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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
NATIONAL RIVER CONSERVATION DIRECTORATE (NRCD)
MINISTRY OF ENVIRONMENT AND FORESTS

THE STUDY ON WATER QUALITY MANAGEMENT PLAN FOR GANGA RIVER IN THE REPUBLIC OF INDIA

FINAL REPORT

VOLUME II RIVER POLLUTION MANAGEMENT PLAN

JULY 2005

TOKYO ENGINEERING CONSULTANTS CO., LTD.
CTI ENGINEERING INTERNATIONAL CO., LTD.

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FINAL REPORT

ON

WATER QUALITY MANAGEMENT PLAN FOR GANGA RIVER

JULY 2005

GENERAL TABLE OF CONTENTS

VOLUME I	SUMMARY
VOLUME II	RIVER POLLUTION MANAGEMENT PLAN
VOLUME III	MASTER PLAN FOR PROJECT CITIES
VOLUME III-1	SEWERAGE MASTER PLAN FOR LUCKNOW CITY
VOLUME III-2	SEWERAGE MASTER PLAN FOR KANPUR CITY
VOLUME III-3	SEWERAGE MASTER PLAN FOR ALLAHABAD CITY
VOLUME III-4	SEWERAGE MASTER PLAN FOR VARANASI CITY
VOLUME III-5	NON-SEWERAGE SCHEME
VOLUME III-6	SOCIAL CONSIDERATION AND HYGIENE EDUCATION PLAN
VOLUME III-7	RECOMMENDATIONS ON SOLID WASTE MANAGEMENT
VOLUME III-8	GIS DATA MANAGEMENT
VOLUME III-9	INSTITUTIONAL DEVELOPMENT PROGRAMME
VOLUME III-10	FINANCIAL AND ECONOMIC EVALUATION
VOLUME III-11	(SUPPORTING REPORT) CASE STUDY OF SEWAGE TREATMENT PLANTS

VOLUME IV FEASIBILITY STUDY FOR PROJECT CITIES

VOLUME IV-1 FEASIBILITY STUDY FOR LUCKNOW CITY

PART 1 SEWERAGE SCHEME
PART II NON-SEWERAGE SCHEME
PART III PUBLIC PARTICIPATION AND AWARENESS PROGRAMME
PART IV INSTITUTIONAL DEVELOPMENT PROGRAMME
PART V ECONOMIC AND FINANCIAL EVALUATION
PART VI STAKEHOLDER MEETING
PART VII DRAWINGS

VOLUME IV-2 FEASIBILITY STUDY FOR KANPUR CITY

PART 1 SEWERAGE SCHEME
PART II NON-SEWERAGE SCHEME
PART III PUBLIC PARTICIPATION AND AWARENESS PROGRAMME
PART IV INSTITUTIONAL DEVELOPMENT PROGRAMME
PART V ECONOMIC AND FINANCIAL EVALUATION
PART VI STAKEHOLDER MEETING
PART VII DRAWINGS

VOLUME IV-3 FEASIBILITY STUDY FOR ALLAHABAD CITY

PART 1 SEWERAGE SCHEME
PART II NON-SEWERAGE SCHEME
PART III PUBLIC PARTICIPATION AND AWARENESS PROGRAMME
PART IV INSTITUTIONAL DEVELOPMENT PROGRAMME
PART V ECONOMIC AND FINANCIAL EVALUATION
PART VI STAKEHOLDER MEETING
PART VII DRAWINGS

VOLUME IV-4 FEASIBILITY STUDY FOR VARANASI CITY

PART 1 SEWERAGE SCHEME
PART II NON-SEWERAGE SCHEME
PART III PUBLIC PARTICIPATION AND AWARENESS PROGRAMME
PART IV INSTITUTIONAL DEVELOPMENT PROGRAMME
PART V ECONOMIC AND FINANCIAL EVALUATION
PART VI STAKEHOLDER MEETING
PART VII DRAWINGS

VOLUME V PILOT PROJECT FOR SANITARY IMPROVEMENT OF MANIKARNIKA GHAT

VOLUME II

RIVER POLLUTION MANAGEMENT PLAN

Table of Contents
List of Tables
List of Figures
Appendix
Abbreviations

TABLE OF CONTENTS

CHAPTER 1 CURRENT WATER QUALITY AND STANDARDS 1-1

1.1 WATER QUALITY STANDARDS 1-1
1.1.1 River Water Quality Standards 1-1
1.1.2 Effluent standard 1-3
1.2 CURRENT WATER QUALITY 1-4
1.2.1 Available Data 1-4
1.2.2 Ganga Main River 1-4
1.2.3 Yamuna River 1-5
1.2.4 Gomati River System and Other Major Tributaries 1-5
1.3 WATER AND WASTEWATER QUALITY MONITORING 1-6
1.3.1 Objectives 1-7
1.3.2 Scope of work and methodology 1-7
1.3.3 Findings of the Water Quality Survey 1-9
1.3.4 Wastewater Loads from Nalas 1-13
1.3.5 Monitoring of Sewage Treatment Plants 1-14
1.3.6 Pollution Load Survey 1-15
1.3.7 Characterization of Sediment from Gomati 1-15

CHAPTER 2 WATER QUALITY ESTIMATION 2-1

2.1 GENERAL 2-1
2.1.1 Limitation of the Inventory 2-2
2.1.2 Objective River Sub-basin 2-2
2.1.3 Modeling of Entire Ganga Basin 2-3
2.1.4 Linkage with GIS 2-3
2.2 ESTIMATION OF WATER QUALITY 2-4
2.2.1 Existing Pollution Load Generation 2-4

2.2.2 Point Pollution Load Generation 2-4
2.2.3 Non-point Pollution Load Generation 2-5
2.2.4 Other Pollution Sources 2-5
2.2.5 Population Distribution in Ganga Basin 2-6
2.2.6 Total Existing Pollution Load Generation 2-7
2.2.7 Future Pollution Load Generation Without Project 2-9
2.2.8 Pollution Load Runoff 2-11
2.2.9 Simulated River Water Quality 2-13
2.3 HIGHLIGHT OF THE FOUR CITIES 2-15

CHAPTER 3 POLLUTION REDUCTION CONTROL 3-1

3.1 GENERAL 3-1
3.2 ESTIMATION OF ORGANIC POLLUTION 3-2
3.3 ESTIMATION OF BACTERIAL POLLUTION 3-5
3.3.1 General 3-5
3.3.2 Japanese Case Study on Bacterial River Water Quality 3-5
3.3.3 Longitudinal Profile of Coliform Number 3-7
3.3.4 Simulation Study for Faecal Coliform Number 3-8
3.4 POLLUTION REDUCTION PLAN FOR UPSTREAM AREA OF FOUR CITIES 3-10
3.5 JAPANESE SCHEME OF POLLUTION CONTROL AND WATER QUALITY MANAGEMENT 3-15
3.5.1 Current Situation of River Pollution in India 3-15
3.5.2 Regulation of Total Maximum Daily Loading 3-15
3.5.3 Case Study of Comprehensive Pollution Control in Japan 3-18

CHAPTER 4 RECOMMENDATION OF INDUSTRIAL POLLUTION CONTROL 4-1

4.1 INDUSTRIAL POLLUTION IN THE ENTIRE GANGA BASIN 4-1
4.1.1 Database System for Industrial Pollution Load Estimation 4-1
4.1.2 Category-wise Distribution of Industrial Pollution 4-1
4.1.3 Geographical Distribution of Industrial Pollution 4-2
4.2 INDUSTRIAL POLLUTION FROM 4 CITIES 4-4
4.2.1 City-wise Industrial Pollution Load 4-4
4.2.2 Industrial profile of Kanpur 4-5
4.2.3 Tanneries Industry in Kanpur 4-5
4.2.4 Industrial pollution Management in Tanneries 4-6
4.2.5 Wastewater Treatment Plants at Jajmau and Unnao 4-6
4.2.6 Current Assessment of Industrial Pollution in Jajmau and Unnao 4-7
4.3 STATUS OF ENVIRONMENTAL LEGISLATION IN INDIA 4-8
4.3.1 Legislative Enforcement of Industrial Pollution Control in Ganga Basin 4-10

4.3.2 Current Enforcement of Industrial Effluent Monitoring 4-10
4.3.3 Initiative on Industrial Pollution Control along Rivers 4-13
4.3.4 Comparative system of Effluent Monitoring in Various Countries 4-14
4.4 RECOMMENDATIONS FOR IMPROVEMENT OF EXISTING INDUSTRIAL POLLUTION MANAGEMENT 4-15
4.4.1 Technical recommendations 4-15
4.4.2 Legislative Recommendations 4-16
4.4.3 Institutional Recommendations 4-19

CHAPTER 5 WATER QUALITY MONITORING PLAN 5-1

5.1 RELEVANT ORGANIZATION FOR WATER QUALITY MONITORING 5-1
5.1.1 Organization 5-1
5.1.2 Laboratories and Staff Involved in Water Quality Monitoring 5-1
5.2 EXISTING MONITORING SYSTEM 5-2
5.2.1 Water Quality Monitoring Network 5-2
5.2.2 Sampling Locations for Water Quality Monitoring 5-2
5.2.3 Water Quality Sampling Covered by each Organization 5-3
5.2.4 Parameters to be monitored 5-3
5.3 CURRENT ISSUES ENCOUNTERED IN WATER QUALITY MONITORING 5-3
5.3.1 Technical Problems 5-3
5.3.2 Administrative Problems 5-4
5.3.3 Scarcity of Capacity of Optimum Monitoring Activities 5-4
5.3.4 Analytical Quality Control (AQC) 5-4
5.4 MONITORING PROGRAMME FOR GANGA RIVER BY UPPCB 5-5
5.4.1 Existing Laboratory Conditions in 4 Cities 5-5
5.4.2 Issues Related To Laboratory Performance Improvement 5-6

CHAPTER 6 RECOMMENDATIONS 6-1

6.1 NECESSITY OF VARIOUS STUDIES FOR BASIN-WIDE INVENTORY 6-1
6.2 IMPROVEMENT OF RIVER WATER QUALITY 6-1
6.3 IMPROVEMENT OF EXISTING INDUSTRIAL POLLUTION MANAGEMENT 6-2
6.3.1 Technical Recommendations 6-2
6.3.2 Legislative Recommendations 6-2
6.3.3 Organizational Recommendations 6-2
6.4 OPTIMIZATION OF MONITORING NETWORK 6-2
6.4.1 Capacity Building for Optimum Monitoring 6-2
6.4.2 Reconsideration of Monitoring Stations 6-3
6.4.3 Additional Monitoring Programme 6-4
ANNEX AN-1

LIST OF TABLES

Table 1.1 Key indicators of inland surface water quality under the revised criteria proposed by CPCB 1-3
Table 1.2 Discharge Standards 1-3
Table 1.3 Average & 90% Water Quality of Main Tributary at Lowest Point........ 1-6
Table 1.4 Salient Features of Pollution Load Survey 1-8
Table 1.5 Number of Drains and Sewer Outfalls Monitored........ 1-8
Table 1.6 Number of Samples Collected from Sewage Treatment Plants........ 1-8
Table 1.7 Schematic Showing River WQM Locations........ 1-9
Table 1.8 Summary of Nala Flows in four Cities........ 1-14
Table 1.9 Summary of Performance Monitoring at STPs 1-15
Table 2.1 Objective River System and Sub-basins........ 2-3
Table 2.2 Unit BOD Pollution Load Generation from Non-point Sources 2-5
Table 2.3 River System Wise Population and Its Density 2-6
Table 2.4 Pollution Load Generation from Each River System 2-7
Table 2.5 Density of Pollution Load Generation in Each River System 2-8
Table 2.6 Future Population in Each River System (2010) 2-9
Table 2.7 Future Population in Each River System (2015) 2-9
Table 2.8 Future Population in Each River System (2030) 2-9
Table 2.9 Future Growth Rate of Industry........ 2-10
Table 2.10 Future Pollution Load Generation (Without Project) 2-11
Table 2.11 Future Pollution Load Generation (With Project)........ 2-11
Table 2.12 Existing Pollution Load Runoff........ 2-12
Table 2.13 Density of Pollution Load Runoff 2-12
Table 2.14 Simulated River Water Quality (1) 2-14
Table 2.15 Simulated River Water Quality (2) 2-14
Table 2.16 Simulated River Water Quality (3) 2-15
Table 3.1 Urban Populations in 4 Cities........ 3-1
Table 3.2 Simulated Water Qualities 3-3
Table 3.3 Future Simulated Water Qualities........ 3-4
Table 3.4 Japanese Regulation/Guideline for the Hygienic Condition........ 3-6
Table 3.5 Unsatisfactory Ratios for Coliform Criteria in Japan (1997) 3-6
Table 3.6 Relations between Future Faecal Coliform and Various Scenarios (1) 3-9
Table 3.7 Relations between Fecal Coliform and Simulation Cases........ 3-9
Table 3.8 Relations between Future Fecal Coliform and Various Scenarios (2) 3-10
Table 4.1 Category-wise industrial BOD load distribution in Ganga basin 4-1

Table 4.2 Predominant Categories of Water Polluting Industries..4-2
Table 4.3 Top 10 Districts in Terms of BOD Load Generation in the Ganga basin..........................4-3
Table 4.4 State-wise Industrial BOD Load Distribution in Ganga Basin...4-3
Table 4.5 Basin/ Sub-basin wise Industrial BOD Load Distribution in the Ganga Basin.................4-4
Table 4.6 Industrial Pollution Load Discharged from 4 Cities..4-4
Table 4.7 List of Environmental Legislation..4-9
Table 4.8 Frequency of Inspection for Industrial Effluent 4-12
Table 4.9 List of Grossly Polluting Industries and their Status in India...4-13
Table 4.10 Comparative System of Effluent Monitoring in Various Countries...............................4-14
Table 4.11 Laboratory Analytical analysis 4-16
Table 4.12 Comparison of Effluent Standards of India and Japan 4-18
Table 5.1 Staff Line-up for each Laboratory 5-1
Table 5.2 Distributions of Water Quality Monitoring Stations in Ganga Basin 5-3

LIST OF FIGURES

Figure 1.1 Longitudinal and transverse profile of BOD in Ganga river at Kanpur........................ 1-10
Figure 1.2 Longitudinal and transverse profile of BOD in Gomati river at Lucknow 1-11
Figure 1.3 Longitudinal and transverse profile of BOD in Ganga river at Allahabad..................... 1-12
Figure 1.4 Longitudinal and transverse profile of BOD in Ganga river at Varanasi 1-13
Figure 2.1 Linkage with GIS.. 2-4
Figure 2.2 Population Density.. 2-7
Figure 2.3 Ratio of Each Category Pollution Load Generation 2-8
Figure 2.4 Density of Pollution Load Generation 2-8
Figure 2.5 Industrial Growth Rate During Last Eight Years 2-10
Figure 2.6 Ratio of Each Pollution Load Runoff.. 2-12
Figure 2.7 Density of Pollution Load Runoff.. 2-13
Figure 2.8 City-wise Reaching Domestic Pollution Load to Trighat 2-16
Figure 3.1 Longitudinal Profile of Coliform (Ganga Main)... 3-7
Figure 3.2 Longitudinal Profile of Coliform (Yamuna Main).. 3-8
Figure 3.3 Longitudinal Profile of Coliform (Gomati River)... 3-8
Figure 3.4 Descending Order of Urban Population in 2030 (Ganga Basin)................................... 3-11
Figure 3.5 City Wise Reaching Pollution Load to Kanpur (Ganga)... 3-12
Figure 3.6 City Wise Reaching Pollution Load to Allahabad (Ganga) 3-12
Figure 3.7 City Wise Reaching Pollution Load to Allahabad (Yamuna).. 3-13
Figure 3.8 City Wise Reaching Pollution Load to Varanasi (Ganga)... 3-13
Figure 3.9 Pollution Load Reductions in Japan.. 3-18
Figure 3.10 Historical Industrial Pollution Load Reduction 3-18
Figure 4.1 Flow Diagram for 36 MLD CETP at Jajmau 4-6
Figure 4.2 Flow Diagram for 2.15 MLD CETP at Unnao.. 4-7
Figure 4.3 Presentation of Relation between Present Permit Systems with Normal Standards for Industrial Discharge.. 4-17

APPENDIX

APPENDIX A WATER QUALITY STANDARDS, WATER QUALITY MONITORING & INDUSTRIAL POLLUTION LOAD A-1
APPENDIX B RIVER POLLUTION CONTROL PLANNING B-1
APPENDIX C RELEVANT RIVER ACTION PLANS C-1

ABBREVIATIONS

ADB	Asian Development Bank
AIWPS	Advanced Integrated Wastewater Ponding System
AQC	Analytical Quality Control
APHA	American Public Health Association
ASP	Activated Sludge Process
AWWA	American Water Works Association
BAT	Best Available Technology
BOD_5	5 day Biochemical Oxygen Demand
BOD/d	Biochemical Oxygen Demand per day
CETP	Combined Effluent Treatment Plant
CLRI	Central Leather Research Institute
CMC	CETP Monitoring Committee
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board, Ministry of Environment and Forests
CPHEEO	Central Public Health and Environmental Engineering Organization
CRP	Chrome Recovery Plant
CSE	Centre for Science and Environment
CSO	Central Statistical Organization
CWC	Central Water Commission, Ministry of Water Resources
DBU	Designated Best Use
DFID	Department for International Development
DF/R	Draft Final Report
DLW	Diesel Locomotive Works
DO	Dissolved Oxygen
DPR	Detailed Project Report
D/s	Downstream
EC	Electro Conductivity
EIA	Environmental Impacts Assessment
EPA	Environmental Protection Agency
ETPs	Effluent Treatment Plants
EWQS	Environmental Water Quality Standard
F/R	Final Report
F/S	Feasibility Study
FICCI	Federation of Indian Chamber of Commerce & Industries
FPU	Final Polishing Unit

GAP	Ganga Action Plan
GEMS	Global Environmental Monitoring Systems
GIS	Geographic Information System
GoAP	Gomti Action Plan
GoI	Government of India
GPI	Grossly Polluting Industries
GRP	Green Rating Project
IC/R	Inception Report
IEE	Initial Environmental Evaluation
IIT	Indian Institute of Technology
IRR	Internal Rate of Return
IT/R	Interim Report
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
KNN	Kanpur Nagar Nigam
LCS	Low Cost Sanitation
MINARS	Monitoring of Indian National Aquatic Resources
MINAS	Minimum National Acceptable Standards
MoEF	Ministry of Environment and Forests
MoUD	Ministry of Urban Development
MLD	Million Litter per Day
M/P	Master Plan
MPN	Most Probable Number
NGO	Non-Governmental Organization
NOC	No Objection Certificate
NPDES	National Pollution Discharge Elimination System
NRCD	National River Conservation Directorate, Ministry of Environment and Forests
NRCA	National River Conservation Authority
ODA	Overseas Development Assistance
O&M	Operation and Maintenance
OJT	On-the-job Training
PCC	Pollution Control Committee
PHE	Public Health Engineering
P/R	Progress Report
QUAL2E	Enhanced Stream Water Quality Model
Rs.	Indian Rupees
SC	Steering Committee
SMF	Sankat Mochan Foundation
SPCB	State Pollution Control Board

SRI	Sriram Institute for Industrial Research
SSI	Small Scale Industries
STP	Sewage Treatment Plant
S/W	Scope of Work
t	tons
t/d	tons per day
TDS	Total Dissolved Substance
TMDL	Total Maximum Daily Loading
TOR	Terms of Reference
T/T	Technology Transfer
UASB	Upflow Anaerobic Sludge Blanket
UNIDO	United Nations Industrial Development Organisation
UP	State of Uttar Pradesh
UPJN	UP Jal Nigam
UPSIDC	Uttar Pradesh State Industrial Development Corporation
UPPCB	Uttar Pradesh Pollution Control Board
USAID	The United States Agency for International Development
U/s	Upstream
YAP	Yamuna Action Plan
WB	The World Bank
WPCL	Water Pollution Control Law
WQAA	Water Quality Assessment Authority
YAP	Yamuna Action Plan

CHAPTER 1

CURRENT WATER QUALITY AND STANDARDS

RIVER POLLUTION MANAGEMENT PLAN

CHAPTER 1 CURRENT WATER QUALITY AND STANDARDS

1.1 WATER QUALITY STANDARDS

1.1.1 River Water Quality Standards

Until recently the only criteria available for classification of water bodies was as per the 'Designated Best Use' (DBU) prescribed by Bureau of Indian Standards and Central Pollution Control Board (CPCB) way back in 1981. According to this concept, out of various purposes for which the water body is used, the one that requires highest quality of water is taken as the benchmark and classified as 'Designated Best Use'. According to this criteria waste bodies are divided in five categories viz.:

Class A : Drinking water source without conventional treatment, but with chlorination

Class B : Outdoor bathing

Class C : Drinking water source with conventional treatment

Class D : Propagation of wildlife and fisheries

Class E : Irrigation, industrial cooling and controlled waste disposal

This criteria lay down reference values for pH, dissolved oxygen, biological oxygen demand, Coliform, etc. For instance specified limits for DO, BOD and coliform for Class A are 6 ppm, 2 ppm and 50/100 ml, respectively. For lower category such as Class D, specified values for these indicators are 4 ppm, 6 ppm and 5000/100 ml, respectively. A detailed parameter-wise criteria is presented in Appendix A.

Recently, primary quality for class B regarding coliform number has been revised as follows; fecal coliform: <500 MPN/100ml (Desirable), <2,500 MPN/100ml (Maximum permissible).

As of now this criteria is followed by various agencies responsible for management and control of water quality in the country including the two ongoing programmes viz. National River Conservation Plan and National Lake Conservation Plan.

However, in the current context of increased pollution loads and concerns for long-term ecological sustainability, it is felt that this criteria has certain fundamental limitations. Some of these are listed below:

(1) The DBU criteria consider only human requirements and exclude ecological aspects and their relation to the human beings. In certain cases ecological violations are not identified while the desired criteria may be satisfied.
(2) It recognizes only organized uses and ignores the requirements of large rural community.
(3) Two decades back when the criteria were developed, concerns on non-domestic sources of pollution were not pronounced.
(4) In case of large water bodies including rivers, adhering to one particular class of water is practically difficult and has high costs associated with any technical intervention.
(5) There is inherent inconsistency with regard to the set of parameters applicable to higher and lower classes. For instance the category captioned as 'irrigation, industrial cooling and controlled waste disposal" specifies limits for TDS, sodium absorption ratio, etc. but does not cover BOD, coliform, helminthes, toxicants.

Recognising these limitations, the Central Pollution Control Board has proposed new criteria for classification of water bodies. The new approach is based on the premise of maintaining and restoring 'wholesomeness' of water for the health of ecosystem and environment in general; and protecting the designated organized uses of water by human beings and involving community for water quality management. The term 'Wholesomeness' here pertains to taking an ecosystem approach to aquatic environment and including socio-cultural aspects into consideration.

The new classification system proposes three categories or tiers of indicators of water quality depending on the ease or complexity involved in their determination with regard to knowledge, skills, and equipment. Secondly, it classifies water bodies into three broad categories viz.:

Class A : Excellent (long term goal)

Class B : Desirable level of wholesomeness (medium term goal)
Class C : Minimum acceptable level (Short term goal)

The detailed parameter-wise criteria are presented in Appendix A. The three key parameters typically used for assessments are presented below and salient features are described in the paragraphs that follow. (Water quality criteria and goals, CPCB, February 2002).

Table 1.1 Key indicators of inland surface water quality under the revised criteria proposed by CPCB

Indicator	Unit	A- Excellent	B- Desirable	C- Acceptable
DO	(% saturation)	90-110	80-120	60-140
BOD	(mg/l)	< 2	< 5	< 8
Faecal Coliform	MPN/100 ml	< 20	< 200	< 2000

It is assumed that efforts being put in to restore and manage the quality of various water bodies will move them from Class C to Class A over a period of time. First tier of parameters pertains to visual and sensual observations and includes among others, ecological indicators such as presence of fish and insects. The second tier of parameters includes typical chemical and biological indicators, which can be measured by skilled chemists in a water quality laboratory. The lacunae observed in the criteria is that while the 'Acceptable' category specifies a BOD level of 8 mg/l or less, it does not recognize 'extremely poor' and 'challenged' categories or status in which many of the major water bodies are currently found to be in. For instance typical BOD levels in Yamuna and Ganga in critically polluted stretches are between 25 to 35 mg/l and these values are way above the reference values provided in the criteria. Similarly, in case of dissolved oxygen, which is referred in terms of % saturation, the criteria has not recognized 'extremely challenged' status of several water bodies wherein the DO levels are very low or almost zero.

The third tier of parameters is recommended only for detailed investigations and it includes among others, nutrients, phenols, pesticides, and heavy metals.

1.1.2 Effluent standard

Effluent discharge standards are specified with reference to the type of industry, process or operations and in relation to the receiving environment or water body such as inland surface water, sewers, land or sea. While the Environment Protection Act has laid down discharge standards for a range of industries keeping in view the manufacturing processes, raw materials, technological feasibility etc., it has also laid down vide Schedule VI of The Environment (Protection) Rules, 1986 general discharge standards which are applicable across the board. Point 7 of the accompanying Appendix A of the Schedule specifies applicability of these general standards to discharge of sewage. These standards are given in Table 1.2.

The standards vary depending on the nature of the receiving environment or water body. For instance the limits imposed for discharge into inland water bodies are most stringent followed by those specified for discharge onto land for irrigation, and then marine outfalls. The most relaxed standards are specified for discharge into public sewers that are leading to a sewage treatment plant and it is assumed that the wastewater will eventually receive adequate treatment at the plant.

Table 1.2 Discharge Standards

Indicator	Inland surface water	Public sewers	Land for irrigation	Marine outfall
Suspended solids	100	600	200	100
Oil and grease	10	20	10	20
BOD	30	350	100	100

Note : All values are in mg/l and are the maximum permissible levels.

Source: Pollution control acts, rules and notifications issued hereunder, CPCB, September, 2001.

The general BOD limit specified for discharge of wastewater from typical industrial sources or domestic wastewater is same at 100 mg/l. However, the rules specify that the discharge limits can be made further stringent if the concerned pollution control authority finds it appropriate depending on the condition of the receiving environment and severity of the discharges from various sources.

With regard to application of sewage for land farming the 'Manual on sewerage and sewage treatment', CPHEEO, Ministry of Urban Development, Govt. of India, provides guidelines on characteristics of irrigations water. These include conductivity/ salinity sodium absorption ratio, chlorides, boron, etc. In addition, the manual provides maximum permissible concentrations of toxic heavy metal, etc. Constituent wise values are given in Appendix A. However, it is noted that while salinity and toxicity aspects have been addressed in these standards and guidelines, the issue of infection to agriculture workers and consumers of cultivated products due to bacterial population in sewage has not been addressed here.

1.2 CURRENT WATER QUALITY

1.2.1 Available Data

CPCB has been periodically analyzing the river water quality in the Study Area since 1976. The water quality-monitoring program has been gradually extended based on the availability of resources and need. The CPCB has taken up the exercise in coordination with the SPCBs and PCCs through a series of meetings and analysis of data. Apart from the activities of CPCB, there are several periodical monitoring plans conducted by SPCBs.

For various rivers, the identified polluted-stretches are Yamuna (Delhi to Mathura), the Chambal (D/s of Nagda to D/s of Kota), the Kali (D/s of Modinagar to its confluence with Ganga), the Hindon (Saharanpur to its confluence with Yamuna), the Khan (Indore and D/s of Ganga), the Kshipra (city limits of Ujjain and D/s of Ujjain), the Damodar (D/s of Dhanbad to Haldia), the Gomati (Lucknow to its confluence with Ganga) and the Betwa (along Mandideep and Vidisha).

The longitudinal profile of river water quality in the Ganga basin with respect to BOD, DO and Total-coliform for the period 1997 to 2001 is given in attached Figure B.3.2 to Figure B.3.4, respectively in Appendix B. All figures indicate that river water quality deteriorates immediately downstream of large cities such as Kanpur, Allahabad, Varanasi, Lucknow, Delhi and so on.

1.2.2 Ganga Main River

(1) Upper Ganga Main River System

The water quality in the upstream reach from Rishikesh to Hardwar is satisfactory. The annual average BOD value varies between 1-2.5 mg/l with an average value of 1.3-2.0 mg/l. BOD and DO values in this river reach are within the water quality criteria limits; however, total coliform exceeds the criteria limit slightly. In this river reach, although the impact of contamination is rather small compared to river flow, untreated domestic wastewater affects the total and faecal coliform value. Further, river water quality in the downstream reach from Hardwar to Kannauj becomes worse due to the small flow in river caused by the huge quantity of intake at Hardwar.

On the other hand, much polluted tributaries such as Kalinadi and Ramganga join the Ganga Main at Kannauj City. These tributaries transport and add pollution load into Ganga Main and thus affect the river water quality slightly at Kannauj D/s.

(2) Middle Ganga Main River System

BOD rises sharply up to 8.2 mg/l downstream of Kanpur. In this river reach, BOD exceeds the desired water quality criteria limit at D/s Kanpur, D/s Varanasi and Trighat. Total coliform is much higher than the criteria limit in the river stretch up to Rajmahal, and thereafter, it is well within the criteria limit of desired class. On the other hand, DO level meets the desired level at all the monitoring stations except Varanasi D/s.

(3) Lower Ganga Main River System

According to Figure B.3.2 in Appendix B, the BOD concentration drops sharply after Varanasi D/s and low concentration of BOD continues until Rajmahal due to the sufficient dilution effect owing to its confluence with many large tributaries such as Sone, Ghaghra and Gandak. Further, after bifurcating at the country border between India and Bangladesh, Ganga River is joined by large tributaries such as Ajay, Damodar and Rupnarayan. Calcutta is located at the lowest point of Ganga River and is the second largest city in India where more than 10 million people live. Although the City of Calcutta discharges a huge quantity of wastewater into Ganga River, the river water still remains less polluted due to the dilution capacity of river caused by the abundant river flow.

1.2.3 Yamuna River

(1) Upper Yamuna River System

Yamuna River maintains good condition of water quality in upstream reach, i.e., Hathnikund to Palla. However, there is a gradual increase of BOD value between Hathnikund and Delhi, mainly caused by the inflow of untreated domestic and industrial wastewater from Panipat and Sonepat through drains in the state of Haryana.

DO drops after Wazirabad Barrage in Delhi due to addition of large amount of wastewater in Yamuna River through various drains. Whatever water flows in the downstream of Wazirabad barrage is the untreated or partially treated domestic and industrial wastewater contributed through 16 drains along with the water being transported by Haryana irrigation Department from Western Yamuna Canal to Agra Canal via Najafgarh Drain and the Yamuna. The annual average BOD value also increases from 1.1 mg/l at Hathnikund to 14.4 mg/l at Nizamuddin Bridge. This high value of BOD beyond permissible limit prevails over the entire stretch of the Yamuna River in the downstream of Delhi also until the Chambal River provides dilution effect.

BOD in Yamuna River at Mazawali varies between 3-34 mg/l, with an average of 10.6 mg/l, which improves by the time it reaches to Mathura. BOD level at Mathura downstream varies between 2-17 mg/l with an average of 7.5 mg/l and it remains consistent up to Agra upstream. However, downstream of Agra, the water quality is degraded to a very high extent due to the discharge of untreated wastewater inflow from Agra City and non-availability of considerable dilution effect. The stretch of Yamuna River between Agra and Etawah continues to remain in degraded condition with BOD level varying between 1-15.6 mg/l with an average of 14.2-15.3 mg/l. The longitudinal profile of DO, BOD, total coliform and faecal coliform reflects that the water quality of river is in deteriorated condition between Delhi and Etawah.

(2) Lower Yamuna River System

After the confluence of Chambal River shortly downstream of Etawah City, water quality in Yamuna River again becomes normal as is evident from the annual average BOD value (see Appendix B, Chapter 3, Table 3.3 to 3.4). The Yamuna River water quality recovers after joining of the Chambal River at Juhika, which provides significant dilution effect with fairly clean water to the extent of 5-10 times. Due to this dilution, Yamuna River regains its water quality with its BOD concentration at Allahabad ranging between 1-3 mg/l with an annual BOD average of 1.6 mg/l.

1.2.4 Gomati River System and Other Major Tributaries

(1) Gomati River

Gomati River is highly contaminated by domestic and industrial wastewater inflow. Especially, river flow becomes very low in drought season and in monsoon it swells with considerably high flow. Sitapur District is located in the upstream reach, and highly contaminated wastewater effluent from distilleries and sugar factories in the area is discharged into the upper reach of Gomati River. On the other hand, Lucknow City is located in the middle reach of Gomati River and is presently inhabited by approximately 2.39 million people. Just at the entrance to the city, almost 300 MLD of water is lifted from the river at Gaughat Intake Works for domestic use in the city.

The water quality of Gomati River before its confluence with Ganga River and Ganga River at Trighat is found to be in a relatively better condition complying with the B category, which implies that the river water is suitable for bathing, swimming and water related sports.

(2) Main Tributaries

Ganga River consists of many tributaries and CPCB has periodically monitored river water quality, as shown in Table 1.3. According to this table, BOD and Total Coliform values are high in the Kalinadi, Hindon and Ramganga rivers located in the Upper Ganga and Yamuna River stretches due to the domestic wastewater inflow from riverside cities. On the other hand, BOD values of the Chambal, Sind and Betwa rivers located in the Lower Yamuna stretch are moderate, and those of Sone, Ghaghra and Gandak rivers located in Lower Ganga stretch are low.

Table 1.3 Average & 90% Water Quality of Main Tributary at Lowest Point

Grouping	**Parameter**	**Ramganga**	**Kalinadi**	**Tons**	**Sone**	**Ghaghra**	**Gandak**
Average	DO (O_2) (mg/l)	7.3	7.9	7.3	7.4	8.2	8.4
	BOD (mg/l)	3.3	4.0	2.6	0.5	0.5	0.5
	Total coliform (MPN/100ml)	$3.9*10^5$	$5.4*10^5$	$2.4*10^3$	$8.9*10^1$	$9.3*10^3$	$5.4*10^3$
Grouping	Parameter	Damodar	Rupnarayan	Hindon	Chambal	Sind	Betwa
Average	DO (O_2) (mg/l)	6.8	7.0	3.6	8.9	4.9	7.8
	BOD (mg/l)	3.4	1.4	8.5	1.6	2.4	3.1
	Total coliform (MPN/100ml)	$2.2*10^5$	$1.1*10^5$	-	$1.2*10^5$	-	$2.1*10^5$
Grouping	Parameter	Ramganga	Kalinadi	Tons	Sone	Ghaghra	Gandak
90%	DO (O_2) (mg/l)	6.2	6.4	6.7	6.5	7.5	8.0
	BOD (mg/l)	4.0	6.2	4.1	2.7	1.0	1.0
	Total coliform (MPN/100ml)	$1.0*10^6$	$1.4*10^6$	-	$3.0*10^2$	$2.4*10^4$	$2.4*10^4$
Grouping	Parameter	Damodar	Rupnarayan	Hindon	Chambal	Sind	Betwa
90%	DO (O_2) (mg/l)	5.9	5.7	2.4	6.5	-	6.7
	BOD (mg/l)	8.5	2.1	11.8	2.0	3.0	4.0
	Total coliform (MPN/100ml)	--	-		$1.8*10^5$	-	$8.2*10^5$

1.3 WATER AND WASTEWATER QUALITY MONITORING

The ongoing Study on Ganga Water Quality Management Plan aims to formulate a master plan and carry out a feasibility study for improving the water quality of Ganga River with a focus on four major towns in the basin, i.e., Lucknow, Kanpur, Allahabad and Varanasi.

In order to generate inputs for the master plan, an intensive and extensive field monitoring activity was undertaken during the months of May and June 2003 to develop indicators of water quality of River Ganga and its major tributaries along the stretches characterized by the four towns. In addition, other components and aspects of the drainage systems and urban domestic waste discharges were assessed in terms of their quantity and quality. These are:

(1) Unit pollution loads from domestic sources
(2) Discharge and waste loads of major nalas carrying domestic wastewater
(3) Performance of sewage treatment plants
(4) Sediment loads on riverbed

Salient aspects of these activities are described in the sections that follow.

1.3.1 Objectives

Obviously, the objectives of river water quality monitoring were to:

(1) Generate primary set of data specifically for stretches perceived to be critically polluted along the four cities
(2) Provide cross check on the river quality data available from secondary sources, and
(3) Provide inputs for mathematical modeling being attempted during the study

The objectives of undertaking assessment of nala loads were to:

(1) Identify critical point loads of wastewater for inclusion into the modeling exercise
(2) Assess the hydraulic loads and thereby the required capacity of pumps for diversion of nalas to existing or 'to be recommended' sewage treatment plants
(3) Assess hydraulic and organic loads for which sewage treatment capacity needs to be augmented or to be provided
(4) Selectively validate background flow values made available by UPJN

The objectives of assessing the performance of sewage treatment plants were to:

(1) Assess available capacity for sewage treatment and the level of capacity utilisation
(2) Identify requirements for capacity augmentation of both the delivery system and the treatment plants, and
(3) Identify measures for improvement in treatment systems to be proposed under the ongoing study

In addition, unit pollution load survey was carried out to enable making realistic assessment of organic waste loads from the domestic sector. Moreover, river bed sludge monitoring was carried out only for Gomati River in Lucknow. This stretch of the river is considered to be highly polluted due to discharge of untreated sewage and municipal solid waste and the volume of sediment deposit on the bed of the river is estimated to be significant. Sediment deposits are high due to a barrage across the river on the downstream of the city. The objectives of this component were to assess the quantum of benthic sludge that may be required to be removed from the river bed, should an intervention on that aspect be recommended and planned in the course of the feasibility study; and analyse for its chemical quality (toxicity) with the objective of assessing the feasibility of its safe disposal.

1.3.2 Scope of work and methodology

The detailed scope of work under each of the above mentioned components of the field monitoring activity are presented in Appendix A and a summary is provided in the succeeding paragraphs.

(1) Pollution load survey

Under this component four types of surveys were carried out to estimate present per capita pollution load in terms of BOD_5 from high, middle and low-income residential areas in each of the four cities.

The salient features for this component are given in Table 1.4.

Table 1.4 Salient Features of Pollution Load Survey

Component	Particulars	Nr. of locations per town
Type 1: Area covered by sewerage network (representing high income community)	Composite 24 hour sewage sample, and a brief profile of the locality e.g., population, sources of water and consumption, etc.	1
Type 2: Unsewered area (representing medium to low income community)	Composite 24 hour sample of gray water for estimation of quantity and characterization.	1
Type 3: Unsewered area (representing low income community)	Night soil analysis from community toilets	1
Type 4: Unsewered area (representing medium income community)	Night soil analysis from individual household toilets	3

(2) Nala monitoring

The total number of major drains and outfall of sewers in the four cities considered under the current study is shown in Table 1.5. Out of the 101 identified nalas, flow rate of major 34 nalas and 2 sewer outfalls were measured and composite 24 hour samples were collected. Flow measurements were carried out by adopting appropriate methods specific to the site conditions viz. size of the drain and the magnitude of flow. The methods comprised V-notch, current meter, and velocity-area method using a float.

Table 1.5 Number of Drains and Sewer Outfalls Monitored

Items	Lucknow	Kanpur	Allahabad	Varanasi	Total
Number of drains and sewer outfalls	29	23	24	25	101
Number of drains for monitoring	9	8	8	9	34
Sewer outfalls for monitoring	1	0	0	1	2
Frequency of monitoring	1	1	1	1	-
Total no. of measurements	10	8	8	10	36

(3) Monitoring of sewage treatment plants

For all the existing sewage treatment plants in the four cities, 24 hour composite samples of raw and treated sewage were collected at the inlet and outlet points, respectively. Care was taken that the sampling is carried out on fine weather day under normal operation of the STPs. The numbers of samples drawn are shown in Table 1.6.

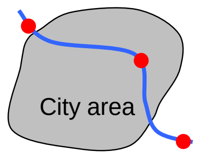
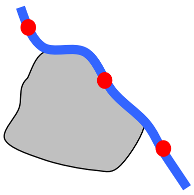
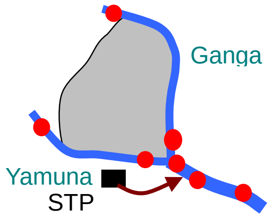
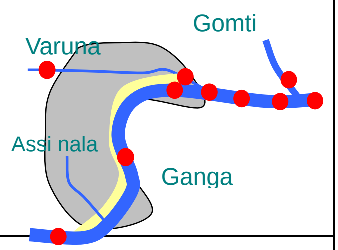
Table 1.6 Number of Samples Collected from Sewage Treatment Plants

Items	Lucknow	Kanpur	Allahabad	Varanasi	Total
No. of STPs	1	3	1	3	8
No. of samples	2	6	2	6	16

(4) River water quality monitoring

Various locations where the river water quality was monitored are shown in Table 1.7 below. In addition to river Ganga, samples have also been drawn from tributaries joining it at Allahabad and Varanasi viz. Yamuna, Varuna and Gomati.

Table 1.7 Schematic Showing River WQM Locations

City	Lucknow	Kanpur	Allahabad	Varanasi
Location sketch				
Type A (a maximum set of water quality parameters)				
Along the River stretch	3 Points (Gomati)	3 points (Ganga)	5 points (Ganga) 2 points (Yamuna)	5 points (Ganga) 2 points (Varuna) 3 points (U/s and d/s of the Ganga-Gomati confluence)
Across the river section	3 points	5 points	5 points	5 points (Ganga) 1 point (Varuna) 3 points (around the confluence)
Sub-total	9	15	35	36
Frequency	2 (dry season)	2 (dry season)	2 (dry season)	2 (dry season)
Total	18	30	70	72

At each of the above identified locations, river water quality was monitored two times during the entire field activity. This was done to observe possible variation, if any, over a period of 2-3 weeks and to get an additional set of representative data.

(5) Benthic sediment load assessment

Benthic sludge samples were collected at six points in river Gomati upstream of the barrage. Sampling points were selected downstream of confluence of large drains and thickness of sludge layer was measured at these locations. The samples are analysed for toxic content including heavy metals to assess the feasibility of its safe disposal, in case a dredging intervention is carried out.

(6) Methodology

The field monitoring work was planned to be completed before the onset of monsoon. The entire work was awarded to Sriram Institute for Industrial Research (SRI), New Delhi and it was completed as per the schedule by the third week of June, 2003. SRI carried out in-situ measurement of pH and DO and rest of the parameters were analysed in their laboratory in Delhi. The samples were collected, preserved and transported as per the procedure recommended for each specific parameter under relevant sections of “Standard Methods for the Examination of Wastewater” published by APHA or AWWA and/or Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, and/or Methods and Guidance for the Analysis of Water, Version 2 published by U.S. Environmental Protection Agency (EPA) or equivalent.

1.3.3 Findings of the Water Quality Survey

This section presents findings of the water quality monitoring activity described in previous section. River water quality for the four cities is described here in terms of BOD and DO values and compared with the designated best use water quality criteria for inland water bodies. The tabular data on water quality is presented in Appendix A.

(1) River water quality in Kanpur

Three sections along the river were selected in Kanpur stretch for water quality assessment. At each section, samples were drawn at one-eighth width, one-fourth width, half width, three-fourth width and at seven-eighth width from the right bank of the river. The BOD envelope in the longitudinal and transverse direction in this stretch is presented in Figure 1.1. The average value varies from 3 mg/l in upstream to 4 mg/l in mid stretch and to 6 mg/l near Jajmau. In the last section BOD on the right bank (city side) is 6 mg/l while on the opposite bank it is 13 mg/l. It is possibly attributed to the discharge of large quantity of sewage from Shuklaganj, which is located across the river.
Build up of suspended solids is noticeable from 26 mg/l in upstream to 60 mg/l on downstream (along the right bank). DO in this stretch is recorded between 6-7 mg/l in upstream and mid stretch while it declines to around 4 mg/l on the downstream near Jajmau in response to discharge of urban and industrial wastes. It is reported that in comparison to previous years, during this year the summer season flow in the river was on a higher side (as informed by IIT Kanpur which has been carrying out long term water quality monitoring on behalf of NRCD). This aspect has made a positive impact on the indicators of water quality described above, i.e., BOD values may appear to be low in comparison to the past trend.

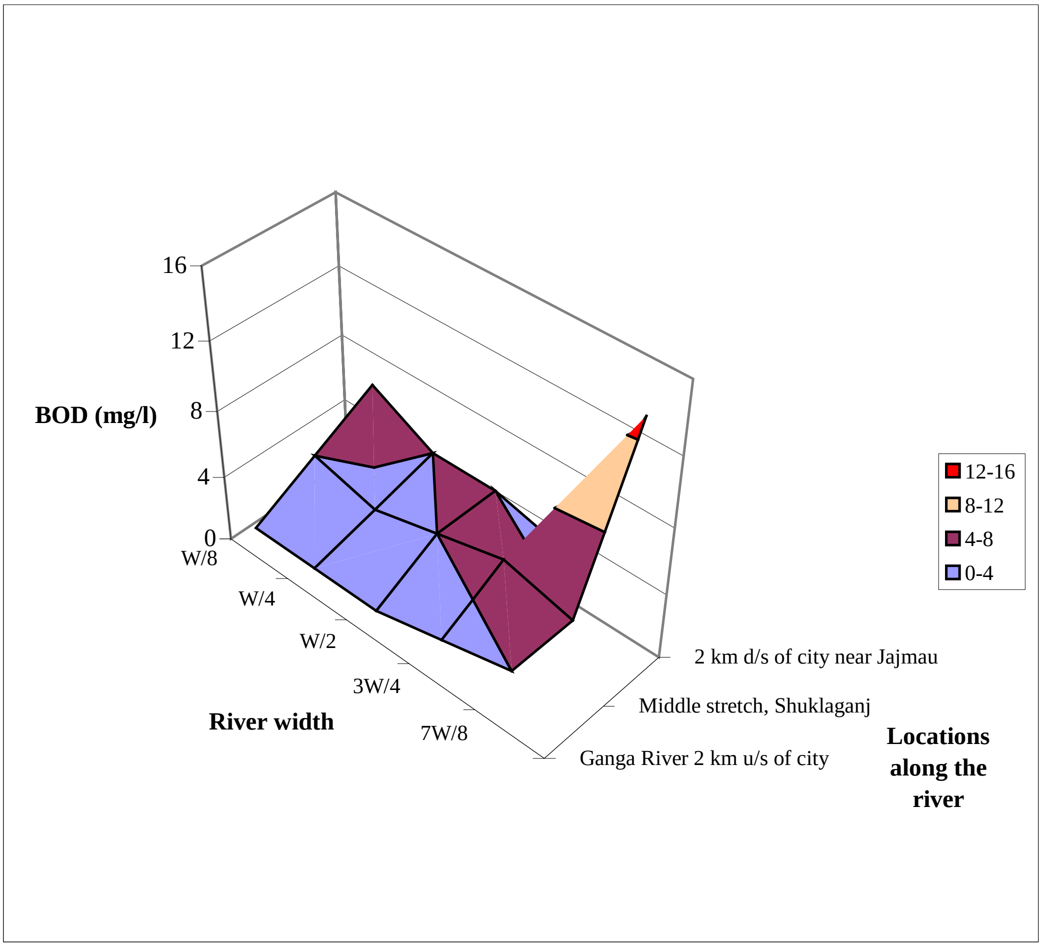


Figure 1.1 Longitudinal and transverse profile of BOD in Ganga river at Kanpur

(2) River Water Quality in Lucknow

The profile of BOD in Gomati is shown in Figure 1.2. BOD values in Gomati are recorded to be in the range of 3 to 7 mg/l. On the upstream, the value in the middle of the channel is 3 mg/l while on the right bank it is 6 mg/l. As the river flows down through the city, it receives large quantity of sewage, however the recorded BOD values which are in the range of 3-4 mg/l. (Values provided by CPCB for this section are in the range of 5 – 9 mg/l, water quality status and statistics, CPCB, 1998). However, about 2 km downstream of the city, there is a measurable increase in the BOD which is recorded in the range of 5-7 mg/l. About 200 km downstream another sample was collected on Gomati River before it joins Ganga. The BOD is in the range of 5-7 indicating entry of organic pollution from smaller towns and rural areas as well as from non-point sources along the way. DO values in Lucknow stretch are consistently in the range of 5-7 mg/l.

