	520	490
B.O.D.	360	480	390
C.O.D.	540	720	610
Chloride	210	222	214
Oil and grease	traces	traces	traces
H <sub>2</sub> S	1.2	1.9	1.3
Nitrogen as NH <sub>3</sub>	1.5	1.7	1.52

Physico-chemical characteristics of the water of Kalinadi before its confluence in Hindan

Characteristics	Values		
	Minimum	Maximum	Average
Appearance	Light blackish	Light blackish	Light blackish
pH	7.7	8.1	7.9
Alkalinity as HCO <sub>3</sub>	280	360	310
B.O.D. (5 days at 37 °C)	40	120	50
C.O.D.	55	135	90
Total solids	360	480	435
Suspended solids	80	130	110
Sulphate Chloride	15	25	21.5
Oil and grease	192	206	190
Total nitrogen	8	22	17

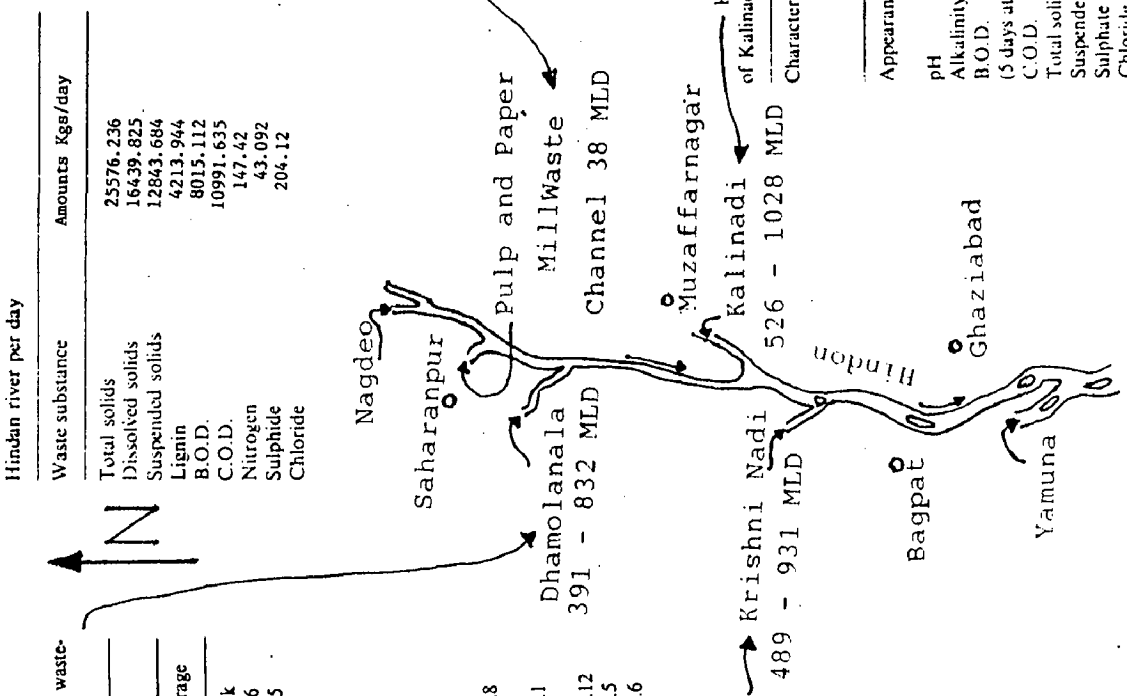


FIG.2.3 SKETCH OF RIVER HINDAN SHOWING MAJOR TRIBUTORIES/DISCHARGES ALONGWITH THEIR CHARACTERISTICS FOR 1971 - 73 (VERMA ET AL..1980)

### 2.2.3.1 Dairy Industry

Wastewaters in dairy industry originate from equipment washing, product spillage and losses. The waste is a dilute solution of decomposable organic matter. Wastes include buttermilk and milk plant washing containing constituents of milk such as protein, lactose, a small quantity of fat plus mineral constituents of milk and traces of sanitizers and detergents used for cleaning and sanitization of dairy plant equipment. General range of BOD in dairy wastes is 500 mg/kg to 1680 mg/kg (Eckenfelder 1970). Nemerow (1971) also point out that milk plant wastes are highly rich in dissolved organic matter, containing around 1000 mg/l BOD and are nearly neutral in pH.

The high concentration of organic matter especially of the carbohydrate, lactose and the temperature ideally suited for the bacteria make the dairy waste a burden on the DO balance of most streams (Mohan Rao and Subrahmanyam, 1972). One kg BOD was found to correspond to 10 litre of milk loss. It was concluded that dairy wastes can be rapidly and easily treated biologically because the BOD:COD ratio was found 0.63 and BOD:N:P ratio 100:5.4:0.9.

### 2.2.3.2 Pulp and Paper Industry

The characteristics of the pulp and paper wastes depend on the type of pulping process used. The effluent characteristics varies somewhat, depending on the bleaching practices. Suspended solids range from 20 to 50 ppm and are primarily fibers (about 0.5 percent of the total product); dissolved solid concentrations range from 1000 to 1500 ppm of which about 60% is ash. The BOD values range from 100 to 200 ppm (Moggio, 1954). The effluent is coffee brown colored (colour value about 500). Dhaneshwar et al., (1970) studied the characteristics of effluents from pulp and paper mill located on the Hoogly river in the West Bengal. The composite effluents being disposed from the mills were found to contain high BOD, COD and lignin. Pollutional characteristics of the composite effluents from these mills included depletion of D.O., objectionable odour and formation of slime and foam. Untreated effluents may be toxic to aquatic life in low concentrations, treatment can reduce or eliminate toxicity. Rajman and Oblisami (1979) have studied the environmental pollution due to paper industry in the rural area of Tamil Nadu. The nature of combined effluent samples being disposed off from factories were alkaline and contained large amount of suspended and dissolved solids resulting in the high concentrations of BOD and COD. The contents of carbonates were high in one paper mill effluent whereas the calcium, magnesium and chloride concentrations were high in the other paper and board mill effluents. Gosh and Konar (1980)

mentioned that the important chemicals used by most of the pulp and paper mills are sodium sulphate, sodium hydroxide, sodium sulphide, sodium carbonate, calcium hypochlorite and magnesium bisulphite. Obviously, waste waters which contain various amounts of these chemicals may be hazardous to aquatic life.

#### **2.2.3.3 Distillery Industry**

Nemerow (1971) pointed out that the effluents from distilleries contain large amount of dissolved organic matter. The matter is decomposed by biological action. Rao and Viraraghvan (1985) reported that the effluents from distilleries are characterised by high BOD (40,000 to 50,000 mg/l), low pH (3.5 to 4.5), high dissolved solids (70,000 to 80,000 mg/l), high levels of sulphates (4000 to 8000 mg.l), high levels of sulphates (4000 to 8000 mg/l) and considerable amount of potassium (8000 to 12000 mg/l). the waste water is highly coloured and has a distinct molasses odour. The distillery effluent resulting from cane molasses based alcohol industry is one of the highly polluting industrial effluents.

#### **2.2.3.4 Electroplating Industry**

The character and strength of electroplating wastes vary considerably, depending on plating requirements and type of rinsing.

used. The total plant waste may be either acidic or alkaline, depending on the type and quantity of bath used (Nemerow, 1971).

#### **2.2.4 DO, BOD, COD Profiles (1971-73)**

Different chemical characteristics were analysed by Verma et al (1980) for a period from 1971-73. Profiles of DO, BOD, COD and solids are shown in Fig. 2.4 for river stretch of 150 km in length starting from road bridge on Saharanpur - Dehradun road near Kailashpur to Road bridge on Meerut-Bagpath road. Based on physico-chemical and biological conditions, Hindon was divided into various zones along length. These zones are shown in Fig. 2.5.

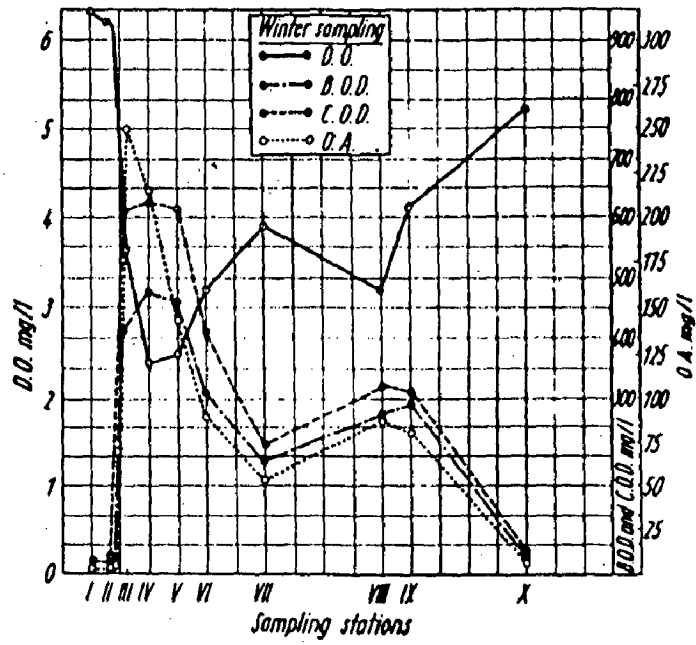


FIG.2.4 . DO . BOD .COD PROFILES (VERMA ET AL..1980)

**Polysaprobic (Degeneration) Zone:**  
 In this zone there is a steep fall of oxygen which is accompanied by high value of BOD and COD. The pH is highly alkaline. The water is brownish in colour, containing sufficient amount of organic matter, paper fibres, cellulose and total and dissolved solids. The species and number of fishes have been remarkably reduced and are represented only by 5 to 10 species and 7 to 10 fish number. The bottom is made up of oozing black mud.

**Oligosaprobic (Clear water) Zone:**  
 The water in this zone is characterized by moderate alkaline medium, low turbidity, low biochemical and chemical oxygen demand and fair DO. The species and number of fishes are quite good, ranging from 21 to 22 species and 40 to 51 numbers

**B - Mesosaprobic (Recovery) Zone :**  
 In this zone DO attains saturation with the lowering of BOD & COD values. The colour water changes to light brown. The fish species and fish number increases to 25 and 42 - 44 respectively.

**α - Mesosaprobic (Active Decomposition) Zone :**  
 The DO values shows some improvement in the amount of dissolved oxygen coupled with the reduction of BOD & COD. The substratum is still made of oozing mud though not so much as in polysaprobic zone. The number of protozoans have declined while that of rotifers and Entomostraca had increased.

**Oligosaprobic (Clear Water) Zone :**  
 It can be considered as repurified zone. In this zone physicochemical and biological conditions are almost similar to first zone.

