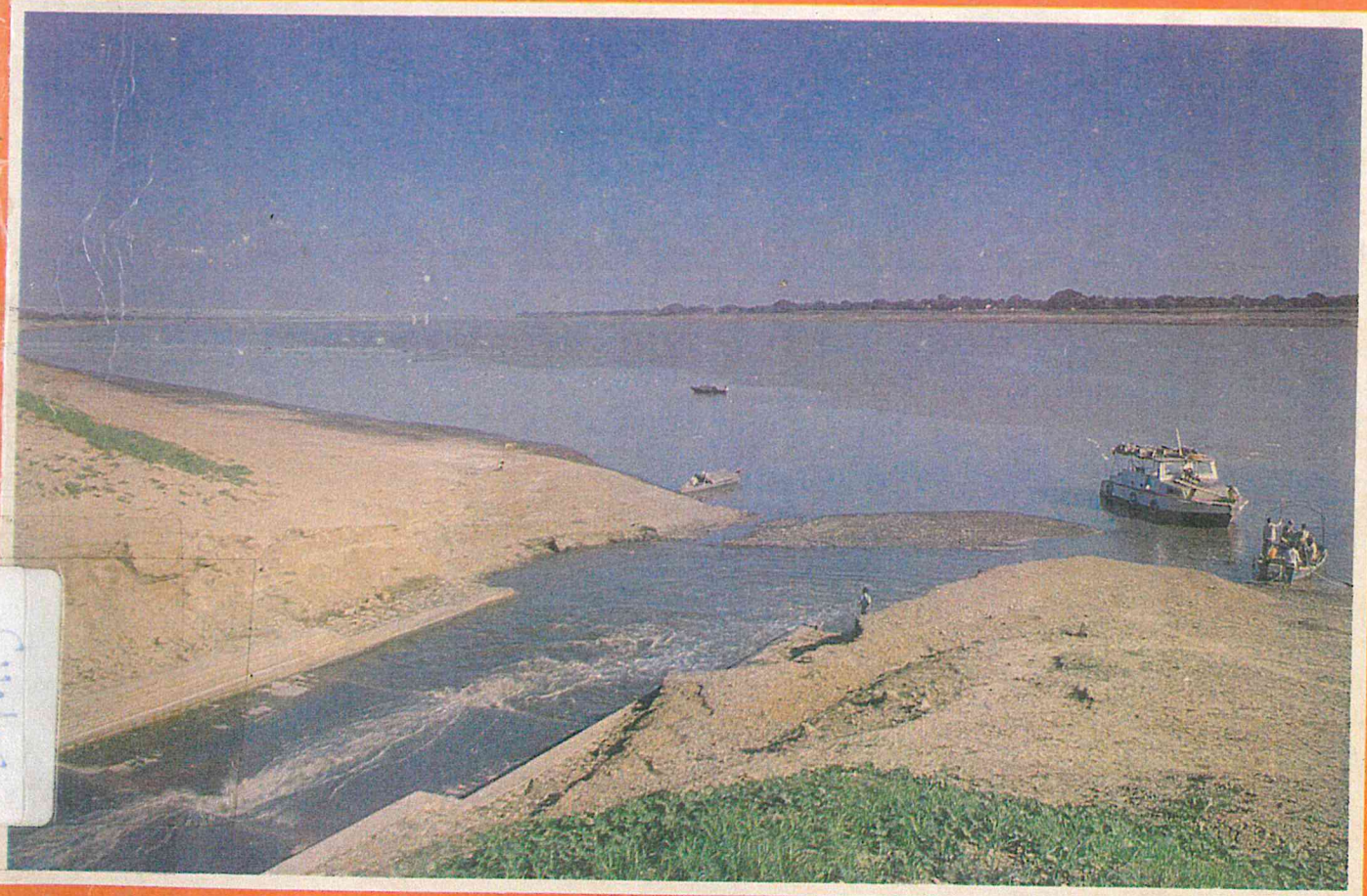
GOVERNMENT OF INDIA

CENTRAL WATER COMMISSION

WATER QUALITY STUDIES GANGA SYSTEM STATUS REPORT

(1978-85)



NEW DELHI

1987

GOVERNMENT OF INDIA
MINISTRY OF WATER RESOURCES

सत्यमेव जयते

WATER QUALITY STUDIES
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STATUS REPORT
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PREFACE

The Central Water Commission is the pioneer organisation which has to act as a central fact finding, planning and coordinating organisation in the field of water resources. It has the basic responsibility for initiating, coordinating and pressing forward the schemes for control, regulation and utilisation of water and waterways. The organised optimum utilisation of the water resources of the Nation requires a detailed basic knowledge of the availability of the water resources intime and space both in respect of the quantum and the quality of the waters. In accordance with these needs, the CWC initiated the monitoring of the quality of the surface waters as an integral part of the hydrological observations network.

Civilisations all over the world have sprung up along the great rivers and have thrived based on the water resources. The story of development in India particularly North India is closely inter-woven with the Ganga. Shri Jawahar lal Nehru in the course of an inspiring address to Water Resources Engineers in 1952 said:—

> "let us take the story of the Ganga. It will be the story of India. Northern India more especially, of course, far more important, far more living and real than all your trumpery history books that you have; it will be the story of the growth of Indian culture and civilisation....."

Elsewhere Shri Jawahar Lal Nehru said:—

> "..... the Ganges, above all the river of India, which has held India's heart captive and drawn uncounted millions to her banks since the dawn of history. The story of the Ganges, from her source to the sea, from old times to new, is the story of India's civilisation and culture."

3. With the growth of cities and the advent of the modern era and its industrial complexes, sprang the evils of pollution. The rivers were no longer mere sustainers of growth, but were transformed into channels to receive the waste waters of the cities. The traditionally pure waters soon became highly polluted and the time was long overdue to have a hard look at this undesirable development and to take the corrective measures.

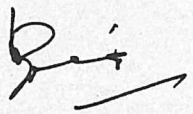
4. The water quality monitoring of the Central Water Commission, since the early sixties, initially was limited for the purpose of determining the suitability of the waters for irrigation purposes. Soon with the realisation of the growing threat of the vast pollution loads being thrown ito the rivers, it was considered necessary to monitor the pollution parameters also. Accordingly, in 1978 a special scheme was taken up on the Ganga and its main tributaries to study various quality aspects including pollution parameters.

This special study ended by 1985 and the work of river quality monitoring for the Ganga now continues as a normal routine. A separate scheme for National Monitoring of the surface waters of the various rivers of the country including the Ganga is under consideration.

5. This report gives in a summary form the work done by the CWC on the water quality survey in the Ganga. The field work was organised through the field Circles and Divisions of the Commission engaged in hydrological observations. While the number of engineers and scientists who contributed to this task is a large one, the noteable efforts of the successive Superintending Engineers who were incharge of the Circles presently known as the Upper Ganga, Middle Ganga and Lower Ganga should be recognised. Sarvashri M.S. Rao, A.K. Hungund and S.S. Sohani served as the coordinating officers in this venture during the period of the report, namely, 1978 to 1985. A special mention has to be made of the sincere and significant contribution of Dr. D.K. Sundd who was the principal Scientist incharge of these operations during the entire period. He was assisted by a number of other scientists whose services are acknowledged.

6. This Status Report has been prepared, based on the valuable work done by the field officers and the drafting initiated at the field levels was finalised through the headquarters officers of the River Management Wing of the Commission. The analysis and the inferences presented in the Report are based on the data compiled from 1978 to 1985 relating to 42 monitoring stations in the Ganga system. The preparation of this Status Report owes a lot to the hard work put in by Sarvashri D.K. Sundd, S.S. Sohani, A.K. Hungund and M. Hegde. The valuable contribution's made by these officers in bringing together the vast data in a presentable form's commendable.

7. It is hoped that this Report will be highly useful to the various organisations and institutions connected with the river quality monitoring and management in the Ganga and would act as a spur for similar activities in the various river systems of India. The principal driving force which guided and encouraged in the monitoring work is that of Shri M.A. Chitale, Chairman, CWC. I have great pleasure in acknowledging the guidance of the Chairman, CWC and the sincere and hard work put in by the various field officers which culminated in the preparation of this Status Report. It is hoped that in the different successive future years the material presented in this Status Report will be updated by the presentation of the additional data collected.



(R. Rangachari)
Member (RM)
Central Water Commission
and ex-officio Additional
Secretary to Govt. of India.

New Delhi,
June 30, 1987.

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Ganga Upstream of Haridwar

THE GANGA

भागीरथि सुखदायिनि मातस्तवजलमहिमा निगमे ख्यातः।
नाहं जाने तव महिमानं पाहि कृपामयि मामज्ञानम् ।।

"Sankaracharya in Gangastotram"

"Oh mother Bhagirathi (Ganga), the source of delight, the great qualities of your waters are well known in the books of Knowledge. I am not aware of all these great attributes; please protect this ignorant person."

1.1 The Life Line

1.1.1 The river Ganga is the lifeline for the millions of the Indian people and has been praised from the ancient days as the mother sustainer of the people. The Ganga rises in the Himalayas from the ice cave of Gomukh at the snout of the Gangotri Glacier at an altitude of about 7000 m. above sea level. The river, known by the name of the Bhagirathi, cuts its path through the Himalayas till the other head stream Alaknanda joins it at Deoprayag. Below this confluence point, the united stream is known as the Ganga. The 2525 km. long river drains 8 States of India, viz, the Himachal Pradesh, Haryana, Uttar Pradesh, Delhi, Rajasthan, Madhya Pradesh, Bihar and West Bengal. It continues its exquisite journey across the northern and eastern plains of India to the Bay of Bengal.

1.1.2 Because of its enormous potential of water resources and the extraordinary life giving qualities of its waters, the river has been venerated as a Holy one and has been associated intimately with the growth of civilisation in the valley. So legendary has been the socio-economic, cultural and religious saga of this great river that Indian mythology and history are full of stories and incidents woven around the numerous places and spots along its entire length. A number of pilgrim and urban centres like Rishikesh, Hardwar, Kannauj, Prayag, Varanasi and Patliputra have existed since time immemorial; with the advent of the modern era equally a large number of industrial complexes also sprang up along its course.

1.1.3 The Ganga in the plains, after Hardwar, receives many small and large tributaries, Ramganga being the principal tributary from the left bank in this reach. At Allahabad the Ganga is joined from the right by the Yamuna which at that point contributes more water to the river than the main river itself. After Allahabad the Tons and the Sone from the right and the Gomti, Ghaghra, Gandak, Burhi Gandak and Kosi from the left join the river till it reaches its deltaic head near Farakka. Below Farakka the Ganga bifurcates into the original channel known as the Bhagirathi and the Padma Channel. The Bhagirathi which flows through West Bengal is treated by the inhabitants as the main Ganga for all purposes. The Padma, which carries a major share of the flows of the Ganga, eventually crosses over to Bangladesh where it meets the Brahmaputra at Golundo. The Bhagirathi which in its tidal reaches becomes the Hoogli-enters the Bay of Bengal near Sagar in India.

1.2 Urbanisation, Industrialisation and Pollution

1.2 The Ganga basin is the home of around 40% of the Indian population. One third of India's urban population lives in the towns of the basin. There are some 692 towns and cities in the basin of which about 62 have a population of over one lakh people each. Along the main river alone, there are 27 towns each with over 1 lakh population and 73 others with less. These cities thrive on the water resources of the Ganga but in turn generate and discharge huge quantities of waste water, a large portion of which eventually reaches the natural drainage system. The numerous industrial complexes which sprang up along the river also brought with them the curse of the technological age by creating an imbalance in ecology due to the pollution loads they dump into the river. Over the years the rivers were no longer merely sources of water for survival and growth. They became the channels of transport and worse were the drains to receive the waste waters of the cities. It's estimated that 900 million litres of sewage is dumped into the Ganga every day. Three fourths of the pollution in the Ganga is from untreated municipal sewage. In particular the middle reach of the basin between Kanpur and Buxar is the most urbanised and industrialised as also the most polluted segment of the basin. Municipal and industrial wastes in dangerous concentration and proportions perennially find entry into the water courses of the region and pose real threat.

Among the major towns and industrial complexes in this segment are Kanpur, Allahabad, Mirzapur, Varanasi, Ghazipur and Balia. Waste water effluents from Panipat, Sonepat, Delhi, Ghaziabad, Faridabad, Ballabgarh, Mathura, Agra, Ferozabad, Shikohabad, Etawah and Naini also enter via the Yamuna river. Industrial complexes at Kota and Dholpur discharge their waste through the river Chambal. The Gomti river is forced to flush out municipal and industrial wastes from Lucknow, Rai Bareilli, Amethi, Sultanpur and Jaunpur into the main Ganga stem.

Water quality regimes in long stretches in the middle segment of the basin have become critical in recent years. The Central Board for Prevention and Control of Water Pollution had estimated that the total urban organic pollution load in the Ganga basin is of the order of 2.5 million Kg. BOD per day. The Central Board similarly estimated the pollution load from the rural population as over 3 million Kg. BOD per day. The pollution thus forced on the river by human interference was a serious health hazard to the dense population of the basin. It is in recognition of the magnitude of this problem and realising the importance of water quality as a cardinal element of river management that the Govt. of India started the planning and execution of a time bound programme to prevent the pollution of the river Ganga.

The Central Water Commission have regularly been monitoring water quality of the rivers as a part of their network of key hydrological stations since the early sixties. While in the beginning the emphasis related to the study of the river water quality with specific reference to the suitability for irrigation use, soon the monitoring of the pollution load was also integrated with the system. Since 1978, to start with under a special research programme, study of the pollution loads in the Ganga at selected stations commenced. This would soon develop into a system which would cover the entire river system of India on a continuing basis.

2 WATER QUALITY SURVEY

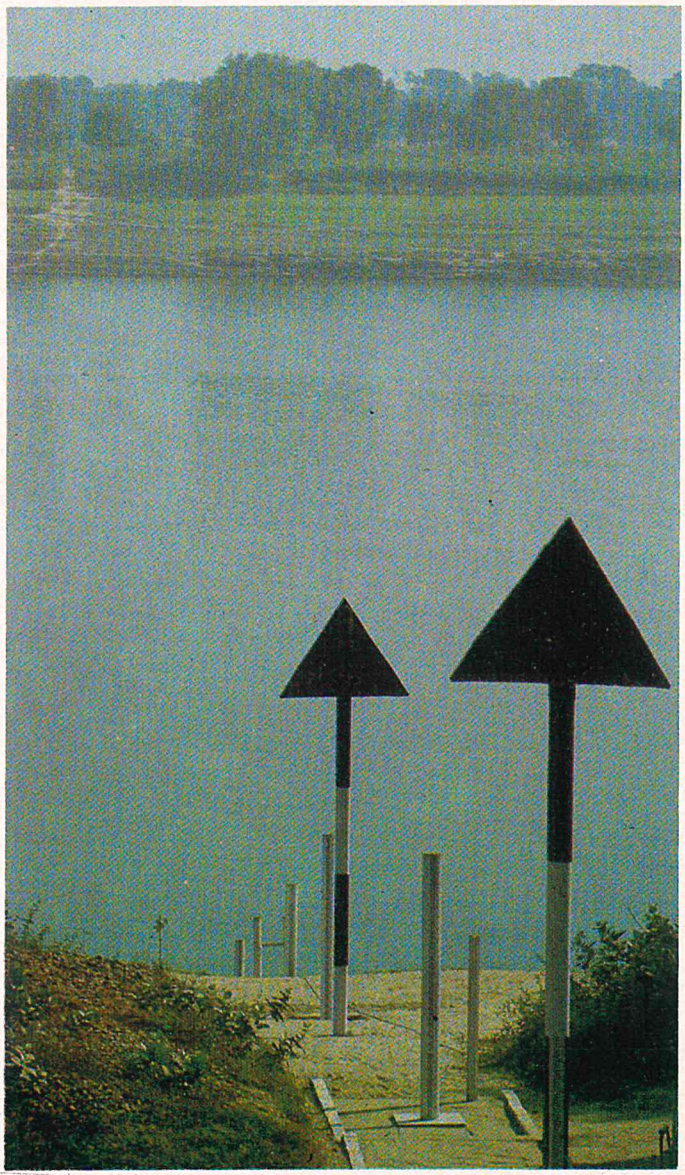
2.0.1 Necessity of Water Quality Survey

Water Quality management programme, in any river basin requires adequate basic information about the past and existing status of Water Quality and the influence of man's activities on Water Quality incorporating both present position and planned future development. Such information can be generated only from a record of long-term Water Quality data and the past experience of use of water of known quality for various purposes. Water Quality measurements are also necessary to enforce laws developed on the basis of above informations as also to evaluate the effectiveness of the management programme. Water Quality surveys were adopted as an integral part of hydrological observation in Ganga Basin since the early sixties. The water quality survey programme carried out for more than two decades, by the erstwhile Ganga Basin Water Resources Organisation of the then Ministry of Irrigation and Agriculture, with the objectives of classifying river waters for irrigation purposes and related applications thus provides the chronological bench mark information.

2.1 Water Quality Survey Programme in the Central Water Commission

2.1.1 The Water Quality Network

Water Quality survey network established in early sixties was gradually expanded both in respect of monitoring stations and coverage of streams, to cope up with the development of irrigation potential in the basin. Currently the Central Water Commission, which now is incharge of the entire hydrological observations in the Ganga basin, operates 122 stations on 57 different stream of the system, listed in Annex I, for Water Quality surveillance programme. This accounts for about 40% of the total hydrological observation network.



Wooden staff Gauges and Targets Measuring Cross Section in Ganga

2.1.2 Scope of Routine Water Quality Survey

At each of the 122 Water Quality observation stations, samples for chemical and physico-chemical examinations of river waters are collected at a regular frequency of once in a month on the first working day at demarcated gauging sections. The samples are collected in clean and pre-rinsed polyethene bottles from the main flowing portion of the stream and then despatched to the Water Quality Research Laboratory for further tests. The soluble salt contents of the river

waters are determined at site every day by gravimetric procedure as a part of sediment load observations in rivers. Alongwith the river water samples, a sample of the ground water sample collected from nearby selected wells are also sent to the Water Quality Research Laboratory for obtaining information on chemistry of the base flow received by the stream. As many as 9 Water Quality Research Laboratories of level II status attached to various divisional headquarters namely Dehradoon, Jaipur, Agra, Lucknow-I, Lucknow-II, Varanasi, Patna-I, Patna-II and Berhampore share the responsibility for analysis of samples received from stations falling under their respective jurisdiction. Both river and well-water samples are tested for the following 20 parameters in addition to the recording of daily river discharges and suspended sediment loads.

1. Temperature
2. Velocity & Flow rate
3. Turbidity
4. Total & fixed solids
5. Specific Conductivity
6. pH
7. Sodium
8. Potassium
9. Calcium
10. Magnesium
11. Iron
12. Aluminium
13. Boron
14. Carbonates
15. Bi-carbonates
16. Chlorides
17. Sulphates
18. Nitrites
19. Fluorides
20. Dissolved silica

Chemical indices namely Sodium Percentage, Sodium Adsorption Ratio, Residual Sodium Carbonate and Hardness Number are calculated to classify river and well water samples for the purpose of irrigation and industrial applications. The chemical analysis results are tabulated in format-1 of Annex VI and are sent to the Research and Development Section in the Circle office where it is scrutinised for arithmetical and technical discrepancies. Annual appraisal of the results of sediment and Water Quality observations are prepared for various divisions.

2.1.3 Trends in Water Quality of Streams in Ganga Basin

Under a sampling frequency of once in a month, Time series of the sample results for various parameters can be developed over years of observations taking the middle component of this series as the origin. Trend equations between time component 'X' (No. of years) and particular Water Quality Parameter 'Y' have been statistically computed by the least square method for each month of the year. A typical set of trend equations for Varanasi site on Ganga in respect of different chemical parameters is reproduced in Table 4. These equations present a typical set of trends and cyclic changes in the chemical equilibrium from month to month or season to season. Obviously positive or negative tendencies can be expected in the variations of ionic species signifying shifts in their concentrations with every fresh equilibrium state configuration of river water chemistry arising from a large number of factors. Conventionally the stream flow is ascribed to three major components, namely, surface run off, interflow and base flow, each of them significantly divergent in their chemical nature. Variations in the quality and proportions of water entering a stream in different stages are thus governed by run off dynamics. Final adjustments in the quality dimensions of water occur in the streams. Flow volumes, flow velocities, sediment concentrations, temperature and associated DO levels, BOD loadings from waste effluents and activities of aquatic life are amongst the numerous factors responsible for bringing a final shape to the quality of river water. Interaction, between sediment and solution phase may also result in adsorption, ion-exchange, co-precipitation and chelation mechanisms, Several of these mechanisms, being pH dependent, help in fixation or remobilisation, of various ions in solution phase. Some compounds may also be released under reducing conditions (e.g. Hg and Fe bound compounds). Additionally, plant neutrients, like nitrites, phosphates, potassium etc. may also appear or disappear in water through release and uptake by aquatic plants, weeds and micro-organisms. Such processes therefore lead to spatial and temporal variations in the quality parameters of river waters.

2.1.4 Classification of Waters

The data on chemistry of river waters collected over the years points out to a distinct increasing trend in the soluble salt concentrations at different stations on various streams in the basin. For this purpose the U.S. Dept. of Agriculture classification of Irrigation water in Ireland. While C_1 S_1 types of waters were generally available even during the low flow period in the sixties and early seventies, observations made in recent years indicate that C_1 S_1 type of waters in the streams of Ganga Basin are gradually becoming extinct. Barring the river Ganga in the reaches upstream of Fatehgarh, the river Ghaghra in the reaches upstream of Ayodhya and the upper reaches of Sone and Mahananda sub basins, the river waters in the rest of the basin are presently classified as C_2 S_1. River waters in the Yamuna sub basin on the other hand vary from C_2 S_1 to C_3 S_1 around the year.

Ganga waters in the middle segment of the basin

* USDA Agr. Handbook 60, 1954 P 807

3 POLLUTION LOADS IN THE GANGA RIVER SYSTEM

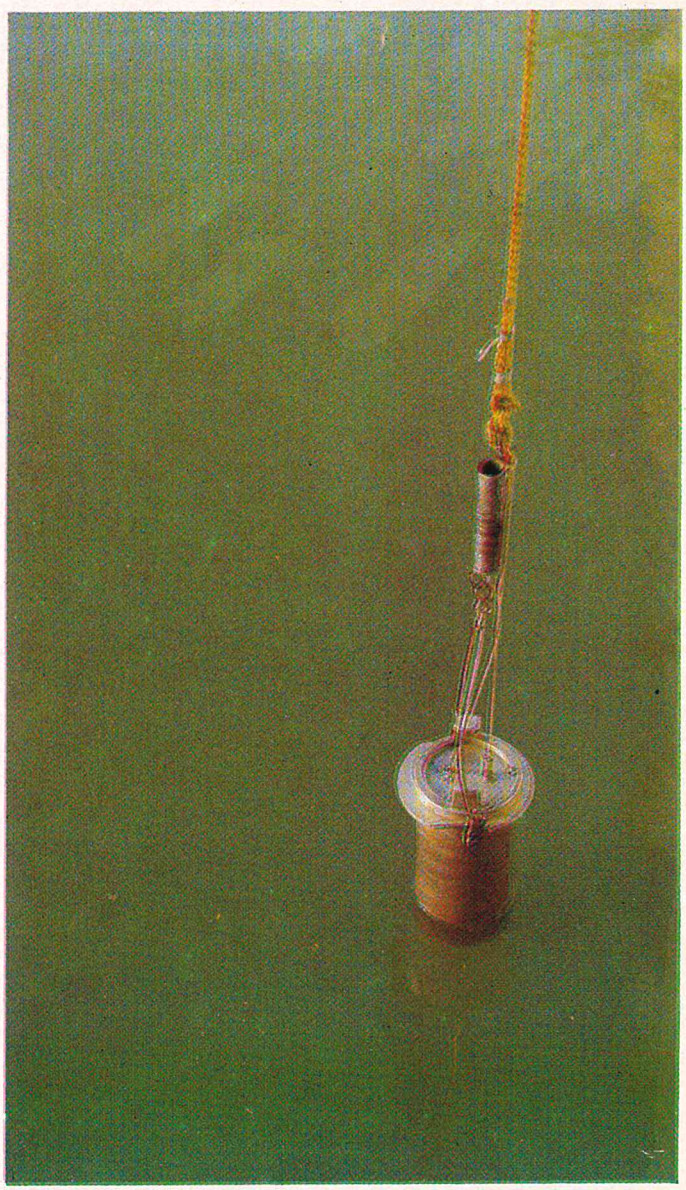
3.0.1 The Ganga River System makes a substantial source of fresh water in the northern half of the subcontinent. Pollutionary hazards emanating from municipal, industrial and agricultural waste waters and their indiscriminate disposals in the streams have in recent years alarmingly threatened this important fresh water resource. Gradually the available waters in Ganga river system are becoming less and less useful for more and more restricted purposes. The growing population, the increasing irrigation requirements and the fast expanding industrialisation simultaneously exert more and more demand of waters of acceptable quality. Water quality management programmes in Ganga Basin have lately received the due attention of the Union and State Governments as their adoption could not wait any longer. Choice and extent of water quality management of a basin or part thereof, constrained as it is with various socio-economical, regional, environmental and political factors, requires a reliable and long term information on changes in the chemical, bio-chemical and biological characteristics of available waters and identification of causes bringing about such effects.

3.0.2 The foregoing considerations necessiated the launching of a research project entitled "A Study of the Flow of Pollution Loads in the Ganga River System" in 1978 itself by the Central Water Commission. The scheme was financed by the National Committee on Science and Technology through the Central Board of Irrigation and Power and laid stress on the following objectives.

(i) Regular assessment of the quality of surface waters at various reaches in the Ganga basin in terms of inorganic, organic and biological pollutants flowing from time to time; effects of industrial wastes and city effluents on the water quality of the rivers at the receiving ends and evaluating the same as per various standards for different inputs.

(ii) Compilation of the base line water quality data at various reaches of the basin.

(iii) Studies on the seasonal and periodic shifts in the chemistry of surface waters as compared to the basin datum level.



Dissolved Oxygen Sampler

(iv) Evolving mathematical models relating the hydrological and water quality parameters of various rivers in the basin.

(v) Microbiological and bacteriological examination of river waters at critical points around densely populated areas of the basin.

are dominated by alkaline earths followed by alkali metals in the sequence $Ca^{+2} > Mg^{+2} > Na^{+} > K^{+}$ On the anionic side Ganga waters are classified as $HCO_3^- - Cl^- - SO_4^{-2}$ types from Kanpur to Patna. In the still lower reaches, SO_4^{-2} starts dominating Cl.

2.1.5 Suitability for Agricultural Applications

Excepting the River Ganga in the reaches upstream of Kanpur and the river Sone, the Rapti, the Ghaghra and the Gandak, most of the remaining rivers posses high positive RSC values. Such waters have a tendency to deposit Na_2CO_3 scales upon evaporation on the soils when used for irrigation, raising thereby the soil pH in small increments, which in turn can lower soil permeability. Augmentation of Ca/Mg ratio by way of periodic gypsum-application need be judiciously practiced in the agricultural soils to alleviate such long term structural damages. The River Ghaghra and Rapti, generally show high concentrations, exceeding 2 mg/l, of Boron which is toxic to plant life. Boron concentrations within tolerable limits (<2mg/l), also appear occasionally in Gandak, Burhi-Gandak, Kosi and Ganga waters in the reaches below Kanpur. Dilution with Boron-free waters where high incidence of Boron is indicated, appears desirable for healthier growth of less tolerant plants.

2.1.6 Suitability for Industrial Applications

Softest available river waters in the basin are found in the river Sone. In most of the other river basins the available waters are slightly hard (Hardness No. 100-150) to moderately hard (Hardness No. 150-200). Hard waters (Hardness No. 200 to 300) are generally found in Ramganga at Bareilly, Gomti at Lucknow and Ganga at Patna and Hathidah. Appropriate softening treatment in the case of waters exhibiting slight to high hardness appears necessary before using them as boiler-feeds.

Pneumatic Water level Recorder

The investigations planned under the special scheme as described here-under were completed in March 1985, but the work continues as routine now.

3.1 Pollution Monitoring Network

3.1.1 Criteria for Network

From the existing 122 water quality observation sites, 42 key stations spread over 18 rivers as listed in Annex II were identified on the following criteria:

(a) Stations constituting major urban and industrial centres.

(b) Terminal stations on tributaries for distinguishing pollution contribution of tributaries/sub basin

(c) A station each on major streams to obtain information on the background water quality.

Monitoring of certain parameters like BOD, microbiological examinations and bacteriological studies were restricted to a few relevant stations. At each of the selected 42 stations, two sampling sections were demarcated; one in the upstream reach and the other in the downstream reach, so that all effluent outfalls from the concerned city or project were located in the reach bracketed by the two sampling sections.

3.1.2 Establishment/Strengthening of the Water Quality Research Laboratories.

In accordance with the recommendation of the Panel on Environmental Monitoring Instrumentation regarding Electronic Information and Planning (Vol. IV No. 5, Feb. 1977) a three-tier laboratory formation was adopted for testing of water quality parameters with varying permissible holding times.

LEVEL I

The existing field sediment laboratories at the 42 stations were equipped in 1978-79 with insitu monitoring instruments, different types of sampling devices, special glassware and stocks of chemicals to serve as Level I monitoring stations. All these stations, since they form part of hydrological observation network of the Commission, were already equipped with powered boats/crafts navigation and survey instruments, site fixtures etc. and are also adequately staffed in respect of motor launch crew, boatmen and other workcharged helpers.

LEVEL II

Similarly the Water Quality Research Laboratories functioning at the divisional head quarters under the routine water quality surviellance programme of Central Water Commission were upgraded in 1978-79 to level II monitoring status through the introduction of refrigerators, BOD incubators, DO meters, spectrophotometers and other analytical appliances.

LEVEL III

A level III Water Quality monitoring laboratory was also developed at Varanasi during 1978-83 for undertaking analysis of trace and toxic elements, bacteriological and microbiological tests etc. Automated and sophisticated analytical instruments like B-26 series sample processing cum-fraction collection double beam UV/VIS Spectrophotometer (2 units), Model 850 Jarrel Ash double beam Atomic Absorption Spectropotometer with Flameless accessory (1 No.), O_2/Temp. Monitors (4 Nos.), Model 8610 Ultramicrobalance, DC Polarograph, Precision Carlzeiss microscopes with photographic attachments were installed and other laboratory facilities like Inoculating chambers, High speed centrifuge, Colony Counters, Autoclaves, Magnetic stirrer, Deep freeze etc. were provided.

3.1.3 Deployment of Scientific Personnel

A Junior Scientist of the rank of Research Assistant is permanently posted at each of the 42 pollution monitoring stations, primarily to carry out sediment observations in rivers which forms a componet of regular hydrological observations being conducted by the CWC. The duties of sampling and monitoring of in situ determined parameters under the research scheme were also assigned to him. A Junior Engineer also permanently stationed at the site for discharge observations was found helpful to fill the gap during the leave period of Research Assistant. Thus the field programme at Level I stage could be carried out uninterrupted barring the periods of unusual and inclement weather conditions. In the level II Water Quality Research Laboratories, it was contemplated to post a Scientist of the rank of Assistant Research Officer to be assisted by two Senior Research Assistants and a Lab Assistant. However no additional staff could be availed and the existing staff comprising of one Senior Research Assistant, a Research Assistant and a Lab Assistant managed the analytical work load at level II stage. For the level III laboratory, following additional staff strength was sanctioned in 1978:

(1) Chief Research Officer — 1 No.
(2) Asstt. Research Officer — 3 Nos.
(3) Senior Research Assistant — 6 Nos.

(4) Senior Computer — 2 Nos.
(5) Senior Lab. Technicians — 2 Nos.
(6) Senior Draftsman — 1 No.

On account of administrative procedures,the gazetted posts vide Sl. No. 1 and 2 above remained vacant. The regular Research Officer of the Commission stationed at Varanasi performed the functions of the principal investigator and coordination of the work at different levels. Fortunately the scant staff utilised in the Research scheme were highly experienced in the related field.

3.2.0 Investigations Carried out at the Field Stations (Level I)

3.2.1 Extent of Sampling

As already indicated earlier, two sampling sections respectively located upstream and downstream of the reach, receiving the waste water drains were demarcated at each of the 42 stations. Following categories of samplings and in situ determination of water quality parameters at frequencies mentioned against each were carried out at the field stations:

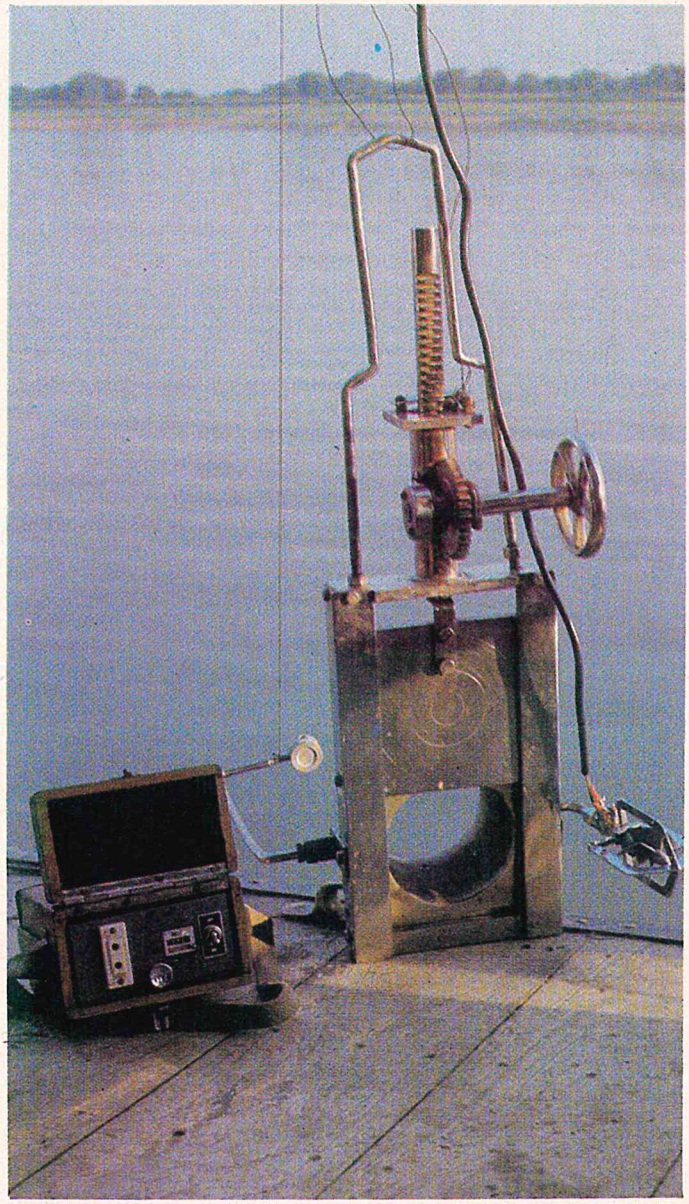
(a) One sample at each of the U/S and D/S sections was collected in prerinsed polythene bottle at 0.6 depth from the main flowing portion of the stream, using a point integrating sampler, for detailed chemical examination, at a frequency of once in ten days.

(b) One additional sample each from the main flowing portion of the stream at U/S and D/S location was collected at 0.6 depth for estimating trace heavy metals at a frequency of once in a month.

(c) Three samples were collected at 1/3, 1/2 and 2/3 width of the river at U/S and D/S sections from a depth of 1 m below surface for in situ determination of pH, Specific Conductivity, temperature, dissolved oxygen and colour at a frequencey of once in ten days.

(d) Requisite number of samples at 1/3, 1/2 and 2/3 of cross-sectional widths at U/S and D/S reaches were collected for the estimation of Bio-chemical Oxygen Demand at selected eleven stations listed in Annex III at a regular frequency of once in a week.

(e) Intensive surveys for longitudinal dispersion of organic pollution ($^5BOD_{20}$ tests) below the outfalls of various waste water drains were carried out at 10 stations (5 of which cover the main Ganga river) twice a year, once during the critical premonsoon months and again during the post monsoon period.



Plankton Sampler Fitted with Pigmy Current Meter

(f) Point velocities and depths of river at each sampling spot were simultaneously determined.

(g) Investigation on bacteriological, microbiological studies and indentification of Indicator Plankton species were carried out during the final stages of the project at selected stations, namely, Allahabad, Varanasi on Ganga and Delhi, Mathura and Agra on Yamuna.

Typical sampling sections and sampling locations alongwith the frequencies of sampling for

various tests conducted are depicted in plate I. Typical outfit including staff and equipment in use for water quality survey is given in Annex IV.

3.2.2 Sampling Techniques

All the samplings were carried out as per standards laid down by American Public Health Association/World Health Organisation using prescribed devices specific to various parameters. Sampling devices like point integrating samplers, Dissolved Oxygen Samplers, Plankton Samplers were deployed. Direct measuring instrument and probes were used at major stations for in situ measurement of DO, pH, Sp. Conductivity and temperature.

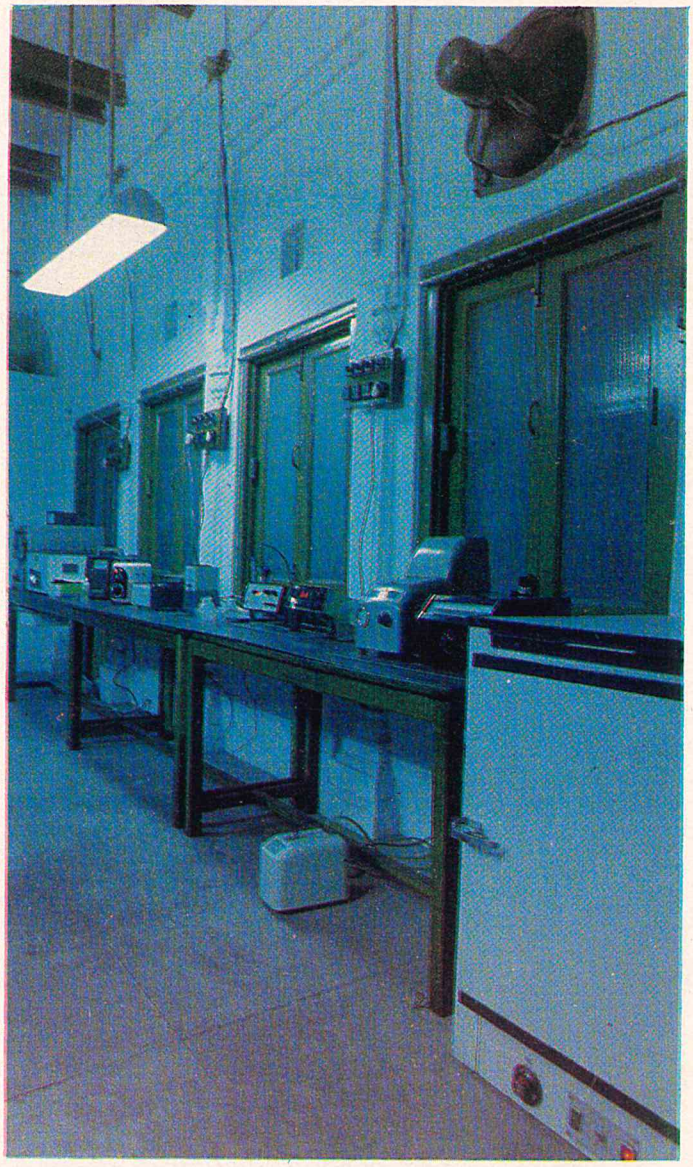
3.2.3 Preservation and Transportation of Samples

A large number of water quality parameters allow limited holding time for analysis (Annex V). Since the nine level II Water Quality Research Laboratories are evenly distributed over the basin it was possible to transfer the samples collected at various stations to the nearest level II laboratory within a span of 24-48 hours. Samples for BOD determination and biological samples were transported in ice boxes within 6 hrs. of collection. Special messengers were detailed for transporting the samples to level II and level III laboratories with a time drill. The modus operandi of transportation of samples to the laboratories is depicted in plate III. Results of in situ determined parameters, and other hydrologic and weather information were also sent alongwith the samples as per specimen formats No. 2,3,4, & 5 vide Annex VI to level II formation and subsequently to level III laboratory.