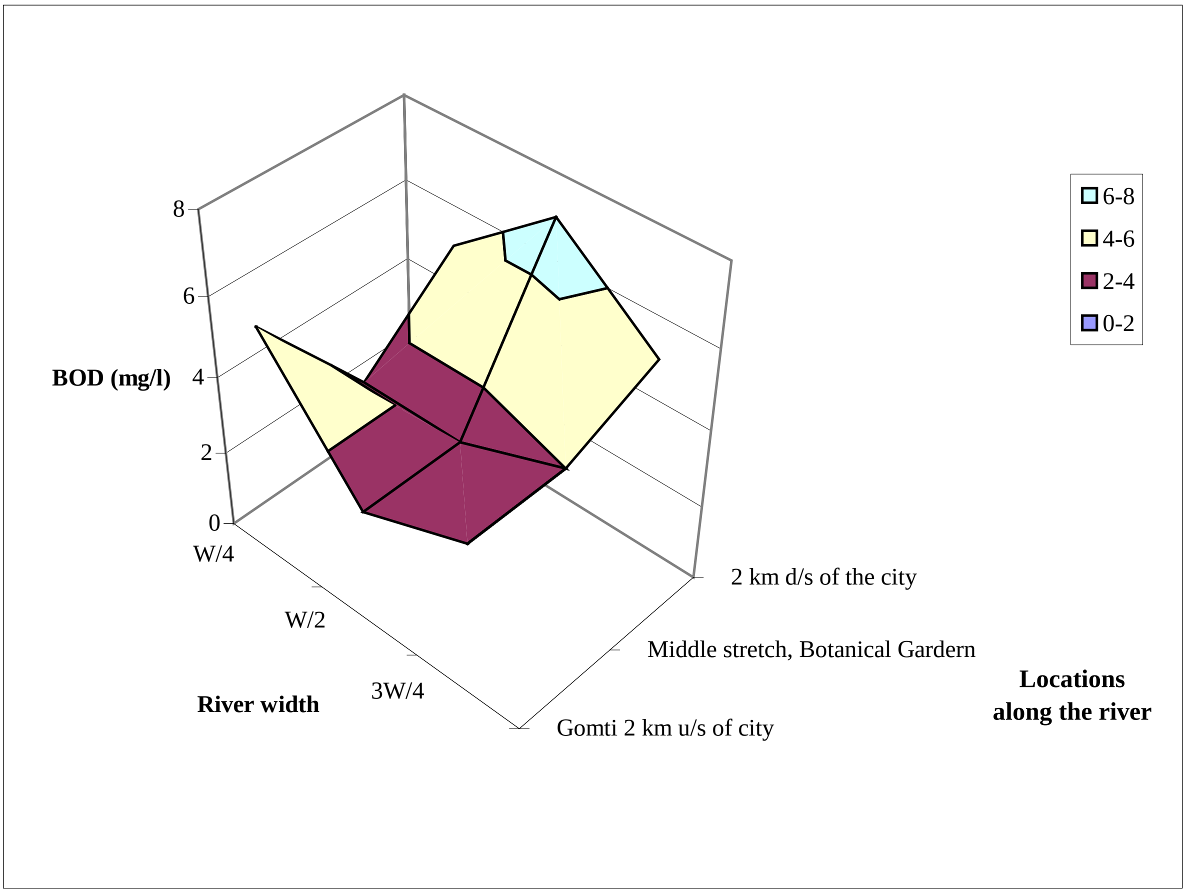


Figure 1.2 Longitudinal and transverse profile of BOD in Gomati river at Lucknow

(3) River Water Quality in Allahabad

The BOD profile for Ganga at Allahabad is shown in Figure 1.3. The values are varying from 4 mg/l in the upstream to 9 mg/l near Sangam (Confluence of Ganga and Yamuna) and then go down to 2 mg/l on the downstream of the city. At the downstream section, BOD of 8 mg/l is recorded on the opposite bank, which represents dispersion and also contribution from the STP outfall, which is located on the other side of the river. Based on these values the Allahabad stretch of Ganga during the summer of 2003 was found to be conforming to Class D near Sangam. It is to be noted that BOD value 1 km downstream of STP outfall is in the range of 2-4 km indicating a combination of factors, i.e., acceptable performance of the STP, adequate dilutions and good dispersion. DO values are recorded to be uniform in the range of 5 – 7 mg/l at all the five sections. Water quality of river Yamuna was also measured in Allahabad. On both the upstream and near the Sangam BOD values are recorded to be between 5-7 mg/l and the corresponding DO values are close to 6 mg/l. Considering a sizable flow of over 100 cum/sec in Yamuna at this point, the BOD values correspond to a large quantum of organic pollution load in the river system.

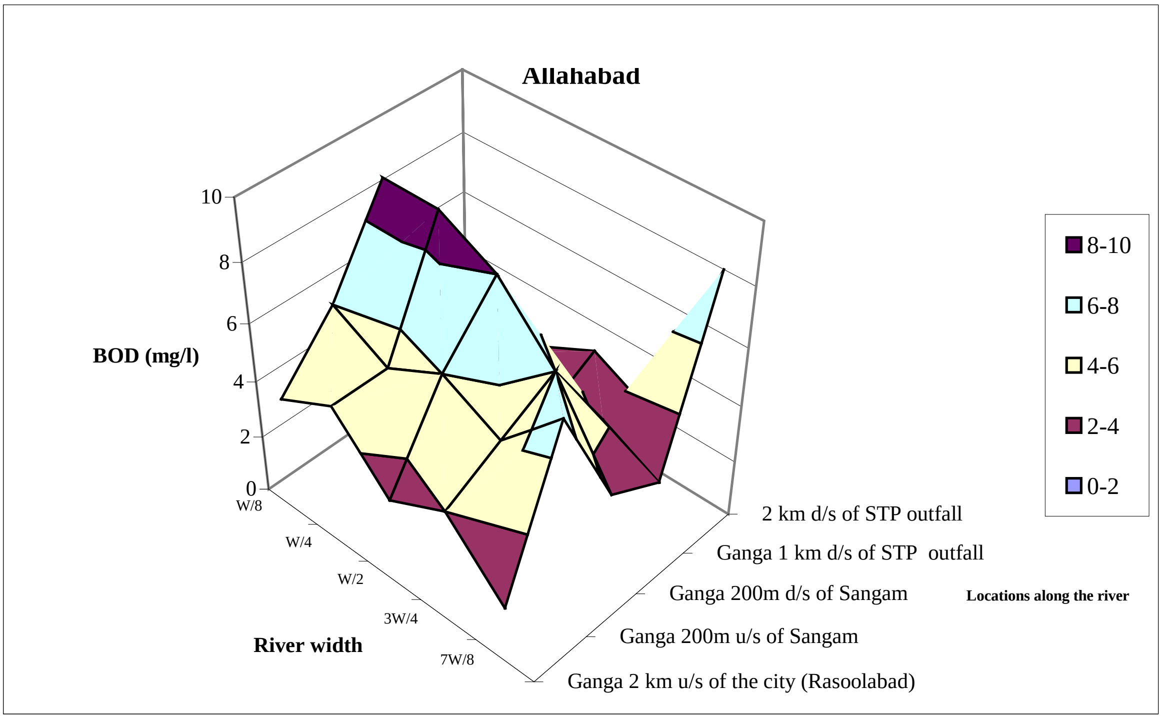


Figure 1.3 Longitudinal and transverse profile of BOD in Ganga river at Allahabad

(4) River Water Quality in Varanasi

Profile of BOD envelope along the length and breadth of the Ganga river at Varanasi is presented in Figure 1.4. In the upstream reach, the BOD is in the range of 5 to 9 mg/l. In the middle reach near Rajendra Prasad Ghat, BOD rises to 22 mg/l near the left bank. Across the width it declines to 7 mg/l near the mid point and then rises again to 22 mg/l near the right bank. Average BOD across the section is 18 mg/l. Lateral dispersion of wastewater discharges from Nagua nala and others on the upstream could be the reason for such high BOD values on the other bank where otherwise there is no human activity taking place. River water quality conforms to 'Class D'

On the downstream of Varuna confluence, where over 60 mld of sewage is introduced, BOD along the left bank shoots up to 50 mg/l. Average BOD at this section is 15 mg/l, however it drops significantly to 2 mg/l at one quarter and three quarter width.

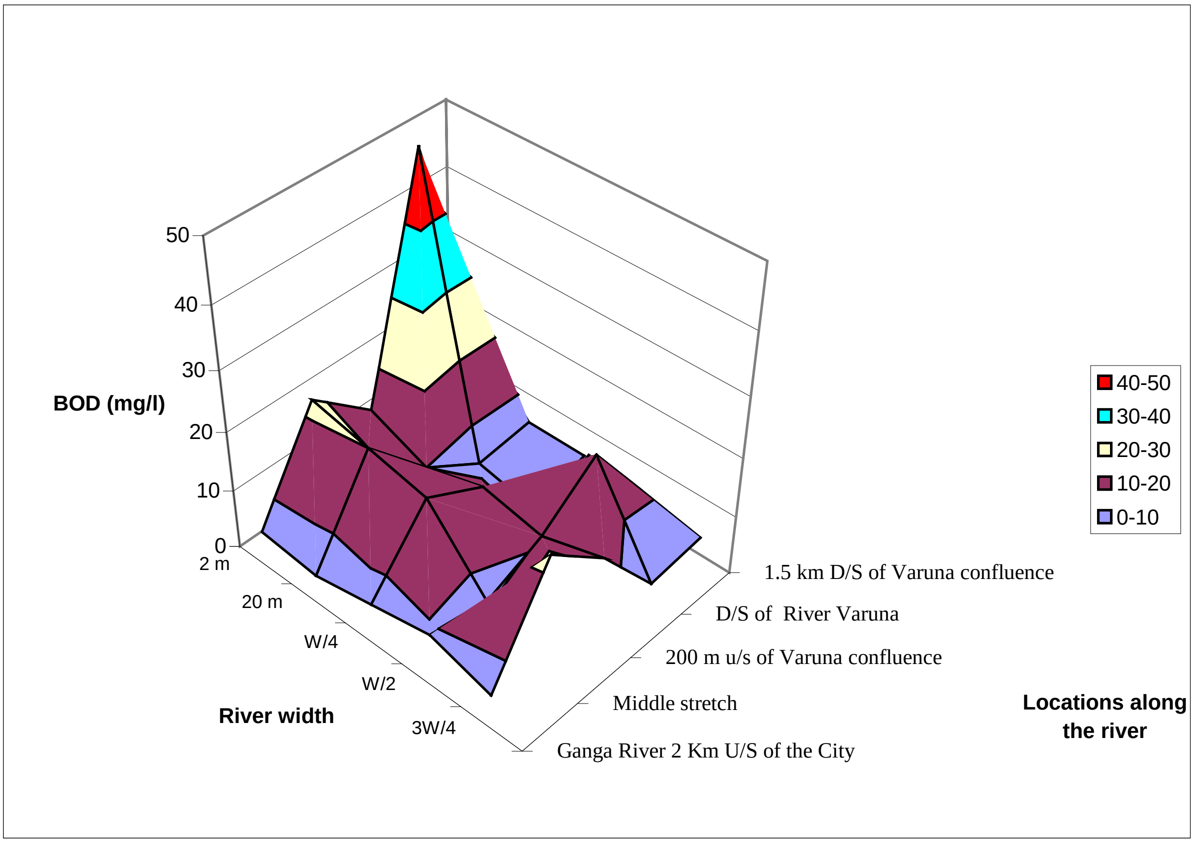


Figure 1.4 Longitudinal and transverse profile of BOD in Ganga river at Varanasi

Further 2 km downstream of the above location, BOD varies from 15 mg/l at left bank to 3 mg/l on the right bank with an average of 6 mg/l. At this point a sand island has formed which divides the flow into two separate channels. Interestingly the water is found to be very clean in the zone where flow separation is taking place. BOD at this point is 3 mg/l and suspended solids have dropped (from 33 mg/l on the left bank) to 4 mg/l, while DO is measured to be close to 7 mg/l. This self-purification can be attributed to specific hydraulic situation due to the formation of Sand Island during the summer season.

About 30 km further downstream before Gomati confluence, the average BOD and DO values are found to be 6 mg/l each. On the downstream of the confluence, while average BOD is found to have increased to 7.7 mg/l (10 mg/l in the mid stream) there is a corresponding drop in average DO value to 5.7 mg/l.

1.3.4 Wastewater Loads from Nalas

Out of the 101 odd storm water drains or nalas identified in the four cities, 36 major ones were selected for monitoring where the flow is still entering into the river and which could be targeted in the subsequent phase for engineering interventions. A detailed listing of these nalas is given in Appendix A while the hourly flow measurement values and graphs depicting diurnal flow variations over a 24 hour period are provided in Appendix A. A summary of the daily wastewater loads is provided in Table 1.8 below, which corresponds to a typical dry weather day in the summer of year 2003. The major nalas with flows over 10 mld, which are discharging in to the river, are highlighted.

Table 1.8 Summary of Nala Flows in four Cities

City : Varanasi			City : Allahabad		
Name of nala/location	**24 hr Flow mld**	**BOD mg/l**	**Name of nala/location**	**24 hr Flow mld**	**BOD mg/l**
Talia Bagh Nala	**14.1**		Mawaiya Nala	9.3	18
Nai Basti Nala	3.4		**Chachar Nala**	**17.9**	32
Central Jail Nala	2.9		Salori 1	6.4	20
Orderly Bazaar Nala	2.8		**Salori 2**	**10.4**	21
Narokhar Nala	6.6	55	Kodara Nala	8.3	10
Konia Bypass	**44.8**	130	**Rajapur - Ada Colony**	**14.0**	20
Varuna (Confluence)	**62.7**	46	**Emergency Outfall**	**20.2**	70
Shivala Nala	2.0	64	**Ghaghar Nala**	**21.4**	22
Nagua Nala	**17.0**				
Varuna 2 Km u/s	17.3	44			
City : Lucknow			**City : Kanpur**		
Kukrail Nala	**73.1**		Jageshwar Nala	8.1	
Wazirganj Nala	10.8		Ranighat Nala	1.6	
Mohan Meaken Nala	5.2		Guptar ghat Nala	1.6	
Sewer Outfall (B. Garden)	**29.8**		Muir Mill Nala	1.2	
Daliganj Nala	7.2		**Sisamau Nala**	**117.0**	
G H Canal	**100.7**		**Ganda Nala**	**56.2**	
China Bazaar Nala	4.1		COD Nala	11.3	
Gomati Nagar Nala	3.7		**Pandu River**	**181.3**	
Laplace Nala	**16.3**				
Ghasiyari mandi Nala	14.9				

Note : BOD values for nalas are found to be low.

In Varanasi, the major nalas of concerns representing concentrated nodes of organic load on the river in decreasing order of magnitude are Varuna river, Konia by-pass (sewer outfall), Nagua nala and Teliabagh nala, respectively. In case of Allahabad, the major nalas are Ghaghar nala, Emergency nala, Chachar nala. In case of both Lucknow and Kanpur, it is observed that there are certain channels that have dry weather wastewater flows close to or over 100 mld. These are GH canal and Kukrail nala; and Pandu river and Sisamau nala, respectively. Future interventions should accord priority to these nalas for interception and diversion so as to get perceptible improvement in the immediate or short term.

Highly erratic diurnal flow pattern is observed in the nalas across the city. In many cases while the peaks and troughs are in concurrence with the typical water usage pattern, i.e., peak flows are observed in early or late morning hours and secondary peaks are observed during late evening hours. However, in many cases, the flow pattern is dependent on the functioning of pumping stations installed on the upstream for interception and diversion of flows and on the status of power supply. Very often the peak flows are observed during irregular hours on account of temporary stoppage of pumping operations. In such nalas, the ratio between peak and minimum flows are very large being of the order of 200 while in normal circumstances with the ratio is in the range of 2-5.

1.3.5 Monitoring of Sewage Treatment Plants

A summary of monitored data for the eight separate STPs in the project cities is presented in Table 1.9. It is noted that capacity utilisation at Dinapur STP at Varanasi (125%), 5 mld pilot STP at Kanpur (100%) and Daulatganj STP at Lucknow (105%) is close to or above 100 % while at all the rest of the STPs it is around 50-70 %. In case of many STPs, continuous flow of raw wastewater is disrupted due to frequent power failures experienced in the cities.

Table 1.9 Summary of Performance Monitoring at STPs

ALLAHABAD					
	Flow			**BOD**	
STP	**Daily total (mld)**	**Max (m3/hr)**	**Min (m3/hr)**	**Inlet (mg/l)**	**Outlet (mg/l)**
Naini (60 mld)	33.5	2496	0*(PF)		
KANPUR					
5 mld Pilot	5	227	196		
130 mld ASP	62.5	3460	604		
36 mld UASB	19.8	963	509		
VARANASI					
	Flow			**BOD**	
STP	Daily total (mld)	Max (m3/hr)	Min (m3/hr)	Inlet (mg/l)	Outlet (mg/l)
Bhagwanpur (10 mld)	7.8	554	157	11*	13
DLW (12 mld)	3.6	370	0*(PF)	38*	30
Dinapur (80 mld)	99.7	6773	0*(PF)	180	100
LUCKNOW					
Daulatganj / Gaughat (42)	44	557	3560		

* : Unusually low values on a dry weather day. Need to be crosschecked through re-sampling.

Inlet BOD values recorded at Bhagwanpur and DLW are very low and need to be crosschecked. Outlet BOD at two of the STPs in Varanasi is in compliance, while that at the new STP at Dinapur is over 3 times the permissible limit.

BOD of the 36 mld UASB at Kanpur is typically over 150 mg/l and it is attributed to the industrial wastewater received from Jajmau Tannery Complex.

1.3.6 Pollution Load Survey

In case of sewered area in Varanasi, the findings of the pollution load survey for sewage loads are:
Per capita sewage generation: 247 lpcd (inclusive of sullage discharges)
Per capita BOD generation: 18 gpcd (inclusive of sullage discharges)

The volume of sewage generation is high due to copious supply of domestic water and the high income locality. However, the BOD values that are inclusive of the gray water component are rather low. These are attributed to difficulties experienced in the sampling methodology.

In case of unsewered area in Varanasi, the findings of the survey for gray water component are:
Per capita gray water generation: 63 lpcd
Per capita BOD generation: 2 gpcd

The BOD component of gray water appears to be very low.

In case of wastewater from toilets (which comprises feces, urine and wash water) covering community latrines and individual latrines the per capita BOD load is estimated to be ranging from 0.8 to 4.8 gpcd. The values appear to be on a lower side. However, it needs to be noted that the sampling team encountered logistical difficulties in collecting representative samples.

1.3.7 Characterization of Sediment from Gomati

Sediment samples taken at 6 locations upstream of Gomati Barrage in Lucknow prima facie show higher levels of Tetanus Bacillus (Clostridium positive) and heavy metals such as Chromium. The analysis has also detected presence of Nickel, Cobalt, and Mercury. The detailed analysis report on characterization is presented in Appendix A.

In view of the initial characterization results, the sediment can be considered as hazardous waste. Any intervention related to dredging of the channel would need to incorporate measures for safe disposal of the sediment such that subsequent contamination of any part of the eco-system is prevented.

CHAPTER 2

WATER QUALITY ESTIMATION

CHAPTER 2 WATER QUALITY ESTIMATION

2.1 GENERAL

The former inventory of pollution load generation in the entire Ganga Basin was prepared in the year 1984 and some parts of the information provided are still available for the present Study. However, it is essentially necessary to update the former inventory using the latest data, e.g., river water quality, river flow, population, sewerage service area and so on, in order to analyze the status of water quality in the basin.

Adequate knowledge of the existing nature, magnitude and sources of various pollution loads in water bodies is much needed for any rational formulation of water pollution control policies and measures. As for the Ganga, being the largest river basin in the country, it is very important that reconnaissance is extensively carried out to assess the water quality in the basin.
The need and importance of basin-wise study of water quality and the various factors that determine the pollution load generation and its runoff is required as the basic information for the river water pollution control. Based on the analysis of collected data, it is observed that water pollution arising from industrial and urban wastewater is very significant. At the same time the rural surroundings and agricultural fields are also found to be the potential sources of pollution.

In the formulation of water pollution control programs, it has been emphasized that on account of the present trend of rapid industrialization, modernization of farming practices, fast urbanization, introduction of sewer systems in many towns, and supply of potable water to a number of villages, the pollution load in the Ganga Basin is also undergoing rapid changes. In other words, assessment of the current situation is not sufficient in the formulation of pollution control programmes, especially for such a vast drainage network as the Ganga Basin.

The main objectives of the inventory study may be briefly stated as follows:

(1) To collect detailed data relevant to water pollution for the entire Ganga Basin including information on the hydrology, climate, demography, land use, agriculture, wastewater disposal, etc.
(2) To analyze the data with a view to finding out possible relationship between human activities and the different aspects relating to water quality in the Ganga Basin.
(3) To present the data through maps, charts, tables, and texts in the form of a technical report, so that it may be useful for the control and prevention of water pollution in the Ganga Basin.
(4) To assess the impact of the various development programmes on the use and quality of water in the basin.

In this report, the basic policy of the inventory study is that sub-basin wise totality of the pollution load generation as well as city or state wise pollution load generation has been adopted.

In this inventory study, sub-basin wise pollution load generation and pollution load runoff at the confluence point with the main river stem such as Ganga and Yamuna are calculated.

While estimation of pollution load generation is carried out city wise, the influence of only riverside cities on the river water quality can be taken into account. However, the pollution load generated from cities located far from the tributaries or main river stem, reduces significantly until it reaches the main river stem due to the self-purification effect. Accordingly, it is essential to consider the sub-basin wise pollution load generation and runoff to the main river stem in order to estimate the pollution load exactly. In this Study, the pollution load generation from the entire Ganga Basin and pollution load runoff into the main river stems are estimated using the latest data and information considering the following assumptions:

(1) Class I cities and Class II towns located nearby the riverside of the main river stem and primary/secondary tributaries were selected as the point pollution sources. The point pollution load consists of the domestic and industrial wastewater effluent. However, the cities located at a distance of 30 km or more from the rivers are assumed to be non-point pollution sources.
(2) Among the above-mentioned cities designated as the point pollution sources, the population in the urban centers is treated as the point pollution sources and the remaining rural population is considered as the non-point pollution sources.
(3) The whole of livestock is treated as the non-point pollution sources, and total sub-basin wise urban heads of cattle, buffaloes, goats and sheep based on projected values for 2001 is considered for the pollution load estimation.
(4) The pollution load from land under different uses is assumed to be non-point pollution sources.
(5) Effluent from solid waste dumping site, throwing of unburnt/half-burnt human bodies and animal carcasses, laundry (dhobi) Ghats, cattle wallowing, etc., are not taken into consideration because the actual magnitude and unit pollution loads generation from these categories is not available for this Study.
(6) Non-point pollution load from human population has been estimated using district wise census data; however, in case a particular district is shared by several sub-basins, the population is divided based on the proportional area of the relevant sub-basins.

2.1.1 Limitation of the Inventory

Much of data of this report have been collected from secondary sources. Hence, the database presented here should be taken as indicative. However, it is sufficient for presenting a reasonably correct picture of the situation regarding water pollution in the Ganga Basin.

This inventory study aims at the entire Ganga Basin that covers 840,000 km^2 of catchment area (more than twice as large as the total area of Japan); hence, information on certain aspects, like water quality and hydrological characteristics of streams in the basin, has been rather inadequate and incomplete at several places. On the basis of the available data it has been sometimes difficult to draw accurate conclusion of quantitative nature. However, certain patterns of the river pollution have emerged from the findings of this Study by application of statistical techniques and coverage of whole area in Ganga Basin.

2.1.2 Objective River Sub-basin

For the grasp of river water quality, the pollution load generation needs to be calculated for the entire Ganga Basin, which has a total area of 840,000 km^2. The objective Ganga River Basin is divided into six (6) major sub-basins and further subdivided into 38 sub-basins, as shown in Table 2.1, for the estimation of existing and future pollution load generation. For location of the above six (6) major sub-basins and 38 sub-basins, see Figure B.2.2. Main features of the 38 sub-basins are shown in Table B.5.1.

Table 2.1 Objective River System and Sub-basins

River System	Sub-basin
Upper Ganga Main	(1) Upper Ganga I, (2) Upper Ganga II, (3) Ramganga and (4) Kalinadi
Middle Ganga Main	(4) Middle Ganga I, (5) Middle Ganga II, (6) Middle Ganga III, (7) Middle Ganga IV and (8) Tons
Lower Ganga Main	(22) Karmanasa, (23) Ghaghra, (24) Sone, (25) Gandak, (26) Punpun, (27) Falgu, (28) Kiul, (29) Burhi Gandak, (30) Kosi and (31) Dwarka, (32) Jalangi, (33) Ajay, (34) Damodar, (35) Rupnarayan, (36) Haldi, (37) Lower Ganga I, (38) Lower Ganga II
Upper Yamuna River	(10) Upper Yamuna I, (11) Hindon, (12) Upper Yamuna II, (13) Upper Yamuna III
Lower Yamuna River	(14) Chambal, (15) Sind, (16) Betawa, (17) Ken, (18) Lower Yamuna
Gomati River	(19) Upper Gomati, (20) Lower Gomati, and (21) Sai

Note: Number in bracket is sub-basin number in Figure B.5.4.

The Ganga River Basin extends through the territories of eleven (11) states, either covering the whole state or only part of it. The area of each state covered by different river sub-basins in each river system can be seen in Table 2.3. Further, for the detailed relation between different state areas and each sub-basin, see Table B.5.2.

2.1.3 Modeling of Entire Ganga Basin

In order to estimate the influence of water quality deterioration in the entire Ganga Basin, it is necessary to construct a basin runoff model for easier understanding of water quality trend. In this Study, the basin runoff model targeting the entire Ganga Basin was formulated for the purpose of rough estimation of pollution load generation and runoff on the sub-basin basis under the following assumptions:

(1) Pollution load generated in each sub-basin is discharged into small ditches, drainage channels and secondary tributaries, and is never excreted into canals for irrigation or domestic water supply.
(2) Non-point loads are not controlled and are constant even in future except for rural population.
(3) Population in urban centers of Class I and Class II towns and other major cities is assumed to be point pollution sources, and population in remaining rural area and small towns are considered to be non-point pollution sources.

2.1.4 Linkage with GIS

Calculation of sub-basin wise pollution load generation is ambitious, extremely extensive and complex; therefore, efficient data management, accumulation and assembly are necessary. In this circumstance, linkage with GIS is useful for the basin runoff model as shown in Figure 2.1. For detail description, refer to the report on GIS.

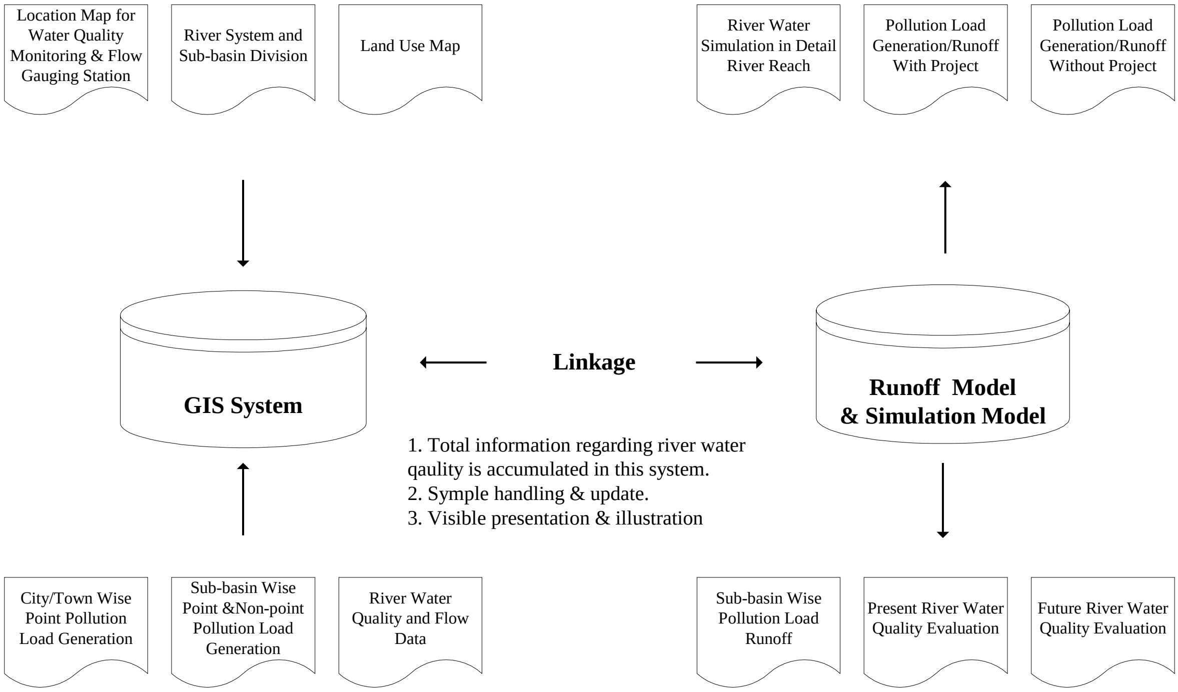


Figure 2.1 Linkage with GIS

2.2 ESTIMATION OF WATER QUALITY

The Ganga River is highly polluted by organic material of domestic and industrial origin. This has resulted in a high concentration of organic material, low dissolved oxygen and high concentration of bacteria in the river water. BOD has been used as indicator of water quality of the Ganga River.

2.2.1 Existing Pollution Load Generation

In this Study, pollution load is classified into point and non-point loads. The point load includes: (i) municipal wastewater discharged into rivers from sewerage system; (ii) industrial wastewater discharged into rivers either directly or from sewerage system. The non-point pollution loads include wastewater from households (not covered by the sewerage system), livestock and lands (agricultural land, pasture and shrub/forest).

2.2.2 Point Pollution Load Generation

There are 101 Class I cities and 122 Class II towns in the Ganga Basin. In this basin where nearly 50% of the Class I cities and Class II towns are located on the riverbanks, the mode of discharge of municipal wastewater is mainly into the river systems. The recent survey of Class I and Class II cities indicated that about 8,250 MLD of wastewater is generated in the Ganga Basin, out of which treatment facilities are available only for 3,500 MLD of wastewater. Out of the 3,500 MLD treatment capacities, 880 MLD is to be created under the Ganga Action Plan, 720 MLD under the Yamuna Action Plan, and about 1,927 MLD by Government of Delhi for the restoration of water quality in the Yamuna River.

The industrial data has been divided into the following major categories: Abattoir, Carpets, Chemicals & Caustic Soda, Dairy, Distillery, Cluster of Dyeing & Printing, Dyes, Engineering, Fertilizer, Cluster of Jute Processing, Pesticides, Pharmaceuticals, Pulp & Paper, Sugar, Tannery, Textile, Thermal Power Plant and Vegetable Oil & Vanaspati. The total number of target industries amounts to 1,289 in the entire Ganga Basin distributed over 234 districts. Out of these, there are 30 that represent clusters of Small Scale Industries (SSIs). The Ganga River Basin report indicated that Uttar Pradesh contributed the major share of more than 55% of the total urban industrial pollution load to the basin.

2.2.3 Non-point Pollution Load Generation

Water runoff from rural settlements, cattle pens, agricultural farms, etc., in the basin is likely to be toxic enough to pollute the prevailing water bodies and drainage systems and the heavy silt load brought down by the runoff also affects the water quality and causes navigational problems and other environmental hazards in the Ganga Basin. The generation of pollution load from agricultural land, livestock and rural households would be more or less uniformly spread over large areas.

After land disposal of the wastewater, the pollutants do not reach the water bodies directly but get decomposed by microorganisms present in the soil or are consumed by other living beings. Some parts of wastewater may also percolate into the soil. Thus, there is feeble chance for these sources to directly deteriorate river water quality through such a phenomenon.

During the onset of the monsoon, with the first showers of the season, the flushing of the whole catchment area takes place. As a result, the pollution load from land surface present in small or large quantities may find its way to recipient water bodies such as rural drains, along with storm water. However, in the course of flow downstream, these pollutants may undergo physical, chemical and biological changes and a considerable portion of particular substances settles down by the time the flow joins the main river course. Thus, the pollution load in rural areas regarded as non-point sources does not cause a serious problem to river water quality during the dry season.

In this Study, non-point pollution load is assumed to be generated from livestock, lands (agricultural land, pastureland, shrubs/forests) and households in the rural area. The number of livestock, rural population and land use area in each sub basin has been estimated, as shown in Table B.5.1.

BOD unit pollution load generation of each non-point source category is assumed, as shown in Table 2.2, based on previous studies and report.

Table 2.2 Unit BOD Pollution Load Generation from Non-point Sources

Sources		Unit Load of BOD	Reference
Livestock	Bovine	600 g/head/day	Guideline for Basin-wide Water Pollution Control Master Plan, Japan Sewage Works Association, 1996, p41
	Sheep and Goats	60 g/head/day	Guideline for Basin-wide Water Pollution Control Master Plan, Japan Sewage Works Association, 1996, p41
	Others	200 g/head/day	Guideline for Basin-wide Water Pollution Control Master Plan, Japan Sewage Works Association, 1996, p41
Agricultural Land		8.57 $kg/km^2/day$	Preparation of Unit Pollutant Load for Environmental Assessment, Nomura Synthetic Institute Japan
Pastureland		1.00 $kg/km^2/day$	Assumed by the Study Team
Shrub/Forest		0.75 $kg/km^2/day$	Preparation of Unit Pollutant Load for Environmental Assessment, Japan Sewage Society
Household (After Septic Tank Treatment)		14.0 g/person/day	Preparation of Unit Pollutant Load for Environmental Assessment, Japan Sewage Society

In the table above, unit population load generation from households is the pollution load generated after septic tank treatment. Further, non-point pollution load from cattle is considered to reduce by about 80% of the unit pollution load (600g/head) owing to its use as manure and fuel.

2.2.4 Other Pollution Sources

Pollution caused by in-stream use of river water is as follows: Cattle wading, Open defecation, Washing of clothes and so on. The rural population resides in areas located on both banks of the entire stretch of Ganga River Basin. The main activities in these areas are agricultural and cattle farming. The cattle from local farms frequently visit the river for various activities especially for wading in the

river water. This activity affects the river water quality through many ways. The fecal matter of the cattle contributed during wading may directly increase the BOD and coliform load of the river water.
In the Hindi mythology, bathing in the rivers and other water bodies are considered sacred and great significance is assigned to it on some auspicious day or moment. It is believed that it is one of the ways to wash out the sins. Therefore, in the entire country mass bathing in the rivers is a very common phenomenon. The water quality may deteriorate further through activities related to bathing, eg., offering of flowers, milk, sweets, etc., into the river water.

Some parts of the river course in Ganga Basin are highly polluted and sanitary facilities in rural and urban centers are either not existing or not developed. Hence, a large part of the population uses the river catchment area for open defecation. Moreover, dumping of dead animals and human dead bodies in the river may also affect the water quality of the river.

Washing of clothes along the riverbank is a common feature both in rural and urban centers. This may not only cause inorganic, organic and biological contamination but also increase the detergent contents.

However, pollution load generation from the above-mentioned sources is unaccountable; hence, in this Study; these sources should be excluded from the pollution load estimation.

2.2.5 Population Distribution in Ganga Basin

Class I cities and Class II towns in each sub-basin are given in Table B.5.3. Further, the sub-basin wise total population including small towns classified as Class III and Class IV is shown in Figure B.5.1. According to the 2001 census data, the total population in the entire Ganga Basin amounts to 397 million, and approximately 22% of the people are living in the Class I cities and Class II towns.

Based on Figure B.5.1, the Upper Yamuna II and Lower Ganga II sub-basins are the most congested areas and large quantities of domestic wastewater are generated from these sub-basins.

The population density of each sub-basin is shown in Figure B.5.2, and it is obvious that the Middle Ganga II, III and IV sub-basins, as well as the Upper Yamuna II and Lower Ganga II sub-basins, have high population densities. Further, river system wise population and its density is summarized in Table 2.3 and Figure 2.2.

Table 2.3 River System Wise Population and Its Density

No.	River System	Population	Total Area (km^2)	Population Density ($person/km^2$)	Main Cities
1	Upper Ganga	34,352,486	80,585	426	
2	Middle Ganga	30,883,036	36,365	849	Kanpur, Allahabad, Varanasi
3	Lower Ganga	152,530,853	319,729	477	Patna, Culcatta
4	Upper Yamuna	72,826,333	108,664	670	Delhi, Agra
5	Lower Yamuna	80,114,263	259,387	309	Jaipur, Indore, Bhopal
6	Gomati	26,951,239	33,403	807	Lucknow
	Total	397,658,210	838,583	474	

The Figure 2.2 shows that population density ranges from 309 to 849 person/km^2 and population densities of Upper Ganga, Middle Ganga, Upper Yamuna and Gomati river systems are slightly higher than those of other river systems.

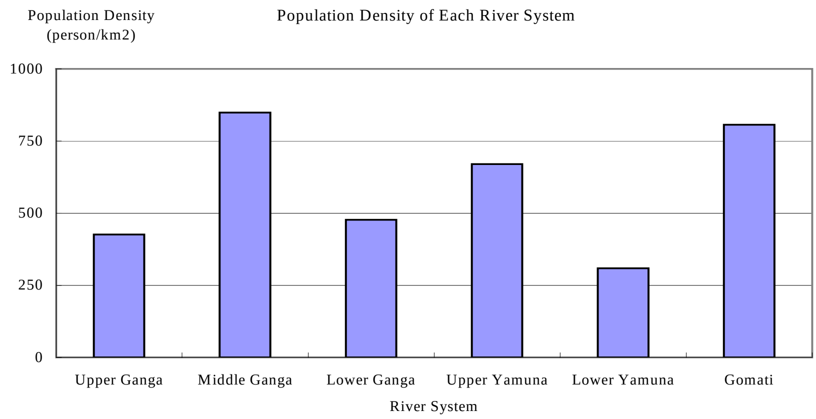


Figure 2.2 Population Density

2.2.6 Total Existing Pollution Load Generation

The existing total pollution load generation of BOD in the entire Ganga River Basin (estimation objective area: approximately 840,000 km^2) is broken down by pollution source, as shown in Table 2.4.

Table 2.4 Pollution Load Generation from Each River System

(Unit: kg/day)

Source	Upper Ganga	Middle Ganga	Lower Ganga	Upper Yamuna	Lower Yamuna	Gomati	Total	(%)
Point (sewerage)	188,346	89,423	498,260	364,618	303,497	71,960	1,516,103	13
Point (industry)	37,864	19,337	123,208	84,270	39,969	6,941	311,589	3
Sub-total	226,210	108,760	621,468	448,888	343,466	78,901	1,827,692	16
Non-point (households)	284,061	269,041	1,406,795	515,587	731,247	260,689	3,467,421	30
Non-point (livestock)	69,578	34,927	273,010	164,609	266,467	26,084	834,675	7
Non-point (land)	462,262	257,250	2,023,308	824,766	1,578,516	280,092	5,426,194	47
Sub-total	815,901	561,218	3,703,113	1,504,962	2,576,230	566,865	9,728,290	84
Total	1,042,111	669,978	4,324,581	1,953,850	2,919,696	645,766	11,555,982	100.0

The existing pollution load generation of BOD by source and in each sub-basin is illustrated in Figure B.5.3. Further, it is broken down by source and by sub-basin, as shown in Table B.5.7.

The ratio of existing pollution load generation of each source in the objective Ganga River Basin is shown in Figure 2.3. Of the total pollution load generation, non-point pollution load generation of BOD shares 84%. However, the runoff of the non-point pollution load is very small during the dry season and does not affect the river water quality.

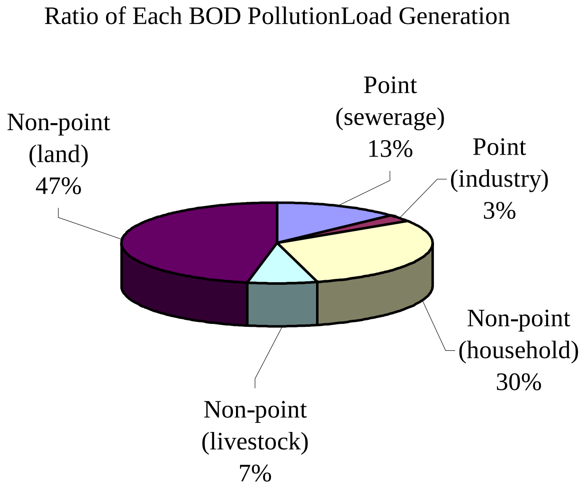


Figure 2.3 Ratio of Each Category Pollution Load Generation

Further, the density of existing BOD pollution load generation in each river system is shown in Table 2.5 and Figure 2.4. For sub-basin wise density, see Figure B.5.5.

Table 2.5 Density of Pollution Load Generation in Each River System

No.	River System	Pollution Load Generation (kg/d)	Total Area (km^2)	Pollution Density ($kg/d/km^2$)	Main Cities
1	Upper Ganga	1,042,111	80,585	12.93	
2	Middle Ganga	669,978	36,365	18.42	Kanpur, Allahabad, Varanasi
3	Lower Ganga	4,324,581	319,729	13.53	Patna, Calcutta
4	Upper Yamuna	1,953,850	108,664	17.98	Delhi, Agra
5	Lower Yamuna	2,919,696	259,387	11.26	Jaipur, Indore, Bhopal
6	Gomati	645,766	33,403	19.33	Lucknow
	Total	11,555,982	838,583	13.78	

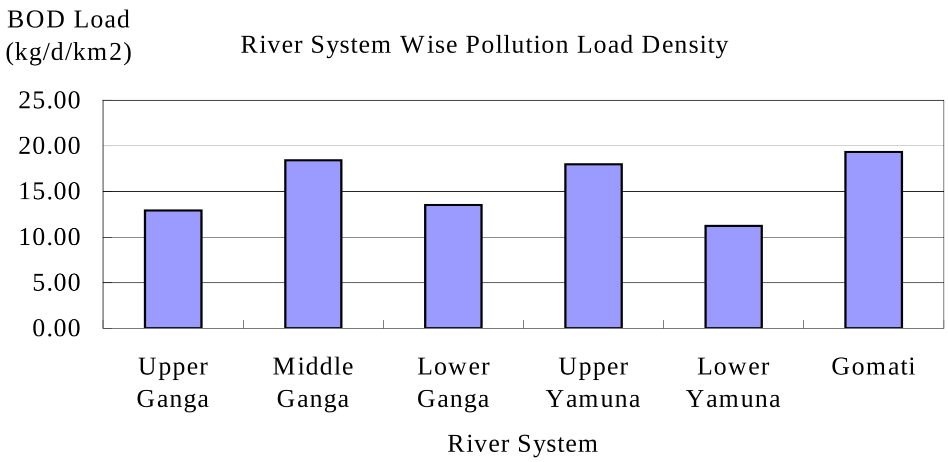


Figure 2.4 Density of Pollution Load Generation

According to the Figure above, pollution load generation density of Gomati, Middle Ganga and Upper Yamuna is relatively high compared to other river systems. However, in all the river systems, pollution load generation density ranges from 10 to 20 $kg/day/km^2$. In order to estimate the exact impact on the river water quality, it is essential that sub-basin-wise pollution load runoff be considered as mentioned in later part of this report.

2.2.7 Future Pollution Load Generation Without Project

(1) Basis for Future Frame of Population/Economic Growth

Municipal wastewater will increase according to the growth of sewerage served population and per capita wastewater quantity, while industrial wastewater will increase according to the growth of industrial production.

(a) Future Population

The future population in the objective basin has been estimated based on the projection study on the actual past census data and state-wise future projection. The target years for the future projection are 2010, 2015 (F/S) and 2030 (M/P). Estimated future population for the respective years is given in Table 2.6 (2010), Table 2.7 (2015) and Table 2.8 (2030).

Table 2.6 Future Population in Each River System (2010)

No.	River System	Population	Area (km^2)	Population Density ($person/km^2$)	Main Cities
1	Upper Ganga	41,500,189	80,585	515	
2	Middle Ganga	37,596,538	36,365	1,034	Kanpur, Allahabad, Varanasi
3	Lower Ganga	178,468,210	319,729	558	Patna, Culcatta
4	Upper Yamuna	90,373,580	108,664	832	Delhi, Agra
5	Lower Yamuna	97,243,451	259,387	375	Jaipur, Indore, Bhopal
6	Gomati	38,653,948	33,403	1,157	Lucknow
Total		483,835,916	838,583	577	

Table 2.7 Future Population in Each River System (2015)

No.	River System	Population	Area (km^2)	Population Density ($person/km^2$)	Main Cities
1	Upper Ganga	46,036,308	80,585	571	
2	Middle Ganga	41,839,398	36,365	1,151	Kanpur, Allahabad, Varanasi
3	Lower Ganga	197,231,125	319,729	617	Patna, Culcatta
4	Upper Yamuna	103,495,500	108,664	952	Delhi, Agra
5	Lower Yamuna	107,934,932	259,387	416	Jaipur, Indore, Bhopal
6	Gomati	43,089,647	33,403	1,290	Lucknow
Total		539,626,910	838,583	643	

Table 2.8 Future Population in Each River System (2030)

No.	River System	Population	Area (km^2)	Population Density ($person/km^2$)	Main Cities
1	Upper Ganga	60,240,639	80,585	748	
2	Middle Ganga	55,104,871	36,365	1,515	Kanpur, Allahabad, Varanasi
3	Lower Ganga	256,987,502	319,729	804	Patna, Culcatta
4	Upper Yamuna	145,231,321	108,664	1,337	Delhi, Agra
5	Lower Yamuna	140,764,011	259,387	543	Jaipur, Indore, Bhopal
6	Gomati	57,030,415	33,403	1,707	Lucknow
Total		715,358,759	838,583	853	

(b) Future Economic Growth

The future economic growth in the objective basin was estimated based on the projection study on the actual information published by the industrial sectors. The target years for the future projection are 2010, 2015 (F/S) and 2030 (M/P).

Considering the wide geographical and category spread of the future industrial products, it is rather difficult to arrive at uniform or singular number indicating the growth rate in industrial pollution for next decade or beyond. However, an attempt was made to develop a representative scenario. The Figure 2.5 gives the industrial growth rate for past 8 years.

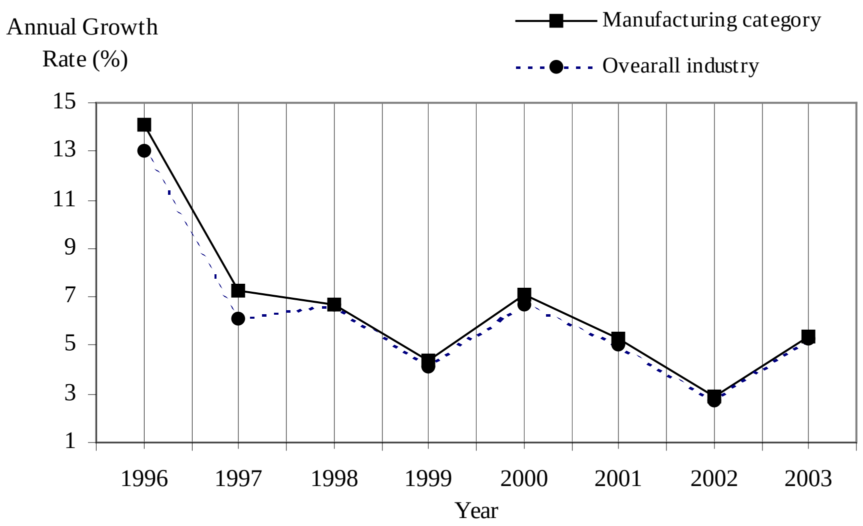


Figure 2.5 Industrial Growth Rate During Last Eight Years

In this context, a rather flat growth rate of 2% for the industrial pollution load is assumed for the period between 2010 and 2030. As results, the aggregate basin-wide BOD loads for the years 2010, 2015 and 2030 are estimated as shown in Table 2.9.

Table 2.9 Future Growth Rate of Industry

Year	2003	2010	2015	2030
Annual Growth Rate (%)	-	4.0	3.6	2.0
BOD (ton/d)	308.8	406.4	475.6	603.8
Constant	1.00	1.31	1.54	1.95

(2) Future Point Pollution Load Generation

The future point pollution load generation without project in the objective Ganga River Basin in the target years of the F/S (2015) and Master Plan (2030) are estimated in the same manner as in the case of existing ones.

(3) Future Non-point Pollution Load Generation

In this Study, non-point pollution load from livestock, lands (agricultural land, pastureland, shrubs/forests) is assumed to be in the same condition as in existing one because non-point pollution loads are not controlled and predicted. However, households in the rural area are taken into account as in future condition based on the projection.