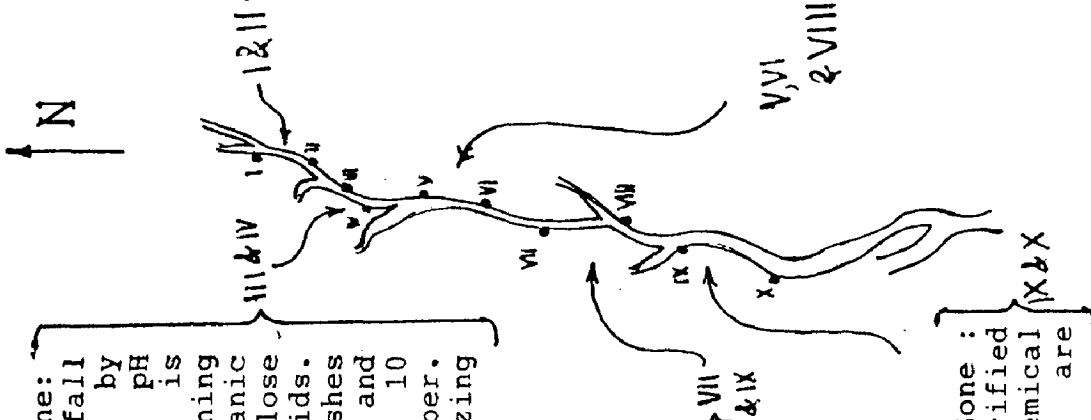


FIG.2.5 . ZONAL CHARACTERISTICS (VERMA ET AL., 1980)

## WATER QUALITY MONITORING :METHODOLOGY

## 3.1 GENERAL :

For having adequate knowledge about the various pollutional parameters a definite methodology have to be followed. A typical chart of water quality monitoring may be shown as in Fig.

2.1

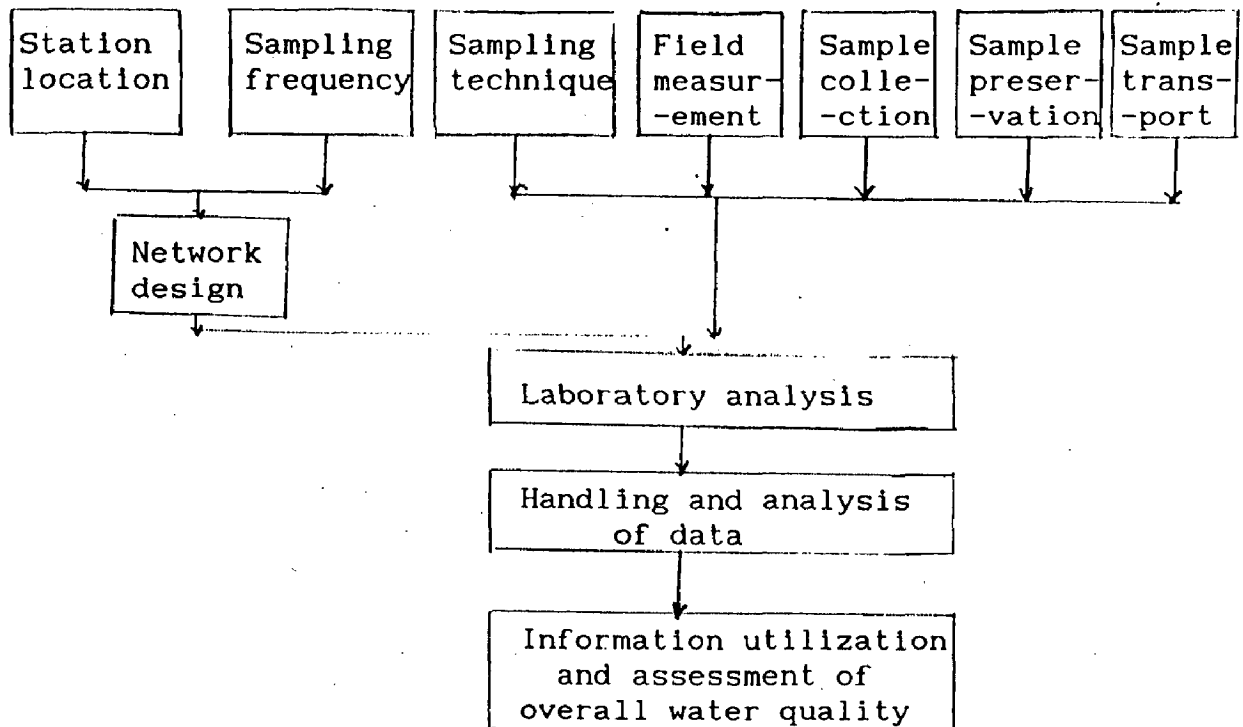


Fig.3.1 FLOW CHART SHOWING WATERQUALITY MONITORING PROGRAMME

## 3.2 SELECTION OF SAMPLING STATIONS :

On the basis of reconnaissance survey, five sampling stations were selected in the study area keeping in view the following points :

- Objectives of the study
- Accessibility
- Flow
- Mixing and other physical characteristics of the water body, and
- Chemical source location

In view of relatively small depth and width of the river in most of the stretches and reasonably good mixing, there is enough justification to resort to grab sampling technique for the purpose of representativeness. The locations of five sampling stations selected in the study area are shown in Fig. 2.1. The abbreviations used for various sampling stations are given in Table 3.1.

**TABLE 3.1 DETAILS OF SAMPLING STATIONS**

Sampling Location	Abbreviation Used
Near Road Bridge, Maheshpur (Saharanpur)	MH
Near Road Bridge, Barnawa (Meerut)	BA
Near Road Bridge. Daruhara (Meerut)	DH
Near Road Bridge, Mohan Nagar (Ghaziabad)	MN
Near Road Bridge. Noida (Ghaziabad)	NO

### 3.3 SAMPLING FREQUENCY

Hindon river water samples were collected for analysis on 11th, 11th and 21st of Dec., 1993 and Jan. and Feb. 1994.

### 3.4 SAMPLE COLLECTION, HANDLING AND PRESERVATION

Water samples were collected at both the banks at each station. Water samples were collected in two litre capacity plastic containers. As the period of study was winter, so there was no need to preserve the samples in the ice bags. The samples were brought to the laboratory in plastic containers. All the samples were brought to the laboratory within 8 hours of the

collection. DO was fixed just after collection. Flow was measured by surface float method. Depth, width of river were also measured.

In addition on 21st Feb., 1994 water samples were collected to enable the BOD determinations for periods of 1,2,3,4 and 5 days in order to estimate deoxygenation rate coefficient ( $K_1$ ) and ultimate BOD ( $L_0$ ).

### 3.5 ANALYSIS OF SAMPLES :

The Samples were analysed in accordance with Standard Methods (1985). Different analytical methods adopted in the present study for characterisation of the water samples are given in Table 3.2.

TABLE 3.2 SUMMARY OF ANALYTICAL METHODS

Sl. No.	Parameter	Technique
1.	Dissolved Oxygen	Modified Winkler's Method
2.	Chemical Oxygen Demand	Reflux Method
3.	Biochemical Oxygen Demand	Modified Winkler's Method
4.	Ammonical Nitrogen	Direct Nesslerization Method
5.	Nitrate Nitrogen	Phenoldisulplonic method
6.	Nitrite Nitrogen	Sulphanilamide method

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## RESULTS AND DISCUSSIONS

### 4.1 GENERAL :

Different wastewater streams join river Hindon at regular intervals as shown in Fig.2.2. Quantity of wastewaters generated in four major cities are given in Fig.4.1 (YAP,1992).The characteristics of wastewaters of different streams changes continuously depending on variations in quality and flow of domestic and industrial wastewaters with time (Verma et al.,1980). In addition canal water is released into Hindon near Khatauli and Jani. Although variation in quantity of canal water released in Hindon is sharp but quality remains almost uniform as far as organic matter is concerned. In one of the recent round the year study, Mehrotra and Kumar(1993) found that canal water contains good amount of DO and organic matter is not present in significant concentrations. Table 4.1 gives quality of canal water. Variation of DO and COD is shown in Fig. 4.2.

The prediction of resultant quality of Hindon water is almost impossible. However, in this chapter firstly an attempt has been made to study temporal and spatial changes in water quality in