3.3.0 Analysis of Samples in the Water Quality Research Labs

3.3.1 Pollution Parameters and Analytical Techniques

Water samples in the laboratories were kept under refrigeration at 4°C until analyses were completed. Determination of pH, Sp. conductivity and BOD of the samples were promptly undertaken. A list of parameters determined at level II and level III laboratories is depicted in plate IV alongwith the total No. of samples of each category analysed during the course of investigation. A brief description of analytical methods and techniques employed for testing of various water quality parameters is given in the following table:



Electronic Equipments for Determining Physico-chemical Parameters

Sl. No.	Parameter	Methodology used	Technique employed	Units of reporting results	Tolerance limit as per ISI for inland surface waters Cl-A*	Max. permissible level as per WHO**
1	2	3	4	5	6	7
	Physico-chemical					
1	Temperature	In situ	Thermometer/ Tamp. probe	°C	—	—
2	pH	Potentiometeric	pH meter	$\log\left[\frac{1}{H^+}\right]$	6.5 to 8.5	6.5 to 9.2
3	Sp. conductivity	Measurement of resistance	Conductivity Bridge	Micro-Mhos/ Cm	750-800	2300-2400
4	Dissolved Oxygen	Winkler Method/ O_2 *potential*	DO monitor	mg/l	6 (Min)	—
5	$^5BOD_{20}$	Incubation at 20°C for 5 days	DO monitor & incubator	mg/l	2	—
	Non-metals					
6	Amonical nitrogen	Nesleriazation and reading absorption at 400 nM	UV/VIS Spect-rophotometer	mg/l	—	—
7	Nitrites	Diazotisation with Naphthylamine Reading absorption at 520 nM	UV/VIS Spect-rophotometer	mg/l	—	—
8	Nitrates	Acidification and reading absorption at 220 and 275 nM	UV/VIS Spect-rophotometer	mg/l	20	100
9	Cyanides	Conversion to CNCl and colour production with Pyridine barbituric acid Reading absorption at 578 nM	UV/VIS Spectro-photometer	mg/l	0.05	0.05
10	Phosphates	Read absorption of blue colour of phosphomolybdic acid at 850 nM.	—do—	mg/l	—	—
11	Sulphites	Iodometeric titration	Chemical Titration	mg/l	—	—
12	Sulphates	Barium Sulphates colloidal suspension and read optical density	Nephelometery	mg/l	400	400

1	2	3	4	5	6	7
13	Chlorides	Argentometeric titration	Chemical titration	mg/l	250	1000
14	Fluorides	Read colour with Acid Zirconyl Alizarine reagent at 520 nM	UV/VIS Spectro-photometer	mg/l	1.50	1.5
15	Carbonates	Acid base titration using phenolphthel-ene indicator	Chemical titration	mg/l	—	—
16	Bi-Carbonates	Acid base titration using methyl orange indicator	Chemical titration	mg/l	—	—
17	Silicate	Reduction of Molybdo-silicic acid by aminonaptho-sulphonic acid & reading absorption of blue colour at 650 nM	UV/VIS Spectro-photometer	mg/l	—	—
18	Boron	Reading absorption by Rosecyanine dye at 540 nM	UV/VIS Spectro-photometer	mg/l	—	—
	Metals					
19	Calcium hardness	EDTA-Titration using alkaline Muroxide indicator	Chemical titration	mg/l	200	200
20	Magnesium	EDTA Titration using BT dye indicator	Chemical titration	mg/l	100	100
21	Sodium	Emmission Spectroscopy	Flame photometer	mg/l	—	—
22	Potassium	Emmission Spectroscopy	Flame photometer	mg/l	—	—
23	Iron	Atomic Absorption Spectroscopy	A.A. Spectro-photometer	mg/l	0.3	1.0
24	Aluminium	Atomic Absorption Spectroscopy	A.A. Spectro-photometer	mg/l	—	—
25	Lead	Atomic Absorption Spectroscopy	A.A. Spectro-photometer	mg/l	0.1	0.1
26	Copper	Atomic Absorption Spectroscopy	A.A. Spectro-photometer	mg/l	1.5	1.5
27	Manganese	Atomic Absorption Spectroscopy	A.A. Spectro-photometer	mg/l	0.5	0.5
28	Silver	Atomic Absorption Spectroscopy	A.A. Spectro-photometer	mg/l	0.05	—

1	2	3	4	5	6	7
29	Cadmium	Atomic Absorption Spectroscopy	A.A. Spectro photometer	mg/l	0.01	0.01
	Biological/Bacteriological					
30	Standard Plate Count	Culture development on nutrient agar	Colony counters	No. of colonies/ml	—	—
31	Total coliforms	Multiple tube dilution method	Biological incubator	M.P.N. per 100 ml	50	—
32	Fecal coliforms	Fermentation of Lactose at 44.5°C in 24±2 hrs.	Biological incubator	M.P.N.	—	—
33	Phytoplankton	Centrifuging and wetmounting	Microscope	Identification & population index	—	—
34	Zoo-Plankton	Centrifuging and Wetmounting	Microscope	Indentification & population index	—	—

N.B. The tolerance limits as indicated are maximum permissible.
* IS-2296-1982
** W.H.O. (1971) International Standards for drinking water 3rd Edition, Geneva

Model 850 Double Beam Atomic Absorption Spectro-photometer

3.3.2 Formats for Reporting Results

Annex VI gives a set of formats for reporting of data from sampling operations at level I to analysis of sample at level II and III laboratories. Standard formats for tabulation of computed and compiled data are also included in the list.

3.4.0 Quality Control, Data Scrutiny and Data Compilation

3.4.1 Complete analysis of batches of samples received on ten daily basis were completed in the laboratories within 8-10 days. After computing the results in appropriate units and working out the classification indices the water quality data on ten daily statements were received in the coordination unit viz. the Research and Development Section at the Circle office.

3.4.2 The data received at the coordination unit were first technically and arithmatically scrutinised to single out odd anamalies and sudden changes in concentrations over the earlier results. Such discrepancies were promptly communicated to the concerned laboratories and field staff for repeat analysis and reconfirmation of the test results. If deemed necessary, additional sample, shift in sampling location or sampling in more number of sections or depths integrated samplings etc. were resorted to. Inter laboratory and intra-laboratory checking of analysis of standard or identical samples have also been practiced as a part of quality control programme. Once the data was technically cleared, it was recompiled in formats 3,4,5,6,7 & 8 given in Annex VI on seasonal basis (Winter-November to February, Summer—March to June, Monsoon—July to October). The compiled data was then subjected to statistical analysis for interpretation.

3.5.0 Data Processing and Data Interpretation

3.5.1 The entire water quality data and the associated hydrological parameters were statistically correlated using the following techniques:

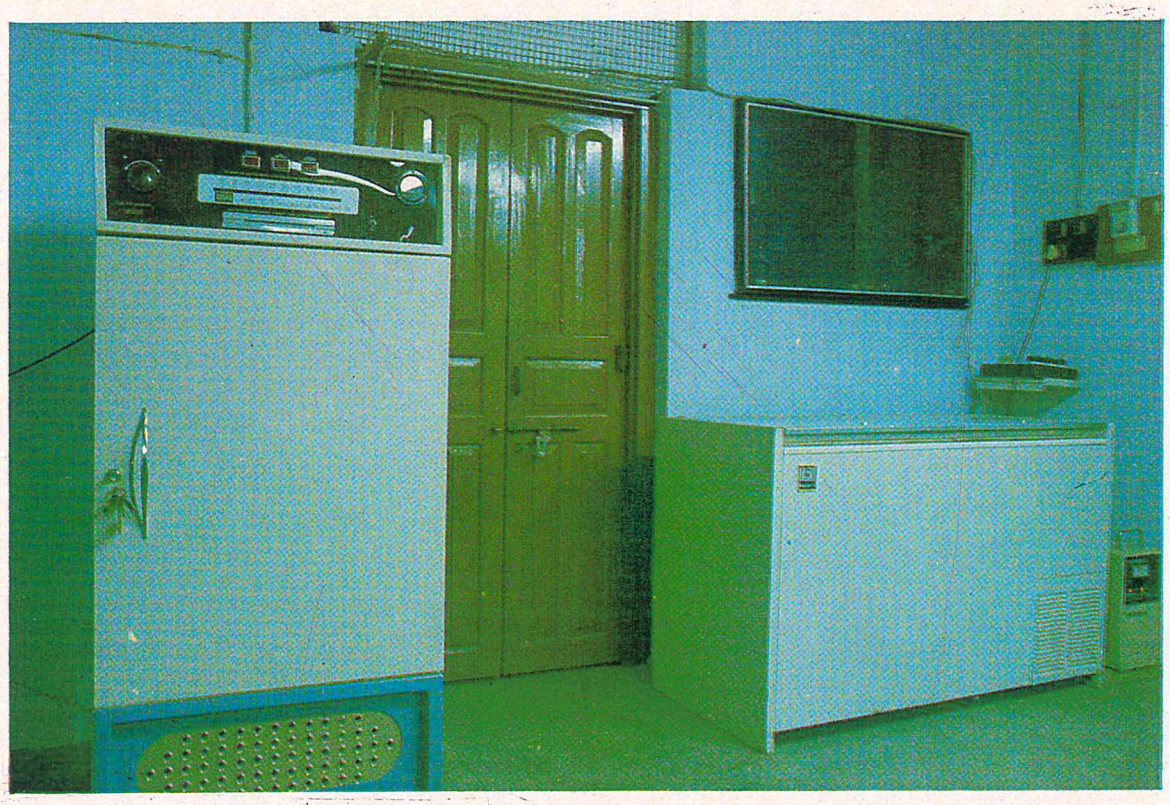
(i) Mean values
(ii) Standard deviations
(iii) Graphical displays to obtain water quality trend
(iv) Regression analysis between river discharge and various water quality parameters
(v) Least square fittings
(vi) Time series analysis based on static and moving averages
(vii) Frequency and Power spectrum analysis.

Model B 26 Sample Processing cum Fraction Collector Double Beam UV/Visual Spectro Photometer

3.5.2 A general equation of the form $Y=AQ^{\alpha}$ has been satisfactorily tried to correlate the quality and the quantity dimensions of river waters. In the above equation 'Y' is the concentration (mg/l) or load (Tonnes/day) of the particular water quality parameter, Q is the river discharge (M^3/sec), 'A' and α are the constant and the exponent of regression. The magnitudes of 'A' and α are found to be specific to a reach for a stable spell of river regime. Their values, however, are subject to change with the improvement or deterioration in water quality. Constant 'A' represents the raw pollutant mass received in the river in the immediate upstream reaches which is still in the process of assimilation in the water body; while the exponent α represents the chemical load in equilibrium state flowing as a part of back ground water quality. The variation of the constant and the exponent of the regression equation for various water quality parameters at successive stations on a stream exhibit significantly rhythemic trends pulsating with successive prelude of ingress of pollutants and their digestion through the self purification faculties of the stream. This statistical treatment of the various water quality parameters have been carried out separately for the Summer (March-June), Monsoon (July-October) and Winter (November-February) seasons, each representing stable riverine regime. A sample result of regression equations in respect of the selected stations on Ganga for the summer season of 1980 is reproduced in table 5. The sampling frequency of once in ten days provided 12 sets of values of each water quality parameter and the corresponding river discharge during a particular season. The correlations find useful application in delineating spatial water quality trends.

3.5.3 Temporal trends in water quality parameters at a particular sampling station were also studied for a few stations by Time-series-analysis already referred in para 2.2.3. Trend equations for the time series components in the case of Ganga at Varanasi are reproduced in table 4.

3.5.4 A certain degree of periodicity is always associated with the waste water flows in the effluent drains especially in the case of municipal drains where the peak discharges are received around 1100 hrs. and again towards the evenings. Such diurinal nature of waste water inflow introduces short term cyclic variations in the water quality of streams. Additionally, the stream in itself characterises seasonal and long term cycles in its chemistry and biology due to superimposition of hydrological cycles in the system.



BOD Incubator & Sample Preservation Facility

Identification of the magnitude and contribution of regular cyclic components of the total variance of ionic concentrations and BOD loadings by spectrum analysis using Fourier Transform Coefficients was attempted for a few stations. Simulation of the observed trends in various water quality parameters were carried out through harmonic analysis choosing long term, 12 months, 6 months, 4 months, 1 month, a fortnight and 24 hour cycles in accordance with their predominance reflected in the frequency bands. Simulation of water quality parameters was achieved through the equation:

$$X = 1.27 + \frac{\leq}{K} A_K \, Sin \frac{2\Pi}{N} KJ + \frac{\leq}{K} B_K \, Cos \frac{2\Pi KJ}{N}$$

where 'J' denotes the lag number i.e. periodicity of sampling interval and N = Total No. of sample data, 'X' is the particular water quality parameter e.g. specific conductance, BOD etc. Observed and simulated values of specific conductance in Micro-Mhos/cm, chloride ion in mg/litre and $^5BOD_{20}$ in mg/litre in the case of Ganga waters at Varanasi are presented in Fig. 3.6.1, 3.6.2 and 3.6.3 respectively alongwith their frequency bands histograms. In the case of BOD spectrum, in Ganga at Varanasi, a distinct long term cycle over the years of observation is prominent.

3.6.0 Assessment of B.O.D. loads and Waste Assimilation Capacity of Streams

3.6.1 Disposal of raw municipal waste waters is the prime factor accredited to major portion of river water pollution in Ganga basin. The degradable organic matter when introduced in surface waters, sequentially undergoes reductive and oxidative decompositions that are brought about by anaerobic and aerobic bacteria. The anaerobes devour the complex organic matter and extract hydrogen from water to produce reduced compounds of carbon, sulphur, phosphorous and nitrogen. Any dissolved oxygen, if made available from atmosphere, is also reduced continuously to provide favourable environment for multiplication of anaerobes. In such a polysaprobic state, all healthy aquatic life like fish etc languish for want of sufficient food and oxygen. The murky water stinks of hydrogen sulphide, methane, ammonia and phosphene. Upon completion of the reductive process, fresh supply of oxygen from atmosphere is accelerated and gradually the anaerobe population is replaced by aerobic and nitrifying bacteria which oxidise the reduced compounds to simpler inorganic minerals like sulphates, phosphates, and nitrates. These mineral nutrients help development of aquatic vegetation which speeds up the supply of oxygen through their photosynthetic activity in sunlight. Other aquatic life like fish etc. also reappear and healthy condition is restored. This entire sequence of reductive and oxidative cycle is what is known as the organic self purification of surface waters. In streams, the turbulance and flow of water facilitates speedier aeration from atmosphere and the reaction scenes of the entire reductive and oxidative processes are carried down the stream to a distance (critical distance) and in times (critical time) that are governed by hydrological and climatic factors. During lean flows and summer months, the reductive process is faster and predominent to longer stretches because of lower dilution of pollutants and slower rate of aeration from atmosphere at higher ambient temperatures. During high floods, the oxygen supply being abundant and coupled with a large dilution of pollutants by volumes of oxygen-rich water, the reductive process is soon over.

3.6.2 In situ surveys of the kinetics of biochemical decay process and the associated rates of depletion of dissolved oxygen in the longitudinal stretches below the entry of effluent drains into the streams were carried out twice a year—once each during the premonsoon and the post monsoon period. Typical observed DO and BOD profiles along the longitudinal reaches of Ganga at Kanpur, Allahabad, Varanasi, Patna and Hathidah (Mokameh) have been presented in figures 3.7.1 to 3.7.9. Experimentally determined values of critical DO deficits, critical distances and the critical travel times (time of passage) under varying stages of rivers and ambient conditions as revealed from these surveys provide useful information for computing the aeration and degeration constants of the reaction process and further evaluation of the self purification factor of the stream.

3.6.3 From the observed data the deaeration rate constant K_1 was evaluated using the exponential relation:

$$K_1 = \frac{1}{\Delta t} \log \frac{L_A}{L_B}$$

where L_A and L_B are the ultimate first stage BOD values in mg/litre at U/S and D/S location on the longitudinal BOD profile and Δt is the travel time in days between the U/S and D/S locations. The aeration rate constant, K_2 was worked out from Streeter Phelphs(1) model:

$$K_2 = K_1 \frac{\bar{L}}{\bar{D}} - \frac{\Delta D}{2.303 \, \Delta t \, \bar{D}}, \text{ where}$$

$\bar{L}$ is the average ultimate BOD between U/S and D/S locations, $\bar{D}$ is the average in situ DO deficit in the reach,

ΔD is the difference of oxygen deficit between U/S and D/S locations. The values of K_1 and K_2 were corrected to the observed river water temperature by the relation:

$$K_1\ (T°C) = K_1\ (20°C)\ 1.047^{(T-20)} \text{ and}$$

$$K_2\ (T°C) = K_2\ (20°C)\ 1.024^{(T-20)}$$

The self purification capacity 'f' of the stream as defined by Fair[2] is the ratio of aeration and deaeration constant:

$$f = \frac{K_2}{K_1}$$

The statistical values of 'f' was then utilised for predicting critical DO deficits by the Streeter Phelphs model:

$$\log D_C = \frac{1}{f} \log L_A - K_1 . t_c$$

where D_C is the critical DO deficit at the sag point on the DO profile and t_c is the critical time of travel from the point of entry of waste waters to the DO sag point.

Average values of critical parameters, aeration and deaeration constants and self purification factors as derived from a number of longitudinal surveys for the 5 stations on Ganga namely Kanpur, Allahabad, Varanasi, Patna and Hathidah during the period 1978 to 1985 are summarised in the table given below:

Logically, the critical parameters would vary from season to season. High ambient temperatures and lower discharges during summer months accelerate the carbonaceous decay process yielding high BODs due to rapid amortisation, Low velocities during summer months however result in an earlier occurrence of DO sag point. Additionally, the solubility of oxygen in water at the prevailing temperatures during summer months being lowered, the liability and asset ratio of the stream becomes critical. Lower temperature and relatively higher velocities prevailing during the post monsoon seasons carries the reaction scene to longer distances below the effluent outfalls. On account of slower reaction rates and higher solubility at the ambient temperatures, the dissolved oxygen sags are not as steep during the winter months as those obtained during summer season.

3.6.4 Another important observation revealed by the average values of aeration and deaeration constants is their unusually high configuration in the case of Kanpur. Allahabad and Varanasi. Two major factors contribute to this anomaly:

(i) Ratio of fresh water to waste water i.e. the dilution available at Kanpur, Allahabad and Varanasi during the non-monsoon period is very unconfortable.

(ii) Due to the combined storm water and sewage drains in the urban centres, solid fraction both degradable and non-degradable is extremely high.

3.6.5 Very high amortisation rate in the river just below the outfall of drains as reflected by high 'K'1 values is largely due to the settling of solids to form sludge piles in the form of small delta on the river bed. Invariably the mouths of the effluent drains terminate under gravity-outfalls either in the dry bed of the river (during low flow) or pour into static pools along the bed. The sludge deposits progressively grow into piles, the lower portion of which decays into benthal material. The extent of accumulation in the sludge pile depends upon the prevailing and preceding hydrograph

Station	Critical time of travel in days 't_c'	Critical DO deficit in mg/1 'D_C'	Deaeration constant 'K_1'	Aeration constant 'K_2'	Self purification factor 'f'
Kanpur	0.264	82.4*	4.73	34.91	7.38
Allahabad	0.105	8.93*	3.67	48.20	13.13
Varanasi	0.278	3.90	6.07	48.07	7.92
Patna	0.278	2.78	1.40	1.92	1.37
Hathidah	0.461	0.52	1.68	3.20	.190

* D_C greater than saturation value of oxygen in water at ambient temperature.

1(a) Streeter, H and Phelphs E "Stream Sanitation," John Wiley and Co., New York, 1944.

1(b) Streeter, H and Phelphs, E "A study of the Purification of the Ohio River" U.S. Publ. Health Service Bull No. 146, Washington D.C. 1925.

2. Fair "The Dissolved Oxygen Sag Analysis", Sewage Works J. 11 (10): 445, 1939.

which predicts the interval over which solid deposition can take place without interruption or scour can occur from a freshet. With daily addition of fresh BOD to the pile and constant amortisation from the pile an equilibrium accumulation is reached. When the two are in balance the demand upon the DO of the stream from the benthal deposits is equivalent to the total BOD of the daily addition to the sludge pile. During low flows when the prevailing velocities in the deposit areas are not greater than 0.18m/sec. the sludge pile may attain equilibrium in a matter of 40 to 50 days unless intervention from scouring freshet disturb the equilibrium. The monthly averages of BOD concentration observed at U/S and D/S sections at a frequency of once in a week have been computed and presented in figures 3.1 to 3.5.

Low BOD loadings during the period starting from winter season of 1981-82 to the end of monsoon season of 1982 in the case of Ganga at Kanpur are possibly due to less than equilibrium conditions of the sludge pile. The accumulated load in the sludge pile was later released to the river in abundance during the following year as reflected by very high BOD loadings in the overlying water. These high values of BOD during 1983-84, of course, do include the additional BOD loads due to normal growth rate of waste waters from the town.

3.7.0 River Liabilities Projected to Critical Regimes

3.7.1 Assessment of River Liabilities

The programme of investigation under the scheme was confined to the assessment of pollution loads in the rivers at the receiving end only. Although major effluent drains of municipal and industrial origin from various stations were identified and catalogued, intensive analysis of effluent samples were not undertaken excepting BOD levels near the mouth of the effluent drains. The total pollutionary loads generated at each station at the river front have however been worked out through differences in their concentrations loads within the river body both at the U/S and D/S reaches of various stations, BOD loadings for three different seasons averaged from weekly sampling frequency in respect of Ganga at Kanpur, Allahabad, Varanasi, Patna and Hathidah would respectively represent the background BOD loadings and nett amortisation taking place. Monthly mean $^{5}BOD_{20}$ in Mg/litre units for the above stations are depicted in figures 3.1 to 3.5.

3.7.2 Role of Hydrological Cycle

As already explained in para 3.6.3, the natural self purification capacities of the streams were assessed with the help of Streeter Phelphs model for oxidation of carbonaceous impurities through data obtained from longitudinal surveys. The total liability in terms of BOD and other pollutants in the Ganga river system have also been assessed. Water, however, possess two unique characteristics. Firstly, it is a multiple use resource and secondly, it is a dynamic resource. Unlike a fixed mineral deposit, water varies in the amount that is available at any location from day to day and season to season. In this context, water is dynamic, but observed over a period of years, stream flow, although variable, is orderly, following the law of chance occurrance unless the natural setting has been altered. Statistical analysis of the run-off records determine the range of stream flow available and the drought severity that can be expected. Each river system, because of its dynamic, hydrologic and meteorologic setting and pattern of water resource development and use, is unique. No arbitrary blanket solution applied whole sale can be expected to meet the varied need of a technological society. Stream sanitation practice need, therefore, be specifically designed for each particular river using a combination of defensive and offensive strategies to ensure maximum efficiency at minimal cost.

3.7.3 Role of Severity and Recurrence Interval of Drought

Low flow records in the river Ganga around Kanpur, Allahabad, Varanasi, Patna and Hathidah available from the daily discharge observation conducted by Central Water Commission have been subjected to drought frequency analysis to obtain minimum flows prevailing upon seven days continuous spell with recurrance intervals of 2 years, 5 years, 10 years and 20 years. Expected drought severity with a ten years return cycle form the basis of water quality management of a river system. Such studies are necessary for devising and adopting pollution abatement programme through optimum treatment of effluents and also for planning any water utilisation scheme in the reach.

3.7.4 The Projected Situation

The critical flows in Ganga at Kanpur, Allahabad and Varanasi as determined through drought frequency reference frame, suffice to provide a meagre dilution ratio of 1:6 to 1:10 for the city waste waters leading to a none too happy situation in so far as adoption of offensive strategies are concerned at the present state of water resource development and drought control measure.

4 CONCLUSIONS

4.1 The Prevailing Picture of Water Quality in the Ganga Basin

The present picture of water quality status in the Ganga river system as revealed from the data collected by the Central Water Commission affords three distinct zones:

(i) The upper reaches consisting the main river Ganga upto Narora and the Ramganga sub-basin where the deterioration in the water quality is found to be within tolerable limits.

(ii) The middle reach extending from Kanpur to Buxar on the main Ganga and including the most seriously affected Yamuna sub-basin especially between Delhi and Etawah. This middle zone is marked by dense urbanisation, excessive growth of industry and intensive agriculture practices. A large number of municipal towns depend for their water supplies and waste disposals on the rivers.

(iii) The segment of the basin below Buxar including the Ghagra, the Sone, the Gandak, the Kosi, the Mahananda and other sub-basins. Higher mean run-offs due to increased contributions from tributaries helps to maintain lower concentrations of pollutionary loads in the lower segment of Ganga basin.

The middle segment of Ganga Basin including the Yamuna sub-basin is seriously threatened from disposal of raw municipal sewages from a number of large cities, industrial wastes and agricultural run-off waters. Raw waters in this reach carry a large flux of toxic elements and pathogenic bacteria and need to be thoroughly treated before use as municipal supplies. Around major municipal towns, the DO balance during the lean flows has been observed to be critically low even during the day time when oxygen production by the photo synthetic activity of aquatic plant life is in full operation, making it unfit for fish propagation. Organic loads introduced by waste water discharge around Kanpur, Allahabad, Varanasi Patna and Hathidah on Ganga are found to be beyond the rivers' capacity to digest and assimilate within a reasonable distance through their self purification capacities. In the lower reaches below Buxar, the dissolved Oxygen levels are not seriously disturbed by the waste waters from Urban & Industrial centres at Patna and Hathidah.

4.2 The Causes of Growing Trend in Pollution

The entire water quality data collected under the scheme have been segregated over 3 seasons covering winter (November to February) summer (March to June) and monsoon months (July to October) to statistically correlate the water quality parameters and the corresponding river discharges. The values of constants and exponents of the regression equations obtained over different years for each season show a generally rising trend in the concentration of chemical constituents both in the equilibrium state and the active stage. The studies lead to the following broad conclusion on the quality status of waters in the Ganga River System.

(a) The middle segment of the Ganga from Kanpur to Buxer is alarmingly exposed to pollutionary threats from municipal and industrial wastes on account of lower quantum of fresh waters in the streams as compared to the waste waters recovered.

(b) Municipal effluents around Delhi, Mathura, Agra on the Yamuna and Kanpur Allahabad and Varanasi on the Ganga carry high immediate Oxygen Demand causing steeper and high oxygen sags below the effluent outfalls.

(c) Large scale sludge deposits and bed growths acting as garbage traps help in very sharp drop in the dissolved oxygen far beyond what can be accounted for by the time of passage through the reach. Slime growths around such zones are favourable areas of intense biological activity resulting in very brisk amortization.

(d) In sufficiently lower reaches below the outfalls of municipal effluents excessive mineralisation of waters particularly in respect of nitrates and phosphates produced from Oxidation of organic wastes is observed. Prolific growth of aquatic weeds and various types of algae introduced further complications in normal stream analysis. During daytime, these aquatic vegetations impart an over-

5 EPILOGUE

5.1 Necessity of Continuing Water Quality Monitoring in Various River Basins.

The research programme entitled "A Study of the Flow of Pollution Loads in the Ganga River System" was executed from 1978 to 1985. Salient features of the data collected under the scheme and conclusion drawn thereof in respect of monitoring stations on the main stem of Ganga have been discussed in the foregoing paragraphs. During the seven years of operation of the scheme 34 parameters were monitored at a frequence of once in ten days. The compiled information presents a valuable bench mark data for adoption of water quality management programme in the basin. The Ganga Project Directorate of the Ganga Control Authority have already initiated clean-up programme on the main stem of Ganga around major urban centres. The other sub-basins in the Ganga river system, espicially the Yamuna catchment are in equally bad shape in so far as their water quality regimes are concerned. In not too distant a future remedial measures would have to be taken up in these sub-basins as well as in other river systems of the country. Water quality data-base constitute the first and essential step for water quality management programme and the monitoring of water quality parameters in the river basins is also needed during and in the post-management period for assessment of the effectiveness of the measures adopted and as a surveillance activity for accidental or deliberate spills of toxic waste waters in the streams.

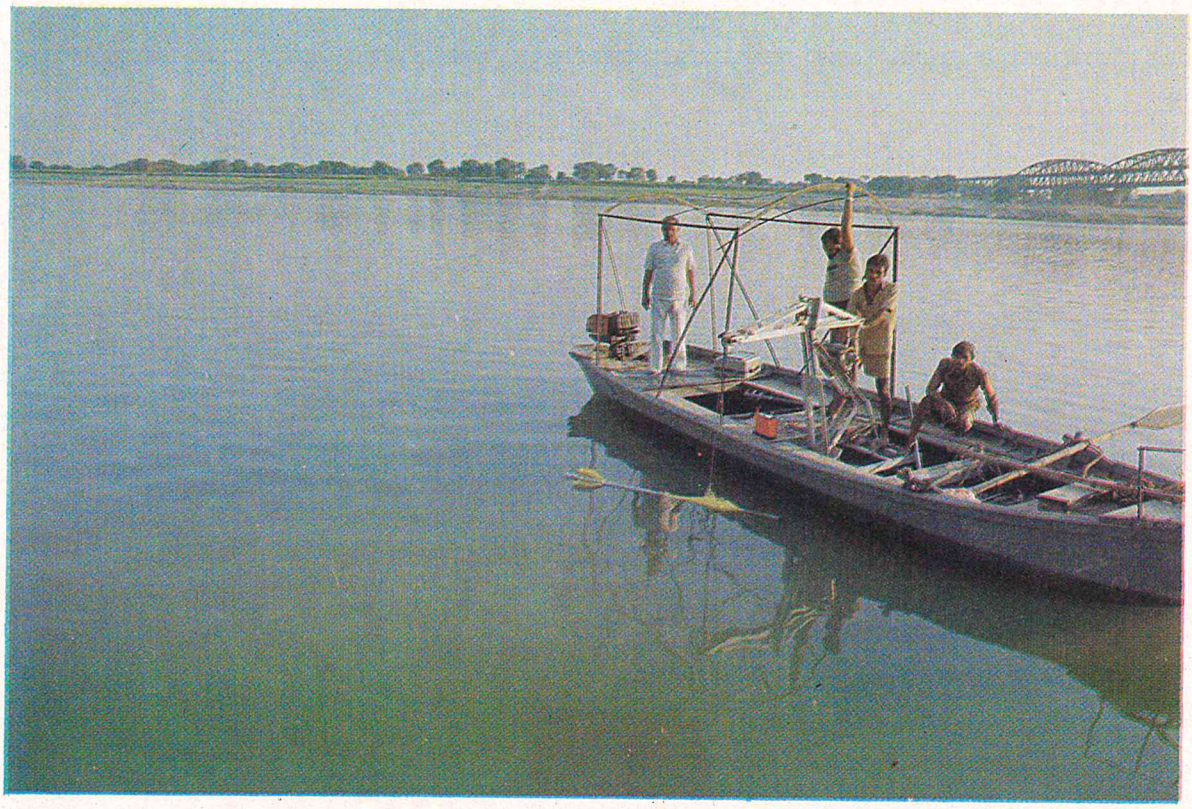
5.2 Programme of Water Quality Monitoring in Central Water Commission

A list of stations where water quality was monitored from 1978 to 1985 by the Central Water Commission is indicated in Table 6(A) alongwith the water quality sites under routine observation of CWC since 1963. The pollution monitoring stations operated by Central Water Commission on the main stem of Ganga and the existing level II and level III Water Quality Research Laboratories of Central Water Commission are indicated in the index maps of Ganga basin attached with this report. The winter and summer pollution loads are indicated in separate maps at Annex-VII. The monsoon quality of water is generally good due to heavy flows. A list of parameters monitored by C.W.C. is given in Table 6(B). With the closure of the research programme entitled "A Study of the Flow of Pollution Loads in the Ganga River System" and with a view to continue the monitoring work in Ganga basin and also to initiate establishment of netwrok in the rest of the river basins in the country a proposal entitled, "Stream-Lining and Strengthening of Water Quality Survey" in Central Water Commission, has been submitted to the Ministry of Water Resources and is under consideration. The work in the Ganga basin would however be continued.

dose of oxygen generated through photosynthesis, projecting a false picture of dissolved oxygen balance. More respiration by plant life and less generation of oxygen during night time brings down the general level of dissolved oxygen by as much as 80%. In cases like Ganga at Kanpur, Allahabad and Varanasi where the dissolved oxygen dips below the red mark of 3.0 mg/l for a fairly long reach even during day-time; it is but certain that when the nature sleeps during night, shutting off its oxygen generating units these water bodies serve no better than death traps for fish and other useful aquatic life. Probable anaerobic conditions prevailing during nocturnal hours increase the BOD burden of the rivers in still lower reaches.

4.3 Suggested Remedial Measures

In order to mitigate the present acute water quality regime of Ganga, especially in the middle reaches, it is imperative to bring a healthier liability/ assets balance in the river around major Municipal and Industrial centres by drastic reduction in the disposal of raw waste waters and undertake specific waste water treatment measures.



Velocity Observation using A. OTT Propeller Type Current Meter

Table 1.1

MONTHLY MEAN $^{5}BOD_{20}$ CONCENTRATIONS IN MG/LITRE AT U/S AND D/S SECTIONS IN GANGA AT KANPUR

Period		Winter Season				Summer Season				Monsoon Season			
		November	December	January	February	March	April	May	June	July	August	September	October
1979-80	U/S	0.44	0.53	0.53	0.60	0.70	0.72	0.49	0.75	1.44	2.06	1.44	1.44
	D/S	2.60	2.87	2.68	2.44	4.02	7.07	6.70	20.46	1.77	3.36	4.13	5.90
1980-81	U/S	1.24	1.38	0.51	0.58	1.57	1.03	0.79	0.91	0.78	0.79	0.59	0.76
	D/S	15.00	19.73	19.13	32.91	33.93	45.52	42.32	21.70	3.13	2.22	3.08	2.63
1981-82	U/S	—	1.09	—	—	0.69	0.36	0.52	0.69	0.98	0.89	1.02	0.72
	D/S	—	12.68	—	—	11.36	18.22	17.19	22.31	7.91	2.63	1.44	3.14
1982-83	U/S	0.59	0.78	0.56	1.10	0.90	0.75	—	0.92	1.52	0.62	1.48	1.89
	D/S	2.68	93.29	70.01	13.41	52.07	35.62	—	90.78	40.68	8.54	3.90	5.61
1983-84	U/S	1.08	—	2.11	1.54	—	2.94	—	—	—	—	1.38	1.50
	D/S	8.65	—	110.24	53.24	—	C/L	—	—	—	—	C/L	C/L
1984-85	C/L	1.35	1.40	1.57	2.35	3.64	2.28	3.52	4.31	2.54	1.76	1.19	—

(—) Indicate samples were not collected.

Table 1.2

MONTHLY MEAN $^{5}BOD_{20}$ CONCENTRATION IN MG/LITRE AT U/S AND D/S SECTIONS IN GANGA AT ALLAHABAD

Period		Winter Season				Summer Season				Monsoon Season			
		November	December	January	February	March	April	May	June	July	August	September	October
1979-80	U/S	0.69	0.64	0.70	0.62	0.59	0.60	0.50	0.63	0.58	0.52	0.61	0.55
	D/S	1.18	1.09	1.10	1.02	0.93	0.89	0.98	0.93	1.00	1.20	1.01	0.99
1980-81	U/S	—	—	—	—	—	0.54	0.64	0.80	0.87	0.68	0.67	0.75
	D/S	—	—	—	—	—	0.75	0.68	0.75	1.00	0.99	1.09	0.76
1981-82	U/S	0.76	—	—	0.91	0.80	0.76	0.61	0.77	0.78	—	—	—
	D/S	1.13	—	—	1.39	1.02	1.14	0.88	1.25	1.22	—	—	—
1982-83	U/S	0.63	0.28	0.23	0.42	0.74	—	—	0.85	—	0.20	0.28	1.10
	D/S	0.75	0.30	0.54	0.46	0.94	—	—	1.20	—	0.80	1.93	1.30
1983-84	U/S	1.57	2.12	2.28	2.02	1.85	1.29	2.14	—	1.04	0.75	1.17	0.59
	D/S	1.97	1.42	2.56	2.34	2.49	1.11	2.25	—	1.44	1.09	2.33	1.34
1984-85	U/S	1.18	1.48	0.72	0.84	1.05	0.94	0.80	1.32	2.57	1.01	1.05	0.57
	D/S	2.71	1.95	1.70	2.77	1.41	1.58	2.06	1.42	1.73	1.61	0.87	0.86

(—) Indicate samples were not collected.

MONTHLY MEAN $^{5}BOD_{20}$ CONCENTRATION IN MG/LITRE AT U/S AND D/S SECTION IN GANGA AT VARANASI

Table 1.3

Period		Winter Season				Monsoon Season				Summer Seasons			
		November	December	January	February	March	April	May	June	July	August	September	October
1979-80	U/S	1.25	0.97	1.77	1.18	1.00	1.18	1.13	1.46	0.63	0.56	0.53	0.50
	D/S	1.80	0.60	1.93	1.28	1.45	1.65	1.42	2.26	1.17	0.44	0.55	0.43
1980-81	U/S	0.82	0.99	2.55	2.02	1.20	1.97	1.39	0.84	1.05	0.37	0.65	0.97
	D/S	0.54	1.20	2.60	1.77	1.61	2.54	2.13	2.08	1.82	0.75	1.34	1.27
1981-82	U/S	1.05	0.85	1.45	1.02	1.87	1.06	1.43	1.03	0.97	0.97	0.72	0.90
	D/S	1.36	1.70	2.14	1.53	2.63	2.05	2.40	1.85	1.43	1.46	1.31	1.18
1982-83	U/S	0.89	0.93	0.76	0.75	1.57	1.13	1.38	2.03	1.11	0.85	0.36	0.62
	D/S	1.21	1.39	1.74	1.56	1.80	1.33	1.74	1.07	1.14	0.92	0.56	0.76
1983-84	U/S	0.67	0.62	0.38	0.47	1.29	0.95	1.53	1.11	0.65	0.43	0.47	0.65
	D/S	1.32	1.70	1.66	1.65	2.52	1.44	2.45	4.02	0.81	0.77	0.68	0.75
1984-85	U/S	0.71	0.77	0.41	1.46	1.39	1.39	0.79	1.38	1.49	0.68	0.88	0.88
	D/S	1.43	1.33	2.19	4.41	4.79	4.29	3.39	3.44	1.66	1.37	1.87	1.61

Table 1.4

MONTHLY MEAN $^{5}BOD_{20}$ CONCENTRATION IN MG/LITRE AT U/S AND D/S SECTION IN GANGA AT PATNA

Period		Winter Season				Summer Season				Monsoon Season			
		November	December	January	February	March	April	May	June	July	August	September	October
1979-80	U/S	—	0.63	0.67	0.44	0.25	0.23	0.52	0.37	0.30	0.26	0.22	0.34
	D/S	—	0.78	0.91	0.97	0.53	0.39	0.97	0.76	0.57	0.42	0.43	0.55
1980-81	U/S	0.53	0.68	0.60	0.69	0.72	0.68	0.59	0.53	0.67	0.72	0.78	0.59
	D/S	0.66	0.93	0.86	0.84	0.78	0.75	0.77	0.68	0.84	0.82	0.86	0.75
1981-82	U/S	0.69	0.65	0.64	0.69	0.70	0.67	0.55	0.65	0.88	0.64	0.44	0.62
	D/S	0.91	0.85	0.88	0.89	0.84	0.86	0.72	0.81	1.12	0.70	0.57	0.85
1982-83	U/S	0.65	0.52	0.77	0.59	0.61	0.62	0.61	0.59	0.59	0.69	0.87	0.88
	D/S	0.82	0.60	1.01	0.81	0.82	0.82	0.83	0.83	0.76	0.57	1.29	1.10
1983-84	U/S	1.01	0.92	0.95	0.92	1.29	0.92	0.94	0.83	0.79	0.68	0.74	0.90
	D/S	1.28	0.98	0.98	1.24	1.28	1.08	1.09	0.91	0.85	0.87	0.83	0.98
1984-85	U/S	0.85	0.83	0.98	1.00	0.92	0.98	0.98	0.95	0.93	0.78	0.96	0.98
	D/S	0.98	0.94	1.09	1.11	1.07	1.09	1.09	1.08	1.07	0.94	1.09	1.07

(—) Indicate samples were not collected.

Table 1.5

MONTHLY MEAN $^{5}BOD_{20}$ CONCENTRATIONS IN MG/LITRE AT U/S AND D/S SECTIONS IN GANGA AT HATHIDAH

Period		Winter Season				Summer Season				Monsoon Season			
		November	December	January	February	March	April	May	June	July	August	September	October
1979-80	U/S	—	—	—	—	0.26	0.43	0.51	0.32	0.36	0.38	0.27	0.41
	D/S	—	—	—	—	0.65	0.46	0.75	0.69	0.61	0.53	0.44	0.50
1980-81	U/S	0.40	0.47	NA	0.83	0.87	0.78	0.86	0.49	0.79	0.80	0.78	0.66
	D/S	0.48	0.81	NA	0.93	1.00	0.93	0.94	0.70	0.89	0.87	0.92	0.85
1981-82	U/S	0.77	0.80	0.67	0.77	0.77	0.80	0.67	0.70	0.75	0.67	0.59	0.65
	D/S	0.98	1.01	0.95	0.96	0.97	0.93	0.76	0.85	0.91	0.85	0.83	0.88
1982-83	U/S	0.74	0.72	0.69	0.64	0.64	0.66	0.63	0.64	0.65	0.74	0.75	1.05
	D/S	0.87	0.85	0.86	0.85	0.89	0.90	0.85	0.83	0.84	0.80	1.19	1.26
1983-84	U/S	0.62	1.26	0.98	1.07	1.14	1.07	1.05	0.67	0.76	0.83	0.87	0.94
	D/S	0.72	1.37	1.11	1.26	1.37	1.20	1.20	1.04	0.92	0.96	1.00	1.00
1984-85	U/S	0.89	0.96	0.98	1.00	1.00	1.05	1.09	1.09	0.98	0.89	0.87	0.96
	D/S	1.04	1.13	1.07	1.15	1.18	1.20	1.20	1.18	1.09	0.98	0.98	1.05

(—) Indicate samples were not collected.