(4) Total Future Pollution Load Generation

The future pollution load generation in the objective Ganga River Basin in the target years of the F/S (2015) and Master Plan (2030) are estimated, as shown in Table B 5.9 to 5.12. The total future pollution load generation of BOD in the objective Ganga River Basin (estimated objective area: 840,000 km^2) is summarized in Tables 2.10 and 2.11. In case of the future condition pollution load estimation with project, it is assumed that 80% of domestic pollution load generation is cut down.

Table 2.10 Future Pollution Load Generation (Without Project)

(Unit: kg/d)

Target Year	Source	Lower Ganga	Upper Ganga	Middle Ganga	Upper Yamuna	Lower Yamuna	Gomati	Total	(%)
2010	Point	757,819	277,983	147,207	535,562	422,205	98,518	2,239,295	18.0
	Non-Point	3,942,649	875,196	619,582	1,624,859	2,732,536	688,879	10,483,701	82.0
	Total	4,700,468	1,153,179	766,789	2,160,421	3,154,741	787,398	12,722,996	100
2015	Point	848,179	312,087	172,252	598,512	473,434	111,229	2,515,693	19.0
	Non-Point	4,120,596	912,833	656,422	1,710,095	2,829,760	732,796	10,962,502	81.0
	Total	4,968,775	1,224,920	828,674	2,308,608	3,303,194	844,025	13,478,195	100
2030	Point	1,091,818	407,085	244,781	787,828	620,233	149,006	3,300,751	21.0
	Non-Point	4,689,614	1,030,713	771,498	1,977,476	3,127,548	870,820	12,467,670	79.0
	Total	5,781,432	1,437,798	1,016,280	2,765,304	3,747,782	1,019,826	15,768,420	100

Table 2.11 Future Pollution Load Generation (With Project)

(Unit: kg/d)

Target Year	Source	Lower Ganga	Upper Ganga	Middle Ganga	Upper Yamuna	Lower Yamuna	Gomati	Total	(%)
2010	Point	280,686	95,278	49,707	195,427	126,329	26,978	774,404	7.0
	Non-Point	3,942,649	875,196	619,582	1,624,859	2,732,536	688,879	10,483,701	93.0
	Total	4,223,335	970,474	669,288	1,820,286	2,858,865	715,857	11,258,105	100
2015	Point	321,428	109,066	58,273	223,523	143,929	30,797	887,016	7.0
	Non-Point	4,120,596	912,833	656,422	1,710,095	2,829,760	732,796	10,962,502	93.0
	Total	4,442,024	1,021,899	714,695	1,933,618	2,973,688	763,593	11,849,518	100
2030	Point	410,568	140,485	79,122	289,027	186,398	40,629	1,146,229	8.0
	Non-Point	4,689,614	1,030,713	771,498	1,977,476	3,127,548	870,820	12,467,670	92.0
	Total	5,100,182	1,171,197	850,620	2,266,503	3,313,947	911,450	13,613,899	100

2.2.8 Pollution Load Runoff

The existing total pollution load runoff of BOD in the entire Ganga River Basin (simulation objective area: 840,000 km^2) is broken down by pollution source, as shown in Table 2.12 (for detail, see Table B.5.13) and Figure B.5.5.

Table 2.12 Existing Pollution Load Runoff

(Unit: kg/day)

Source	Upper Ganga	Middle Ganga	Lower Ganga	Upper Yamuna	Lower Yamuna	Gomati	Total	(%)
Point (sewerage)	51,164	56,794	75,948	149,748	19,522	42,950	396,126	79.4
Point (industry)	11,291	12,078	18,727	25,749	2,215	3,248	73,308	14.7
Sub-total	62,455	68,873	94,674	175,498	21,736	46,198	469,434	94.1
Non-point (household)	964	2,188	3,323	2,138	1,239	1,002	10,854	2.2
Non-point (livestock)	201	285	730	713	474	114	2,517	0.5
Non-point (land)	1,493	2,120	5,122	3,549	2,781	1,193	16,258	3.3
Sub-total	2,659	4,592	9,175	6,400	4,494	2,309	29,629	5.9
Total	65,113	73,465	103,849	181,898	26,231	48,507	499,063	100.0

The ratio of pollution load runoff at each source in the objective Ganga River Basin is shown in Figure 2.6. On the runoff basis, point pollution load shares a large portion of the total load unlike that on the generation basis, of which sewerage effluent contributes 79% and Industrial effluent contributes 15%.

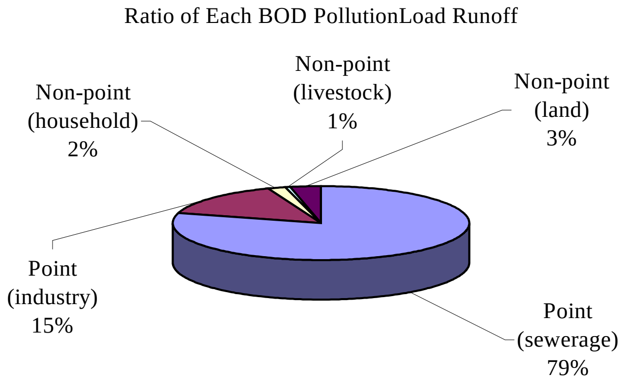


Figure 2.6 Ratio of Each Pollution Load Runoff

Further, the density of sub-basin wise pollution load runoff is illustrated in Figure B.5.6. Among them, Middle Ganga II (Kanpur), Middle Ganga III (Allahabad), Middle Ganga IV (Varanasi) sub-basins indicate very high density of pollution load runoff. In addition, sub-basins of Hindon, Upper Yamuna II (Delhi), Upper Gomati (Lucknow), Lower Ganga I (Patna) and Lower Ganga II (Calcutta) have also high density of runoff load. Using these results, the density of each river system is calculated as shown in Table 2.13 and Figure 2.7.

Table 2.13 Density of Pollution Load Runoff

No.	River System	Pollution Load Runoff (kg/d)	Total Area (km^2)	Pollution Density ($kg/d/km^2$)	Main Cities
1	Upper Ganga	65,113	80,585	0.81	
2	Middle Ganga	73,465	36,365	2.02	Kanpur, Allahabad, Varanasi
3	Lower Ganga	103,849	319,729	0.32	Patna, Culcatta
4	Upper Yamuna	181,898	108,664	1.67	Delhi, Agra
5	Lower Yamuna	26,231	259,387	0.10	Jaipur, Indore, Bhopal
6	Gomati	48,507	33,403	1.45	Lucknow
	Total	499,063	838,583	0.60	

Figure 2.7 indicates that the pollution load runoff density of Upper Yamuna, Middle Ganga and Gomati River system is much higher than that of the other river systems. Hence, it may be concluded that the river water quality in these river stretches is much affected by the excessive pollution load discharged into the river.

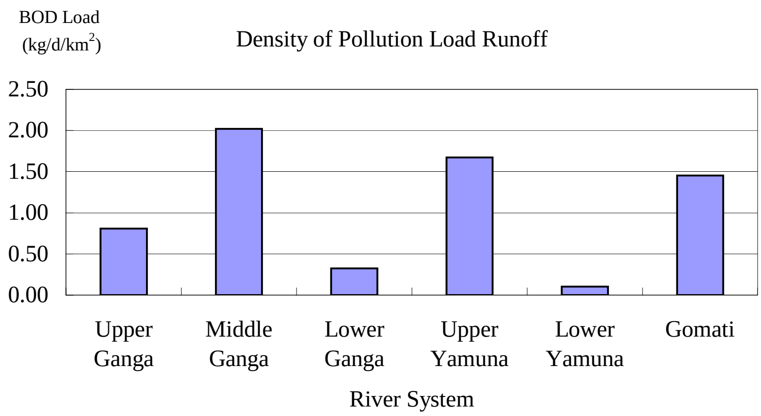


Figure 2.7 Density of Pollution Load Runoff

2.2.9 Simulated River Water Quality

(1) Self-purification Rate of Main River

The pollution load runoff to the main river (i.e., pollution load entering the main river) is naturally purified while it flows down the main river. BOD concentration decreases as explained below according to the Streeter-Phelps.

The pollution load runoff that enters the main river is naturally purified while it flows along the main river. BOD concentration decreases as given below according to the Streeter-Phelps.

Decreasing Reduction Rate of BOD: $dC/dt = - K \bullet \cdot C$

Where, C: BOD concentration (mg/l), t: time (day), K: self-purification constant (1/day)

The self-purification constant K of the Ganga Main River is estimated to be 0.123 (1/day), based on the water quality data at the Kanpur D/s and Allahabad U/s monitoring stations. This constant is also applied for the Yamuna River and the Gomati River. For the runoff coefficient and calculation methods, see Appendix B subsection 5.5.3.

(2) Existing and Future River Water Quality Without Project

The above-mentioned pollution load runoffs and self-purification rates are used in the simulation of river water quality at the principal stations of three (3) main rivers.

The simulated river water quality is used in the detail simulation (QUAL2E) model as the head-water condition. The simulated water quality (BOD) under the existing and future conditions without project F/S (2015) and M/P (2030) are summarized in the Table 2.14.

Table 2.14 Simulated River Water Quality (1)

(Unit: BOD mg/l)

River	Location	Existing (2001)	Future Without (2010)	Future Without (2015)	Future Without (2030)
Ganga	Kanpur U/s	3.3 (3.6)	4.1	4.6	6.0
	Allahabad U/s	3.4 (3.4)	4.7	5.3	7.1
	Varanasi U/s	3.2 (3.2)	4.1	4.6	6.1
Yamuna	At Allahabad	3.4 (3.3)	4.2	4.7	6.2
Gomati	Lucknow U/s	2.8 (3.0)	4.8	4.9	5.0

Note: Values in parentheses are the observed quality.

(4) Future River Water Quality With Project

(a) Basic Assumption for the Simulation

River water quality is estimated under the following assumptions:

(i) By the year 2030, all the domestic wastewater generated from the urban centers in the entire Ganga Basin will be treated to meet the permissible limits.
(ii) There are more than 1200 large and medium scale industries in the entire Ganga Basin at present.
(iii) It is assumed that the condition of industrial wastewater effluent will be the same as current situation.
(iv) Non-point pollution loads are not controlled.
(v) River water quality is evaluated at the river flow rate of 90% probability.

(b) Simulated River Water Quality

The simulated river water quality (BOD) at the five (5) principle stations in the year 2030 is shown in Table 2.15.

Table 2.15 Simulated River Water Quality (2)

(Unit: BOD mg/l)

River	Location	Existing (2001)	Future With (2010)	Future With (2015)	Future With (2030)
Ganga	Kanpur U/s	3.3 (3.6)	1.6	1.9	2.4
	Allahabad U/s	3.4 (3.4)	2.0	2.2	2.7
	Varanasi U/s	3.2 (3.2)	1.5	1.7	2.1
Yamuna	At Allahabad	3.4 (3.3)	1.5	1.7	2.2
Gomati	Lucknow U/s	2.8 (3.0)	1.8	2.0	2.6

Note: Values in parentheses are the observed quality.

(c) Case Study Regarding Reduction Ratio of Domestic Pollution Load

In the above, the domestic sewage generated from the entire basin is assumed to be treated by 80%. Table 2.16 shows the relationship between reduction ratio of domestic pollution load and simulated values in the year 2030.

Table 2.16 Simulated River Water Quality (3)

(Unit: BOD mg/l)

Item		Case 1	Case 2	Case 3	Case 4
Assumption for Future Prediction (Reduction Ratio)		Domestic: 0% Industry: 0% Non-point: 0%	Domestic: 50% Industry: 0% Non-point: 0%	Domestic: 75% Industry: 0% Non-point: 0%	Domestic: 80% Industry: 0% Non-point: 0%
Simulation Results	Kanpur U/s	6.0	3.7	2.6	2.4
	Allahabad U/s	7.1	4.3	3.0	2.7
	Varanasi U/s	6.1	3.6	2.4	2.1
	At Allahabad	6.2	3.7	2.5	2.2
	Lucknow U/s	5.0	3.5	3.0	2.6

Note: Values in parentheses are the observed quality.

According to the table above, in order to meet the water quality standard of BOD value (3 mg/l) at the monitoring stations of 4 cities, it is necessary to reduce at least 75% of domestic pollution load generated from all the urban area of the entire Ganga Basin.

2.3 HIGHLIGHT OF THE FOUR CITIES

The various urban centers located in the Ganga Basin mostly dispose the sewerage wastewater generated both in treated and untreated form into the nearest tributary. This practice has deteriorated the water quality in the tributaries resulting in low dissolved oxygen and is usually blackish in colour.
Large quantities of river water are withdrawn for irrigation and domestic purpose at the upper reaches of Ganga and Yamuna; resulting in the shortage of river flow especially in downstream. Among the specified river stretches, river water quality worsens after intakes due to the influence of a huge quantity of wastewater especially during drought time.

In the Ganga Basin, an intricate network of the irrigation canals and wastewater drainages exists; however, it is very easy to distinguish one from the other based only on the colour. The water in irrigation canals is green in color, while water in drainage channels is blackish. Except for some river stretches, Ganga River has a high self-purification capacity; ie., the river water quality tends to improve as the organic pollutants get decomposed biologically while flowing down the river stretch. Further, the river water quality downstream improves and becomes stable due to the abundant dilution effect caused by the influence of large tributaries. Due to the above stated reasons, there is no major issue on river water quality in the upper reach, e.g., Rishikesh and Hardwar. In the downstream of Ganga River, the water quality is not such an important issue, even though major urban centers like Kolkatta and Patna are located along the riverside due to dilution caused by the increasing water flow resulting from the confluence of large tributaries like Sone, Ghaghra, Burhi Gandak and so on.
However, the reach of Yamuna from Delhi to Agra in Yamuna River, middle reach of Ganga from Kanpur to Varanasi and the reach of Gomati downstream of Lucknow are excessively polluted. The pollution in the river reach of Yamuna from Delhi to Agra is being addressed under the Yamuna Action Plan, which has schemes for the improvement of the river water quality.

Urgent improvement of river water quality is necessary in the middle reach of Ganga Main where Kanpur, Allahabad and Varanasi are located, and Gomati River where Lucknow is located. Further, apart from the Yamuna river system, the estimated density of pollution load runoff is very large in the Middle Ganga and Gomati river systems compared to others.

On the other hand, reaching domestic pollution loads discharged from Varanasi, Lucknow, Allahabad and Kanpur is dominant at the confluence point of Ganga Main and Gomati River (Trighat) as shown in Figure 2.8.

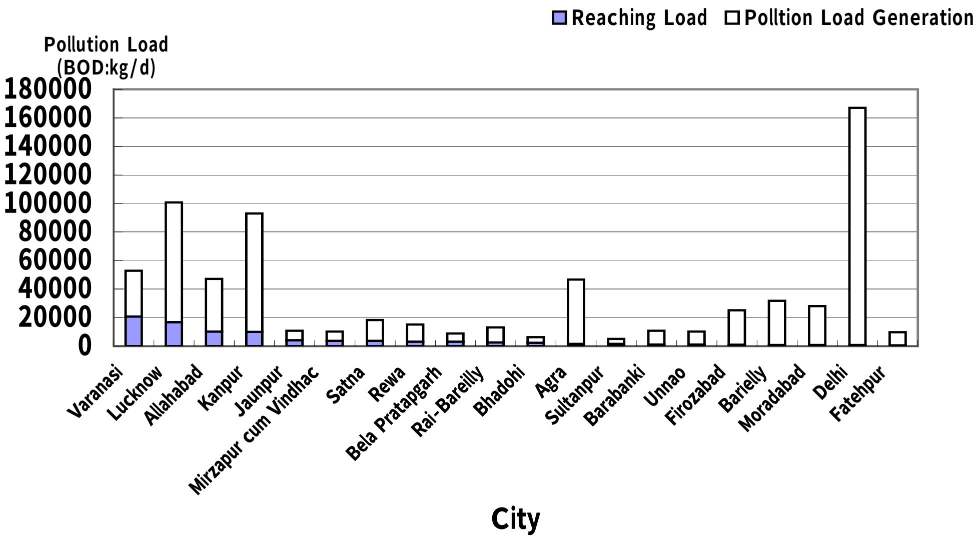


Figure 2.8 City-wise Reaching Domestic Pollution Load to Trighat

Hence, a detailed river water quality simulation for the area of four (4) cities is necessary for the estimation of existing/future river water quality and urgent development of the sewerage treatment system.

CHAPTER 3

POLLUTION REDUCTION CONTROL

CHAPTER 3 POLLUTION REDUCTION CONTROL

3.1 GENERAL

The four selected cities i.e. Kanpur, Varanasi, Allahabad and Lucknow are located in Uttar Pradesh and middle part of Ganga Basin. These cities are extremely congested and discharge the untreated wastewater generated from urban centers directly into the river. Hence, the river water quality of Ganga and Gomati has drastically deteriorated in these 4 cites. Urgent sewerage development projects are necessary in these cities for the improvement of the river water quality. Existing and future condition of urban population of 4 cities is estimated as in the following Table 3.1.

Table 3.1 Urban Populations in 4 Cities

City	2001 ($*10^3$)	2010 ($*10^3$)	2015 ($*10^3$)	2030 ($*10^3$)
Kanpur	2,880	3,513	3,916	5,183
Allahabad	1,214	1,481	1,651	2,185
Varanasi	1,269	1,548	1,725	2,283
Lucknow	2,342	2,857	3,185	4,216

The basic conditions of the objective areas are summarized below.

(1) Kanpur

Kanpur is the biggest city of Uttar Pradesh and famous for the industrial activities. It is situated on the right bank of Ganga River, which enters the city from the western side and flows out in the eastern direction. Currently, there are 26 drains in Kanpur which discharge untreated wastewater into the river Ganga.

(2) Allahabad

Allahabad is a major urban agglomeration located in the southeastern region of Uttar Pradesh. Allahabad being located at the confluence of two major rivers, namely, Ganga and Yamuna has navigational importance and potential. An industrial zone was created in Naini area and major industrial establishments started operation within this zone. Currently, altogether 11 of existing nalas (drains) tapping arrangements collect sewage from various nalas and discharge them into the present system of sewerage, which ultimately discharges into the river.

(3) Varanasi

Ganga traverses a distance of around 10km along the city of Varanasi. The pollution of river Ganga in this region has been derived from the rapid urbanization, industrialization, tourism activities, throwing of unburned and partly burnt dead bodies, discharge of excreta along banks, dumping of animal carcasses, agricultural runoff and similar activities. Although a sewerage system was laid in Varanasi during 1917 from Assi to Rajghat (Trunk Sewer) for the disposal of domestic sewage and drainage of storm water in the river Ganga as a result of unplanned and haphazard growth of population, sewage has started overflowing through the drains directly unto the river.

(4) Lucknow

The urban area of Lucknow is located on both banks of Gomati River called CIS side and TRANS side respectively. Currently, there are 26 drains in Lucknow, which discharge the untreated wastewater generated from Lucknow into Gomati River. Out of the 26 drains, 14 are in the CIS side of the river and 12 are in the TRANS side.

3.2 ESTIMATION OF ORGANIC POLLUTION

(1) Methodology

QUAL2E simulation model has been utilized for the detailed modeling of the four cities. It is widely known that the Enhanced Stream Water Quality Model (QUAL2E) is a comprehensive and versatile stream water quality model. It can simulate DO, BOD, Coliform Number and other parameters. The model is applicable to dendritic streams that are well mixed. It uses a finite-difference solution of the advective depressive mass transport and reaction equations. The model is intended for use in water quality planning.

The Streeter-Phelps Model is widely applied to estimate the self-purification effect of river water on BOD. In this Study, this model was used to estimate the self-purification effect of the main rivers.

The stream water quality model QUAL2E is widely used for waste load allocations, discharge permit determinations, and other conventional pollutant evaluations. The Enhanced Stream Water Quality Model (QUAL2E) is a comprehensive and versatile one-dimension stream water quality model. The model is intended as a water quality-planning tool for developing total maximum daily loads (TMDLs) and can also be used in conjunction with field sampling for identifying the magnitude and quality characteristics of non-point sources. QUAL2E has been explicitly developed for steady flow and steady waste load conditions and is therefore a “steady state model” although temperature and algae functions can vary on a diurnal basis. The reason to subdividing sections of a stream into reaches is that it assumes that some 26 physical, chemical and biological parameters are constant along a reach.

(2) Basis for Detail Simulation

Simulation for future river water quality was conducted with QUAL2E Model developed by US-EPA in case of one dimension analysis. Moreover, in order to predict the river water quality of the bank side where many ghats are located, lateral distribution analysis was done for simulation study of the river water quality.

(a) Objective Cities and Target Year

The objective basin for water quality simulation involved four (4) cities; namely, Kanpur, Allahabad, Varanasi and Lucknow. Target year for simulation study is 2001 as an existing condition, 2015 as a feasibility study and 2030 as a master plan study. The future population of four cities is estimated by exponential equation based on the census data from 1971 to 2001.

(b) Objective Water Quality Parameter

The Ganga River is highly polluted by organic material of domestic and industrial origin. This has resulted in a high concentration of organic material and low dissolved oxygen in the river water. This Study has focused on the most obvious water quality parameter. These parameters (BOD and DO) are also used as indicators of water quality of the Ganga River.

(c) Calibration for Existing Condition

Ganga and Gomati rivers flow through objective 4 cities, and the river water quality has been periodically monitored by CPCB and UPPCB at the upstream and downstream of each city. After calibration for existing condition, future prediction of river water quality was made using the confirmed constant and coefficient common to all the simulation cases (for detail, see Appendix B, sub-section 6.2).

(d) River Flow

90% river flow values are employed for QUAL2E Model as well as the basin runoff model (for detail, see Appendix B, sub-section 5.9).

(e) Existing Pollution Load

In case of objective four cities, pollution load is discharged into the recipient rivers through nalas. Accordingly, pollution load can be calculated as discharge multiplied by water quality of each nala. The discharge and water quality of nala was measured during 1993 to 2000, however the data of existing condition (2003) is not available. The wastewater generation is assumed to increase in proportion to the population growth rate.

(f) Simulation Constant and Coefficient

Simulation constant and coefficient used for QUAL2E is common to all the cities (for detail, see Appendix B, Table B.6.1 to B.6.4).

(g) Results of Calibration

Simulated existing river water quality is given in below.

Table 3.2 Simulated Water Qualities

Monitoring Station		**DO (mg/l)**	**BOD (mg/l)**
Ganga at Kanpur d/s	Observed	5.0	8.2
	Simulated	5.7	8.2
Ganga at d/s of Mawaiya, Allahabad*	Observed	7.1	3.4
	Simulated	6.5	3.6
Ganga at Varanasi d/s (Kaithy)	Observed	5.7	3.2
	Simulated	5.9	2.7
Gomati at Lucknow d/s*	Observed	0.0	16.0
	Simulated	1.9	14.9

Note: The simulated river water quality of Allahabad is slightly different due to the stagnation of river flow of Yamuna River before confluence with Ganga River (These are to be confirmed later)

(h) Simulation of Future River Water Quality (2030)

Future river water quality in case of without/with project was predicted at the year 2030 (M/P). An assumption for future prediction is as follows:

(i) River Flow:
River flow is assumed to be constant and employed the current data even in future condition.

(ii) Future Condition of River Water Quality:
The 90 % river water quality of upstream area predicted by the basin runoff model was employed as a headwater condition of QUAL2E Model.

(iii) Future Pollution Load:

Future wastewater generation is assumed to increase in proportion to the population growth rate from 2003 to 2030. Intercepted wastewater quantity is assumed to be the same as 2003 in case of existing condition (2003), is assumed to be 80 to 99% tapping rate in case of with project. Further, deducting value of intercepted wastewater from generated wastewater is corresponding to the inflow quantity into the river. Future pollution load is estimated under the assumption that water quality of nala is the same as existing condition.

(3) Results of Detail Simulation

Simulated river water quality at 2030 is illustrated in attached figure Annex 3.1 to 3.5 (attached to following this main part of the report). The results of detail simulation of the four cities are summarized in Table 3.3.

Table 3.3 Future Simulated Water Qualities

(1) BOD

	Present Condition in 2003 (mg/l)	Future Condition in 2030 (mg/l)			
		Without Project	Without Project Including On-going project	With Project Reduction Rate =80%	With Project Reduction Rate =100%
Kanpur d/s	8.2	19.3	16.9	5.1	1.6
Allahabad d/s (Mawaiya)	3.6	7.3	6.9	2.4	1.9
Varanasi d/s (Kaithy)	2.7	4.9	4.8	1.7	1.4
Lucknow d/s	14.9	30.0	17.0	8.0	1.5

(2) DO

	Present Condition in 2003 (mg/l)	Future Condition in 2030 (mg/l)			
		Without Project	Without Project (On-going projects included)	With Project Reduction Ratio =80%	With Project Interception Rate =100%
Kanpur d/s	5.0	4.6	5.0		6.4
Allahabad d/s (Mawaiya)	6.5	6.0	6.0		6.6
Varanasi d/s (Kaithy)	5.9	5.5	5.6		6.2
Lucknow d/s	1.9	0.0	0.0		3.8

Assumption and Scenario for Reduction Rate of Wastewater of Basin-wide and 4 City Level

Domestic wastewater of four main cities	Same as present condition	80 %	100 %
Industrial wastewater of four main city	Same as present condition	100 % Jajmau Tannery Complex at Kanpur	
Domestic wastewater at all the cities/ towns located in the basin	Same as present condition	80 %	
Industrial wastewater at all the cities/ towns located in the basin	0 %	0 %	

The following assumptions were made for the simulation of future water quality for the four cities. It has been assumed that the treated domestic wastewater shall be utilized completely for irrigation purposes hence shall not contribute to River pollution. Apart from the two conclusions below, the effluent from Jajmau Tannery complex located in Kanpur should be treated completely.

(4) Conclusion

The general conclusions drawn are:

(a) Apart from the four cities it is necessary to reduce the pollution load generation by overall sewerage development in all the cities/towns located in the river basin in order to achieve the goal.

(b) In case of Kanpur and Lucknow, though some amount of sewerage developments has taken place but to achieve the river water standards almost the entire domestic wastewater generated needs to be treated.

3.3 ESTIMATION OF BACTERIAL POLLUTION

3.3.1 General

Coliform bacteria are used as the index of the hygienic quality of water for several beneficial uses and for many foods. About one-quarter of the 100 to 150 grams of feces produced per person per day is bacterial cells. These circumstances are thought same in case of livestock such as cattle, pigs and sheep. It is reported that coliform organisms are at an output of 300 billion per capita per day. Further, $100*10^9$ MPN/100ml of coliform bacteria contains in a fresh domestic wastewater in Japan. Thus, there is tremendous quantity of point and non-point pollution sources in the entire Ganga Basin, and the influence of bacterial organisms from anywhere is unavoidable.

The river water quality will tend to deteriorate more rapidly in future than that of the present one due to the enormous population increase. In order to diminish the impact on the river pollution, sewerage system should be introduced to the growing urban centres such as the objective 4 cities. For the purpose of improvement of river water quality, various kinds of measures can be studied. From available countermeasures, it is necessary to make elaborate selection such that the measure is efficient to solve the river pollution of Ganga Basin. Especially, mitigation of bacterial contamination such as a coliform number is important to make the water suitable for bathing in the Ganga River.

According to the monitoring data analysed by CPCB, coliform number indicates extremely high value in the middle reach of Ganga River due to not only the point sources but also non-point sources such as cattle excreta, human’s open defecation and so on. It is essential to reduce the coliform number for maintaining the hygienic condition along the riverine area. For the purpose of mitigating the hygienic condition, sewerage treatment system should be constructed in the major cities.

However, the effect of reduction of coliform number is limited because sewerage system cannot completely treat bacteria and cattle excreta also degrade the hygienic condition of the riverine area. In order to effectively cope with the standard of river water quality, non-sewerage scheme is necessary besides the sewerage schemes. The Ganga Basin shows a specific feature that coliform number exceeds the criteria at all the river courses. Especially, hygienic condition worsens just downstream of large cities due to the influence of untreated wastewater.

3.3.2 Japanese Case Study on Bacterial River Water Quality

In case of Japan, hygiene condition of surface water and various water uses is regulated as shown in Table 3.4. As shown in table below, total coliform number is employed as criteria for the national regulation of the surface water, category AA type is designated as the cleanest waters area, hence, the criteria of total coliform number is very strictly regulated (50 MPN/100ml). On the other hand, fecal coliform number is regulated in bathing water, and its criterion is 100MPN/100ml.

Table 3.4 Japanese Regulation/Guideline for the Hygienic Condition

Grouping	Standard	Parameter	Criteria
Surface Water	River/Lake/Sea Water	Total Coliform Number	AA Type: 50MPN/100ml
			A Type: 1,000MPN/100ml
			B Type: 5,000MPN/100ml
	Bathing Water	Fecal Coliform	100MPN/100ml
			Temporary 100MPN/100ml
Tap Water		Total Coliform Number	Non-detected
		General Bacteria Number	1,000 colony/100ml
Wastewater	Factory Effluent	Total Coliform Number	300,000MPN/100ml
	Sewerage Treatment Effluent	Total Coliform Number	300,000MPN/100ml
	Night Soil Treatment Effluent	Total Coliform Number	300,000MPN/100ml
Recycle Water Use	Flush Toilet	Total Coliform Number	1,000MPN/100ml
	Sprinkle Water	Total Coliform Number	Non-detected
	Landscape Irrigation Use	Total Coliform Number	1,000MPN/100ml
	Amenity Use	Total Coliform Number	50MPN/100ml
Specified Water Use	Public Bath	Total Coliform Number	100MPN/100ml
	Swimming Pool	Total Coliform Number	5MPN/100ml
	School Pool	Total Coliform Number	Non-detected
		General Bacterial Number	2,000 colony/100ml

On the other hand, Table 3.5 shows the ratio of stations that did not satisfy defined coliform criteria based on the annual data monitored in 1997 covered by all the first-class rivers in Japan.

Table 3.5 Unsatisfactory Ratios for Coliform Criteria in Japan (1997)

Category	Monitoring station number that exceeds criteria of coliform	Total monitoring station number	Unsatisfactory Ratio (%)
AA	3,286	4,049	81.2
A	15,574	22,769	68.4
B	5,715	11,044	51.7
Total	24,575	37,862	64.9

As reflected from above results, monitoring station number that exceeds criteria of coliform totally amounts to 24,575 all over the country and shares 64.9% of all the monitoring stations. Especially, category AA that requires the cleanest condition of river water quality indicates a high unsatisfactory ratio for coliform criteria (Total coliform number: 50 MPN/100ml). The reason for high unsatisfactory ratio may be attributed to the fact that not only fecal coliform but also the bacteria number derived from soils and another non-point sources is simultaneously analysed.

The high unsatisfactory ratio extracted from above results reflects the difficulty to improve the hygienic condition of surface water.

3.3.3 Longitudinal Profile of Coliform Number

CPCB has periodically monitored both total-coliform and fecal coliform in the entire Ganga Basin since 1976. Using the data monitored during 1997 to 2001, longitudinal profiles of fecal coliform number in three rivers are summarized as below:

(1) Ganga Main Stem

Figure 3.1 shows the longitudinal profile of coliform number in the Ganga main stem, and it is easily recognized that middle stretch from Kannauj to Varanasi is the most contaminated by coliform due to the huge quantity of wastewater inflow into the river. Further, the two tributaries namely Ramganga and Kalinadi are very polluted by untreated wastewater, meeting with Ganga main stem at the upstream of Kannauj, therefore, the bacterial water quality worsens significantly and highly exceeds the water quality of fecal coliform for bathing in the river water until influx of Buxar. In addition to the wastewater inflow, non-point pollution sources such as cattle wallowing and agricultural activities significantly affect the bacterial water quality of the polluted stretch of Ganga.

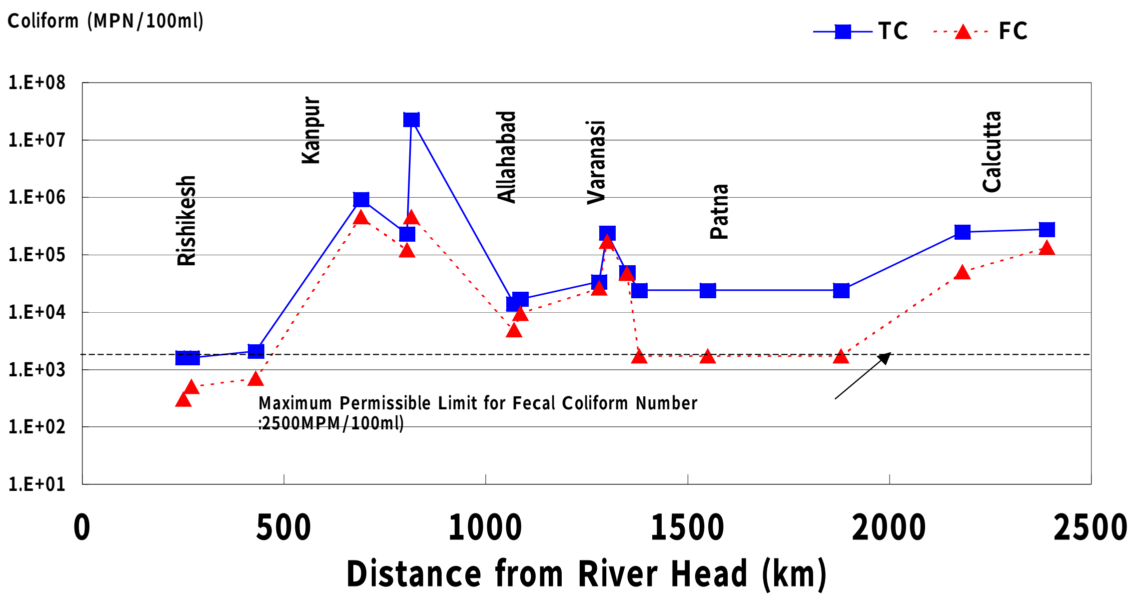


Figure 3.1 Longitudinal Profile of Coliform (Ganga Main)

(2) Yamuna Main Stem

Before influx of the large tributaries like Chambal, Sind, Betwa and Ken, river flow of Yamuna main stem during dry season continues to be low and the river stretch from Delhi to Etawah is playing the role as almost wastewater drainage.

Figure 3.2 explains longitudinal profile of coliform in the Yamuna main stem. According to this figure, fecal coliform number varies in the range of 10^4 to 10^6 in the polluted river stretch from Delhi to Etawah because of the large quantity of wastewater inflow. Moreover, fecal coliform number lowers in the river stretch from the confluence point with Chambal to Allahabad due to the dilution and decay effect.

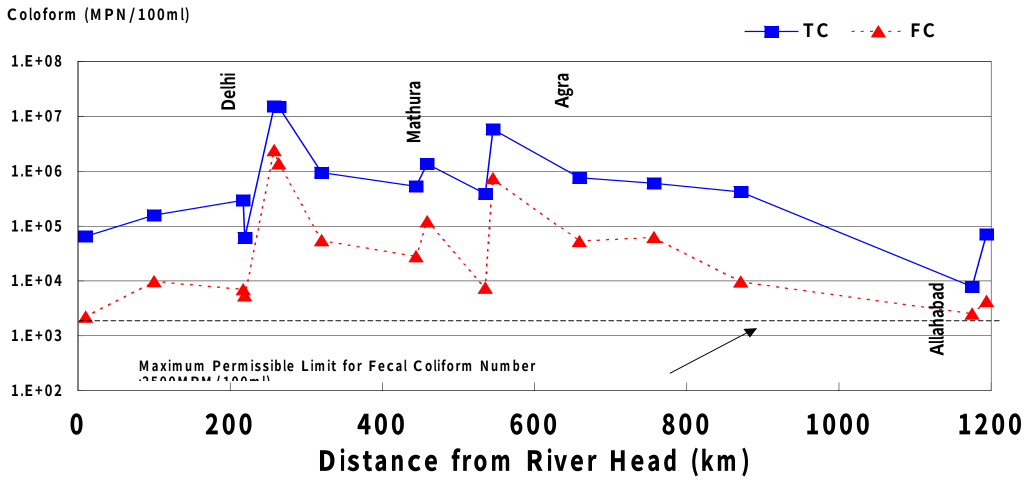


Figure 3.2 Longitudinal Profile of Coliform (Yamuna Main)

(3) Gomati River

Lucknow is located on the riverbanks of Gomati River, and untreated and treated sewerage wastewater severely affects the hygiene condition of this river stretch. Figure 3.3 indicates the longitudinal profile of coliform number, and high values are obviously shown after Lucknow. Hence, it is essential to improve the bacterial water quality at Lucknow.

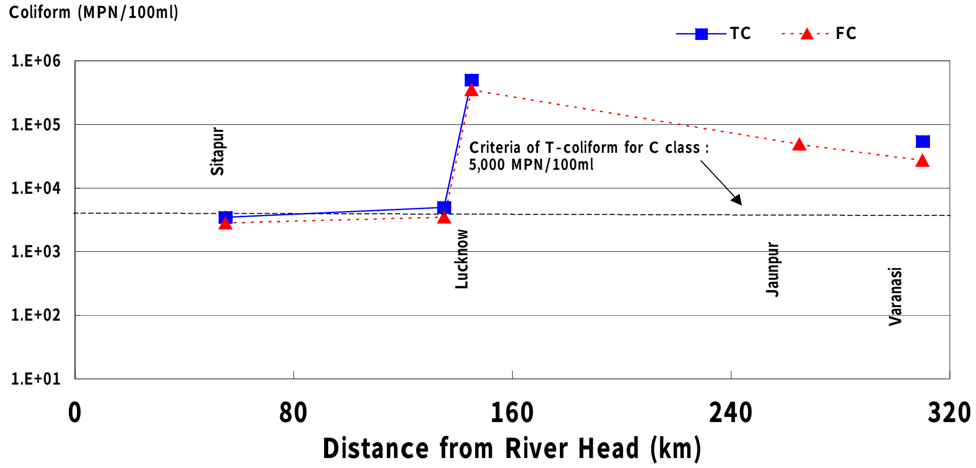


Figure 3.3 Longitudinal Profile of Coliform (Gomati River)

3.3.4 Simulation Study for Faecal Coliform Number

In this Study, detail simulation study targeting each objective city was already conducted and mentioned in Appendix B. Chapter 6. Apart from the detail simulation model, another QUAL2E simulation model was formulated in order to evaluate the future hygienic condition in the upstream area of the objective four cities.

(1) Future Trend of Hygiene Condition

Future trend of hygienic condition will change depending on the presence of sterilization process in the STP. Table 3.6 shows a relation between future bacterial water quality of fecal coliform targeting objective 4 cities and various scenarios simulated by QUAL2E Model. Further, in case of Lucknow, water quality standard of Gomati is designated as class C and T-coliform is employed in the standard (desirable limit: 5,000MPN/100ml). In consideration of the relation between total and faecal coliform number, 2,500 MPN/100ml can be adopted as the class C criteria of fecal coliform.

Table 3.6 Relations between Future Faecal Coliform and Various Scenarios (1)

Scenarios	Kanpur d/s	Allahabad d/s	Varanasi d/s	Lucknow d/s	Remarks
Existing 2001	$4.6*10^5$	$9.4*10^3$	$1.7*10^5$	$3.5*10^5$	Actual monitoring data (90%)
Future Without Project	$9.2*10^5$	$1.5*10^4$	$3.4*10^5$	$6.1*10^5$	
Future With Project Without Disinfection	$4.1*10^5$	$8.0*10^3$	$1.6*10^5$	$2.7*10^5$	80% STP coverage
A. Future With Project With Disinfection	$2.0*10^5$	$5.1*10^3$	$8.0*10^4$	$1.3*10^5$	80% STP coverage & Treatment at 10,000MPN/100ml
B. Future With Project With Disinfection (Targeted only 4 cities)	$1.9*10^4$	$2.5*10^3$	$1.5*10^4$	$3.5*10^3$	100% STP coverage & Treatment at 1,000MPN/100ml
C. Future With Project With Diversion (Targeted only 4 cities)	$1.9*10^4$	$2.5*10^3$	$1.5*10^4$	$3.2*10^3$	100% STP coverage & diverted into irrigation channel

Note: [yellow box] : Satisfactory with maximum permissible criteria for fecal coliform number (2,500 MPN/100ml), Non-coloured: Exceeds criteria. Unit: Fecal coliform MPN/100ml

Table 3.6 explains that it is very difficult to meet the water quality of fecal coliform except for Allahabad D/s. The main reason for the unsatisfactory condition is summarized as below:

(a) Ratio of Non-point Sources

In this simulation study, fecal coliform caused by non-point sources is considered to share approximately 25% of point pollution sources. Especially a high ratio of non-point pollution sources are given in the upstream reaches of Kanpur, Varanasi and Lucknow. On the other hand, in case of organic pollution, BOD runoff coefficient of non-point sources was estimated to be only 1% of total pollution load generation during dry season.

Compared to the case of BOD runoff, the values of 25% in terms of ratio of fecal coliforms from nonpoint sources may be too much higher than expected. However, if a low ratio of non-point pollution sources such as 2.5% is given to QUAL2E Model, although simulated fecal coliform number at downstream monitoring points of Kanpur, Varanasi and Lucknow is well in agreement with the observed one, simulated fecal coliform number at upstream monitoring points becomes much lower than actual monitoring data as shown in Table 3.7.

Table 3.7 Relations between Fecal Coliform and Simulation Cases

Simulation Cases	Kanpur U/s	Allahabad U/s	Varanasi U/s	Lucknow U/s	Remarks
Actual Data	$1.2*10^5$	$4.9*10^3$	$2.6*10^4$	$3.5*10^3$	
Non-point Ratio: 25%	$2.6*10^4$	$3.6*10^3$	$1.5*10^4$	$3.2*10^3$	
Non-point Ratio: 2.5%	$1.2*10^3$	$5.8*10^2$	$1.3*10^3$	$6.5*10^2$	

(b) Influence of Non-point Pollution Sources

The mechanism and unit pollution load of contamination caused by coliform has been rarely reported in India as well as worldwide and is not available for this study. Particularly, it is very hard to know the influence of non-point pollution sources such as cattle wallowing and open defecation taking place along the riverbanks and in the river. However, these activities have been often observed in the entire Ganga Basin, for instance, thousands of buffalos were seen wallowing at the Sangam located at the confluence point of Ganga and Yamuna during the monitoring survey of this Study. Hence, the actual influence of non-point pollution sources is supposed to be probably significant.

(c) Monitoring Data of Faecal Coliform

Monitoring data and sampling location should be representative of each monitoring station. However extremely high values are frequently seen in CPCB's monitoring data. If the actual data of fecal coliform is much lower at the upstream monitoring stations of the objective 4 cities than that of observed one, influence of non-point pollution sources can be estimated to be much less.

Figure B.7.6 to B.7.9 show the detail sampling location of existing monitoring station of 4 cities. All the upstream and downstream monitoring stations are located in the city area, hence, the water quality of upstream monitoring stations might be much affected by point pollution load. These monitoring stations should be replaced or newly stationed at further upstream of each city.

(2) Additional Future Simulation Cases

Using the lower ratio of non-point pollution loads (2.5%), future trend of hygiene condition was additionally simulated by QUAL2E Model as shown in Table 3.8.

The ultimate simulation cases, namely: 100% STP coverage & treatment at 1,000MPN/100ml or diverted into irrigation channel, indicate that the future river water quality at the downstream monitoring station of each city can meet the standard.
Further, considering various reasons regarding the high value of fecal coliform number at the upstream monitoring stations of the four cities, the lower ratio of non-point pollution loads (2.5%) is likely to be suitable for the simulation of bacterial pollution.

3.4 POLLUTION REDUCTION PLAN FOR UPSTREAM AREA OF FOUR CITIES

In the entire Ganga Basin, more than 200 large cities categorized into class I and II are widely scattered and discharging a huge quantity of wastewater into the river courses. Many of them are situated along the riverbanks or close to the water body due to the convenience to use the water resources and the inland waterway transportation. Figure B.7.2 shows the city distribution in the upstream area of objective four cities.

Table 3.8 Relations between Future Fecal Coliform and Various Scenarios (2)

Scenarios	Kanpur d/s	Allahabad d/s	Varanasi d/s	Lucknow d/s	Remarks
Existing 2001	$4.6*10^5$	$9.4*10^3$	$1.7*10^5$	$3.5*10^5$	Actual monitoring data (90%)
Future Without Project	$9.0*10^5$	$1.7*10^4$	$3.3*10^5$	$6.0*10^5$	
Future With Project Without Disinfection	$4.0*10^5$	$7.8*10^3$	$1.5*10^5$	$2.7*10^5$	80% STP coverage
A. Future With Project With Disinfection	$1.8*10^5$	$3.8*10^3$	$6.6*10^4$	$1.2*10^5$	80% STP coverage & Treatment at 10,000MPN/100ml
B. Future With Project With Disinfection (Targeted only 4 cities)	$1.2*10^3$	$4.4*10^2$	$1.7*10^3$	$4.1*10^2$	100% STP coverage & Treatment at 1,000MPN/100ml
C. Future With Project With Diversion (Targeted only 4 cities)	$1.2*10^3$	$4.3*10^2$	$1.7*10^3$	$2.0*10^2$	100% STP coverage & diverted into irrigation channel

Note: [yellow] Satisfactory with desirable criteria for fecal coliform number (500 MPN/100ml), [light yellow] Satisfactory with maximum permissible criteria for fecal coliform number (2,500 MPN/100ml), Non-coloured: Exceeds criteria. Unit: Fecal coliform MPN/100ml

Figure 3.4 explains a descending order of each city's population covered by the upstream area of the meeting point of Ganga and Gomati Rivers. As for the population rank of the objective 4 cities, in

order to meet the water quality standard, efficient countermeasures is indispensable to give full play to its ability of the necessary reduction of the pollution loads. Originally, huge amount of pollution loads is generated and discharged into the Ganga Basin. Hence, the river water quality is already extremely polluted before reaching the objective 4 cities even if the self-purification and dilution effects are considered.
According to the results below, reduction of pollution load regarding objective 4 cities does not reflect sufficient effect on the recovery of river water quality. Huge amounts of pollution loads discharged into upstream area of the objective 4 cities already affect the river water quality in the middle stretch of Ganga River. In order to apparently improve the river water quality in the middle stretch of Ganga River, pollution loads have to be drastically reduced in all the cities located upstream of the objective 4 cities. As for the reduction ratio suitable for meeting the standard, 65% of reduction ratio is at least required.

(1) City-wise Contribution for River Water Quality

Large cities obviously affect the river water quality due to the huge quantity of the point pollution loads. However, the impact on the river water quality caused by each city is different because the distance from each city to the middle stretch of Ganga River is widely spreading over and their self-purification effect is extensively ranged. Table B.7.1 explains the reaching domestic pollution loads discharged from each city to the final point where the Ganga Main and Gomati River meets. In this Study, the first priority of the project is to mitigate the river pollution especially in the middle stretch of the Ganga River. Hence, the efficiency for the reduction of the domestic pollution loads is important.

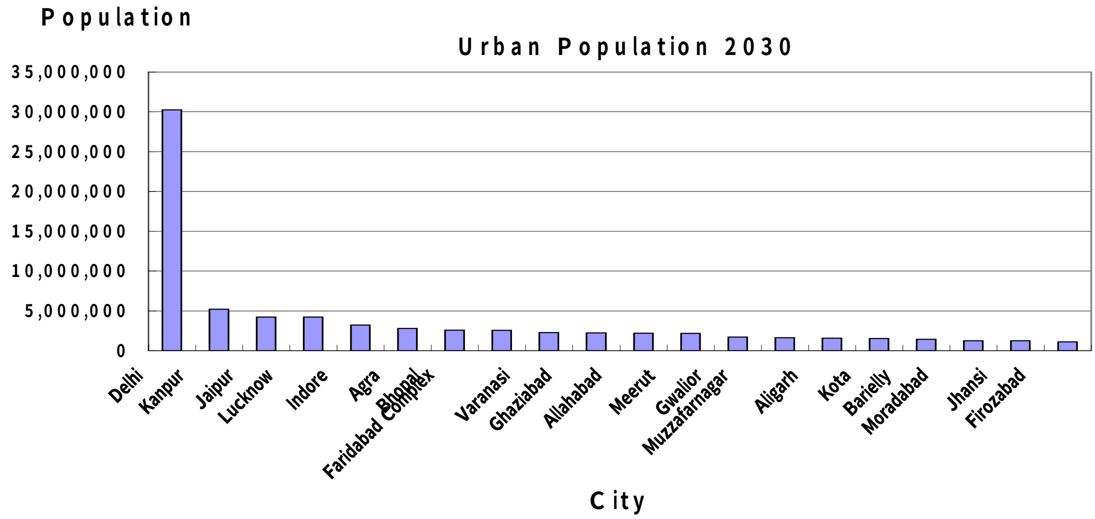


Figure 3.4 Descending Order of Urban Population in 2030 (Ganga Basin)

Figure 3.5 to 3.7 explains the descending order of the reaching pollution load to Kanpur (Ganga), Allahabad (Ganga) and Allahabad (Yamuna), respectively.