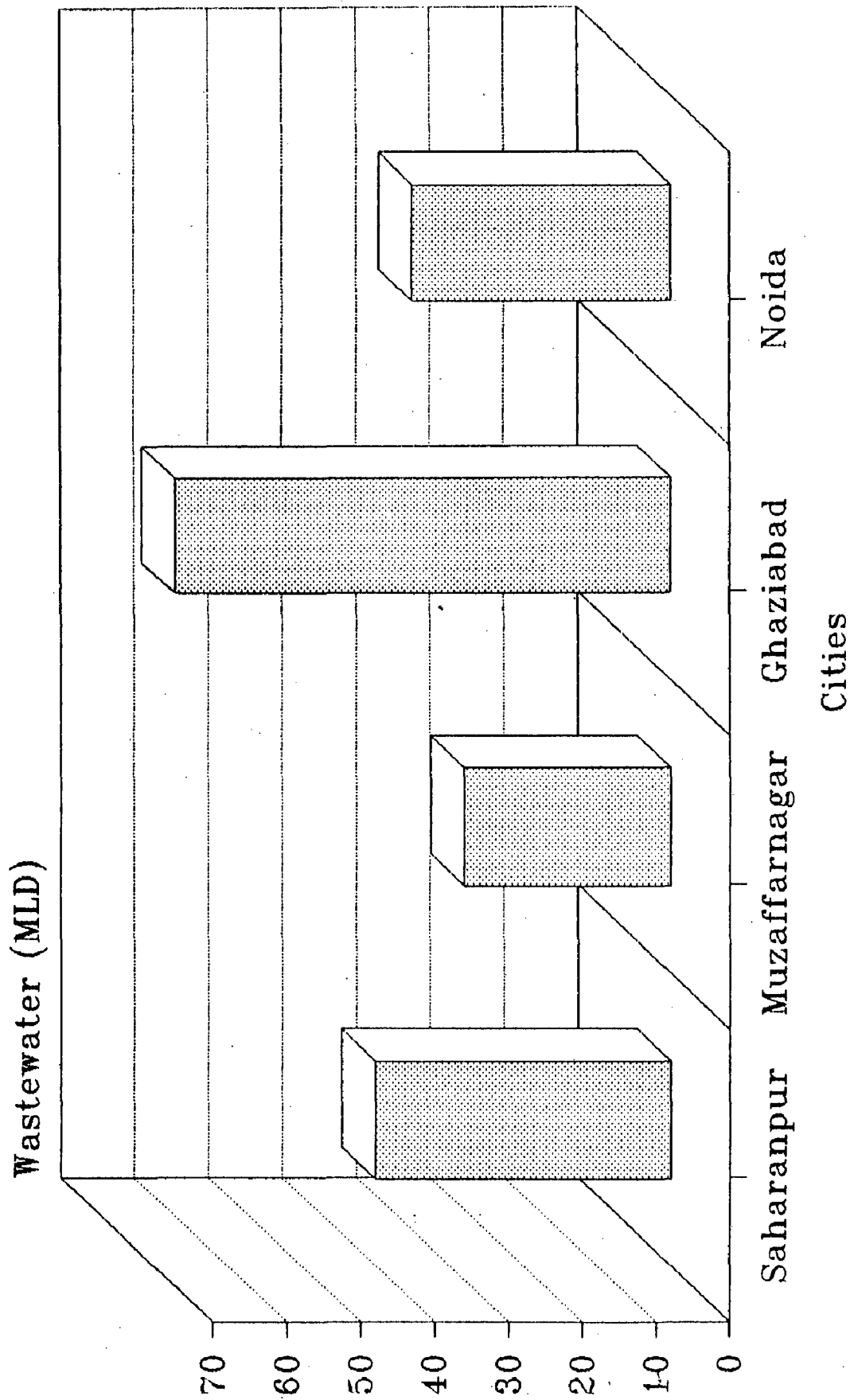


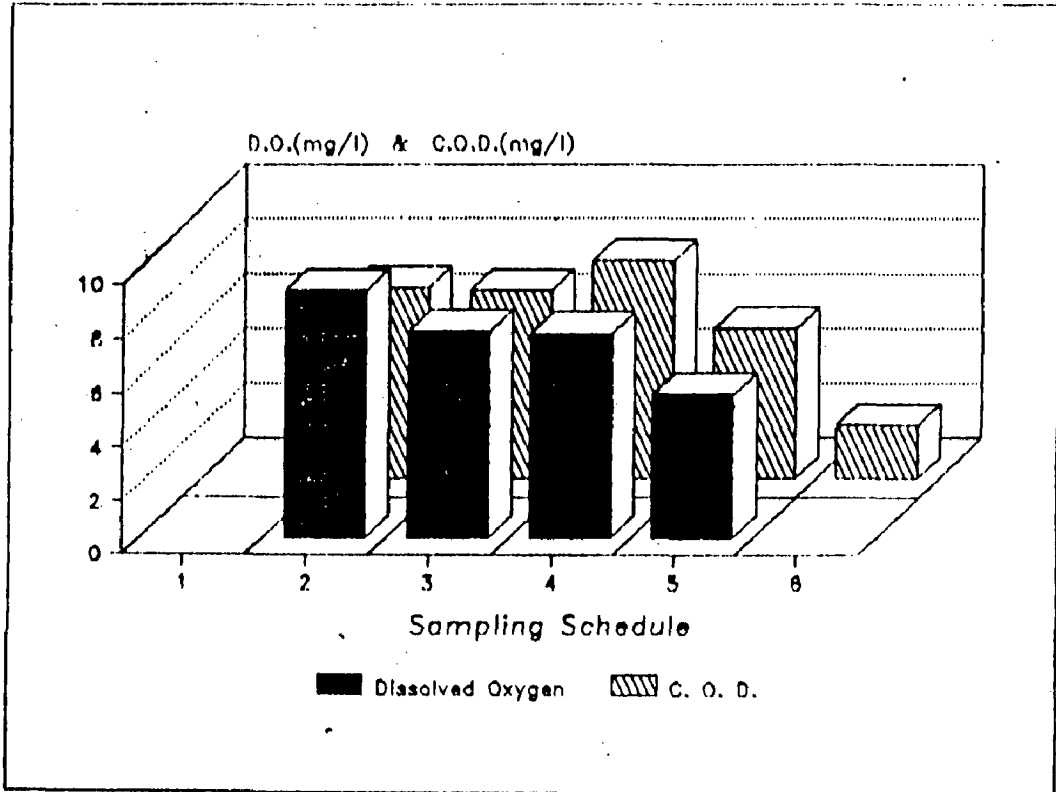
Fig. 4.1 WASTEWATERS GENERATED IN FOUR MAJOR CITIES IN HINDON CATCHMENT (YAP, 1992)

**Table 4.1 - Quality of Canal Water (Mehrotra & Kumar)**

Parameter	Values as per Sampling Schedule No.					
	1	2	3	4	5	6
<b>(A) Physical :</b>						
(1) Temperature, °C	15	-	-	18	-	-
(2) pH	8.14	8.23	8.08	7.55	7.81	7.06
(3) Turbidity, NTU	10.0	70.0	50	-	6	17.5
<b>(4) Solids :</b>						
(i) Total solids, mg/l	206.5	490.0	440	190	180	169.8
(ii) Dissolved solids, mg/l	166.0	120.0	100	150	171.4	76.8
(iii) Suspended solids, mg/l	40.5	370.0	340	40	8.6	93
<b>(B) Chemical :</b>						
(1) Total hardness, mg/l as CaCO <sub>3</sub>	123	96	81.5	90	92	67
(2) Chlorides, mg/l	15	5	42	30	7	12
(3) Dissolved oxygen, mg/l	-	9.1	7.6	7.5	5.3	-
(4) Alkalinity, mg/l as CaCO <sub>3</sub>	104	62	82	87	89	60
(5) Acidity, mg/l as CaCO <sub>3</sub>	2	0.9	1.7	6.2	7.0	7
(6) Chemical oxygen demand, mg/l	-	7.0	6.9	8.0	5.5	2.0
(7) Sulphates, mg/l	24.7	-	-	37.0	39.0	19.0
(8) Calcium hardness, mg/l CaCO <sub>3</sub>	60	43	-	-	-	-

**Sampling Schedule**

Sampling No.	Date
1	20th February, 1992
2	8th July, 1992
3	5th September, 1992
4	29th November, 1992
5	31st January, 1993
6	8th May, 1993



**Fig.4.2 - Variation of Dissolved Oxygen and COD in Canal Water**  
**(Mehrotra & Kumar,1993)**

various stretches of the river. Verma et al.(1980) studied quality of river 20 years back. Results of two studies have been compared and significant changes have been listed. Thirdly deoxygenation and reaeration constants have been calculated and profile of sag curve has been plotted. Lastly, BOD of Hindon water being discharged into Yamuna has been extrapolated.

#### 4.2 TEMPORAL AND SPATIAL VARIATIONS :

The values of different parameters determined through the chemical analysis in laboratory at five stations for a period of three months from Dec.1993 to Feb.1994 are shown in Fig.4.3 to Fig.4.8. and Tables A to H given in Appendix.

##### 4.2.1 Stretch 1 : MH to BA :

It is clear from Fig.4.3 that most of the time DO is zero at Maheshpur(MH) and Barnawa(BA). DO gives an idea about extent of pollution of the river. Absence of oxygen in this approximately 115 km long stretch is an indication of higher degree of pollution. Reasons for this could be explained with the help of Fig.2.2. At MH river contained only wastewaters from Dec.1993 to Feb.1994.

5 day  $20^{\circ}\text{C}$  ranged from 32 to 38mg/l at MH. There is no major discharge after MH till Kalinadi joins Hindon. In natural