Table 2.1.A

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT RISHIKESH WINTER SEASON (NOVEMBER TO FEBRUARY)

Parameters	1978-79		1979-80		1980-81		1981-82		1982-83		1983-84	
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S
Sp. Conductivity (λ)	195	218	194	235	196	283	187	255	154	298	225	192
pH	7.70	7.70	8.24	8.28	7.92	7.87	8.50	8.58	8.26	8.21	8.21	8.17
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	Tr.	Tr.	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	2.97	2.16	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	26.60	28.40	22.40	25.20	26.80	34.00	23.60	33.40	23.60	46.80	18.40	34.00
Magnesium (Mg^{+2})	6.31	6.79	11.28	12.25	10.67	13.22	9.70	11.64	8.01	16.38	4.12	2.67
Sodium (Na^{+})	3.22	2.07	3.91	4.60	3.91	5.52	3.68	4.14	5.06	14.72	1.38	1.15
Potassium (K^{+})	1.56	1.56	Tr.	Tr.	0.78	0.79	0.39	0.39	2.73	3.51	2.34	1.95
Carbonate (CO_3^{-2})	NIL	NIL	NIL	NIL	4.80	6.00	3.90	9.00	5.40	6.60	9.90	8.70
Bicarbonate (HCO_3^{-})	120.78	124.44	112.85	123.83	101.87	132.37	117.12	140.30	104.92	220.21	115.90	93.33
Cloride (Cl^{-})	7.09	8.15	7.80	8.86	10.28	13.12	15.95	14.89	12.76	16.66	8.15	8.86
Fluoride (F^{-})	NA	NA	NA	NA	NA	NA	2.28	3.42	0.95	0.95	0.38	0.38
Sulphate (SO_4^{-2})	14.88	19.20	5.28	6.72	16.32	21.12	8.16	14.88	11.04	40.80	12.00	8.16
Nitrate (NO_3^{-})	NIL	NIL	NIL	Tr.	0.62	2.48	NIL	NIL	Tr	0.60	NIL	NIL
Nitrite (NO_2^{-})	NIL	NIL	NIL	Tr.	NIL	Tr.	NIL	NIL	Tr.	Tr.	Tr.	NIL
Phosphate (PO_4^{-3})	13.30	16.78	NIL	NIL	1.58	0.63	1.90	1.27	0.32	2.53	0.63	0.63
Silicate (SiO_3^{-2})	4.50	4.75	1.13	1.22	0.38	12.76	22.87	36.28	16.10	35.27	12.47	9.33
Boron (B)	NIL	NIL	NIL	NIL	0.07	0.08	0.03	0.07	0.08	0.09	0.04	0.04

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.1.C

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT RISHIKESH MONSOON SEASON (JULY TO OCTOBER)

Parameters	1978	1979		1980		1981		1982		1983	
	C/L	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S
Sp. Conductivity (λ)	264	160	223	158	252	188	209	160	161	198	191
pH	7.63	8.12	8.23	7.80	7.60	8.03	8.11	8.07	8.18	8.17	8.18
Iron (Fe^{+3})	NIL	NIL	NIL	0.56	1.12	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	4.32	4.68	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	28.00	20.60	24.40	17.00	23.60	23.60	29.40	21.20	23.60	20.00	20.20
Magnesium (Mg^{+2})	6.22	8.33	18.15	10.81	15.91	9.07	8.95	5.22	6.46	9.45	8.70
Sodium (Na^{+})	2.30	2.30	2.99	1.37	1.62	0.75	0.87	0.75	0.75	0.69	0.92
Potassium (K^{+})	1.17	1.56	1.56	0.78	0.39	1.17	1.17	2.34	2.34	2.34	1.95
Carbonate (CO_3^{-2})	0.90	NIL	1.20	0.90	1.80	0.30	1.50	4.80	5.70	5.70	6.30
Bicarbonate (HCO_3^{-})	98.82	80.52	115.90	93.33	122.61	121.39	134.20	93.94	99.43	88.45	92.11
Cloride (Cl^{-})	9.22	7.09	7.44	13.83	12.41	11.34	11.34	11.70	11.70	9.22	9.93
Fluoride (F^{-})	NA	NA	NA	NA	NA	NA	NA	1.71	1.71	0.38	0.76
Sulphate (SO_4^{-2})	6.24	12.00	21.12	9.60	21.60	7.68	7.68	7.20	16.80	5.76	7.68
Nitrate (NO_3^{-})	NIL	NIL	NIL	0.62	NIL	6.20	9.92	NIL	NIL	NIL	NIL
Nitrite (NO_2^{-})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	Tr	Tr	NIL	NIL
Phosphate (PO_4^{-3})	NIL	1.58	3.16	1.58	1.58	0.26	0.26	0.79	0.53	0.26	0.26
Silicate (SiO_3^{-2})	0.13	NIL	NIL	10.53	17.88	10.41	12.89	8.67	9.85	10.38	9.68
Boron (B)	NA	NIL	NIL	0.33	0.33	0.04	0.05	0.06	0.02	0.03	0.03

N.B. Units of concentrations for cations and anions ar : in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. s ands for trace concentrations and NA indicate samples not analysed.

Table 2.1.B

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT RISHIKESH SUMMER SEASON (MARCH TO JUNE)

Parameters	1978	1979		1980		1981		1982		1983	
	C/L	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S
Sp. Conductivity (λ)	328	337	241	111	129	186	205	186	275	156	200
pH	8.55	7.73	7.73	7.88	7.83	8.38	8.31	8.20	8.26	8.20	8.10
Iron (Fe^{+3})	NIL	NIL	NIL	Tr	0.19	NIL	0.19	0.19	0.38	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	Tr	0.09	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	46.60	19.80	19.40	23.60	26.00	23.60	23.00	20.40	27.60	19.80	23.40
Magnesium (Mg^{+2})	17.77	8.82	9.07	8.08	10.32	6.71	7.58	6.34	10.81	7.71	11.81
Sodium (Na^{+})	7.13	1.84	1.84	2.99	3.22	2.30	1.84	2.76	3.22	0.46	2.30
Potassium (K^{+})	0.19	NIL	NIL	Tr	Tr	Tr	Tr	0.19	0.19	0.76	0.76
Carbonate (CO_3^{-2})	0.24	NIL	NIL	4.50	3.60	2.70	4.50	7.50	8.70	3.90	5.10
Bicarbonate (HCO_3	99.43	101.26	102.48	91.50	103.70	90.89	93.33	95.16	129.32	89.06	113.46
Cloride (Cl^{-})	15.95	12.05	12.05	6.38	6.74	10.28	10.64	10.28	12.41	9.93	9.93
Fluoride (F^{-})	1.71	NA	NA	NA	NA	NA	NA	1.33	1.33	0.57	0.76
Sulphate (SO_4^{-2})	NIL	17.28	21.60	16.32	20.64	7.20	6.72	6.72	14.40	7.68	10.08
Nitrate (NO_3^{-})	NIL	NIL	NIL	NIL	NIL	1.86	3.05	NIL	NIL	NIL	NIL
Nitrite (NO_2^{-})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	Tr	Tr	Tr	0.46
Phosphate (PO_4^{-3})	NIL	7.36	7.63	1.32	1.84	0.26	0.53	0.26	0.53	0.53	0.79
Silicate (SiO_3^{-2})	1.02	38.00	37.00	2.03	4.69	9.13	11.93	14.78	24.35	13.43	16.72
Boron (B)	NA	NIL	NIL	NIL	NIL	0.08	0.07	NIL	NIL	0.06	0.09

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.2.A

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT GARHMUKHTESHWAR WINTER SEASON (NOVEMBER TO FEBRUARY)

Parameters	1978-79	1979-80		1980-81		1981-82		1982-83		1983-84		1984-85
	C/L	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L
Sp. Conductivity (λ)	175	231	263	245	244	182	179	227	222	267	260	225
pH	7.73	8.12	8.45	8.06	8.04	8.34	8.35	8.41	8.41	8.10	8.05	9.05
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	4.32	4.49	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	30.20	39.40	40.40	36.60	37.80	28.80	30.60	31.00	34.20	30.80	32.60	24.00
Magnesium (Mg^{+2})	10.19	10.69	11.44	11.19	10.69	12.55	13.67	11.44	11.68	13.55	11.81	19.76
Sodium (Na^{+})	4.83	4.60	5.29	9.20	9.66	8.51	12.42	10.58	11.27	12.42	9.89	4.60
Potassium (K^{+})	2.73	0.39	0.78	2.34	2.73	3.12	3.51	3.12	3.90	3.51	2.73	1.17
Carbonate (CO_3^{-2})	1.20	NIL	NIL	0.90	2.70	NIL	NIL	4.20	3.30	NIL	NIL	NIL
Bicarbonate (HCO_3^{-})	143.96	119.56	132.37	172.67	171.41	176.29	189.10	152.50	168.36	167.75	162.87	135.42
Cloride (Cl^{-})	6.03	7.80	9.93	9.22	10.28	7.09	8.51	8.15	8.51	9.57	9.57	7.80
Fluoride (F^{-})	NA	NA	NA	Tr	Tr	0.19	0.19	0.38	0.38	3.61	3.42	NA
Sulphate (SO_4^{-2})	22.08	Tr	0.48	9.12	5.76	16.32	18.24	14.88	16.32	12.96	12.00	23.04
Nitrate (NO_3^{-})	NIL	NIL	NIL	NIL	NIL	1.86	2.48	2.48	1.24	3.10	1.24	NA
Nitrite (NO_2^{-})	NIL	NIL	NIL	NIL	NIL	Tr	Tr	Tr	Tr	Tr	Tr	NIL
Phosphate (PO_4^{-3})	0.26	0.26	0.52	Tr	Tr	0.26	0.26	NIL	NIL	Tr	Tr	NA
Silicate (SiO_3^{-2})	10.75	1.35	1.57	7.44	8.76	9.83	9.40	10.44	8.68	9.22	10.47	4.50
Boron (B)	NIL	NIL	NIL	0.03	0.03	0.01	0.08	0.01	0.03	0.36	0.03	NA

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.2.B

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT GARHMUKHTESHWAR SUMMER SEASON (MARCH TO JUNE)

Parameters	1978	1979		1980		1981		1982		1983		1984	1985
	C/L	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L	C/L
Sp. Conductivity (λ)	288	285	299	177	180	312	326	252	255	250	232	245	285
pH	7.83	7.77	7.78	7.94	7.85	8.31	8.32	8.01	7.98	8.31	8.27	8.73	9.18
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	Tr	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	29.80	26.40	28.80	27.60	31.00	32.40	33.40	25.60	27.80	25.40	27.40	20.60	27.20
Magnesium (Mg^{+2})	11.56	14.92	19.52	14.42	15.41	11.06	13.30	9.32	9.70	7.58	7.83	18.15	22.75
Sodium (Na^{+})	5.98	2.76	4.14	6.67	7.59	10.35	14.03	8.51	5.52	14.95	15.87	4.83	8.51
Potassium (K^{+})	0.39	NIL	0.39	0.78	0.78	3.51	3.51	5.85	3.90	4.29	3.90	1.56	1.56
Carbonate (CO_3^{-2})	NIL	1.20	1.20	9.30	14.40	NIL	Tr	3.30	3.00	3.30	2.70	NIL	NIL
Bicarbonate (HCO_3^{-})	176.29	117.12	139.08	142.13	140.30	158.60	176.90	116.51	114.68	132.37	125.05	142.74	154.33
Cloride (Cl^{-})	11.34	10.64	10.99	17.73	17.02	14.18	13.47	9.22	8.86	9.57	7.80	7.80	10.64
Fluoride (F^{-})	NA	NA	NA	NA	NA	0.38	0.19	0.19	0.19	1.14	0.76	NA	NA
Sulphate (SO_4^{-2})	NIL	16.80	23.04	6.24	11.52	19.20	20.16	22.08	19.68	15.36	15.36	29.28	33.60
Nitrate (NO_3^{-})	NA	NIL	NIL	NIL	NIL	NIL	NIL	2.48	3.10	1.24	1.24	NA	NIL
Nitrite (NO_2^{-})	NIL	NIL	NIL	NIL	NIL	Tr	Tr	Tr	Tr	Tr	Tr	NIL	NA
Phosphate (PO_4^{-3})	NA	4.47	8.15	3.16	2.89	Tr	Tr	Tr	Tr	Tr	1.32	NA	NA
Silicate (SiO_3^{-2})	NIL	16.25	22.50	3.76	4.74	10.34	8.85	8.38	8.46	7.90	8.58	1.80	4.31
Boron (B)	NA	NIL	NIL	NIL	NIL	0.21	0.09	0.03	0.08	0.04	0.09	NA	NIL

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples ont analysed.

Table 2.2.C

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT GARHMUKHTESHWAR MONSOON SEASON (JULY TO OCTOBER)

Parameters	1978	1979		1980		1981		1982		1983		1984	1985
	C/L	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L	C/L
Sp. Conductivity (λ)	114	231	242	183	220	227	214	190	199	206	200	206	205
pH	7.65	7.64	7.64	7.45	7.53	8.11	8.07	8.25	7.86	8.32	8.33	8.81	9.21
Iron (Fe^{+3})	NIL	NIL	NIL	Tr	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	7.01	7.37	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	17.60	23.20	24.00	20.20	19.00	25.40	24.60	24.00	24.20	23.60	23.40	19.80	18.60
Magnesium (Mg^{+2})	6.59	9.07	9.07	10.19	11.81	4.85	4.60	5.59	5.84	8.58	7.83	16.03	14.42
Sodium (Na^{+})	3.22	3.45	3.68	2.76	2.76	5.29	5.29	3.68	3.91	4.60	4.83	1.84	2.30
Potassium (K^{+})	1.17	2.73	2.73	1.17	1.17	4.29	4.29	3.90	3.90	3.12	2.73	1.56	1.56
Carbonate (CO_3^{-2})	NIL	1.20	1.20	3.60	4.50	0.90	0.60	0.45	0.30	NIL	NIL	NIL	NIL
Bicarbonate (HCO_3^{-}))	104.92	101.26	119.56	106.75	106.14	107.36	104.31	100.65	101.87	102.60	114.68	113.46	122.00
Cloride (Cl^{-})	5.67	7.09	7.09	16.66	16.31	6.38	6.03	8.15	8.51	8.15	8.15	7.80	7.09
Fluoride (F^{-})	NA	NA	NA	NA	NA	0.19	0.19	Tr	Tr	0.19	0.19	NA	NA
Sulphate (SO_4^{-2})	3.36	7.20	5.76	9.60	8.64	21.12	20.16	20.16	18.72	20.16	19.20	31.68	27.84
Nitrate (NO_3^{-})	NA	NIL	NIL	NIL	NIL	0.62	0.62	0.62	0.62	2.48	1.86	NA	NIL
Nitrite (NO_2^{-})	NIL	NIL	NIL	NIL	NIL	Tr	Tr	Tr	Tr	Tr	Tr	NIL	NA
Phosphate (PO_4^{-3})	NA	1.84	2.10	1.84	2.10	NIL	NIL	Tr	Tr	NIL	NIL	NA	NA
Silicate (SiO_3^{-2})	NIL	NIL	NIL	11.78	11.28	6.13	7.46	6.75	9.18	11.00	9.50	6.67	3.75
Boron (B)	NA	NIL	NIL	0.34	0.34	NIL	NIL	0.01	0.25	0.04	0.09	NA	NIL

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.3 A

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT FATEHGARH WINTER SEASON (NOVEMBER TO FEBRUARY)

Parameters	1978-79		1979-80		1980-81		1981-82		1982-83		1983-84		1984-85
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L
Sp. Conductivity (λ)	420	440	349	387	319	296	222	219	330	314	333	345	328
pH	7.73	7.73	8.22	8.50	8.24	8.28	8.44	8.48	8.46	8.46	7.99	7.96	8.82
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	34.40	29.80	33.00	34.60	40.40	39.60	34.20	34.80	42.00	41.60	37.40	39.60	28.40
Magnesium (Mg^{+2})	12.43	13.92	15.91	16.78	14.17	13.80	15.29	15.54	14.92	15.28	17.77	15.91	22.37
Sodium (Na^{+})	31.05	21.62	17.94	15.41	18.63	13.80	16.79	15.87	17.48	17.71	16.10	18.86	12.88
Potassium (K^{+})	0.78	1.95	1.56	1.95	3.90	3.90	5.46	4.68	5.07	8.58	3.90	4.29	2.34
Carbonate (CO_3^{-2})	15.00	24.00	4.80	9.60	15.90	14.40	0.90	NIL	4.20	3.60	0.90	0.60	NIL
Bicarbonate (HCO_3^{-})	190.32	183.61	190.32	207.40	221.43	218.99	214.11	217.77	220.21	223.87	231.80	229.36	185.44
Cloride (Cl^{-})	18.08	23.40	11.34	12.06	14.89	11.70	11.34	10.28	12.41	12.76	13.12	13.12	11.70
Fluoride (F^{-})	NA	NA	NA	NA	0.19	Tr	0.19	0.19	0.38	0.57	3.42	3.42	NA
Sulphate (SO_4^{-2})	51.84	36.00	3.36	4.80	23.04	19.20	18.72	17.28	20.16	19.20	15.36	11.52	34.08
Nitrate (NO_3^{-})	NA	NA	NIL	NIL	NA	NA	1.86	1.86	1.24	1.24	1.86	1.24	NA
Nitrite (NO_2^{-})	NIL	NIL	NIL	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	NIL
Phosphate (PO_4^{-3})	0.26	0.26	1.30	1.58	Tr	Tr	0.26	Tr	Tr	Tr	Tr	Tr	NIL
Silicate (SiO_3^{-2})	4.33	15.45	0.43	0.57	6,30	5.59	9.21	8.73	7.68	7.73	10.10	10.89	4.56
Boron (B)	NIL	NIL	NIL	NIL	0.11	0.15	0.07	NIL	0.12	0.10	0.10	0.09	NIL

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.3 B

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT FATEHGARH

SUMMER SEASON (MARCH TO JUNE)

Parameters	1978	1979		1980		1981		1982		1983		1984	1985
	C/L	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L	C/L
Sp. Conductivity (λ)	392	447	513	214	221	344	351	289	291	286	288	363	423
pH	7.83	7.78	7.78	7.80	7.88	8.34	8.22	8.52	8.41	8.26	8.29	8.35	8.90
Iron (Fe^{+3})	NA	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NA	7.20	8.01	0.18	0.18	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	33.20	38.20	40.80	24.60	23.20	34.00	33.20	25.80	25.60	31.80	32.40	27.00	28.00
Magnesium (Mg^{+2})	16.28	17.40	20.01	14.92	15.54	13.17	12.92	10.07	11.68	10.57	11.4	26.35	25.61
Sodium (Na^{+})	5.29	15.64	15.64	12.42	12.88	13.80	13.57	6.90	7.36	22.54	22.31	15.87	19.55
Potassium (K^{+})	6.24	0.39	0.39	1.95	1.95	4.68	5.07	5.46	4.68	6.24	5.46	2.34	3.12
Carbonate (CO_3^{-2})	NIL	1.20	6.00	9.30	12.00	0.90	1.20	6.90	5.70	4.50	6.00	NIL	NIL
Bicarbonate (HCO_3^{-})	230.58	212.28	204.96	187.88	194.59	197.64	194.59	140.91	139.69	159.21	162.87	192.76	212.28
Cloride (Cl^{-})	19.14	13.12	12.05	12.05	13.12	9.93	11.70	11.34	12.41	10.64	11.34	9.59	12.41
Fluoride (F^{-})	NA	NA	NA	NA	NA	0.57	0.57	0.19	0.38	0.95	1.52	NA	NA
Sulphate (SO_4^{-2})	19.20	23.52	32.64	8.16	8.16	25.92	26.40	24.00	22.08	16.32	17.28	34.56	46.56
Nitrate (NO_3^{-})	NA	NIL	NIL	NIL	NIL	NIL	NIL	1.86	1.86	1.24	1.24	NA	NIL
Nitrite (NO_2^{-})	NIL	NIL	NIL	NIL	NIL	Tr	Tr	Tr	Tr	Tr	Tr	NIL	NA
Phosphate (PO_4^{-3})	NA	7.62	7.62	7.36	7.89	Tr	Tr	Tr	Tr	Tr	Tr	NA	NA
Silicate (SiO_3^{-2})	4.17	47.00	41.75	4.33	4.30	6.33	9.18	6.25	7.04	7.38	7.20	2.75	5.29
Boron (B)	NA	NIL	NIL	NIL	NIL	0.01	0.03	0.18	0.10	0.05	0.08	NIL	NIL

N.B. Units of concentrations for cations and anions are in mg/1. Specific conductance values λare in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.3 C

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT FATEHGARH
MONSOON SEASON (JULY TO OCTOBER)

Parameters	1978	1979		1980		1981		1982		1983		1984	1985
	C/L	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L	C/L
Sp. Conductivity (λ)	389	228	233	221	227	243	242	237	221	252	229	265	230
pH	7.63	8.17	8.20	7.39	7.36	8.12	8.10	8.37	8.37	8.25	8.25	8.50	9.02
Iron (Fe^{+3})	NA	NA	NA	2.81	2.43	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NA	NA	NA	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	24.00	28.80	30.20	21.60	24.80	26.60	26.40	27.00	27.40	26.20	25.40	24.00	20.60
Magnesium (Mg^{+2})	10.69	9.07	11.31	12.31	11.81	5.22	5.34	6.71	3.98	9.82	8.83	20.01	19.27
Sodium (Na^{+})	3.68	6.67	6.67	4.37	2.30	9.66	7.59	5.52	5.98	9.89	8.28	5.75	4.14
Potassium (K^{+})	Tr	3.12	2.73	1.56	1.56	5.07	5.07	9.75	5.46	4.68	3.90	1.95	1.95
Carbonate (CO_3^{-2})	NIL	2.40	3.60	4.50	5.10	0.90	0.90	1.50	1.20	NIL	NIL	NIL	NIL
Bicarbonate (HCO_3^{-})	129.93	126.88	122.00	117.12	121.39	114.68	120.78	123.83	121.39	130.54	118.95	131.76	142.74
Cloride (Cl^{-})	10.99	12.05	12.41	14.53	15.24	8.15	7.80	12.41	8.86	11.70	8.51	9.57	9.22
Fluoride (F^{-})	NA	NA	NA	NA	NA	0.19	0.38	Tr	Tr	0.19	Tr	NA	NA
Sulphate (SO_4^{-2})	12.00	8.64	13.44	8.64	7.26	18.72	20.64	18.72	16.32	20.16	21.12	40.32	39.84
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	NA	0.62	0.62	1.86	1.86	NA	NIL
Nitrite (NO_2^{-})	NIL	NIL	NIL	NIL	NIL	0.46	0.46	Tr	0.46	Tr	Tr	NIL	NA
Phosphate (PO_4^{-3})	NA	0.26	1.32	1.32	3.42	NIL	NIL	Tr	Tr	Tr	Tr	NA	NA
Silicate (SiO_3^{-2})	2.55	NIL	NIL	13.13	10.66	7.88	6.14	9.17	8.67	7.44	10.64	5.62	4.50
Boron (B)	NA	NIL	NIL	0.33	0.35	0.05	0.08	0.04	0.02	NIL	NIL	NIL	NIL

N.B. Units of concentrations for cations and anions are in mg/1. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.4.A

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT KANPUR
WINTER SEASON (NOVEMBER-FEBRUARY)

Parameters	1978-79		1979-80		1980-81		1981-82		1982-83		1983-84		1984-85
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L
Sp. Conductivity (λ)	331	398	361	415	378	400	260	280	369	385	367	408	434
pH	8.45	8.54	8.37	8.36	8.25	8.24	8.51	8.35	8.44	8.36	8.00	8.01	8.66
Iron (Fe^{+3})	NIL	2.62	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	3.96	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	39.40	40.80	41.20	43.80	43.20	45.40	32.20	39.60	47.60	45.80	43.00	43.00	28.40
Magnesium (Mg^{+2})	16.28	17.28	17.40	18.89	20.88	21.50	23.99	19.27	19.14	19.14	19.14	20.01	25.61
Sodium (Na^{+})	20.01	21.62	26.91	33.35	23.92	28.98	20.93	22.54	20.93	23.92	18.86	21.39	23.69
Potassium (K^{+})	2.73	3.12	4.29	5.07	3.90	4.68	4.29	4.68	5.46	5.07	3.90	4.29	2.34
Carbonate (CO_3^{-2})	12.60	3.00	7.50	6.60	0.90	2.10	0.90	NIL	7.20	3.30	NIL	NIL	NIL
Bicarbonate (HCO_3^{-})	91.54	204.35	256.20	272.67	281.82	265.96	254.37	270.84	264.74	269.01	269.62	271.45	217.16
Cloride (Cl^{-})	17.37	19.14	15.60	23.75	15.24	19.50	11.70	17.73	14.89	18.43	13.82	16.31	12.05
Fluoride (F^{-})	NA	NA	0.38	0.38	Tr	0.19	0.38	0.19	0.19	0.19	0.38	0.38	NA
Sulphate (SO_4^{-2})	28.32	36.96	28.80	28.80	26.88	31.20	23.04	25.92	25.92	25.92	16.32	14.88	41.76
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	1.86	1.86	2.48	1.86	2.48	2.48	NA
Nitrite (NO_2^{-})	Tr	Tr	Tr	Tr	Tr	Tr	0.46	Tr	Tr	Tr	Tr	0.46	NIL
Phosphate (PO_4^{-3})	NA	NA	0.26	0.78	Tr	0.26	Tr	0.52	Tr	Tr	Tr	Tr	NA
Silicate (SiO_3^{-2})	4.19	4.10	5.22	6.26	9.06	6.13	9.43	9.15	9.07	8.72	9.17	8.97	4.50
Boron (B)		0.03	0.53	0.24	0.02	0.04	0.06	0.14	0.04	0.16	0.15	0.36	NIL

N.B Units of concentrations for cations and anions are in mg/l. Specific conductance values λare in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT KANPUR
SUMMER SEASON (MARCH TO JUNE)

Table 2.4 B

Parameters	1979		1980		1981		1982		1983		1984	1985
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L	C/L
Sp. Conductivity (λ)	504	522	437	479	431	524	377'	401	403	412	514	569
pH	8.48	8.44	8.42	8.04	8.25	8.14	8.17	8.16	8.42	8.25	8.18	8.70
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	34.20	36.40	37.00	37.40	34.20	40.20	29.20	30.20	36.00	39.00	25.00	32.60
Magnesium (Mg^{+2})	12.55	12.18	17.90	17.65	20.88	20.01	16.03	16.16	19.76	15.41	23.00	31.45
Sodium (Na^{+})	26.45	22.77	28.98	32.66	23.23	30.59	14.03	16.10	25.76	25.07	24.15	35.65
Potassium (K^{+})	2.34	2.34	5.85	7.41	5.07	6.24	5.85	7.80	6.24	6.24	3.12	4.68
Carbonate (CO_3^{-2})	4.80	9.60	15.00	9.60	0.90	NIL	9.30	6.30	13.50	5.10	NIL	NIL
Bicarbonate (HCO_3^{-})	179.34	175.04	222.04	236.07	255.59	281.21	189.71	198.86	265.35	174.46	209.84	259.86
Cloride (Cl^{-})	21.97	22.69	18.43	24.11	15.95	24.11	14.89	19.50	37.58	20.92	13.12	16.66
Fluoride (F^{-})	NA	NA	NA	NA	0.38	0.57	0.19	0.19	Tr	0.19	NA	NA
Sulphate (SO_4^{-2})	33.60	30.72	1.92	2.40	30.72	37.92	20.64	26.40	26.40	16.32	36.96	53.28
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	2.48	4.34	2.48	1.44	NA	NIL
Nitrite (NO_2^{-})	NIL	1.84	Tr	0.92	NIL	0.46	Tr	0.46	Tr	0.46	NIL	NA
Phosphate (PO_4^{-3})	NA	NA	1.32	0.53	NIL	0.26	Tr	0.26	0.26	0.26	NA	NA
Silicate (SiO_3^{-2})	9.00	11.00	9.30	8.60	9.30	10.80	7.70	10.50	9.50	8.70	4.25	4.81
Boron (B)	0.18	0.03	0.10	0.12	0.13	0.09	0.01	0.09	0.09	0.04	NIL	NIL

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.4 C

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT KANPUR MONSOON SEASON (JULY TO OCTOBER)

Parameters	1979		1980		1981		1982		1983		1984	1985
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L	C/L
Sp. Conductivity (λ)	340	351	233	244	275	296	257	261	257	276	288	280
pH	8.48	8.46	8.13	8.33	8.12	8.00	8.34	8.19	8.33	8.32	8.47	8.85
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	29.40	32.40	25.40	26.00	26.20	28.60	26.80	27.20	27.00	27.00	24.00	22.00
Magnesium (Mg^{+2})	9.82	8.82	8.70	8.82	8.95	7.46	8.58	8.20	10.81	11.31	19.02	19.27
Sodium (Na^{+})	16.56	18.63	10.35	11.96	11.50	13.11	8.28	8.51	9.66	11.27	8.51	6.67
Potassium (K^{+})	3.12	3.12	5.46	5.46	4.68	4.68	5.07	5.46	3.12	3.90	1.95	1.95
Carbonate (CO_3^{-2})	6.00	4.80	0.90	0.90	1.50	0.60	3.60	4.20	NIL	NIL	NIL	NIL
Bicarbonate (HCO_3^{-})	120.78	141.52	142.74	143.96	145.18	153.72	141.52	142.13	134.81	124.44	149.45	154.94
Cloride (Cl^{-})	13.82	15.60	10.64	10.28	10.99	11.34	10.64	10.28	10.28	11.70	8.86	9.57
Fluoride (F^{-})	0.38	0.19	0.57	NIL	0.19	0.19	NIL	Tr	0.19	0.19	NA	NA
Sulphate (SO_4^{-2})	24.48	24.48	14.40	14.88	16.32	17.76	13.44	18.72	17.28	16.80	29.76	35.52
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	1.24	1.24	1.86	1.86	NA	NIL
Nitrite (NO_2^{-})	NIL	Tr	Tr	Tr	0.46	0.92	Tr	Tr	Tr	0.92	NIL	NA
Phosphate (PO_4^{-3})	NIL	NIL	Tr	0.26	Tr	Tr	Tr	Tr	NIL	NIL	NA	NA
Silicate (SiO_3^{-2})	7.30	6.50	8.30	8.30	8.70	9.30	8.90	9.70	11.70	12.10	4.50	4.00
Boron (B)	0.21	0.04	0.26	0.26	0.01	0.03	NIL	0.08	0.04	0.03	NIL	NIL

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.5 A

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT ALLAHABAD
WINTER SEASON (NOVEMBER TO FEBRUARY)

Parameters	1978-79		1979-80		1980-81		1981-82		1982-83		1983-84		1984-85
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L
Sp. Conductance (λ)	350	456	382	502	415	461	273	308	393	451	410	464	438
pH	8.59	8.49	8.47	8.50	8.23	8.29	8.40	8.50	8.37	8.45	8.04	8.03	8.49
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	37.00	39.40	43.00	41.40	37.80	36.80	34.80	32.80	42.20	40.80	51.60	40.60	41.60
Magnesium (Mg^{+2})	17.77	19.14	16.03	19.14	19.76	22.87	20.51	24.49	19.14	19.64	15.91	19.76	18.77
Sodium (Na^{+})	24.15	29.90	29.67	49.45	29.90	41.86	23.46	37.95	29.44	37.49	31.28	39.79	33.58
Potassium (K^{+})	3.51	2.73	4.68	3.90	4.68	3.90	4.29	4.29	4.29	4.68	3.51	3.51	5.85
Carbonate (CO_3^{-2})	7.20	4.80	8.40	5.40	NIL	0.30	NIL	0.90	4.20	2.70	NIL	NIL	NIL
Bicarbonate (HCO_3^{-})	229.36	233.02	259.25	267.18	251.32	290.97	254.98	279.38	251.93	261.69	256.81	307.44	311.10
Cloride (Cl^{-})	21.27	24.11	22.69	47.50	25.88	34.39	19.50	34.03	24.82	29.42	23.60	32.26	37.22
Fluoride (F^{-})	NA	NA	0.76	0.57	0.19	Tr	0.19	0.19	0.38	0.38	0.57	0.57	0.38
Sulphate (SO_4^{-2})	32.64	46.08	37.92	58.56	36.00	43.20	27.36	27.84	30.72	36.00	16.80	22.56	28.80
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	1.86	1.86	2.48	1.86	2.48	3.10	NA
Nitrite (NO_2^{-})	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	0.46	0.46	Tr
Phosphate (PO_4^{-3})	NA	NA	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
Silicate (SiO_3^{-2})	4.26	4.70	5.59	5.71	4.51	5.76	6.51	7.75	7.72	9.75	9.02	9.47	7.10
Boron (B)	0.05	0.09	0.67	0.96	0.06	0.09	0.03	0.10	0.47	0.19	0.07	0.09	0.15

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.5 B

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT ALLAHABAD
SUMMER SEASON (MARCH TO JUNE)

Parameters	1978		1979		1980		1981		1982		1983		1984	1985
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L	C/L
Sp. Conductivity (λ)	472	540	506	608	519	569	526	640	419	443	437	444	708	603
pH	8.55	8.63	8.36	8.45	8.43	8.37	8.21	8.27	8.01	8.01	8.23	8.28	8.28	8.21
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	28.40	27.80	37.60	35.80	38.00	36.00	30.80	39.80	29.40	29.80	34.00	34.80	34.60	31.20
Magnesium (Mg^{+2})	15.04	19.30	11.93	17.65	18.77	20.51	24.86	25.11	15.66	16.78	18.52	17.77	23.74	25.36
Sodium (Na^{+})	27.83	35.42	23.92	35.42	41.17	50.83	32.43	42.78	18.40	22.31	30.13	36.57	47.05	44.62
Potassium (K^{+})	2.73	2.73	2.73	2.34	7.02	6.24	6.24	5.07	5.85	6.63	6.63	5.85	13.65	3.90
Carbonate (CO_3^{-2})	4.80	9.00	8.40	10.20	14.40	15.30	1.80	0.90	9.10	5.70	5.10	5.70	10.50	12.00
Bicarbonate (HCO_3^{-})	210.45	219.60	172.63	171.41	281.82	247.05	270.84	312.32	190.32	204.35	237.29	222.04	303.17	289.14
Cloride (Cl^{-})	26.23	33.32	16.31	23.40	49.98	37.58	25.52	34.74	23.40	26.59	32.26	44.67	45.73	29.42
Fluoride (F^{-})	NA	NA	NIL	Tr	0.95	0.95	0.57	0.57	0.38	0.38	1.14	1.71	0.19	0.19
Sulphate (SO_4^{-2})	36.48	40.80	42.72	44.16	28.80	32.64	38.40	43.20	29.76	38.40	31.68	28.80	39.36	30.72
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	NA	NA	1.24	1.24	1.86	2.48	NA	NA
Nitrite (NO_2^{-})	NIL	NIL	Tr	3.68	4.60	4.60	Tr	Tr	Tr	Tr	4.60	Tr	4.60	Tr
Phosphate (PO_4^{-3})	NA	NA	NA	NA	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	0.79	Tr
Silicate (SiO_3^{-2})	1.10	1.25	9.50	11.50	10.15	10.15	8.02	8.85	6.87	6.77	7.36	7.09	8.37	9.73
Boron (B)	NIL	NIL	0.02	0.04	0.37	0.37	0.03	0.05	0.06	0.05	0.11	0.11	0.37	0.20

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values (λ) are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.5 C

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT ALLAHABAD

MONSOON SEASON (JULY TO OCTOBER)

Parameters	1978		1979		1980		1981		1982		1983		1984	1985
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L	C/L
Sp. Conductance (λ)	297	443	380	451	241	267	295	326	260	284	270	293	292	304
pH	8.30	8.31	8.30	8.38	8.05	8.11	8.11	8.23	8.28	8.23	8.31	8.28	8.29	8.12
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	34.60	39.80	30.60	31.20	25.60	27.80	26.80	29.00	27.00	28.60	26.00	28.40	34.60	23.40
Magnesium (Mg^{+2})	8.08	12.18	9.57	10.07	7.46	6.96	8.08	8.58	8.95	10.69	9.57	7.96	8.45	15.29
Sodium (Na^{+})	21.16	34.96	22.31	36.34	12.65	18.40	12.42	23.00	9.43	15.87	11.50	13.80	10.81	17.02
Potassium (K^{+})	2.34	3.90	2.73	2.73	5.46	3.90	4.68	4.29	5.07	5.07	3.90	3.12	8,58	4.29
Carbonate (CO_3^{-2})	7.20	0.90	5.40	8.40	0.30	0.30	1.20	1.20	3.00	2.40	NIL	NIL	NIL	4.80
Bicarbonate (HCO_3^{-})	155.55	164.09	149.45	172.02	148.84	170.19	153.72	161.04	149.45	161.04	144.57	132.98	203.74	170.19
Cloride (Cl^{-})	18.08	33.68	20.56	23.75	12.76	19.85	15.24	18.08	12.05	15.24	13.12	16.66	15.24	19.85
Fluoride (F^{-})	NA	NA	0.19	Tr	NIL	NIL	0.19	0.76	Tr	0.19	0.38	0.38	Tr	0.19
Sulphate (SO_4^{-2})	30.72	35.04	25.92	29.76	16.32	10.08	20.16	20.64	17.76	18.72	17.28	19.68	19.20	18.24
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	NA	NA	1.24	1.86	2.48	1.86	NA	NA
Nitrite (NO_2^{-})	NIL	NIL	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	0.46	Tr
Phosphate (PO_4^{-3})	NA	NA	NIL	0.26	Tr	Tr	Tr	NIL	0.26	Tr	Tr	Tr	0.26	Tr
Silicate (SiO_3^{-2})	0.81	0.69	12.50	13.00	8.13	8.38	5.58	6.51	10.52	7.56	9.63	10.01	6.08	6.10
Boron (B)	NIL	Tr	0.19	0.31	0.18	0.20	0.08	NIL	0.12	0.10	0.08	0.05	0.08	0.09

N.B.: Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.6 A

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT MIRZAPUR

WINTER SEASON (NOVEMBER TO FEBRUARY)

Parameters	1978-79		1979-80		1980-81		1981-82		1982-83		1983-84		1984-85
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L
Sp. Conductivity (λ)	462	472	470	483	441	442	303	331	405	444	477	454	436
pH	8.56	8.53	8.48	8.43	8.29	8.32	8.13	8.48	8.47	8.45	8.11	8.14	8.11
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	35.60	38.40	39.80	41.00	40.80	40.20	27.80	28.00	40.40	41.40	41.00	41.20	39.60
Magnesium (Mg^{+2})	15.79	18.89	19.64	20.26	22.50	24.74	23.62	26.23	20.88	19.89	18.65	20.51	17.28
Sodium (Na^{+})	31.51	32.20	53.82	52.67	42.09	47.61	31.74	31.51	36.80	37.03	36.57	37.95	31.97
Potassium (K^{+})	1.95	2.34	3.90	3.90	3.51	3.51	3.90	3.90	3.90	3.90	3.51	3.51	8.58
Carbonate (CO_3^{-2})	2.40	3.60	9.60	5.40	1.50	0.90	0.90	1.20	2.70	4.50	Tr	Tr	1.20
Bicarbonate (HCO_3^{-})	236.07	254.98	272.06	269.01	279.99	284.87	264.13	270.84	269.01	269.62	262.91	267.79	247.05
Cloride (Cl^{-})	31.20	33.68	41.83	44.31	32.26	32.61	30.84	34.03	32.61	29.78	30.49	30.49	28.71
Fluoride (F^{-})	NA	NA	0.38	0.57	0.19	0.19	0.38	0.19	0.19	0.38	0.57	0.38	0.19
Sulphate (SO_4^{-2})	24.48	30.24	44.16	46.56	43.20	42.24	28.32	37.44	28.80	33.60	29.28	18.72	27.36
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	1.86	2.48	1.86	1.86	3.10	3.72	NA
Nitrite (NO_2^{-})	NA	NA	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
Phosphate (PO_4^{-3})	NA	NA	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
Silicate (SiO_3^{-2})	9.00	0.50	4.25	2.80	0.73	7.71	9.08	8.08	8.34	9.13	9.10	8.92	6.38
Boron (B)	0.12	0.10	0.54	0.53	0.06	0.07	0.08	0.03	0.11	0.08	0.07	0.13	0.06

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentations and NA indicate samples not analysed.