In the case of Varanasi, located in downstream of Allahabad, city wise reaching pollution load of Kanpur and Allahabad is dominant compared to that of other cities as shown in Figure 3.5. Subsequent large reaching pollution loads are discharged from other cities such as Satna and Rewa located along Tons River.

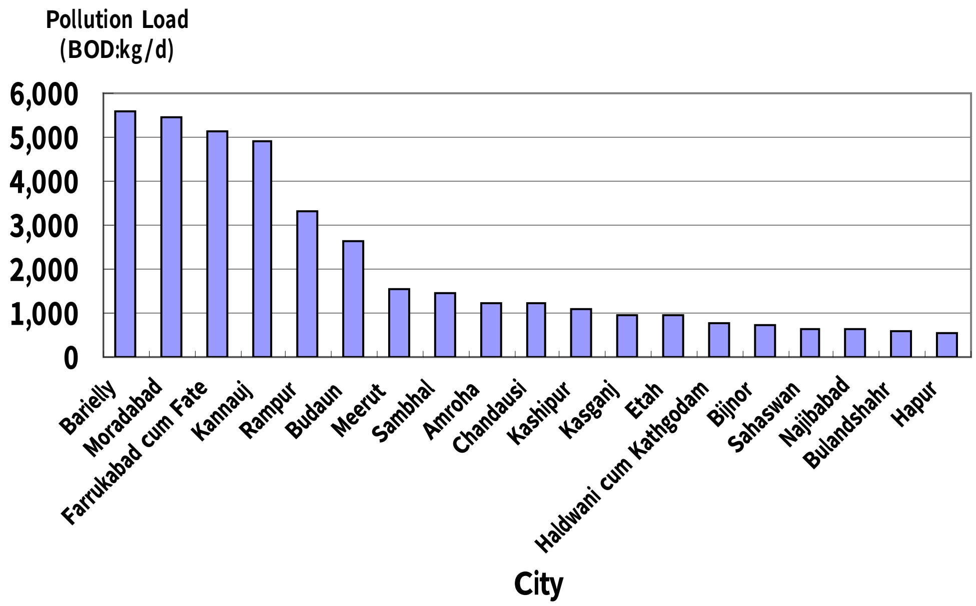


Figure 3.5 City Wise Reaching Pollution Load to Kanpur (Ganga)

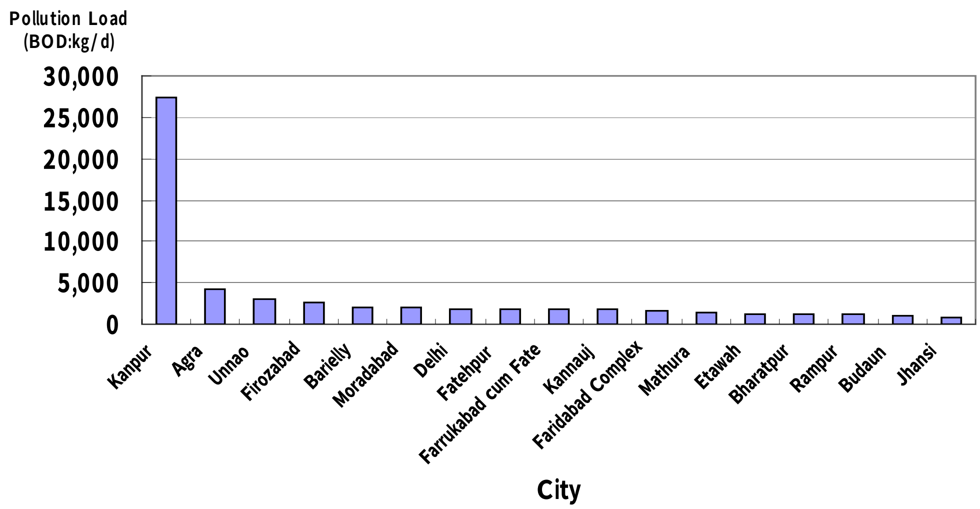


Figure 3.6 City Wise Reaching Pollution Load to Allahabad (Ganga)

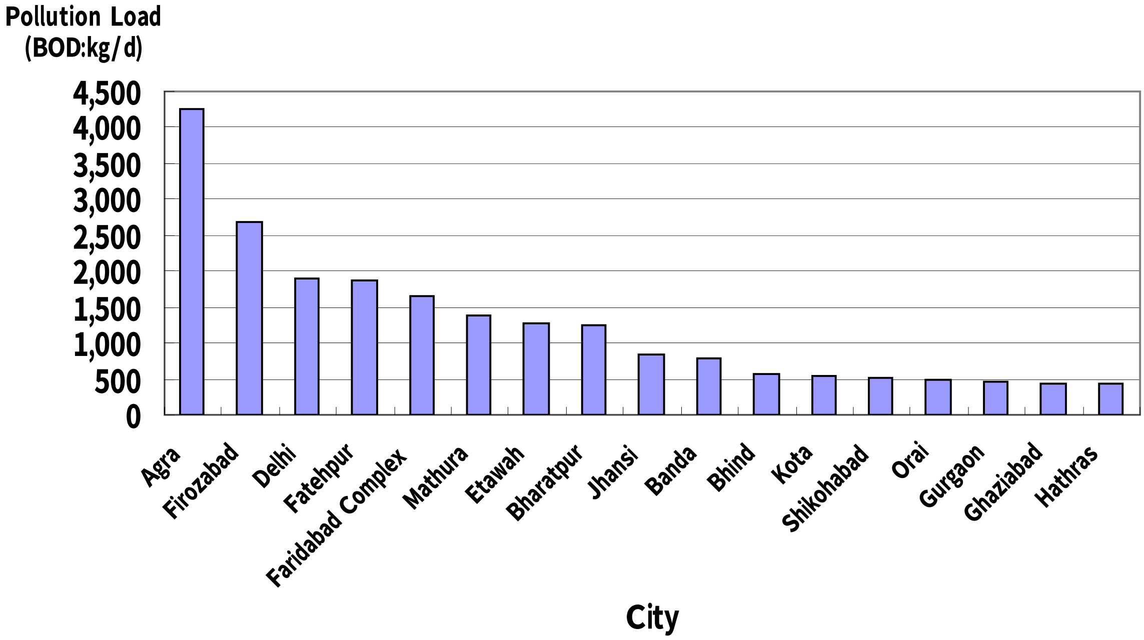


Figure 3.7 City Wise Reaching Pollution Load to Allahabad (Yamuna)

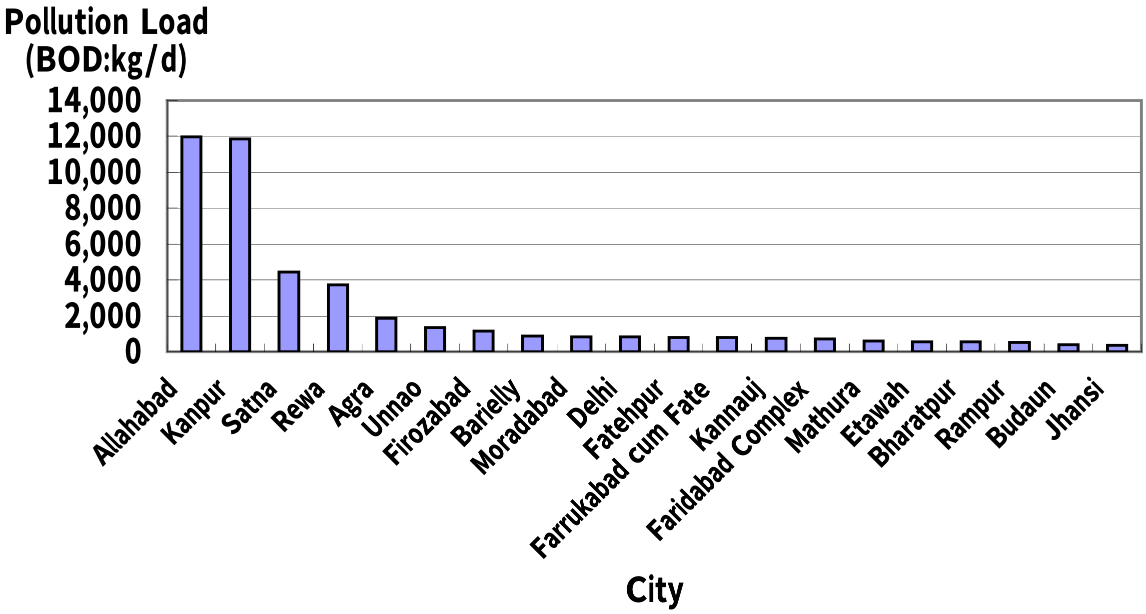


Figure 3.8 City Wise Reaching Pollution Load to Varanasi (Ganga)

Finally, in case of Lucknow, reaching pollution loads from upstream cities are estimated and observed to be small.

(2) Necessity of Pollution Load Reduction

The monitoring station wise (Kanpur U/s, Allahabad U/s of Ganga and Yamuna and Varanasi U/s) relation between pollution load reduction and future water quality is shown in Table B.7.2 of Appendix B.

There may be a few cities located in the upstream area of objective 4 cities among the selected priority cities with less contribution to river pollution, which means that, it is difficult to identify the recipient river that accepts the wastewater discharged from urban centres located on the sub-basin boundary during dry season due to the long distance from the recipient river or irrigation use. Typical case is obviously taking place in the city of Aligarh, wastewater effluent is flowing into a small lake at first and then most of the wastewater is used for irrigation purposes. Another case can be cited for the city of Jaipur where all the wastewater infiltrates into the sandy riverbed before confluence with Chambal River. In addition to Aligarh and Jaipur, Jhunjhunun, Alwar and Pilibhit are located very far from the Yamuna/Ganga main stems or primary tributaries. Therefore, wastewater discharged from these cities is unlikely to reach final recipient rivers during dry season. Accordingly, these five large cities should be omitted from necessary future sewerage development explained in Figure 7.3 to 7.4 and Table B.7.1.

On the other hand, most cities are located in the vicinity of the riverbanks or rather far from the river. In order to select the priority cities for future sewerage development for the purpose of the river water quality improvement of the middle stretch of Ganga including the existing YAP and GAP, contribution for the reaching pollution load to the target 4 cities should be considered instead of the pollution load generation discharged from each city. Table B.7.3 shows the necessity of the sewerage development in the upstream area for the purpose of the abatement of reaching pollution load to the 4 cities. However, in this study, main Study Area for formulation of Master Plan is focused on the target 4 cities. Therefore, information on selected 35 cities shown in Table B.7.2 of Appendix, like reaching process of domestic pollution load to primary tributary or Ganga/Yamuna main stem, is partially inaccurate because selected cities are widely scattered in upstream area of Ganga/Yamuna Basin. Hence, in order to improve the accuracy of above said information, it is necessary to conduct supplementary studies on each selected city.

According to the results base on the city wise pollution load reduction scenarios, priority sewerage development is summarized as follows:

(a) Kanpur

In order to meet the water quality standard at Kanpur U/s, 70% of domestic pollution load discharged from 9 cities shown below should be at least reduced by 2030. Among them, sewerage treatment facility has been developed only in Farrukabad cum Fate under GAP and in the remaining 9 cities sewerage development have not been considered so far. Hence, in addition to GAP, sewerage development planning for remaining 9 cities is also considered to be necessary.

Barielly, Moradabad, Farrukabad cum Fate, Kannauj, Rampur, Budaun, Meerut, Sambhal, Amroha and Chandausi.

(b) Allahabad

Pollution loads reach to Allahabad from upstream cities located along Ganga and Yamuna rivers. In order to meet the water quality standard at Allahabad U/s of both two main rivers, Ganga and Yamuna, 70 to 80 % of domestic pollution load discharged from 27 cities listed below should be at least reduced by 2030. Of these cities, in the cities of Farrukabad cum Fate and Kanpur, sewerage treatment systems have been developed under GAP. On the other hand, the towns of Agra, Delhi, Faridabad Complex, Mathura, Etawah, Gurgaon and Ghaziabad have had sewerage network development under YAP. The remaining cities do not have any STP so far. Hence, sewerage development for these cities should be considered for the river water quality improvement at Allahabad U/s.

Ganga: Kanpur, Unnao, Barielly, Moradabad, Farrukabad cum Fate, Kannauj, Rampur, Budaun, Meerut and Sambhal Yamuna: Agra, Firozabad, Delhi, Fatehpur, Faridabad Complex, Mathura, Etawah, Bharatpur, Jhansi, Banda, Bhind, Kota, Shikohabad, Orai, Gurgaon, Ghaziabad, and Hathras.

(c) Varanasi

Varanasi is located in the lower part of middle stretch of Ganga main stem. Estimated reaching pollution loads are dominant in adjacent cities, namely: Allahabad, Satna, Rewa, Bhadehi and Mirzapur cum Vindhac as well as above mentioned 27 cities. 70% of pollution loads reduction in 27 cities can meet the water quality standard at Varanasi U/s. Hence, sewerage development for these cities is indispensable for the improvement of river water quality.

(d) Lucknow

In case of Gomati River, no major city is located in upstream area of Lucknow. Further, the most critical reach is defined to be from Lucknow to downstream of Gomati River. The river water quality exceeds the water quality standard in these stretch. Accordingly, capacity development of sewerage treatment in Lucknow is essential to satisfy the water quality standard of class C in this river stretch.

Selected priority cities for pollution load reduction is shown in Annex 3.11

3.5 JAPANESE SCHEME OF POLLUTION CONTROL AND WATER QUALITY MANAGEMENT

Japan is regarded as one of the most highly developed countries to have suffered and made significant recovery from severe pollution problems. The recovery was based largely on environmental management policies, standards and regulatory procedures adopted specifically to the situation in Japan. These experiences are very much helpful to the critical situation of river water pollution in developing management plans and recovering water quality. However, it is important to keep in mind that successful procedure in Japan might not be fully transferable to Indian condition due to differences in environmental settings, proposed water use and cultural perspectives. Apart from the question of differences, some part of Japanese scheme for pollution control and water quality management is meaningful and useful to solve the critical situation of river pollution as mentioned below:

3.5.1 Current Situation of River Pollution in India

As discussed in previous Chapter, the circumstances regarding the water pollution of Ganga River is quite severe and somehow irretrievable unless the sound countermeasures are taken against the indiscriminate pollution load discharge. Especially, reaching pollution load from the upstream area of 4 cities will amount to huge quantity in near future due to the enormous increase of population and economic growth. Unless the suitable countermeasure are adopted, level of river water quality indicators will highly exceed the water quality standard. Hence, it is indispensable to consider not only the sewerage development but also multiple pollution control measures such as enforcement of relevant institutions and regulations for improvement of river water quality.

3.5.2 Regulation of Total Maximum Daily Loading

In order that pollution load runoff does not exceed the environmental allowable capacity of each river basin, it is necessary to regulate not only the water quality of the pollutants but also the total maximum daily loading as follows:

(1) Limitation of Regulations for Effluent Water Quality

In Japan, the Water Pollution Control Law legislated in 1970 defined Environmental Water Quality Standards (EWQS) as targets for water quality management and regulated effluent quality from industry to comply with the targets. In addition to these regulations, prefectural governments legislated more stringent effluent standards.
The regulation for effluent water quality have been effective in Japan, whereas the following legal limitation have been pointed out:

(a) Although the decrease in total loading is necessary to comply with the Environmental Water Quality Standards (EWQS), loading from inland area are difficult to control. This is because more stringent prefectural effluent standards are legislated by each prefectural government and not necessarily based on water quality in estuaries.
(b) The loading from industries decreased significantly due to the effluent regulations. However, domestic wastewater has not been controlled effectively except for sewerage effluent, but their contribution to the total loading has increased considerably. Especially, little effort has been made to control gray waters.
(c) The effluent quality regulations could not prevent the increase in total loading associated with the increase in productivity nor the dilution of effluent to comply with the regulation.

(2) Regulation of Total Maximum Daily Loading

Thus, improved effluent quality was not enough to restore water quality in large-scale closed waters. Regulations for the total amount of loading not only from industrial and domestic sources but also non-point sources are necessary. The regulation of total maximum daily loading (TMDL) started in 1978 in order to comply with the EWQS as amendments of "Water Pollution Control Law (WPCL) and " the Law Concerning Special Measures for Conservation of the Environment of the Seto Inland Sea" in 1973.

(3) Regulatory System of TMDL in Japan

The purpose of TMDL is to reduce the pollution loads into large and closed water bodies faced with serious pollution problems. The pollution load reduction must be uniform and effective for all the activities in the basin including the inland area. The governmental ordinance defines specific water bodies and parameters to be regulated for the regulation of TMDL. Specified waters are highly polluted and enclosed water bodies with a drainage basin having concentrated human activities and high potential of pollution load generation, like Ganga Basin in India.

The Prime Minister is responsible for the basic TMDL policy. The governor of each prefecture is responsible for making the TMDL plan based on the basic policy for TMDL and necessary countermeasures to attain TMDL as follows:

(a) Reduction of Large Domestic Pollution Load
  (i) Increase in the percentile service by public owned sewerage system and domestic wastewater treatment systems (Gappei-Jyokaso, Sewerage systems for farming villages and community plants).
  (ii) Advanced treatment processes and improved maintenance.
  (iii) Environmental education to reduce domestic loading.
(b) Reduction of Loading with Equality among Industries
  (i) Regulation of industrial effluent according to TMDL standards.
  (ii) Guidelines for small-scale and non-controlled industries, and increases in the number of industries to be regulated.

(c) Reduction of Non-point Pollution Load
- (i) Management of livestock wastewater.
- (ii) Improvement of systems for the control of combined sewerage overflow.
- (iii) Dredging of riverbed sediment.
- (iv) Ecosystem management to restore and maintain natural purification capacity.

Contemporary regulation controlled the concentration of effluent at the discharging point. The TMDL regulations, however, controls the maximum permissible daily loading from industries located in the specified basin and having a daily discharge quantity of more than 50 m^3, calculated as follows:

$$L = C \bullet Q \times 10^{-3}$$

Where,

L: Maximum permissible pollution load (kg/d)
C: COD value specified by the governor (mg/l)
Q: Volume of specified effluent (m^3/day)

Specified effluents are discharged from specified industries except for waters without pollution load such as cooling water. Further, the latest TMDL regulation requires more stringent control of pollution load from new and expanded plants built after 1980.

The above-mentioned COD value is so called “C-value”. Every governor decides C-value for each industrial category based on the permissible upper and lower limits specified by Environmental Ministry. There were totally 217 industrial categories in the first TMDL regulation and finally it increased up to 232 in the latest TMDL regulation.

(4) Outcome of TMDL Regulation

Tokyo Bay, Ise Bay and Seto Bay are regarded as the representative enclosed water bodies and accept a large quantity of pollution load discharged from megalopolis. Figure 3.9 explains the reduction of TMDL into specific water zones from the beginning of the 1^{st} to the end of 3^{rd} TMDL regulations. The pollution load reduction from domestic sources in Tokyo was significant, whereas that of industrial sources was not enough. Both domestic and industrial sources decreased in the Seto Inland Sea. Implementation of various measures to control domestic loads effected decreasing its contribution in recent years.

(5) Pollution Load Reduction from Industries

Industries have carried out various measures to reduce pollution load generation. They tried to save water, improved production process and maintenance of wastewater treatment plants. Improvement in production process such as proper use of chemicals and additives, and better process control seem to be effective for reduction of pollution load generation.

Figure 3.10 explain the historical pollution load reduction per unit production in recent years and clearly show significant improvement on pollution load reduction among all the industrial categories.

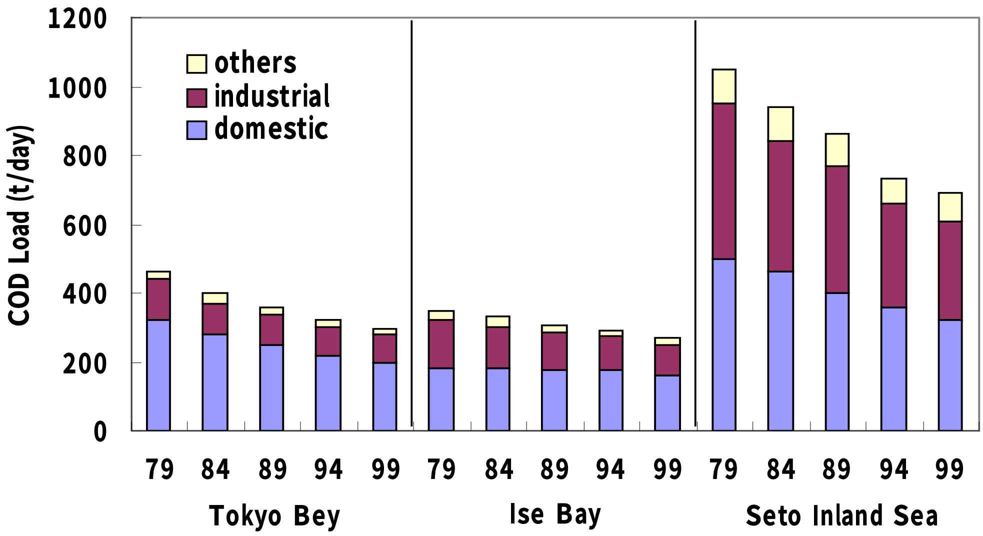


Figure 3.9 Pollution Load Reductions in Japan

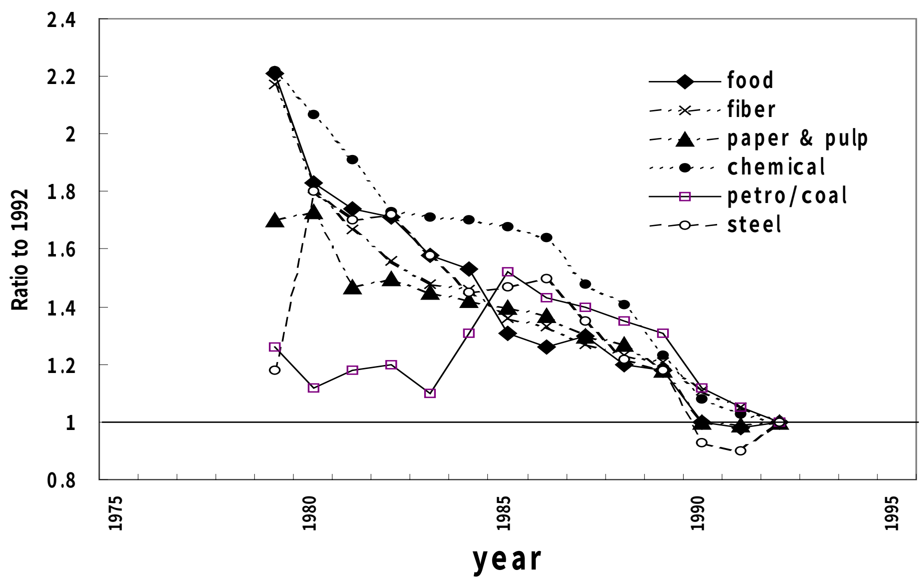


Figure 3.10 Historical Industrial Pollution Load Reduction

3.5.3 Case Study of Comprehensive Pollution Control in Japan

Biwa Lake is the largest in Japan and the most symbolic lake for the country. However, Biwa Lake has been polluted due to the increasing pollution load inflow discharged from lake shore and exceeded the water quality standards at the several monitoring stations almost 20 years ago. Figure B.7.10 shows the comprehensive pollution control in Japan and explains various measures for water quality improvement undertaken in Biwa Lake.

In order to recover the severe pollution of water quality, it is important to consider the comprehensive measures not only the sewerage development but also another measures such as reinforcement of regulation for industrial pollution load reduction, various measures for non-point pollution load reduction, reinforcement of water quality monitoring, environmental education and set-up of financing system for projects. Biwa Lake has gradually recovered the lake water quality under the various measures so far.

CHAPTER 4

RECOMMENDATION
OF
INDUSTRIAL POLLUTION CONTROL

CHAPTER 4 RECOMMENDATION OF INDUSTRIAL POLLUTION CONTROL

4.1 INDUSTRIAL POLLUTION IN THE ENTIRE GANGA BASIN

4.1.1 Database System for Industrial Pollution Load Estimation

The database system that includes 1289 entries in the database system representing over 234 districts in the Ganga basin has been established. Of these, 30 entries represent clusters of SSIs. Thus the database corresponds to 1259 individual industrial units and a large number of SSIs across the basin. Out of the former, currently 194 units are either temporarily or permanently closed due to a host of reasons and for which the effluent and BOD loads are taken as zero.

From the remaining 1065 operational individual units and 30 clusters of SSIs, the quantum of BOD load entering into the river system is estimated to be 308,838 kg/d. With respect to the estimated BOD load from the domestic sector (approximately 2,225 tonnes/day for 2001 population) this comes out to be around 14%.

4.1.2 Category-wise Distribution of Industrial Pollution

Category-wise industrial BOD load distribution is shown in Table 4.1. The categories are arranged in descending order of their contribution. The top four categories, i.e., abattoir, distillery, pulp and paper and tannery together account for 77% of the total BOD load. Number of entries for these and two other prominent categories is shown in Table 4.2. While the abattoir category is estimated to be the largest contributor of BOD loads, its nature as a non-point source has to be kept in mind while developing a strategy to address the problem of wastewater discharges from this sector.

In case of distilleries while all units are understood to have installed ETPs, there are inherent technology limitations in attaining the discharge limits specified in the Environment Protection Act. The current trend is to utilize the treated effluent for bio-composting of press-mud and other agriculture waste. As of now about 12 distilleries in UP have attained zero discharge status. In this regard Central Pollution Control Board has also issued guidelines to facilitate adoption of this practice among a wider target group. As a result of this, it is expected that in due course of time BOD contribution from the distillery sector will decline.

Table 4.1 Category-wise industrial BOD load distribution in Ganga basin

Sr. No.	Industry category	BOD (t/d)	% of total
1	Abattoir	87.3	28
2	Distillery	64.9	21
3	Pulp & Paper	51.2	17
4	Tannery	33.1	11
5	Textile dye & print	18.3	6
6	Fertilisers & Chemicals	18.3	6
7	Food processing	13.2	4
8	Sugar	7.3	2
9	Rice mills	4.3	1
10	Pharmaceutical	1.8	1
11	Engineering	1.4	0.5
12	Integrated Iron & Steel	1.3	0.4
13	Coal washery	1.1	0.4
14	Vegetable oil & Vanaspati	1.1	0.3
15	Others	4.3	1.3
	Total	**308.8**	**100**

Pulp and paper industry comprises units based on three different types of raw materials, i.e., pulp, agriculture residue and waste paper. There are 249 units in this category out of which 98 units (39%) use only pulp, 73 units (29%) use waste paper while the remaining 32% use a combination of all the three raw materials as their feedstock. Concentration of pulp and paper industry is found in the districts of Muzaffarnagar, Saharanpur, Gaziabad and Meerut in UP; Nainital and Udham Singh Nagar in Uttaranchal and; Burddhaman in West Bengal. Large industries are understood to have installed adequate pollution control measures. However, in the small scale category the agriculture residue based industries (typically without chemical recovery system) have severe problem of water pollution and the effluent BOD is in the range of 300 to 500 mg/l. Aggregate BOD discharge from this category of industry is over 51 t/d which is about 17% of the total estimated industrial discharge in the basin.

Tanneries are concentrated at Kanpur, Mokemaghat, Kolkata and few units in Agra. The three main clusters together represent over 900 small and medium sized tanneries. The category as a whole accounts for almost 33% total industrial BOD load in the basin. This figure includes the potential load that will be discharged once the tanneries in Kolkata are relocated and commissioned and the proposed CETP there is made operational.

Table 4.2 Predominant Categories of Water Polluting Industries

Category	No. of operational units	No. of closed units	Total entries in the category	Remarks
Abattoir	NA	NA	196	Non-point source. Numbers correspond to erstwhile districts in various states except Uttaranchal and Jharkhand for which state level meat production data are not available
Distillery	95	5	100	
Pulp & Paper	158	91	249	Comprises all sub-categories e.g., pulp, agriculture residue and waste paper as the feed stock
Tannery	38	7	45	The operational units also include 3 clusters of Kanpur, Kolkata and Mokemaghat (Bihar) that together represent 903 SSIs.
Sugar	178	16	194	
Vegetable oil & Vanaspati	69	41	110	Comprises all categories e.g., solvent extraction, refining, vanaspati (margarine) etc.
		Total entries	894	The six categories put together account for almost 70% of the total entries in the database.

While the sugar industry and vegetable oil and vanaspati industry have fairly large number of units in the basin, their aggregate BOD load discharge is not significant in comparison to the categories of industries described above. In the overall ranking the sugar industry appears at 8th position (2% of total load) and the vegetable oil and vanaspati industry appears at 14th position (0.3% of total load). This can be attributed to the fact that the effluents from these industries are easily biodegradable and the individual industrial units are by and large complying with the discharge standards.

When the generation from the 30 odd clusters alone is considered, it adds up to around 75 t-BOD/d. This is primarily from the SSI sector and accounts for almost 24% of the total.

4.1.3 Geographical Distribution of Industrial Pollution

In terms of geographical distribution of BOD generation, the top ten districts in descending order are listed in Table 4.3. Largest generation is in South 24 Parganas district. Saharanpur is the second largest generator and it is way above Kanpur Nagar (primarily the city based industries), which is normally considered to be a large source of industrial pollution. The two adjacent districts of Saharanpur and Muzaffarnagar put together generate 26 t of BOD/d and their combined load is discharged into river

Hindon (a tributary of Yamuna). The top 10 districts put together account for almost 43% of the total industrial BOD load generation.

Table 4.3 Top 10 Districts in Terms of BOD Load Generation in the Ganga basin

Sr. No.	District	State	BOD Generation (t/d)	Sub-basin
1	South 24 Parganas	WB	18.25	Lower Ganga II
2	Saharanpur	UP	17.02	Hindon
3	Kolkata	WB	16.60	Lower Ganga II
4	North 24 Parganas	WB	15.72	Lower Ganga II
5	Delhi	Delhi	14.00	Upper Yamuna II
6	Jaipur	Rajasthan	12.67	Chambal
7	Barddhaman	WB	11.08	Ajay
8	Kanpur Nagar	UP	10.59	Middle Ganga II
9	Muzaffarnagar	UP	8.80	Hindon
10	Ghaziabad	UP	7.79	Kalinadi
	Total		132.52 = 43% of total	

State-wise BOD generation in descending order is presented in Table 4.4. As expected, UP is the largest generator accounting for 38% of the total, followed by West Bengal at 30%.

Table 4.4 State-wise Industrial BOD Load Distribution in Ganga Basin

Sr. No.	State	BOD (t/d)	% of total
1	Uttar Pradesh	116.50	38
2	West Bengal	91.52	30
3	Rajasthan	20.31	7
4	Bihar	18.04	6
5	Madhya Pradesh	17.61	6
6	Haryana	14.76	5
7	Delhi	14.00	5
8	UTA	13.30	4
9	Himachal Pradesh	2.79	1
10	Jharkhand	0.01	0
	Total	**308.84**	**100**

Sub-basin wise industrial BOD load generation is presented in Table 4.5. Sub-basins with significant load generation are Lower Ganga II, Upper Yamuna II, Chambal, Ramganga and Hindon. The corresponding districts draining into these sub-basins are also listed in Table 4.5. The top five sub-basins account for 57% of the total load generation. The Top ten sub-basins account for 83% of the total load generation and the remaining 26 sub-basins with individual share of 0-3% account for the rest 17%.

Table 4.5 Basin/ Sub-basin wise Industrial BOD Load Distribution in the Ganga Basin

Sr. No.	Sub basin	BOD (t/d)	% of total	Remarks
1	Lower Ganga II	65.23	21.1	Five industrialized districts of Haora, Hugli, Kolkata, North and South 24 Parganas contribute to this sub-basin.
2	Upper Yamuna II	30.14	9.8	Intensively industrialized districts of Delhi, Karnal, Kurukshetra, Panipat, Sonipat and Yamunanagar drain into this sub-basin.
3	Chambal	28.01	9.1	Entire western MP and most of Rajasthan drain into this sub-basin
4	Ramganga	27.48	8.9	The sub-basin drains districts with concentration of agro-based industries, i.e., sugar, distillery and pulp & paper. The districts are Bareilly, Bijnor, Moradabad, Nainital, Pilibhit, Shahjahanpur and Udhamsingh Nagar
5	Hindon	25.82	8.4	Muzaffarnagar and Saharanpur, two industrially developed districts in western UP drain into this sub-basin.
6	Upper Yamuna III	20.15	6.5	Main districts draining in this sub-basin are Noida, Mathura, Agra, Faridabad, Gurgaon, and Alwar
7	Middle Ganga II	17.38	5.6	Industries in Kanpur Nagar and Unnao districts drain into this sub-basin
8	Kalinadi	15.85	5.1	Top eight sub-basins carry 75% of the total industrial BOD load generated in the Ganga basin.
9	Ghaghra	15.68	5.1	Districts in north-eastern UP
10	Ajay	11.30	3.7	Barddhaman district (WB)
11	Others	51.81	16.8	Remaining 26 sub-basins with industrial BOD loads in the range of 0 to 3% of the total
	Total	308.84	100	

4.2 INDUSTRIAL POLLUTION FROM 4 CITIES

4.2.1 City-wise Industrial Pollution Load

Uttar Pradesh where target 4 cities of Kanpur, Lucknow, Allahabad and Varanasi are located is the largest state in the entire Ganga Basin. The industrial pollution load generation is estimated to be 116.5 t/d that shares 38% of total in the entire Ganga Basin. Sub-basin wise industrial pollution load mainly discharged from each 4 cities is calculated and is shown in Table 4.6.

As shown, the Ganga basin receives the maximum pollution load from Kanpur, among the four cities. This industrial pollution in the Ganga is mainly from tanneries, distillery, dying units and thermal power generation units. These industries discharge their effluents into Ganga via their tributaries at downstream and upstream points in these four cities

Table 4.6 Industrial Pollution Load Discharged from 4 Cities

Sub-basin	City	Pollution Load (BOD: kg/d)		Main Industrial Category
		Generation	Runoff	
Middle Ganga II	Kanpur	10,679	7,232	Tanneries, Thermal power plants, automobile industry, electroplating industries, steel Mills
Middle Ganga III	Allahabad	398	314	Battery, Pharmaceutical, Sugar, Textile Mills,
Middle Ganga IV	Varanasi	1,384	999	Sugar Mill, Textile Printing & Dying,
Upper Gomati	Lucknow	5,346	3,085	Pharmaceutical, Distillery

Since, the industrial pollution load discharged from Kanpur is calculated as the largest, followed by Lucknow, this report is mainly focused on Kanpur.

4.2.2 Industrial profile of Kanpur

The industrialization era of Indian economy marked the city landscape with about 75 large and medium scale industries, which followed western direction of expansion along the railway line and G.T. road. These industries mainly include government owned units viz. Elgin Mills, Muir Mill, Caw pore woolen Mills, Ordinance factories, New Victoria Mill, M.P. Udyog, HVOC, and Lalimli. But due to old technology, gigantic workforce, high input cost and low output, these industrial units are facing closure threats. In spite of this grim scenario Kanpur is still a major industrial center with majority of industries consisting of tanneries followed by textile mills, defense establishments, power plants, fertilizer units, and automobile & oil mills. The majority of tanneries are operating in Jajmau and Unnao.

Apart from these large-scale units, the city also has about 5,457 mixed type of Small Scale Industries (SSIs). These SSI has grown as ancillary to major units with the predominance of metal products (830), Leather products (819), Food Products (443), Rubber & plastics (416), Machinery parts (396), Hosiery & garments (387), Chemical (337), paper products (318) and Cotton textile (246). Most of the industries are located in Uttar Pradesh State Industrial Development Corporation (UPSIDC) (Kalpi Road and Fazalganj), Industrial Estate, Co-operative Industrial estate (Dada Nagar), Panki Industrial Area and Jajmau Industrial area. The tanneries, having a total number of 312 numbers are located in Jajmau area in clustered form (surrounded slums, village settlement) on the bank of river Ganga. This area was characterized with degraded environmental conditions. The initiation of Ganga Action Plan (GAP) had helped in improving environmental conditions in this area. The engineering industries of armaments, automobiles and steel fabrication units are located at Kalpi road industrial belt. The large-scale engineering units like painting and electro-plating discharge toxic metal into River panda, a tributary of river Ganga.

4.2.3 Tanneries Industry in Kanpur

The Kanpur leather industry is known for sole leather, industrial shoes and saddlery products. It is the largest center of buffalo based leather in India. The tannery industry in Kanpur began during the British government, when the first tannery to produce leather for use in saddlery was set up. The industry has continued to grow since then. It has experienced particularly sharp growth during the last ten years. The number of tanneries has increased from 175 in 1990 to more than 350 during 2000. Most of these tanneries are located in a small area by the river Ganga, called Jajmau. A large majority of tanneries in Kanpur (as in other tannery clusters in India) are small. Out of 354 registered tanneries in Kanpur, 90% are small. While most of the small tanneries cater to the local market, some are involved (directly and indirectly) with exports. The large tanneries, on the other hand are primarily export oriented. A handful (20) of tanneries have also been set up in the nearby town of Unnao. In addition to these, Kanpur city has a number of leather product manufacturers. Many of them have either a tannery in the Jajmau cluster and or long-term association with Jajmau tanneries.

The Jajmau is comparatively bigger area in terms of total hides processing capacity as compared to Unnao. Information compiled by U.P. Pollution Control Board (UPPCB) puts the total leather tanning units as 295, which has a total capacity of 320 hides/day, as compared to a cluster of 28 tanneries in Unnao having a capacity of 47.5 ton of hides per day.

Most of the tanneries in Jajmau cluster use outdated and inefficient technologies and their environmental performance are poor. Until the mid-1990s, the tanneries in the cluster did not have facilities to treat effluent, which was discharged directly into the river Ganga. This has been a cause of serious environmental degradation. These tanneries produce about 7.75 million liters/day (MLD) of effluent in Jajmau as compared to 1.9 MLD in Unnao area. In addition to this wastewater, these tanneries produce hazardous chrome bearing shave waste.

4.2.4 Industrial pollution Management in Tanneries

The industrial pollution control in tanneries initiated after the intervention of Supreme Court as well as result of initiation of Ganga action plan I. In order to treat the effluent emanating from the tanneries in the cluster, a Combined Effluent Treatment Plant (CETP), based on Upflow Anaerobic Sludge Blanket (UASB) system was set up under the Indo-Dutch project. 65% of the cost of construction was borne by the central government and the Dutch government, while state government as well as the tanneries contributed 17.5% each. The plant, which has a capacity to handle 36 MLD, treats a combination of tannery effluent and municipal waste in the ratio of 1:3. In addition to the CETP, the tanneries are also required to provide primary treatment. Most tanneries in the cluster now have a primary ETP plant, which are operated occasionally. The discharge from the primary ETPs is taken to the CETP through a covered drain.

4.2.5 Wastewater Treatment Plants at Jajmau and Unnao

(1) 36 MLD CETP at Jajmau

The objective of the plant was to treat the 9 MLD of effluent from the toxic leather industry. This was supposed to be done by mixing the tannery effluent and sewage in the ratio of 1:3 and treating it by UASB technology, which is based on biomethanation process followed by Final Polishing Unit (FPU).

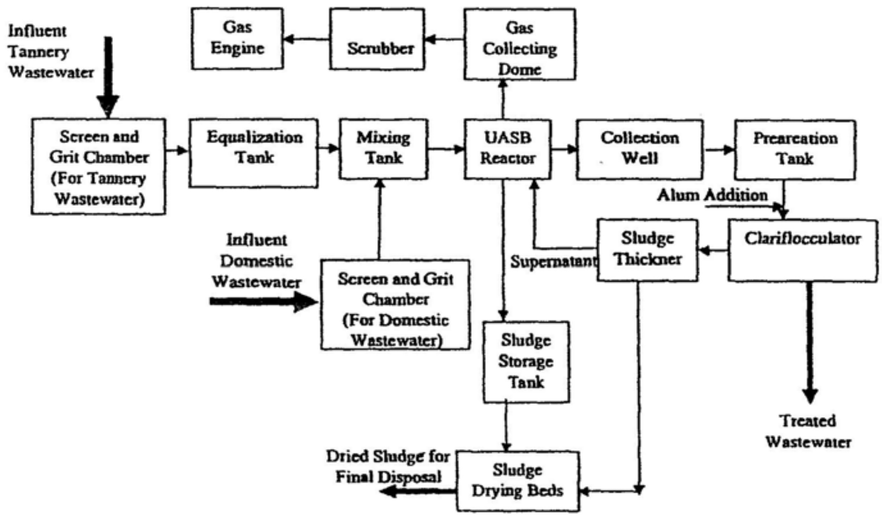


Figure 4.1 Flow Diagram for 36 MLD CETP at Jajmau

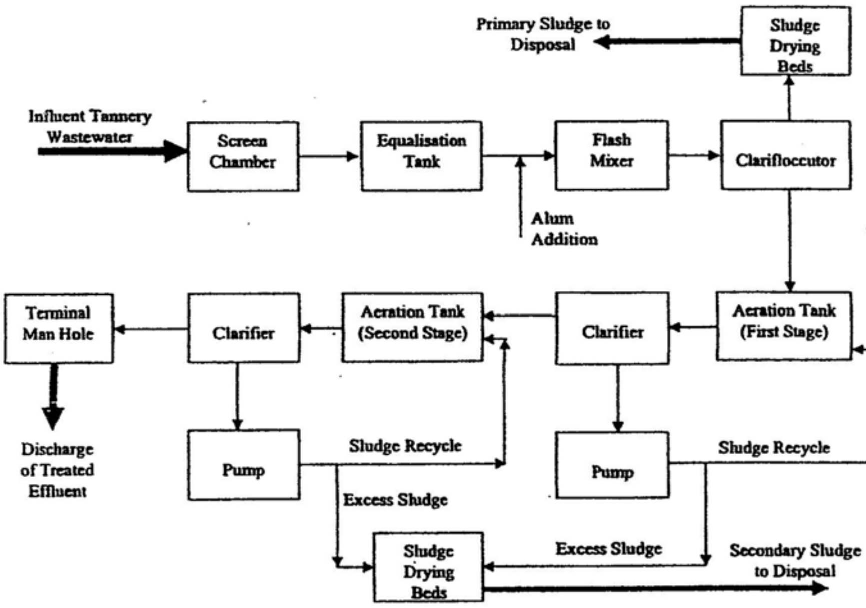


Figure 4.2 Flow Diagram for 2.15 MLD CETP at Unnao

(2) 2.15 MLD CETP at Unnao

The CETP based on Activated Sludge Process (ASP) of 2.15 MLD capacity was set up in 1995, to treat the effluent of 28 tanneries in the area. The tanneries operate and maintain the CETP on Co-operative basis. The plant was built at a cost of Rs. 20 million, 50% of which was provided by the central and state governments as subsidy. Of the remaining 50%, the World Bank has provided 30%. The tanneries had to provide only 20% of the total cost of the plant. The tanneries bear the operational cost of CETP.

4.2.6 Current Assessment of Industrial Pollution in Jajmau and Unnao

(1) Lack of Continuous Electric Supply

Since its time of commissioning, the 36 MLD CETP at Jajmau is being operated and maintained by U.P. Jal Nigam. The plants at present are not functioning properly due to frequent power cuts. It is also learnt that the dual fuel engines are also not being used due to poor gas generation.

(2) Low Performance of 36 MLD CETP

The performance of UASB reactor is not satisfactory, which may be due to high chromium concentration in the influent and frequent power cuts. The Chromium being a heavy metal is toxic to biomethanation bacteria above their threshold value.

(3) Chrome Recovery Plants (CRP)

There are 220 chrome-tanning units in Kanpur. These units are cause of concern as they discharge chromium into the waste stream. Out of these 220, 110 units process more than 50 hides per day, and are required to install CRP individually and more than 80 have set up their own CRPs. But these plants are operated occasionally. The reason is high cost of chemicals and a long payback period of 7 years that discouraged the tanneries to operate CRP on continuous basis (UNIDO study, 1999). For industrial tanning units having capacity less than 50 hides/day (small industries), a common CRP was proposed to be set up. A project proposal for the establishment of common chrome recovery facility, prepared by Central Leather Research Institute (CLRI) has been submitted to National River Conservation Directorate (NRCD), Ministry of Environment and Forests (MoEF), Government of India (GoI) for approval.

(4) Groundwater Contamination from 36 MLD CETP Sludge

The CETP at Jajmau produces chromium-containing sludge, which is toxic and hazardous. This sludge is being dried on 61 nos. sludge-drying beds. The dried sludge was previously used for agricultural purpose. Later a study found dried sludge to contain Chromium, which was a health hazard and caused groundwater pollution due to alluvial soil and high groundwater table (conducted by IIT Kanpur and CPCB regional office, Kanpur). Also due to the absence of impervious lining in sludge drying beds, groundwater contamination due to Chromium leaching has occurred. Thereafter, it was decided that the disposal of hazardous tannery sludge generated at the 36 MLD CETP shall be done by laying plastic sheets in allocated pits at Rooma, till the final landfill facility is established. However at present, this procedure is not being followed. The project of Kanpur Nagar Nigam (KNN) for establishment of final landfill facility at Rooma still awaits approval.

4.3 STATUS OF ENVIRONMENTAL LEGISLATION IN INDIA

The GoI has enacted several legal provisions, laws and policies for management of industrial pollution in the country. Some legislation has also been enacted by State government. These legal procedures facilitate pollution control enforcement through appropriate actions against the defaulter polluting industries and other polluting sources.

A comparative account of existing environmental legislations is given below:

Table 4.7 List of Environmental Legislation

Name of Legislation	Year of enactment	Purpose
National Level Enacted Legislations		
The water (Prevention & Control of Pollution) act	1974	Legislation Framework for Water pollution Control
The water (Prevention & Control of Pollution) rules	1975	Water Pollution Control, Issuing of permit for Industrial Discharge
The water (Prevention & Control of Pollution) (Procedure for Transaction of Business) rules	1975	Rules for Transaction of Business
The water (Prevention & Control of Pollution) Second Amendment Rules	1976	Water Pollution Control, Issuing of permit for Industrial Discharge, Penalties for Discharging Industrial Wastewater into Fresh water bodies
The water (Prevention & Control of Pollution) Cess Act, as Amended by Amendment Act, 1991	1991	Water Pollution Control, Issuing of permit for Industrial Discharge
The water (Prevention & Control of Pollution) Cess Rules	1978	Legislation Framework for Charging Cess for Water consumed in industry
The water (Prevention & Control of Pollution) Amended Rules	1989	Water Pollution Control, Issuing of permit for Industrial Discharge
The Environment (Protection) Act,	1986	Legislation Framework for Empowering Central Government with enhanced Environmental Control powers
The Environment (Protection) Rules	1986	Empowering Central Government with enhanced Environmental Control powers
The Environment (Protection) Amendment Rules	1987	Setting up Emission Standards, Prohibition of Industrial Location, Submission of Environmental Statement, Conducting Environmental Impact Assessment, Notification on Coastal Zone Regulation
The Environment (Protection) Third Amendment Rules	1987	Environmental Impact Assessment, Notification on Coastal Zone Regulation
The Environment (Protection) Amendment Rules	1997	Environment Pollution Control
Notification on Emission standards & Guidelines for Location of Industries for various areas	1997	Emission standards & Guidelines for Location of Industries
The Public Liability Insurance Act	1991	Industrial Pollution Risk Minimization and Compensation
Hazardous waste (Management and Handling) Rules	1989	Legislative Framework for Laws enactment related to storage and handling of Hazardous chemicals
Manufacture, Storage and import of Hazardous Chemical Rules	1989	Rules for Manufacture, Storage and import of Hazardous Chemical Rules
Municipal Solid waste (Management and Handling) Rules	1999	Rules for Municipal Solid waste Management at urban cities
Guidelines for Seeking Environmental Clearance	1997	Criterion for Clearance of New projects on Environmental grounds
State Level Enacted Legislations		
The Orissa River Pollution Prevention Act	1953	Pollution Control in Inland water bodies, Rules for Discharge permits Issue, Laying of Discharge Standards
The Maharastra Prevention of water Pollution Act	1969	Pollution Control in Inland water bodies, Rules for Discharge permits, Laying of Discharge Standards

As shown above, there has been less enactment of legislation at state level with more stringent standards as compared to national level. In this context, a new legislation is very essential for the state of U.P. in terms of resolutions of industrial pollution control measures. The existing Orissa River

Pollution Prevention Act, 1953 is an example of such Act.