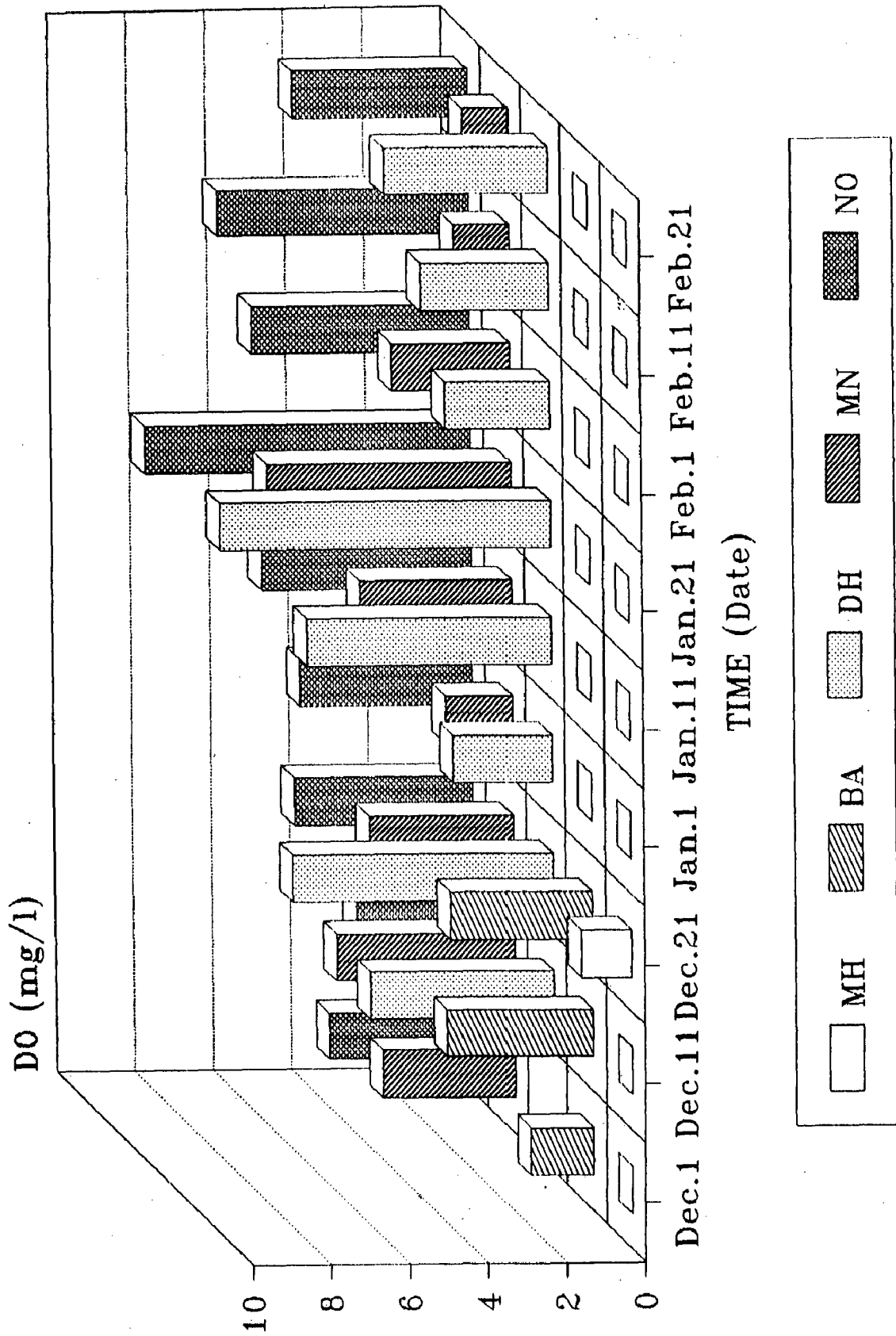


Fig. 4.3 , TEMPORAL & SPATIAL VARIATION  
in  
D.O. VALUES

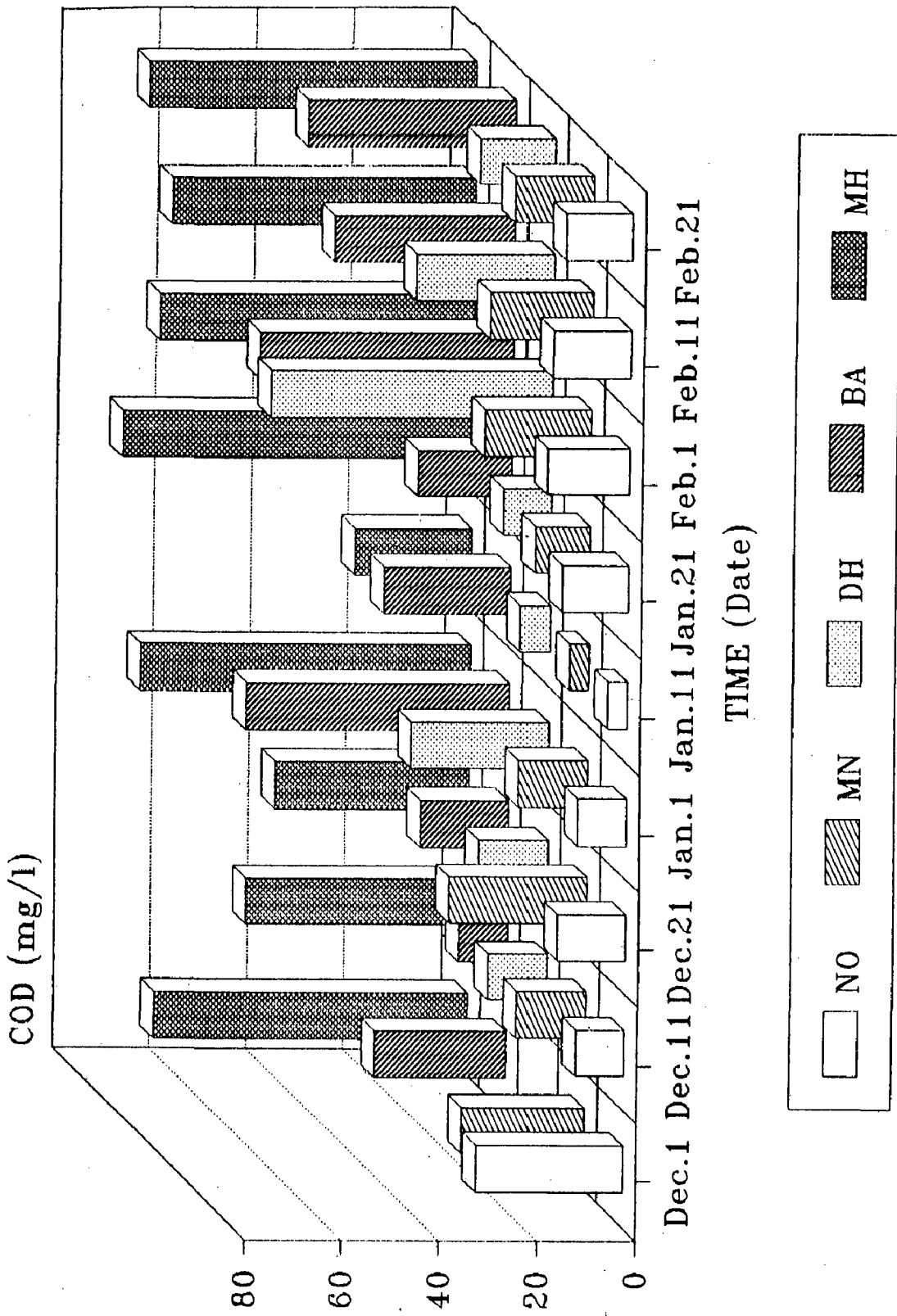


Fig. 4.4 , TEMPORAL & SPATIAL VARIATION  
in  
C.O.D. VALUES

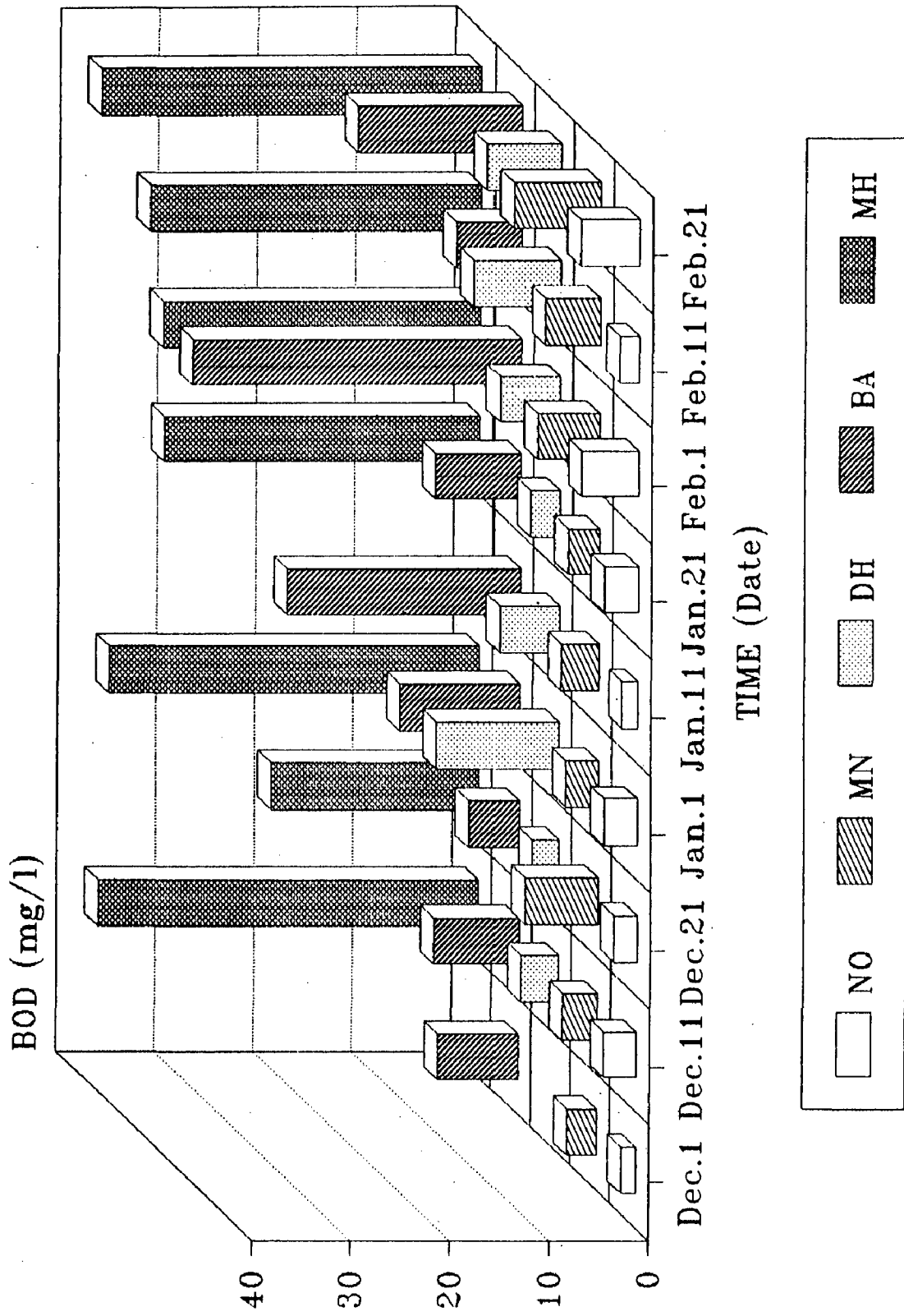


Fig. 4.5 , TEMPORAL AND SPATIAL VARIATION  
in  
B.O.D. VALUES

NH<sub>3</sub>-N (mg/l)