Table 2.6 B

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT MIRZAPUR

SUMMER SEASON (MARCH TO JUNE)

Parameters	1978		1979		1980		1981		1982		1983		1984	1985
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L	C/L
Sp. Conductivity (λ)	556	653	650	641	584	590	602	656	458	444	523	528	713	650
pH	8.51	8.18	8.23	8.25	8.26	8.29	8.34	8.34	8.19	8.11	8.42	8.33	8.28	8.39
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	26.40	32.40	35.40	37.20	33.00	32.80	36.60	32.60	28.80	29.20	32.80	33.40	35.60	27.60
Magnesium (Mg^{+2})	17.53	18.40	15.79	15.54	23.99	25.11	26.97	30.08	18.52	19.02	20.63	21.88	23.37	28.09
Sodium (Na^{+})	43.47	48.30	41.40	43.47	52.67	54.97	59.11	57.96	19.32	23.69	50.83	48.76	56.35	57.50
Potassium (K^{+})	2.34	5.85	2.34	2.34	5.07	5.07	4.68	5.07	4.29	4.68	7.02	5.46	14.82	5.07
Carbonate (CO_3^{-2})	7.20	5.40	3.60	1.20	17.70	15.30	2.70	3.90	7.80	6.90	8.10	4.50	15.90	15.60
Bicarbonate (HCO_3^{-})	221.43	291.58	207.40	217.77	267.79	270.84	306.22	298.29	208.62	215.94	237.90	243.39	287.92	295.24
Cloride (Cl^{-})	39.00	49.63	28.01	29.42	47.86	50.69	44.66	45.02	29.42	32.26	40.41	40.41	46.79	48.57
Fluoride (F^{-})	NA	NA	0.19	0.19	0.57	0.76	0.38	0.57	0.38	0.38	1.71	0.95	0.19	0.38
Sulphate (SO_4^{-2})	27.84	25.92	50.88	45.60	40.80	41.76	36.48	50.40	40.32	39.84	33.12	28.80	40.32	35.52
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	NA	NA	1.86	1.86	1.86	2.48	NA	NA
Nitrite (NO_2^{-})	NIL	0.92	3.22	NIL	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	0.46	Tr
Phosphate (PO_4^{-3})	NA	NA	NA	NA	Tr	NIL	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
Silicate (SiO_3^{-2})	11.00	12.00	10.00	10.00	11.14	8.90	9.25	11.15	6.25	5.67	8.33	9.47	11.03	8.65
Boron (B)	NIL	NIL	0.01	0.01	0.37	0.18	0.02	0.07	NIL	0.04	0.04	0.21	0.29	0.23

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.6 C

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT MIRZAPUR
MONSOON SEASON (JULY TO OCTOBER)

Parameters	1978		1979		1980		1981		1982		1983		1984	1985
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L	C/L
Sp. Conductivity (λ)	270	251	378	451	236	239	310	324	287	285	258	284	321	316
pH	8.35	8.49	8.30	8.38	8.14	8.19	8.21	8.19	8.31	8.36	8.32	8.33	8.13	8.25
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	31.80	26.00	30.60	31.20	26.60	26.20	26.20	26.80	29.40	29.40	26.40	25.80	30.80	26.00
Magnesium (Mg^{+2})	4.97	7.46	9.57	10.07	6.71	8.45	9.32	8.08	8.45	8.95	8.70	9.57	8.83	11.44
Sodium (Na^{+})	18.86	17.02	22.31	36.34	14.26	14.72	16.56	18.17	13.11	10.35	15.18	14.26	21.39	19.09
Potassium (K^{+})	2.34	2.34	2.73	2.73	4.29	2.07	3.90	4.29	2.07	2.30	1.84	1.61	5.52	2.07
Carbonate (CO_3^{-2})	2.40	7.20	5.40	8.40	2.70	1.50	2.10	1.50	3.00	3.00	NIL	NIL	2.40	3.60
Bicarbonate (HCO_3^{-})	145.18	124.44	149.45	141.52	147.01	150.06	161.04	155.55	142.13	148.84	140.30	143.35	170.19	180.56
Cloride (Cl^{-})	17.37	14.18	20.56	23.75	15.95	15.95	19.85	17.73	15.95	15.95	18.08	18.43	19.85	22.34
Fluoride (F^{-})	NA	NA	0.19	Tr	Tr	Tr	0.38	0.19	Tr	0.19	0.95	0.38	0.19	0.19
Sulphate (SO_4^{-2})	20.64	17.76	25.92	29.76	9.12	8.64	16.80	12.96	16.32	15.36	19.20	14.40	14.40	14.40
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	3.10	3.72	1.24	1.24	2.48	3.10	NA	NA
Nitrite (NO_2^{-})	NIL	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
Phosphate (PO_4^{-3})	NA	NA	NIL	0.26	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
Silicate (SiO_3^{-2})	0.18	0.32	13.00	13.00	12.51	9.08	8.33	7.66	8.49	9.85	10.49	9.34	5.32	7.25
Boron (B)	NIL	0.30	0.66	0.66	0.34	0.14	0.03	0.12	0.18	0.09	NIL	NIL	0.04	0.05

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.7 A

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT VARANASI
WINTER SEASON (NOVEMBER TO FEBRUARY)

Parameters	1978-79		1979-80		1980-81		1981-82		1982-83		1983-84		1984-85
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L
Sp. Conductivity (λ)	472	472	474	478	443	439	304	298	412	425	440	438	462
pH	8.58	8.55	8.51	8.54	8.32	8.36	8.45	8.47	8.45	8.54	8.03	8.05	8.21
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	36.60	35.60	39.40	39.80	39.00	39.60	33.00	29.20	42.00	40.80	39.00	37.40	46.00
Magnesium (Mg^{+2})	18.40	17.65	18.40	19.52	21.01	21.38	23.49	22.87	20.01	20.88	18.65	19.52	15.54
Sodium (Na^{+})	34.96	34.73	49.22	51.52	40.94	42.09	34.50	35.42	37.49	39.79	34.96	32.20	31.74
Potassium (K^{+})	2.34	2.34	3.61	4.29	3.51	3.90	3.90	3.90	3.51	4.68	3.12	3.12	8.58
Carbonate (CO_3^{-2})	2.40	2.40	9.90	12.00	NIL	0.90	1.20	0.90	5.10	3.90	NIL	NIL	2.40
Bicarbonate (HCO_3^{-})	244.00	242.78	270.23	271.45	287.92	290.36	252.54	260.47	259.86	281.82	262.91	259.86	207.40
Cloride (Cl^{-})	35.80	41.83	40.77	42.19	34.39	34.03	32.61	34.39	34.03	35.45	29.78	32.26	33.68
Fluoride (F^{-})	NA	NA	0.76	0.38	0.19	0.19	0.38	0.19	0.76	0.38	0.76	0.57	1.71
Sulphate (SO_4^{-2})	35.52	39.84	43.68	46.56	38.88	39.84	34.56	36.96	33.12	34.08	21.12	19.20	28.80
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	2.48	2.48	2.48	2.48	2.48	1.86	NA
Nitrite (NO_2^{-})	NIL	NIL	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	0.46	Tr	0.46
Phosphate (PO_4^{-3})	NA	NA	Tr	NIL	Tr	NIL	Tr	0.26	Tr	Tr	Tr	Tr	Tr
Silicate (SiO_3^{-2})	6.48	9.53	5.53	4.18	6.84	5.83	8.95	9.87	7.45	7.79	9.70	9.78	8.28
Boron (B)	NIL	0.06	0.67	0.51	0.03	0.08	0.08	0.04	0.23	0.14	0.26	0.18	0.28

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.7 B

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT VARANASI

SUMMER SEASON (MARCH TO JUNE)

Parameters	1978		1979		1980		1981		1982		1983		1984	1985
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L	C/L
Sp. Conductivity (λ)	562	686	625	629	604	610	666	673	468	481	508	467	681	642
pH	8.38	8.56	8.36	8.44	7.05	5.76	7.46	6.84	8.34	8.38	7.93	7.59	8.25	8.25
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	27.80	44.00	34.40	36.20	33.80	33.80	29.80	29.40	28.80	25.00	31.80	32.20	31.20	35.40
Magnesium (Mg^{+2})	24.24	19.27	13.92	14.29	23.87	24.24	30.33	30.95	15.54	17.03	20.88	22.74	26.60	24.11
Sodium (Na^{+})	43.93	37.95	37.49	37.03	51.98	54.97	58.19	54.97	21.39	27.83	24.15	28.29	53.59	50.83
Potassium (K^{+})	2.73	5.07	2.34	2.34	5.46	5.07	5.07	5.07	5.46	6.24	4.29	4.29	12.87	3.90
Carbonate (CO_3^{-2})	12.00	18.60	5.40	4.80	15.30	14.40	2.40	2.40	11.10	14.10	6.30	6.90	12.90	17.40
Bicarbonate (HCO_3^{-})	225.09	295.85	204.35	206.18	272.67	276.94	297.68	299.51	172.63	179.95	254.98	237.29	195.20	290.97
Cloride (Cl^{-})	40.41	52.46	31.91	31.91	50.69	51.04	33.60	44.66	30.84	25.52	29.70	40.76	46.79	49.63
Fluoride (F^{-})	NA	NA	0.38	0.19	0.38	0.76	0.57	0.57	0.38	0.38	0.95	0.76	0.38	8.55
Sulphate (SO_4^{-2})	20.16	36.96	47.52	44.16	38.88	34.08	50.40	48.96	42.24	43.68	36.96	34.08	39.36	34.56
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	NA	NA	1.86	1.86	1.24	1.24	NA	NA
Nitrite (NO_2^{-})	NA	NA	8.28	3.22	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	0.46	Tr
Phosphate (PO_4^{-3})	NA	NA	NA	NA	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
Silicate (SiO_3^{-2})	0.27	0.22	10.00	10.00	12.00	11.27	8.85	11.83	7.67	5.78	8.02	8.71	8.23	9.65
Boron (B)	0.02	0.01	0.20	0.21	0.24	0.36	0.08	0.05	0.22	0.12	0.05	0.23	0.08	0.15

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.7 C

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT VARANASI MONSOON SEASON (JULY TO OCTOBER)

Parameters	1978		1979		1980		1981		1982		1983		1984	1985
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	C/L	C/L
Sp. Conductivity (λ)	295	277	426	435	262	259	340	326	297	298	293	292	302	318
pH	8.31	8.39	8.33	8.40	7.98	7.99	8.14	8.16	8.38	8.31	8.24	8.27	8.01	8.19
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	28.40	29.60	29.60	31.20	26.40	27.40	27.80	27.40	26.80	26.20	26.40	27.20	33.00	24.40
Magnesium (Mg^{+2})	10.06	10.31	9.44	8.07	8.20	7.45	7.20	8.82	10.56	10.56	9.07	9.57	7.45	15.28
Sodium (Na^{+})	20.24	15.41	26.22	26.91	16.33	16.56	18.40	19.32	13.11	12.42	14.95	15.87	13.11	5.98
Potassium (K^{+})	2.34	2.34	2.73	3.12	4.68	3.90	4.29	4.68	3.90	3.90	3.12	3.51	8.97	3.90
Carbonate (CO_3^{-2})	6.60	NIL	3.60	9.60	3.00	1.80	0.60	0.30	3.90	2.10	NIL	NIL	4.80	7.20
Bicarbonate (HCO_3^{-})	139.69	152.50	170.19	167.75	165.92	158.60	165.31	151.28	151.89	147.62	163.48	139.69	159.82	174.46
Cloride (Cl^{-})	16.66	17.37	22.68	24.10	17.72	15.95	21.97	19.85	18.07	17.01	17.72	17.01	20.20	23.75
Fluoride (F^{-})	NA	NA	Tr	NIL	NIL	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.38	0.19
Sulphate (SO_4^{-2})	32.64	44.64	26.40	25.44	12.96	11.52	19.20	25.44	19.20	14.88	19.20	17.28	17.76	22.56
Nitrate (NO_3^{-})	NIL	NIL	NA	NA	NA	NA	4.34	2.48	1.24	1.24	2.48	3.10	NA	NA
Nitrite (NO_2^{-})	NA	NA	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
Phosphate (PO_4^{-3})	NA	NA	Tr	0.26	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
Silicate (SiO_3^{-2})	0.50	0.37	11.75	16.50	9.10	8.28	8.20	8.19	7.82	9.71	8.87	10.41	5.66	6.73
Boron (B)	NIL	0.01	0.01	0.07	NIL	0.05	0.07	0.01	0.12	0.06	NIL	NIL	0.12	0.05

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.8.A

SEASONAL MEAN CONCENTRATION OF CHEMICAL PARAMETERS IN GANGA WATERS AT PATNA
WINTER SEASON (NOVEMBER TO FEBRUARY)

Parameters	1978-79		1979-80		1980-81		1981-82		1982-83		1983-84		1984-85	
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	U/S
Sp. Conductivity (λ)	221	384	373	353	332	331	252	246	338	353	353	351	348	368
pH	8.38	8.41	8.30	8.32	8.26	8.20	8.14	8.30	8.40	8.42	7.99	8.04	7.95	8.03
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	32.80	33.80	42.80	42.00	36.60	37.40	29.20	28.80	40.00	39.20	37.60	31.40	31.40	34.80
Magnesium (Mg^{+2})	13.18	17.90	17.15	17.40	19.39	14.05	21.01	21.88	15.41	16.53	16.03	16.28	25.11	24.11
Sodium (Na^{+})	22.31	25.99	30.82	28.29	23.00	23.00	20.01	18.40	22.31	22.08	17.25	18.86	44.39	47.15
Potassium (K^{+})	1.95	1.95	3.90	3.90	2.73	3.12	3.51	3.12	3.90	3.51	3.51	3.51	19.89	25.35
Carbonate (CO_3^{-2})	3.60	4.80	6.00	6.60	0.30	0.30	NIL	NIL	0.90	3.00	NIL	NIL	33.60	37.80
Bicarbonate (HCO_3^{-})	214.11	204.96	245.83	230.58	245.83	245.83	232.41	235.46	239.12	233.63	232.41	225.70	231.19	224.48
Cloride (Cl^{-})	22.69	21.98	23.04	23.04	18.43	19.85	17.37	18.08	19.85	20.56	18.08	16.66	2.84	3.19
Fluoride (F^{-})	NA	NA	0.38	0.19	Tr	Tr	0.19	0.38	0.19	0.19	0.38	0.38	NA	NA
Sulphate (SO_4^{-2})	22.56	31.68	32.64	23.52	19.68	20.64	20.16	21.21	20.64	21.12	12.96	15.36	13.92	17.76
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	2.48	2.48	1.24	1.24	1.86	NIL	NIL	NIL
Nitrite (NO_2^{-})	NIL	NIL	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	NA	NA
Phosphate (PO_4^{-3})	NA	NA	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	NA	NA
Silicate (SiO_3^{-2})	7.48	8.00	4.07	4.57	6.20	6.00	9.75	8.86	10.35	10.33	9.07	10.32	25.74	31.15
Boron (B)	0.13	0.18	0.50	0.67	0.09	0.04	0.01	0.03	0.11	0.02	0.11	NIL	NA	NA

N.B. Units of concentrations for cations and anions are mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.8 B

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT PATNA

SUMMER SEASON (MARCH TO JUNE)

Parameters	1978		1979		1980		1981		1982		1983		1984		1985	
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S
Sp. Conductivity (λ)	373	380	473	473	395	394	391	386	400	401	428	408	345	349	379	391
pH	8.78	8.78	8.33	8.41	8.20	8.19	8.29	8.16	8.07	8.22	8.31	8.31	8.05	8.05	8.10	8.20
Iron (Fe^{+3})	NA	NA	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NA	NA	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	35.80	34.00	33.20	34.40	31.20	32.00	39.60	33.40	25.80	22.20	33.20	32.00	37.00	38.20	36.60	40.00
Magnesium (Mg^{+2})	13.05	15.79	12.68	13.55	16.28	16.90	16.41	15.91	17.28	19.39	17.77	19.27	23.00	22.75	25.36	24.61
Sodium (Na^{+})	13.57	13.11	29.90	31.05	23.00	23.00	20.47	19.09	15.64	14.49	33.12	24.61	46.69	48.30	53.59	56.81
Potassium (K^{+})	1.56	1.56	1.95	1.95	3.90	3.90	2.73	2.73	4.29	4.29	6.24	5.07	30.03	33.54	30.81	33.15
Carbonate (CO_3^{-2})	16.80	18.00	8.40	7.20	11.70	9.30	3.00	1.80	4.50	4.20	3.90	4.20	30.00	32.40	37.80	41.10
Bicarbonate (HCO_3^{-})	162.26	167.14	184.22	191.54	206.79	189.71	210.45	201.91	187.27	190.93	208.01	212.28	222.04	234.24	231.19	229.97
Cloride (Cl^{-})	30.13	28.01	24.11	25.17	23.75	20.92	19.85	19.50	23.40	20.56	24.82	23.75	3.19	3.19	3.19	3.55
Fluoride (F^{-})	NA	NA	0.19	NIL	0.57	0.76	0.57	0.57	0.38	0.38	0.95	0.95	NA	NA	NA	NA
Sulphate (SO_4^{-2})	41.28	36.96	30.64	29.38	20.16	21.60	26.88	26.40	23.04	26.88	23.04	19.68	20.64	22.56	18.24	20.64
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	NA	NA	1.24	1.24	1.24	2.48	NIL	NIL	NIL	NIL
Nitrite (NO_2^{-})	NIL	NIL	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	NA	NA
Phosphate (PO_4^{-3})	NA	NA	NA	NA	NIL	NIL	Tr	Tr	Tr	Tr	Tr	Tr	NA	NA	NA	NA
Silicate (SiO_3^{-2})	12.54	9.98	9.50	9.00	9.18	10.48	6.42	6.05	7.42	4.98	8.13	7.62	29.81	31.68	33.75	38.24
Boron (B)	Tr	NIL	0.10	0.16	0.25	0.23	Tr	0.01	0.05	0.11	0.14	0.12	NA	NA	NA	NA

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.8 C

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT PATNA

MONSOON SEASON (JULY TO OCTOBER)

Parameters	1978		1979		1980		1981		1982		1983		1984		1985	
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S
Sp. Conductivity (λ)	164	190	289	303	215	219	265	264	237	232	269	277	327	345	361	374
pH	8.55	8.40	8.43	8.40	8.00	8.00	8.15	8.15	8.11	8.10	8.29	8.29	7.95	8.03	7.88	7.98
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	22.60	22.20	31.80	32.80	27.60	27.80	26.40	26.00	28.80	28.20	27.20	28.00	28.00	31.40	34.40	36.20
Magnesium (Mg^{+2})	12.31	10.94	6.96	7.09	6.34	6.09	7.83	7.58	7.83	7.46	8.83	9.45	23.49	23.49	24.11	25.61
Sodium (Na^{+})	16.10	14.72	16.79	17.48	9.20	9.20	10.35	11.50	6.90	7.36	11.27	11.73	42.78	48.53	42.32	48.76
Potassium (K^{+})	1.95	1.95	2.34	2.34	3.90	4.29	3.12	3.12	4.29	3.90	3.12	3.12	18.33	24.57	28.08	29.64
Carbonate (CO_3^{-2})	9.00	6.00	6.00	4.80	NIL	0.30	0.90	1.50	2.70	3.30	NIL	NIL	27.60	30.00	33.00	36.00
Bicarbonate (HCO_3^{-})	132.37	139.08	135.42	137.25	134.81	140.30	140.91	141.52	139.08	137.86	141.52	145.79	234.85	222.04	200.69	200.69
Cloride (Cl^{-})	14.53	12.76	14.53	14.89	14.89	13.12	11.34	12.05	11.70	12.05	14.53	13.83	2.13	2.84	2.84	3.55
Fluoride (F^{-})	NA	NA	Tr	0.76	Tr	NIL	0.38	0.19	Tr	Tr	0.38	0.38	NA	NA	NA	NA
Sulphate (SO_4^{-2})	12.96	15.84	14.40	21.12	5.28	4.80	7.20	8.16	13.44	14.88	14.40	16.80	50.88	75.84	17.28	19.20
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	1.86	3.10	1.24	1.24	1.24	1.86	NIL	NIL	NIL	NIL
Nitrite (NO_2^{-})	NIL	NIL	NIL	NIL	NIL	Tr	Tr	Tr	Tr	Tr	Tr	Tr	NA	NA	NA	NA
Phosphate (PO_4^{-3})	NA	NA	0.26	0.26	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	NA	NA	NA	NA
Silicate (SiO_3^{-2})	15.00	21.00	21.00	14.50	7.68	9.20	8.09	7.53	8.92	9.20	9.69	10.17	21.12	25.74	30.36	25.29
Boron (B)	NIL	NIL	NIL	NIL	0.20	0.26	0.01	0.01	0.12	0.17	NIL	NIL	NA	NA	NA	NA

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.9 A

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT HATHIDAH
WINTER SEASON (NOVEMBER TO FEBRUARY)

Parameters	1978-79		1979-80		1980-81		1981-82		1982-83		1983-84		1984-85	
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	U/S
Sp. Conductivity (λ)	360	361	342	344	297	303	244	237	298	314	338	338	354	384
pH	8.43	8.44	8.33	8.29	8.19	8.28	8.30	8.32	8.47	8.49	8.04	8.03	8.03	8.15
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	29.80	29.40	42.40	42.00	38.80	37.40	29.60	28.00	40.00	38.60	35.40	37.60	31.80	36.20
Magnesium (Mg^{+2})	17.78	13.18	15.04	15.54	16.66	16.41	21.38	21.26	16.28	15.79	13.80	15.17	24.61	24.36
Sodium (Na^{+})	25.07	24.61	23.92	23.46	18.86	18.86	16.56	15.41	20.70	20.24	17.02	18.17	45.08	49.00
Potassium (K^{+})	1.56	2.34	3.12	3.12	2.73	2.73	3.51	2.73	3.51	3.90	3.12	3.12	23.01	26.91
Carbonate (CO_3^{-2})	3.00	NIL	6.30	5.10	NIL	NIL	NIL	NIL	2.70	3.00	NIL	NIL	33.00	36.00
Bicarbonate (HCO_3^{-})	205.57	252.54	224.48	231.80	228.14	226.31	215.32	226.92	231.19	223.26	217.16	216.55	201.91	214.11
Cloride (Cl^{-})	19.50	21.27	21.27	21.27	17.73	17.73	15.60	17.37	20.92	18.43	34.74	17.72	2.84	3.19
Fluoride (F^{-})	NA	NA	0.38	0.38	Tr	Tr	0.38	0.19	0.19	0.19	0.19	0.19	NA	NA
Sulphate (SO_4^{-2})	25.92	31.20	24.00	24.48	18.72	21.12	24.48	22.08	23.04	21.60	12.96	12.00	13.92	17.28
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	1.86	1.24	3.10	1.24	1.86	1.86	NIL	NIL
Nitrite (NO_2^{-})	2.30	NIL	NIL	NIL	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	NA	NA
Phosphate (PO_4^{-3})	NA	NA	NIL	Tr	Tr	Tr	Tr	Tr	Tr	Tr	NIL	NIL	NA	NA
Silicate (SiO_3^{-2})	4.25	3.76	4.88	5.01	6.54	6.54	7.90	7.90	8.02	7.50	10.57	9.81	23.00	28.00
Boron (B)	NIL	0.01	0.38	0.46	0.03	0.01	0.12	0.11	0.12	0.12	0.03	0.08	NA	NA

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.10 A

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT FARAKKA

WINTER SEASON (NOVEMBER TO FEBRUARY)

Parameters	1978-79		1979-80		1980-81		1981-82		1982-83		1983-84	
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S
Sp. Conductivity (λ)	370	370	281	282	284	287	221	223	291	291	303	302
pH	8.13	8.36	8.33	8.31	8.27	8.25	8.43	8.38	8.38	8.44	8.05	8.06
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	31.80	33.80	38.60	38.80	37.40	38.00	32.20	30.00	38.60	37.60	29.40	31.40
Magnesium (Mg^{+2})	13.92	12.80	13.30	13.55	14.67	13.55	16.78	18.77	13.42	13.92	16.66	16.16
Sodium (Na^{+})	21.62	21.39	16.79	17.02	16.56	16.33	14.95	14.26	16.10	15.18	14.49	14.26
Potassium (K^{+})	1.95	1.95	3.12	3.12	2.73	3.12	3.51	3.51	3.51	4.29	2.73	2.73
Carbonate (CO_3^{-2})	2.40	4.80	3.30	3.30	0.90	0.60	NIL	NIL	1.20	2.40	NIL	Tr
Bicarbonate (HCO_3^{-})	184.22	179.34	192.15	197.64	206.79	207.40	215.94	227.53	204.96	208.62	200.69	199.47
Cloride (Cl^{-})	15.95	15.24	14.53	15.60	13.12	16.31	14.18	14.89	15.95	15.24	14.89	14.53
Fluoride (F^{-})	NA	NA	0.38	0.38	Tr	Tr	0.19	0.19	0.38	0.38	0.19	0.38
Sulphate (SO_4^{-2})	27.84	27.36	21.12	19.68	17.76	18.24	15.84	17.28	15.84	16.32	18.72	15.36
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	1.86	1.86	1.24	1.24	1.86	1.86
Nitrite (NO_2^{-})	0.46	NIL	Tr	Tr	0.92	0.92	Tr	Tr	Tr	0.46	Tr	Tr
Phosphate (PO_4^{-3})	NA	NA	0.26	Tr	Tr	Tr	1.32	0.79	Tr	Tr	NIL	NIL
Silicate (SiO_3^{-2})	8.55	10.03	5.67	6.30	7.28	8.02	7.44	9.78	8.61	9.96	9.95	10.62
Boron (B)	0.16	0.20	0.11	0.39	0.04	0.07	0.02	0.05	Tr	0.03	0.08	0.18

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.10 B

SEASONAL MEAN CONCENTRATION OF CHEMICAL PARAMETERS IN GANGA WATERS AT FARAKKA
SUMMER SEASON (MARCH TO JUNE)

Parameters	1978	1979		1980		1981		1982		1983	
	C/L	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S
Sp. Conductivity (λ)	526	431	435	359	361	345	365	339	339	363	352
pH	7.95	7.95	7.99	8.15	8.13	8.29	8.33	8.19	8.17	8.29	8.10
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	43.80	33.60	34.00	33.20	36.40	31.60	32.60	27.60	28.20	32.80	30.40
Magnesium (Mg^{+2})	9.70	12.43	12.55	13.18	12.06	14.17	15.66	15.41	15.04	15.16	14.17
Sodium (Na^{+})	35.88	20.47	20.47	17.25	17.02	14.03	15.18	12.42	12.65	23.23	19.55
Potassium (K^{+})	0.78	1.56	1.95	4.29	4.68	3.51	3.90	4.29	4.29	4.68	5.07
Carbonate (CO_3^{-2})	6.00	3.60	4.80	10.20	9.60	3.00	2.40	11.40	9.90	4.20	7.50
Bicarbonate (HCO_3^{-})	167.14	184.22	185.44	162.26	162.87	202.52	201.91	170.80	171.41	189.71	180.56
Cloride (Cl^{-})	14.53	19.14	20.56	20.56	18.43	16.66	17.02	15.24	14.89	18.43	18.79
Fluoride (F^{-})	NA	Tr	Tr	0.57	0.38	0.57	0.38	0.19	0.38	0.76	0.76
Sulphate (SO_4^{-2})	36.98	32.64	32.64	11.52	12.96	20.64	20.64	20.64	19.20	18.72	18.24
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	NA	NA	0.62	0.62	1.24	1.24
Nitrite (NO_2^{-})	NA	NA	NA	Tr	Tr	Tr	Tr	NIL	NIL	NIL	NIL
Phosphate (PO_4^{-3})	NA	Tr	Tr	Tr	NIL	Tr	Tr	NIL	NIL	Tr	Tr
Silicate (SiO_3^{-2})	18.60	8.00	10.00	10.53	9.58	6.09	7.48	6.08	6.98	8.92	8.36
Boron (B)	NA	0.02	0.15	0.27	0.15	0.21	0.05	0.02	0.05	0.16	9.10

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. stands for trace concentrations and NA indicate samples not analysed.

Table 2.10 C

SEASONAL MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN GANGA WATERS AT FARAKKA
MONSOON SEASON (JULY TO OCTOBER)

Parameters	1978	1979		1980		1981		1982		1983	
	C/L	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S
Sp. Conductivity (λ)	533	238	240	200	200	248	246	229	229	236	234
pH	7.58	8.41	8.40	7.99	8.05	8.14	8.14	8.20	8.16	8.32	8.29
Iron (Fe^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Aluminium (Al^{+3})	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Calcium (Ca^{+2})	57.40	20.20	25.60	26.80	26.00	27.20	25.20	29.60	28.80	25.20	25.80
Magnesium (Mg^{+2})	6.71	8.20	8.70	5.47	6.22	6.46	5.72	6.46	7.09	8.20	7.58
Sodium (Na^{+})	1.61	10.58	11.27	11.04	11.27	9.66	9.43	5.52	5.29	8.05	8.28
Potassium (K^{+})	0.39	1.56	1.95	4.68	5.07	3.51	3.90	3.90	3.90	3.12	3.51
Carbonate (CO_3^{-2})	5.70	NIL	NIL	0.90	0.30	2.70	2.10	1.80	1.80	1.50	0.90
Bicarbonate (HCO_3)	184.83	139.69	137.86	129.32	137.86	123.22	124.44	137.25	139.08	133.59	134.81
Cloride (Cl^{-})	13.83	13.12	13.12	10.64	10.28	10.28	9.22	13.47	10.64	13.12	13.83
Fluoride (F^{-})	NA	Tr	NIL	NIL	Tr	0.19	Tr	Tr	Tr	Tr	Tr
Sulphate (SO_4^{-2})	114.24	13.44	16.80	3.84	3.36	4.80	7.68	12.48	10.08	11.52	12.96
Nitrate (NO_3^{-})	NA	NA	NA	NA	NA	0.62	0.62	1.24	1.24	1.24	1.86
Nitrite (NO_2^{-})	NA	Tr	Tr	Tr	Tr	Tr	Tr	Tr	0.46	Tr	Tr
Phosphate (PO_4^{-3})	NA	NA	NA	2.63	NIL	Tr	Tr	2.63	Tr	NIL	NIL
Silicate (SiO_3^{-2})	31.50	9.75	11.00	9.43	10.08	8.03	7.98	8.89	9.19	10.14	11.50
Boron (B)	NA	NIL	0.49	0.22	0.17	0.06	0.01	0.15	0.09	NIL	NIL

N.B. Units of concentrations for cations and anions are in mg/l. Specific conductance values λ are in Micro-Mhos/cm. Tr. Stands for trace concentrations and NA indicate samples not analysed.

MICRO-BIOLOGICAL EXAMINATION OF RIVER WATER ALONG THE LONGITUDINAL SECTION

Table 3
(Contd.)

RIVER: GANGA **SITE: VARANASI**

Lab No.	Date	pH	Location	Time of sampling	Weather	River water colour	Odour	In Situ temp. °C
1	2	3	4	5	6	7	8	9
M 1	20.4.83	7.80	Ram Nagar	11.00	Clear	Clear	Odourless	27.5
M 2	—do—	7.60	Assi Ghat	12.35	Clear	Clear	Odourless	27.5
M 3	—do—	7.60	Shivala Ghat	13.00	Clear	Clear	Odourless	27:5
M 4	—do—	7.80	Harischandra Ghat	13.30	Clear	Brownish	Bad Odour	27.5
M 5	—do—	7.80	Dasashwamedh Ghat	14.00	Clear	Brownish	Bad Odour	28.0
M 6	—do—	7.60	Manikarnika Ghat	14.30	Clear	Brownish	Bad Odour	28.0
M 7	—do—	7.80	Telia Nala	15.00	Clear	Blackish	Pungent	28.0
M 8	—do—	8.20	Below Raj Ghat	16.00	Clear	Blackish	Pungent	28.0
M 9	21.5.83	7.80	Ram Nagar	11.30	Clear	Clear	Odourless	33.0
M 10	—do—	7.80	Assi Ghat	12.15	Clear	Clear	Odourless	33.0
M 11	—do—	7.60	Shivala Ghat	13.00	Clear	Clear	Odourless	33.5
M 12	—do—	7.60	Harischandra Ghat	13.30	Clear	Brownish	Bad Odour	33.5
M 13	—do--	7.80	Dasashwamedh Ghat	14.15	Clear	Brownish	Bad Odour	33.5
M 14	—do—	8.00	Manikarnika Ghat	15.00	Clear	Brownish	Bad Odour	33.5
M 15	—do—	8.20	Telia Nala	15.45	Clear	Greyish	Pungent	33.5
M 16	—do—	8.00	Raj Ghat	16.30	Clear	Blackish	Pungent	33.5

MICRO-BIOLOGICAL EXAMINATION OF RIVER WATER ALONG THE LONGITUDINAL SECTION

Table 3

(Contd.)

RIVER: GANGA **SITE: VARANASI**

Lab. No.	Date	pH	Location	Time of Sampling	Weather	River water colour	Odour	In situ temperature °C
1	2	3	4	5	6	7	8	9
M 17	21.6.83	7.60	Ram Nagar	10.30	Cloudy	Clear	Odourless	33.0
M 18	—do—	7.60	Assi Ghat	11.15	Cloudy	Clear	Odourless	33.0
M 19	—do—	7.80	Shivala Ghat	12.00	Cloudy	Brownish	Bad Odour	33.0
M 20	—do—	7.80	Harishchandra Ghat	12.45	Cloudy	Brownish	Bad Odour	33.0
M 21	—do—	7.60	Dasashwamedh Ghat	13.30	Cloudy	Brownish	Bad Odour	33.0
M 22	—do—	8.00	Manikarnika Ghat	14.15	Cloudy	Brownish	Bad Odour	33.5
M 23	—do—	8.20	Telia Nala	15.00	Cloudy	Greyish	Pungent	33.5
M 24	—do—	8.20	Raj Ghat	16.15	Cloudy	Blackish	Pungent	33.5
M 25	3.7.83	8.20	Below Sewage Out fall	12.00	Cloudy	Blackish	Very Pungent	32.0
M 26	—do—	7.90	Above Sewage Out fall	12.15	Cloudy	Greyish	Pungent	32.0
M 27	—do—	7.90	Near Bridge	12.30	Cloudy	Greyish	Pungent	31.5
M 28	—do—	8.10	Telia Nala	13.00	Cloudy	Blackish	Pungent	31.5
M 29	—do—	8.00	Below Telia Nala	13.30	Cloudy	Blackish	Pungent	31.5
M 30	—do—	7.80	Above Telia Nala	14.00	Cloudy	Greyish	Bad Odour	31.5
M 31	—do—	7.80	Manikarnika Ghat	14.30	Cloudy	Brownish	Odourless	31.5
M 32	—do—	7.40	Dasashwamedh Ghat	15.00	Cloudy	Brownish	Odourless	31.5
M 33	—do—	7.80	Assi Ghat	15.30	Cloudy	Brownish	Odourless	31.5

MICRO-BIOLOGICAL EXAMINATION OF RIVER WATER ALONG THE LONGITUDINAL SECTION

Table 3 (Contd.

RIVER : GANGA

SITE : VARANASI

Lab No.	Date	Presence of weeds	Standard Plate Count			Coliform Count		Fecal Strepto Cocei Test	
			Media of growth	No. of total colonies	No. of colonies per C.C.	Media of growth	M.P.N. index per 100cc	Media of growth	M.P.N. index per 100 cc
1	2	10	11	12	13	14	15	16	17
M 1	20.4.83	No	Agar-Agar	1780	178	Lactose broth	11	Azide dextrose broth	7
M 2	—do—	No	"	1460	146	"	11	"	7
M 3	—do—	No	"	1300	130	"	11	"	4
M 4	—do—	No	"	1980	198	"	11	"	4
M 5	—do—	No	"	2600	260	"	11	"	4
M 6	—do—	No	"	2420	242	"	11	"	4
M 7	—do—	Weeds Present	"	1460	146	"	11	"	4
M 8	—do—	No	"	3800	380	"	11	"	4
M 9	21.5.83	No	"	1340	134	"	4	"	3
M 10	—do—	No	"	1580	158	"	7	"	3
M 11	—do—	No	"	2100	210	"	7	"	7
M 12	—do—	No	"	2310	231	"	11	"	7
M 13	—do—	No	"	2400	240	"	11	"	3
M 14	—do—	No	"	1980	198	"	11	"	4
M 15	—do—	Weeds Present	"	1720	172	"	11	"	3
M 16	—do—	No	"	4800	480	"	11	"	7

MICRO-BIOLOGICAL EXAMINATION OF RIVER WATER ALONG THE LONGITUDINAL SECTION

Table 3 (Contd.)

RIVER : GANGA **SITE : VARANASI**

Lab No.	Date	Presence of Weeds	Standard Plate Count			Coliform Count		Fecal Strepto Cocei Test	
			Media of growth	No. of total colonies	No. of colonies per C.C.	Media of growth	M.P.N. index per 100cc	Media of growth	M.P.N. index per 100 cc
1	2	10	11	12	13	14	15	16	17
M 17	21.6.83	No	Agar-Agar	1490	149	Lactose broth	4	Azide dextrose broth	3
M 18	—do—	No	"	2140	214	"	7	"	3
M 19	—do—	No	"	3100	310	"	4	"	3
M 20	—do—	No	"	2180	218	"	7	"	3
M 21	—do—	No	"	1960	196	"	11	"	4
M 22	—do—	No	"	1380	138	"	11	"	7
M 23	—do—	Weeds Present	"	1400	140	"	11	"	11
M 24	—do—	No	"	4310	431	"	11	"	11
M 25	3.7.83	No	"	3980	398	"	11	"	4
M 26	—do—	No	"	1380	138	"	11	"	<3
M 27	—do—	No	"	1300	130	"	11	"	3
M 28	—do—	No	"	2100	210	"	11	"	3
M 29	—do—	No	"	1800	180	"	7	"	7
M 30	—do—	No	"	2140	214	"	7	"	3
M 31	—do—	No	"	1700	170	"	11	"	4
M 32	—do—	No	"	2340	234	"	7	"	7
M 33	—do—	No	"	1570	157	"	11	"	11

MICRO-BIOLOGICAL EXAMINATION OF RIVER WATER ALONG THE LONGITUDINAL SECTION

Table 3 (Contd.)