4.3.1 Legislative Enforcement of Industrial Pollution Control in Ganga Basin

For monitoring and control of pollution from industry, 68 gross polluting industries located on the banks of Ganga and responsible for about 80% of the total industrial pollution were identified in 1985. These industries have been monitored rigorously. At the time of GAP, only 14 units were equipped with proper ETPs. In June 1995, 55 units of these had set up the ETPs and 12 units had been closed down permanently with the remaining one unit having changed the technology and thereby not needing an ETP.

Currently, ETPs in 45 units are operating satisfactorily and 23 units have been closed down. According to recent surveys on grossly polluting industries, in addition to the 68 units already identified, another 119 units have been listed for monitoring purposes. Of these, 37 units are complying with the discharge standards, 9 units have been closed down and action has been initiated against the remaining 73 units under the Environmental Laws. The enforcement of the water (Prevention and Control of Pollution) Act and the Environment Protection Act against the defaulting industrial units are being done by the CPCB and the SPCBs.

4.3.2 Current Enforcement of Industrial Effluent Monitoring

The present method of enforcement of industrial effluents monitoring in India follows, issuing of discharge permits by SPCBs. This procedure requires entrepreneurs to obtain clearance from Central/State Air and Water Pollution Control Boards before setting up the industry. These discharge permits stipulate that air (gases) and water (effluents) emanating from the industry should adhere to certain quality standards as per the guidelines.

According to the environmental guidelines, the concerned SPCB is required to certify that the proposal meets with the environmental requirements and that the equipment installed or proposed to be installed are adequate and appropriate to the requirement. In this context, a variety of measures have been taken to ensure that enforcement goes through proper environmental approvals from the nodal enforcement agencies like SPCBs.

Before issuing the letter of Intent, a No Objection Certificate (NOC) is required from the concerned SPCB. This NOC specifies the particular pollution control methods to be used in the factory. It also recommends effective manufacturing processes for reducing pollution.

Mandatory Requirements:

(a) Industrial Siting Criterion:

The Siting criterions for establishment of new industries were enacted under the Environment Protection Act, 1986 and are applicable for any upcoming new industrial or other projects. In respect of certain industrial development projects it is not only necessary to install suitable pollution control equipment but also to identify appropriate sites for their location.

Initially a selected group of 20 industries were covered by the Department of Industrial Development, under these industrial Siting criterions. At present, the total number of industries covered under these Siting criterions is 28. A formalized procedure has been stipulated for site selection from environmental point of view to minimize the adverse impact of the industries on the immediate neighborhoods as well as distant places. Some of the natural life sustaining systems and some specific land uses are sensitive to industrial impacts because of the nature and extent of fragility and with a view to protecting. These industrial Siting criterions are as follows:

(i) Coastal Areas: at least 1/2 km from high tide line;

(ii) Flood Plain of the Riverine Systems: At least 1/2 km from flood plain or modified flood plain affected by dam in the upstream or by flood control systems;

(iii) Transport/Communication System: At least 1/2 km from high way and railway;

(iv) Major Settlements (3,00,000 population): Distance from settlements is difficult to maintain because of urban sprawl. At the time of Siting of the industry if any major settlement's notified limit is within 50 km, the spatial direction of growth of the settlement for at least a decade must be assessed and the industry shall be sited at least 25 km from the projected growth boundary of the settlement.

(v) No forestland can be converted into non-forest activity for the sustenance of the industry (Ref: Forest Conservation Act, 1980);

(vi) No prime agricultural land can be converted into industrial site;

(vii) Within the acquired site the industry must locate itself in the lowest location to remain obscured from general sight;

(viii) Land acquired should be sufficiently large to provide space for appropriate treatment of wastewater still left for treatment after maximum possible reuse and recycle. Reclaimed (treated) wastewater shall be issued to raise green belt and to create water body of aesthetics, recreating and if possible, for agriculture. The green belt shall be 1/2 km wide around the boundary limit of the industry. For industry having odor problem it shall be a kilometer wide;

(ix) The green belt between two adjoining large scale industries shall be one kilometer;

(x) Enough space should be provided for storage of solid wastes so that these could be available for possible reuse;

(xi) Lay out and form of the industry that may come up in the area must conform to the landscape of the area without affecting the scenic features of that place;

(xii) Associated township of the industry must be created at a space having physiographic barrier between the industry and the township;

(xiii) Each industry is required to maintain three ambient air quality-measuring stations within 120-degree angle between stations.

(b) Environmental audit mandatory for Industries

A notification making environmental audit mandatory has been issued during the year 1992-93, which requires all industries applying for environmental clearance to submit an annual environmental audit report to the concerned State Pollution Control Board. The Department of Company Affairs had amended the Companies Act, 1956 to include the Environment statement in the Annual Reports of Companies. After the enactment of above notification, CPCB conducted environmental audit in selected units belonging to the 17 heavily polluted industrial sectors units, with the following objectives:

(i) To evaluate the performance of the pollution control systems;

(ii) To identify good pollution prevention and control systems for demonstration;

(iii) To impart on the job training to industry personnel in environmental monitoring including sampling and analysis of effluents/emissions

(c) Permission from Central/State Pollution Control Boards

The permission from CPCB and SPCBs has become mandatory under the Environmental Protection Act, 1986 and Environmental Impact Notification, 1994 for setting up of all new upcoming projects and existing projects or industries seeking expansion in operations. According to these rules:

(i) The entrepreneur should provide the details of proposed project site, pollution abatement measures and such other relevant information as required for review from environmental angle.
(ii) The entrepreneur will be required to submit half-yearly progress report on installation of pollution control devices to the respective State Pollution Control Boards.
(iii) Depending on the nature and location of the project, the entrepreneur will be required to submit comprehensive Environmental Impact Assessment Report, and Environmental Management Plans.

(d) Inspection for the Industrial Effluent

The inspection for the industrial effluent has been conducted according to the Water (Prevention and Control of Pollution) Act, 1974 and the Environment (Protection) Act, 1986. The main contents of both Acts for the inspection and penalty system for the violated industries are follows:

Frequency of Inspection for Industrial Effluent

Frequency of inspection for industrial effluent conducted in Uttar Pradesh is listed in Table 4.8.

Table 4.8 Frequency of Inspection for Industrial Effluent

Classification	Frequency	Remarks
Grossly Polluting Industries	4 times per year and ad-hoc basis	
Medium Polluting Industries	2 times per year and ad-hoc basis	
Low Polluting Industries	1 time per year and ad-hoc basis	

Procedure for Violated Industries

The Pollution Control Boards has been vested powers under Water Act, which can issue any directions in writing to any violated industries. Directions that violated industries shall comply with are as follows:

(i) The closure, prohibition or regulation of any industry, operation or process.
(ii) The stoppage or regulation of supply of electricity, water or any other service.

Penalties for Violated Industries

Water Act prescribes that any industries failing to comply with any direction given under the provision regarding the prevention of water pollution within such time as may be specified in the direction shall, on conviction, be punishable with imprisonment for a term which may extend to three months or with fine, which may extend to ten thousand rupees or with both and in case of the failure continues, with an additional fine which may extend to five thousand rupees for every day during failure period.

4.3.3 Initiative on Industrial Pollution Control along Rivers

An initiative to identify polluting industries along the rivers in India for priority actions for control of industrial discharges into rivers was undertaken in 1993-94. While this process of Inventorisation continued, the National River Conservation Authority (NRCA) in its meeting held on July 12, 1997 under the Chairmanship of the Honorable Prime Minister, decided that the polluting industries which are discharging their effluents into rivers and lakes should be directed to install the requisite effluent treatment systems within three months, failing which closure notices should be issued. Accordingly, the Chairman, (CPCB) at the instance of MoEF, issued directions under Section 18(1) (b) of the Water (Prevention and Control of Pollution) Act, 1974, to all the SPCBs on July 14, 1997, requiring them to:

(i) Submit (within 10 days) a list along with the names and addresses of Grossly Polluting Industries (GPI) discharging their effluents into rivers and lake, which has taken requisite measures for meeting the respective effluent standards.
(ii) Submit (within 10 days) a list along with the names and address of GPIs discharging their effluent into rivers and lakes, which have not taken requisite measures for meeting the respective effluent standards, prescribed the stoppage or regulation of supply of electricity, water or any other service.
(iii) Direct the defaulting industries to take necessary action for effluent treatment within 3 months failing which closure notices shall be issued against the defaulting industries discharging 100 kg BOD per day or more.

Table 4.9 List of Grossly Polluting Industries and their Status in India

S. No.	Name of the State/UT	No. of defaulters as in August '97	No. of Industries Closed	No. of Industries which have provided requisite treatment/disposal facilities after issuance of directions	No. of defaulters
1.	Andhra Pradesh	60	18	42	00
2.	Arunachal Pradesh	00	00	00	00
3.	Assam	07	06	01	00
4.	Bihar	14	04	10	00
5.	Goa	00	00	00	00
6.	Gujarat	17	03	14	00
7.	Haryana	21	09	12	00
8.	Himachal Pradesh	00	00	00	00
9.	Jammu & Kashmir	00	00	00	00
10.	Karnataka	20	02	18	00
11.	Kerala	36	04	32	00
12.	Madhya Pradesh	02	01	00	01
13.	Maharashtra	06	03	03	00
14.	Manipur	00	00	00	00
15.	Meghalaya	00	00	00	00
16.	Mizoram	00	00	00	00
17.	Nagaland	00	00	00	00
18.	Orissa	09	03	04	02
19.	Pondicherry	04	00	04	00
20.	Punjab	18	01	16	01
21.	Rajasthan	00	00	00	00
22.	Sikkim	00	00	00	00
23.	Tamil Nadu	366	118	248	00
24.	Tripura	00	00	00	00
25.	UT-Andaman & Nicobar	00	00	00	00
26.	UT-Chandigarh	00	00	00	00
27.	UT-Daman & Diu, Dadar & Nagar Haveli	00	00	00	00
28.	Delhi	CSP*	-	-	-
29.	UT-Lakshadeep	00	00	00	00
30.	Uttar Pradesh	241	59	181	01
31.	West Bengal	30	07	23	00
	Total	851	238	608	05

The status of penalty for industries with special reference to Uttar Pradesh is that only one unit was found defaulter and the UPPCB authorities closed about 59. Overall assessment of current penalty system shows that very few industries throughout India has been declared defaulter. This could be due to lack of industrial monitoring frequency, submission of fabricated environmental audit reports by industries and delay of initiating penalizing process, etc.

4.3.4 Comparative system of Effluent Monitoring in Various Countries

A comparison of industrial effluent monitoring system in India, Japan and U.S. has been presented in Table 4.10.

Table 4.10 Comparative System of Effluent Monitoring in Various Countries

Issues of Industrial pollution Minimization	India	Japan	USA
Legislation for industrial Wastewater pollution monitoring	Water Act-1974 Water Cess Act Environmental Protection Act-1986	The article 15 of the Water Pollution Control Law, enacted in 1970	1977 Clean Water Act
Types of Permits Issued	Normal Industrial Discharge types, No Site specific	Industrial types and site specific	Municipal and Industrial types, site specific type
Basis of Environmental Discharge standards Enforcement	Minimum National acceptable standards MINAS	National industrial Discharge standards	National pollution Discharge Elimination system NPDES
Water Quality Criteria	Best designated Criteria based upon A, B, C, D and E class	Utilization of specific water bodies for human use, recreation and drinking	Utilization of specific water bodies for human use, recreation and drinking
Industrial Application Criteria	Industries using more than 50 Kl of water / hr	Industries using more than 25 Kl of water / hr	Industries using more than 25 Kl of water / hr
Discharge Monitoring agency	CPCB and SPCB	Each Prefectural Government, further can entrust Mayors of cities	Environmental protection agency and states Environmental protection departments
Frequency of Monitoring	Annually	Monthly	Monthly
Criteria for wastewater discharging body	No specific criteria, based upon MINAS	Specific Criteria, based upon daily and monthly pollution COD loading	Based upon available technology and discharge standards
Permission required for discharge into Municipal sewers	No	Yes	Yes
Stringent discharge measures for site specific discharges	No	Yes	Yes

As can be seen in Table above, in India:

(i) There is no criterion for issuing permits for industrial discharge based upon designated use of inland water bodies.
(ii) There is no provision for issuing local permits at local level for industrial effluent discharges to inland water bodies.
(iii) No permission is required for discharge of industrial effluent to municipal sewers.
(iv) Absence of stringent discharge standards for site-specific discharges.

4.4 RECOMMENDATIONS FOR IMPROVEMENT OF EXISTING INDUSTRIAL POLLUTION MANAGEMENT

4.4.1 Technical recommendations

(1) Improvement of Leather tanning technology

Various studies have shown that leather tanning process in Jajmau industrial areas are highly water consuming and outdated. Therefore in the long run, it is necessary to upgrade their technology for chrome minimization and water recycling. There are various technological options available and some of them are:

(a) Aluminum Tanning Technology:

One of the best ways to combat chrome pollution is to avoid chromium itself in tanning. With this view, a chrome-free combination tanning system has been established using aluminum, tannic acid, a precursor to vegetable tannins and silica. Since tannic acid has low molecular weight compared to vegetable tannins, it can be successfully used to make a variety of leathers. This technology has already been adopted by TATA International ltd., Dewas, M.P. and could be demonstrated in Jajmau and Unnao as well. The presence of aluminum not only improves the hydrothermal stability of leather but also gives a pleasant pastel color to the leather due to the formation of aluminum-tannic acid complex, which produces color in the matrix thus leading to the concept of natural dyeing.

(b) Recycling of Chromium in Tanning Operation

The biggest problem with tanneries at Jajmau is the disposition of chrome-tanned solid wastes. To keep the chromium from tanned wastes within control limits, a technology based upon modified enzymatic dechromation technology is available, which has been developed into an industrial scale with a daily capacity of three metric tons of chrome shavings. The chromium-containing sludge, isolated by this technology, contains 10-15% magnesium oxide, which is used (here) as a precipitator for chromium in spent tanning liquor. This chrome removal from the spent tanning liquor, using the chrome sludge from digestion of the chrome-tanned solid wastes, effectively provides a closed loop for chromium in tanning operations. (American Leather Technologist Association, 2002).

(2) Reduction of Chromium Induced Toxicity to CETP:

The existing 36 MLD CETP should be made more efficient by providing a primary settling tank, thereby reducing the entry of Cr into UASB reactor thus minimizing chromium induced toxicity to UASB based reactors. An impervious lining should also be laid below the sludge drying beds in order to prevent leaching of chromium into groundwater.

(3) Establishment of CRP Plant

The majority of tanneries operating in Jajmau area consist of small-scale units. These units account for most of chromium-laden wastewater from tanneries and for these tanneries, a CRP was proposed. The DPR for this plant was prepared by CLRI, Chennai. The approval is pending with NRCD, Ministry of Environment and Forests (MoEF) since 2000. NRCD should provide clearance to this project on priority basis.

(4) Effective Monitoring of CRP Functioning in tanneries

The design and establishment of CETP was promulgated on the basis of chromium recovery at industrial units via installation of CRPs. It was assumed that setting of CRP for pre-treatment of tanneries effluent shall reduce the influent chromium concentration at CETP to 11 mg/l. But the current chromium concentration of 45 ppm received at CETP influent stream shows that, these CRPs are being operated occasionally (IIT Kanpur report, 2003). High Chromium concentration is also attributed to the absence of a common CRP for small tanneries. It is recommended that UPPCB should increase the monitoring frequency of CRPs operation and industrial discharges as well. This monitoring should be linked with a feedback monitoring of Chromium in the influent and effluent of CETP.

(5) Capacity Building of CETP Performance Monitoring System

The CETP effluent was found to contain chromium, which is a human health hazard. It is recommended that the CETP effluent should be restricted for irrigation purpose, till removal of chromium within discharged limits is achieved from CETP effluent. These additional parameters are shown in Table 4.11.

Table 4.11 Laboratory Analytical analysis

Name of Parameter	Significance	Analytical Method	Frequency
Total Organic Content	Indicator of Total Organic loading	Wilkley Black titration Method / TOC analyser	Twice a week
C/N Ratio	Optimised Biomethanation Feed Ratio	Ratio of TOC and Total Nitrogen	Twice a week
Total Suspended Solids	Suspended Solids concentration	Imhoff Cone method	Everyday
Total Volatile Solids	Inference of Biogas Formed	Ash Detection Method	Everyday
Total Chromium	Chromium presence	Spectrophotometer	Once a week
Total Coliform	Faecal Contamination Presence	Microbiological Incubation Method	Once a week
Methane Composition	Biomethanation activity	Orsat Apparatus/Gas Chromatograph	Once a week

For above mentioned parameters analysis, following additional lab facilities as well as increased manpower should be provided:

(i) Microbiological Lab (Including Culturing tubes, Chemicals, Glassware, autoclave, Laminar Flow, centrifuge, Cell counter)
(ii) Orsat Apparatus for Methanogenesis activity
(iii) Kjeldahl Nitrogen analyser assembly.

In addition to above analytical capability, the manpower should combine the following team:

(i) Analytical Chemist / Environmental Science Graduate
(ii) Microbiological analyst
(iii) Laboratory attendant

The plant operators should be sent for in-plant training to other CETP at Ankleshwar (Gujarat) and Ranitec (Tamilnadu) to improve their operational skills. The analytical staff should be provided analytical training at institutions like IIT, Kanpur and Central Pollution Control Board (CPCB) regional office at Kanpur for refining their analytical skills.

4.4.2 Legislative Recommendations

(1) Need for Special Water Discharge Permits:

The present system of issuing discharge permit into inland waters is based only upon seeking consent under the Water Act 1984 & Air Act, 1986. Based upon this a permit is issued to industry for discharges into designated inland water body. This discharge permit is based upon the industrial standards set on type of industry, not on the type of inland water body best designated use. The wastewater discharge permit should be issued on the basis of system, which is followed in countries like Japan.

a. Industrial Discharge standards: The industrial discharge permits shall be issued on the basis of national standards of MINAS.
b. Municipal sewer discharge standards: The concerned municipality shall issue the municipal discharge permit. The municipality of Kanpur shall set up the sewer discharge standards. The municipality shall be authorized to monitor the effluent discharges by the concerned industry using its public health engineering department. The municipality shall be authorized to withdraw municipal discharge permit and further recommend the state pollution control board to initiate legal action against violating industry.
c. Inland water body discharge standards: The inland water body discharge permit shall be issued on the basis of discharge criteria for inland waters.

As shown in Figure 4.3, the degree of normal industrial discharge standards shall become more stringent with localization of industrial discharge permits. This shows increased effective regulation of industrial discharge with increased stakeholder's participation in implementation process.

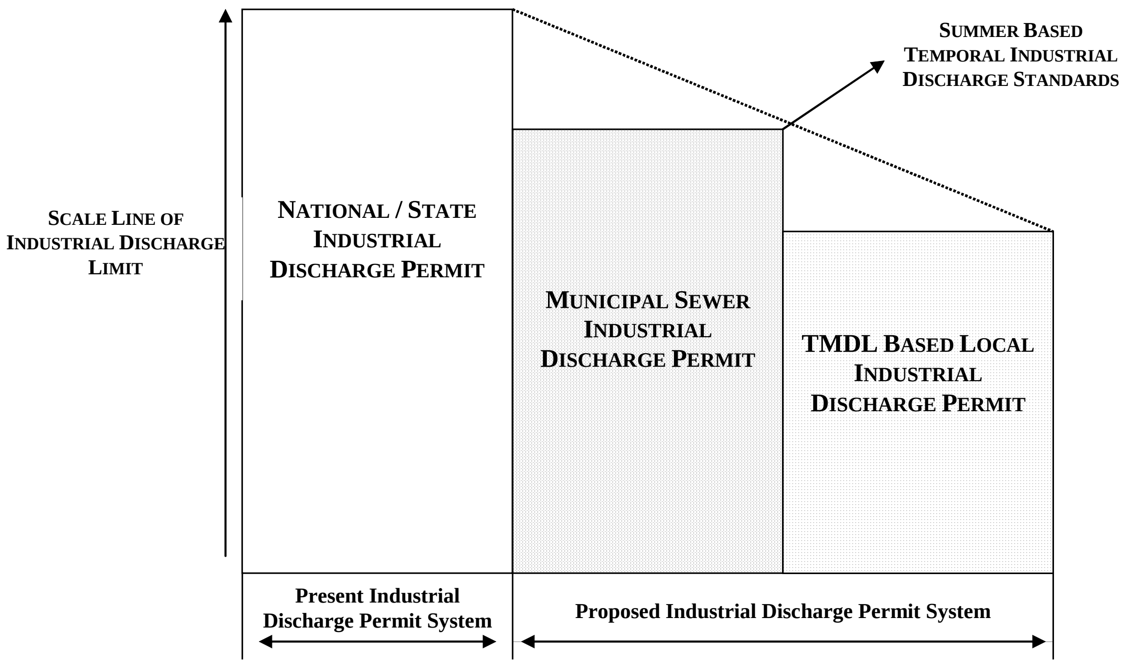


Figure 4.3 Presentation of Relation between Present Permit Systems with Normal Standards for Industrial Discharge

(2) Effluent Water Quality Standards for Sewerage System in Japan and India

The below comparison in Table 4.12 says that municipality discharge standards in terms of BOD_5 as well as suspended solids are still high in India in comparison to Japan. The standards for suspended solids could be reduced in India, as they may not be expensive with respect to technology up-gradation and expansion of current existing treatment facilities in India.

Table 4.12 Comparison of Effluent Standards of India and Japan

Parameters	Japan	India
Temperature	40°C	-
pH	5.7-8.7	5.5-9.0
BOD_5	300	350
Suspended Solids	<300	600
Cyanide	< 2 mg	2 mg
Total Cr	< 3 mg	2 mg

(3) Temporal Discharge Standards:

The National effluent discharge standards are not based upon the weather and flow conditions of natural riverine systems and their pollutant dilution capacity. The desired water quality is not maintained, when the flow is reduced during summer. There is need for framing of temporal industrial standards for dry weather flow, which could be a bit more stringent from the normal discharge standards for high water intensive industries.

(4) Proper Technology based Legislative Specifications:

As per the legislation, the current discharge standards, which are based upon the best available technology (BAT), which should be used by industries for achieving these discharge standards. But no specific technology based upon the type of discharging industries is provided in the legislation. There is urgent need to create a database of BAT for various industries, which should be adopted by various industries for meeting their discharge standards.

(5) Proper Cognizance of Legislative Guidelines:

The guidelines under Schedule VI of Environment protection Act, 1986 (EPA), says that while permitting the discharges of effluent and emissions into environment, state boards are required to take account of assimilative capacities of the receiving bodies, especially water bodies so that quality of the intended use of the receiving water is not affected. These guidelines should be considered, while reviewing and issuing the discharge licenses to various industries.

(6) Need for Mass Based Standards:

The present standards are based on the concentration of pollutants in effluents and in emissions. The norms should be revised to lay down mass-based standards, which will set specific limits to encourage the minimization of waste, promote recycling and reuse of materials, as well as conservation of natural resources, particularly water. Since the standards will be source related, they will require for the most polluting industrial processes, particularly those using toxic substances, application of the best available technological solutions, and also be an instrument for technological up-gradation.

(7) Increased Frequency of Industrial Discharge Monitoring

The present system promulgates the industries to prepare and submit the environmental statement or audit report on annual basis or on 6 monthly bases. Presently, private consultants perform this environmental audit exercise and report is submitted by the industries to SPCB. After submission, the SPCB authorities generally accept the report. For ensuring more transparent assessment of submitted environmental audit reports, we recommend following additions in the existing system:

a. The industries should be asked to submit an interim report after the onset of summer in addition to annual environmental report submitted normally.
b. A panel of certified environmental auditors, which should be empanelled maintained by respective PCB's, should prepare the environmental audit reports.
c. The same auditors should not be assigned auditing work for following subsequent year. But he could be sanctioned assignment after a gap of one year.
d. The environmental audit reports should be sent to industries and they should be made available to general public.

4.4.3 Institutional Recommendations

(1) Stake Holder Participated Management of CETP:

As per Supreme Court ruling, it was decided to transfer the 36 MLD CETP to Kanpur Nagar Nigam (KNN) after it's commissioning. Following these ruling, an initiative should be undertaken to prepare handover of CETP operation to Kanpur Nagar Nigam (KNN). This should be supported by a capacity building programme for KNN. A CETP Monitoring Committee (CMC) should be framed consisting of General Manager, U.P. Jal Nigam, Mayor, KNN and Representative of Jajmau Tanneries Association to ensure representation of all stakeholders of CETP. This committee should monitor the operation and maintenance of CETP. For operation of CETP, the staff from U.P. Jal Nigam should be deputed to KNN. Public Health Engineering (PHE) of KNN shall perform the routine supervision of CETP. The tanneries shall be required to pay the recurring charges for operation and maintenance of CETP. The CMC shall be responsible for

a. Monitoring of CETP itself;
b. Monitoring discharges of various tanneries, which are members of this CETP; and
c. Fixing of wastewater treatment tariff for industries.

(2) Pollutant Concentration and Incentive Based Cost Sharing of CETP

At Jajmau, the recurring charges for cost sharing of CETP operation is based upon the total volume of pollutant generated by the tanneries. But at CETPs located in Ankleshwar (Gujarat) and at Ranitec (Tamilnadu), the recurring charges are computed based on the COD concentration of the influent (for a fixed pre-decided volume) and these charges also increase non-linearly with rise in concentration level of the influent. These types of pollutant concentration and volume-based charges should be applied in Jajmau also. Rebates should be given to those units, which reduced the volume of effluents discharged and/or concentrations of pollutants at the outlet. The charge revision may be done at regular intervals as appropriate.

(3) Waste Load Allocation for Industrial Discharge for Ganga River at Kanpur

As per guidelines of Water Quality Assessment Authority constituted by MoEF in 2001, there is a provision for allocation of waste load in discharging water bodies. A special study should be commissioned for Ganga from up-stream Kanpur to downstream Varanasi and for Gomati at Lucknow. This study should be based upon TMDL method and shall provide total pollutant discharge load for above-mentioned areas.

(4) Designation of Kanpur as Polluted Water Quality Hot Spot

Under the act, WQAA can review the status of quality of National water resources (both surface and ground water) and identify "Hot Spots" for taking necessary action for improvement of water quality. Water bodies in Kanpur can be designated as one of the Hot spots and need to be under constant review of monitoring by WQAA.

(5) Forced Benchmarking of Industrial Water Consumption

A database for National benchmarks for water consumption should be created and promoted with collaboration of Ministry of Commerce and Heavy Industries, Ministry of environment and Forest as well as Ministry of Science and Technology.

(6) Transfer of Technology for Cleaner Production

The technology transfer should be facilitated to these tanneries at various levels by industrial associations like Federation of Chamber of Commerce and Industries (FICCI) in collaboration with appropriate government ministries. Government for smaller industries should subsidize the technology transfer.

(7) Demonstration Projects

A demonstration project based upon earlier mentioned Aluminium tanning process in association with Tata International Unit, Dewas, Madhya Pradesh, could be set up in any selected tanneries for the purpose of technology transfer, demonstration, performance and Operation and Maintenance data, etc.

(8) Development of Economic Instruments

Industries at Jajmau showing willingness to adopt cleaner technology should be provided with tax holiday, duty free import of technology, other related benefits and incentives.

(9) Adoption of ISO 14000 Environmental Management Systems

The adoption of ISO 14000 Environmental Management System should be formulated for tanneries in Jajmau. This shall include adoption of environmental policy and an internal environmental monitoring system by tanneries.

The main objective of this monitoring system shall increase information dissemination on company environmental issues to general public. The benefits of these shall be:

i. This shall increase their public credibility of their products as well as affirm their commitment for environmental conservation.
ii. In terms of market capitalization, they shall be benefited with increased product acceptance and market shares with normal public, which is more environmental conscious these days.
iii. Other benefits shall include their reduced public liability in terms of pollution hazards and less exposure to penalization.

(10) BOD Based Water Quality Trading

This recommendation, based upon U.S. Environmental Protection Agency (EPA) plan calls on states and local municipalities to develop programs that allow polluters to exchange pollution reduction credits in an effort to clean up impaired rivers, streams and lakes throughout the country. The Water Quality Trading Program allows one pollution source to meet its regulatory obligations by using pollutant reductions created by another source that has lower pollution control costs. The water quality standards stay the same, but the efficiency of implementing the standards is increased and cost decreased.

Such a system should be studied in India with reference for Kanpur. The industrial houses, creating pollution in Ganga with their discharges, should be encouraged to explore trading of effluents by investing in non-point pollution control. These measures could be providing low cost treatment plants and sanitation in rural areas.

(11) Environmental Performance Rating of Tanneries

An environmental performance rating of tanneries similar to Green Rating Project (GRP) of paper and pulp industry by Center for Science and Environment (CSE) should be commissioned. The major criteria for this rating should be:

i. Criteria for raw material source and processing
ii. Criteria for production plant level environmental performance
iii. Criteria for product use performance
iv. Criteria for product disposal performance
v. Criteria for corporate environmental policy and management systems
vi. Criteria for community and regulatory perception and compliance status

CHAPTER 5

WATER QUALITY MONITORING PLAN

CHAPTER 5 WATER QUALITY MONITORING PLAN

5.1 RELEVANT ORGANIZATION FOR WATER QUALITY MONITORING

Surface water quality must periodically be observed to manage the river water quality in compliance with the standards and, for this purpose, the existing monitoring network system must be reconsidered due to the various problems. The improvement of the existing monitoring plan is strongly recommended, as discussed below.

5.1.1 Organization

There are several existing water quality monitoring system in the Study Area at present, many of them are conducted by CPCB, SPCBs and PCCs, which cover the entire Ganga Basin and periodically monitor the surface water quality of rivers/lakes/drainages and ground water.
Relevant organizational charts are given in Figure B.8.1 (CPCB) and Figure B.8.2 (UPPCB), respectively. Monitoring Division of Pollution Assessment wing shown in chart is responsible for water quality monitoring. The laboratories of State Pollution Control Board of respective States in the Ganga are associated with this programme of CPCB.

5.1.2 Laboratories and Staff Involved in Water Quality Monitoring

(1) Laboratories

The laboratories involved in water quality monitoring are listed in Appendix B, Table B.8.1. There are three CPCB’s laboratories (Delhi, Kanpur and Kolkata) and 44 SPCB’s laboratories in the entire Ganga Basin.

(2) Staff

The staff working in each laboratory is tabulated in Table 5.1. Among them, totally 26 persons are affiliated with CPCB Central Laboratory. There is acute shortage of manpower for field monitoring as well as for laboratory analysis due to restriction on recruitment. In the laboratories of regional offices of SPCBs, same laboratory personnel are engaged in the activities of water quality and air quality monitoring. Hence they are overloaded with work.

(3) Responsibility of CPCB and SPCB

The programme of CPCB/SPCB on National Water Monitoring Programme including the coverage of Ganga Basin is indicated in Appendix B, Table B.8.2

Table 5.1 Staff Line-up for each Laboratory

Name	Laboratory Work (Person)	Sampling Work (Person)	Remarks
CPCB Central Laboratory	18	8	
U.P. SPCB Kanpur Laboratory	34	22	
Bihar SPCB Laboratory	14	9	
West Bengal SPCB Laboratory	20	15	
Rajasthan SPCB Laboratory	8	6	
Madhya Pradesh SPCB Laboratory	36	20	
Haryana SPCB Laboratory	6	5	
Himachal Pradesh SPCB Laboratory	5	3	

(4) Mandate of Pollution Control Boards for Water Quality Monitoring

The Pollution Control Boards in India are responsible for restoring and maintaining the wholesomeness of aquatic resources. To ensure that the water quality is being maintained or restored at desired level, it is important that the pollution control boards regularly monitor the water quality. The water quality monitoring is performed with following main objectives in mind:

(i) Rational planning of pollution control strategies and their prioritization;
(ii) To assess nature and extent of pollution control needed in different water bodies or their part;
(iii) To evaluate effectiveness of pollution control measures already in existence;
(iv) To evaluate water quality trend over a period of time;
(v) To assess assimilative capacity of a water body thereby reducing cost on pollution control;
(vi) To understand the environmental fate of different pollutants; and
(vii) To assess the fitness of water for different uses.

On the other hand, the State Pollution Control Boards are taking action on the polluted water bodies identified by Central Pollution Control Board to contain the level of pollution and restoration of water quality in accordance with the desired water quality class for different stretches of water bodies. National River Conservation Directorate is preparing plan for restoration of water quality based on the identified polluted water bodies in the country.

5.2 EXISTING MONITORING SYSTEM

5.2.1 Water Quality Monitoring Network

The Central Pollution Control Board has been monitoring water quality of national aquatic resources in collaboration with concerned State Pollution Control Boards at 784 stations. Of these, 710 stations are under MINARS (Monitoring of Indian National Aquatic Resources), 50 stations are under GEMS (Global Environmental Monitoring Systems) and 24 stations are under YAP (Yamuna Action Plan) programmes. Out of 784 stations, 514 stations are on rivers, 181 stations are on ground water, 57 stations are on lakes and 32 stations are on canals, creeks, drains, ponds and tanks.

5.2.2 Sampling Locations for Water Quality Monitoring

Many sampling locations are scattered in the entire Ganga Basin for evaluation of current situation of river water quality. In order to grasp the exact condition of river water pollution, sampling points must represent the average location of the river flow condition. Moreover, lowest sampling points of each major tributary are very important for estimation of pollution load. In Ganga Basin, totally 117 sampling locations are stationed as shown in Table 5.2. According to the existing sampling locations, in the case of several major tributaries such as Sind, Ken, Tons, Karmanasa, Kiul and Jalangi, monitoring locations have not been stationed at the lowest point. Hence, information for pollution load generated from major tributaries is not available, and to be estimated at these major tributaries.

Table 5.2 Distributions of Water Quality Monitoring Stations in Ganga Basin

River (main stream), Tributaries and Sub-Tributaries	Total Stations
Ganga Main (34) **Tributaries**-Barakar (1), Betwa (3), Chambal (7), Damodar (5), Gandak (1), Saryu-Ghaghra (3), Gomti (5), Hindon (3), Kali (West) (2), Kali Nadi (2), Khan (1), Kshipra (3), Mandakini (Madhya Pradesh) (1), Parvati (2), Ramganga (1), Rapti (1), Rihand (2), Rupanarayan (1), Sai (1), Sone (5), Tons (Madhya Pradesh) (2), Yamuna (23), Sind (1), Johila (1), Sankh (1), Gohad (1), Kolar (1), Sai (1), Churni (1), Tons (Himachal Pradesh) (1)	117

5.2.3 Water Quality Sampling Covered by each Organization

Monitoring under YAP is being carried by CPCB, Head Office and Monitoring at Daman Diu and Dadar Nagar Haveli is being carried out by Zonal Office Vadodara, CPCB. For remaining stations the monitoring is being carried out by respective SPCBs/PCCs. The monitoring of water quality at 254 stations is being done on monthly basis, 178 stations on half yearly basis, 349 stations on quarterly basis and at 3 stations on yearly basis.

5.2.4 Parameters to be monitored

CPCB is analysing 29 parameters consisting of physio-chemical and bacteriological parameters for ambient water samples. Besides this, 9 trace metals and 7 pesticides are analyzed in site-specific samples. Biomonitoring is also carried out in specific locations. However, CPCB mainly monitors organic substances rather than toxic ones because current river pollution is caused by the domestic pollution and non-point organic pollution load. Needless to say, toxic substances must be periodically observed due to the necessity of the confirmation on the health damage of the residents.

5.3 CURRENT ISSUES ENCOUNTERED IN WATER QUALITY MONITORING

CPCB published the report " Rationalization and Optimization of Water Quality Monitoring Network" in July 2001, in which it has been cited that many problems were encountered during execution of the water quality monitoring programme and that have impeded the wholesome monitoring activities. CPCB covers wide area of whole country for monitoring network, therefore, it is still difficult to conduct the sufficient water quality monitoring due to the technical and administrative problems. To achieve the satisfactory water quality monitoring, it is worth considering some of these persisting problems as mentioned below:

5.3.1 Technical Problems

Main technical problems are related to items that can be enumerated as sampling station, sampling procedures, preservation of samples, transportation of samples from sampling sites to the laboratory and availability of competent persons involved in sampling, analysis and reporting of data. Some of them are described below:

(i) Location of sampling site is very important to represent the water quality, however, the right samples have not been taken in some monitoring stations. If wrong sample is collected, the precision and accuracy used in analysis becomes futile. These problems have occurred due to the following reasons: difficulty of approach to exact sampling sites, unrepresentative samples, lack of availability of boat for sampling and no flow in the river during dry season.

(ii) After sampling, adequate storage and preservation of samples is essential for accurate water quality analysis. However, many times these necessary measures have been neglected during water quality sampling.

(iii) Many times field parameters like temperature and dissolved oxygen are not analyzed in the field.

(iv) Data reporting has been often hindered by various problems such as lack of information regarding climatic and hydraulic condition, deficiency of all the parameters to be analyzed, abnormal results, inadequate procedure of data format and data transmission, etc.

Among the above items, optimum location of sampling site is considered to be one of the important issues for carrying out the sound water quality monitoring. Moreover, new additional monitoring stations should be set up in the entire Ganga Basin considering the necessity of monitoring. Because in some major tributaries the river water quality have not been monitored up to now.

5.3.2 Administrative Problems

A number of administrative problems such as scarcity of fund and trained manpower, facilities, delayed in repairing of instrument and low priority towards monitoring have been noticed. The major administrative problems are listed below:

(i) Many times due to inadequate fund, the monitoring is not being done as per schedule.
(ii) Due to the pressure of some other urgent work, water quality monitoring does not get priority.
(iii) In some cases untrained manpower is engaged in water quality monitoring.
(iv) Delayed transmission of data is reported in many cases.
(v) Delayed response of CPCB's communication is many cases.
(vi) Attendance of repair work due to administrative problems is also reported.
(vii) Freedom to the monitoring staff according to work schedule is not observed in many cases.
(viii) To assess the fitness of water for different uses.

5.3.3 Scarcity of Capacity of Optimum Monitoring Activities

(1) Laboratory and Field Equipment

The existing laboratories involved in water quality monitoring are widely positioned in the entire Ganga Basin and hence not functioning adequately for water quality monitoring activities. Moreover, laboratory and field equipment for monitoring is not enough at present due to the larger coverage area and high number of samples.

(2) Staff Training

The staff training is indispensable for water quality analysis using improved technology and should be periodically executed. However, it is reported that satisfactory staff training has not been conducted so far due to the various reasons. To obtain accurate analytical results, laboratory staff must be periodically trained.

5.3.4 Analytical Quality Control (AQC)

In order to conduct accurate monitoring, analytical quality control is necessary for all the laboratory staff. CPCB and SPCBs/PCCs are doing AQC activities as follows:

(i) There should be a habit of preparing control charts and conducting regular intra-lab AQC in all the laboratories in water quality monitoring programme.
(ii) It is necessary for CPCB to visit the SPCBs/PCCs laboratories more frequently and interact with Laboratory officials for discussing their problems.
(iii) Internal communication and joint monitoring of CPCB and SPCBs/PCCs is required for

the improvement of AQC.

(iv) Concerned laboratories are doing various precision control such as control by duplicate analysis, using pooled and certified reference material, use of control chart and Inter-laboratory analytical quality control.

In addition to the existing AQC, crosscheck analysis between CPCB and SPCBs/PCCs using the standard solution is recommendable for the improvement of the accuracy control.

5.4 MONITORING PROGRAMME FOR GANGA RIVER BY UPPCB

5.4.1 Existing Laboratory Conditions in 4 Cities

The water quality monitoring programmes at all four places are commonly consisting of monitoring of rivers as well as lakes and other surface water bodies. CPCB sponsors the Ganga water quality-monitoring programme and the entire funding is provided to SPCB for these monitoring activities. The normal steam structure of these state laboratories consists of:

Assistant Scientific Officer

Monitoring Assistant	Laboratory Assistant	Scientific Assistant
3	1	3

The above-mentioned staff is deployed at Kanpur, Allahabad and Varanasi, but at Lucknow the total staff dedicated to water quality monitoring is 25. The above mentioned team is normally deployed being responsible for following tasks:

(i) Collection of Sample.
(ii) Transportation of sample
(iii) Storage and Analysis of Samples
(iv) Reporting of Results

The results are then sent to CPCB as per the prescribed format by the CPCB.

The comparative analysis of laboratories shows that the laboratory set up is comparatively better at Lucknow, as it is the headquarter of the UPPCB. The laboratories at STP were not functioning well with respect to their capacity of functioning, manpower as well as data reliability. The Jal Nigam department, who were not competent at par with the UPPCB laboratories and CPCB, managed these laboratories. The list of common analytical equipments is satisfactory with respect to inorganic analysis and general laboratory equipments in UPPCB laboratories, but it was not up to the mark in case of STP and CETP laboratories. The water quality monitoring equipments are also adequate as far as the lists of equipments specifically used for water quality monitoring as shown in Appendix B, Table B.8.4.

5.4.2 Issues Related To Laboratory Performance Improvement

The laboratory conditions are good in all the four cities, but still they need some improvement with respect to the following issues:

(1) Monitoring up gradation at STP and CETP laboratories: Under the current monitoring system, U.P. Jal Nigam has been managing the water quality monitoring performance of STP and CETP. As per our visit and analysis, the Jal Nigam has not adequate expertise and laboratory infrastructure for ensuring smooth reporting and smooth analysis of water quality monitoring programme. The Parameters reported by the Jal Nigam authorities were not including the microbiological parameters like E.Coli, which is very important parameter and cannot be neglected during routine monitoring reporting. The laboratories at STP needs up gradation in terms of manpower as well as analytical capability. It is strongly recommended that the monitoring work of STP and CETP should be either handed over to CPCB regional office or it should be entrusted to UPPCB. A separate team led by private entrepreneur could also be established and funds could be provided for up gradation of laboratories as these were lacking necessary equipment.

(2) Staff Capability Improvement**:** The staff present at the state pollution control board laboratories are not updated on issues related to water quality monitoring aspects from the samples collection to its result dissemination. They are engaged in variety of works other than water quality monitoring. No scientific journals or manuals are present in the laboratories, which prescribe the guidelines with respect to sampling point allocations, inference of non point sources with sampling results and other issues. The general perception of water quality monitoring staff is that the water sampling work is among the routine jobs they are engaged in. This aspect of water quality monitoring activity should be improved with increased interest generation among staff engaged in water quality monitoring equipments.

(3) Analytical Capability**:** The comparative list of combined instrument inventory shows that the list of instruments seems adequate with normal water monitoring exercise, but it is not supportive to exhaustive sampling exercises, which includes more sensitive parameters like organic residues and other carcinogenic parameters, which are of more environmental concern, in addition to routine parameters monitored. This analytical capability should be compensated with adequate and sophisticated instrumentation provision with respect to organic compound analysis.

(4) Capacity building measures: Normally the capacity building measures are not adequate with respect to training component for the staff engaged in the water quality monitoring exercise. The training programmes are organized with resource mobilization and support from CPCB. This needs additional support and resource persons should be taken up from other educational and research institutes like Indian Institute of Technology, Kanpur, Banaras Hindu University, Varanasi, National Environmental Engineering Research Institute (NEERI) and other related institutions. The frequency of these training programmes should be maximized after every 4 months. The staff at ground level instead of policy level should be encouraged to attend these training programmes. This shall increase the competency level of staff engaged in analysis and supervision of work of water quality monitoring.

(5) Easy Administration**:** The set up of state pollution control board laboratories was analyzed and it was found that the administration set up was not transparent and flexible with respect to various decision making exercises ranging from purchase of equipment to sanctioning of grant for equipments. This led to the delay in operation and maintenance of various advance instruments. The present bidding based purchase policy encouraged the purchase of low cost equipments, which leads to drop in quality of analytical results as well as data produced. The purchase of various advanced analytical instruments should be made with respect to quality

assurance of instrument provider. These instruments should be purchased from a specified equipment provider, which could be referred by the leading research and development institutions.

(6) Availability of Sufficient Funds**:** The present monitoring programme for river Ganga has suffered a lot due to paucity of funds. Though the water quality monitoring has been a Central Pollution Control Board funded scheme, the monitoring scheme at normal riverine system was very smooth as compared to the monitoring of Sewerage Treatment Plant (STP) as well as Combined Effluent Treatment plant (CETP). Comparative analysis of the system present for water quality monitoring at UPPCB and at STP facilities shows clear disfunctioning and irregularities during the visit. Funds were not managed at the STP monitoring sites as the monitoring agency U.P. Jal Nigam were not quiet capable of monitoring adequately with respect to the water quality objectives and standards. Additional Funds should be provided exclusively by CPCB to UPPCB for the monitoring of STP and CETP functioning.

(7) Wide Publicity of water Quality Monitoring Date: Normally the common public conceives the publicity of water quality monitoring data as irrational thing. This vital information, which is crucial with respect to finalizing different environmental projects and other important decisions, related to future planning of water resources. The information should be widely disseminated among various public groups through regular publishing in various newspapers as well as other public target groups. The water quality monitoring data should not be conceived as scientific information and it should be conveyed to public as important as other environmental issues.

CHAPTER 6

RECOMMENDATIONS

CHAPTER 6 RECOMMENDATIONS

6.1 NECESSITY OF VARIOUS STUDIES FOR BASIN-WIDE INVENTORY

A basin-wide inventory survey covering the entire Ganga Basin has been conducted in this Study. Despite the lack of data and the difficulty in quantitative evaluation of findings to draw an accurate conclusion, certain patterns of river pollution had become apparent. However, the coverage area is extremely extensive and various sorts of information such as hydrology, geography, sanitary engineering, demography and so on, are still inadequate for a more accurate evaluation of river pollution. Hence, additional studies are necessary to upgrade the basin-wide inventory, as mentioned below:

(1) Study on the unit pollution load from non-point pollution sources such as bacterial contamination, in-stream use of river water like cattle-wading, bathing, open–defecation, washing of clothes and so on.

(2) Study on the mechanism of natural purification in river courses.

(3) Study on the transport of domestic pollution load from major cities to primary tributaries or Ganga/Yamuna mainstream.

(4) Study on intensive bacterial pollution distribution in the entire Ganga Basin.

6.2 IMPROVEMENT OF RIVER WATER QUALITY

For water quality improvement, some extent of sewerage development is necessary in the four cities under this Study. The necessity of sewerage development is recommended on the basis of the results of the simulation study. To attain improvement of future river water quality conditions, sewerage development is indispensable, as mentioned below:

(1) The future river water conditions are very much related with the sewerage development of the entire Ganga Basin. The river water quality at each upstream monitoring station of the four cities will be greatly influenced by pollution load transported from upstream areas in the future. Master plan studies such as future planning for the sewerage development of upper areas of the four cities have been conducted and priority cities requiring pollution load reduction have been selected. To improve the river water quality in the four cities, sewerage development at the selected cities is deemed to be indispensable.

(2) In case of the entire basin model, the future condition of industrial pollution load generation is assumed to be the same in with- and without-project scenario. If the necessary countermeasures were taken on the industrial effluent treatment, the future river water quality would improve more significantly than predicted. Hence, for the acceleration in improvement of river water quality, it is essential to reduce not only the domestic pollution load but also the industrial pollution load. It might be effective to impose a more stringent legal control on grossly polluted industries such as the regulation of TMDL (Total Maximum Daily Loading) enforced in Japan.

(3) The issues on bacterial contamination caused by untreated domestic wastewater and non-point pollution sources are very serious throughout the entire Ganga Basin. Hence, it is recommendable to consider both the sewerage improvement and the measures for mitigation of non-point bacterial pollution sources.