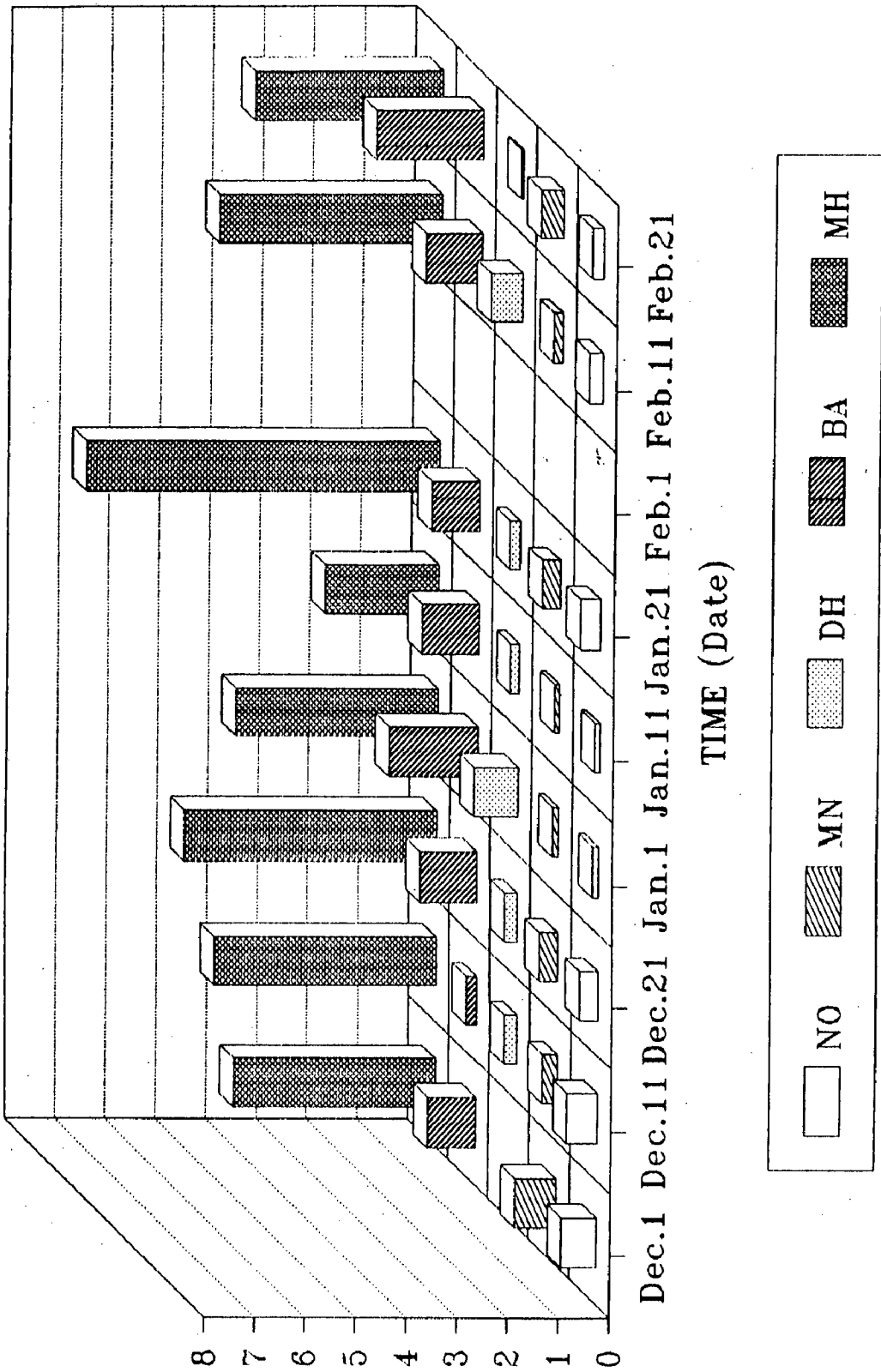


Fig. 4.6 TEMPORAL AND SPATIAL VARIATION  
in  
AMMONICAL - NITROGEN

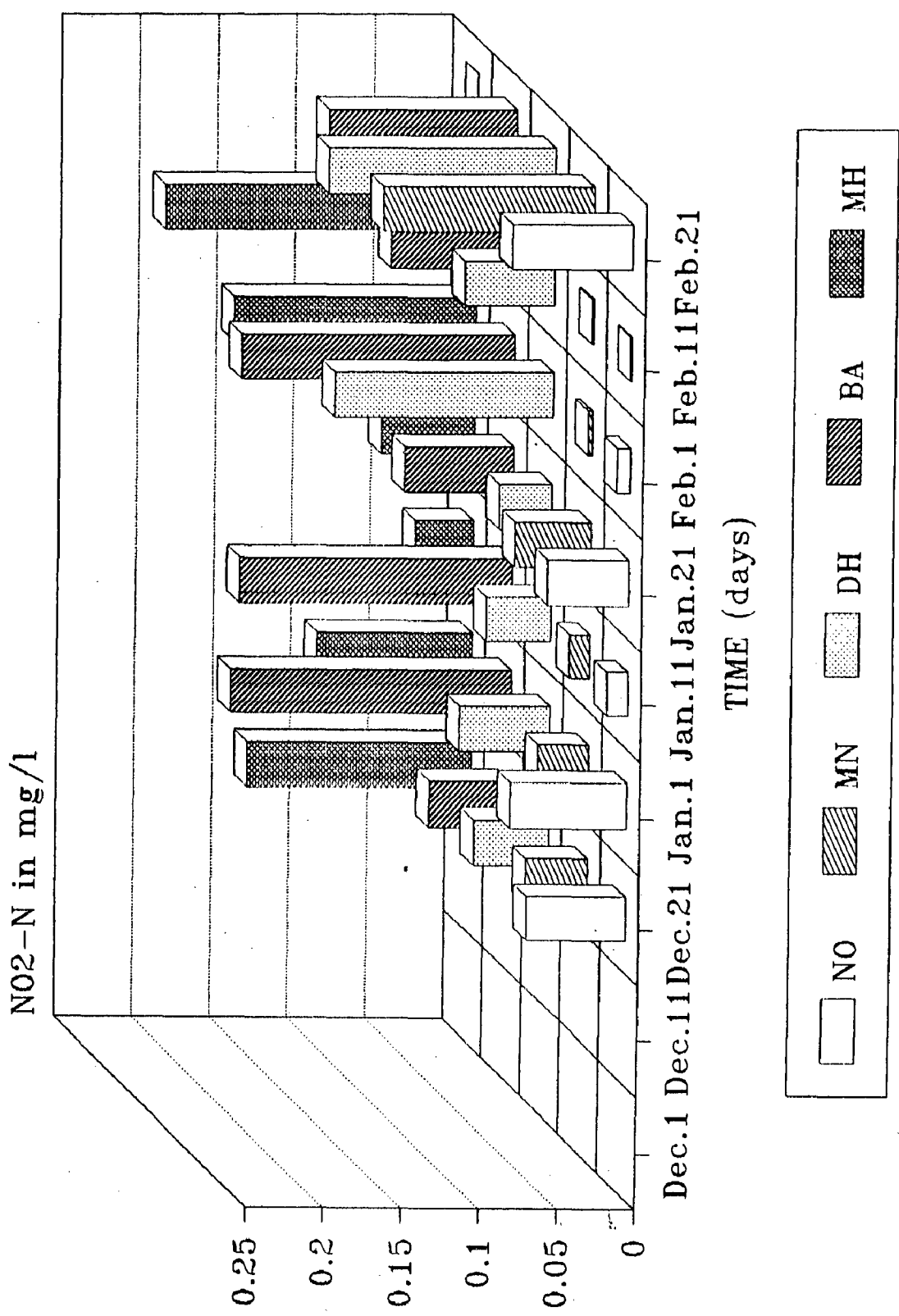


Fig. 4.7 , TEMPORAL AND SPATIAL VARIATION  
in  
NITRITE-NITROGEN

NO<sub>3</sub>-N in mg/l

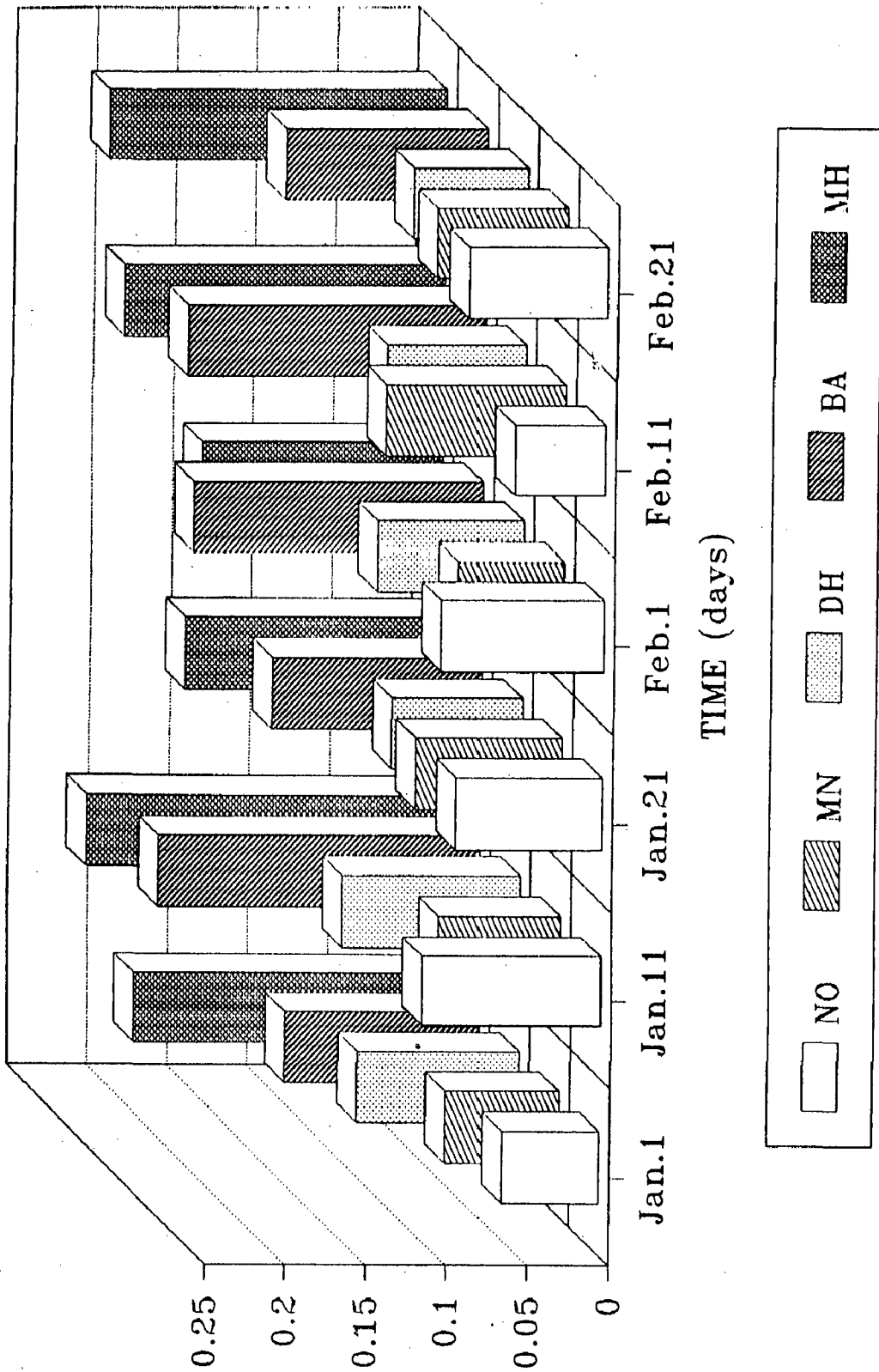


Fig. 4.8 , TEMPORAL AND SPATIAL VARIATION  
in  
NITRATE-NITROGEN

course river water should have gained some DO due to reaeration since organic load is not very high. However, it is not reflected through DO values recorded at BA. Kalinadi which brings wastewater from Muzaffarnagar joins before BA and discharges fresh load of pollutants. Whatever DO gained due to contact with atmosphere from MH to BA is further consumed. Compared to present study Verma et al.(1980) found very high values of BOD and COD. At or near MH, BOD & COD values were found of the order of 450 & 550 mg/l respectively.

In winter months DO was recorded more than 2 mg/l. Significant difference in BOD, COD and DO values in present study and that conducted by Verma et al.(1980) is sometimes difficult to explain unless detailed study of sources is conducted. Pulp and paper Mill, the largest contributor of waste load upstream of Maheshpur installed Activated Sludge Process in early 1980's. It appears that factory operates treatment plant quite religiously and releases a well treated wastewater. However it is apparent that ASP installed by factory is unable to reduce dark brown colour imparted by the presence of lignin. It is difficult to compare the colour in 1970's and now in 1990's. Recently, Kumar(1994) did substantial work on the measurement of colour in Hindon River System and found it maximum at MH. It reduces as river flows. Saharanpur continues to discharge untreated wastewater.

The values of different forms of nitrogen were found higher at MH than BA. The ammonical nitrogen were in the range of 4 to 6 mg/l at MH (Fig.4.6). Verma et al.(1980) found  $\text{NH}_4\text{-N}$  of the order of 2 mg/l. Other nitrogen forms i.e. nitrate and nitrate<sup>3</sup> were also found more at MH. Generally  $\text{NH}_4\text{-N}$  decreases and nitrate increases as a river flows. However, in present study<sup>3</sup> nitrate were found lesser at BA compared to MH. This may be due to the dilution provided by canal water.

#### 4.2.2 Stretch 2 : BA to DH :

Between BA and DH (25 km), river Krishni and Jani Escape Joins Hindon. Water was found to contain DO in all the samplings. Krishni water contains very less or nil DO while canal water is very rich in DO. Sharp fluctuations in DO levels were because of sharp variation in the quantity of water being released through Jani escape.

Sometimes greater values of COD and BOD were found at DH. This may be due to lesser or no release of water from Jani Escape, leading to lesser dilution or alternatively more pollutional loads discharged by Krishni into Hindon. The values of DO, BOD & COD for this stretch as given by Verma et al.(1980) were in the range of 4 to 5 mg/l, 25 to 200 mg/l & 25 to 250 mg/l respectively. Higher BOD and COD values are mainly due to small quantity of flow at this time.

Ammonical nitrogen (Fig.4.6) was found around 1 mg/l in BA and 0.2 to 0.9 mg/l at DH.

#### 4.2.3 Stretch 3 : DH to MN :

This stretch is about 50 km long. The DO values show a general decline from DH to MN. Water upstream of Mohan Nagar barrage has maximum depth and movement is relatively slow. BOD values were found to have consistently decreasing trend from DH to MN. No significant change in the different nitrogen forms was noticed except a decreasing trend in ammonical form of nitrogen.

#### 4.2.4 Stretch 4 : MN to NO :

This stretch is only 4.5 km long. Water is withdrawn into Hindon Cut canal. Fall at barrage provides turbulence. Sometimes, there is a complete stagnation of water in Hindon due to higher water demand in Agra Canal system. DO values were observed ranging from 3.0 to 8.3 mg/l. The BOD and COD values have general reducing trend from MN to NO (Fig. 4.4 and Fig. 4.5).