RIVER: GANGA **SITE: VARANASI**

Lab No.	Date	pH	Location	Time of sampling	Weather	River water colour	Odour	In situ temp. °C
1	2	3	4	5	6	7	8	9
M 34	9.8.83	8.20	Below Sewage out fall	11.30	Clear	Greyish	Pungent	31.0
M 35	—do—	8.00	Above Sewage out fall	12.00	Clear	Greyish	Odourless	31.0
M 36	—do—	8.20	Near Malaviya Bridge	12.30	Clear	Silty	Odourless	31.0
M 37	—do—	8.00	Manikarnika Ghat	13.30	Clear	Silty	Odourless	30.5
M 38	—do—	8.00	Dasashwamedh Ghat	14.00	Clear	Silty	Odourless	30.5
M 39	—do—	7.80	Harischandra Ghat	15.30	Clear	Silty	Odourless	30.5
M 40	24.10.83	7.80	3 km d/s of C/L	13.00	Clear	Silty	Bad Smell	29.0
M 41	—do—	8.20	Near the entry of Varuna	13.30	Clear	Silty	Odourless	29.5
M 42	—do—	8.20	Sewage Pumping Station	14.00	Clear	Silty	Pungent	30.0
M 43	—do—	7.60	Telia Nala	14.30	Clear	Silty	Bad Odour	29.0
M 44	—do—	7.80	Manikarnika Ghat	15.00	Clear	Silty	Bad Odour	29.0
M 45	—do—	7.90	Dasashwmedh Ghat	15.25	Clear	Silty	Bad Odour	29.0
M 46	—do—	8.00	Khemeswar Ghat	15.45	Clear	Silty	Odourless	29.0
M 47	—do—	8.00	Shivala Ghat	16.00	Clear	Silty	Odourless	29.0
M 48	—do—	7.80	Near Water Supply Works	16.30	Clear	Silty	Odourless	29.0
M 49	—do—	8.00	Assi Ghat	17.00	Clear	Silty	Bad Smell	29.0
M 50	—do—	8.00	Nagwa	17.30	Clear	Silty	Odourless	29.0

Table 3

MICRO-BIOLOGICAL EXAMINATION OF RIVER WATER ALONG THE LONGITUDINAL SECTION

RIVER : GANGA **SITE : VARANASI**

Lab No.	Date	Presence of weeds	Standard Plate Count			Coliform Count		Fecal Strepto Cocei Te	
			Media of growth	No. of total colonies	No. of colonies per C.C.	Media of growth	M.P.N. index per 100cc	Media of growth	M.P.N. index per 100 cc
1	2	10	11	12	13	14	15	16	17
M 34	9.8.83	No	Agar-Agar	1310	131	Lactose broth	11	Azide dextrose broth	11
M 35	—do—	No	"	1940	194	"	11	"	4
M 36	—do—	No	"	2410	241	"	7	"	7
M 37	—do—	No	"	790	79	"	7	"	7
M 38	—do—	No	"	840	84	"	11	"	4
M 39	—do—	No	"	910	91	"	7	"	4
M 40	21.10.83	No	"	1380	138	"	7	"	4
M 41	—do—	No	"	1760	176	"	7	"	4
M 42	—do—	No	"	1840	184	"	11	"	7
M 43	—do—	No	"	940	94	"	11	"	< 3
M 44	—do—	No	"	820	82	"	7	"	4
M 45	—do—	No	"	1780	178	"	7	"	4
M 46	—do—	No	"	460	46	"	7	"	4
M 47	—do—	No	"	1720	172	"	11	"	4
M 48	—do—	No	"	840	84	"	7	"	7
M 49	—do—	No	"	1340	134	"	7	"	< 3
M 50	—do—	No	"	340	34	"	4	"	3

Table 4

TREND EQUATIONS FOR TIME SERIES COMPONENTS GANGA AT VARANASI DURING 1967 TO 1979 (13 YEARS) DATUM YEAR 1973 SAMPLING FREQUENCY ONCE/MONTH

Sl No	Month	λ	Ca^{++}	Mg^{++}	$Na^{+(*)}$	$K^{+(*)}$
1	2	3	4	5	6	7
1.	January	392 + 22X (117.67, 1.00)	1.63 — 0.01X (0.25 , 1.00)	1.66 — 0.01X (0.34, 1.00)	1.55 — 0.04X (0.44, 1.00)	0.08 + 0.01X (0.03, 1.00)
2.	February	391 + 26X (139.58, 0.72)	1.40 + 0.06X (0.47, 0.48)	1.53 + 0.01X (0.37, 0.10)	1.62 + 0.22X (0.52, 0.93)	0.07 — 0.003X (0.02, 0.30)
3.	March	445 + 36X (169.62, 0.83)	1.22 + 0.04X (0.38, 0.44)	1.73 — 0.01X (0.31, 0.17)	1.90 + 0.04X (0.33, 0.28)	0.10 — 0.01X (0.08, 0.32)
4.	April	467 + 34X (175.96, 0.76)	1.06 + 0.03X (0.32, 0.34)	1.71 — 0.03X (0.33, 0.40)	2.05 + 0.07X (0.41, 0.38)	0.09 — 0.001X (0.02, 0.20)
5.	May	509 + 45X (200.93, 0.87)	1.07 + 0.04X (0.39, 0.37)	1.71 — 0.02X (0.16, 0.58)	2.02 + 0.06X (0.29, 0.43)	0.08 — 0.01X (0.03, 0.73)
6.	June	474 + 30X (169.97, 0.68)	1.08 + 0.04X (0.27, 0.52)	1.69 — 0.04X (0.20, 0.70)	1.75 + 0.06X (0.24, 0.49)	0.10 — 0.01X (0.03, 0.87)
7.	July	342 + 26X (156.12, 0.65)	1.11 + 0.03X (0.18, 0.70)	1.11 — 0.02X (0.50, 0.18)	1.24 + 0.01X (0.65, 0.04)	0.09 — 0.01X (0.03, 0.68)
8.	August	217 + 14X (81.51, 0.69)	1.07 + 0.03X (0.22, 0.50)	0.51 — 0.002X (0.41, 0.08)	0.53 + 0.05X (0.27, 0.42)	0.06 + 0.0003X (0.02, 0.04)
9.	September	203 + 17X (83.01, 0.78)	1.13 + 0.04X (0.22, 0.77)	0.61 + 0.02X (0.36, 0.18)	0.57 + 0.07X (0.22, 0.68)	0.06 — 0.001X (0.02, 0.20)
10.	October	257 + 23X (114.65, 0.79)	1.40 + 0.04X (0.21, 0.79)	0.74 — 0.03X (0.22, 0.46)	0.76 + 0.08X (0.24, 0.72)	0.05 — 0.003X (0.02, 0.30)
11.	November	323 + 26X (124.43, 0.83)	1.63 + 0.0002X (0.26, 0.004)	1.11 + 0.03X (0.30, 0.34)	1.08 + 0.18X (0.47, 0.82)	0.07 + 0.01X (0.03, 0.37)
12.	December	356 + 28X (125.30, 0.87)	1.57 + 0.05X (0.43, 0.45)	1.39 — 0.01X (0.43, 0.11)	1.07 + 0.16X (0.56, 0.62)	0.06 + 0.01X (0.03, 0.44)

TREND EQUATIONS FOR TIME SERIES COMPONENTS
GANGA AT VARANASI DURING 1967 TO 1979 (13 YEARS) DATUM YEAR 1973
SAMPLING FREQUENCY ONCE/MONTH

Sl No	Month	pH	CO_3^-	HCO_3^-	Cl^-	SO_4^-
1	2	8	9	10	11	12
1.	January	8.40 + 0.02X (0.25, 1.00)	0.10 + 0.005X (0.15, 1.00)	3.79 — 0.01X (0.64, 1.00)	0.95 + 0.03X (0.18, 1.00)	0.38 + 0.03X (0.25, 1.00)
2.	February	8.45 — 0.01X (0.18, 0.15)	0.21 + 0.0004X (0.24, 0.007)	4.01 + 0.11X (0.88, 0.49)	1.00 + 0.02X (0.21, 0.42)	0.65 + 0.05X (0.37, 0.57)
3.	March	8.41 + 0.002X (0.28, 0.03)	0.26 — 0.003X (0.22, 0.06)	3.75 + 0.06X (0.59, 0.43)	1.10 + 0.01 X (0.11, 0.24)	0.53 + 0.03X (0.28, 0.40)
4.	April	8.40 + 0.01X (0.24, 0.24)	0.30 — 0.0004X (0.26, 0.007)	3.69 + 0.05X (0.56, 0.33)	1.08 — 0.01X (0.36, 0.08)	0.46 + 0.01X (0.35, 0.15)
5.	May	8.26 + 0.03X (0.35, 0.30)	0.28 — 0.02X (0.33, 0.25)	4.18 + 0.04X (0.51, 0.29)	1.21 — 0.03X (0.20, 0.56)	0.66 + 0.07X (0.43, 0.65)
6.	June	8.51 + 0.03X (0.36, 0.30)	0.24 — 0.004X (0.21, 0.08)	3.83 — 0.03X (0.51, 0.24)	1.26 — 0.01X (0.21, 0.21)	0.63 + 0.05X (0.44, 0.40)
7.	July	8.42 + 0.01X (0.26, 0.10)	0.27 + 0.002X (0.22, 0.03)	2.84 + 0.03X (0.67, 0.16)	0.84 — 0.002X (0.25, 0.03)	0.54 + 0.02X (0.43, 0.15)
8.	August	8.39 — 0.02X (0.33, 0.19)	0.09 + 0.004X (0.19, 0.07)	1.82 + 0.03X (0.26, 0.43)	0.37 + 0.01X (0.09, 0.46)	0.21 + 0.004X (0.21, 0.08)
9.	September	8.45 — 0.03X (0.33, 0.31)	0.02 — 0.01X (0.04, 0.50)	2.02 + 0.05X (0.32, 0.64)	0.36 + 0.01X (0.09, 0.50)	0.26 + 0.02X (0.20, 0.41)
10.	October	8.50 — 0.003X (0.35, 0.03)	0.14 + 0.03X (0.19, 0.64)	2.52 + 0.07X (0.43, 0.60)	0.51 + 0.03X (0.14, 0.75)	0.28 + 0.03X (0.26, 0.45)
11.	November	8.46 — 0.03X (0.22, 0.54)	0.08 + 0.01X (0.13, 0.39)	3.28 + 0.08X (0.48, 0.66)	0.72 + 0.05X (0.26, 0.69)	0.50 + 0.05X (0.41, 0.43)
12.	December	8.50 — 0.01X (0.34, 0.10)	0.11 + 0.04X (0.18, 0.79)	3.73 + 0.07X (0.46, 0.59)	0.91 + 0.07X (0.34, 0.78)	0.49 + 0.07X (0.44, 0.62)

X = Number of years; λ = Specific Conductance in Micro-Mhos/cm
All other ionic concentrations are expressed in mg/l.
The values in parenthesis respectively denote the standard deviation of sample data in respect of Water Quality parameter and correlation coefficient between W.Q. parameter and time component (Year)

* Sample data from 1973 to 1977 hence datum year for Na^+ and K^+ ions in 1976

Table - 5

RELATIONSHIP OBTAINED BETWEEN THE IONIC CONCENTRATION (m.e./1) AND THE RIVER DISCHARGE IN M^3/Sec. FOR THE PERIOD MARCH'80 TO JUNE'80.

Sl. No.	River/ Site		λ	pH	Ca^{+2}	Mg^{+2}	Na^{+}
1	2		3	4	5	6	7
1.	Ganga/ Rishikesh	U/S	—0.6699 4113.20 Q (0.88,55.10)	—0.0522 10.92 Q (0.68, 0.38)	—0.3671 8.60 Q (0.67, 0.34)	—0.2131 1.94 Q (0.28, 0.23)	—0.4605 1.61.Q (0.83, 0.05)
		D/S	—0.4929 1857.15.Q (0.69,58.21)	—0.0466 10.14.Q (0.59,0.40)	—0.2025 3.91.Q (0.53,0.29)	—0.4993 10.62.Q (0.41,0.52)	—0.4966 2.03.Q (0.83, 0.05)
2.	Ganga/ Garhmukt-eshwar	U/S	—0.1331 318.82.Q (0.39, 60.42)	0.0101 7.57.Q (0.21, 0.44)	—0.1469 2.52.Q (0.45, 0.52)	0.0125 1.05.Q (0.05, 0.39)	—0.4674 1.93.Q (0.81, 0.20)
		D/S	—0.1535 349.75.Q (0.42, 66.58)	—0.0079 8.16.Q (0.21, 0.33)	—0.2248 4.02.Q (0.66, 0.52)	—0.0658 1.54.Q (0.17, 0.52)	—0.4773 2.18.Q (0.72, 0.23)
3.	Ganga/ Fatehgarh	U/S	—0.3454 606.12.Q (0.82, 71.25)	—0.0436 9.01.Q (0.69, 0.46)	—0.1758 2.22.Q (0.48, 0.51)	—0.0710 1.41.Q (0.15, 0.41)	—0.5961 3.18.Q (0.76, 0.30)
		D/S	—0.3496 657.60.Q (0.76, 85.40)	—0.0457 9.17.Q (0.72, 0.47)	0.2049 2.30.Q (0.58, 0.40)	—0.6433 8.91.Q (0.75, 0.49)	—0.5866 3.13.Q (0.73, 0.32)
4.	Ganga/ Kanpur	U/S	—0.3528 1724.63.Q (0.96, 55.04)	—0.0141 8.89.Q (0.23, 0.32)	—0.0726 2.31.Q (0.17, 0.46)	—0.3839 6.32.Q (0.77, 0.43)	—0.6495 15.10.Q (0.80, 0.43)
		D/S	—0.3439 1824.35.Q (0.90, 91.44)	—0.0049 8.20.Q (0.89, 0.29)	—0.0739 2.42.Q (0.15, 0.50)	—0.4075 6.81.Q (0.79, 0.39)	—0.3850 6.57.Q (0.68, 0.43)

Table - 5 (Contd.)

Sl. No.	River/ Site		λ	pH	Ca^{+2}	Mg^{+2}	Na^{+}
1	2		3	4	5	6	7
5.	Ganga/ Allahabad	U/S	—0.2678 1381.63.Q (0.54,111.16)	0.0007 8.33.Q (0.01, 0.025)	0.0255 1.66.Q (0.03, 0.56)	—0.2759 4.13.Q (0.51, 0.36)	—0.3120 5.33.Q (0.37, 0.69)
		D/S	—0.6625 16299.72.Q (0.69, 135.76)	0.0022 8.27.Q (0.02, 0.27)	0.0106 1.63.Q (0.01, 0.51)	—0.3298 8.68.Q (0.38, 0.44)	—1.3073 1577.14.Q (0.69, 0.98)
6.	Ganga/ Mirzapur	U/S	—0.2190 1842.11.Q (0.52,79.98)	0.0420 6.62.Q (0.43, 0.27)	0.3284 0.25.Q (0.17, 0.70)	—0.6201 50.36.Q (0.71, 0.55)	—0.4945 30.33.Q (0.64, 0.59)
		D/S	—0.2313 1982.11.Q (0.54,83.90)	0.0478 6.43.Q (0.41, 0.31)	0.3139 0.28.Q (0.18, 0.66)	—0.6308 54.20.Q (0.66, 0.56)	—0.5266 37.49.Q (0.68, 0.62)
7.	Ganga/ Varanasi	U/S	—0.1209 1162.64.Q (0.39, 66.37)	0.0404 6.53.Q (0.27, 0.44)	—0.6698 58.04.Q (0.40, 0.63)	0.0493 1.42.Q (0.07, 0.54)	—0.0216 2.41.Q (0.02, 0.76)
		D/S	—0.3836 1220.94.Q (0.41,68,52)	0.0363 6.68.Q (0.24, 0.42)	—0.5410 28.41.Q (0.32, 0.65)	—0.0856 3.00.Q (0.11, 0.56)	—0.1457 5.14.Q (0.22, 0.59)
8	Ganga/ Patna	U/S	—0.3836 4931.01.Q (0.51,94.80)	—0.0635 12.53.Q (0.64, 0.52)	—0.2590 7.91.Q (0.17, 0.52)	—1.1096 2079.02.Q (0.65, 0.62)	—0.3908 12.89.Q (0.45, 0.35)
		D/S	—0.4912 10076.34.Q (0.68, 98.95)	—0.0753 13.55.Q (0.73, 0.60)	—0.1763 4.91.Q (0.18, 0.60)	—1.2410 4432.55.Q (0.59, 0.66)	—0.7311 120.93.Q (0.59, 0.29)

Table - 5 (Contd.)

Sl. No.	River Site		K^+	$CO_3^{-2}+HCO_3^-$	Cl^-	SO_4^{-2}
1	2		8	9	10	11
1.	Ganga/ Rishikesh	U/S	Data inconsistent	0.0018 1.63.Q (0.01, 0.16)	—0.4393 1.91.Q (0.72, 0.07)	0.5197 0.01.Q (0.37, 0.69)
		D/S	Data inconsistent	0.1241 0.90.Q (0.46, 0.38)	—0.5878 4.80.Q (0.82, 0.09)	0.6349 0.01.Q (0.45, 0.75)
2.	Ganga/ Garhmukteshwar	U/S	—0.5374 0.09.Q (0.28, 0.02)	—0.2185 6.72.Q (0.76, 0.89)	—0.2675 1.26.Q (0.38, 0.40)	0.6093 0.01.Q (0.51, 0.14)
		D/S	–0.7438 0.32.Q (0.50, 0.02)	—0.2613 8.51.Q (0.83, 1.03)	—0.2251 0.91.Q (0.27, 0.42)	0.0177 0.15.Q (0.02, 0.11)
3.	Ganga/Fatehgarh	U/S	—1.1870 1.41.Q (0.64, 0.02)	—0.2127 6.69.Q (0.83, 0.74)	—0.4382 1.29.Q (0.74, 0.16)	—0.1127 0.19.Q (0.22. 0.07)
		D/S	—1.1870 1.41.Q (0.64, 0.02)	—0.2272 7.60.Q (0.83, 0.76)	—0.4661 1.49.Q (0.73, 0.18)	—0.2061 0.31.Q (0.42, 0.09)
4.	Ganga/ Kanpur	U/S	—0.1103 0.23.Q (0.20, 0.05)	—0.3008 13.33.Q (0.77, 0.79)	—0.3982 2.40.Q (0.72, 0.17)	—0.1786 0.65.Q (0.16, 0.14)
		D/S	—0.0858 0.25.Q (0.20, 0.05)	—0.2899 12.91.Q (0.77, 0.77)	—0.3798 2.96.Q (0.80, 0.16)	0.2962 0.17.Q (0.64, 0.19)

Table - 5 (Contd.)

Sl. No.	River/ Site.		λ	pH	Ca^{+2}	Mg^{+2}	Na^{+}
1	2		3	4	5	6	7
9.	Ganga/ Hathidah.		—0.4352	—0.0193	0.1164	—1.1004	—0.3089
		U/S	7731.80.Q	9.46.Q	0.59.Q	2545.92.Q	7.62.Q
			(0.67, 93.20)	(028, 0.23)	(0.11, 0.56)	(0.64, 0.67)	(0.39, 0.27)
			—0.3718	—0.0201	—0.2186	—0.8040	—0.2623
		D/S	5121.89.Q	9.41.Q	7.12.Q	523.91.Q	5.75.Q
			(0.64, 85.95)	(0.23, 0.28)	(0 21, 0.54)	(0.46, 0.55)	(0.31, 0.30)
10.	Ganga/ Farakka.		—0.4120	0.0135	—0.2692	—0.7104	—0.8049
		U/S	6344.53.Q	7.40.Q	10.77.Q	139.50.Q	264.30.Q
			(0.82, 101.82)	(0.35, 0.20)	(0.64, 0.43)	(0.69, 0.57)	(0.48, 5.19)
			—0.4162	0.0114	0.2661	—0.6952	—0.7778
		D/S	6581.69.Q	7.50.Q	11.61.Q	116.77.Q	215.41.Q
			(0.84, 99.71)	(0.35, 0.16)	(0.68, 0.44)	(0.79, 0.47)	(0.46, 5.03)

λSpecific conductance in micro mhos/centimeter (μmhos/cm).
The values in parenthesis respectively denote 'r' correlation coefficient between river discharge and W.Q. parameter and 'a' standard deviation of sample data of W.Q. parameter taken as logarithmic functions.

Table - 5 (Contd.)

Sl. No.	River/ Site		K^+	$CO_3^{-2}+HCO_3^-$	Cl^-	SO_4^{-2}
1	2		8	9	10	11
5.	Ganga/ Allahabad.		0.2731	—0.1234	—0.4860	0.2533
		U/S	0.06.Q (0.46, 0.05)	7.55.Q (0.05, 2.40)	5.99.Q (0.38, 0.80)	0.20.Q (0.14, 0.23)
			—0.1863	—0.2075	0.2791	—0.2408
		D/S	0.40.Q (0.17, 0.05)	12.88.Q (0.25, 0.91)	0.23.Q (0.13, 0.42)	2.17.Q (0.17, 0.24)
6.	Ganga/ Mirzapur		—0.5309	0.0594	—0.4871	—0.0445
		U/S	1.99.Q (0.53, 0.05)	3.62.Q (0.15, 0.63)	17.39.Q (0.71, 0.30)	1.05.Q (0.07, 0.18)
			—0.5034	—0.0287	0.4401	—0.1546
		D/S	1.78.Q (0.59, 0.04)	5.73.Q (0.08, 0.56)	14.45.Q (0.84, 0.25)	1.95.Q (0.29, 0.15)
7.	Ganga/ Varanasi		0.0760	—0.0366	—0.1447	—0.1864
		U/S	0.09.Q (0.10, 0.04)	6.01.Q (0.09, 0.76)	3.12.Q (0.31, 0.24)	2.20.Q (0.36, 0.16)
			—0.0102	—0.0061	—0.1829	—0.5359
		D/S	0.13.Q (0.01, 0.05)	5.16.Q (0.02, 0.60)	3.86.Q (0.38, 0.26)	12.69.Q (0.73, 0.15)
8.	Ganga/ Patna		—0.3624	—0.6458	—0.4710	—0.3697
		U/S	1.05.Q (0.41, 0.03)	265.77.Q (0.83, 0.79)	14.97.Q (0.68, 0.19)	4.65.Q (0.35, 0.18)
			—0.6242	—0.5554	—0.8303	—0.3453
		D/S	5.92.Q (0.64, 0.03)	134.12.Q (0.84, 1.04)	139.53.Q (0.74, 0.16)	4.06.Q (0.24, 0.16)

Table 6(A)

STATEMENT OF WATER QUALITY OBSERVATION STATIONS ON MAIN STEM OF GANGA AND TERMINAL STATIONS ON MAJOR TRIBUTARIES

Sl. No.	CWC sites for routine observations (1963 onwards) once a month	Sites included in NCST programme (1978-85) U/S and D/S three times a month	Sites proposed by the CWC in the estimate submitted to Min. of W.R for intensive survey
1	2	3	4
1.	Joshimath		Joshimath
2.	Rudraprayag		Rudraprayag
3.	Tehri		Tehri
4.	Deo Prayag		Deo Prayag
5.	Rishikesh	Rishikesh	Rishikesh
6.	Balwali		Balwalighat
7.	Rawalighat		Rawalighat
8.	Garhmukhteshwar	Garhmukhteshwar	Garhmukhteshwar
9.	Kachla Bridge		Kachla bridge
10.	Fatehgarh	Fatehgarh	Fatehgarh
11.	Ankinghat		Ankinghat
12.	Kanpur	Kanpur	Kanpur
13.	Bithaura		Bithaura
14.	Shahzadpur		Shahzadpur
15.	Allahabad	Allahabad	Allahabad
16.	Mirzapur	Mirzapur	Mirzapur
17.	Varanasi	Varanasi	Varanasi
18.			
19.	Buxar		Buxar
20.	Turtipar (Gogra)	Turtipar	Turtipar
21.	Koelwar (Sone)	Koelwar	Koelwar
22.	Patna	Patna	Patna
23.	Mokameh	Mokameh	Mokameh
24.	Azmabad		Azmabad
25.	Farakka	Farakka	Farakka
26.	Berhampur	Berhampur	Berhampur
27.	Purbasthali		Purbasthali
28.	Kalna (Ebb)	Kalna (Ebb)	Kalna
29.	Kalna (Flow)	Kalna (Flow)	
30.			Palta
31.			Dakshineshwar
32.			Uluberia

(Contd.)

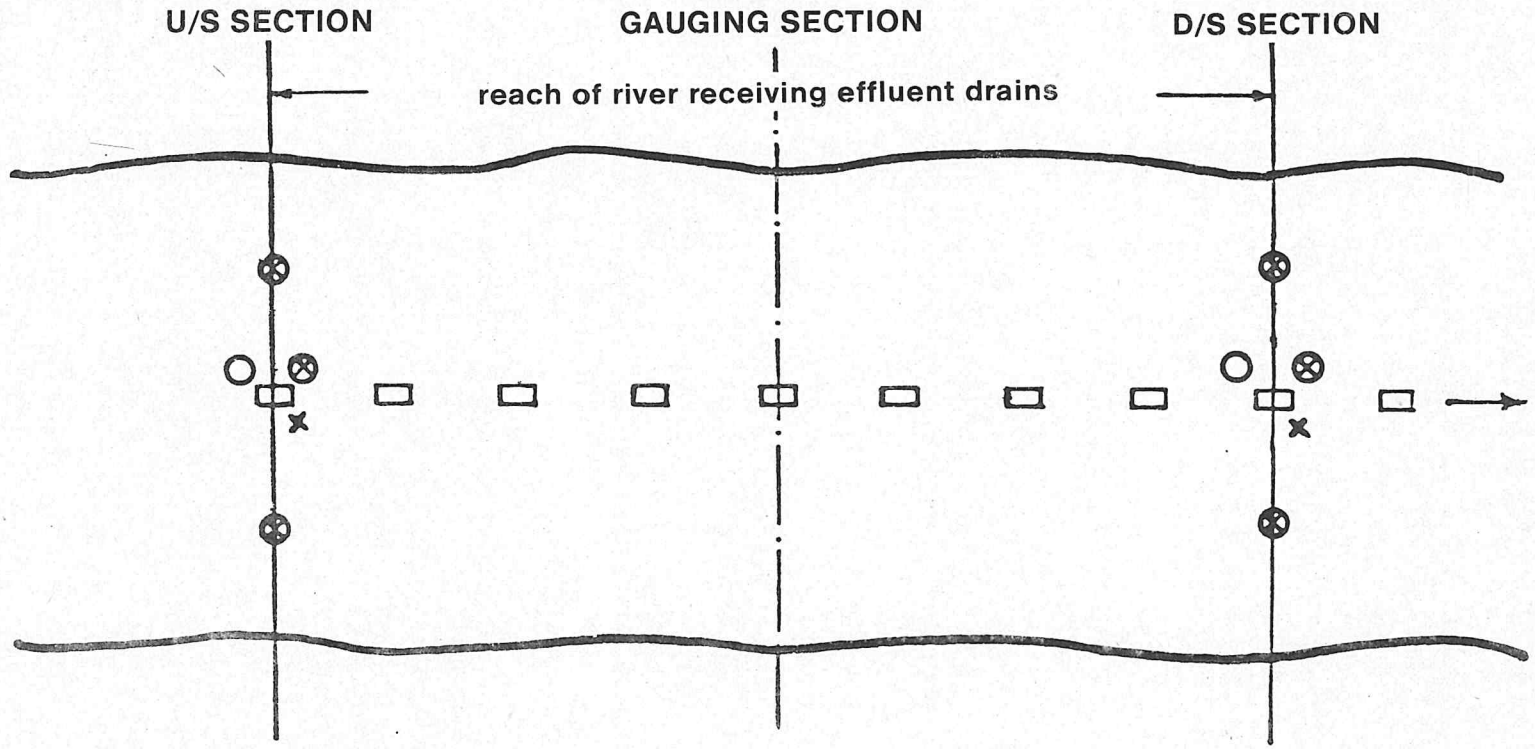
Sl No.	River/ Site		K^+	$CO^{-2}_3+HCO_3$	Cl^-	SO_4^{-2}
1	2		8	9	10	11
9.	Ganga/ Hathidah	U/S	—0.2950 0.73.Q (0.39, 0.03)	—0.3764 46.47.Q (0.69, 0.72)	—0.2178 2.66.Q (0.31, 0.16)	—0.0673 0.68.Q (0.07, 0.17)
		D/S	—0.4440 2.19.Q (0.44, 0.03)	—0.4592 85.59.Q (0.67, 0.95)	—0.2490 3.63.Q (0.39, 0.16)	—0.0857 0.80.Q (0.12, 0.11)
10.	Ganga/ Farakka	U/S	—0.3330 1.20.Q (0.34, 0.15)	—0.3000 23.93.Q (0.59, 0.92)	—0.4222 10.85.Q (0.82, 0.19)	0.0034 0.29.Q (0.01, 0.10)
		D/S	—0.2783 0.79.Q (0.27, 0.15)	—0.3269 29.92.Q (0.74, 0.81)	—0.4236 9.70.Q (0.73, 0.18)	—0.1591 0.95.Q (0.28, 0.12)

The values in parenthesis respectively denote 'r' correlation coefficient between river discharge and W.Q. parameter and 's' standard deviation of sample data of W.Q. parameter taken as logarithmic functions.

Table 6(B)

PARAMETERS OBSERVED AND PROPOSED

Sl. No.	CWC routine observation	Additional parameters under NCST programme (1978-85)	Parameters in CWC estimates proposed to Min. of W.R.
1	2	3	4
1.	Temperature		
2.	Velocity and flow rate		
3.	Turbidity		
4.	Total and fixed solids		
5.	Conductivity		
6.	pH		
7.	Chlorides		Will continue to be observed as indicated in Col. 2
8.	Sulphates		
9.	Sodium		
10.	Calcium		
11.	Magnesium		
12.	Total hardness		
13.	Alkalinity		
14.	Nitrite Nitrogen		
15.	Phosphate		
16.	Iron		
17.		Total Plate-count	Total plate-count
18.		BOD	BOD
19.		Nitrate Nitrogen	Nitrate-Nitrogen
20.		Total Kjeldahl-Nitrogen	Total Kjeldahl-Nitrogen
21.		Amonical Nitrogen	Amonical Nitrogen
22.		Dissolved Oxygen	Dissolved Oxygen
23.		Arsenic	Arsenic
24.		Chromium	Chromium
25.		Lead	Lead
26.		Cadmium	Cadmium
27.		Manganese	Manganese
28.		Copper	Copper
29.		Nickel	Nickel
30.		Zinc	Zinc
31.			
32.			
33.			
34.			
35.			
36.			
37.			



○ SAMPLE FOR CHEMICAL ANALYSIS ..... 10 DAILY

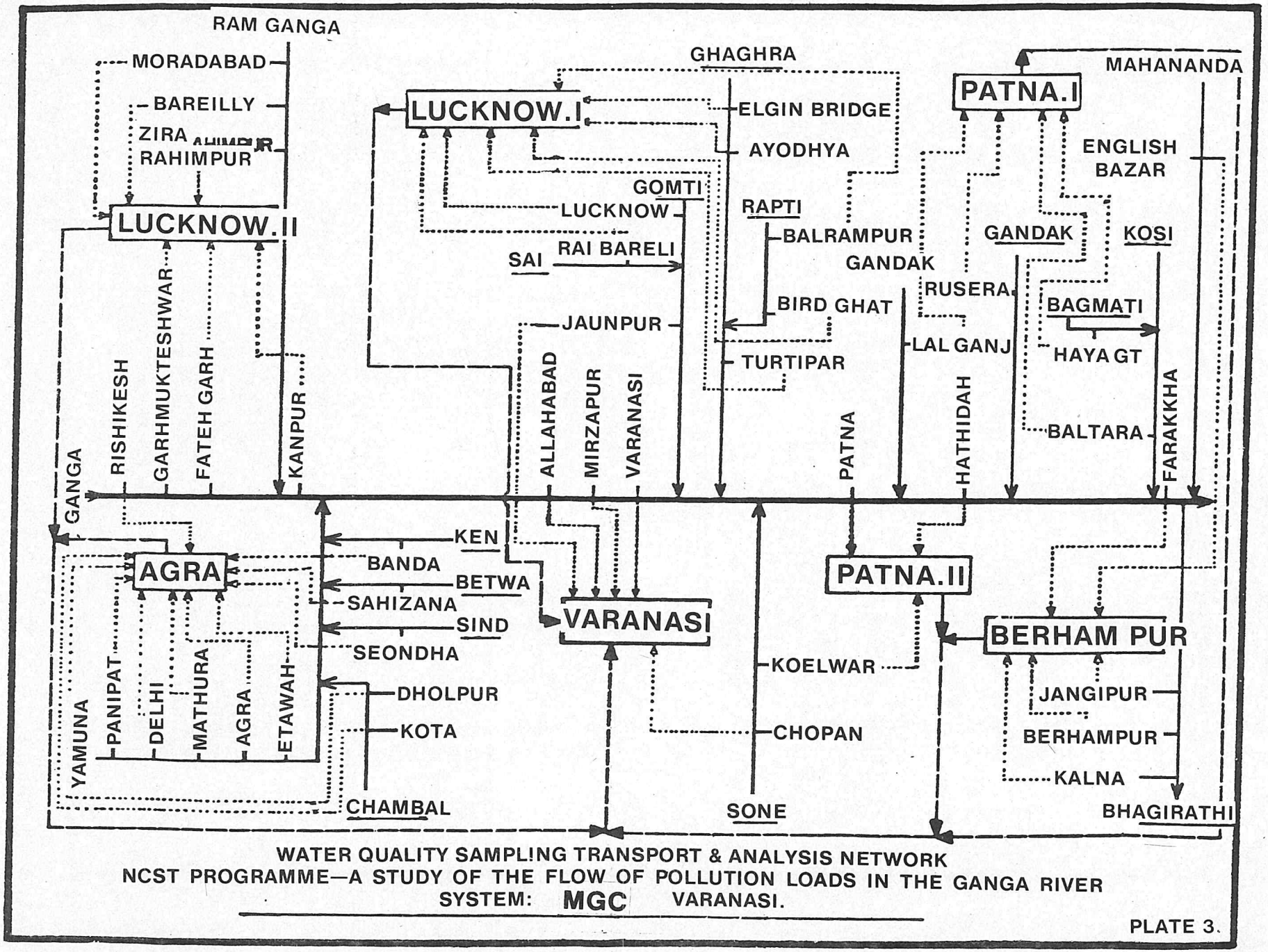
⊗ SAMPLE FOR D.O. & B.O.D. TEMPERATURE pH, CONDUCTIVITY } ... WEEKLY

× SAMPLE FOR TRACE ELEMENTS ..... 10 DAILY

▭ SAMPLING FOR LONGITUDINAL VARIATION OF TEMPERATURE, D.O. & B.O.D. } ... TWICE A YEAR

SAMPLING FOR WATER QUALITY PARAMETERS

PLATE-1



WATER QUALITY SAMPLING TRANSPORT & ANALYSIS NETWORK
NCST PROGRAMME—A STUDY OF THE FLOW OF POLLUTION LOADS IN THE GANGA RIVER
SYSTEM: MGC VARANASI.

PLATE 3.

SAMPLES TESTED	NO. OF STNs COVERED	NO.
1. DETAILED CHEMICAL ANALYSIS	42	14200
2. IN SITU DISSOLVED OXYGEN	42	39500
3. $^{5}BOD_{20}$	12	16000
4. LONGITUDINAL SURVEY FOR DO & BOD	10	80
5. IDENTIFICATION OF FRESH WATER AND POLLUTED WATER PLANKTONS	05	70

ANALYSIS

1. WATER QUALITY TREND STUDIES
2. REGRESSION ANALYSIS BETWEEN RIVER DISCHARGE AND WATER QUALITY PARAMETERS $Y=AQ^{x}$
3. SPECTRUM AND HARMONIC ANALYSIS
4. SPATIAL AND TIME VARIATION OF POLLUTANTS

DETAILS OF SAMPLE TESTED AND ANALYSED DURING 1978—85
NCST PROGRAMME—A STUDY OF THE FLOW OF POLLUTION LOADS
IN THE GANGA RIVER SYSTEM WR & FF CIRCLE (CWC) VARANASI

PLATE-2

WATER QUALITY PARAMETERS

PHYSICO CHEMICAL PARAMETERS

- TEMPERATURE
- COLOUR
- ODOUR
- pH
- SPECIFIC CONDUCTANCE
- INSITU DO
- HARDNESS No.
- SODIUM PERCENTAGE
- RESIDUAL SODIUM CARBONATE SODIUM
- SODIUM ADSORPTION RATIO
- CLASSIFICATION

NON METALS

- CARBONATES
- BICARBONATES
- CHLORIDES
- FLUORIDES
- SULPHITES
- SULPHATES
- NITRITES
- NITRATES
- CYANIDES
- NITROGEN (AMMONICAL)
- PHOSPHATES
- BORON
- SILICATES

METALS

- IRON
- ALUMINIUM
- MANGANESE
- CALCIUM
- MAGNESIUM
- SODIUM
- POTASSIUM
- CADMIUM
- CHROMIUM
- COPPER
- SILVER
- ZINC
- LEAD

ORGANICS

- B.O.D
- MPN COUNT
- PLATE-COUNT
- PHYTO-PLANKTONS
- ZOO PLANKTONS

ANALYSIS OF WATER SAMPLES

NCST PROGRAMME— A STUDY OF THE FLOW OF POLLUTION LOADS IN THE GANGA RIVER SYSTEM, AT MGC C.W.C., VARANASI

PLATE-4

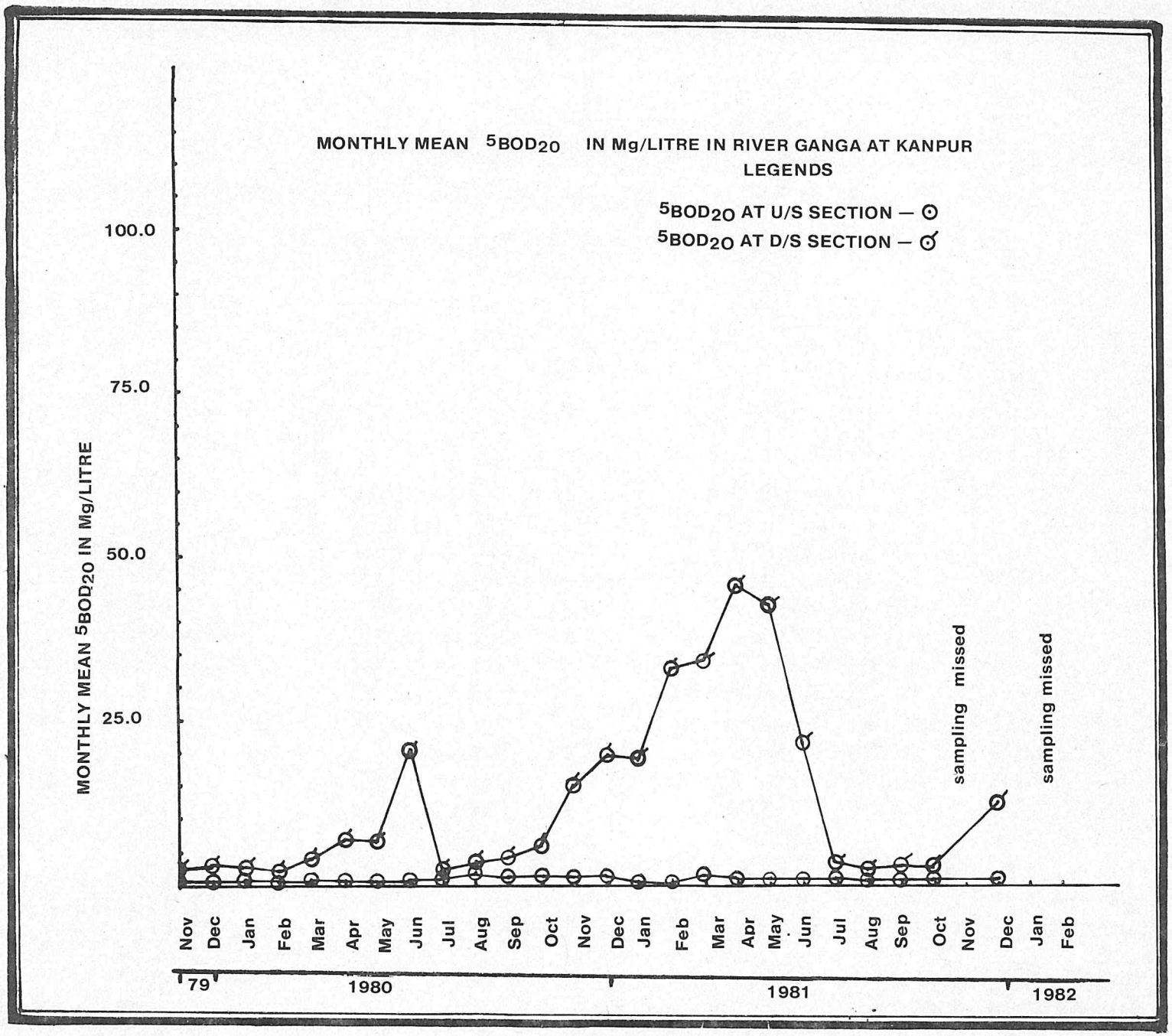

MONTHLY MEAN $^5BOD_{20}$ IN Mg/LITRE IN RIVER GANGA AT KANPUR
LEGENDS
$^5BOD_{20}$ AT U/S SECTION — ⊙
$^5BOD_{20}$ AT D/S SECTION — ⊙
MONTHLY MEAN $^5BOD_{20}$ IN Mg/LITRE
100.0
75.0
50.0
25.0
sampling missed
sampling missed
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb
79
1980
1981
1982

Fig- 3.1

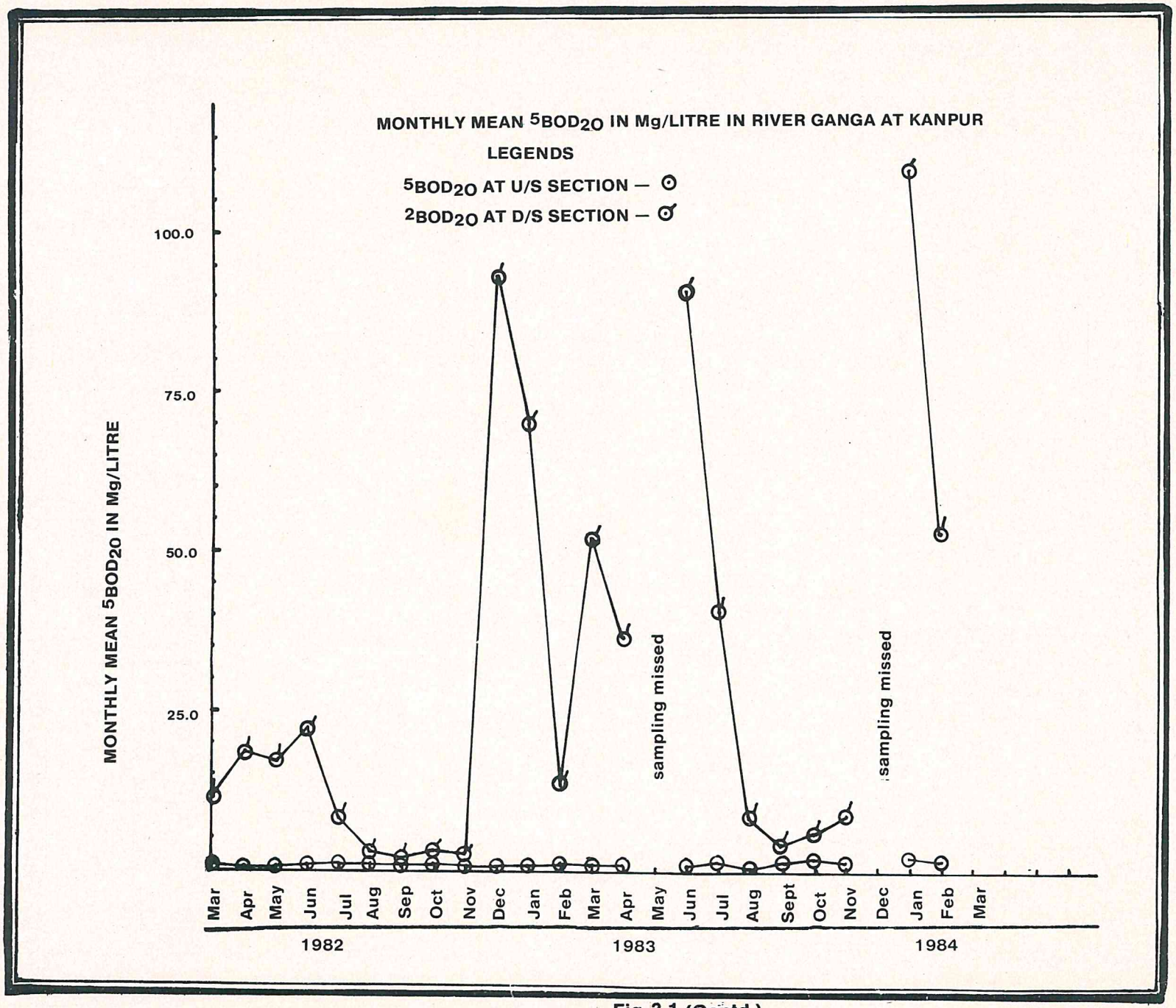

MONTHLY MEAN 5BOD20 IN Mg/LITRE IN RIVER GANGA AT KANPUR
LEGENDS
5BOD20 AT U/S SECTION —
2BOD20 AT D/S SECTION —
MONTHLY MEAN 5BOD20 IN Mg/LITRE
100.0
75.0
50.0
25.0
sampling missed
sampling missed
Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec Jan Feb Mar
1982
1983
1984

Fig-3.1 (Contd.)