6.3 IMPROVEMENT OF EXISTING INDUSTRIAL POLLUTION MANAGEMENT

6.3.1 Technical Recommendations

The technical recommendations for improvement of the existing industrial pollution management in Kanpur are as follows:

(a) Improvement of Leather Technology
(i) Aluminium Tanning Technology
(ii) Recycling of Chromium in Tanning Operations
(b) Reduction of Chromium Induced Toxic to CETP
(c) Establishment of CRP Plant
(d) Effective and Monitoring of CRP Functioning in Tanneries
(e) Restricted Use of CETP Effluent
(f) Capacity Building of staff and CETP Performance Monitoring System

6.3.2 Legislative Recommendations

The legislative recommendations for improvement of the existing industrial pollution management in Kanpur are as follows:

(a) Need for Special Water Discharge Permits
(b) Comparison of Effluent Water Quality Standards for Sewerage System in Japan and India
(c) Temporal Discharge Standards
(d) Proper Technology Based on Legislative Specifications
(e) Proper Cognisance of Legislative Guidelines
(f) Need for Mass Based on Standards
(g) Increased Frequency of Industrial Discharge Monitoring

6.3.3 Organizational Recommendations

The organizational recommendations for improvement of the existing industrial pollution management in Kanpur are as follows:

(a) Stake Holder Participated Management of CETP
(b) Pollutant Concentration and Incentive Based on Cost Sharing of CETP
(c) Waste Land Allocation for Industrial Discharge for Ganga River at Kanpur
(d Designation of Kanpur as Polluted Water Quality Hot Spot
(e) Forced Benchmarking of Industrial Water Consumption
(f) Transfer of Technology for Cleaner Production
(g) Demonstration Projects
(h) Development of Economic Instruments
(j) Adoption of ISO 14000 Environmental Management Systems
(k) BOD Based Water Quality Trading
(l) Environmental Performance Rating of Tanneries

6.4 OPTIMIZATION OF MONITORING NETWORK

6.4.1 Capacity Building for Optimum Monitoring

(1) Laboratory Equipment and Operation and Management

In the case of CPCB's Central Laboratory in Delhi as well as the UPPCB's laboratories in the four cities, many of the existing equipment for water quality analysis are out-of-date and inefficient. Besides, trained manpower for field and in-house work for water quality monitoring is inadequate. Hence, to monitor water quality under the recommended basis, laboratory equipment and training must be improved. Moreover, to maintain the full functioning of laboratory equipment, operation and maintenance (O&M) financing is required. This has been a very common situation among all state laboratories; namely, the lack of funds for operation and maintenance of costly and advanced equipment provided for the water quality monitoring supportive programme. This can be tackled by initiating an exercise at UPPCB with some provision of funds for O&M of laboratory equipment for some time. This should ensure the full operational mode of equipment.

(2) Adequate Capacity Building Measures

Normally, the capacity building measures are not adequate with respect to the training of staff engaged in the water quality monitoring work. Although the training programmes are organized with resource mobilization and support from CPCB, these need additional support and resource persons should be taken from other educational institutions like the India Institute of Technology, Kanpur; the Banaras Hindu University, Varanasi; the National Environmental Engineering Research Institute (NEERI), and other related institutions. The frequency of these training programmes should be maximized at every 4 months. The staff at ground level instead of the policy level should be encouraged to attend these training programmes, because these programmes will increase the competency of staff engaged in analysis and supervision of water quality monitoring work.

6.4.2 Reconsideration of Monitoring Stations

(1) Basic Concept for the Selection of Monitoring Station

Sampling locations should be selected based on the following aspects; (i) the location of water use; (ii) the location where polluted water is sufficiently diluted after it has been discharged to the river and the location upstream of such wastewater discharge, (iii) the location where water from a tributary is sufficiently mixed with water of the mainstream and before the confluence point of the mainstream and tributary; (iv) the location adjacent to the intake points of public water and irrigation uses; and (v) any other location to be established as required. Reference monitoring stations for quality standards should always be included in the water quality monitoring survey.

(2) Reconsideration of Current Sampling Sites

An exact sampling location would lead to the collection of representative monitoring data, so that some of the currently existing sampling points in the Ganga Basin have to be replaced or newly stationed at the correct sites, as explained below:

(a) Upstream sampling points in the case of each city should be located at the front area where the river water quality is not affected by any point pollution load inflow.

(b) Fecal coliform number significantly exceeds the water quality standards (Desirable: 500 MPN/100ml and Maximum Permissible: 2,500 MPN) at the existing upstream monitoring stations, especially, Kanpur, Varanasi and Lucknow. The reasons of bacterial contamination at the upstream monitoring stations might be as follows: (i) contamination due to non-point pollution sources such as cattle-wallowing, open-defecation and so on along the river banks; and (ii) inappropriate location of upstream monitoring station which does not take into account the inflow of point pollution load. Hence, additional monitoring stations should be established at appropriate distances further upstream from the existing ones in each city.

(c) Downstream sampling points in each city should be located at the central area where all the pollution loads are well mixed and representative samples of river water quality can be taken.

(d) The sampling points where river flow is stagnant should be avoided, and replaced to well flowing points.

(e) The most convenient way is to take samples on a bridge, because the foothold is stable and well-mixed points can be found easily.

(f) The edge of a river is not suitable to take samples because river water quality is not generally well mixed at such locations. If no bridge is located in the vicinity of a sampling point, using a boat is recommendable.

The upstream and downstream monitoring stations in four cities are located in the city area and their locations seem to be already affected by point pollution inflow. Hence, the sampling points located at the upstream and downstream of Kanpur, Allahabad, Varanasi and Lucknow need to be minutely investigated to adjust them to the correct sites.

(3) Selection of Additional Monitoring Stations

Along with the existing monitoring stations, Tables B.8.7 and B.8.8 also enumerate the additional monitoring stations recommended for the Ganga Basin. Necessary monitoring stations have been selected based on the following considerations:

(a) There are few major tributaries where monitoring locations were not included in the currently existing water quality monitoring plan. Therefore, the additional monitoring stations should be selected at the lowest point and confluence points of tributaries, taking into account the pollution load balance in the entire Ganga Basin.

(b) In the case of Varanasi City, there are two different monitoring stations at the downstream area in Ganga Main River. However, one new additional monitoring station should be set up at a lower point because the existing monitoring stations are much affected by Varuna River and river water is not well mixed. Further, there has not been any water quality monitoring in Varuna River, hence it is necessary to set up a new monitoring station at the lowest point of Varuna River.

6.4.3 Additional Monitoring Programme

(1) Intensive Dry Weather Feedback Monitoring

A one-month intensive dry weather monitoring system is recommended in addition to the current monitoring. Measurement of discharge and concentration is recommended to be carried out every 2^{nd} to the 7^{th} day (depending upon the manpower) in the upstream part of the river and the main lateral inflow of the river system. This monitoring is to be combined with water level/discharge and concentration measurements within the river system. Detailed recommendation to where in the system the monitoring has to be carried out can be done based upon available resources and for which focus should be paid. In the second half of the monitoring period, it is recommended that diurnal variation in flow and water quality parameters should be monitored. Monitoring should be done through continuous sampling and data collection every 2 to 6 hours over a period of 2 to 3 days. This should help in studying the fluctuation of pollutants in the river and the river’s capacity to assimilate pollution load in the critical period of low flow and thus create the basis for improvement of the predictable water quality.

(2) Season Transition Monitoring

Season transition monitoring should be performed and the existing monitoring should be supplemented by more intensive monitoring activities using conventional methods and covering 1 to 6 months depending upon available resources and a well-defined objective. Also recommended is supplementary monitoring over a dry season transition to the monsoon season. Data of such monitoring would be highly relevant and can give valuable information about the effect of first flushes through the catchment and drainage system.

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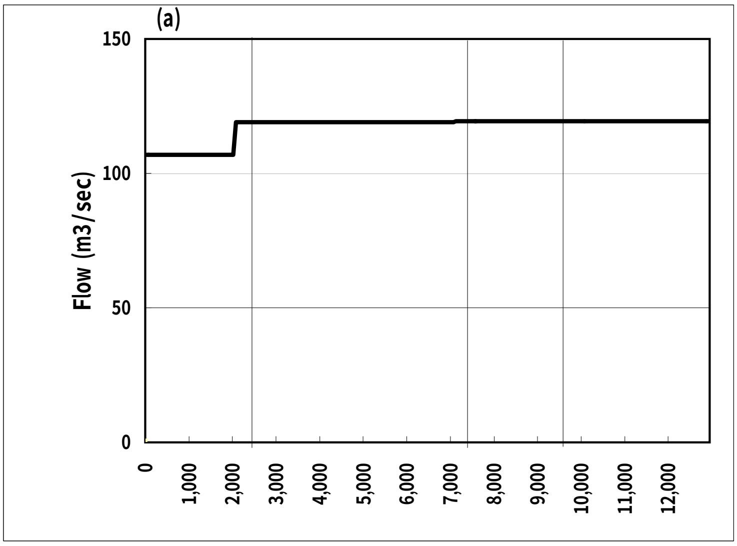
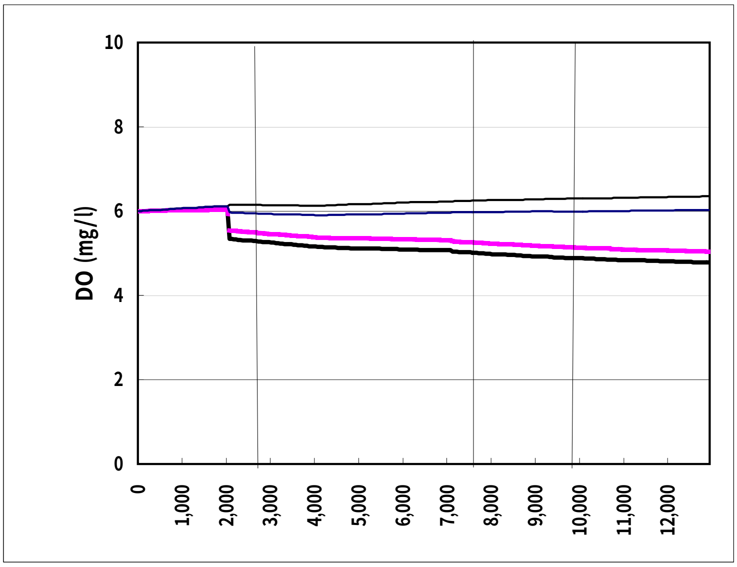
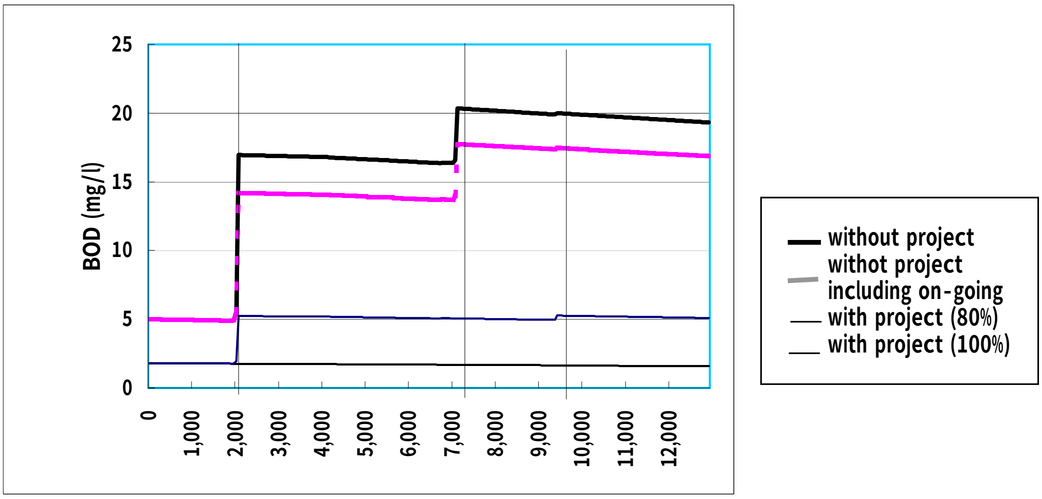
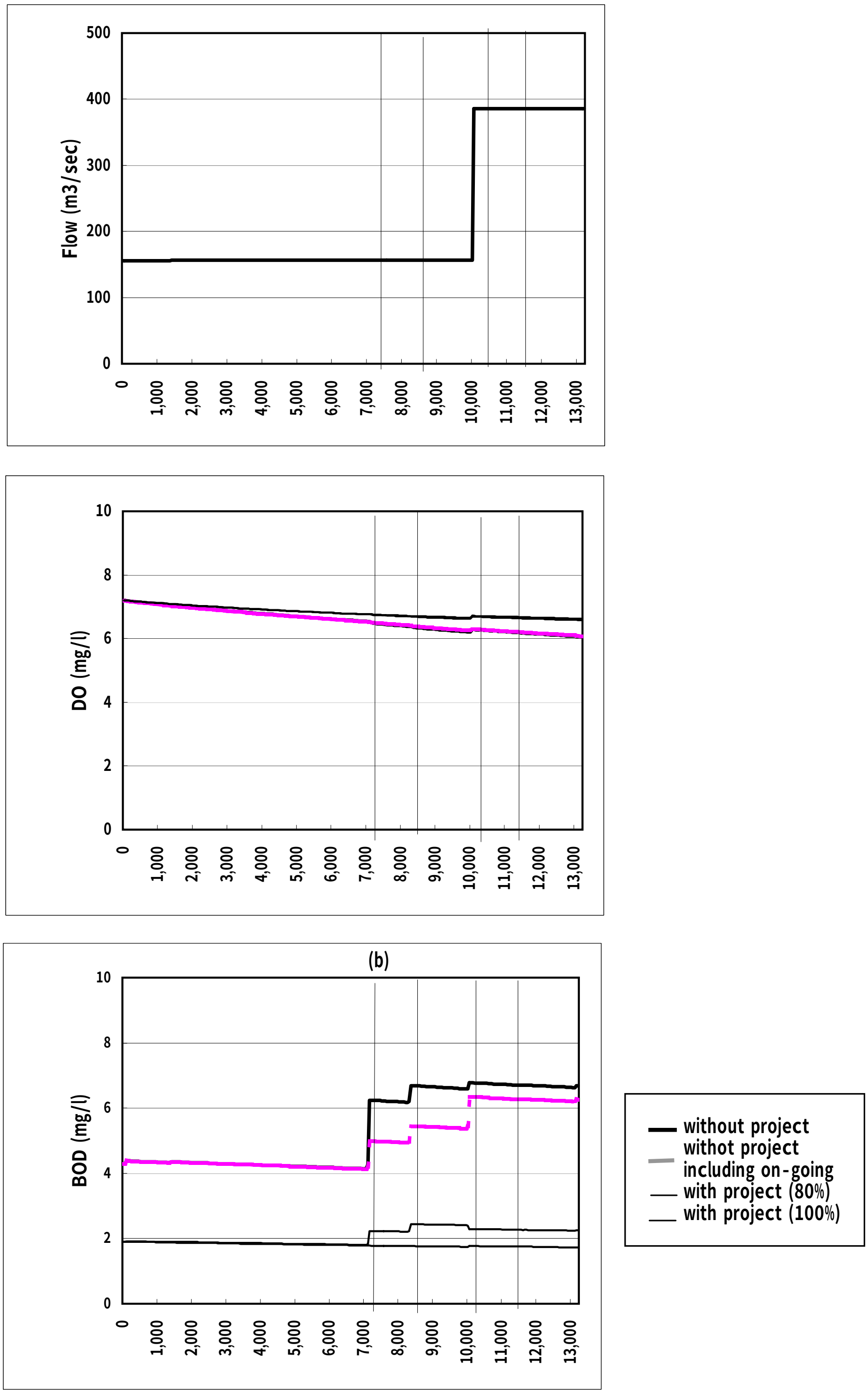
Annexure







Annex 3.1 Calculated Water Quality of Ganga River at Kanpur (in 2030)



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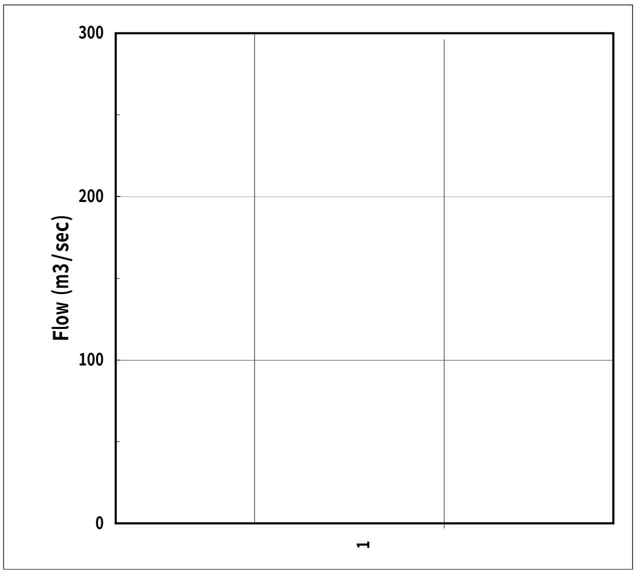
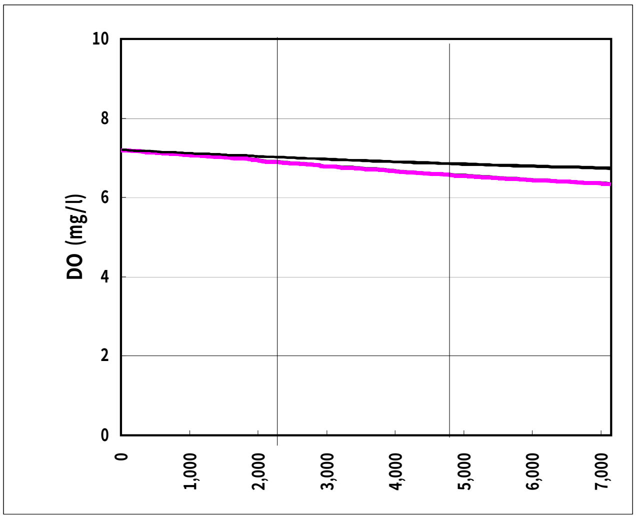
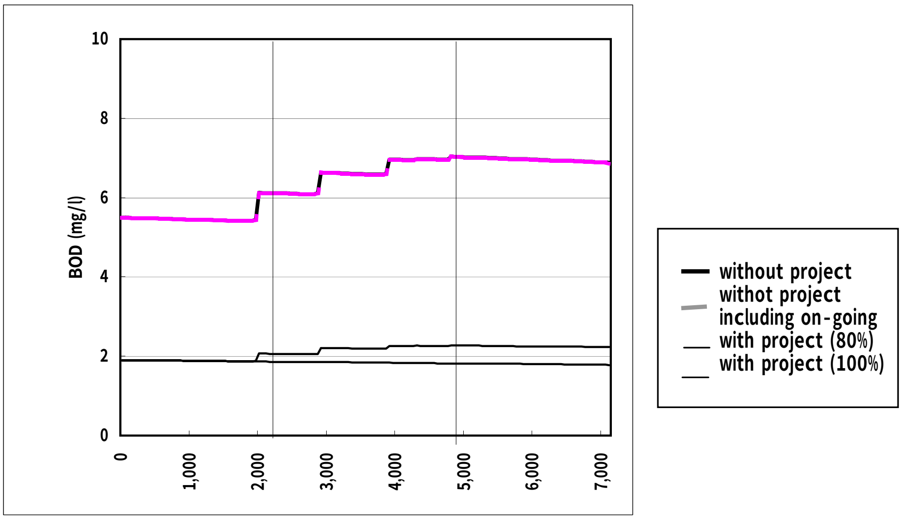
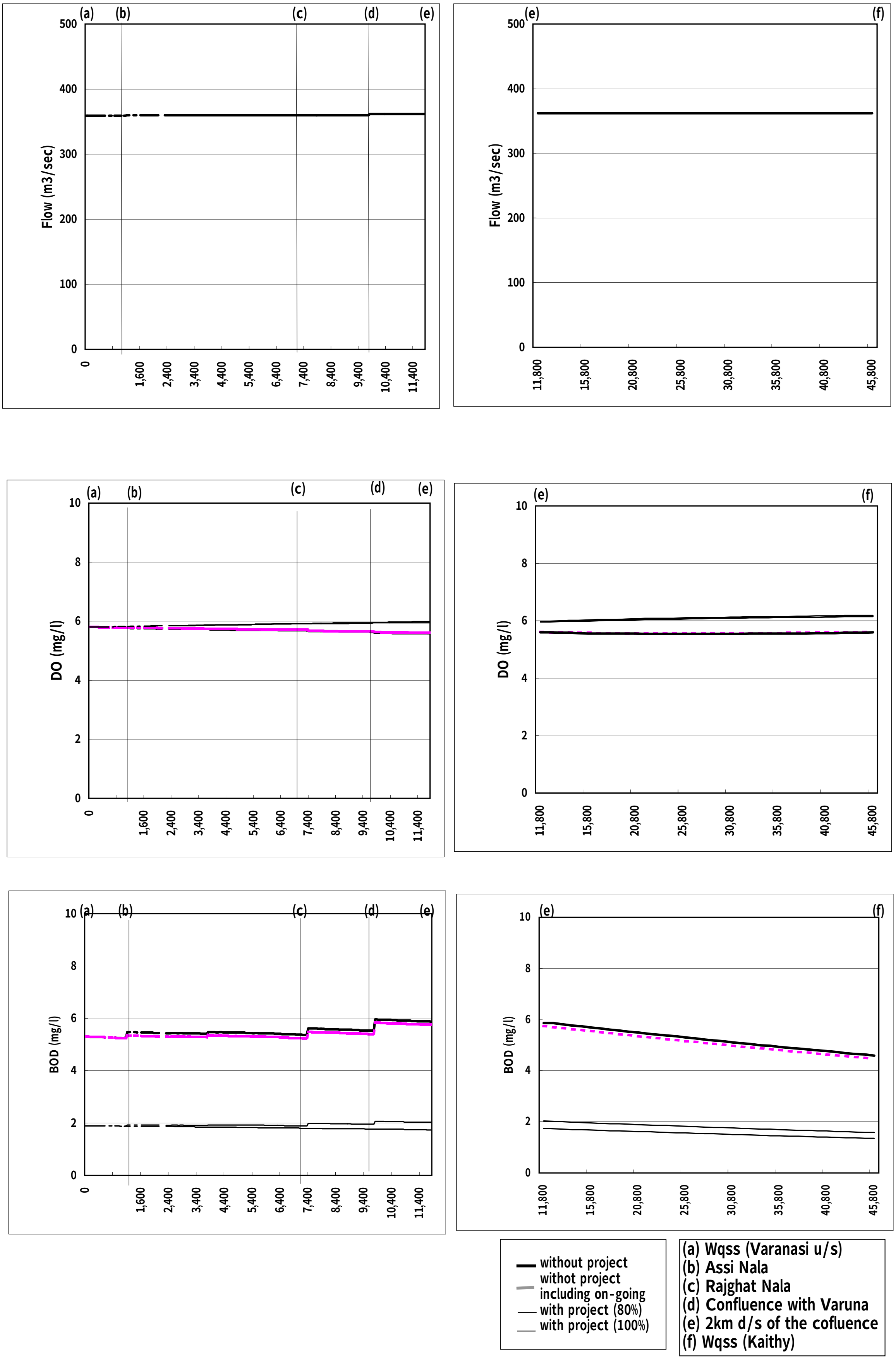


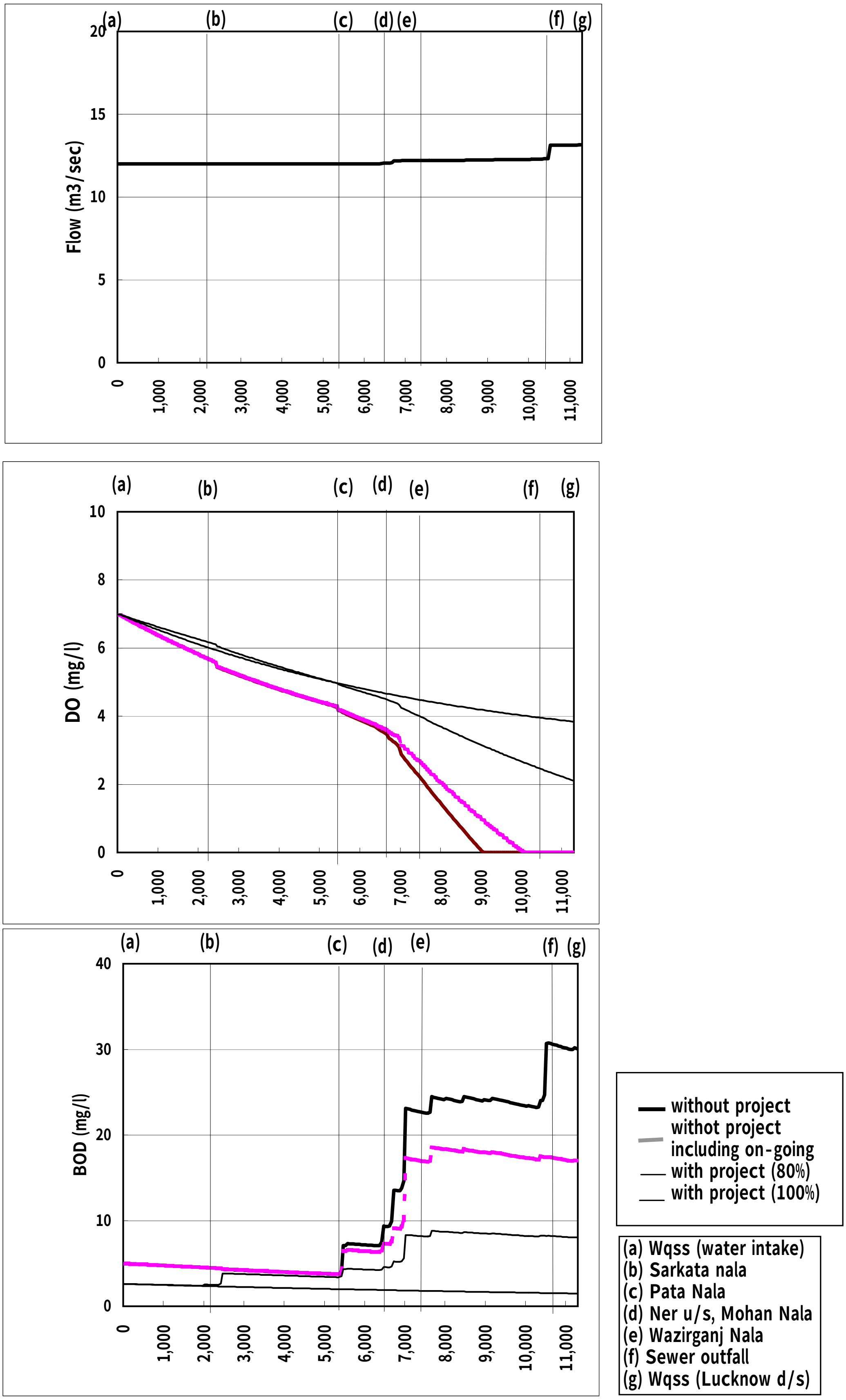




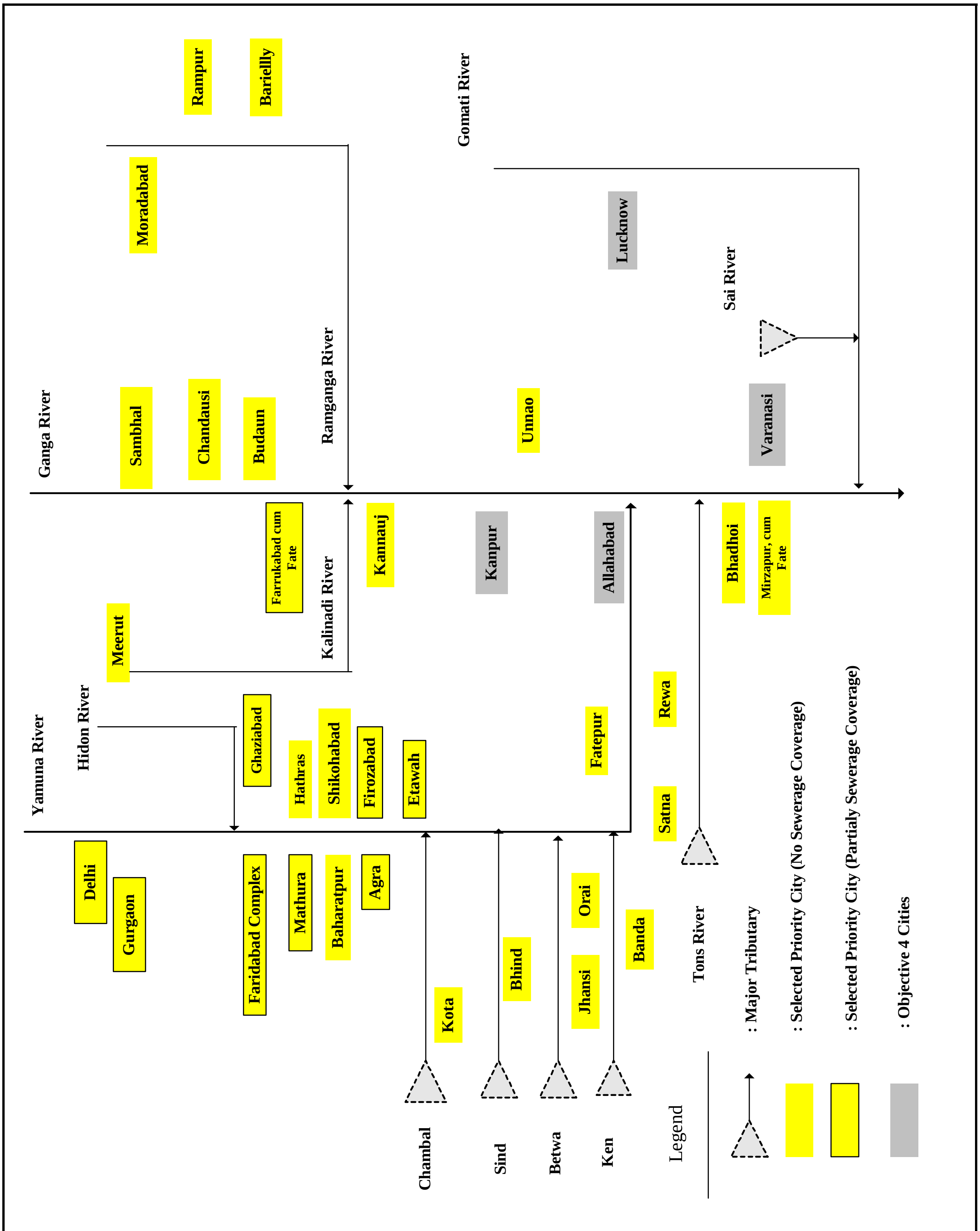
Annex 3.3 Calculated Water Quality of Yamuna River at Allahabad (in 2030)



Annex 3.4 Calculated Water Quality of Ganga River at Varanasi (in 2030)



Annex 3.5 Calculated Water Quality of Gomti River at Lucknow (in 2030)



THE STUDY ON WATER QUALITY MANAGEMENT PLAN FOR GANGA RIVER IN THE REPUBLIC OF INDIA	Annex 3.11 Selected Priority Cities Located in Upstream Area of the 4 Cities
JAPAN INTERNATIONAL COOPERATION AGENCY	

Appendix A

APPENDIX A

WATER QUALITY STANDARDS, WATER QUALITY MONITORING & INDUSTRIAL POLLUTION LOAD

Table of Contents
List of Tables
List of Figures

TABLE OF CONTENTS

CHAPTER 1 POLLUTION INDUSTRIAL PROFILE IN GANGA BASIN A-1

1.1 OBJECTIVE A-1
1.2 APPROACH TO SYSTEM ANALYSIS A-1
1.3 ASSESSMENT OF WASTEWATER LOADS A-5
1.4 PROJECTION OF INDUSTRIAL POLLUTION LOADS A-16

CHAPTER 2 WATER QUALITY STANDARDS A-32

2.1 REVISED CRITERIA FOR CLASSIFICATION OF INLAND WATER QUALITY PROPOSED BY CPCB A-32
2.2 DISCHARGE CRITERIA FOR WASTEWATERS USED FOR IRRIGATION A-33

CHAPTER 3 FIELD WORK CARRIED OUT FOR RIVER WATER QUALITY SAMPLING IN THE FOUR TOWN A-35

3.1 VARANASI A-35
3.1.1 River A-35
3.1.2 STP A-35
3.1.3 Nala and Sewers A-35
3.1.4 Pollution Load Survey A-36
3.2 ALLAHABAD A-36
3.2.1 River A-36
3.2.2 STP A-36
3.2.3 Nala and Sewers A-37
3.2.4 Pollution Load Survey A-37
3.3 LUCKNOW A-37
3.3.1 River A-37

3.3.2 STP A-38
3.3.3 Nala and Sewers A-38
3.3.4 Pollution Load Survey A-38
3.4 KANPUR A-39
3.4.1 River A-39
3.4.2 STP A-39
3.4.3 Nala and Sewers A-39
3.4.4 Pollution Load Survey A-39

LIST OF TABLES

Table 1.1 Wastewater Generation Standards A-6
Table 1.2 Clusters of SSIs in the Ganga basin..... A-7
Table 1.3 Assessment of effluent loads from cluster of carpet industries at Bhadoi..... A-7
Table 1.4 Status of the cluster of tannery industries and CETP at Jajmau, Kanpur A-10
Table 1.5 Status of the cluster of tanneries and CETP at Kolkata A-11
Table 1.6 Statistics of meat production in the study area A-12
Table 1.7 Unit wastewater loads for discharges from slaughterhouse..... A-12
Table 1.8 Category-wise industrial BOD load distribution in Ganga basin A-13
Table 1.9 Predominant categories of water polluting industries..... A-14
Table 1.10 Top ten districts in terms of BOD load generation in the Ganga basin A-15
Table 1.11 State-wise industrial BOD load distribution in Ganga basin A-15
Table 1.12 Basin/ Sub-basin wise industrial BOD load distribution in the study area..... A-16
Table 2.1 Simple Parameters A-32
Table 2.2 Regular Monitoring Parameters..... A-32
Table 2.3 Special parameters (Only in cases of need/apprehensions) A-33
Table 2.4 Suggested Values for Major Inorganic Constituents in Water Applied to the Land A-33
Table 2.5 Suggested Limits for Salinity in Irrigation Waters A-34
Table 2.6 Maximum Permissible Concentration of Toxic Elements in Irrigation Waters A-34

LIST OF FIGURES

Figure 1.1 Data Input Form..... A-3
Figure 1.2 Database Output Form A-4
Figure 1.3 SCHEMATIC OF EFFLUENT DISCHAGES FROM JAJMAU TANNERY COMPLEX A-9
Figure 1.4 Industrial Growth Rates During Last Eight Years..... A-17

APPENDIX A WATER QUALITY STANDARDS, WATER QUALITY MONITORING & INDUSTRIAL POLLUTION LOAD

CHAPTER 1 POLLUTION INDUSTRIAL PROFILE IN GANGA BASIN

A database on industrial profile in the Ganga basin has been developed for the grossly water polluting industries. The following paragraphs provide a description of the objectives, approach, methodology and the structure of the database.

1.1 OBJECTIVE

The objective of this component of the 'Study on Ganga Water Quality Management Plan' is to generate values of BOD loads across the basin from industrial sources of water pollution, which could in turn be utilized for simulation of water quality in the river Ganga. The output of this component will serve as an input to the water quality modeling component, which is one of the major activities of the ongoing study.

1.2 APPROACH TO SYSTEM ANALYSIS

There are 11 states of north, central and east India, which comprise the entire drainage basin of the Ganga river. The major centres of industrial production in the basin are of relevance for this component. While background information on grossly polluting industries is available from respective State Pollution Control Boards, and the Central Pollution Control Board, there is no single source which provides updated and recent information on quantum of industrial wastewater discharges specific to Ganga river basin and its numerous sub-basins. Moreover, when the information is to be utilized for mathematical modeling, it would require additional parameters, e.g., corresponding distances of the industrial sources of pollution from the main Ganga channel, the tributaries conveying the waste loads to the main channel, etc.

In this context, a fresh data-base has been developed for assessment of industrial waste loads on district and sub-basin level. A combination of approaches have been adopted for individual and cluster of industrial sources of water pollution which are summarized below:

- Industries have been grouped district-wise.
- The geographical unit of a district is then considered as a representative area source and the major industrial discharges emanating in that particular district are assigned to that area source.
- The district/area source is then assigned to a particular sub-basin/tributary and the corresponding channel distance from district headquarter is considered as the length over which the wastewater will travel before joining the main channel of Ganga river. In case of a district falling in more than one sub-basin, the dominant sub-basin has been taken as the representative.
- Profile of large and medium industries have been developed based on available information and an estimate of corresponding BOD loads has been arrived at.
- In case of small scale industries for which unit specific data are not available, cluster approach has been adopted for estimation of BOD loads.

Basis of selection of industries

The major premise on which the industry categories have been identified is that Ganga basin is agriculturally fertile and therefore agriculture/forest input based industries are predominant. Primarily these comprise sugar, distillery, pulp and paper, vegetable oil, food processing, rice mills etc. Secondary agriculture based industries are dairy, tanneries and abattoirs (all livestock based).

Pulp and paper industry has been further categorized according to the raw material used i.e., wood pulp, agricultural waste, waste paper etc. This has been done to account for disparities in the wastewater loads.

Abattoir / slaughterhouses are equally strong sources of water pollution. They are under the administrative control of respective municipal corporations and are typically not registered as an industry under public sector. However, in this study these quasi-industrial sources of water pollution have also been considered in view of their high pollution generation potential.

While the fertilizer and thermal power plants are included in the list, their contribution to organic pollution load has been considered as negligible. This is essentially because of the specific manufacturing processes whereby the effluents do not carry high concentration of organic matter. However, in future, if the user so desires, the corresponding BOD values can be included in the database.

In addition to the above, other categories that have been considered are pharmaceutical, chemical, textile dyeing, integrated iron and steel plants, petroleum refineries, coal washries, engineering, etc.

Jute retting industry in West Bengal has been excluded because it is limited to small water bodies/village ponds and the wastewater does not reach the river system.

Structure of the data base

The available data has been compiled in Microsoft Access. The database contains information on industry location (city/village, district and state), status, products, industry category, installed capacity, river sub-basin, quantity of generated effluent, existence of ETP, and eventual BOD load discharged into the river system. The input form is shown in Figure 1. Detailed description on the format for data input is provided in Annexure - I. A typical output of the database (complete tabular form) is shown in Figure 2.

Over 230 districts across 11 states have been covered and major water polluting industries have been included in the database. There are in all 1289 entries in the data base, out of which 30 correspond to clusters of SSIs while the rest 1259 correspond to independent large and medium sized grossly polluting industries.

As a result of compilation of industrial profile on the above lines, it would be possible to generate reports providing BOD distribution along the following lines:

- Industry category wise loads
- District wise loads
- State wise loads, and
- River sub basin wise loads

Sources of information

Two of the starting documents for development of the database were the CPCB publications entitled "Status of the industrial pollution control programme along the river Ganga (Phase-I) Probes/64/1994-95 and "An inventory of major polluting industries in the Ganga basin and their pollution control status" Probes/65/1995-96 respectively. This list was further augmented and updated with the help of the information available from association of industries e.g., sugar, distillery, pulp and paper, vanaspati and vegetable oils, fertilizer, etc.

Figure 1.1 **Details of Industries**

Name	Indian Oil Corporation		
City	Howrah	Sub Basin	
Distric	24 Parganas (N)	Distance from Ganga (km	0
State	WB	Effluent generation (kld)	24
Status	Operational	ETP	☑
Product(s)	Oil terminal	BOD (kg/d)	2
Industrial Categor	Oil Terminal		
Capacity (tpd)			

Add Delete

Name	SH 24 Parganas (N)		
City		Sub Basin	
District	24 Parganas (N)	Distance from Ganga (km	
State	WB	Effluent generation (kld)	2787
Status	Operational	ETP	☐
Product(s)	Meat	BOD (kg/d)	14900
Industrial Categor	Abattoir		

Figure 1.2 : **Typical output of the industrial database prepared for Ganaga water quality management plan study**

Name	City	District	State	Status	Product(s)	Ind Cat	Capacity	Sub Basin	Dist (km)	Effl (kld)	ETP	BOD (kg/d)
Premier Board industries	Nunihai	Agra	UP	Operational	Paper	Pulp & P		Upper Yamu	209	0	☑	0
Biological Evans Ltd.	Bodla	Agra	UP	Operational	Drugs	Pharma		Upper Yamu	209	70	☐	28
SH Agra		Agra	UP	Operational	Meat	Abattoir		Upper Yamu	209	102	☐	511
Imperial Leather Ind. Ltd.	Agra	Agra	UP	Closed	Leather	Tannery		Upper Yamu	209	5	☐	0
Park Leather Ind. Ltd.	Agra	Agra	UP	Operational	Leather	Tannery		Upper Yamu	209	250	☑	42
Slaughterhouse - Agra Nagar Ni	Agra	Agra	UP	Operational	Meat	Abattoir	500	Upper Yamu	209	0	☐	0
Wasan & Co.	Bodala	Agra	UP	Operational	Leather	Tannery		Upper Yamu	209	200	☑	29
Prem Board Industry	Nunihai	Agra	UP	Operational	Paper	Pulp & P	1980	Upper Yamu	209	396	☑	12
Cluster of petha units	Agra	Agra	UP	Operational	Sweet meat	SSI-Foo		Upper Yamu	209		☐	5931
Mahajan Tanners Ltd.	Bodla Road	Agra	UP	Operational	Leather	Tannery		Upper Yamu	209	200	☑	6
Taj Tennery Pvt. Ltd.	Tajganj	Agra	UP	Closed	Leather	Tannery		Upper Yamu	209	0	☐	0
SH Ajmer		Ajmer	Raj	Operational	Meat	Abattoir		Chambal		44	☐	131
Hardwaganj Thermal Project	Kasimpur	Aligarh	UP	Operational	Power	TPP		Kalinadi	241	0	☑	0
Heinz India Pvt. Ltd.	Aligarh	Aligarh	UP	Operational	Milk Products	Dairy		Kalinadi	241	1000	☑	26
Hind Agro Indust.Ltd.	Aligarh	Aligarh	UP	Operational	Meat	Abattoir		Kalinadi	241	35	☑	26
Kisan Sahkari Chini Mills Ltd.	Satha	Aligarh	UP	Operational	Sugar	Sugar	1250	Kalinadi	241	500	☑	15
SH Aligarh		Aligarh	UP	Operational	Meat	Abattoir		Kalinadi	241	56	☐	283
Prag Van. Prods.	Aligarh	Aligarh	UP	Closed	Vanaspati Gh	Veg oil	15000	Kalinadi	241	0	☐	0
Rama Dairy Products Ltd.	Aligarh	Aligarh	UP	Operational	Milk Products	Dairy		Kalinadi	241	600	☑	18
Peeal Papers Pvt. Ltd.	Aligarh	Aligarh	UP	Closed	Paper	Pulp & P	2400	Kalinadi	241	3	☐	0
Darshan Vanaspati Ltd.	Vill. Bhikam	Aligarh	UP	Operational	Vanaspati Gh	Veg oil	30000	Kalinadi	241	240	☐	24
IFFCO	Phulpur	Allahabad	UP	Operational	Fertilizer	Fertiliser		Middle Gang	3	0	☑	0
ITI	Naini	Allahabad	UP	Operational		Engg.		Middle Gang	3	0	☑	0
TSL	Naini	Allahabad	UP	Operational		Engg.		Middle Gang	3		☐	0
Jeep Industrial Syndicate (Batter	Allahabad	Allahabad	UP	Operational		Engg.		Middle Gang	3	0	☑	0
Jeep Industrial Syndicate (Torch)	Allahabad	Allahabad	UP	Operational		Engg.		Middle Gang	3	0	☑	0

Additional relevant information was received from NRCD, Central Pollution Control Board, Ministry of Agriculture, etc. NRCD provided an updated list of grossly polluting industries including the BOD loads, receiving water bodies etc. This has been selectively cross- checked with communication and / or visits to the State Pollution Control Boards of UP, Uttaranchal, Bihar and West Bengal. Field visits were made to Kanpur and Varanasi to get first hand information. The visit to Kanpur and interaction with UPJN and IIT Kanpur enabled a realistic assessment of the pollution loads discharged by the tannery complex and the CETP at Jajmau.

1.3 ASSESSMENT OF WASTEWATER LOADS

Wherever the discharge data is not available, estimates of wastewater loads is based on the installed production capacity and corresponding unit wastewater loads recommended by the Central Pollution Control Board for various categories of industries. These unit loads are presented in Table 1. Installed capacity values have been taken from published industry association directories. Ideally the current production figures should be taken, however these are not available as widely and uniformly as the capacity figures. Production has been assumed to be equal to the installed capacity, however, this is subjective since there could be significant variations in the level of capacity utilization among the industries.

However, in several cases it has been possible to get the flow and BOD data as recorded by the respective State Pollution Control Boards. The Industrial Pollution Monitoring Cell of the NRCD has provided this data. This data has been appropriately incorporated in the database and it has also served as a cross check for the long list of polluting industries developed as a base frame for the study. Before incorporating these values, they have also been cross checked with respect to the generally expected pattern along the lines of unit loads / typical BOD concentrations.

In most cases the treated effluent BOD concentration has been considered to be 30 mg/l (i.e., industry complying unless otherwise stated). However, in case of highly polluting industries e.g., distillery, agro-residue (small without chemical recovery) and waste paper based pulp and paper industries, the treated effluent BOD concentrations have been taken as 1000 mg/l, 300 mg/ and 30 mg/l, respectively. In case of a combination of pulp and agricultural residue or pulp and waste paper, an average of discharge and BOD values has been adopted. Similarly, in case of tanneries, the BOD of raw effluent is considered as 2500 mg/l.

There are certain distilleries in UP which have achieved zero discharge status as a result of adopting composting of press mud along with the treated effluent. For such distilleries the BOD load is taken as zero.

Table 1.1 Wastewater Generation Standards

Sr. No.	Industry	Quantity	Remarks
1	Integrated iron and steel	16 m^3/t of finished steel	
2	Sugar	0.4 m^3/t of cane crushed	Applied extensively
3	Large pulp and paper		
	Pulp and paper	174 m^3/t of paper produced	--do--
	Viscose staple fibre	150 m^3/t of product	
	Viscose filament Yarn	500 m^3/t of product	
4	Small pulp and paper		
	Agro residue based	150 m^3/t of paper produced	--do--
	Waste paper based	50 m^3/t of paper produced	--do--
5	Distilleries	12 m^3/KL of alcohol produced	--do--
7	Dairy	3 m^3/KL of milk	
6	Tanneries	28 m^3/t of raw hide	
	Vegetable oil and vanaspati industry		
	Solvent extraction	2 m^3/t of product	Effluent BOD @ 100 mg/l
	Refinery/ Vanaspati	2 m^3/t of product	--do--
	Integrated unit of extraction and refinery / vanaspati	4 m^3/t of product	--do--

(Source: Pollution control acts, rules and notifications issued there under, CPCB, September 2001, pp. 372)

There are around 110 units in vegetable oil and vanaspati (margarine) category in the entire basin. They are involved in a combination of solvent extraction, refining, hydrogenation (vanaspati) or having integrated facilities. Out of these, about 41 units have closed down for various reasons. Among the operational units, wastewater flow and BOD loads are available for only 10 units. Estimates of wastewater loads for the remaining operational units have been made based on the discharge norms recommended by CPCB. Norm for BOD loads is taken as 100 mg/l of BOD3 at 27° C. The available information on installed capacity has been utilized along with the above unit wastewater volume loads. To be on a conservative side, the unit wastewater load of 2 cum/ton of installed capacity has been adopted.

Approach for assessment of wastewater loads from SSI sector

Information on wastewater loads from individual small scale industries is not available with state or central boards. These industries are not registered with state pollution control boards and neither do they have representative industry or trade associations, which collate and provide the relevant information.

However, there are number of clusters of SSIs which are characterized by uniformity of their production processes and varying degrees of wastewater loads. A list of 30 such clusters identified in the study area is provided in Table 2.

Table 1.2 Clusters of SSIs in the Ganga basin

Sr. No.	Cluster	Location (s)	No. of clusters
1	Cluster of carpet SSIs	Bhadoi (UP)	1
2	Cluster of chemical units	Delhi, Noida, Faridabad, Ghaziabad, and Kolkata	5
3	Cluster of cotton furnish and blanket units	Meerut	1
4	Cluster of food processing units	Delhi, Muzaffarpur	2
5	Cluster of tanneries	Kanpur (Jajmau), Kolkata, Mokemaghat (Bihar)	3
6	Cluster of petha (sweet meat) units	Agra	1
7	Cluster of pharmaceutical units	Indore	1
8	Cluster of plywood units	Yamunanagar	1
9	Cluster of paper units	Solan	1
10	Cluster of textile dyeing and printing	Varanasi, Baddi Barotiwala, Jaipur, Panipat, Sanganer, Mathura	6
11	Cluster of rice milling units	Karnal, Kurukshetra, Saharanpur, Muzaffarnagar, Dehradun, Pilibhit, Nainital, Rudrapur	8
	Total no. of clusters		30

(Source : "Restructuring and modernization of small medium enterprise clusters in India", UNIDO, 1997).