### 4.3 COMPARISON OF BOD VALUES

BOD values reported by Verma et al. (1980), YAP (1992) alongwith those observed in present study are plotted in Fig. 4.9

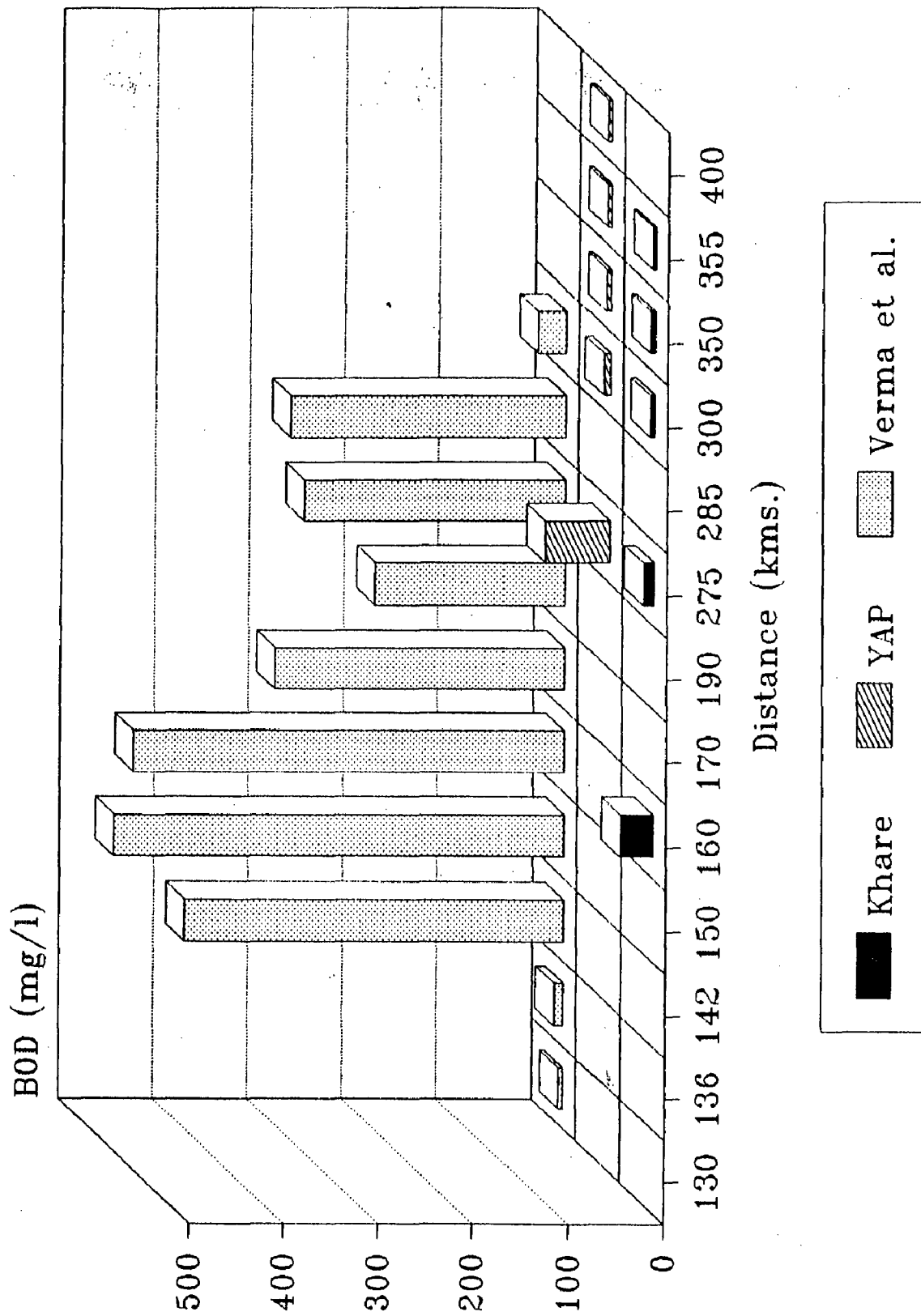


Fig. 4.9 VARIATION OF BOD ALONG LENGTH

for non monsoon period. Different sampling stations were selected by different teams. Fig.4.9 gives variation of BOD along length.

#### 4.4 WATER QUALITY MODELLING :

To reflect the non-conservative or degrading constituents present in the river stream, it is necessary to have a mathematical model representing the existing condition. As it is evident that wastewaters entering the river are organic in nature, oxygen balance could be considered to get the final expression.

Eq. 4.1 represents classical Streeter Phelps equation (Eckenfelder, 1970) derived from the basic relationship of oxygen sag curve.

$$D_t = \frac{K_1 L_0}{K_2 - K_1} \left[ e^{-k_1 t} - e^{-k_2 t} \right] + D_0 e^{-k_2 t} \quad \dots\dots\dots(4.1)$$

where,

$D_t$  = oxygen deficit at time  $t$ , mg/l

$D_0$  = initial oxygen deficit at the point of waste discharge at  $t = 0$ , mg/l

$K_1$  = deoxygenation rate coefficient,  $d^{-1}$

$K_2$  = reaeration rate coefficient,  $d^{-1}$

$L_0$  = ultimate BOD, mg/l

$t$  = time of flow, day

Eq. 4.1 is applicable only to the channels of uniform cross section, where the effects of photosynthesis due to algae, sludge deposits and respiration are negligible.

The critical deficit  $D_c$ , at point  $X_c$  can be found by Eq. 4.2.

$$D_c = \frac{K_1}{K_2} L_0 e^{-K_1 t_c} \quad (4.2)$$

where  $t_c$  = time to reach the critical point

Critical time can be determined by Eq. 4.3

$$t_c = \frac{1}{K_2 - K_1} \ln \frac{K_2}{K_1} \left[ \left[ 1 - \frac{D_0 (K_2 - K_1)}{L_0 K_1} \right] \right] \quad (4.3)$$

#### 4.4.1 Evaluation of Deoxygenation rate coeff. ( $K_1$ )

For the evaluation of deoxygenation rate coefficient, BOD values were determined on day 1, 2, 3, 4 & 5.  $K_1$  values have been calculated for 20°C by using Log Difference Method (Ramalho R.S. 1983). Subsequently, values of  $K_1$  were converted to field temperatures.

The curve showing the plots of BOD ( $y$ ) time ( $t$ ) and  $\ln(dy/dt)$  vs.  $t$  have been given in Fig. 4.10 and Fig. 4.11. Corresponding values of  $y$  vs.  $t$  &  $\frac{dy}{dt}$  vs.  $t$  are given in appendix,