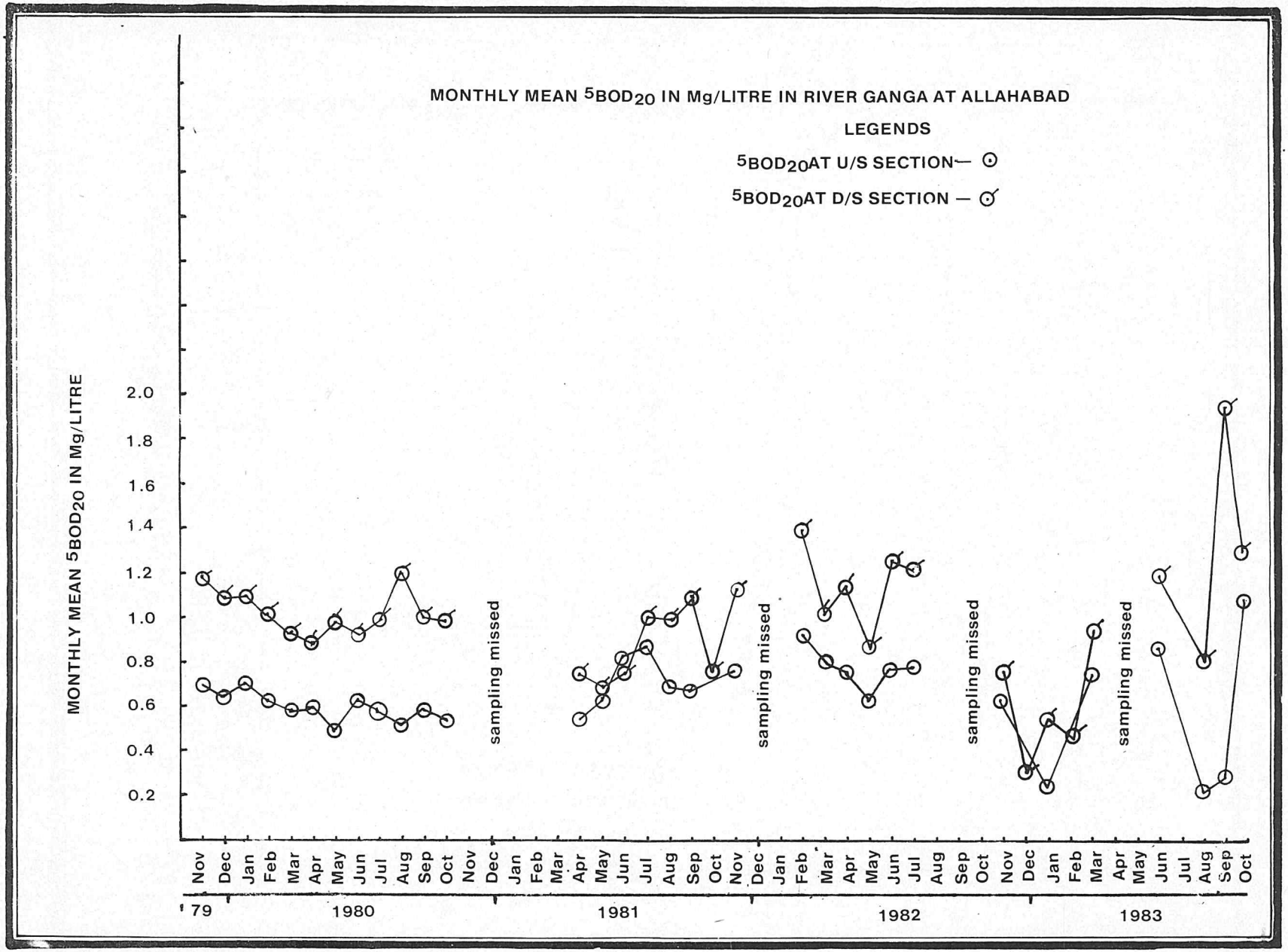

MONTHLY MEAN $^5BOD_{20}$ IN Mg/LITRE IN RIVER GANGA AT ALLAHABAD
LEGENDS
$^5BOD_{20}$AT U/S SECTION
$^5BOD_{20}$AT D/S SECTION
MONTHLY MEAN $^5BOD_{20}$ IN Mg/LITRE
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
sampling missed
sampling missed
sampling missed
sampling missed
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
'79
1980
1981
1982
1983

FIG 3.2

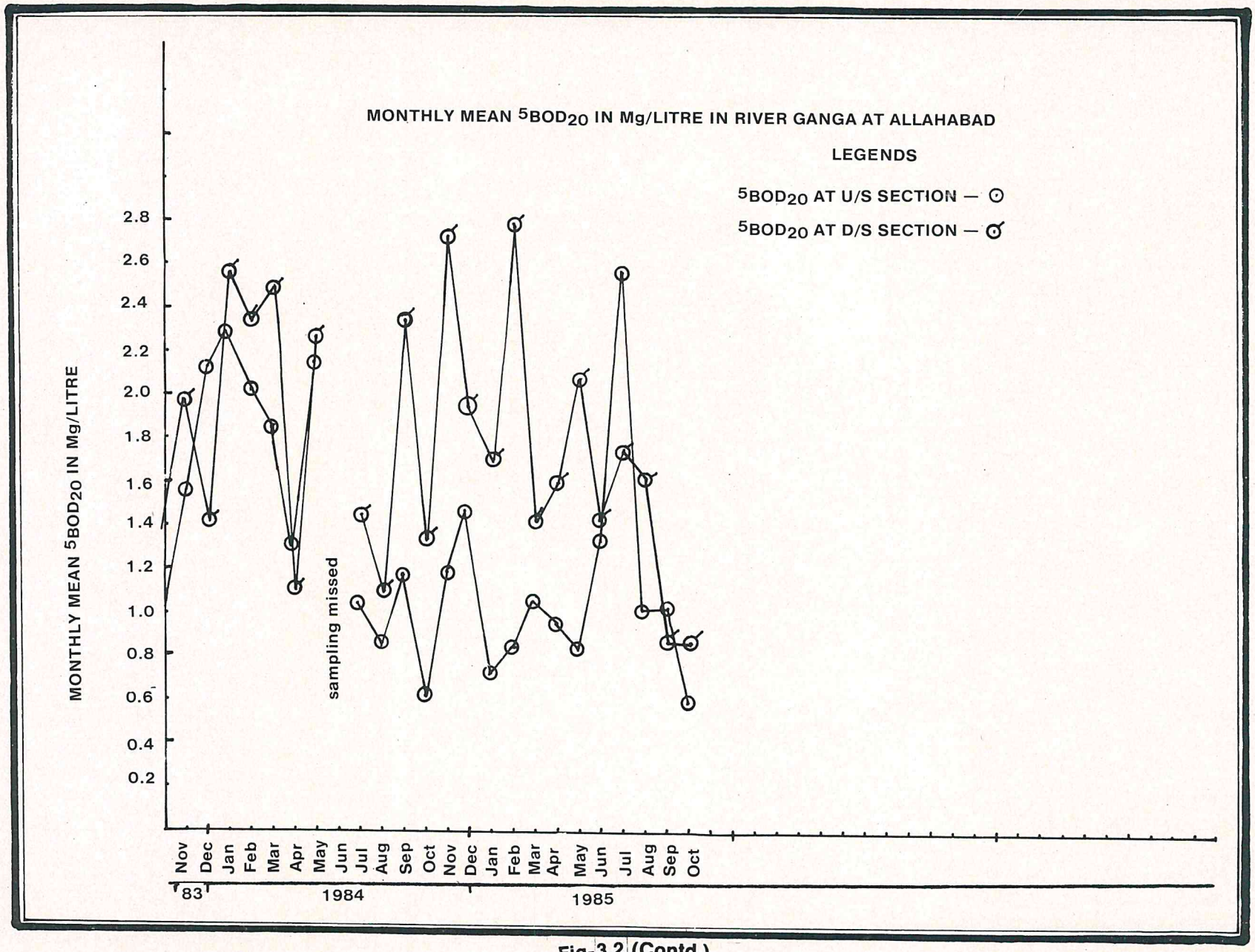

MONTHLY MEAN $^5BOD_{20}$ IN Mg/LITRE IN RIVER GANGA AT ALLAHABAD
LEGENDS
$^5BOD_{20}$ AT U/S SECTION — ⊙
$^5BOD_{20}$ AT D/S SECTION — ⊙
MONTHLY MEAN $^5BOD_{20}$ IN Mg/LITRE
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
sampling missed
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
83
1984
1985

Fig-3.2 (Contd.)

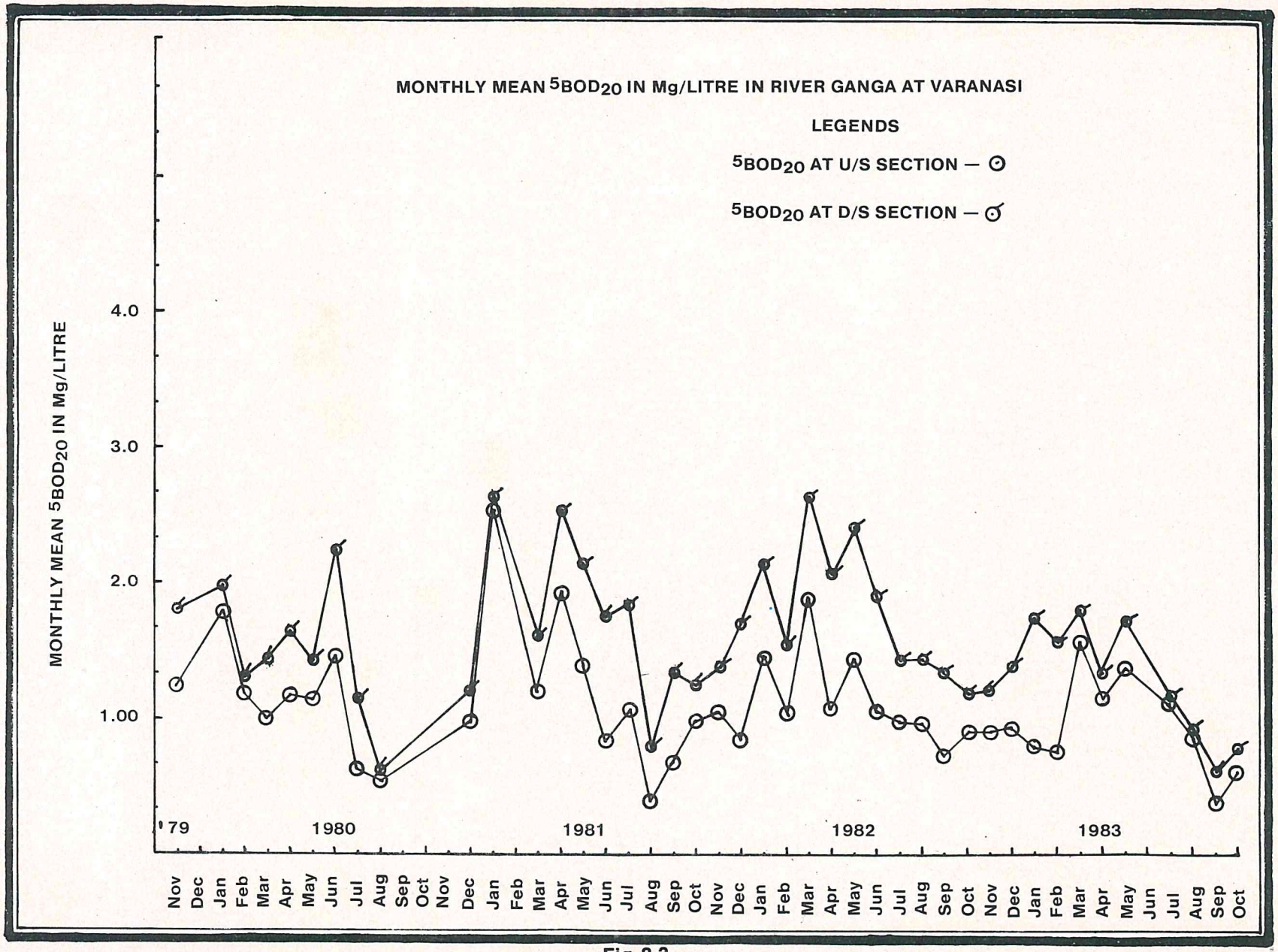

MONTHLY MEAN $^5BOD_{20}$ IN Mg/LITRE IN RIVER GANGA AT VARANASI
LEGENDS
$^5BOD_{20}$ AT U/S SECTION — ⊙
$^5BOD_{20}$ AT D/S SECTION — ⊙
MONTHLY MEAN $^5BOD_{20}$ IN Mg/LITRE
4.0
3.0
2.0
1.00
79
1980
1981
1982
1983
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct

Fig-3.3

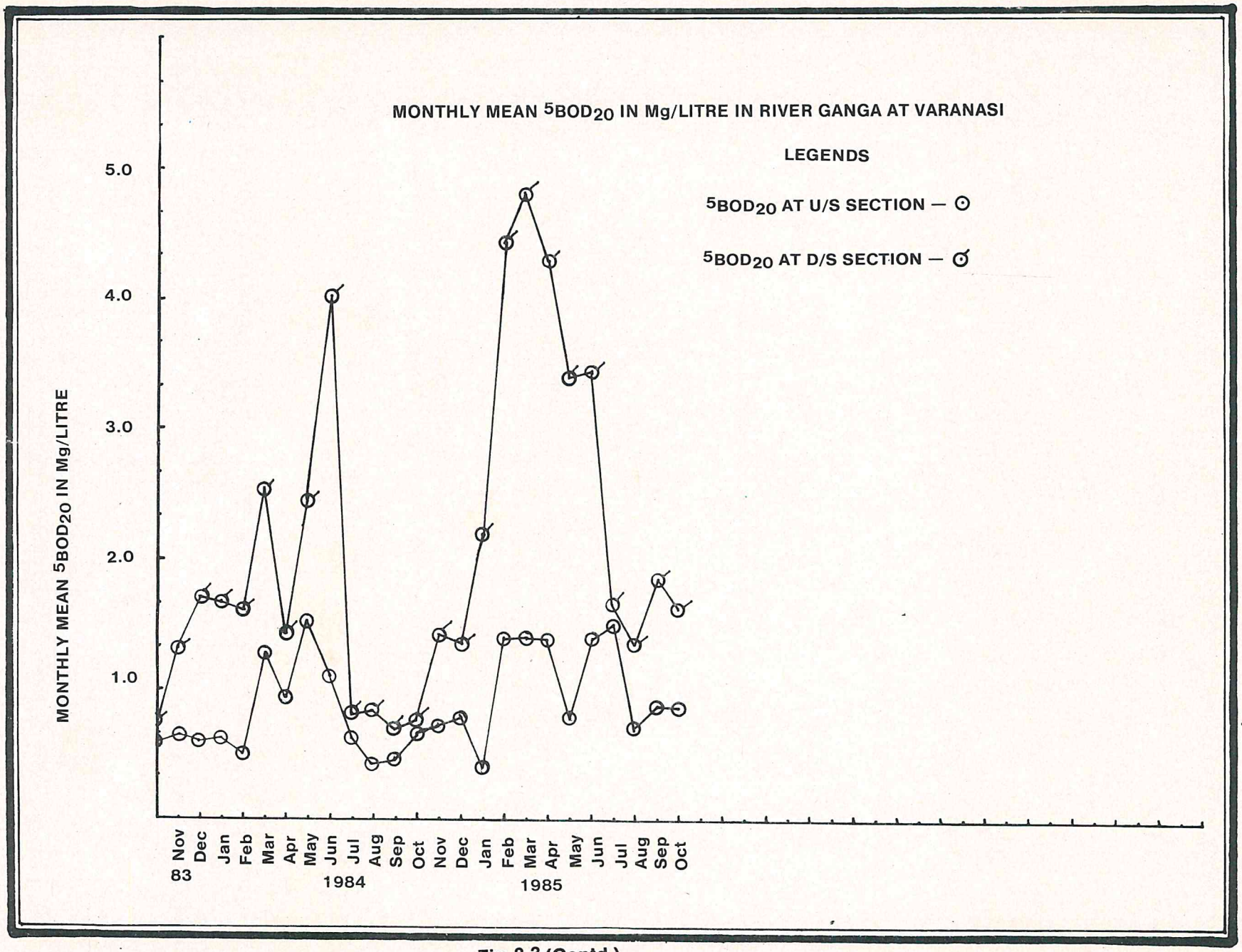

MONTHLY MEAN $^5BOD_{20}$ IN Mg/LITRE IN RIVER GANGA AT VARANASI
LEGENDS
$^5BOD_{20}$ AT U/S SECTION — ⊙
$^5BOD_{20}$ AT D/S SECTION — ⊙
MONTHLY MEAN $^5BOD_{20}$ IN Mg/LITRE
5.0
4.0
3.0
2.0
1.0
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
83
1984
1985

Fig-3.3 (Contd.)

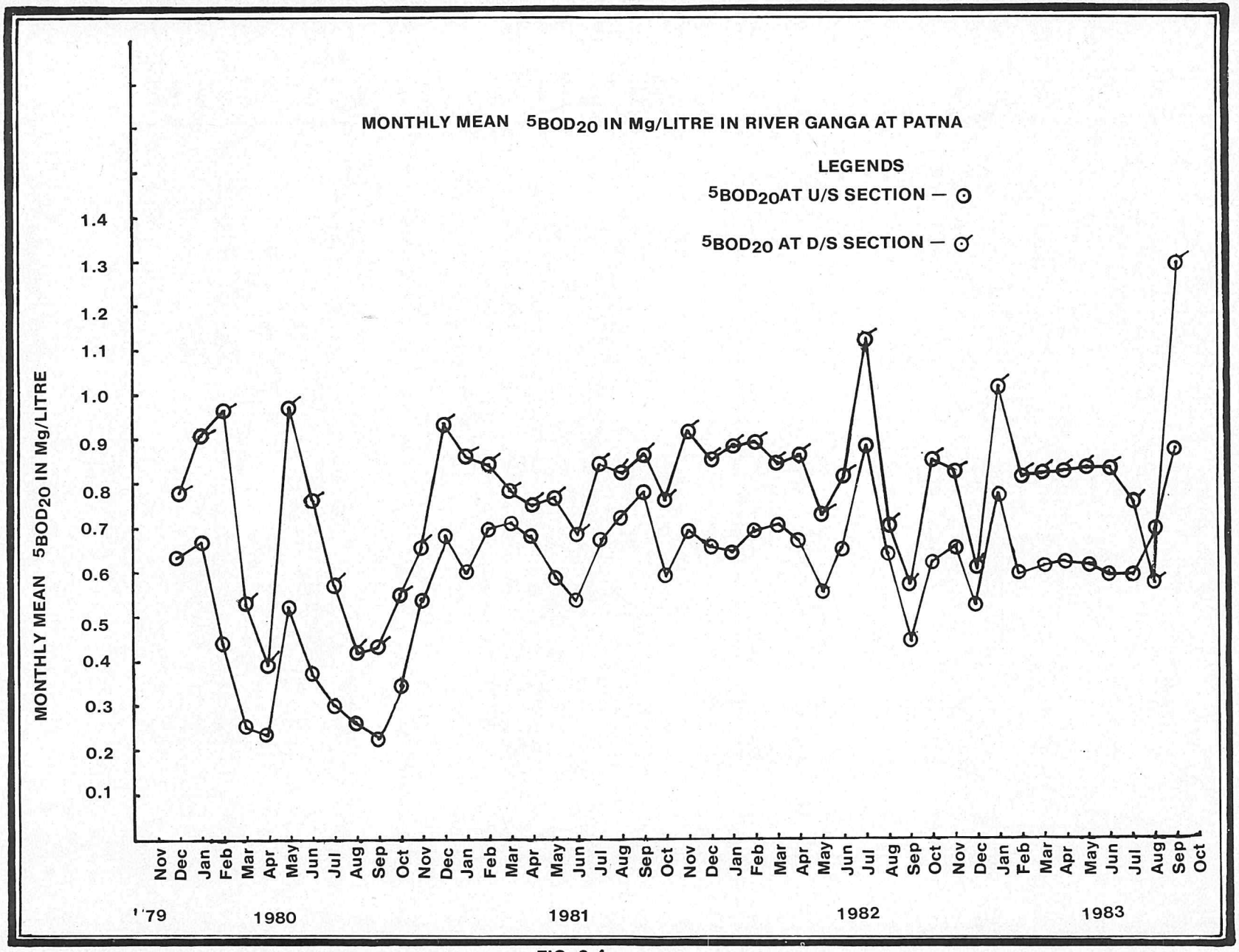

MONTHLY MEAN $^5BOD_{20}$ IN Mg/LITRE IN RIVER GANGA AT PATNA
LEGENDS
$^5BOD_{20}$AT U/S SECTION — ⊙
$^5BOD_{20}$ AT D/S SECTION — ⊙
MONTHLY MEAN $^5BOD_{20}$ IN Mg/LITRE
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
'79
1980
1981
1982
1983

FIG. 3.4

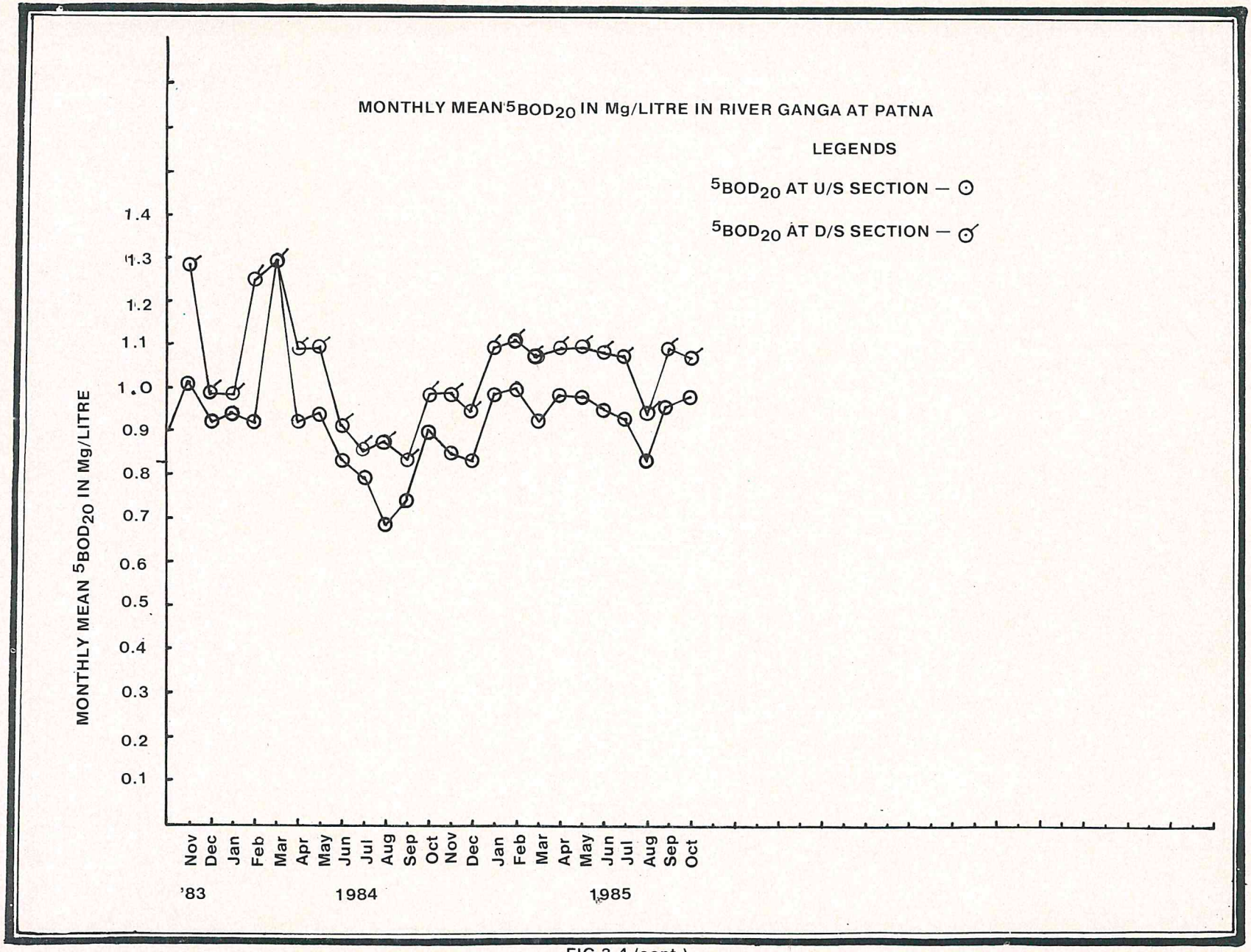

MONTHLY MEAN $^5BOD_{20}$ IN Mg/LITRE IN RIVER GANGA AT PATNA
LEGENDS
$^5BOD_{20}$ AT U/S SECTION — ⊙
$^5BOD_{20}$ AT D/S SECTION — ⊙
MONTHLY MEAN $^5BOD_{20}$ IN Mg/LITRE
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
'83
1984
1985

FIG 3.4 (cont.)

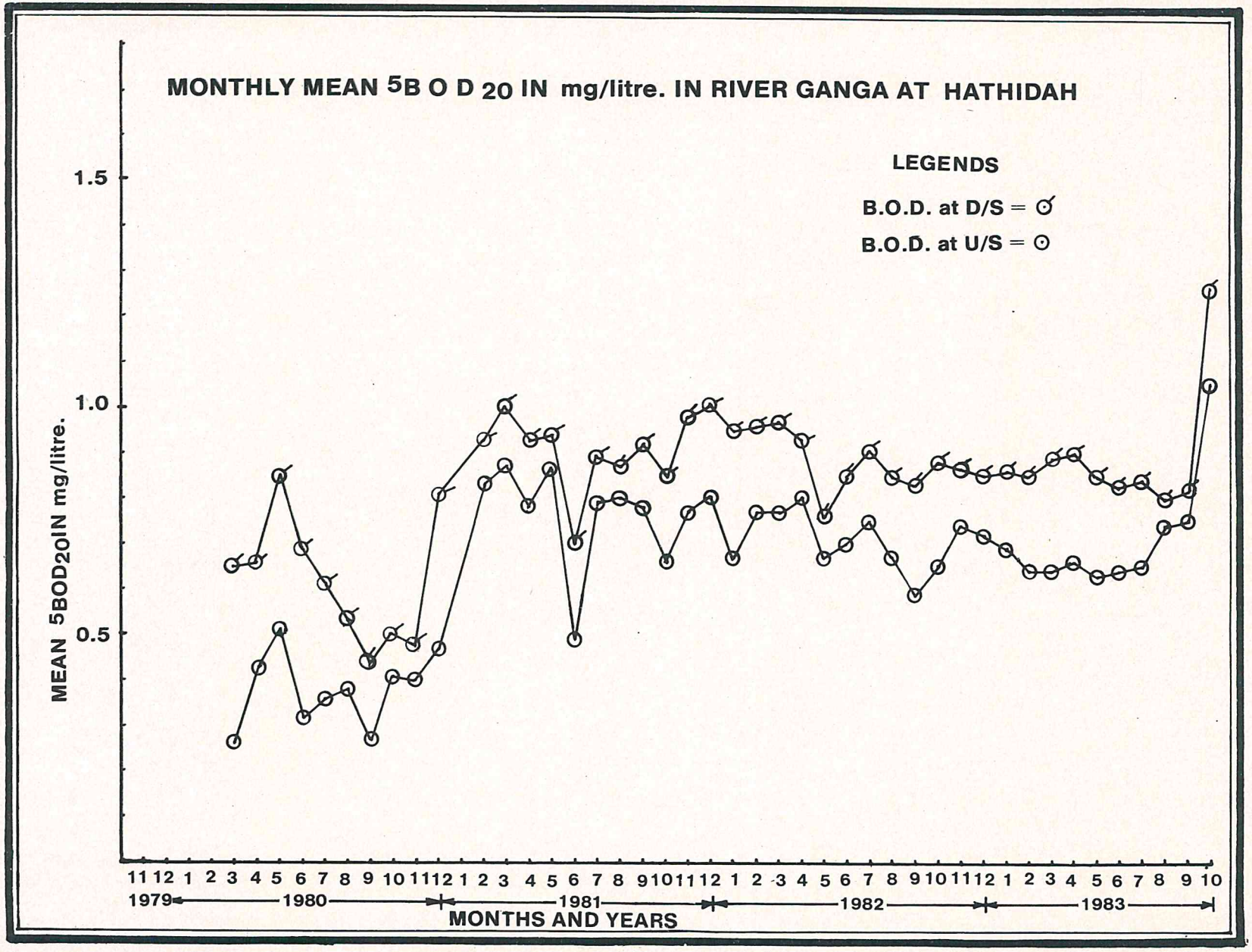
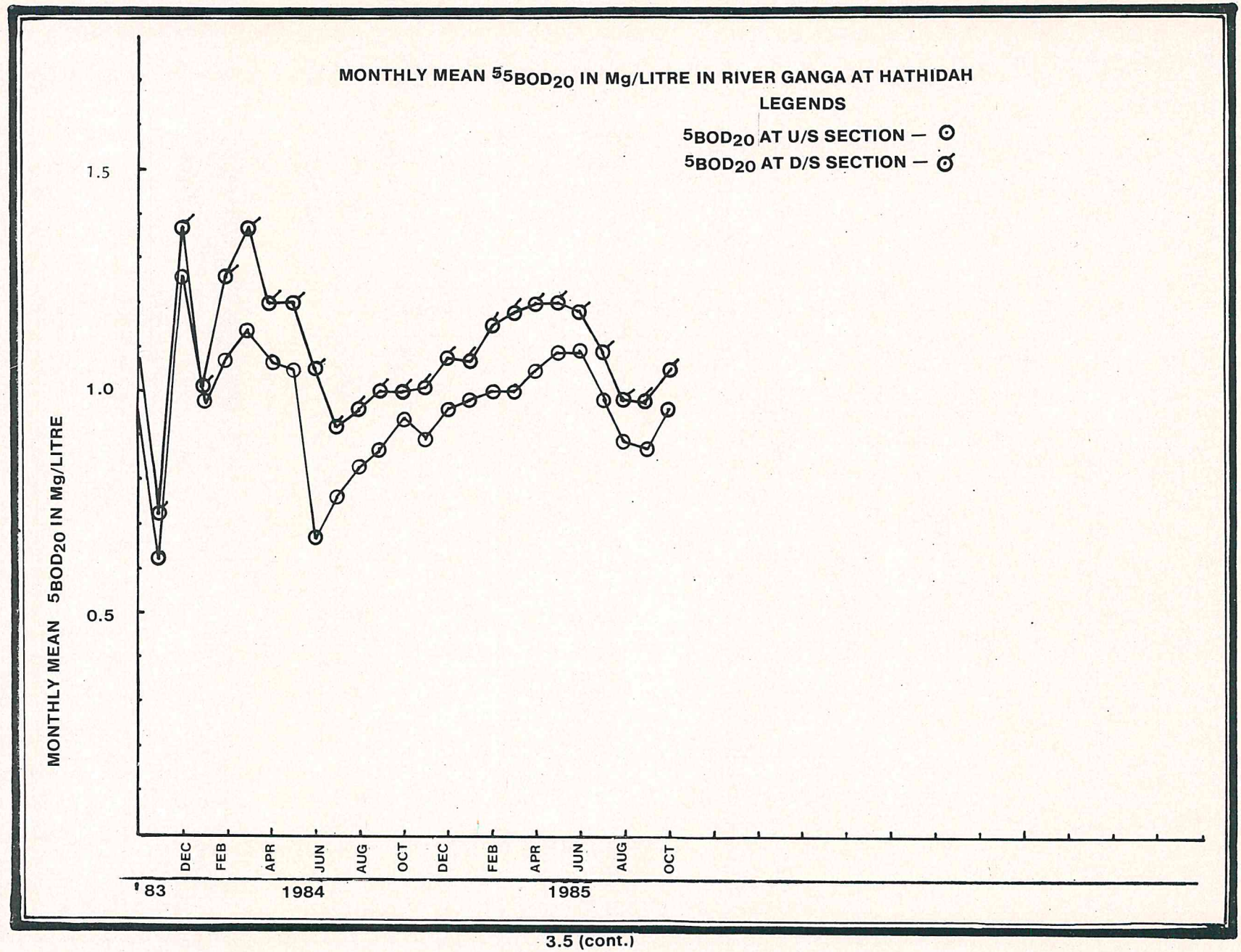

MONTHLY MEAN 5B O D 20 IN mg/litre. IN RIVER GANGA AT HATHIDAH
LEGENDS
B.O.D. at D/S = ⊙
B.O.D. at U/S = ⊙
MEAN 5BOD20IN mg/litre.
1.5
1.0
0.5
11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10
1979
1980
1981
1982
1983
MONTHS AND YEARS

Fig-3.5


MONTHLY MEAN $^5BOD_{20}$ IN Mg/LITRE IN RIVER GANGA AT HATHIDAH
LEGENDS
$^5BOD_{20}$ AT U/S SECTION —
$^5BOD_{20}$ AT D/S SECTION —
MONTHLY MEAN $^5BOD_{20}$ IN Mg/LITRE
1.5
1.0
0.5
DEC
FEB
APR
JUN
AUG
OCT
DEC
FEB
APR
JUN
AUG
OCT
'83
1984
1985

3.5 (cont.)

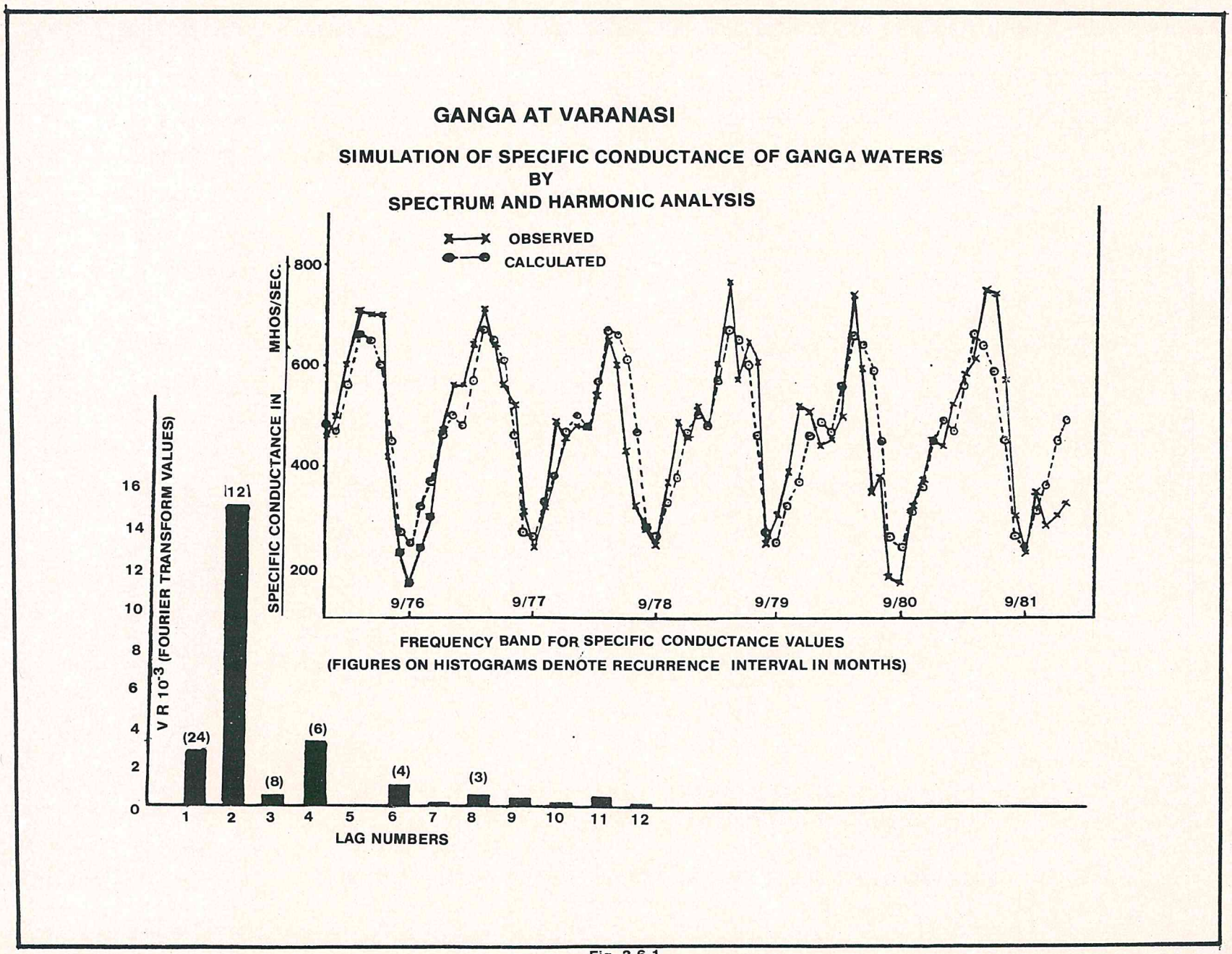

GANGA AT VARANASI
SIMULATION OF SPECIFIC CONDUCTANCE OF GANGA WATERS
BY
SPECTRUM AND HARMONIC ANALYSIS
OBSERVED
CALCULATED
SPECIFIC CONDUCTANCE IN MHOS/SEC.
800
600
400
200
9/76
9/77
9/78
9/79
9/80
9/81
FREQUENCY BAND FOR SPECIFIC CONDUCTANCE VALUES
(FIGURES ON HISTOGRAMS DENOTE RECURRENCE INTERVAL IN MONTHS)
V R 10-3 (FOURIER TRANSFORM VALUES)
16
14
12
10
8
6
4
2
0
(24)
(12)
(8)
(6)
(4)
(3)
1
2
3
4
5
6
7
8
9
10
11
12
LAG NUMBERS

Fig. 3.6.1

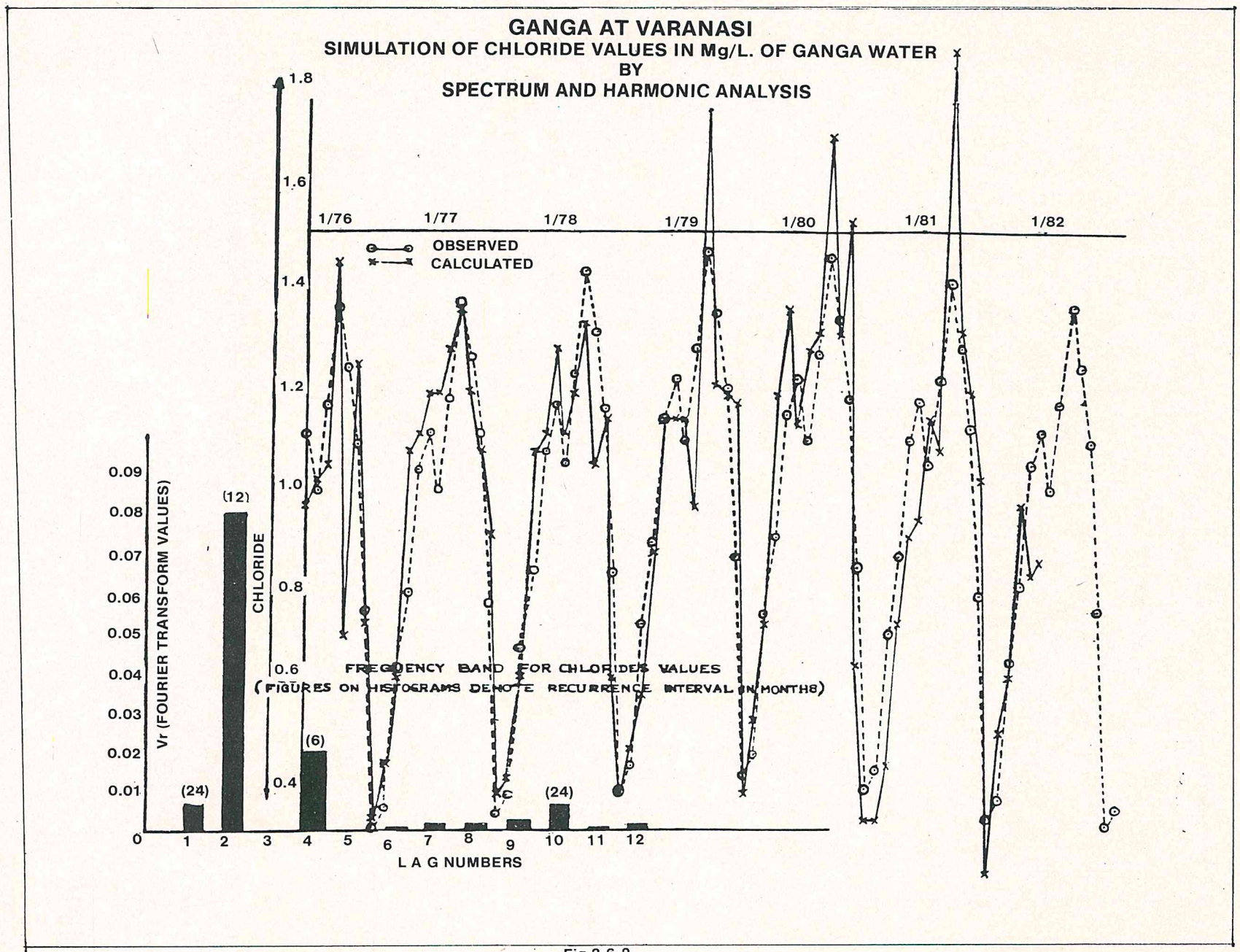

GANGA AT VARANASI
SIMULATION OF CHLORIDE VALUES IN Mg/L. OF GANGA WATER
BY
SPECTRUM AND HARMONIC ANALYSIS
OBSERVED
CALCULATED
1/76
1/77
1/78
1/79
1/80
1/81
1/82
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
CHLORIDE
Vr (FOURIER TRANSFORM VALUES)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
(24)
(12)
(6)
(24)
FREQUENCY BAND FOR CHLORIDES VALUES
(FIGURES ON HISTOGRAMS DENOTE RECURRENCE INTERVAL IN MONTHS)
1
2
3
4
5
6
7
8
9
10
11
12
L A G NUMBERS