In order to assess wastewater loads from SSI sector, a cluster of SSIs has been taken as an area source representing cumulative production capacity. For instance in Panipat there are 469 textile dyeing industries with total wastewater generation of 8 mld and average BOD value of 400 mg/l. The strength of the source is considered as 3200 kg/d of BOD. (Ref. Pre-feasibility study on YAP-II, TEC, Paramount, MOEF, August 2000). In case of cluster of dyeing and printing units in Mathura, the combined strength of all SSI units is represented by the flow of the CETP.

In case of the cluster of carpet industries in Bhadoi (UP) an estimation of wastewater loads is rather difficult because of completely unstructured production processes. However, a rough estimate has been made as per the criteria given in Table 3.

Table 1.3 Assessment of effluent loads from cluster of carpet industries at Bhadoi

Particulars	Quantity	Remarks
Total number of small, medium and large carpet industries in Bhadoi	60	
Number of industries currently operational	20	High level of industrial sickness
Average capacity of yarn dyeing	700 kg/d	
Average discharge of effluent/kg of yarn	200 l/kg	From composite activity of dyeing, washing, bleaching etc.
Total effluent generation	200 x 700 x 20 = 2.8 mld	
Average BOD of a mixture of treated and untreated effluent	150 mg/l	ETPs are claimed to be discharging effluent of BOD 30 mg/l. However there could be variations due to power cuts etc.
Total BOD load from the cluster of carpet industries	420 kg/d	

(Source : Based on discussions with UPSPCB Regional Office, Varanasi)

<u>Wastewater loads from tanneries in Kanpur</u>

There are around 354 tanneries of varying capacity in the Jajmau area of Kanpur. Their aggregate production capacity is between 14,000 to 17,000 hides/d or over 320 tonnes/d. Among these, there are some units which are involved in dry operations e.g., hide splitting, leather processing etc. However, the entire Jajmau area is typically characterized by tanning activity and can be considered as a cluster/ area source.

The aggregate wastewater flow estimated to be between 9 – 12 mld is routed through a separate collection and conveyance system to a common effluent treatment plant. The CETP process comprises UASB and is designed for treating a combined stream of 9 mld of tannery effluent and 27 mld of domestic wastewater (total 36 mld). In the existing scheme, as a precondition the individual tanneries are supposed to carry out pre-treatment for chrome recovery (CRU). However, only some of the large and medium units have installed CRUs.

Due to inherent limitations in the scheme and severe power cuts in the Jajmau area, the total effluent does not get complete treatment. Power cuts are reported to be typically for over 10 hr/d. Under such conditions, part of the effluent does not reach the CETP and that part which reaches there also receives only partial treatment. A part of the effluent is discharged through the existing surface drains directly into the river. The BOD of raw effluent is estimated to be 2500 mg/l while that of the combined treated effluent from the CETP is reported to be around 150 mg/l. The analysis report for one sample of treated effluent collected by UP Jal Nigam gives a value of 192 mg/l.

As per the monitoring study carried out by IIT Kanpur, the entire Jajmau tannery complex, with its numerous surface drains and the CETP can be represented by an area source stretched over 3-5 km along the right bank of the Ganga river. As per this study the strength of the area source exclusively representing the tanneries is estimated to be 12.82 mld carrying organic load of 9.39 tonnes of BOD/d. This comprises of 9.52 mld reaching the CETP and 3.3 mld which is draining directly into the river. A schematic of various channels of effluent discharges from this area source is shown in Figure 3 and a summary of the calculations is presented in Table 4. The calculated values as per this procedure have been used in the database and for the mathematical modeling of the river water quality.

Cluster of tanneries in Kolkata

As in case of Kanpur, there are over 500 tanneries located in the outskirts of Kolkata. Currently these units are closed and being relocated to a new leather complex. In absence of an elaborate field assessment, the pollution load from this cluster of tanneries in West Bengal has been assessed based on unit loads recommended by CPCB. Table 5 illustrates the estimation of loads for the pre and post CETP scenarios.

Other clusters

Information on location of other clusters has been taken from a UNIDO study entitled "Restructuring and modernization of small medium enterprise clusters in India", 1997. This study covered a range of clusters totaling over 360 locations across the country with the objective of improving the industrial productivity and profitability. Out of these, about 25 clusters have been identified for the purpose of this study that have significant potential for river water pollution e.g., food processing, rice milling, textile dyeing and printing, chemicals etc. The database of this study provides information on nature of clusters and the aggregate investment. However, this does not provide wastewater loads discharged from these clusters. An approximate correlation has been made between the two parameters for sari printing cluster of Varanasi, tannery clusters of Kanpur and Kolkata and textile dyeing cluster of Panipat. In absence of any other reliable information, the average BOD discharge per unit of investment (approximately 10.8 kg/Rs. 10 million of invested capital) in these four clusters has been adopted for estimating wastewater loads from other clusters. However, it must be pointed out that there are uncertainties in this procedure on account of different nature of the clusters, associated processes, geographical locations etc. and the estimates are subjective.

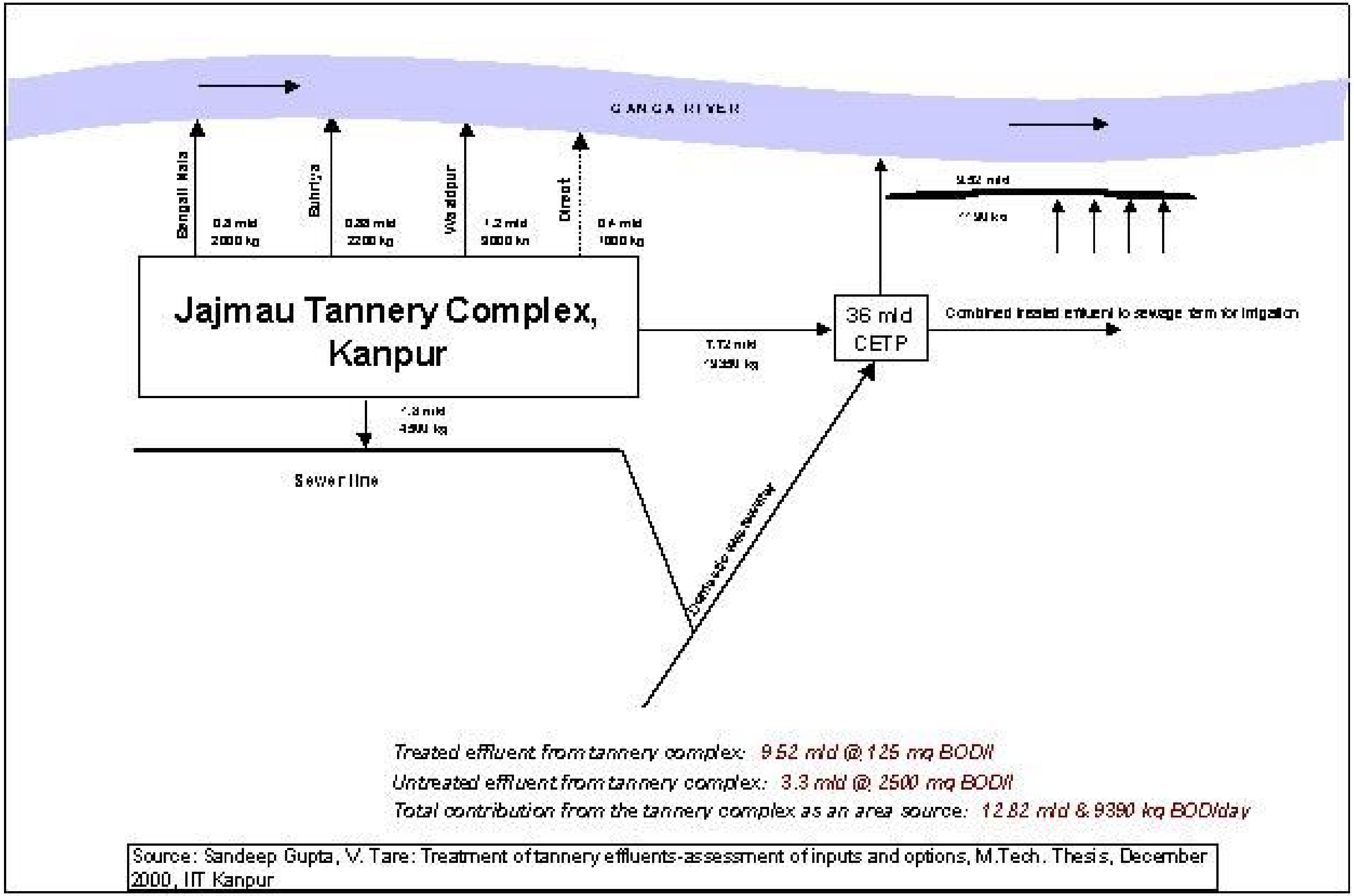


Figure 1.3 SCHEMATIC OF EFFLUENT DISCHAGES FROM JAJMAU TANNERY COMPLEX

Table 1.4 Status of the cluster of tannery industries and CETP at Jajmau, Kanpur

Particulars	Number/quantity	Remarks
Number of tanneries		
Large	6	Capacity > 300 hides/d
Medium	10	Capacity between 200- 300 hides/d
Small	338	Capacity < 200 hides/d. Typically the capacity is between 50-100 hides/d
Total units	354	
Chrome tanning units		
Large and medium	116	47 units have installed chrome recovery units (CRU), at 12 units CRUs are under construction. In remaining 57 units UPSPCB is at various stages of enforcement.
Small	94	A common CRU of 70 kld is proposed. However 38 units have opted out of the scheme and they have been ordered to close down.
Sub-total	210	
Vegetable tanning units	49	
Split leather units	52	Typically dry processing. Effluent discharge is minimal
Closed units	41	
Aggregate processing capacity in the cluster	14000 – 17000 hides/d ~ 320 t/d	Hides of all sizes and various animals
Aggregate effluent quantity generated in the cluster	9-13 mld	CETP was designed for 9 mld in 1986. Over the years the number of tanneries and effluent volumes have gone up.
Effluent reaching the CETP	9.52 mld	Power cuts leading to intermittent operations of the pumping stations (Monitoring study carried out by IIT Kanpur)
Effluent flowing in to nalas/ bypassing pumping stations / draining directly into Ganga	3.3 mld	Untreated effluent overflowing into the river during power cuts. Raw effluent BOD @ 2500 mg/l.
BOD concentration of the combined stream of treated effluent for the 36 mld CETP	125-192 mg/l	As per the effluent quality monitoring carried by UPJN and IIT Kanpur
Strength of an equivalent area source representing the cluster of tanneries in Jajmau	Flow : 12.82 mld & BOD: 9.39 t/d	3.3 mld @ 2500 mg/l ; 9.52 mld @ 125 mg/l

Sources:
1. CPCB : Environmental management in selected industrial sectors – status and needs, pp. 175 – 176, Feb. 2003.
2. Sandeep Gupta, V. Tare : Treatment of tannery effluents - assessment of impacts and options. Masters thesis, December 2000, IIT Kanpur.

Table 1.5 Status of the cluster of tanneries and CETP at Kolkata

Particulars	**Scenario before CETP**	**Scenario after CETP**
No. of units	538 (temporarily closed as per the Supreme Court orders)	534 (proposed to be set up in the leather complex)
Location	Tangra, Topsia, Tiljala	Leather Complex, Bantala
Installed production capacity	800 t/d	NA (may be higher than current)
Capacity utilization	320 t/d	NA (--do--)
Effluent generation	20.5 mld	NA (may be lower due to improved technology)
ETP	None	Proposed CETP capacity 2 x 5 mld
Strength of an equivalent area source representing the cluster of tanneries in Kolkata	Flow : 20.5 mld & BOD : 20.5 x 2500 BOD: 51.25 t/d (assuming raw BOD @ 2500 mg/l)	10 mld x 30 mg/l = 300 kg/d 10.5 mld x 2500 mg/l = 26250 kg/d BOD = 26.55 t/d

Source : CPCB, Environmental management in selected industrial sectors – status and needs, pp 179-180, February 2003.

Assessment of the Wastewater Loads from Slaughterhouses across the Basin

A large number of municipal slaughterhouses are located in the Ganga basin. These are not registered as industries but considered as one of the essential services and therefore operated by the urban local bodies. However, their pollution loads are significant and therefore this sector has been considered as a quasi-industrial source of water pollution for the purpose of the water quality modeling study. Private sector abattoirs are not included in this analysis.

Primarily the municipal slaughterhouses are used for cattle, buffalos, sheep and goat to meet the domestic demand of meat. Pig and poultry are normally not slaughtered here. Most of these unit are over 50 years old and do not have modern facilities for slaughtering, processing, wastewater treatment, solid waste management etc. Depending on the number of large animals or small animals slaughtered per day, typically they fall in the medium (< 200 large animals or 300-1000 goats and sheep/day) and small capacity (< 50 bovines and upto 300 goats and sheep/day) categories. There are very few large capacity (> 200 large animals or > 1000 goats and sheep/day) municipal slaughterhouses e.g., Delhi, Agra etc. State-wise distribution of slaughterhouses and the meat production for the year 200-2001 is provided in Table 6.

Table 1.6 Statistics of meat production in the study area

State	No. of slaughterhouses[a]	Meat production[b] (tones/annum)				Remarks
		Cattle	Buffalos	Sheep	Goat	
Uttaranchal	NA					Data NA
Himachal	36			955	2249	
Haryana	43			3404	3336	
Delhi	1		28063	4626[3]		Idgah SH
Rajasthan	380		7610	10890	24550	
MP	261	438	987	113	1403	
UP	407		126821	4686	27522	
Bihar	47	23449	30869	1680	49345	
Jharkhand	NA					Data NA
WB	11	114313[c]	10124[d]	16181	133334	

Notes:

(a) Source: Comprehensive industry document on slaughterhouse, meat and seafood processing, CPCB, 1992.
(b) Source: Statistics Div., Department of Animal Husbandry and Dairy, Ministry of Agriculture, Govt. of India, New Delhi, 2003.
(c) Combined figures for sheep and goat meat.
(d) The data represent production from registered slaughterhouses. Out of total beef production in the state, this constitutes only 15%.

The following aspects have been considered while making an assessment of the wastewater loads from slaughterhouses:

1. Almost all slaughterhouses are located in urban centers and are catering to the urban population. Based on this premise, geographical distribution of wastewater loads has been worked out in proportion to the urban population in the districts.
2. Average dressing yield in terms of the original live weight are 35% for cattle and 40% for sheep and goat.
3. Unit wastewater and BOD loads have been taken from the CPCB reference cited above. There are significant disparities in unit loads among the large, medium and small capacity slaughterhouses. To account for this factor, 10% capacity is assigned to large category, 30% to medium category and 60% to the small category. The unit load values adopted for calculation of wastewater discharges and BOD are as given in Table 7.

Table 1.7 Unit wastewater loads for discharges from slaughterhouse

Category of SH	Size of SH	Specific wastewater generation (m^3/TLWK)	Specific BOD load (kg/TLWK)
Bovine	Large	1.4	5.5
	Medium	0.5	5.0
	Small	1.0	6.6
Sheep & Goat	All	3.0	8.1

Source : Comprehensive industry document on slaughterhouse, meat and seafood processing, CPCB, 1992.

4. Discharge loads for representative area sources have been arrived at district level.
5. Poultry and pigs are not slaughtered in the municipal slaughterhouses. Moreover, since there are no separate facilities for this, the slaughtering takes place in an unorganized manner on individual or small scale level.

Calculations for various states are presented in Annexure - II. The BOD loads for districts that fall in the Ganga basin have been included in the database.

Findings of the Industrial Pollution Assessment Study

As of now there are 1289 entries in the database representing over 234 districts in the Ganga basin. Out of these, 30 entries represent clusters of SSIs. Thus the database corresponds to 1259 individual industrial units and a large number of SSIs across the basin. Out of the former, currently 194 units are either temporarily or permanently closed due to a host of reasons and for which the effluent and BOD loads are taken as zero.

From the remaining 1065 operational individual units and 30 clusters of SSIs, the quantum of BOD load entering into the river system is estimated to be 308,838 kg/d. With respect to the estimated BOD load from the domestic sector (approximately 2,225 tonnes/day for 2001 population) this comes out to be around 14 %.

Category-wise distribution

Category-wise industrial BOD load distribution is shown in Table 9. The categories are arranged in descending order of their contribution. The top four categories, i.e., abattoir, distillery, pulp and paper and tannery together account for 77% of the total BOD load. Number of entries for these and two other prominent categories is shown in Table 10. While the abattoir category is estimated to be the largest contributor of BOD loads, its nature as a non-point source has to be kept in mind while developing a strategy to address the problem of wastewater discharges from this sector.

In case of distilleries while all units are understood to have installed ETPs, there are inherent technology limitations in attaining the discharge limits specified in the Environment Protection Act. The current trend is to utilize the treated effluent for bio-composting of press-mud and other agriculture waste. As of now about 12 distilleries in UP have attained zero discharge status. In this regard Central Pollution Control Board has also issued guidelines to facilitate adoption of this practice among a wider target group. As a result of this, it is expected that in due course of time BOD contribution from the distillery sector will decline.

Table 1.8 Category-wise industrial BOD load distribution in Ganga basin

Sr. No.	Industry category	BOD (t/d)	% of total
1	Abattoir	87.3	28
2	Distillery	64.9	21
3	Pulp & Paper	51.2	17
4	Tannery	33.1	11
5	Textile dye & print	18.3	6
6	Fertilisers & Chemicals	18.3	6
7	Food processing	13.2	4
8	Sugar	7.3	2
9	Rice mills	4.3	1
10	Pharmaceutical	1.8	1
11	Engineering	1.4	0.5
12	Integrated. Iron & Steel	1.3	0.4
13	Coal washery	1.1	0.4
14	Vegetable oil & Vanaspati	1.1	0.3
15	Others	4.3	1.3
	Total	**308.8**	**100**

Pulp and paper industry comprises units based on three different types of raw materials i.e., pulp, agriculture residue and waste paper. There are 249 units in this category out of which 98 units (39%) use only pulp, 73 units (29%) use waste paper while the remaining 32% use a combination of all the three raw materials as their feedstock. Concentration of pulp and paper industry is found in the districts of Muzaffarnagar, Saharanpur, Ghaziabad and Meerut in UP; Nainital and Udham Singh Nagar in Uttaranchal and; Burddhaman in West Bengal. Large industries are understood to have installed adequate pollution control measures. However, in the small scale category the agriculture residue based industries (typically without chemical recovery system) have severe problem of water pollution and the effluent BOD is in the range of 300 to 500 mg/l. Aggregate BOD discharge from this category of industry is over 51 t/d which is about 17% of the total estimated industrial discharge in the basin.

Tanneries are concentrated at Kanpur, Mokemaghat, Kolkata and few units in Agra. The three main clusters together represent over 900 small and medium sized tanneries. The category as a whole accounts for almost 33% total industrial BOD load in the basin. This figure includes the potential load that will be discharged once the tanneries in Kolkata are relocated and commissioned and the proposed CETP there is made operational.

Table 1.9 Predominant categories of water polluting industries

Category	No. of operational units	No. of closed units	Total entries in the category	Remarks
Abattoir	NA	NA	196	Non-point source. Numbers correspond to erstwhile districts in various states except Uttaranchal and Jharkhand for which state level meat production data are not available
Distillery	95	5	100	
Pulp & Paper	158	91	249	Comprises all sub-categories e.g., pulp, agriculture residue and waste paper as the feed stock
Tannery	38	7	45	The operational units also include 3 clusters of Kanpur, Kolkata and Mokemaghat (Bihar), which together represent 903 SSIs.
Sugar	178	16	194	
Vegetable oil & Vanaspati	69	41	110	Comprises all categories e.g., solvent extraction, refining, vanaspati (margarine) etc.
		Total entries	894	The six categories put together account for almost 70% of the total entries in the database.

While the sugar industry and vegetable oil and vanaspati industry have fairly large number of units in the basin, their aggregate BOD load discharge is not significant in comparison to the categories of industries described above. In the overall ranking the sugar industry appears at 8th position (2% of total load) and the vegetable oil and vanaspati industry appears at 14th position (0.3% of total load). This can be attributed to the fact that the effluents from these industries are easily biodegradable and the individual industrial units are by and large complying with the discharge standards.

When the generation from the 30 odd clusters alone is considered, it adds up to around 75 t-BOD/d. This is primarily from the SSI sector and accounts for almost 24% of the total.

Geographical Distribution

In terms of geographical distribution of BOD generation, the top ten districts in descending order are listed in Table 11. Largest generation is in South 24 Parganas district. Saharanpur is the second largest generator and it is way above Kanpur Nagar (primarily the city based industries) which is normally considered to be a large source of industrial pollution. The two adjacent districts of Saharanpur and Muzaffarnagar put together generate 26 t of BOD/d and their combined load is discharged into river

Hindon (a tributary of Yamuna). The top 10 districts put together account for almost 43% of the total industrial BOD load generation.

Table 1.10 Top ten districts in terms of BOD load generation in the Ganga basin

Sr. No.	District	State	BOD generation (t/d)	Sub-basin
1	South 24 Parganas	WB	18.25	Lower Ganga II
2	Saharanpur	UP	17.02	Hindon
3	Kolkata	WB	16.60	Lower Ganga II
4	North 24 Parganas	WB	15.72	Lower Ganga II
5	Delhi	Delhi	14.00	Upper Yamuna II
6	Jaipur	Rajasthan	12.67	Chambal
7	Barddhaman	WB	11.08	Ajay
8	Kanpur Nagar	UP	10.59	Middle Ganga II
9	Muzaffarnagar	UP	8.80	Hindon
10	Ghaziabad	UP	7.79	Kalinadi
	Total		132.52 = 43% of total	

State-wise BOD generation in descending order is presented in Table 12. As expected, UP is the largest generator accounting for 38% of the total, followed by West Bengal at 30%.

Table 1.11 State-wise industrial BOD load distribution in Ganga basin

Sr. No.	State	BOD (t/d)	% of total
1	UP	116.50	38
2	WB	91.52	30
3	Rajasthan	20.31	7
4	Bihar	18.04	6
5	MP	17.61	6
6	Haryana	14.76	5
7	Delhi	14.00	5
8	UTA	13.30	4
9	HP	2.79	1
10	Jharkhand	0.01	0
	Total	**308.84**	**100**

Sub-basin wise industrial BOD load generation is presented in Table 13. Sub-basins with significant load generation are Lower Ganga II, Upper Yamuna II, Chambal, Ramganga and Hindon. The corresponding districts draining into these sub-basins are also listed in Table 13. The top five sub-basins account for 57% of the total load generation. The Top ten sub-basins account for 83% of the total load generation and the remaining 26 sub-basins with individual share of 0-3% account for the rest 17%.

Table 1.12 Basin/ Sub-basin wise industrial BOD load distribution in the study area

Sr. No.	Sub basin	BOD (t/d)	% of total	Remarks
1	Lower Ganga II	65.23	21.1	Five industrialized districts of Haora, Hugli, Kolkata, North and South 24 Parganas contribute to this sub-basin.
2	Upper Yamuna II	30.14	9.8	Intensively industrialized districts of Delhi, Karnal, Kurukshetra, Panipat, Sonepat and Yamunanagar drain into this sub-basin.
3	Chambal	28.01	9.1	Entire western MP and most of Rajasthan drain into this sub-basin
4	Ramganga	27.48	8.9	The sub-basin drains districts with concentration of agro based industries, i.e., sugar, distillery and pulp & paper. The districts are Barielly, Bijnor, Moradabad, Nainital, Pilibhit, Shahjahanpur and Udhamsingh Nagar
5	Hindon	25.82	8.4	Muzaffarnagar and Saharanpur, two industrially developed districts in western UP drain into this sub-basin.
6	Upper Yamuna III	20.15	6.5	Main districts draining in this sub-basin are Noida, Mathura, Agra, Faridabad, Gurgaon, and Alwar
7	Middle Ganga II	17.38	5.6	Industries in Kanpur Nagar and Unnao districts drain into this sub-basin
8	Kalinadi	15.85	5.1	Top eight sub-basins carry 75% of the total industrial BOD load generated in the Ganga basin.
9	Ghaghra	15.68	5.1	Districts in north-eastern UP
10	Ajay	11.30	3.7	Barddhaman district (WB)
11	Others	51.81	16.8	Remaining 26 sub-basins with industrial BOD loads in the range of 0 to 3% of the total
	Total	308.84	100	

1.4 PROJECTION OF INDUSTRIAL POLLUTION LOADS

Considering the wide geographical and industry category spread of the database it is rather difficult to arrive at a uniform or singular number indicating the growth rate in industrial pollution for next decade or beyond. However, an attempt is made to develop a representative scenario considering various aspects described below.

The growth of pollution load from industrial sector is correlated to the growth of industrial sector in general. The latter is indicated by ‘Index of Industrial Production’, which is calculated annually by the Central Statistical Organisation (CSO) based on a sample survey of a wide spectrum of industries across the country. CSO computes the indices separately for manufacturing industry, mining industry, power sector and then an overall index representing the aggregate growth. For the purpose of this study the index corresponding to the ‘manufacturing industry’ category is of relevance.

While the Tenth Five Year Plan targets an annual growth rate of 10% in the industrial production, the trend in the recent past has not been anywhere close to this figure. It was only in the year 1995-96 that the country recorded an overall growth rate of 13%. Since then the growth rate has been between 5 to 6% and during the year 2001-2002 it declined to 2.7 % representing global slow down. A plot of growth rates in manufacturing sector and the overall industrial sector is shown in Figure 4. As per the Indian Economic Survey of 2002-03, the first six months of the year showed an up trend and the two indices are recorded at 5.4 and 5.3 respectively. It is expected that in the near future the growth rate for the manufacturing sector will continue to be around 5%.

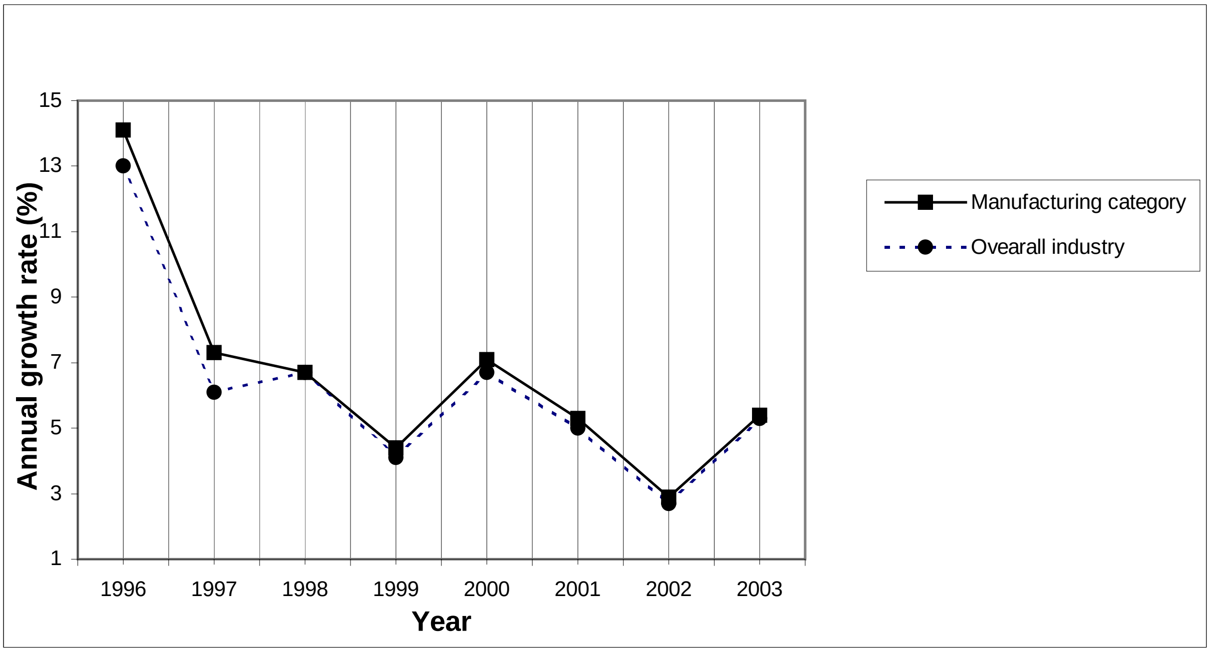


Figure 1.4 Industrial Growth Rates During Last Eight Years

However, if the individual industry categories are considered, the situation can be quite complex. The sugar industry is expected to be stagnant due to excess production capacity. Similarly the pulp and paper industry has been struggling to come out of recession and is growing at a flat rate. There is high level of sickness in the vegetable oil and vanaspati industry. Almost 40% of the units from the latter category included in the database have been closed down.

Tannery industry has been at a receiving end due to environmental pressures both from the domestic and international markets. It has been forced to install pollution control systems and thus discharges from this industry are not expected to grow dramatically.

Among the top polluting categories of industries, those that are expected to grow are abattoir and distillery. Production in registered and unregistered abattoirs is correlated to the growing population of consumers of meat products and the discharges from this sector are completely unregulated. On the other hand, in case of distilleries, it is expected that the recent trend of bio-composting and achieving zero discharge will pick up and thereby the net release of organic load into the river system will decline.

Moreover, it is expected that in coming years implementation of pollution control laws will be more stringent and effective and industry will tend to comply with discharge norms under the emerging international quality and environmental systems. Besides this, the increasingly critical situation on water availability is compelling industries to adopt higher levels of treatment and recycling of effluents. Under this overall scenario a conservative estimate of growth of around 4% in the BOD load is considered for the next 7 years i.e., upto 2010 from the industrial sector in the Ganga basin.

In subsequent years, while the overall infrastructure is expected to improve, it is very difficult to forecast the rate of industrial growth. While the Tenth Five Year Plan aims to achieve an average of 10% growth per annum, the prediction would be subjected to uncertainties associated with the international industrial scenario, liberalizing trade regime, cycles of economic growth and recession and last but not the least the vicissitudes of climate change. While keeping an ambitious growth target, the Tenth Plan document itself states that “unless India is proactive in responding to the imperatives of the changing environment, there is a very serious danger that it would be left far behind in today’s race for the ‘survival of the fittest’. In short, Indian industry has to discard its inward looking approach and become outward-oriented and learn to operate in an unprotected, internationally competitive environment" (Tenth Five Year Plan, 2002-2007, Vol. II pp. 664).

A high rate of growth witnessed in some of the South Asian countries during the last decade has turned out to be unsustainable. On the other hand, in the case of developed and stable economies of Western Europe, US and Japan, the typical annual growth rate is between 2-4%. Indian economy (especially the manufacturing or the secondary sector) could well be entering into that territory of growth by the turn of the current decade. In this context, a rather flat growth rate of 2% for the industrial pollution load is assumed for the period between 2010 to 2030. As a result, the aggregate basin-wide BOD loads for year 2010 and 2030 are estimated as follows:

Year ⇨	**2003**	**2010**	**2015**	**2030**
Growth rate (%) (Compounded annually)		4	3.6	2
Estimated basin-wide BOD load (t/d)	309	406	476	604

Annexure-I

DESCRIPTION OF THE INDUSTRIAL DATABASE

INPUT DATA FORMAT

For the purpose of estimating basin-wise discharges of industrial waste loads in to the Ganga river system a data base has been developed using the Microsoft Access application.

The data is fed through an input form and the user is discouraged to directly handle the data in tabular form. This is done to avoid any accidental alteration or deletion of the previously fed data. The data form is presented below:

Data format for industries

		Unit	Entry
Name			
Location			
	City		
	District		
	State		
Status*			Operational / Closed
Product (s)			
Ind. category			
Capacity			
Sub-basin			
Effluent generation		Kld	
ETP*			Yes / no
BOD		kg/d	

* : Strike out which is not available
Notes :
Opr : Operational
Clsd : Closed
WP : Water polluting
NP : Non-polluting

The top attributes are related to name and location of an individual industrial unit.

Whether the unit is operational or closed is represented by the attribute/field ‘status’. For the units having Status as ‘Closed’, the BOD load is considered as zero.

Attribute ‘Product (s)’ represents the type of product manufactured by an industrial unit, e.g., sugar, alcohol, leather etc.

Attribute ‘Industrial category’ classifies the units broadly into different categories, e.g., sugar industry, distillery industry, tannery industry, pharmaceutical industry etc.

Attribute ‘Capacity’ indicates the installed production capacity of the particular industrial unit. Values for this field have been adopted from the published reports of respective industrial associations. Capacity units adopted for different categories of industries in the data base are as follows:

- Sugar industry : tones of cane crushed per day

- Distillery industry : kilo litres of alcohol/annum
- Pulp and paper : tonnes/annum
- Vegetable oil and vanaspati : tones/annum

The capacity attribute has been utilized only in selected cases for estimation of BOD loads. This value is available only in the above four categories of industries from the respective associations. In the rest of the industrial categories the corresponding values have not been available.

Value for the attribute ‘sub-basin’ has been adopted as per the river system analysis and coding done by the GIS team. The value corresponds to the area of the district. In case a district is falling in more than one sub-basin, then the one that accounts for the largest part is taken as the representative sub-basin. However, in case of Kanpur (Nagar) and Allahabad districts a deviation has been made from this rule. Knowing that all the industries are located in the respective cities, the receiving sub-basin is corresponding to the stretch of Ganga flowing through the city.

Attribute ‘Effluent generation’ is in kilo litre/d. The values have been taken from various sources. In case where it has to be computed based on installed annual or daily capacity, the unit discharge loads recommended by CPCB have been adopted. In case of annual figures, a value of 250 days/annum of production has been assumed and accordingly the daily effluent quantities have been calculated.

Attribute ‘ETP’ is to account for the existence or absence of effluent treatment at the respective unit. The input is a logical value that is in the form of ‘yes’ or ‘no’. In the database it appears in the form of a tick mark in the field or a blank box. It is presumed that almost all the units have now installed ETPs and as a result they have the ‘consent to operate’ from the respective state pollution control boards. However, the database should be fine tuned to reflect the field situation as per the information that would be available with the respective state boards. In all the cases where ETP is known to be existing, the effluent BOD concentration has been taken as 30 mg/l presuming that the industry is complying with the discharge condition. Wherever the data indicates otherwise, actual BOD loads have been adopted.

Attribute ‘BOD’ is in terms of kg/d. It has been individually calculated for each industry/cluster by multiplying the effluent loads and the BOD concentrations or through other approaches as in the case of slaughterhouse effluents.

The Central Pollution Control Board and the respective state Pollution Control Boards can utilize the database. It can be updated and augmented with additional information and reports along various lines can be generated as per specific requirements.

Annexure - II

CALCULATION OF WASTEWATER LOADS FROM

SLAUGHTERHOUSES IN THE GANGA BASIN

Estimation of wastewater loads from slaughterhouses in UP

Statewise estimates of TLWK

State : UP	Cattle	Buffalos	Sheep	Goat
Meat production (tonnes/annum)	0	126821	4686	27522
TLWK (tonnes/d)	0	1449	46.86	275.22

TLWK : tonne of live weight killed

Category of SH	Size of SH	Assumed distribution of TLWK	Specific wastewater generation (m^3/TLWK)	Specific BOD load (kg/TLWK)
Bovine	Large	0.1	1.4	5.5
	Medium	0.3	0.5	5
	Small	0.6	1	6.6
Sheep & Goat	All sizes		3	8.1

Districtwise estimates

Sl No.	District	Population Urban	% of total urban population	Cattle		Buffalos		Sheep & Goat		Total	
				WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d
1	Agra	1,557,345	4.51	0.00	0.00	58.21	393.07	43.60	117.72	101.81	510.79
2	Aligarh	863,385	2.50	0.00	0.00	32.27	217.91	24.17	65.26	56.44	283.18
3	Allahabad	1,213,828	3.52	0.00	0.00	45.37	306.36	33.98	91.75	79.35	398.12
4	Ambedkar Nagar	180,662	0.52	0.00	0.00	6.75	45.60	5.06	13.66	11.81	59.25
5	Auraiya	168,838	0.49	0.00	0.00	6.31	42.61	4.73	12.76	11.04	55.38
6	Azamgarh	301,597	0.87	0.00	0.00	11.27	76.12	8.44	22.80	19.72	98.92
7	Baghpat	229,564	0.67	0.00	0.00	8.58	57.94	6.43	17.35	15.01	75.29
8	Bahraich	238,052	0.69	0.00	0.00	8.90	60.08	6.66	17.99	15.56	78.08
9	Ballia	270,732	0.78	0.00	0.00	10.12	68.33	7.58	20.46	17.70	88.80
10	Balrampur	135,274	0.39	0.00	0.00	5.06	34.14	3.79	10.23	8.84	44.37
11	Banda	244,023	0.71	0.00	0.00	9.12	61.59	6.83	18.45	15.95	80.04
12	Barabanki	247,859	0.72	0.00	0.00	9.26	62.56	6.94	18.74	16.20	81.29
13	Bareilly	1,172,874	3.40	0.00	0.00	43.84	296.03	32.84	88.66	76.67	384.69
14	Basti	115,318	0.33	0.00	0.00	4.31	29.11	3.23	8.72	7.54	37.82
15	Bhadohi	172,633	0.50	0.00	0.00	6.45	43.57	4.83	13.05	11.29	56.62
16	Bijnor	761,585	2.21	0.00	0.00	28.47	192.22	21.32	57.57	49.79	249.79
17	Budaun	557,252	1.61	0.00	0.00	20.83	140.65	15.60	42.12	36.43	182.77
18	Bulandshahr	673,826	1.95	0.00	0.00	25.19	170.07	18.86	50.94	44.05	221.01
19	Chandauli	173,423	0.50	0.00	0.00	6.48	43.77	4.86	13.11	11.34	56.88
20	Chitrakoot	76,496	0.22	0.00	0.00	2.86	19.31	2.14	5.78	5.00	25.09
21	Deoria	270,120	0.78	0.00	0.00	10.10	68.18	7.56	20.42	17.66	88.60
22	Etah	483,557	1.40	0.00	0.00	18.07	122.05	13.54	36.55	31.61	158.60
23	Etawah	309,037	0.90	0.00	0.00	11.55	78.00	8.65	23.36	20.20	101.36
24	Faizabad	281,314	0.82	0.00	0.00	10.51	71.00	7.88	21.26	18.39	92.27
25	Farrukhabad	340,907	0.99	0.00	0.00	12.74	86.04	9.54	25.77	22.29	111.81
26	Fatehpur	237,279	0.69	0.00	0.00	8.87	59.89	6.64	17.94	15.51	77.82
27	Firozabad	621,063	1.80	0.00	0.00	23.21	156.75	17.39	46.95	40.60	203.70
28	Gautam Buddha Nagar	438,212	1.27	0.00	0.00	16.38	110.60	12.27	33.12	28.65	143.73

Sl No.	District	Population Urban	% of total urban population	Cattle		Buffalos		Sheep & Goat		Total	
29	Ghaziabad	1,815,981	5.26	0.00	0.00	67.87	458.34	50.84	137.27	118.72	595.62
30	Ghazipur	232,989	0.68	0.00	0.00	8.71	58.81	6.52	17.61	15.23	76.42
31	Gonda	196,159	0.57	0.00	0.00	7.33	49.51	5.49	14.83	12.82	64.34
32	Gorakhpur	740,565	2.15	0.00	0.00	27.68	186.91	20.73	55.98	48.41	242.89
33	Hamirpur	173,457	0.50	0.00	0.00	6.48	43.78	4.86	13.11	11.34	56.89
34	Hardoi	407,032	1.18	0.00	0.00	15.21	102.73	11.40	30.77	26.61	133.50
35	Hathras	265,021	0.77	0.00	0.00	9.91	66.89	7.42	20.03	17.33	86.92
36	Jalaun	340,478	0.99	0.00	0.00	12.73	85.93	9.53	25.74	22.26	111.67
37	Jaunpur	289,137	0.84	0.00	0.00	10.81	72.98	8.09	21.86	18.90	94.83
38	Jhansi	717,551	2.08	0.00	0.00	26.82	181.11	20.09	54.24	46.91	235.35
39	Jyotiba Phule Nagar	369,435	1.07	0.00	0.00	13.81	93.24	10.34	27.93	24.15	121.17
40	Kannauj	231,912	0.67	0.00	0.00	8.67	58.53	6.49	17.53	15.16	76.06
41	Kanpur Dehat	107,375	0.31	0.00	0.00	4.01	27.10	3.01	8.12	7.02	35.22
42	Kanpur Nagar	2,772,212	8.03	0.00	0.00	103.61	699.69	77.61	209.55	181.23	909.25
43	Kaushambi	91,754	0.27	0.00	0.00	3.43	23.16	2.57	6.94	6.00	30.09
44	Kheri	345,032	1.00	0.00	0.00	12.90	87.08	9.66	26.08	22.56	113.17
45	Kushinagar	132,519	0.38	0.00	0.00	4.95	33.45	3.71	10.02	8.66	43.46
46	Lalitpur	141,831	0.41	0.00	0.00	5.30	35.80	3.97	10.72	9.27	46.52
47	Lucknow	2,342,239	6.79	0.00	0.00	87.54	591.17	65.57	177.05	153.12	768.22
48	Maharajganj	110,409	0.32	0.00	0.00	4.13	27.87	3.09	8.35	7.22	36.21
49	Mahoba	154,787	0.45	0.00	0.00	5.79	39.07	4.33	11.70	10.12	50.77
50	Mainpuri	230,130	0.67	0.00	0.00	8.60	58.08	6.44	17.40	15.04	75.48
51	Mathura	582,387	1.69	0.00	0.00	21.77	146.99	16.30	44.02	38.07	191.01
52	Mau	357,988	1.04	0.00	0.00	13.38	90.35	10.02	27.06	23.40	117.41
53	Meerut	1,457,094	4.22	0.00	0.00	54.46	367.76	40.79	110.14	95.25	477.91
54	Mirzapur	286,750	0.83	0.00	0.00	10.72	72.37	8.03	21.68	18.75	94.05
55	Moradabad	1,163,478	3.37	0.00	0.00	43.49	293.66	32.57	87.95	76.06	381.60
56	Muzaffarnagar	903,829	2.62	0.00	0.00	33.78	228.12	25.30	68.32	59.09	296.44
57	Pilibhit	294,005	0.85	0.00	0.00	10.99	74.21	8.23	22.22	19.22	96.43
58	Pratapgarh	144,313	0.42	0.00	0.00	5.39	36.42	4.04	10.91	9.43	47.33
59	Rae Bareli	273,745	0.79	0.00	0.00	10.23	69.09	7.66	20.69	17.90	89.78
60	Rampur	480,064	1.39	0.00	0.00	17.94	121.17	13.44	36.29	31.38	157.45
61	Saharanpur	744,744	2.16	0.00	0.00	27.84	187.97	20.85	56.30	48.69	244.27
62	Sant Kabir Nagar	101,112	0.29	0.00	0.00	3.78	25.52	2.83	7.64	6.61	33.16
63	Shahjahanpur	526,794	1.53	0.00	0.00	19.69	132.96	14.75	39.82	34.44	172.78
64	Shrawasti	33,347	0.10	0.00	0.00	1.25	8.42	0.93	2.52	2.18	10.94
65	Siddharthnagar	77,703	0.23	0.00	0.00	2.90	19.61	2.18	5.87	5.08	25.49
66	Sitapur	431,870	1.25	0.00	0.00	16.14	109.00	12.09	32.65	28.23	141.65
67	Sonbhadra	276,714	0.80	0.00	0.00	10.34	69.84	7.75	20.92	18.09	90.76
68	Sultanpur	152,251	0.44	0.00	0.00	5.69	38.43	4.26	11.51	9.95	49.94
69	Unnao	411,859	1.19	0.00	0.00	15.39	103.95	11.53	31.13	26.92	135.08
70	Varanasi	1,268,522	3.68	0.00	0.00	47.41	320.17	35.51	95.89	82.93	416.06
	Total	34512629	100.00							2256.19	11319.64

Estimation of wastewater loads from slaughterhouses in Rajasthan

Statewise estimates of TLWK

State : Rajasthan	Cattle	Buffalos	Sheep	Goat
Meat production (tonnes/annum)	0	7610	10890	24550
TLWK (tonnes/d)	0	87	108.9	245.5

TLWK : tonne of live weight killed

Category of SH	Size of SH	Assumed distribution of TLWK	Specific wastewater generation (m^3/TLWK)	Specific BOD load (kg/TLWK)
Bovine	Large	0.1	1.4	5.5
	Medium	0.3	0.5	5
	Small	0.6	1	6.6
Sheep & Goat	All sizes		3	8.1

Districtwise estimates

Sl No.	District	Population Urban	% of total urban population	Cattle		Buffalos		Sheep & Goat		Total	
				WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d
1	Ajmer	2180526	3.86	0.00	0.00	2.99	20.18	41.05	110.84	44.04	131.02
2	Alwar	2990862	5.30	0.00	0.00	4.10	27.68	56.31	152.03	60.41	179.71
3	Banswara	1500420	2.66	0.00	0.00	2.06	13.89	28.25	76.27	30.30	90.16
4	Baran	1022568	1.81	0.00	0.00	1.40	9.46	19.25	51.98	20.65	61.44
5	Barmer	1963758	3.48	0.00	0.00	2.69	18.18	36.97	99.82	39.66	118.00
6	Bharatpur	2098323	3.72	0.00	0.00	2.88	19.42	39.50	106.66	42.38	126.08
7	Bhilwara	2009516	3.56	0.00	0.00	2.75	18.60	37.83	102.15	40.59	120.75
8	Bikaner	1673562	2.96	0.00	0.00	2.29	15.49	31.51	85.07	33.80	100.56
9	Bundi	961269	1.70	0.00	0.00	1.32	8.90	18.10	48.86	19.42	57.76
10	Chittaurgarh	1802656	3.19	0.00	0.00	2.47	16.68	33.94	91.63	36.41	108.32
11	Churu	1922908	3.40	0.00	0.00	2.64	17.80	36.20	97.75	38.84	115.54
12	Dausa	1316790	2.33	0.00	0.00	1.80	12.19	24.79	66.94	26.60	79.12
13	Dhaulpur	982815	1.74	0.00	0.00	1.35	9.10	18.50	49.96	19.85	59.06
14	Dungarpur	1107037	1.96	0.00	0.00	1.52	10.25	20.84	56.27	22.36	66.52
15	Ganganagar	1788487	3.17	0.00	0.00	2.45	16.55	33.67	90.91	36.12	107.47
16	Hanumangarh	1517390	2.69	0.00	0.00	2.08	14.04	28.57	77.13	30.65	91.18
17	Jaipur	5252388	9.30	0.00	0.00	7.20	48.61	98.88	266.99	106.08	315.60
18	Jaisalmer	507999	0.90	0.00	0.00	0.70	4.70	9.56	25.82	10.26	30.52
19	Jalor	1448486	2.56	0.00	0.00	1.99	13.41	27.27	73.63	29.26	87.04
20	Jhalawar	1180342	2.09	0.00	0.00	1.62	10.92	22.22	60.00	23.84	70.92
21	Jhunjhunun	1913099	3.39	0.00	0.00	2.62	17.71	36.02	97.25	38.64	114.95
22	Jodhpur	2880777	5.10	0.00	0.00	3.95	26.66	54.24	146.44	58.18	173.10
23	Karauli	1205631	2.13	0.00	0.00	1.65	11.16	22.70	61.28	24.35	72.44
24	Kota	1568580	2.78	0.00	0.00	2.15	14.52	29.53	79.73	31.68	94.25
25	Nagaur	2773894	4.91	0.00	0.00	3.80	25.67	52.22	141.00	56.03	166.68
26	Pali	1819201	3.22	0.00	0.00	2.49	16.84	34.25	92.47	36.74	109.31
27	Rajsamand	986269	1.75	0.00	0.00	1.35	9.13	18.57	50.13	19.92	59.26
28	Sawai Madhopur	1116031	1.98	0.00	0.00	1.53	10.33	21.01	56.73	22.54	67.06
29	Sikar	2287229	4.05	0.00	0.00	3.13	21.17	43.06	116.26	46.20	137.43
30	Sirohi	850756	1.51	0.00	0.00	1.17	7.87	16.02	43.25	17.18	51.12
31	Tonk	1211343	2.14	0.00	0.00	1.66	11.21	22.81	61.57	24.47	72.79
32	Udaipur	2632210	4.66	0.00	0.00	3.61	24.36	49.56	133.80	53.16	158.16
	Total	56473122	100.00							1140.60	3393.34