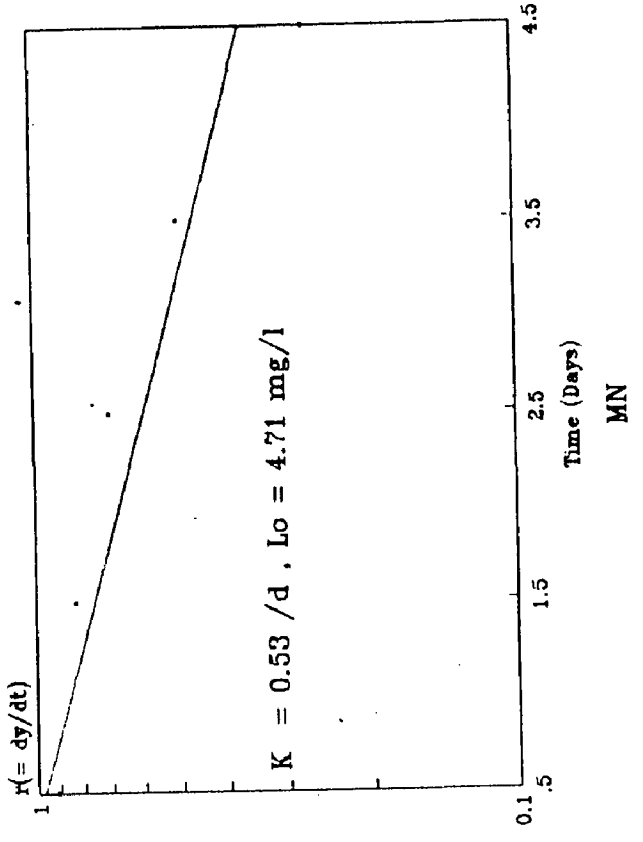
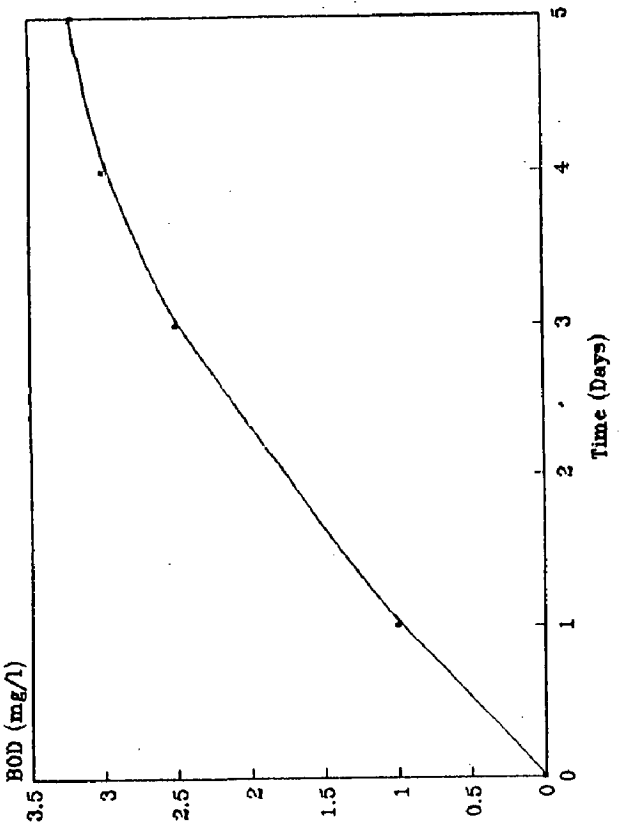
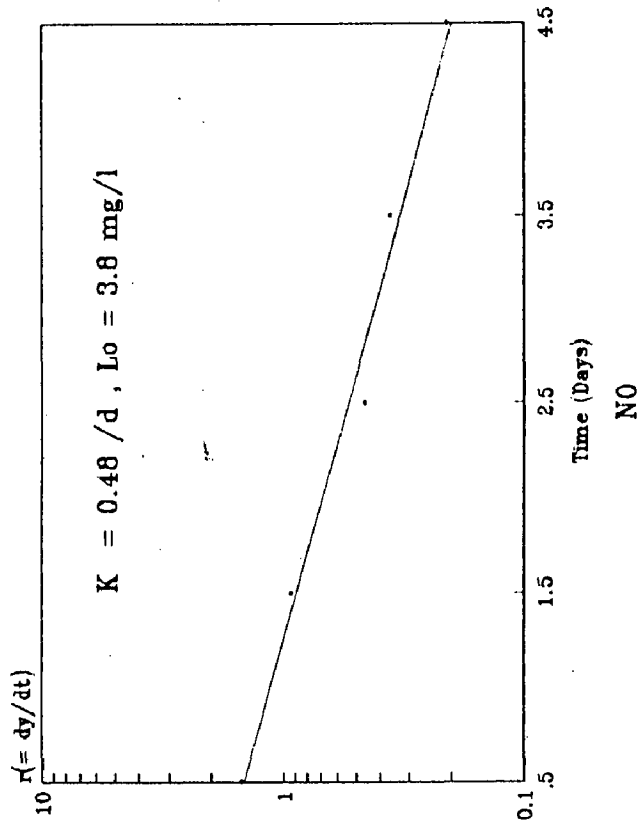
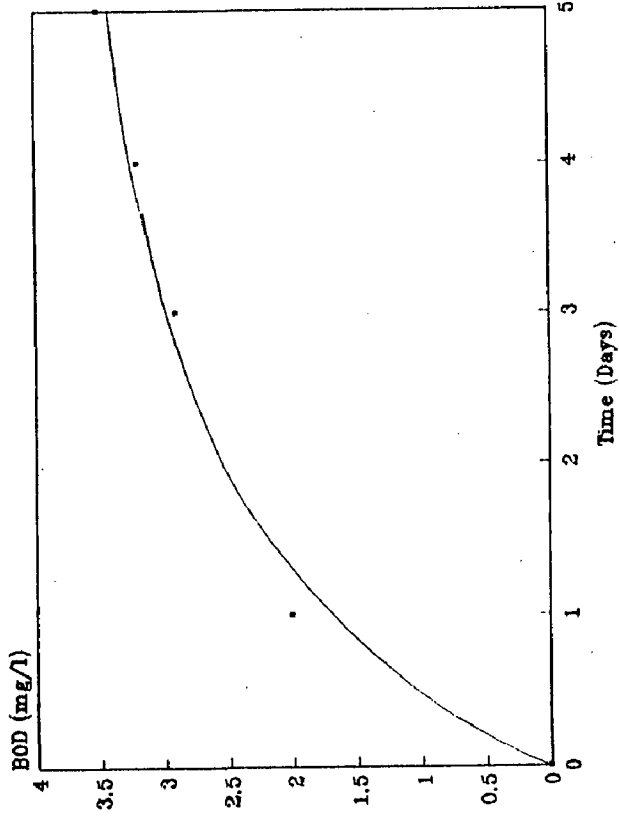
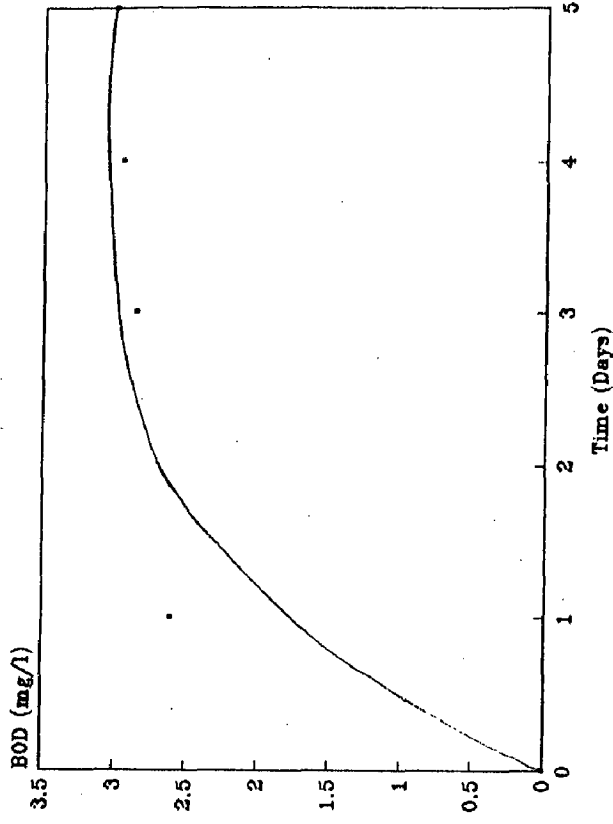
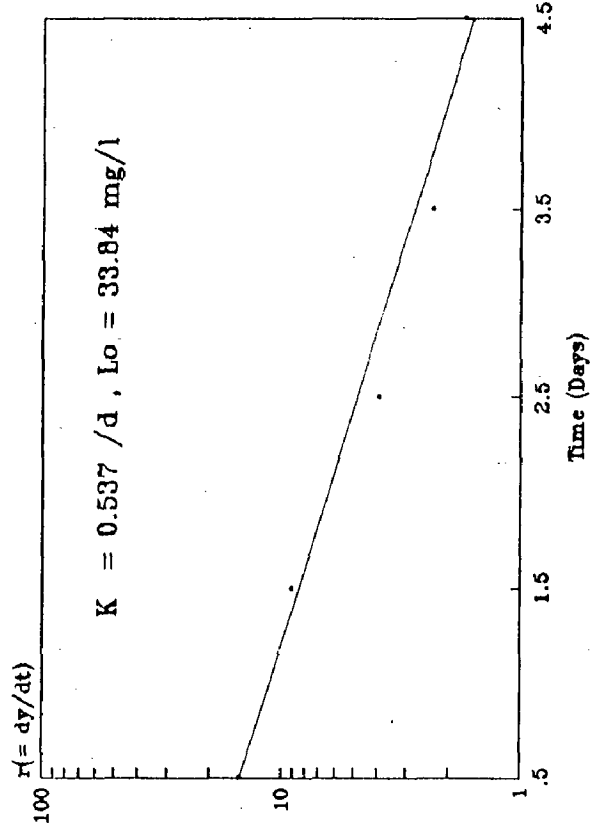
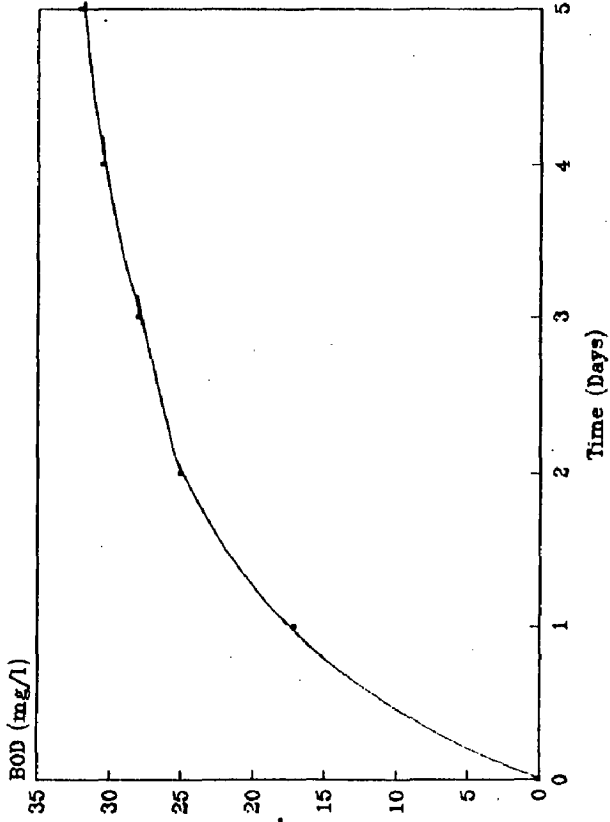


Fig. 4.10, Lo & K1 DETERMINATION



MH

DH

Fig. 4.11, Lo & K1 DETERMINATION

Tables I & J. The  $K_1$  and  $L_0$  values calculated from these graphs are given in Table 4.2.

TABLE 4.2  $L_0$  &  $K_1$  VALUES

	STATIONS			
	NO	MN	DH	MH
temp ( $^{\circ}$ C)	15	16	15.2	12.5
$K_1$ $20^{\circ}$ c ( $d^{-1}$ )	0.48	0.35	0.95	0.537
$K_1$ t $^{\circ}$ c ( $d^{-1}$ )	0.418	0.313	0.832	0.437
$L_0$ (mg/l)	3.80	4.71	3.30	33.84

#### 4.4.2 Evaluation of Reaeration Coefficient ( $K_2$ )

The reaeration coefficient  $K_2$  has usually been defined by a relationship of the type

$$K_2 = A \frac{U^m}{H^n}$$

where,

U = average velocity of stream, ft/sec

H = average stream depth, ft

A = constt. dependent on stream characteristics

m & n = exponents related to stream conditions

Different values of A, m & n are given in Table 4.3

**Table 4.3 Values of A, m & n (Eckenfelder, 1971)**

Reference	A	m	n
O' Connor & Dobbins	5.6	0.5	1.5
Churchill et al.	5.0	1.0	1.67
Langbein & Durum	3.3	1.0	1.33
Owens et. al.	4.41	0.67	1.85
Basal	4.67	0.6	1.4

The values of  $K_2$  have been calculated using Langbein & Durum coefficients. The calculated values of  $K_2$  are tabulated in Table 4.4. The best value of  $K_2$  was found for NO because of shallowest depth most inferior value was found for MN because of maximum depth & least velocity.

**TABLE 4.4 VALUES OF REAERATION COEFF. ( $K_2$ )**

	STATIONS			
	NO	MN	DH	MII
temp ( $^{\circ}$ C)	15	16	15.2	12.5
$U'$ (m/s)	0.563	0.102	0.545	0.222
$U_{\text{mean}}$ (m/s)	0.479	0.087	0.463	0.189
H (m)	0.35	2.85	1.25	0.45
$K_2$ $20^{\circ}$ C ( $d^{-1}$ )	4.315	0.048	0.767	1.219
$K_2$ $t^{\circ}$ C ( $d^{-1}$ )	3.758	0.043	0.672	0.991

#### 4.4.3 Computed DO by Water Quality Model :

The distances observed from map of the are are given in Table 4.5.

TABLE 4.5 DISTANCE ALONG RIVER BETWEEN STATIONS

STATION		Distance (km)
from	to	
MH	BA	115
BA	DH	25
DH	MN	52
MN	NO	4.5

The Streeter Phelps Eq. is applicable to the stream upto a downstream point where no wastewater is discharged. Eq is again applicable for further computations downstream by initializing the various terms used in the equation 4.1.

Table 4.6 shows the computed as well as the observed values of DO in the stream. A comparison of observed and computed values of DO have been given in Fig. 4.12.

The difference in computed and observed values is due to the non existence of applicability conditions of the applied Streeter Phelps equation.

TABLE 5.5 COMPUTATION AND COMPARISON OF DO<sub>COMP.</sub> WITH DO<sub>OBSERVED</sub>

Initial station (t=0)	Station at time t	time of travel	Temp (°C)	DO <sub>obs</sub> (mg/l)	DO <sub>s</sub> (mg/l)	DO <sub>o</sub> (mg/l)	L <sub>0</sub> (mg/l)	D <sub>t</sub> (mg/l)	DO <sub>com</sub> (mg/l)
MH			12.5	0	10.44	10.44	33.84		
	BA	3.4		0				7.54	2.9
DH			15.2	8.4	9.84	1.46	3.02		
	MN	0.545		6.2				1.92	7.9
MN			16.0	6.2	9.71	3.51	4.71		
	NO	0.109		8.3				2.39	7.7