Fig 3.6.2

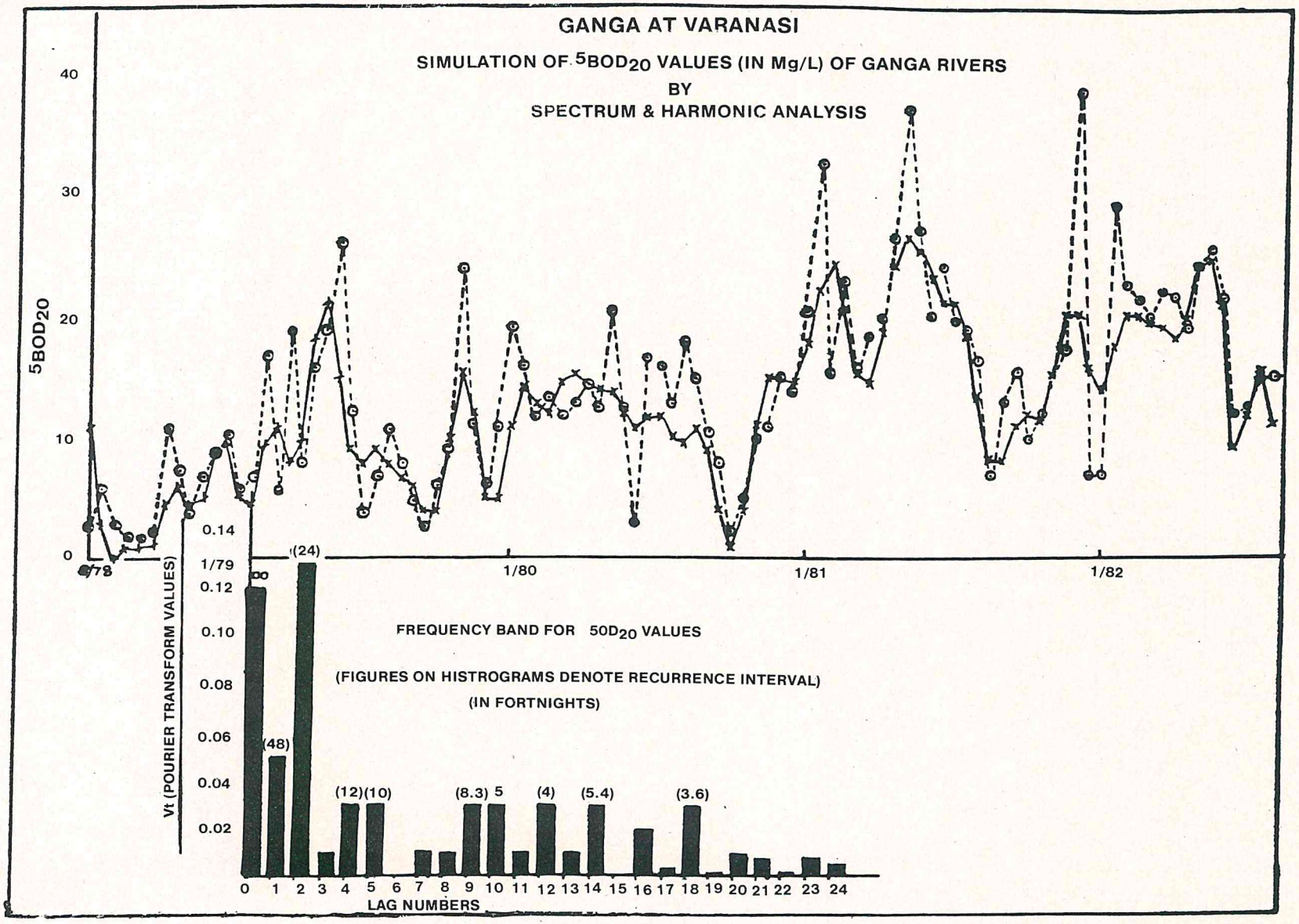

GANGA AT VARANASI
SIMULATION OF $^5BOD_{20}$ VALUES (IN Mg/L) OF GANGA RIVERS
BY
SPECTRUM & HARMONIC ANALYSIS
$^5BOD_{20}$
40
30
20
10
0
1/78
1/80
1/81
1/82
Vt (POURIER TRANSFORM VALUES)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
1/79
(24)
(48)
(12)(10)
(8.3) 5
(4)
(5.4)
(3.6)
FREQUENCY BAND FOR $^{50}D_{20}$ VALUES
(FIGURES ON HISTROGRAMS DENOTE RECURRENCE INTERVAL)
(IN FORTNIGHTS)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
LAG NUMBERS

Fig. 3.6.3

BIOCHEMICAL OXYGEN DEMAND & DISSOLVED OXYGEN BALANCE IN GANGA AROUND KANPUR

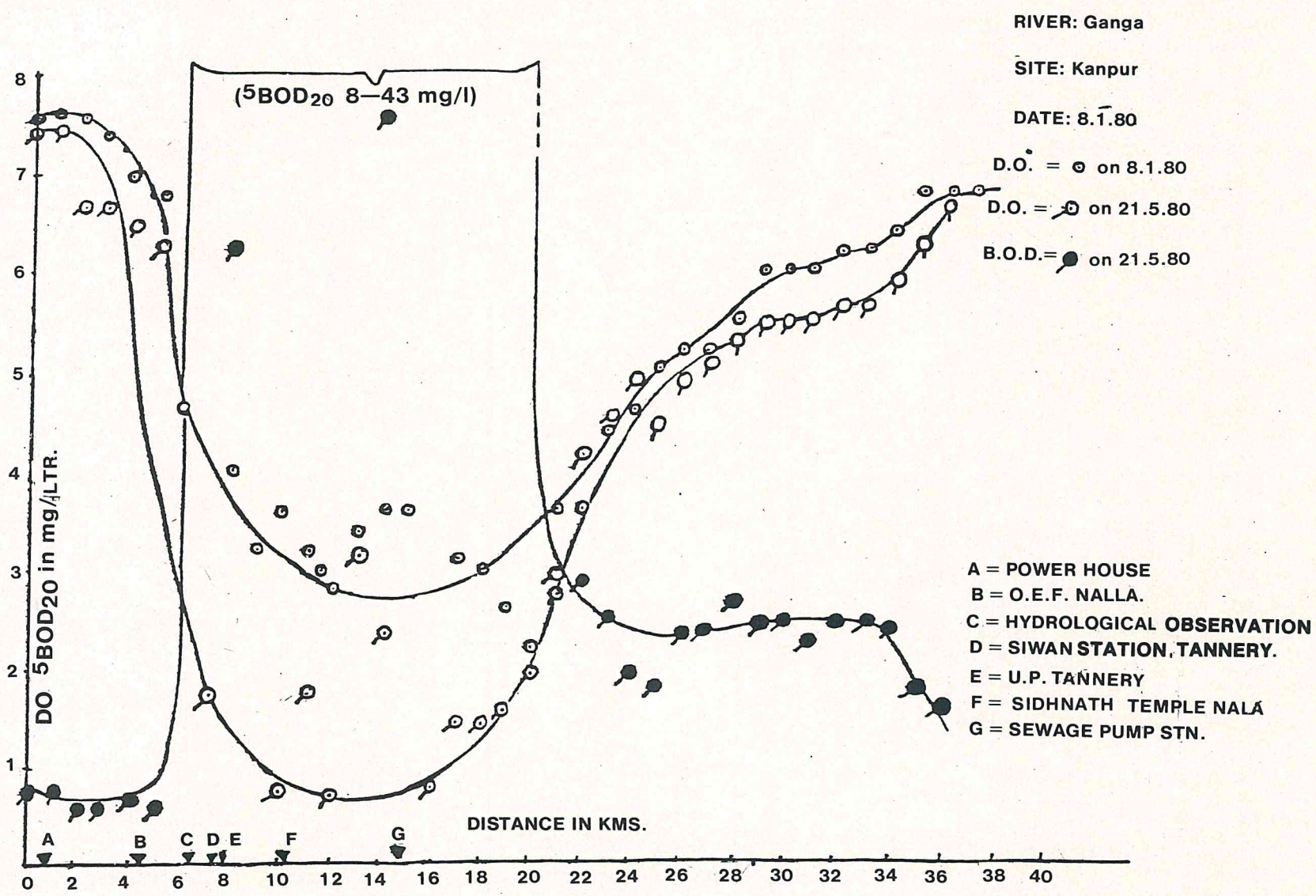


Fig. 3.7.1

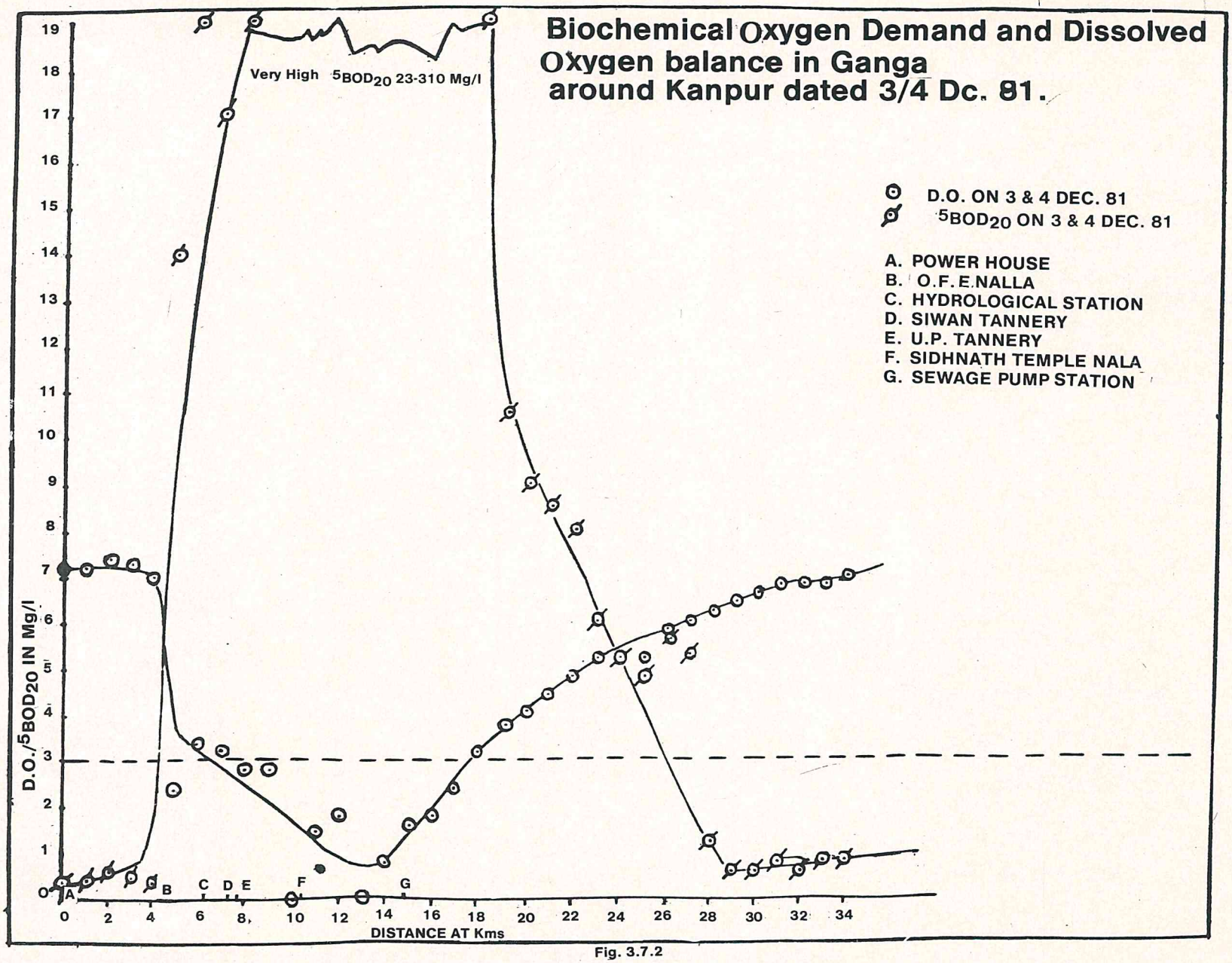

Biochemical Oxygen Demand and Dissolved Oxygen balance in Ganga around Kanpur dated 3/4 Dc. 81.
Very High $^5BOD_{20}$ 23-310 Mg/l
D.O. ON 3 & 4 DEC. 81
$^5BOD_{20}$ ON 3 & 4 DEC. 81
A. POWER HOUSE
B. O.F.E.NALLA
C. HYDROLOGICAL STATION
D. SIWAN TANNERY
E. U.P. TANNERY
F. SIDHNATH TEMPLE NALA
G. SEWAGE PUMP STATION
D.O./$^5BOD_{20}$ IN Mg/l
DISTANCE AT Kms

Fig. 3.7.2

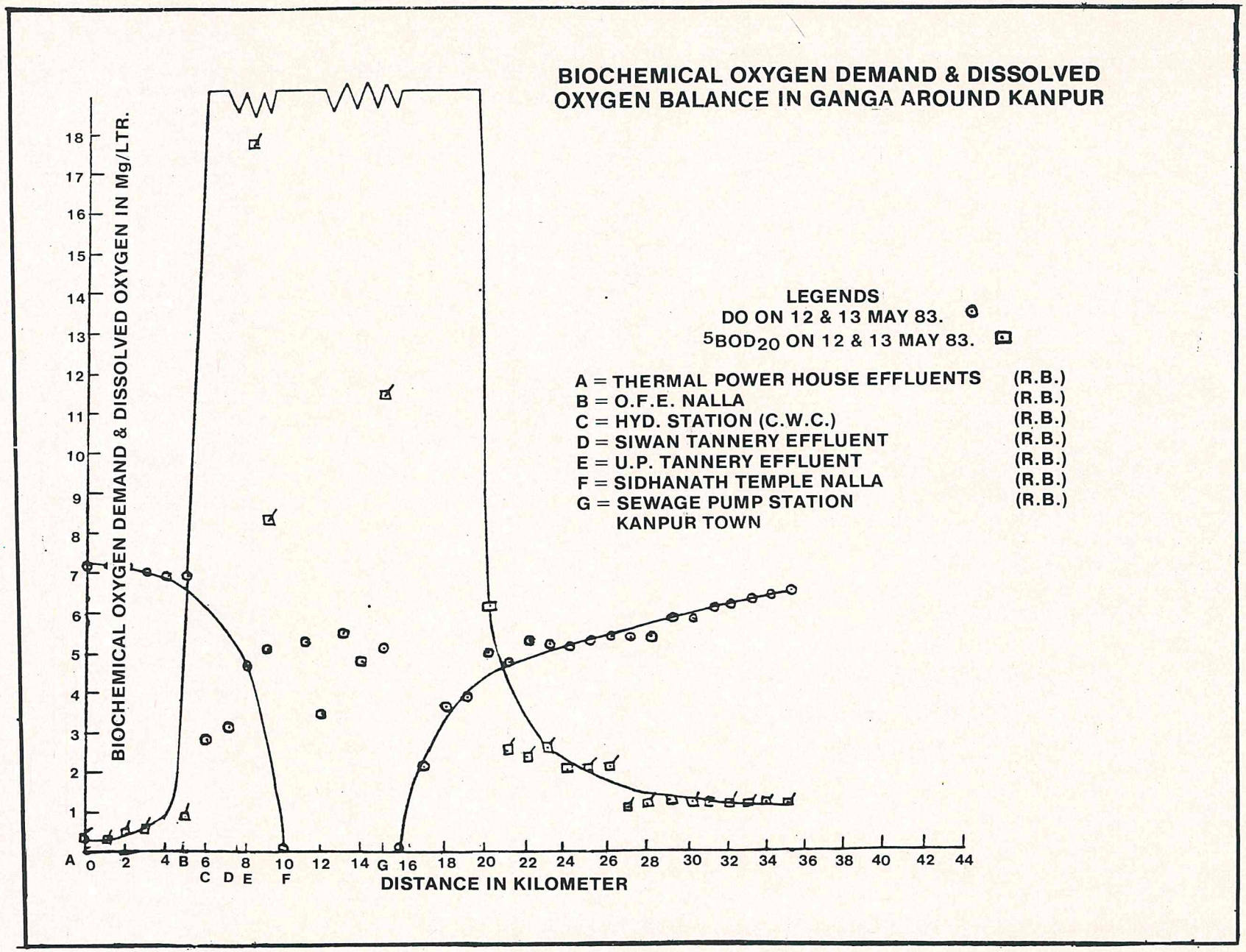

BIOCHEMICAL OXYGEN DEMAND & DISSOLVED OXYGEN BALANCE IN GANGA AROUND KANPUR
BIOCHEMICAL OXYGEN DEMAND & DISSOLVED OXYGEN IN Mg/LTR.
DISTANCE IN KILOMETER
LEGENDS
DO ON 12 & 13 MAY 83.
5BOD20 ON 12 & 13 MAY 83.
A = THERMAL POWER HOUSE EFFLUENTS (R.B.)
B = O.F.E. NALLA (R.B.)
C = HYD. STATION (C.W.C.) (R.B.)
D = SIWAN TANNERY EFFLUENT (R.B.)
E = U.P. TANNERY EFFLUENT (R.B.)
F = SIDHANATH TEMPLE NALLA (R.B.)
G = SEWAGE PUMP STATION KANPUR TOWN (R.B.)

Fig. 3.7.3

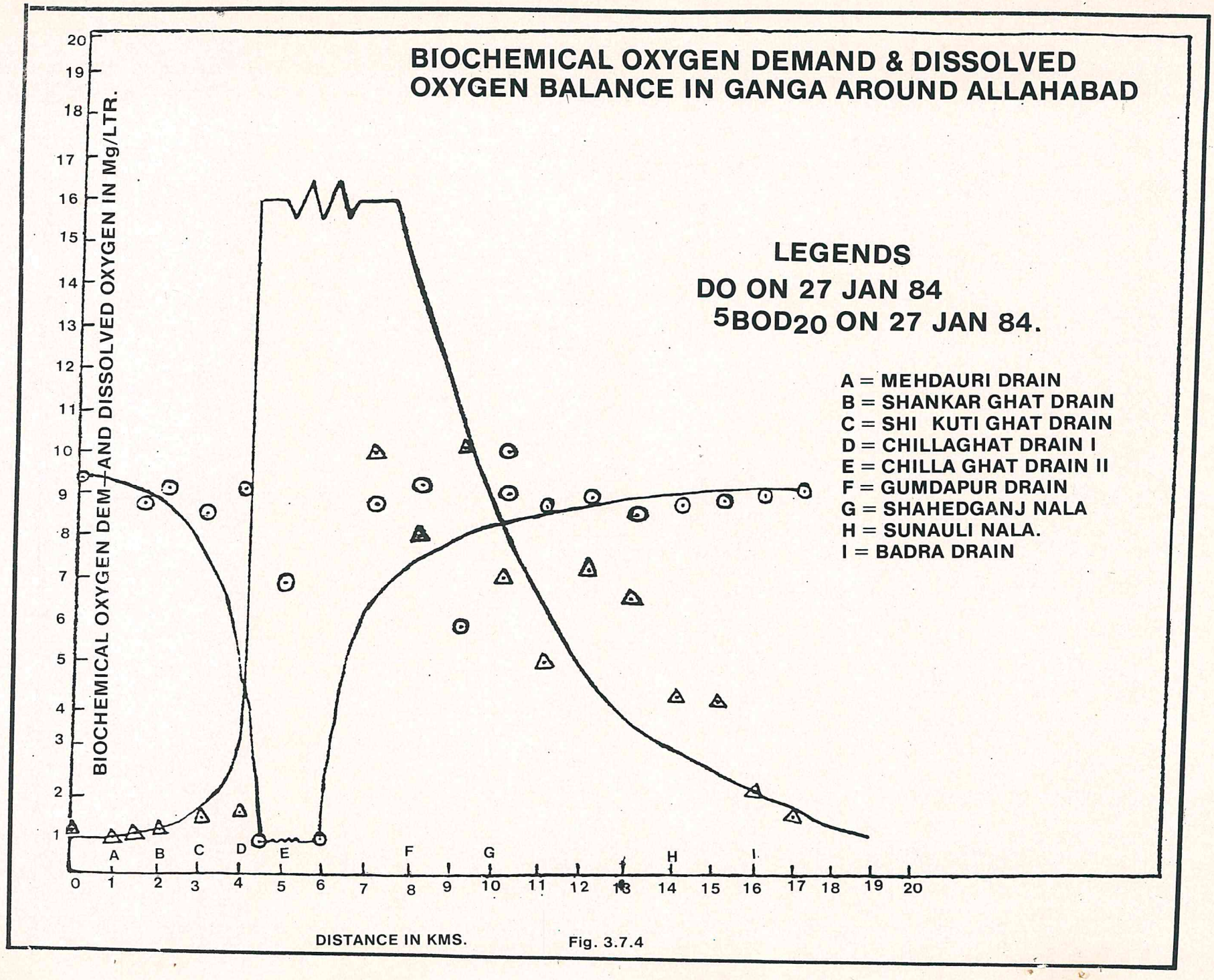

BIOCHEMICAL OXYGEN DEMAND & DISSOLVED OXYGEN BALANCE IN GANGA AROUND ALLAHABAD
BIOCHEMICAL OXYGEN DEM AND DISSOLVED OXYGEN IN Mg/LTR.
LEGENDS
DO ON 27 JAN 84
5BOD20 ON 27 JAN 84.
A = MEHDAURI DRAIN
B = SHANKAR GHAT DRAIN
C = SHI KUTI GHAT DRAIN
D = CHILLAGHAT DRAIN I
E = CHILLA GHAT DRAIN II
F = GUMDAPUR DRAIN
G = SHAHEDGANJ NALA
H = SUNAULI NALA.
I = BADRA DRAIN
DISTANCE IN KMS.

Fig. 3.7.4

Bio-Chemical Oxygen Demand and Dissolved oxygen balance in Ganga around Varanasi dated 31.12.80 and 26.6.81

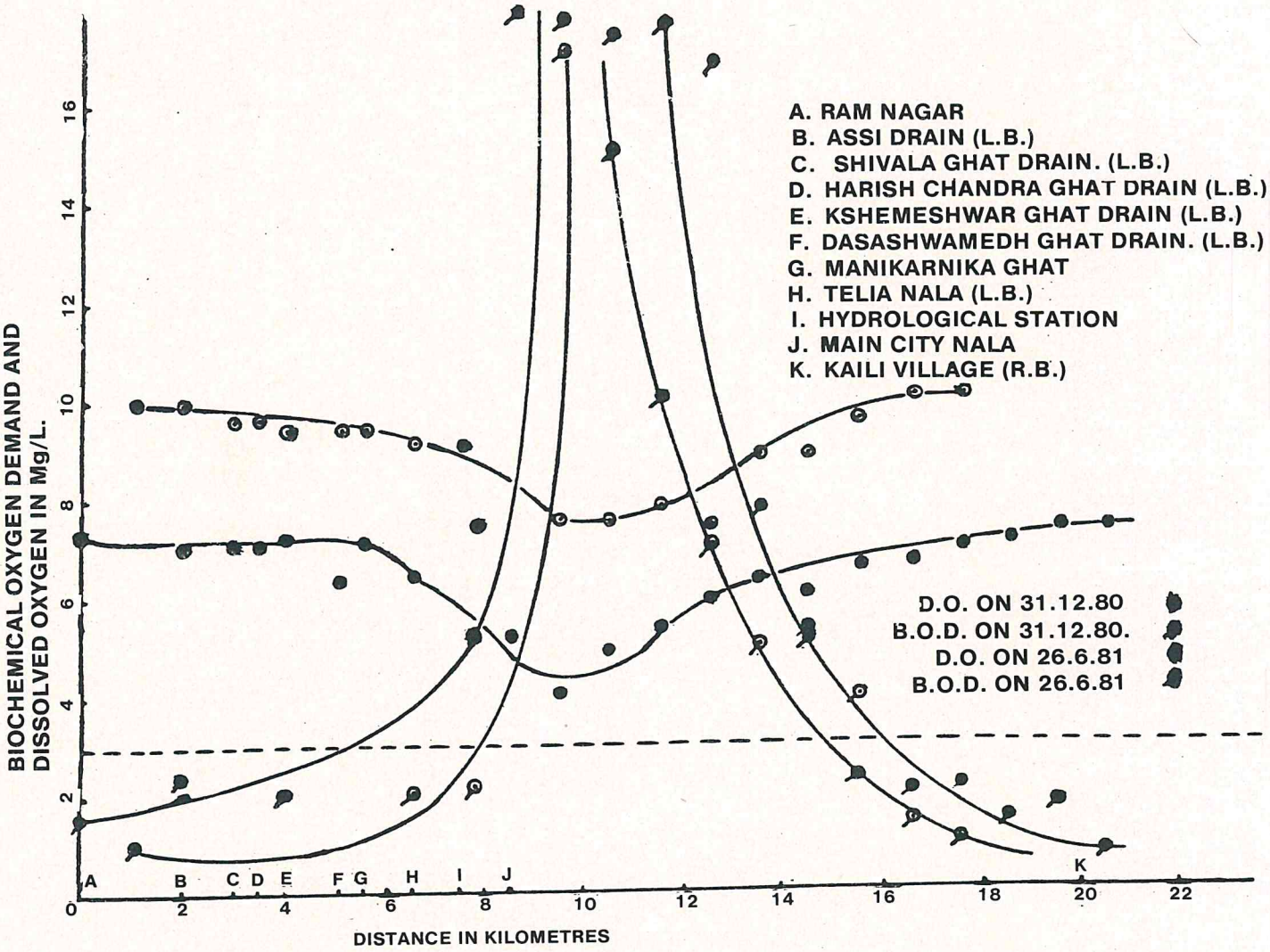


Fig. 3.7.6

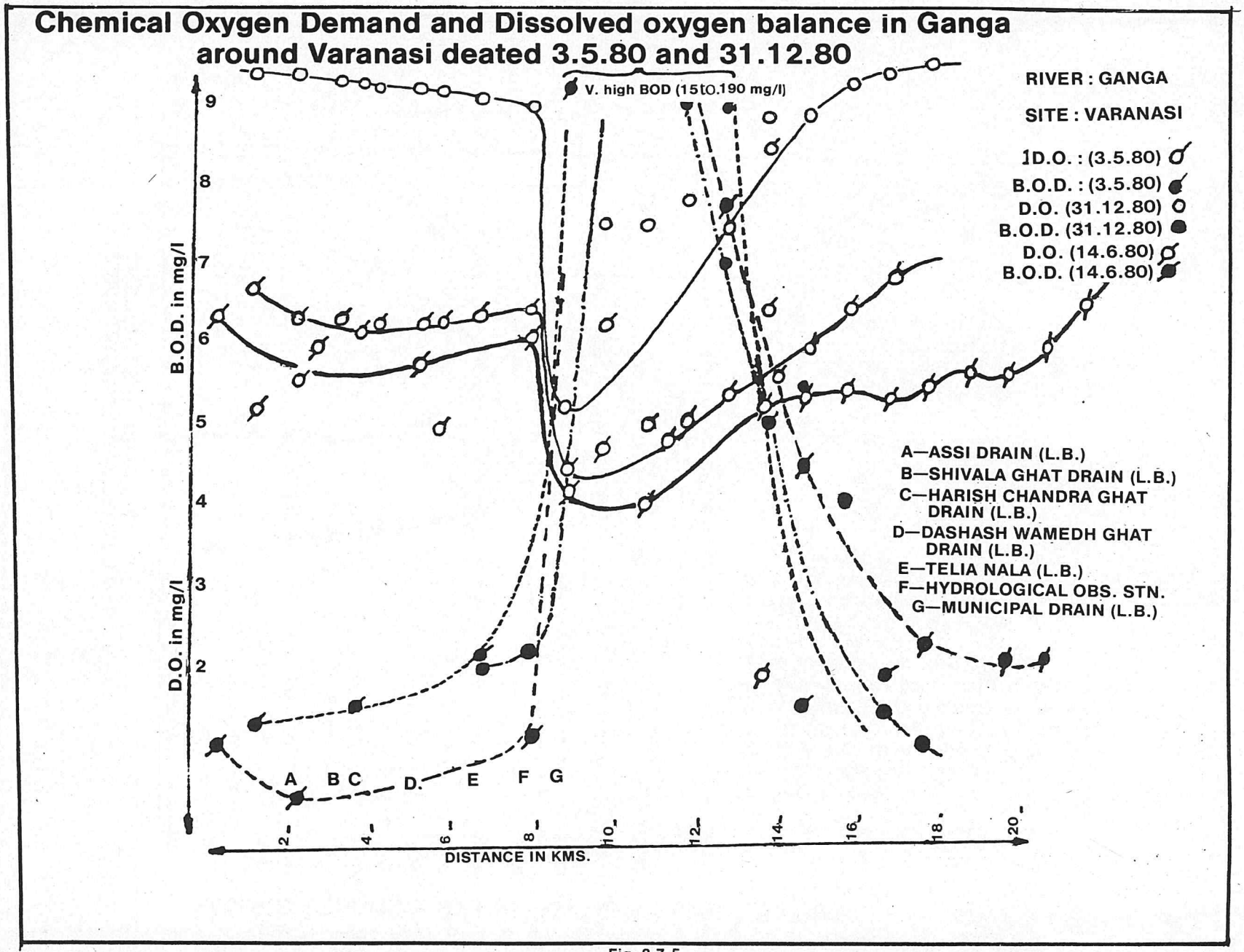

Chemical Oxygen Demand and Dissolved oxygen balance in Ganga around Varanasi deated 3.5.80 and 31.12.80
V. high BOD (150 to 190 mg/l)
RIVER : GANGA
SITE : VARANASI
D.O. : (3.5.80)
B.O.D. : (3.5.80)
D.O. (31.12.80)
B.O.D. (31.12.80)
D.O. (14.6.80)
B.O.D. (14.6.80)
A—ASSI DRAIN (L.B.)
B—SHIVALA GHAT DRAIN (L.B.)
C—HARISH CHANDRA GHAT DRAIN (L.B.)
D—DASHASH WAMEDH GHAT DRAIN (L.B.)
E—TELIA NALA (L.B.)
F—HYDROLOGICAL OBS. STN.
G—MUNICIPAL DRAIN (L.B.)
B.O.D. in mg/l
D.O. in mg/l
9
8
7
6
5
4
3
2
A B C D E F G
2
4
6
8
10
12
14
16
18
20
DISTANCE IN KMS.

Fig. 3.7.5

Biochemical oxygen Demand and Dissolved oxygen balance in Ganga around Patna dated 28.5.80 and 6.12.80.

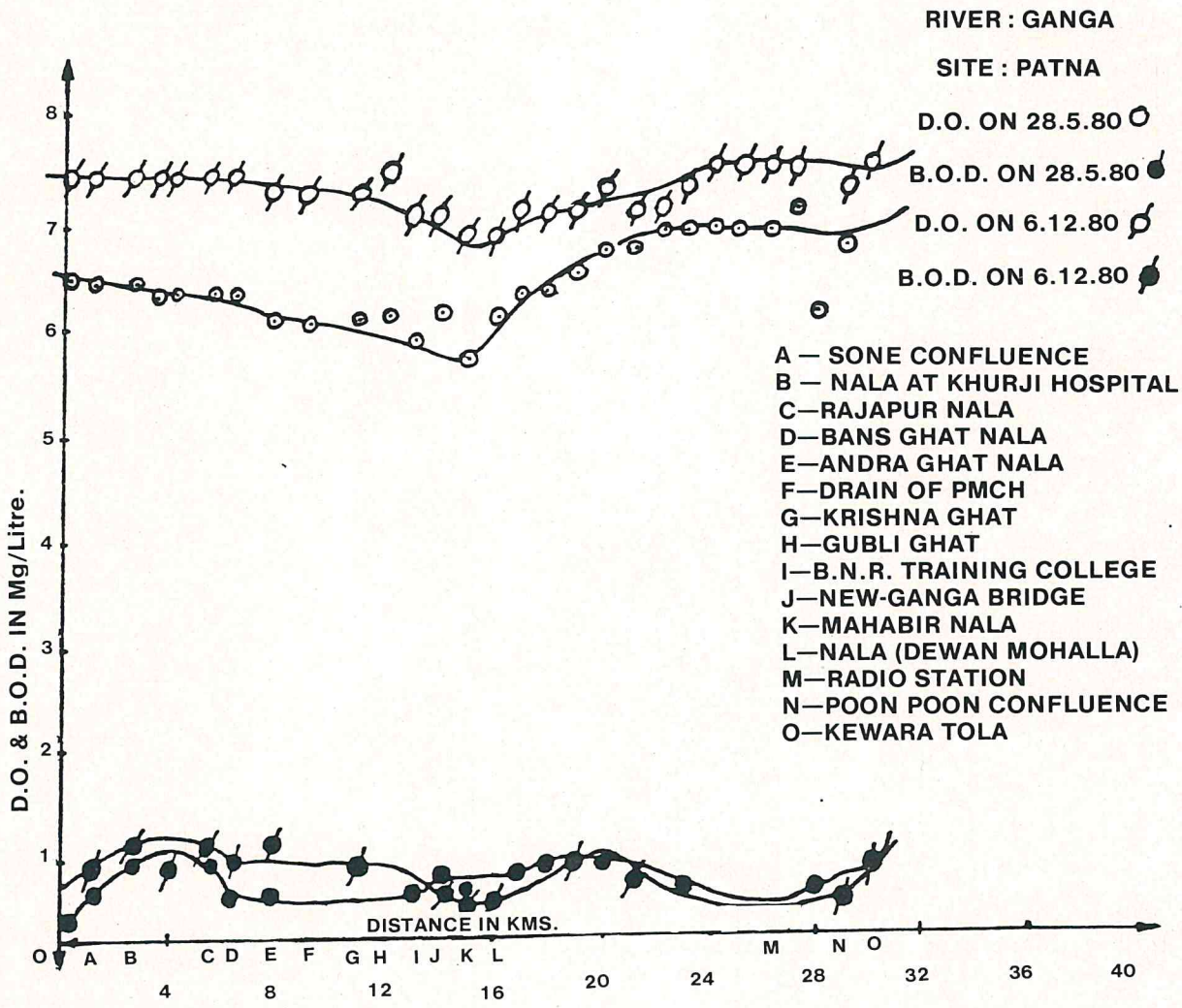


Fig. 3.7.8.

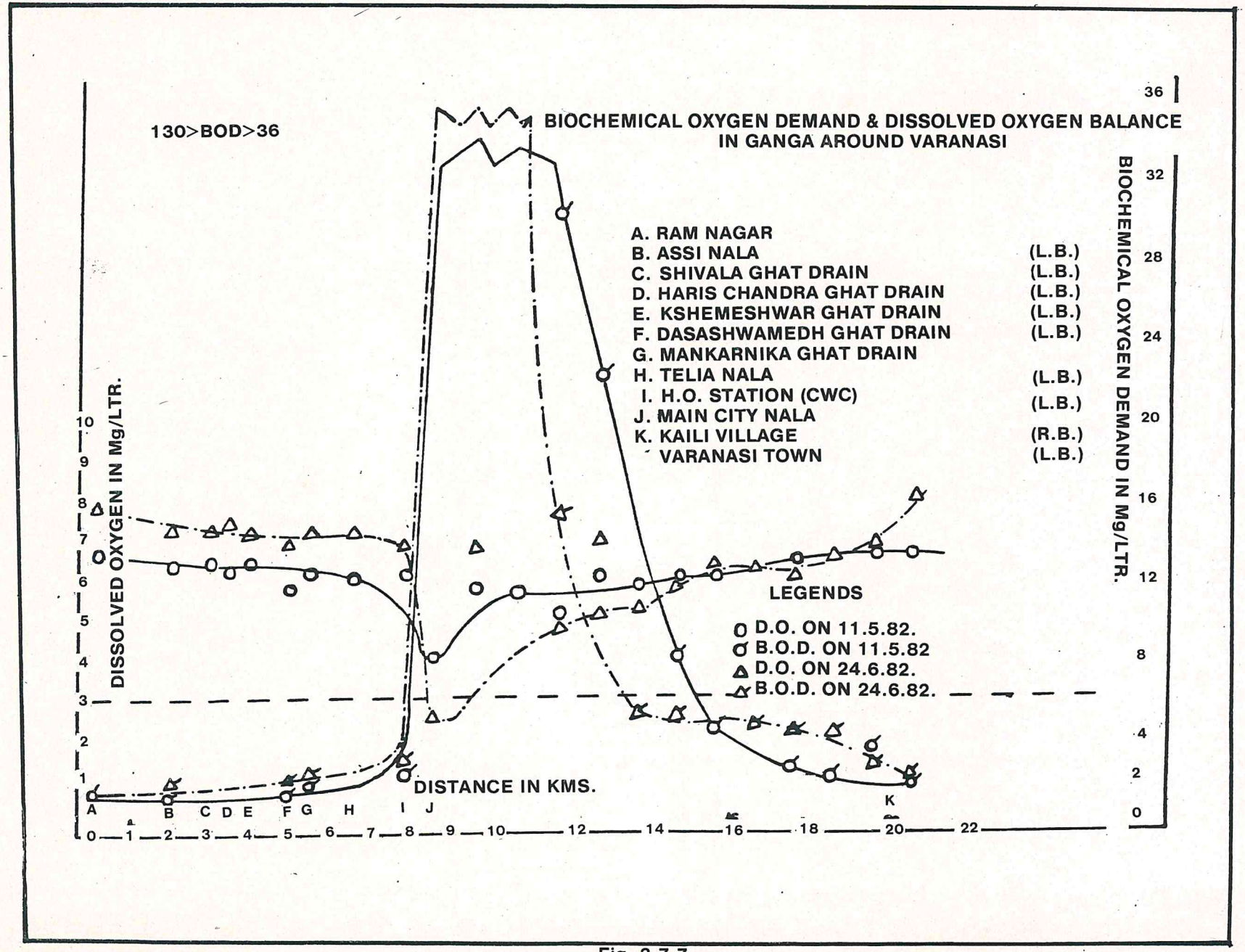

130>BOD>36
BIOCHEMICAL OXYGEN DEMAND & DISSOLVED OXYGEN BALANCE
IN GANGA AROUND VARANASI
A. RAM NAGAR
B. ASSI NALA (L.B.)
C. SHIVALA GHAT DRAIN (L.B.)
D. HARIS CHANDRA GHAT DRAIN (L.B.)
E. KSHEMESHWAR GHAT DRAIN (L.B.)
F. DASASHWAMEDH GHAT DRAIN (L.B.)
G. MANKARNIKA GHAT DRAIN
H. TELIA NALA (L.B.)
I. H.O. STATION (CWC) (L.B.)
J. MAIN CITY NALA
K. KAILI VILLAGE (R.B.)
VARANASI TOWN (L.B.)
LEGENDS
D.O. ON 11.5.82.
B.O.D. ON 11.5.82
D.O. ON 24.6.82.
B.O.D. ON 24.6.82.
DISSOLVED OXYGEN IN Mg/LTR.
BIOCHEMICAL OXYGEN DEMAND IN Mg/LTR.
DISTANCE IN KMS.
A B C D E F G H I J K
0 1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22
0 2 4 8 12 16 20 24 28 32 36

Fig. 3.7.7

Biochemical oxygen Demand and Dissolved oxygen balance in Ganga around Hathidah dated 20.11.80 and 28.1.81.