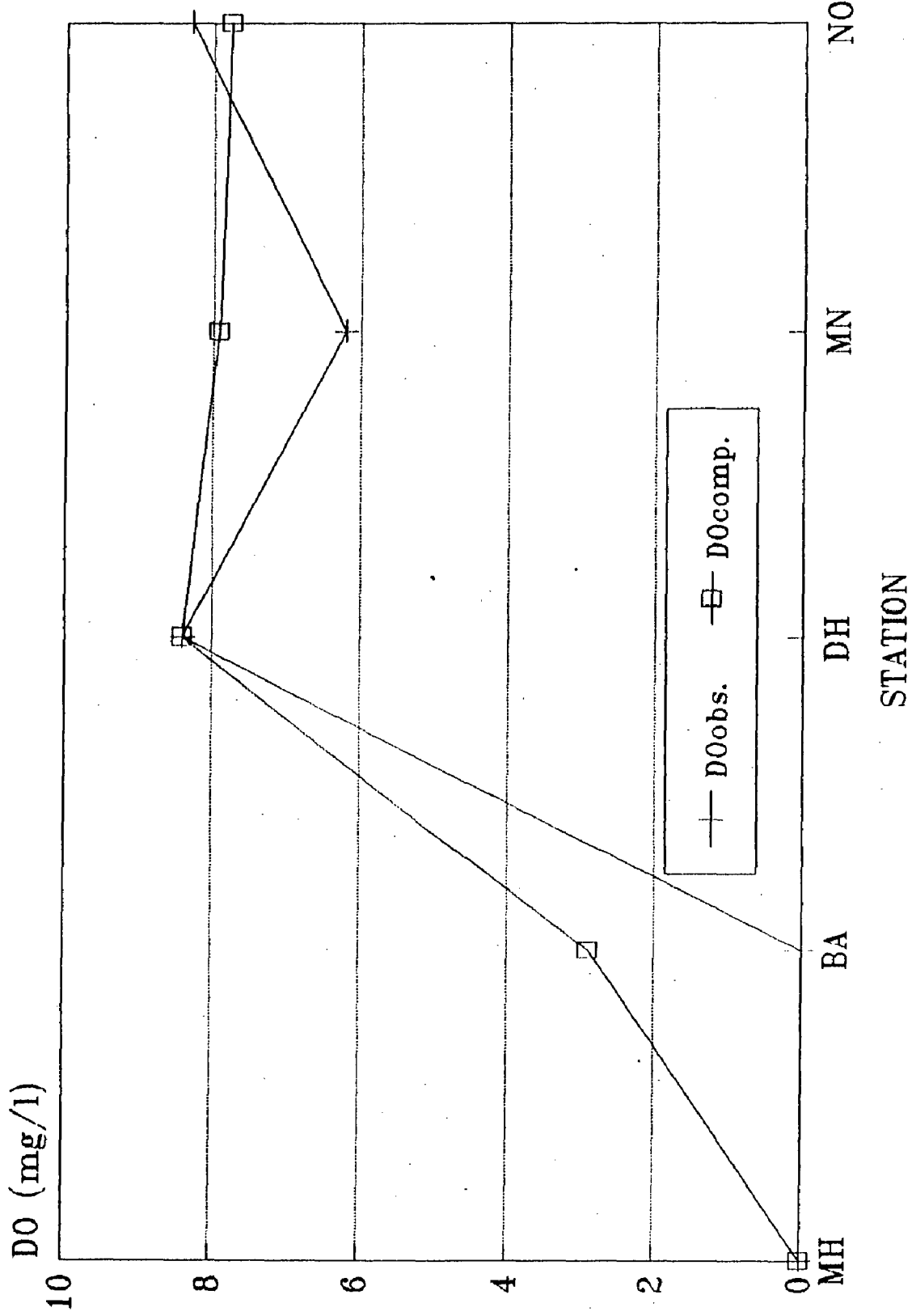


Fig. 4.12, COMPARISON OF COMPUTED & OBSERVED VALUES OF D.O.



#### 4.4.4 Limitations of the model developed

Limitations of the water quality model given in section 4.4 are listed below :

1. Primary requirement of the equation used is that river section shall be uniform throughout the stretch.
2. The data to calculate  $K_1$ ,  $K_2$  and  $L_0$  have been generated only for the samples collected at the time of 5th sampling. It would have been better to find  $K_1$ ,  $K_2$  and  $L_0$  for other sampling schedules also.
3. At most of the stations values of BOD were extremely low ( $< 5$  mg/l). Determination of extremely low 1,2,3,4 and 5 day BOD values is difficult and results in large errors.
4. This equation is valid at a particular time. Fluctuations in flow and pollutional load as observed in case of Hindon alters initial conditions further reducing applicability of Equation.
5. Lastly, a number of non-point sources also meet the river Hindon, which are difficult to be identified. This fact is again in contrast to the basic requirement of applicability of Equation 4.1

#### 4.5 BOD OF WASTEWATER AT TILWARA

From Fig. 4.9 BOD of wastewater being discharged at Tilwara could be extrapolated around 3 mg/l for non monsoon period.

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## CONCLUSIONS

The prime objective of the study was to assess the Hindon river water quality so that the pollutional loads in Hindon at various points and that transferred by Hindon to Yamuna could be quantified. The present water quality as per designated best use is 'E' and the desired one is 'D' to make the Hindon and subsequently Yamuna, cleaner.

From the temporal and spatial variations of different parameters following significant points may be mentioned :

- At MH and BA the nil or near zero DO level is the clear indication relatively higher pollutional loads.
- The improvement in DO content and the decline in the BOD and COD concentrations at DH and further downstream is due to the release of fresh water of Upper Ganga Canal (UGC) from Khatauli and Jani Escapes into Hindon and degradation of organic matter.
- A wider range of temporal variations in the quality parameters can be attributed to the sharp changes in the quantity of UGC water depending on demand in Agra and Gurgaon Canals.

- The dissolved oxygen level at NO (4.4 to 5.5 mg/l mostly) is adequate to support the aquatic life and fish culture there.

From the comparison of BOD values compiled from results of Verma et al. (1980), YAP (1992) and the present study, it can be seen that

- Magnitudes and spatial trend in the BOD values of the present study and YAP (1992) are almost matching.
- BOD and COD values of Verma et al. (1980) are much higher than those of present study and YAP (1992). It is most probably due to the installation of wastewater treatment plants by few industries in the basin and construction of Khatauli and Jani escapes.

The mathematical model developed for DO sag curve reflects that :

- Because of non-existence of applicability conditions of the Streeter Phelps Eq. a very good correlation between computed and observed values could not be obtained.
- The deoxygenation rate coefficient ( $K_1$ ) was found in the range of 0.31 to 0.83  $d^{-1}$ . The reaeration rate coefficient ( $K_2$ ) had a maximum value of 3.758  $d^{-1}$  at NO and a minimum of 0.048  $d^{-1}$  at MN. It is because of low

velocity and large depth at MN and a very low depth of water at NO.

The BOD of the river water being discharged at Tilwara into Yamuna could be extrapolated around 3 mg/l for non monsoon period.

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## APPENDIX

TABLE A TEMPORAL & SPATIAL VARIATION  
IN  
D.O. VALUES

DATE	STATIONS				
	NO	MN	DH	BA	MH
Dec.1 ,1993	3.7	3.35	—	1.6	0.0
Dec.11,1993	3.0	4.5	4.65	3.7	0.0
Dec.21,1993	4.55	3.65	6.6	3.6	1.3
Jan.1 ,1994	4.4	1.7	2.5	0.0	0.0
Jan.11,1994	5.35	3.85	6.2	0.0	0.0
Jan.21,1994	8.3	6.2	8.4	0.0	0.0
Feb.1 ,1994	5.55	3.0	2.65	0.0	0.0
Feb.11,1994	6.4	1.4	3.25	0.0	0.0
Feb.21,1994	4.45	1.15	4.15	0.0	0.0

TABLE B TEMPORAL & SPATIAL VARIATION  
IN  
C.O.D. VALUES (mg/l)

DATE	STATIONS				
	NO	MN	DH	BA	MH
Dec.1 ,1993	29.85	24.9	—	26.9	64.65
Dec.11,1993	9.96	13.94	11.95	9.96	45.82
Dec.21,1993	14.0	28.0	14.0	18.0	40.0
Jan.1 ,1994	10.0	14.0	28.0	54.0	68.0
Jan.11,1994	4.0	4.0	6.0	26.0	24.0
Jan.21,1994	13.6	11.2	9.6	19.2	72.0
Feb.1 ,1994	16.8	21.6	57.6	52.0	64.8
Feb.11,1994	16.0	20.8	28.0	36.8	62.4
Feb.21,1994	13.6	16.0	15.2	42.4	67.2

TABLE C TEMPORAL & SPATIAL VARIATION  
IN  
B.O.D. VALUES (mg/l)

DATE	STATIONS				
	NO	MN	DH	BA	MH
Dec.1 ,1993	1.5	3.0	—	8.0	—
Dec.11,1993	3.3	3.5	3.8	8.5	38.5
Dec.21,1993	2.4	7.4	2.7	5.0	21.0
Jan.1 ,1994	3.4	3.3	12.3	12.0	37.5
Jan.11,1994	1.6	3.8	6.0	23.5	—
Jan.21,1994	3.5	3.2	3.0	8.5	32.0
Feb.1 ,1994	5.8	6.3	6.05	33.0	32.15
Feb.11,1994	2.0	5.6	8.7	6.5	33.5
Feb.21,1994	6.0	8.8	7.4	16.5	38.5

TABLE D TEMPORAL & SPATIAL VARIATION  
IN  
NH<sub>3</sub>- N VALUES (mg/l)

DATE	STATIONS				
	NO	MN	DH	BA	MH
Dec.1 ,1993	0.69	0.82	—	0.94	4.0
Dec.11,1993	0.6	0.3	0.25	0.2	4.4
Dec.21,1993	0.38	0.38	0.25	1.13	5.0
Jan.1 ,1994	0.13	0.13	0.88	1.75	4.0
Jan.11,1994	0.1	0.1	0.17	1.12	2.24
Jan.21,1994	0.4	0.36	0.20	0.94	7.0
Feb.1 ,1994	—	—	—	—	—
Feb.11,1994	0.28	0.18	0.63	1.10	4.4
Feb.21,1994	0.22	0.44	0.04	2.1	3.7

TABLE E TEMPORAL & SPATIAL VARIATION  
IN  
NO<sub>3</sub><sup>-</sup> N VALUES (mg/l)

DATE	STATIONS				
	NO	MN	DH	BA	MH
Dec.1 ,1993	—	—	—	—	—
Dec.11,1993	—	—	—	—	—
Dec.21,1993	—	—	—	—	—
Jan.1 ,1994	0.06	0.07	0.10	0.12	0.19
Jan.11,1994	0.11	0.08	0.11	0.20	0.22
Jan.21,1994	0.09	0.09	0.08	0.13	0.16
Feb.1 ,1994	0.10	0.07	0.09	0.18	0.15
Feb.11,1994	0.06	0.11	0.09	0.19	0.20
Feb.21,1994	0.09	0.08	0.07	0.13	0.21

TABLE F TEMPORAL & SPATIAL VARIATION  
IN  
NO<sub>2</sub><sup>-</sup> N VALUES (mg/l)

DATE	STATIONS				
	NO	MN	DH	BA	MH
Dec.1 ,1993	—	—	—	—	—
Dec.11,1993	—	—	—	—	—
Dec.21,1993	0.064	0.040	0.048	0.052	0.144
Jan.1 ,1994	0.075	0.033	0.058	0.180	0.100
Jan.11,1994	0.140	0.013	0.041	0.175	0.038
Jan.21,1994	0.053	0.049	0.034	0.070	0.600
Feb.1 ,1994	0.009	0.003	0.140	0.175	0.155
Feb.11,1994	0.001	0.001	0.058	0.080	0.200
Feb.21,1994	0.078	0.135	0.145	0.120	0.000

TABLE I VALUES OF BOD (Y) AT DIFFERENT TIME (T)  
FOR THE SAMPLING OF 21ST JAN. 1994

TIME (DAY)	STATION			
	NO	MN	DH	MH
0	0	0	0	0
1	2.4	1.0	2.6	17.0
2	6.4	3.2	4.4	25.0
3	2.9	2.5	2.9	28.0
4	3.2	3.0	2.95	30.5
5	3.5	3.2	3.0	32.0

TABLE J  $dy/dt$  vs  $t$  values for the  
computation of  $L_0$  &  $K_1$

TIME (DAY)	STATION			
	NO	MN	DH	MH
0.5	0	0	0	0
1.5	2.4	1.0	2.6	17.0
2.5	6.4	3.2	4.4	25.0
3.5	2.9	2.5	2.9	28.0
4	3.2	3.0	2.95	30.5
5	3.5	3.2	3.0	32.0