A. BATA TANNERY

B. MC. DOWELL DISTILLERY

C. RAIL AND ROAD BRIDGE

D. HYDROLOGICAL STATION

E. OIL REFINERY OUTFALL

D.O. ON 20.11.80
B.O.D. ON 20.11.80
D.O. ON 28.1.81
B.O.D. ON 28.1.81
D.O. ON 29.4.81
B.O.D. ON 29.4.81
D.O. ON 28.5.81
B.O.D. ON 28.5.81

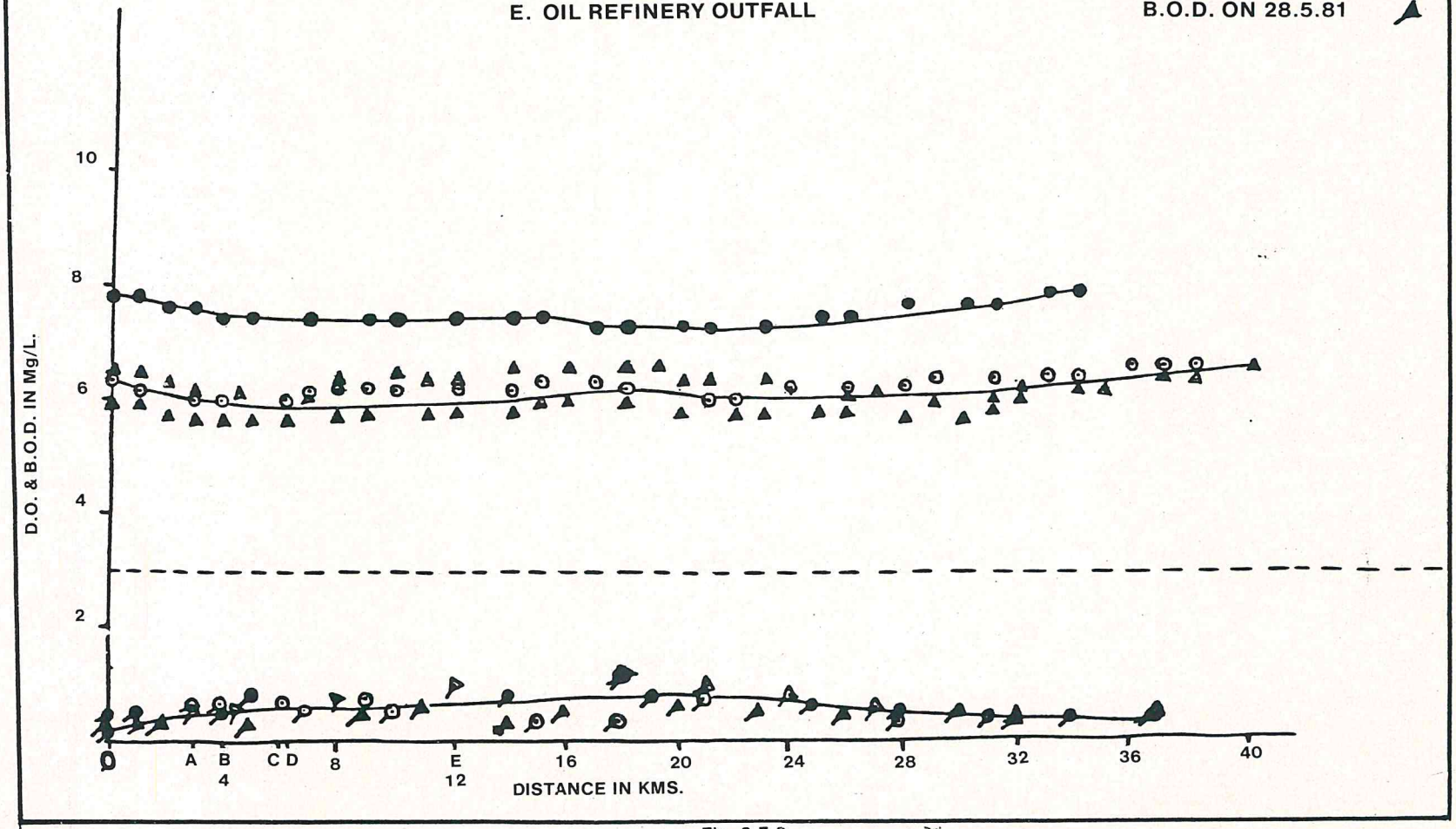


Fig. 3.7.9

Annex-I

LIST OF WATER QUALITY OBSERVATION SITES OPERATED BY CENTRAL WATER COMMISSION IN GANGA BASIN

Sl. No.	River/site	Date of start of observation		
		Water quality	D.O.	B.O.D.
(1)	(2)	(3)	(4)	(5)
1.	Alaknanda/Joshimath	15.8.72	*	*
2.	Alaknanda/Rudraprayag	17.9.77	*	*
3.	Bhagirathi/Tehri	21.8.71	1.9.83	*
4.	Bhagirathi/Deoprayag	16.11.74	8.9.83	*
5.	Ganga/Deoprayag	9.11.74	8.9.83	*
6.	Ganga/Rishikesh	20.10.71	22.9.80	*
7.	Ganga/Balawali	18.6.76	1.10.83	*
8.	Ganga/Rawalighat	15.6.76	1.9.83	*
9.	Yamuna/Kalanour	15.2.73	1.9.83	*
10.	Yamuna/Panipat	9/76	11.6.81	
11.	Yamuna/Delhi	5/76	3.12.79	22.9.80
12.	Yamuna/Sultanpur/Mohana	1.1.81	3.1.83	*
13.	Yamuna/Mathura	7/76	21.6.80	11.9.80
14.	Yamuna/Agra	10/76	11.5.79	21.8.80
15.	Yamuna/Etawah	1/72	1.10.80	*
16.	Yamuna/Auraiya	1.1.81	1.9.84	*
17.	Yamuna/Hamirpur	1.1.81	1.2.80	*
18.	Yamuna/Pratappur	1.1.81	2.8.82	*
19.	Hindon/Galeta	9/76	1.2.83	*
20.	Sind/Pachauli	1.1.81	*	*
21.	Sind/Seondha	11/78	22.9.80	*
22.	Rind/Kora	1.1.81	2.4.83	*
23.	Betwa/Rajghat	1.1.81	1.2.85	*
24.	Betwa/Sahijana	12.1.81	11.12.80	*
25.	Ken/Banda	11/78	1.5.81	*
26.	Tona/Tuini	26.6.76	*	*
27.	Giri/Yashwant Nagar	19.5.76	*	*
28.	Dhasan/Banda/Garroli	1.1.81/1.7.83	2.2.83	*
29.	Chambal/Kota	2.1.78	11.11.80	*
30.	Chambal/Dholpur	12/76	11.9.80	*
31.	Chambal/Udi	1/72	3.1.83	*
32.	Chambal/Tal	2.8.79	2.11.1982	*
33.	Kalisind/Barod	2.1.78	1.3.82	*
34.	Parwati/A.B.Rd. X-ing	16.12.76	2.4.83	*
35.	Parwati/Khatoli	5.5.76	1.5.85	*
36.	Banas/Baranwada	2.1.78	1.2.83	*
37.	Sipra/Mahidpur	1.1.77	1.8.83	*
38.	Parwan/Aklera	15.11.76	1.10.83	*
39.	Parwan/Sangod	1.1.78	1.2.86	*
40.	Ganga/Garmukteshwar	30.5.76	1.1.82	*
41.	Ganga/Kachala Bridge	8.10.74	*	*
42.	Ganga/Fatehgarh	2.7.76	1.10.81	*

(Contd.)

1	2	3	4	5
43.	Ganga/Ankin Ghat	20.12.72	8/80	*
44.	Ganga/Kanpur	7.10.76	16.1.78	16.1.78
45.	Ganga/Bithaura	1.6.76	7/80	*
46.	Ganga/Sahzadpur	1963	31.8.79	*
47.	Ganga/Allahabad	1.1.72	30.1.79	26.7.79
48.	Ganga/Mirzapur	1.6.76	2.11.79	*
49.	Ganga/Varanasi	3.9.63	16.10.75	16.10.75
50.	Ganga/Buxar	1.2.67	*	*
51.	Ganga/Patna	1.5.67	20.9.78	20.9.78
52.	Ganga/Hathidah	17.4.67	18.9.78	18.9.78
53.	Ganga/Azamabad	16.2.67	6/81	*
54.	Ramganga/Moradabad	22.9.76	1.5.81	*
55.	Ramganga/Bareily	25.1.74	11.3.80	11.3.80
56.	Ramganga/Zirarahimpur	17.8.65	1.1.80	*
57.	Ramganga/Thal	27.7.76	*	*
58.	Kosi/Rampur	11.9.76	*	*
59.	Deoha/Husepur	15.11.68	*	*
60.	Gomti/Nimsar	15.1.77	*	*
61.	Gomti/Lucknow	2.7.73	4.1.79	4.1.79
62.	Gomti/Jaunpur	2.4.78	6.6.79	*
63.	Gomti/Maighat	3.9.63	9.11.79	*
64.	Sai/Raibareily	6.8.73	2/79	*
65.	Ghaghra/Katerniaghat	9/64	*	*
66.	Ghaghra/Elgin Bridge	13.1.64	9/79	*
67.	Ghaghra/Aydoya	1.12.71	1.6.79	1.6.79
68.	Ghaghra/Turitpar	3.10.63	30.1.80	*
69.	Sharda/Paliakalan	8.1.64	1/79	*
70.	Kwano/Basti	16.2.66	22.1.82	*
71.	Rapti/Balrampur	1.9.70	1.11.80	*
72.	Rapti/Rigauli	16.7.76	*	*
73.	Rapti/Birdghat	24.8.63	12.1.79	*
74.	Rapti/Bhinga	1.7.75	*	*
75.	Burhi Rapti/Mucharawaghat	10.7.76	*	*
76.	Little Gandak/Bhatparani	15.2.66	*	*
77.	Tons/Satna	1.11.80	*	*
78.	Son/Phaphund	1.11.80	*	*
79.	Sone/Kuldabridge	31.7.86	*	*
80.	Sone/Japla	1.10.76	*	*
81.	Sone/Koelwar	13.8.63	2.1.80	*
82.	Rihand/Sone/Chopan	1.9.63	27.2.79	*
83.	Karamnasa/Karamnasa Rly. Stn.	1.1.72	10.8.79	*
84.	Gopad/Jhokoo	1.11.80	*	*
85.	Kanhar/Kota	1.6.76	22.9.79	*
86.	North Koel/Mohd. Ganj	1.1.77	*	*
87.	Punpun/Sripalpur	16.8.76	*	*
88.	Kiul/Lakhisarai	15.1.77	*	*
89.	Palgu/Gaya	15.9.76	9/78	*

(Contd.)

1	2	3	4	5
90.	Gandak/Tribeni	16.7.63	*	*
91.	Gandak/Dumariaghat	1.9.79	*	*
92.	Gandak/Lalganj	1963	3.10.79	*
93.	Burhi Gandak/Chanpatia	16.8.63	*	*
94.	Burhi Gandak/Sikanderpur	19.7.63	*	*
95.	Burhi Gandak/Rusera	17.4.67	*	*
96.	Bagmati/Dhang Bridge	1.10.76	*	*
97.	Bagmati/Hayaghat	1.8.63	18.3.80	*
98.	Kosidhar/Pipra	15.2.77	*	*
99.	Kosi/Baltara	15.7.63	21.2.80	*
100.	Adhwara/Kamtaul	15.1.77	*	*
101.	Kamla/Jai Nagar	1.8.76	*	*
102.	Kamla/Jhanjharpur	1.1.63 (1963)	*	*
103	Kosidhar/Banmanki	1.1.77	*	*
104.	Sorju/Gaighat	1.6.66	*	*
105.	Kali Nadi/Bewar	16 1.74	*	*
106.	Tons/Meja Road	14.7.76	*	*
107.	Bhairab/Islampur	1.6.77	*	*
108.	Feeder Canal/Farakka	1.9.75	*	*
109.	Ganga/Farakka	31.8.64	1.5.79	*
110	Mahananda/Siliguri	2.1.78	*	*
111.	Mahananda/Sonarpurhat	2.1.78	*	*
112.	Mahananda/Labha	16.1.68	*	*
113.	Mahananda/English Bazar	3.8.64	11.1.80	*
114.	Padma/Dayarampur	30.12.64	*	*
115.	Ajoy/Nutan Hat	24.8.64	*	*
116.	Ajoy/Jamtara	1.3.68	*	*
117.	Bhagirathi/Berhampore	18.7.68	1.8.79	*
118.	Bhagirathi/Purbasthali	31.8.64	*	*
119.	Bhagirathi/Kalna (ebb)	20.8.64	16.7.79	*
120.	Bhagirathi/Kalna (flow)	31.8.64	16.7.79	*
121.	Churni/Hanskali	1.7.77	*	*
122.	Jalangi/Chapra	1.5.68	*	*

* Observations are not carried out

Annex II

LIST OF POLLUTION MONITORING SITES

Sl.No.	River/Site
1.	Ganga/Rishikesh
2.	Ganga/Garhmukteshwar
3.	Ganga/Fatehgarh
4.	Ganga/Kanpur
5.	Ganga/Allahabad
6.	Ganga/Mirzapur
7.	Ganga/Varanasi
8.	Ganga/Patna
9.	Ganga/Hathidah
10.	Ganga/Farakka
11.	Yamuna/Panipat
12.	Yamuna/Delhi
13.	Yamuna/Mathura
14.	Yamuna/Agra
15.	Yamuna/Etawah
16.	Yamuna/Pratappur
17.	Gomti/Lucknow
18.	Gomti/Jaunpur
19.	Sai/Rae-Bareilly
20.	Rapti/Balrampur
21.	Rapti/Birdghat
22.	Ghaghra/Elgin Bridge
23.	Ghaghra/Ayodhya
24.	Ghaghra/Turtipar
25.	Sone/Chopan
26.	Sone/Koelwar
27.	Ramganga/Moradabad
28.	Ramganga/Bareilly
29.	Ramganga/Zira Rahimpur
30.	Chambal/Kota
31.	Chambal/Dholpur
32.	Sind/Seondha
33.	Ken/Banda
34.	Betwa/Sahizna
35.	Gandak/Lalganj
36.	Burhi Gandak/Russera
37.	Bagmati/Hayaghat
38.	Kosi/Baltara
39.	Mahananda/English Bazar
40.	Bhagirathi/Berhampur
41.	Bhagirathi/Kalna (Ebb)
42.	Bhagirathi/Kalna (Flow)

Annex III

LIST OF BOD SITES

Sl. No.	River/Site
1.	Ganga/Kanpur
2.	Ganga/Allahabad
3.	Ganga/Varanasi
4.	Ganga/Patna
5.	Ganga/Hathidah
6.	Yamuna/Delhi
7.	Yamuna/Mathura
8.	Yamuna/Agra
9.	Gomti/Lucknow
10.	Gogra/Ayodhya
11.	Ramganga/Bareilly

Annex IV

TYPICAL OUTFIT REQUIRED FOR WATER QUALITY SAMPLING

Equipment

1. Pneumatic water level recorder.
2. Motor Launch/powered boat (120x2 HP) (45-90 HP)
3. Set of Staff gauges on both banks of the river on the demarcated section line and two sets of slope gauges.
4. Pivot point layout on both the banks for determining the position of boat in the stream.
5. Muste type bench mark connected with GTS datum.
6. Self recording rain gauge, max-min Thermo meter.
7. Survey instruments like Engineers level, theodolite, Sextant etc.
8. Hoisting appliances including A-Crane, winches, gauging reel etc.
9. Echo sounder/log line for measurement of depths.
10. USGS—Moving boat equipment for quick measurement of river discharges.
11. Rated velocity meters propeller type/cup type.
12. Point integrating and depth integrating sediment samplers like L-80 Turbide sonde sampler, AOTTS self integrating sampler, USD-49, Punjab bottle sampler.
13. Bedmaterial and bed load samplers like USBM-54, Pur is Scoop sampler and Russian bed load sampler.
14. Water Quality sampler—point integrating bottle type, Dissolved Oxygen sampler for shallow and deep sampling; Plankton sampler and grap samplers.
15. Insitu water quality moniters for DO, Sp. Conductivity, Temperature, and PH.
16. Water Quality sample transportation Kit, ice boxes etc.
17. Field laboratory (Level I) for insitu testing of sulphides, Dissolved Oxygen, sediment analysis.

Staff at Field Stations

1. Junior Engineer (Civil)	1
2. Research Asstt (Scientist)	1
3. Launch Sarang	1
4. Craft driver	1
5. Greaser	1
6. Pilot	1
7. Khalasis	8

Note: 1. This typical outfit is in usage at most of the water quality monitoring stations.

Note: 2. Besides water quality survey, the staff/equipment are used for hydrological observations conducted at these stations.

Annex V

RECOMMENDATION FOR SAMPLING AND PRESERVATION OF SAMPLES ACCORDING TO MEASUREMENT

(after U.S. Environment production Agency)

Measurement	Vol. Req. (ml)	Container	Preservative	Holding Time (5)
Acidity	100	P, G (1)	Cool, 4°C	24 Hrs
Alkalinity	100	P, G	Cool, 4°C	24 Hrs.
Arsenic	100	P, G	HNO_3 to pH<2	6 Mos.
BOD	1000	P, G	Cool, 4°C	6 Hrs. (2)
Bromide	100	P, G	Cool 4°C	24 Hrs.
COD	50	P, G	H_2SO_4 to pH<2	7 Days
Chloride	50	P, G	None Req.	7 Days
Chlorine Req.	50	P, G	Det. on site	No Holding
Color	50	P, G	Cool, 4°C	24 Hrs.
Cyanides	500	P, G	Cool, 4°C NaOH to pH 12	24 Hrs.
Dissolved Oxygen				
Probe	300	G only	Det. on site	No Holding
Winkler	300	G only	Fix on site	4-8 Hours
Fluoride	300	P,G	Cool, 4°C	7 Days
Hardness	100	P,G	Cool, 4°C HNO_3 to pH<2	7 Days.
Iodide	100	P,G	Cool, 4°C	24 Hrs.
MBAS	250	P,G	Cool, 4°C	24 Hrs.
Metals				
Dissolved	200	P,G	Filter on site HNO_3 to pH<2	6 Mos.
Suspended			Filter on site	6 Mos.
Total	100		HNO_3 to pH<2	6 Mos.
Mercury				
Dissolved	100	P,G	Filter HNO_3 to pH<2	38 Days (Glass) 13 Days (Hard Plastic)
Total	100	P,G	HNO_3 to pH<2	38 Days (Glass) 13 Days (Hard Plastic)
Nitrogen				
Ammonia	400	P,G	Cool, 4°C H_2SO_4 to pH>2	24 Hrs. (3)
Kjeldahl, total	500	P,G	Cool, 4°C H_2SO_4 to pH<2	7 Days
Nitrate	100	P,G	Cool, 4°C H_2SO_4 to pH<2	24 Hrs. (3)
Nitrite	50	P,G	Cool, 4°C	24 Hrs (3)
NTA	50	P,G	Cool, 4°C	24 Hrs.
Oil & Grease	1000	G only	Cool, 4°C H_2SO_4 or HCl to pH<2	24 Hrs.

(Contd.)

1	2	3	4	5
Organic Carbon	25	P,G	Cool, 4°C H_2SO_4 to pH<2	24 Hrs.
pH	25	P,G	Cool, 4°C Det. on site	6 Hrs. (2)
Phenolics	500	G only	Cool, 4°C H_3PO_4 to pH<4 1.0 g $CuSO_4$/1	24 Hrs.
Phosphorus Ortho phosphate,	50	P,G	Filter on site Cool, 4°C	24 Hrs. (3)
Dissolved Hydrolyzable	50	P,G	Cool, 4°C H_2SO_4 to pH<2	24 Hrs. (3)
Total	50	P,G	Cool, 4°C	7 Days
Total Dissolved	50	P,G	Filter on site Cool, 4°C	24 Hrs. (3)
Residue				
Filterable	100	P,G	Cool 4°C	7 Days
Non-Filterable	100	P,G	Cool, 4°C	7 Days
Total	100	P,G	Cool, 4°C	7 Days
Volatile	100	P,G	Cool, 4°C	7 Days
Settleable Matter	1000	P,G	None Req.	24 Hrs.
Selenium	50	P,G	HNO_3 to pH<2	6 Mos.
Silica	50	P only	Cool, 4°C	7 Days
Specific Conductance	100	P,G	Cool, 4°C	24 Hrs. (4)
Sulfate	50	P,G	Cool, 4°C	7 Days
Sulfide	500	P,G	2 ml zinc acetate	24 Hrs.
Sulfite	50	P,G	Det. on site	No Holding
Temperature	1000	P,G	Det. on site	No Holding
Threshold Odor	200	G only	Cool, 4°C	24 Hrs.
Turbidity	100	P,G	Cool, 4°C	7 Days

1. Plastic or Glass
2. If samples cannot be returned to the laboratory in less than 6 hours and holding time exceeds this limit, the final reported data should indicate the actual holding time.
3. Mercuric chloride may be used as an alternate preservative at a concentration of 40 mg/l, especially a longer holding time is required. However, the use of mercuric chloride is discouraged whenever possible.
4. If the sample is stabilized by cooling, it should be warmed to 25°C for reading, or temperature correction made and results reported at 25°C.
5. It has been shown that samples properly preserved may be held for extended periods beyond the recommended holding time.

Annex—VI

FORMATS FOR COMPILATION OF DATA

FORMAT-1

GOVT. OF INDIA
C.W.C.
W.R. & F.F. DIVISION
CHEMICAL ANALYSIS WATER SAMPLES

River: Ganga

RIVER WELL WATER _____ **SITE: VARANASI** _____ **MONTH: JUNE** _____ **YEAR: 1986** _____

Sl.No.	Lab. No.	Date of collection	Date of Analysis	S.S.W.L. Disch. in M3/Sec.	Total dissolved salts conductivity	pH	Parts per Million Cations SiO_2	Fe_2O_3 + Al_2O_3	Ca	Mg	Na	K	SO_4	CO_2	HCO_3	Cl	NO_2	F	PO_4	SiO_2	Anions Fe_2O_3 + Al_2O_3	Cations & Anions Expressed as/E.P.M Ca	Mg	Na	K	SO_4	CO_3	HCO_3	Cl	NO_3	F	PO_4	Boron in P.P.M.	Hardness No. (Ca-I-Mg)	$\frac{NaX100}{CO+Mg+Na+K}$	Remarks
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	4337	2.6.86	6.6.86	219.42	409/640	8.26	4.60	NIL	32.64	22.19	50.00	4.00	38.00	19.20	273.28	44.00	1.07	0.12	0.03	0.15	NIL	1.63	1.82	2.17	0.10	0.79	0.64	4.48	1.24	0.023	1.65	1.67	NIL	173.11	37.96	River Water Sample
2	4338	2.6.86	to	60680	1338/2091	7.70	9.30	NIL	53.32	63.93	68.00	200.00	53.00	14.40	480.68	232.00	0.15	0.20	0.02	0.31	NIL	2.66	5.26	2.96	5.13	1.10	0.48	7.88	6.54	0.003	1.49	0.44	0.23	396.91	18.49	Sub-Soil water Sample

Entered by :

Checked by :

Executive Engineer

W.R. & F.F. DIVISION

H.P.E.W.-GDC/65 (560)—2.6.81-20 Pads

FORMAT-2

GOVT. OF INDIA

Central Water Commission W.R. & F.F. Division, Varanasi.

PHYSICO-CHEMICAL CHARACTERISTICS OF RIVER WATER SAMPLES COLLECTED UNDER N.C.S.T. PROGRAMME

—: POLLUTION STUDY :—

Sl.No.	Lab No.	River/ Stream	Site	Location	Date of Sampling	Time of Sampling	Weather on the Day	Colour of River Water	Odour of River Water	Temp °C	pH	Discharge in M³/Sec.	River Mean Water Level	S.S.W.L.	Remarks
1.	—	Gomti	Janupur	500 km U/S	1/12/86	10.30	Clear	Light Brown	Odour less	22.00	7	101.89	67.850	69.920	
2.	—	Gomti	Jaunpur	8 km D/S	—do—	12.15	—do—	—do—	—do—	—do—	—do—	—do—	— do —	— do —	

Note : All the Water samples collected from main flowing portion of the river.

FORMAT-3

RESULTS OF EXPERIMENTS ON THE BIO-CHEMICAL OXYGEN DEMAND OF RIVER WATER SAMPLES

River-Ganga **Site-Varanasi**

Date	Location		Time in hrs.	Depth m	Velocity in m/Sec.	Temp. °C	Day's disch. at C/L m^3/sec.	Dissolved Oxygen in Mg/lit.			B.O.D. in Mg/lit.	% dilution	Remarks Sampling depth
	L-Sec.	X-Sec.						D.O. at site	Before incubation	After incubation			
1	2	3	4	5	6	7	8	9	10	11	12		13
1.6.85	U/S	¼	8.30	3.68	0.215	31.5	155.28	7.52	5.60	4.40	1.20		
		½	9.50	4.29	0.146	32.0		7.68	6.40	4.70	1.70		
		¾	10.40	4.78	0.160	32.5		7.40	6.10	5.10	1.00		
	D/S	¼	11.25	4.32	0.106	32.5		6.42	7.50	0.50	12.00	50.0	1m below surface
		½	11.45	4.00	0.104	32.5		7.32	5.50	4.50	1.00		
		¾	12.15	3.48	0.104	32.5		7.59	5.90	4.60	1.30		
11.6.85	U/S	¼	8.40	3.0	0.191	32.0	160.29	7.50	6.10	4.70	1.40		
		½	9.20	4.63	0.148	32.0		7.66	6.00	4.90	1.10		
		¾	10.00	2.96	0.136	32.0		7.42	6.30	5.10	1.20		
	D/S	¼	12.20	3.21	0.102	32.0		6.38	7.80	3.60	8.40	50.0	
		½	12.35	3.37	0.100	32.0		7.28	5.00	4.60	1.40		
		¾	12.50	4.44	0.104	32.0		7.40	6.30	4.90	1.40		
21.6.85	U/S	¼	6.35	3.90	0.250	32.0	168.08	8.02	7.30	5.10	2.20		
		½	7.15	4.48	0.163	32.0		7.64	7.00	5.80	1.20		
		¾	8.30	5.00	0.205	32.0		7.83	7.00	5.60	1.40		
	D/S	¼	10.00	3.10	0.098	32.0		6.11	6.80	4.00	2.80		
		½	10.30	3.80	0.106	32.0		7.26	7.00	5.50	1.50		
		¾	11.00	4.30	0.109	32.0		7.06	6.90	5.70	1.20		

Entered by :

Checked by :

Executive Engineer
Central Water Commission
WR & FFD, Varanasi

FORMAT-4

LONGITUDINAL SURVEY OF D.O. AND B.O.D. OF RIVER WATERS

DATE 2.6.86 – 3.6.86 DISCHARGE. 291.42 m3/sec. – 307.85 m³/sec

RIVER-GANGA SITE-VARANASI

S. No.	Distance in Km	Location	Time in Hrs	Depth in M	Velocity M/sec	Temp. °C	River Water Colour	Weather of the Day	Presence of weeds	Dissolve Oxygen mg/l			$^5BOD_{20}$ mg/l	Dilution Factor
										Insitu ppm	Before Incubation	After Incubation		
1.	0.0	Ramnagar	1030	3.900	0.462	33.0	Clear	Clear	Yes	8.7	8.5	7.2	1.30	Nil
2.	1.0	Assighat	1045	2.180	0.316	33.0	Greyish	"	No	7.0	8.6.	6.1	3.13	80%
3.	2.0	Shivalaghat	1100	1.640	0.281	33.0	"	"	No	6.4	8.6	5.9	3.38	"
4.	3.0	Harischandraghat	1120	3.000	0.190	33.5	"	"	Yes	6.2	8.6	4.8	4.75	"
5.	4.0	Kshemeshwarghat	1140	1.980	0.170	33.5	"	"	No	6.5	8.6	4.3	5.38	"
6.	5.0	Dashashwamedh Ghat	1200	2.420	0.759	33.5	"	"	No	5.9	8.6	4.6	5.00	"
7.	5.5	Manikarnikaghat Ghat	1230	2.100	0.162	33.5	"	"	No	5.4	8.6	4.1	5.63	"
8.	6.0	Golaghat	1300	2.400	0.163	33.5	"	"	No	6.2	8.6	3.9	5.88	"
9.	6.5	Tellia Nallah	1330	2.590	0.154	33.5	"	"	No	5.7	8.6	3.0	7.50	'
10.	7.5	Hydrological Observation Station	1400	1.400	0.208	34.0	Clear	"	No	5.2	8.6	4.7	4.88	"
11.	8.0	Main City Nallah	1430	1.720	0.311	34.0	Blackish	"	No	1.5	8.6	5.1	350.00	1%
12.	8.5		945	1.460	0.317	33.5	"	"	No	2.2	8.7	5.9	280.00	1%
13.	9.0	Confluence of Varuna	1015	1.970	0.718	33.5	"	"	No	3.9	8.7	5.9	280.00	1%
14.	9:5		1045	2.590	0.416	34.0	Greyish	"	No	3.2	8.7	3.2	55.00	10%
15.	10.0		1115	3.404	0.226	33.5	"	"	No	4.0	8.7	3.7	50.0	10%
16.	11.0		1200	3.912	0.192	34.0	"	"	No	3.7	8.7	5.4	33.00	10%
17	12.0		1230	3.400	0.512	34.0	"	"	No	5.6	8.7	6.2	25.00	10%
18.	13.0		1310	2.170	0.468	34.0	"	"	No	5.8	8.7	4.9	7.60	50%
19.	14.0		1335	2.820	0.544	34.0	Clear	"	No	4.9	8.7	5.1	5.14	70%
20.	15.0		1400	2.860	0.713	34.5	"	"	No	5.7	8.7	5.9	3.50	80%
21.	16.0		1415	1.700	0.698	34.5	"	"	Yes	6.3	5.8	2.1	3.70	Nil
22.	17.0		1430	1.740	0.702	34.5	"	"	Yes	6.9	6.5	3.2	330	Nil
23.	18.0		1445	2.590	0.660	34.5	"	"	No	7.8	7.5	4.3	3.20	Nil
24.	19.0		1530	2.630	0.640	34.5	"	"	No	8.6	8.2	5.7	2.50	Nil

FORMAT-5

MICROBIOLOGICAL EXAMINATION OF RIVER WATER ALONG THE LONGITUDINAL SECTION

RIVER:GANGA **SITE : VARANASI**

Lab. No.	Date	River discharge M^3/Sec	pH	Location	Time of simplicity	Weather	River Water colour	Odour	In situ temp °C	Presence of weeds	STANDARDPLATE COUNT			COLIFERM COUNT		FOCALSTRIP TO CESSI TEST	
											Media of growth	No. of local colories	No. of colories per sec	Media of growth	M.P.N. index per c.c.	Media of growth	M.P.N. index per c.c.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
M-1	20.4.83	25.4.85	7.8	Ram Nagar	11.00	Clear	Clear	Odourless	27.5	No	Agar-Agar	1780	178	Lactose Broth	11	Azide dextrose broth	7
M-2	"	"	7.6	Assi Ghat	12.35	"	"	"	27.5	No		1460	146		11		7
M-3	"	"	7.6	Shivala Ghat	13.00	"	"	"	27.5	No		1300	130		11		4.

FORMAT-6

GOVT. OF INDIA
CENTRAL WATER COMMISSION
GANGA BASIN WATER RESOURCES ORGANISATION

PHYSICO-CHEMICAL CHARACTERISTICS OF RIVER WATER SAMPLE COLLECTED UNDER NCST PROGRAMME

For the month of January, 1984.

S.No.	Lab No.	River/Stream	Site	Location	Date of Sampling	Time of Sampling Hrs.	Weather on the Day of Sampling	River Water Colour	River Water Odour	Insitu Temperature °C.	River Discharge C.L. M³/Sec.	Insitu D.O. mg/Lit.	Date of Receipt of Sample in W.Q.R. Lab.	Sp. Conductance Mhos./cm.	pH	Mode of Preservation
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	35	Ganga	Kanpur	U/S	2.1.84	10.00	Clear	Clear	Odour less	15.5	307.04	7.20	5.1.84	394	7.70 8.17	
	36			D/S	2.1.84	13.30	Clear	Brownish	Pungent	16.5		6.92	5.1.84	430	8.00 8.18	

(2)

S.No.	Lab.No.	Analytical Instrumental Technique employed	CONCENTRATION OF METALS IN mg/l: Iron	Aluminium	Manganese p.p.b.	Calcium	Magnesium	Sodium	Potassium	Cadmium p.p.b.	Chromium p.p.b.	Copper p.p.b.	Silver p.p.b.	Zinc in p.p.b.	Lead p.p.b.	Arsenic	Selenium	Bismuth	Antimony	Tellurium	Mercury
18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	35	Atomic absorption spy. bic. Photometry & UV/Visual Photometry	0.00	0.00	300	217	1.74	1.04	0.12	10	37	10	5	43	100						
	36		0.00	0.00	6.42	2 25	1.91	1.28	0.14	100	180	12	20	117	800		← Not analysed →				

	CONCENTRATION OF NONMETALS IN m.e./l												CONCN. IN mg./l					CHEMICAL INDICES					
Lab. No.	Carbonates	Bicarbonates	Chlorides	Fluorides	Sulphates	Sulphides	Nitrates	Nitrites	Nitrogen Kjeldahi	Cyanides	Phosphates	Sulphites	Boron	Phenols	Tar Acids	Silicates	B.O.D.	Hardness No.	Sodium Percentage	Sodium Adsorption Ratio	Residual Sodium Carbonate	Classification	REMARKS
40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
35	0.00	4.80	0.34	0.06	0.19	Not analysed	0.03	Traces	0.01	0.00	Traces	0.00	0.00	Not analysed		9.90	0.49	196.81	20.51	0.75	0.91	C_2S_1	
36	0.00	4.88	0.62	0.06	0.19	-do-	0.04	Traces	0.01	0.00	Traces	0.02	0.39	-do-		9.30	1.38	209.62	22.94	0.89	0.72	C_2S_1	

ANALYSED BY:
ENTERED BY:
CHECKED BY:

ASSISTANT RESEARCH OFFICER
WATER QUALITY RESEARCH LAB.
VARANASI

EXECUTIVE ENGINEER
WR & FFD
VARANASI

Seasonal mean concentrations of chemical parameters in Ganga waters at Kanpur Winter/Summer/Monsoon Season

Parameters	1979 U/S	1979 D/S	1980		1981		1982		1983	
λ	504	522								
pH	8.48	8.44								
Fe^{+3}	NIL	NIL								
Al^{+3}	NIL	NIL								
Ca^{+2}	1.71	1.82								
Mg^{+2}	1.01	1.82								
Na^{+}	1.15	1.29								
K^{+}	0.06	0.06								
CO_3^{-2}	0.16	0.32								
HCO_3^{-}	2.94	2.97								
Cl^{-}	0.62	0.64								
F^{-}	0.02	0.03								
SO_4^{-2}	0.70	0.84								
NO_3^{-}	0.04	0.07								
NO_2	NIL	0.04								
PO_4^{-3}	0.05	0.08								
SiO_3^{-2}	9.00	11.00								
B	0.18	0.23								

Note:—Unitsof Concentrations for cations and anions are in ml/l. Specific Conductance values are in micromhos/cm. Boron and SiO_3 concentrations are in mg/l.

FORMAT-8

Time Series Analysis of Ca (linear trend method)

River:— Ganga Period Jan 66 to 78. Site: Varanasi

Year Original Number	X (Unit: 1 year)	Y	XY	X^2	Trend Values
1966	—6	2.02	—12.12	36	1.79
1967	—5	1.97	—9.85	25	1.77
1968	—4	1.63	—6.52	16	1.76
1969	—3	1.54	—4.62	9	1.73
1970	—2	1.89	—3.78	4	1.71
1971	—1	1.63	—1.63	1	1.69
1972	0	1.46	0	0	1.67
1973	1	1.38	1.38	1	1.65
1974	2	1.90	3.80	4	1.63
1975	3	1.08	3.24	9	1.61
1976	4	1.63	6.52	16	1.59
1977	5	1.03	8.15	25	1.57
1978	6	1.93	11.58	36	1.55
1979		1.46			
Total	0	21.69	—3.85	182	

$Y = a + bx$

$\Sigma Y = na + b\Sigma x$.... (1) $\Sigma XY = a\Sigma x + b\Sigma x^2$... (2)

when $\Sigma x = 0$, from equations (1) and (2) $a = \Sigma Y/n$, $b = \Sigma xy / \Sigma xy^2$

$a = \frac{21.69}{13} = 1.67$ $b = \frac{-3.85}{182} = -0.02$

$Yc = 1.67 - 0.02x$.

CORRIGENDUM

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	Table 2.10 C Missing	Table 2.10.C Seasonal mean concentration of chemical parameters during monsoon months in Ganga Waters at Farakka
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.7.1 11th Line	concentrations loads	concentrations/loads
17th Line	nett	net
able 2.1.A		
11th Line	cloride	chloride
able 2.1.B		
10th item	$(HCO_3$	$(\overline{HCO_3})$
11th item	cloride	chloride
able 2.1.C		
11th Line	cloride	chloride
—N.B.	ar	are
—N.B.	s ands	stands

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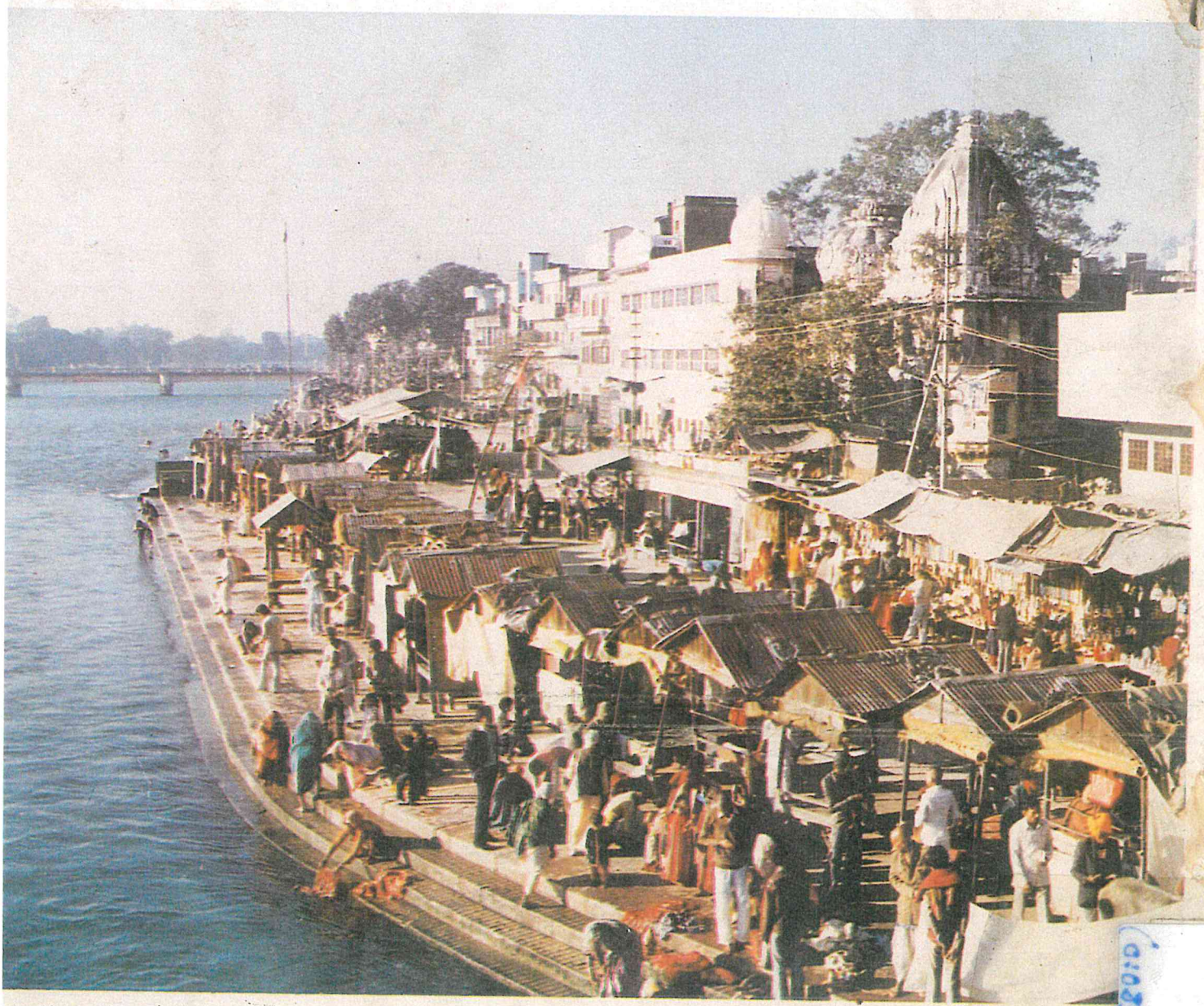

ing Ghats at Haridwar

Rajghat Municipal Drain Pouring into River Ga

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