Estimation of wastewater loads from slaughterhouses in HP

Statewise estimates of TLWK

State : HP	Cattle	Buffalos	Sheep	Goat
Meat production (tonnes/annum)	0	0	955	2249
TLWK (tonnes/d)	0	0	9.55	22.49

TLWK : tonne of live weight killed

Category of SH	Size of SH	Assumed distribution of TLWK	Specific wastewater generation (m^3/TLWK)	Specific BOD load (kg/TLWK)
Bovine	Large	0.1	1.4	5.5
	Medium	0.3	0.5	5
	Small	0.6	1	6.6
Sheep &	All sizes		3	8.1

Districtwise estimates

Sl No.	District	Urban Population	% of total urban population	Cattle		Buffalos		Sheep & Goat		Total	
				WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d
1	Bilaspur	21949	3.69	0.00	0.00	0.00	0.00	3.55	9.58	3.55	9.58
2	Chamba	34518	5.80	0.00	0.00	0.00	0.00	5.58	15.06	5.58	15.06
3	Hamirpur	30173	5.07	0.00	0.00	0.00	0.00	4.88	13.16	4.88	13.16
4	Kangra	72174	12.13	0.00	0.00	0.00	0.00	11.66	31.49	11.66	31.49
5	Kinnaur		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	Kullu	30093	5.06	0.00	0.00	0.00	0.00	4.86	13.13	4.86	13.13
7	Lahul & Spiti		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	Mandi	60958	10.25	0.00	0.00	0.00	0.00	9.85	26.59	9.85	26.59
9	Shimla	166833	28.04	0.00	0.00	0.00	0.00	26.96	72.78	26.96	72.78
10	Sirmaur	47586	8.00	0.00	0.00	0.00	0.00	7.69	20.76	7.69	20.76
11	Solan	91175	15.33	0.00	0.00	0.00	0.00	14.73	39.78	14.73	39.78
12	Una	39422	6.63	0.00	0.00	0.00	0.00	6.37	17.20	6.37	17.20
	Total	594881	100.00							96.12	259.52

Estimation of wastewater loads from slaughterhouses in Haryana

Statewise estimates of TLWK

State : Haryana				
	Cattle	Buffalos	Sheep	Goat
Meat production (tonnes/annum)	0	0	1210	1780
TLWK (tonnes/d)	0	0	12.1	17.8

TLWK : tonne of live weight killed

Category of SH	Size of SH	Assumed distribution of TLWK	Specific wastewater generation (m^3/TLWK)	Specific BOD load (kg/TLWK)
Bovine	Large	0.1	1.4	5.5
	Medium	0.3	0.5	5
	Small	0.6	1	6.6
Sheep & Goat	All sizes		3	8.1

Districtwise estimates

Sl No.	District	Urban Population	% of total urban population	Cattle		Buffalos		Sheep & Goat		Total	
				WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d
1	Ambala	356663	5.83	0.00	0.00	0.00	0.00	5.23	14.13	5.23	14.13
2	Bhiwani	270295	4.42	0.00	0.00	0.00	0.00	3.97	10.71	3.97	10.71
3	Faridabad	1220194	19.96	0.00	0.00	0.00	0.00	17.90	48.33	17.90	48.33
4	Fatehabad	142092	2.32	0.00	0.00	0.00	0.00	2.08	5.63	2.08	5.63
5	Gurgaon	369304	6.04	0.00	0.00	0.00	0.00	5.42	14.63	5.42	14.63
6	Hisar	397980	6.51	0.00	0.00	0.00	0.00	5.84	15.76	5.84	15.76
7	Jhajjar	195081	3.19	0.00	0.00	0.00	0.00	2.86	7.73	2.86	7.73
8	Jind	242031	3.96	0.00	0.00	0.00	0.00	3.55	9.59	3.55	9.59
9	Kaithal	183121	3.00	0.00	0.00	0.00	0.00	2.69	7.25	2.69	7.25
10	Karnal	338632	5.54	0.00	0.00	0.00	0.00	4.97	13.41	4.97	13.41
11	Kurukshetra	215820	3.53	0.00	0.00	0.00	0.00	3.17	8.55	3.17	8.55
12	Mahendragarh	109303	1.79	0.00	0.00	0.00	0.00	1.60	4.33	1.60	4.33
13	Panchkula	208672	3.41	0.00	0.00	0.00	0.00	3.06	8.27	3.06	8.27
14	Panipat	391903	6.41	0.00	0.00	0.00	0.00	5.75	15.52	5.75	15.52
15	Rewari	136305	2.23	0.00	0.00	0.00	0.00	2.00	5.40	2.00	5.40
16	Rohtak	329550	5.39	0.00	0.00	0.00	0.00	4.83	13.05	4.83	13.05
17	Sirsa	292840	4.79	0.00	0.00	0.00	0.00	4.30	11.60	4.30	11.60
18	Sonipat	321432	5.26	0.00	0.00	0.00	0.00	4.72	12.73	4.72	12.73
19	Yamunanagar	392921	6.43	0.00	0.00	0.00	0.00	5.76	15.56	5.76	15.56
	Total	6114139	100.00							89.70	242.19

Estimation of wastewater loads from slaughterhouses in MP

Statewise estimates of TLWK

State : MP	Cattle	Buffalos	Sheep	Goat
Meat production (tones/annum)	438	987	113	1403
TLWK (tonne/d)	5	11	1.13	14.03

TLWK : tonne of live weight killed

Category of SH	Size of SH	Assumed distribution of TLWK	Specific wastewater generation (m^3/TLWK)	Specific BOD load (kg/TLWK)
Bovine	Large	0.1	1.4	5.5
	Medium	0.3	0.5	5
	Small	0.6	1	6.6
Sheep & Goat	All sizes		3	8.1

Districtwise estimates

Sl No.	District	Population Urban	% of total urban population	Cattle		Buffalos		Sheep & Goat		Total	
				WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d
1	Balaghat	193905	1.20	0.05	0.36	0.12	0.82	0.55	1.48	0.72	2.66
2	Barwani	157976	0.98	0.04	0.30	0.10	0.67	0.45	1.20	0.59	2.16
3	Betul	258879	1.61	0.07	0.48	0.16	1.09	0.73	1.97	0.96	3.55
4	Bhind	338153	2.10	0.09	0.63	0.21	1.42	0.96	2.58	1.26	4.63
5	Bhopal	1479119	9.19	0.41	2.76	0.92	6.23	4.18	11.28	5.51	20.27
6	Chhatarpur	324279	2.01	0.09	0.61	0.20	1.37	0.92	2.47	1.21	4.44
7	Chhindwara	452234	2.81	0.13	0.84	0.28	1.90	1.28	3.45	1.68	6.20
8	Damoh	204315	1.27	0.06	0.38	0.13	0.86	0.58	1.56	0.76	2.80
9	Datia	137545	0.85	0.04	0.26	0.09	0.58	0.39	1.05	0.51	1.88
10	Dewas	357362	2.22	0.10	0.67	0.22	1.50	1.01	2.73	1.33	4.90
11	Dhar	288235	1.79	0.08	0.54	0.18	1.21	0.81	2.20	1.07	3.95
12	Dindori	26862	0.17	0.01	0.05	0.02	0.11	0.08	0.20	0.10	0.37
13	East Nimar	460332	2.86	0.13	0.86	0.29	1.94	1.30	3.51	1.71	6.31
14	Guna	354735	2.20	0.10	0.66	0.22	1.49	1.00	2.71	1.32	4.86
15	Gwalior	983331	6.11	0.27	1.84	0.61	4.14	2.78	7.50	3.66	13.48
16	Harda	101087	0.63	0.03	0.19	0.06	0.43	0.29	0.77	0.38	1.39
17	Hoshangabad	335762	2.09	0.09	0.63	0.21	1.41	0.95	2.56	1.25	4.60
18	Indore	1850311	11.49	0.51	3.46	1.15	7.79	5.23	14.11	6.89	25.36
19	Jabalpur	1246504	7.74	0.34	2.33	0.78	5.25	3.52	9.51	4.64	17.08
20	Jhabua	121029	0.75	0.03	0.23	0.08	0.51	0.34	0.92	0.45	1.66
21	Katni	224958	1.40	0.06	0.42	0.14	0.95	0.64	1.72	0.84	3.08
22	Mandla	92005	0.57	0.03	0.17	0.06	0.39	0.26	0.70	0.34	1.26
23	Mandsaur	220633	1.37	0.06	0.41	0.14	0.93	0.62	1.68	0.82	3.02
24	Morena	343199	2.13	0.09	0.64	0.21	1.44	0.97	2.62	1.28	4.70

Sl No.	District	Population Urban	% of total urban population	Cattle		Buffalos		Sheep & Goat		Total	
25	Narsimhapur	153103	0.95	0.04	0.29	0.10	0.64	0.43	1.17	0.57	2.10
26	Neemuch	202253	1.26	0.06	0.38	0.13	0.85	0.57	1.54	0.75	2.77
27	Panna	108144	0.67	0.03	0.20	0.07	0.46	0.31	0.82	0.40	1.48
28	Raisen	206840	1.28	0.06	0.39	0.13	0.87	0.58	1.58	0.77	2.83
29	Rajgarh	217150	1.35	0.06	0.41	0.14	0.91	0.61	1.66	0.81	2.98
30	Ratlam	367397	2.28	0.10	0.69	0.23	1.55	1.04	2.80	1.37	5.03
31	Rewa	320475	1.99	0.09	0.60	0.20	1.35	0.91	2.44	1.19	4.39
32	Sagar	591362	3.67	0.16	1.10	0.37	2.49	1.67	4.51	2.20	8.10
33	Satna	385590	2.39	0.11	0.72	0.24	1.62	1.09	2.94	1.44	5.28
34	Sehore	194424	1.21	0.05	0.36	0.12	0.82	0.55	1.48	0.72	2.66
35	Seoni	120697	0.75	0.03	0.23	0.08	0.51	0.34	0.92	0.45	1.65
36	Shahdol	398135	2.47	0.11	0.74	0.25	1.68	1.12	3.04	1.48	5.46
37	Shajapur	239340	1.49	0.07	0.45	0.15	1.01	0.68	1.83	0.89	3.28
38	Sheopur	88580	0.55	0.02	0.17	0.06	0.37	0.25	0.68	0.33	1.21
39	Shivpuri	239672	1.49	0.07	0.45	0.15	1.01	0.68	1.83	0.89	3.28
40	Sidhi	261390	1.62	0.07	0.49	0.16	1.10	0.74	1.99	0.97	3.58
41	Tikamgarh	212375	1.32	0.06	0.40	0.13	0.89	0.60	1.62	0.79	2.91
42	Ujjain	662327	4.11	0.18	1.24	0.41	2.79	1.87	5.05	2.47	9.08
43	Umaria	82912	0.51	0.02	0.15	0.05	0.35	0.23	0.63	0.31	1.14
44	Vidisha	260279	1.62	0.07	0.49	0.16	1.10	0.74	1.98	0.97	3.57
45	West Nimar	237395	1.47	0.07	0.44	0.15	1.00	0.67	1.81	0.88	3.25
	Total	16102590	100.00							59.97	220.67

Estimation of wastewater loads from slaughterhouse in Delhi

Statewise estimates of TLWK

State : Delhi				
	Cattle	Buffalos	Sheep	Goat
Meat production (tonnes/annum)	0	28063	4626	0
TLWK (tonnes/d)	0	321	46.26	0

TLWK : tonnes of live weight killed

Category of SH	Size of SH	Assumed distribution of TLWK	Specific wastewater generation (m^3/TLWK)	Specific BOD load (kg/TLWK)
Bovine	Large	0.1	1.4	5.5
	Medium	0.3	0.5	5
	Small	0.6	1	6.6
Sheep & Goat	All sizes		3	8.1

Districtwise estimates

Sl No.	District	Urban Population	% of total urban population	Cattle		Buffalos		Sheep & Goat		Total	
				WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d
1	Delhi	14,000,000	100.00	0.00	0.00	449.01	1763.96	138.78	374.71	587.79	2138.67
	Total	14,000,000	100.00							587.79	2138.67

Estimation of wastewater loads from slaughterhouse sector in Bihar
Statewise estimates of TLWK

State : Bihar				
	Cattle	Buffalos	Sheep	Goat
Meat production (tonnes/annum)	23449	30869	1680	49345
TLWK (tonne/d)	268	353	16.8	493.45

TLWK : tonne of live weight killed

Category of SH	Size of SH	Assumed distribution of TLWK	Specific wastewater generation	Specific BOD load (kg/TLWK)
Bovine	Large	0.1	1.4	5.5
	Medium	0.3	0.5	5
	Small	0.6	1	6.6
Sheep & Goat	All sizes		3	8.1

Districtwise estimates

Sl No.	District	Population Urban	% of total urban population	Cattle		Buffalos		Sheep & Goat		Total	
				WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d	WW load (m^3/d)	BOD, kg/d
1	Araria	132538	1.53	3.64	24.60	4.79	32.38	23.38	63.11	31.81	120.09
2	Aurangabad	168833	1.95	4.64	31.33	6.11	41.24	29.78	80.40	40.52	152.97
3	Banka	56346	0.65	1.55	10.46	2.04	13.76	9.94	26.83	13.52	51.05
4	Begusarai	107203	1.24	2.95	19.89	3.88	26.19	18.91	51.05	25.73	97.13
5	Bhagalpur	451919	5.21	12.42	83.86	16.35	110.40	79.70	215.20	108.47	409.47
6	Bhojpur	312294	3.60	8.58	57.95	11.30	76.29	55.08	148.71	74.96	282.96
7	Buxar	128771	1.48	3.54	23.90	4.66	31.46	22.71	61.32	30.91	116.67
8	Darbhanga	266834	3.07	7.33	49.52	9.65	65.19	47.06	127.07	64.05	241.77
9	Gaya	475041	5.47	13.05	88.15	17.19	116.05	83.78	226.21	114.02	430.42
10	Gopalganj	130536	1.50	3.59	24.22	4.72	31.89	23.02	62.16	31.33	118.27
11	Jamui	103176	1.19	2.84	19.15	3.73	25.21	18.20	49.13	24.77	93.48
12	Jehanabad	111893	1.29	3.07	20.76	4.05	27.33	19.73	53.28	26.86	101.38
13	Kaimur (Bhabua)	41507	0.48	1.14	7.70	1.50	10.14	7.32	19.77	9.96	37.61
14	Katihar	218246	2.51	6.00	40.50	7.90	53.32	38.49	103.93	52.38	197.74
15	Khagaria	76219	0.88	2.09	14.14	2.76	18.62	13.44	36.30	18.29	69.06
16	Kishanganj	129006	1.49	3.55	23.94	4.67	31.52	22.75	61.43	30.96	116.89
17	Lakhisarai	117585	1.35	3.23	21.82	4.25	28.73	20.74	55.99	28.22	106.54
18	Madhepura	67936	0.78	1.87	12.61	2.46	16.60	11.98	32.35	16.31	61.55
19	Madhubani	124403	1.43	3.42	23.09	4.50	30.39	21.94	59.24	29.86	112.72
20	Munger	316586	3.65	8.70	58.75	11.45	77.34	55.84	150.76	75.99	286.85
21	Muzaffarpur	348271	4.01	9.57	64.63	12.60	85.08	61.42	165.85	83.59	315.56
22	Nalanda	353443	4.07	9.71	65.59	12.79	86.34	62.34	168.31	84.84	320.24
23	Nawada	138666	1.60	3.81	25.73	5.02	33.87	24.46	66.03	33.28	125.64
24	Pashchim Champaran	309483	3.57	8.50	57.43	11.20	75.60	54.58	147.38	74.28	280.41
25	Patna	1968924	22.69	54.11	365.38	71.23	480.99	347.26	937.60	472.59	1783.97
26	Purba Champaran	251440	2.90	6.91	46.66	9.10	61.42	44.35	119.74	60.35	227.82
27	Purnia	221940	2.56	6.10	41.19	8.03	54.22	39.14	105.69	53.27	201.09
28	Rohtas	326587	3.76	8.97	60.61	11.81	79.78	57.60	155.52	78.39	295.91
29	Saharsa	124015	1.43	3.41	23.01	4.49	30.30	21.87	59.06	29.77	112.37
30	Samastipur	123435	1.42	3.39	22.91	4.47	30.15	21.77	58.78	29.63	111.84
31	Saran	298129	3.43	8.19	55.32	10.79	72.83	52.58	141.97	71.56	270.12
32	Sheikhpura	81300	0.94	2.23	15.09	2.94	19.86	14.34	38.71	19.51	73.66
33	Sheohar	21327	0.25	0.59	3.96	0.77	5.21	3.76	10.16	5.12	19.32
34	Sitamarhi	153251	1.77	4.21	28.44	5.54	37.44	27.03	72.98	36.78	138.85
35	Siwan	147746	1.70	4.06	27.42	5.34	36.09	26.06	70.36	35.46	133.87
36	Supaul	87894	1.01	2.42	16.31	3.18	21.47	15.50	41.86	21.10	79.64
37	Vaishali	186477	2.15	5.12	34.60	6.75	45.55	32.89	88.80	44.76	168.96
	Total	8679200	100.00							2083.24	7863.90

APPENDIX

LONGITUDINAL AND TRANSVERSE WATER QUALITY PROFILE OF RIVER GANGA

City : Kanpur	BOD (mg/l) W/8	W/4	W/2	3W/4	7W/8	Average	DO (mg/l) W/8	W/4	W/2	3W/4	7W/8	Average
Ganga River 2 km U/S of the city(U/S of Rani ghat)	2	2	2	3	4	2.6	6.3	7.1	7.3	6.7	6.6	6.8
Ganga River Middle Stretch of the City (Shuklaganj)	4	3	4	5	4	4	6	6.5	6.6	6.3	6.2	6.32
Ganga River 2 km D/S of the City (Jajmau Pumping Station)	6	4	4	3	13	6	3.8	4	4.3	4.2	3.8	4.02

City : Lucknow	BOD (mg/l)	W/4	W/2	3W/4		Average	DO (mg/l) W/4	W/2	3W/4		Average
Gomti 2 km u/s of City near Gaughat		6	3	4		4.3	6.8	7.2	7		7.0
Gomti middle stretch of the city near Botanical Gardern		3	3	4		3.3	5.3	5.4	5.1		5.3
Gomti 2 km d/s of the city		5	7	5		5.7	6.3	6.9	6.5		6.6
Gomati River 200 m U/S of Confluence with Ganga		6	7	5		6	6.1	6.6	5.4		6.0

City : Allahabad	BOD (mg/l) W/8	W/4	W/2	3W/4	7W/8	Average	DO (mg/l) W/8	W/4	W/2	3W/4	7W/8	Average
Yamuna River 2 km U/S of the Confluence with Ganga	5	2	6	6	6	6.0	5.6	6.1	6.4	6.2	5.7	6
Yamuna River 200 mm U/S of the Confluence with Ganga	6	5	6	5	7	6.0	5.6	6	6.6	6.3	6.8	6.26
Ganga 2 km u/s of the city (Rasoolabad)	4	5	3	4	2	3.0	5.9	6.2	7	6.6	6	6.34
Ganga 200m u/s of Sangam	6	5	6	5	7	6.0	5.6	6	6.6	6.3	5.8	6.06
Ganga 200m d/s of Sangam	9	9	8	6	3	5.7	5.1	5.7	6.8	5.9	5.5	5.8
Ganga 1 km d/s of STP outfall	4	3	2	3	2	2.3	5.4	6	6.4	6.1	5.9	5.96
Ganga 2 km d/s of STP outfall	2	2	3	2	8	4.3	5.7	5.8	6.3	6.1	5.9	5.96

City : Varanasi	BOD (mg/l) 2 m	20 m	W/4	W/2	3W/4	Average	DO (mg/l) 2 m	20 m	W/4	W/2	3W/4	Average
Varuna River 2 Km U/S of the City				44						3.8		
Varuna River 200 m U/S of the confluence with Ganga				45						2.5		
Ganga River 2 Km U/S of the City	6	5	7	9	6	6.6	5.9	6.3	6.8	7.2	7	6.64
Ganmga middle stretch	22	20	18	7	22	17.8	5.9	6.2	6.4	7.1	6.8	6.48
Ganga 200 m u/s of Varuna confluence	14	10	13	11	14	12.4	6.1	6.3	6.7	7	6.9	6.6
Ganga d/s of Varuna confluence	50	4	2	18	2	15.2	3	4.8	5.9	7.3	7	5.6
Ganga 1.5 km d/s of Varuna confluence	15	5	5	5	3	6.6	5.3	5.7	6.7	6.9	6.8	6.28
Ganga 200 m u/s of Gomati confluence			4	6	7	5.7			5.5	6.9	5.9	6.1
Ganga 1 km d/s of Gomti confluence			7	10	6	7.7			6	6.3	4.7	5.7

Monitoring carried out in May-June 2003.

CHAPTER 2 WATER QUALITY STANDARDS

2.1 REVISED CRITERIA FOR CLASSIFICATION OF INLAND WATER QUALITY PROPOSED BY CPCB

Table 2.1 Simple Parameters

Sl. No.	Parameters	Requirement for Waters of Class		
		A-Excellent	B-Desirable	C-Acceptable
(i)	Sanitary Survey	Very clean neighbourhood and catchment	Reasonably clean neighbourhood	Generally clean neighbourhood
(ii)	General Appearance	No floating matter	No floating matter	No floating matter
(iii)	Colour	Absolutely Colourless	Almost colourless, very light shade if any	No colour of anthropogenic origin
(iv)	Smell	Odourless	Almost odourless	No unpleasant odour
(v)	Transparency	>1.0m depth	>0.5m to 1.0m depth	>0.2m to 0.5m depth
(vi)	Ecological* (Presence of Animals)	Fish & insects	Fish and insects	Fish and insects

Note: ***Applicable to only surface water
Source : Water quality criteria and goals, CPCB, February, 2002

Table 2.2 Regular Monitoring Parameters

Sl. No.	Parameters	Requirement for Waters of Class		
		A-Excellent	B-Desirable	C-Acceptable
(i)	PH	7.0 to 8.5	6.5 to 9.0	6.5 to 9.0
(ii)	DO (% Saturation)	90 - 110	80 - 120	60 - 140
(iii)	BOD, mg/l	Below 2	Below 5	Below 8
(iv)	EC, pmhos/cm	<1000	<2250	<4000
(v)	NO_2 + NO_3) - Nitrogen, mg/l	<5	<10	<15
(vi)	Suspended Solid, mg/l	<25	<50	<100
(vii)	Faecal Coliform, MPN/100 ml	<20 per 100 ml	<200 per 100 ml	<2000 per 100 ml
(viii)	Bio-assay (Zebra Fish)	No death in 5 days	No death in 3 days	No death in 2 days

Note:
1) Dissolved Oxygen (DO) not applicable for ground waters
2) Dissolved oxygen in eutrophicated waters should include diurnal variation
3) Suspended solid limit is applicable only during non-monsoon period.
4) Faecal coliform values should meet for 90% times.
5) Static Bio-Assay method may be adopted.
Source : Water quality criteria and goals, CPCB, February, 2002

Table 2.3 Special parameters (Only in cases of need/apprehensions)

Sl. No.	Parameters	Requirement for Waters of Class		
		A-Excellent	B-Desirable	C-Acceptable
1	Total Phosphorous	<0.1 mg/l	<0.2 mg/l	<0.3 mg/l
2	T.K.N.	<1.0 mg/l	<2.0 mg/l	<3.0 mg/l
3	Total Ammonia (NH_4 + NH_3) - Nitrogen	<0.5 mg/l	<1.0 mg/l	<1.5 mg/l
4	Phenols	<2 µg/l	<5 µg/l	<10 µg/l
5	Surface Active Agents	<20 µg/l	<100 µg/l	<200 µg/l
6	Organo Chlorine Pesticides	<0.05 µg/l	<0.1 µg/l	<0.2 µg/l
7	PAH	<0.05 µg/l	<0.1 µg/l	<0.2 µg/l
8	PCB and PCT	<0.01 µg/l	<0.01 µg/l	<0.02 µg/l
9	Zinc	<100 µg/l	<200 µg/l	<300 µg/l
10	Nickel	<50 µg/l	<100 µg/l	<200 µg/l
11	Copper	<20 µg/l	<50 µg/l	<100 µg/l
12	Chromium (Total)	<20 µg/l	<50 µg/l	<100 µg/l
13	Arsenic (Total)	<20 µg/l	<50 µg/l	<100 µg/l
14	Lead	<20 µg/l	<50 µg/l	<100 µg/l
15	Cadmium	<1.0 µg/l	<2.5 µg/l	<5.0 µg/l
16	Mercury	<0.2 µg/l	<0.5 µg/l	<1.0 µg/l

Note: Failure to comply with one or more of the above limits shall imply assignment of the next lower class Source : Water quality criteria and goals, CPCB, February, 2002

2.2 DISCHARGE CRITERIA FOR WASTEWATERS USED FOR IRRIGATION

Table 2.4 Suggested Values for Major Inorganic Constituents in Water Applied to the Land

Problem and Related Consultant	Impact on the Land*		
	No Problem	Increasing Problem	Service
Salinity			
Conductivity of Irrigation Water Millimhos/cm	< 0.75	0.75 - 3.00	> 3.00
Permeability			
Conductivity of Irrigation Water Millimhos/cm	< 0.50	< 0.50	< 0.20
SAR	< 6.00	6.00 - 9.00	> 9.00
Specific lon Toxicity			
From root absorption			
Sodium (evaluated by SAR) me/l	< 3.00	3.00 - 9.00	> 9.00
Chloride, mg/l	< 4.00	4.00 - 10.00	> 10.00
Chloride, mg/l	< 142.00	142.00 - 355.00	> 355.00
Boron, mg/l	< 0.50	0.50 - 2.00	2.00 - 10.00
From foliar absorption (Sprinklers)			
Sodium, mg/l	< 3.00	> 3.00	-
Sodium, mg/l	< 69.00	> 69.00	-
Chloride, mg/l	< 3.00	> 3.00	-
Chloride, mg/l	< 106.00	> 106.00	-
Miscellaneous			-
NO_3 - N, NH_4 - N mg/l for sensitive crops	< 5.00	5.00 - 30.00	> 30.00
HCO_3 - mg/l (only with overhead sprinklers)	< 1.50	1.50 - 8.50	> 8.50
HCO_3 - mg/l	< 90.00	90.00 - 520.00	> 520.00
pH	Normal range 6.5 - 8.4		

* : Interpretations are based on possible effects of constituents on crops and/or soils. Suggested values are flexible and should be modified when warranted by local experience or special conditions of crop, soil and method of irrigation

.SAR : Sodium Absorption Ratio.

Source: Manual on sewerage and sewage treatment', CPHEEO, Ministry of Urban Development, Govt. of India, December 1993.

Table 2.5 Suggested Limits for Salinity in Irrigation Waters

Crop Response	Total Dissolved Solids mg/l	Electrical Conductivity mhos/cm
No detrimental effects will usually be noticed	500	0.75
Can have detrimental effects on sensitive crops.	500 - 1000	0.75 - 1.50
May have adverse effects on many crops.	1000 - 2000	1.50 - 3.00
Can be used for salt tolerant plants on permeable soils with careful management practices	2000 - 5000	3.00 - 7.50

Source : Manual on sewerage and sewage treatment', CPHEEO, Ministry of Urban Development, Govt. of India, December 1993.

Table 2.6 Maximum Permissible Concentration of Toxic Elements in Irrigation Waters

Element		Maximum Permissible Concentration (mg/l)	
		For water used continuously on all soils	For short term use of fine texture soils
Aluminium	Al	1.00	20.00
Arsenic	As	1.00	10.00
Beryllium	Be	0.50	1.00
Boron	B	0.75	2.00
Cadmium	Cd	0.01	0.05
Chromium	Cr	5.00	20.00
Cobalt	Co	0.20	10.00
Copper	Cu	0.20	5.00
Fluorine	F	0.00	10.00
Lead	Pb	5.00	20.00
Lithium	Li	5.00	5.00
Manganese	Mn	2.00	20.00
Molybdenum	Mo	0.01	0.05
Nickel	Ni	0.05	2.00
Selenium	Se	0.05	2.00
Vanadium	V	10.00	10.00
Zinc	Zn	5.00	10.00

Source : Manual on sewerage and sewage treatment', CPHEEO, Ministry of Urban Development, Govt. of India, December 1993.

CHAPTER 3 FIELD WORK CARRIED OUT FOR RIVER WATER QUALITY SAMPLING IN THE FOUR TOWN

3.1 VARANASI

The First town covered in this process was Varanasi. The field work was done between 8/5/2003 to 23/5/2003 during which all activities related to monitoring of river water quality, nala and sewer outfall measurement, sewage treatment plant monitoring and pollution load survey were carried out.

3.1.1 River

The locations of river water quality monitoring are:

1. Ganga River: 2 km upstream of the city
2. Ganga River : Middle Stretch of the city
3. Ganga River : 200 m upstream of the confluence with Varuna
4. Ganga River : 200 m downstream of the confluence with Varuna
5. Ganga River : 1.5 km downstream of the confluence with Varuna
6. Ganga River : 200 m upstream of the Confluence with Gomati
7. Ganga River : 1 km downstream of the Confluence with Gomati
8. Gomati River: 200 m upstream of the Confluence with Ganga

At each section samples were collected from multiple locations across the width. For the first five locations samples were taken at 2m, 50m, one-fourth width, mid-stream and at three quarter width respectively. For the last three locations, samples were taken at three transverse points that are one-fourth width, mid-stream and at three quarter width respectively. DO, pH and temperature were measured on the spot and for rest of of the parameters samples were preserved in the icebox and sent to Delhi for analysis.

3.1.2 STP

There are three STPs in Varanasi viz. :

1. Bhagwanpur
2. Dinapur
3. DLW

Hourly flow measurement was done at the inlet point of the STP over 24 hour and samples were drawn at 3 hour interval. Composite samples were prepared in proportion to the flow at the instant.

3.1.3 Nala and Sewers

Various Nalas which were supposed to be covered in this process were:

1. Telia Bagh Nala
2. Central Jail Nala
3. Orderly Bazar Nala
4. Chamruati Nala (substituted later by Naibasti nala)
5. Narokhar Nala
6. Varuna river 2 km u/s of city
7. Varuna River outfall into Ganga
8. Assighat Nala (Nagwa Nala)
9. Shivala Nala

10. Konia by-pass Sewer outfall

Flow measurement and sampling of all these nalas were done except Chamrauti Nala, because it was found that orderly bazaar nala and chamrauti nala were same. So instead of chamrauti nala, nala of Nai basti was taken and measured. In case of lower and moderate flows, measurement was by installing a V notch. Where the flow was found to be large, such as Konia by-pass, Varuna River and Narokhar Nala, current meter was used. Wastewater samples were taken at three hour intervals over 24 hour duration and composite sample was prepared in proportion to the flow at the instant.

3.1.4 Pollution Load Survey

Specific locations for pollution load survey were decided in consultation with the staff of Varanasi Jal Sansthan. Flow measurements were done for type 1 and type 2 that is area covered by sewerage network and unsewered area (gray water analysis) with the help of current meter and volume measurement method. Sample were taken at every 2 hour for 24 hours. For the others two categories of surveys only grab samples were taken.

Pollution Load Survey has been done on the following locations.

S. No.	Type of Survey	Location
1	Area served by sewerage network	Shastri nagar, Sigra
2	Gray water analysis in area not served by sewerage network	Central jail colony
3	Night soil analysis from a community toilet in area not served by sewerage network	Community Toilet with septic tank at Shivpur constructed by Sulabh International
4	Night soil analysis from an household toilet in an area not served by sewerage network	Central jail colony

3.2 ALLAHABAD

The Second town covered in this series was Allahabad. The duration of work in Allahabad was between 24/5/2003 to 3/6/2003. All the four aquatic environment systems as described in the case of Varanasi were monitored here as well.

3.2.1 River

The locations of river water quality monitoring are :

1. Yamuna River: 2 km upstream of the city
2. Yamuna River : 200 m upstream of the confluence with Ganga
3. Ganga River : 2 km upstream of the city
4. Ganga River : 200 m upstream of the confluence with Yamuna
5. Ganga River : 200 m downstream of the confluence with Yamuna
6. Ganga River : 1 km downstream of the STP nala outfall
7. Ganga River : 1 km downstream of the location 6

Samples were taken at five points across the width of the river. i.e., one eighth width, one fourth width, mid-stream, three quarter width, and (7/8) or 0.875 W. Same procedure as in case of Varanasi was adopted for sampling and chemical analysis.

3.2.2 STP

There is only one STP in Allahabad called Naini STP. Same procedure as in case of STPs in Varanasi was adopted for flow measurement and sample withdrawal.

3.2.3 Nala and Sewers

Various Nalas that were supposed to be covered in this process were

1. Main Ghaghar Nala
2. Chachar Nala
3. Emergency outfall drain
4. Morigate Nala
   (Substituted later by Salori nala-II, also called as Allengunj-Buxibund Nala)
5. Salori Nala
6. Rajapur Nala
7. Mawaiya Nala
8. Kodara Nala

Flow measurement and sampling of all these nalas were done except Morigate Nala, because it was found to be completely intercepted and diverted to the STP. Instead of this, Salori Nala II that is also called as Allengunj-Buxibund Nala was identified for measurement. The hourly flow measurement was done by V notches for lower flow values. In case of Mawaiya Nala that is away from the city and relatively inaccessible, current meter was used.

During the field survey it was found that Rajapur Nala was joining ADA colony nala before outfalling into river Ganga. Therefore on the site decision was taken to measure the combined flow with the help of a current meter. The combined flow in the data presented in the report is represented by the name of Rajapur-ADA colony Nala

3.2.4 Pollution Load Survey

Same procedure was followed as described in case of Varanasi. The survey has been done on the following locations.

S. No.	Type of Survey	Location
1	Area served by sewerage network	Allenganj
2	Gray water analysis in area not served by sewerage network	Fatehpur bichwa
3	Night soil analysis from a community toilet in area not served by sewerage network	Community Toilet with septic tank at Teliarganj constructed by Sulabh International
4	Night soil analysis from an household toilet in an area not served by sewerage network	Thornel road, campus area

3.3 LUCKNOW

The third town covered in this process was Lucknow. The duration of work was between 28/5/2003 to 11/6/2003. All the four aquatic environment systems as described in the case of Varanasi were monitored here as well.

3.3.1 River

The locations of river water quality monitoring are :

1. 2 km upstream of the city (u/s of the water intake point)
2. Middle stretch of the city
3. 2 km downstream of the city

The samples were taken at 0.25 W, 0.5 W and 0.75 W across the width of river. Same procedure as in case of Varanasi was adopted for sampling and chemical analysis.

3.3.2 STP

There is only one STP in Lucknow at Gaughat. Hourly flow measurement was done at the inlet point of the STP for 24 hours with the help of digital flow meter installed at the grit chamber and samples were taken at every 3 hours. Composite samples were prepared as per flow value.

3.3.3 Nala and Sewers

Various Nalas that were supposed to be covered in this process were

1. Sarkata Nala (substituted later by China Bazar nala)
2. Pata Nala (substituted later by Laplace nala)
3. Wazirganj Nala
4. Ghasiyari Mandi Nala
5. G.H. Canal
6. Daliganj U/S Nala
7. Kukrail Nala
8. Mohan Meaken Nala
9. Gomati Nagar Nala
10. Sewer outfall near Botanical Garden

Flow measurement and sampling of all these nalas were done except Sarkata and Pata Nala. Both of these nalas were found to be completely intercepted and diverted to the STP. In lieu of these two nalas, additional nalas were identified for measurement viz. China Bazaar and Laplace nala. However, in case of Wazirganj and Ghasiyari Mandi nalas it was found that the entire flow was being intercepted and lifted with the help of pumps but again discharged in to the river on the downstream near Botanical Gardens. In these cases, readings of the pumping station flow meter were recorded.

In case of nalas having bigger cross sections and carrying large quantity of wastewater, such as sewer outfall near botanical garden, Kukrail Nala and G.H Canal, velocity measurements were done by float method. Wastewater samples were taken at every three hour interval over 24 hour duration and composite sample was prepared in proportion to the flow at the instant.

3.3.4 Pollution Load Survey

Same procedure was followed as described in case of Varanasi. The survey has been done on the following locations.

S. No.	Type of Survey	Location
1	Area served by sewerage network	Napier road colony, thakurganj
2	Gray water analysis in area not served by sewerage network	Railway barrah colony, alambagh
3	Night soil analysis from a community toilet in area not served by sewerage network	Community Toilet with septic tank at Aanad nagar constructed by Sulabh International
4	Night soil analysis from an household toilet in an area not served by sewerage network	Railway barrah colony, alambagh

3.4 KANPUR

The fourth town, which was covered in this regard, was Kanpur. The duration of the work between 12/6/2003 to 18/6/2003. All the four aquatic environment systems as described in the case of Varanasi were monitored here as well.

3.4.1 River

The locations of river water quality monitoring are:

1. 2 km upstream of the city (u/s of Ranighat)
2. Middle stretch of the city
3. 2 km downstream of the city (d/s of Jajmau pumping station)

The samples were taken five points that are W/8, W/4, W/2, 3W/4 and 7W/8 across the width of the River. Same procedure as in case of Varanasi was adopted for sampling and chemical analysis.

3.4.2 STP

There are three STPs in Kanpur

1. 5 MLD UASB
2. 36 MLD UASB
3. 130 MLD ASP

In case of the 5 MLD plant, hourly flow was measured at the proportional weir installed at the inlet of the STP. In case of the 36 MLD plant, hourly flow was measured with the help of flow meters installed at the pumping station and in case of the 130 MLD plant, measurements were done with help of digital flow meter installed at the inlet. Samples were taken at every 3 hours. Composite samples were prepared as per flow value.

3.4.3 Nala and Sewers

Various Nalas which were supposed to be covered in this process were :

1. Guptar ghat Nala
2. Muir mill Nala
3. Sisamau Nala
4. Nawabganj Nala (Substituted later by Ranighat Nala)
5. Jageswar Nala
6. Ganga Nala
7. COD Nala
8. Pandu River (100m u/s of confluence with Ganga)

During the field survey, it was found that Nawabganj Nala was completely intercepted and diverted to the STP. Therefore, another nala called Ranighat Nala was selected for measurement. In case of Sisamau Nala float method for velocity measurement was used whereas for Pandu River current meter was used. Samples were taken at every three hour interval over 24 hour duration and composite sample was prepared as per flow values.

3.4.4 Pollution Load Survey

Same procedure was followed as described in case of Varanasi. The survey has been done on the following locations.

S. No.	Type of Survey	Location
1	Area served by sewerage network	Navsheel apartment, VIP road
2	Gray water analysis in area not served by sewerage network	LIC colony, Sharda nagar
3	Night soil analysis from a community toilet in area not served by sewerage network	Community Toilet with septic tank at shukla ganj constructed by Sulabh International
4	Night soil analysis from an household toilet in an area not served by sewerage network	LIC colony, Sharda nagar

Appendix B

APPENDIX B

RIVER WATER POLLUTION CONTROL PLANNING

Table of Contents
List of Tables
List of Figures

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION............ B-1

1.1 GENERAL............ B-1
1.2 SCOPE OF THE STUDY............ B-2

CHAPTER 2 CLIMATE AND RIVER FLOW............ B-3

2.1 CLIMATE............ B-3
2.1.1 Available Data............ B-3
2.1.2 Climatic Characteristics of the Study Area............ B-3
2.2 RIVER SYSTEM............ B-4
2.3 RIVER FLOW RATE............ B-6
2.3.1 Available Data............ B-6
2.3.2 Seasonal Variation of River Flow Rate............ B-6

CHAPTER 3 EXISTING RIVER WATER QUALITY............ B-7

3.1 AVAILABLE WATER QUALITY DATA............ B-7
3.1.1 Sampling Location and Frequency............ B-7
3.1.2 Water Quality in the Past............ B-7
3.2 EVALUATION OF PRESENT WATER QUALITY............ B-10
3.2.1 Ganga Main River............ B-10
3.2.2 Yamuna River............ B-12
3.2.3 Gomati River System and Other Major Tributaries............ B-13
3.2.4 Seasonal Variation of River Water Quality............ B-13
3.2.5 Past River Water Quality Trend of Ganga............ B-14
3.3 RIVER WATER QUALITY STANDARDS............ B-14

CHAPTER 4 EXISTING WASTEWATER QUALITY IN THE STUDY AREA............ B-16

4.1 WASTEWATER QUALITY B-16
4.1.1 Sewerage Wastewater Quality after Treatment B-16
4.1.2 Wastewater Quality of Nala B-16
4.2 STANDARD OF WASTEWATER QUALITY B-16

CHAPTER 5 INVENTORY OF POLLUTION LOAD GENERATION IN THE ENTIRE GANGA BASIN B-17

5.1 GENERAL B-17
5.2 METHODOLOGY OF INVENTORY B-17
5.2.1 Data Collection Related to River Water Pollution B-18
5.2.2 Objective River Sub-basin B-18
5.2.3 Modeling of Entire Ganga Basin B-19
5.2.4 Linkage with GIS B-20
5.3 EXISTING POLLUTION LOAD GENERATION B-20
5.3.1 Point Pollution Load Generation B-20
5.3.2 Non-point Pollution Load Generation B-29
5.3.3 Total Existing Pollution Load Generation B-33
5.4 FUTURE POLLUTION LOAD GENERATION WITHOUT PROJECT B-35
5.4.1 Basis for Future Frame of Population / Economic Growth B-35
5.4.2 Future Point Pollution Load Generation B-38
5.4.3 Future Non-point Pollution Load Generation B-38
5.4.4 Total Future Pollution Load Generation B-38
5.5 FORMULATION OF BASIN RUNOFF MODEL B-39
5.5.1 Skeleton of Basin Runoff Model B-40
5.5.2 Schematic Diagram for Entire Ganga Basin B-41
5.5.3 Runoff Coefficient B-41
5.5.4 Self-purification Model of Main River Water B-45
5.6 EXISTING POLLUTION LOAD RUNOFF B-45
5.7 FUTURE POLLUTION LOAD RUNOFF WITHOUT PROJECT B-47
5.7.1 Point Pollution Load Runoff B-47
5.7.2 Non-point Pollution Load Runoff B-47
5.7.3 Total Future Pollution Load Runoff B-47
5.8 OBJECTIVE RIVER STATION AND STANDARD FLOW RATE B-48
5.8.1 Objective River Station B-48
5.8.2 Standard River Flow Rate B-48
5.9 DISTRIBUTION OF RIVER WATER POLLUTION IN GANGA BASIN B-49
5.9.1 Distribution of Pollution Load Runoff B-49
5.9.2 Simulated Existing/Future River Water Quality B-49

5.9.3 On-going/Planned Project for Pollution Abatement B-51
5.9.4 Main Target Area for Detail Study B-53

CHAPTER 6 SIMULATION OF RIVER WATER QUALITY FOR DETAILED STUDY ON THE OBJECTIVE BASIN B-54

6.1 FORMULATION OF DETAILED SIMULATION MODEL B-54
6.1.1 Objective Basin for Water Quality Simulation B-54
6.1.2 Selection of Water Quality Parameter B-54
6.1.3 Basis of Detail Simulation for Selected Parameters B-54
6.1.4 QUAL2E Simulation Model B-56
6.1.5 Lateral Distribution Analysis B-59
6.1.6 Basic Condition of Objective Area B-59
6.2 INPUT DATA FOR SIMULATION B-61
6.2.1 Objective Main River Station and River Flow B-61
6.2.2 Simulation Constant and Coefficient B-61
6.2.3 Existing Condition of Pollution Load Generation B-61
6.2.4 Future Condition of Pollution Load Generation B-62
6.3 SIMULATED RIVER WATER QUALITY B-62
6.3.1 Simulated Existing River Water Quality B-62
6.3.2 Simulated Future River Water Quality B-62

CHAPTER 7 SCENARIO FOR POLLUTION LOAD REDUCTION B-64

7.1 POLLUTION LOAD BALANCE IN 2030 .... B-64
7.2 CITY WISE POLLUTION LOAD REDUCTION B-65
7.2.1 General B-65
7.2.2 Breakdown of Cities B-66
7.3 RECOMMENDATION FOR THE SEWERAGE DEVELOPMENT IN THE UPSTREAM AREA B-69
7.4 STUDY ON IMPROVEMENT OF HYGIENIC CONDITION B-70
7.4.1 General B-70
7.4.2 Japanese Case Study on Bacterial River Water Quality B-73
7.4.3 Longitudinal Profile of Coliform Number B-76
7.4.4 Simulation Study for Faecal Coliform Number B-77
7.5 JAPANESE SCHEME OF POLLUTION CONTROL AND WATER QUALITY MANAGEMENT B-85
7.5.1 Current Situation of River Pollution in India B-85
7.5.2 Regulation of Total Maximum Daily Loading B-86
7.5.3 Case Study of Comprehensive Pollution Control in Japan B-88

CHAPTER 8 IMPROVEMENT OF WATER QUALITY MONITORING B-90

8.1 RELEVANT ORGANIZATION FOR WATER QUALITY MONITORING B-90
8.1.1 Organization B-90
8.1.2 Laboratories and Staff Involved in Water Quality Monitoring................................ B-90
8.2 EXISTING MONITORING SYSTEM.. B-91
8.2.1 Water Quality Monitoring Network B-91
8.2.2 Sampling Locations for Water Quality Monitoring.. B-91
8.2.3 Water Quality Sampling Covered by each Organization.. B-92
8.2.4 Wastewater Quality Monitoring of Sewerage Effluent B-92
8.2.5 Parameters to be monitored... B-92
8.2.6 Existing Monitoring Equipment... B-92
8.2.7 Analytical Data Management... B-92
8.3 CURRENT ISSUES ENCOUNTERED IN WATER QUALITY MONITORING.......... B-93
8.3.1 Technical Problems B-93
8.3.2 Administrative Problems... B-93
8.3.3 Scarcity of Capacity of Optimum Monitoring Activities B-94
8.3.4 Analytical Quality Control (AQC)... B-95
8.4 MONITORING PROGRAM FOR GANGA RIVER BY UPPCB B-95
8.4.1 Existing Laboratory Conditions in 4 Cities.. B-95
8.4.2 Issues Related To Laboratory Performance Improvement B-96
8.5 RECOMMENDATIONS B-97
8.5.1 Capacity Building for Optimum Monitoring.. B-97
8.5.2 Current Monitoring Station B-99

REFERENCES B-101

LIST OF TABLES

Table 2.1 Available Data for Climatic Information B-3
Table 2.2 Annual Rainfall in Ganga Basin B-3
Table 3.1 Available River Water Quality Data B-7
Table 3.2 Relevant Agency for NRCD's Monitoring of Ganga B-7
Table 3.3 Average River Water Quality B-9
Table 3.4 90 Percentile River Water Quality B-10
Table 3.5 Existing River Water Quality at Allahabad and Varanasi B-11
Table 3.6 Average and 90% Water Quality of Main Tributary at Lowest Point B-14
Table 3.7 River Water Quality Standard B-15
Table 3.8 Desired Water Quality Criteria of 4 Cities B-15
Table 5.1 Objective River System and Sub-basins B-19
Table 5.2 Area of Each State Covered in Each River System B-19
Table 5.3 Various BOD Unit Pollution Load B-21
Table 5.4 Wastewater Generation Standards B-24
Table 5.5 Unit Wastewater Loads for Discharges from Slaughterhouse B-24
Table 5.6 Predominant Categories of Water Polluting Industries B-25
Table 5.7 Top ten districts in terms of BOD load generation in the Ganga basin B-26
Table 5.8 Statewise Industrial BOD Load Distribution B-26
Table 5.9 River System Wise Population and Its Density B-27
Table 5.10 Basin/ Sub-basin wise Industrial BOD Load Distribution in the Study Area B-28
Table 5.11 Unit BOD Pollution Load Generation from Non-point Sources B-30
Table 5.12 Area of Each Land Use Category B-30
Table 5.13 Percentage of Total Area under Each Land Use Category B-31
Table 5.14 Total Number of Livestock in Each River System B-33
Table 5.15 Total Number of Urban Livestock in River Systems B-33
Table 5.16 Pollution Load Generation from Each River System B-33
Table 5.17 Density of Pollution Load Generation in Each River System B-34
Table 5.18 (a) Future Population in Each River System (2010) B-35
Table 5.19 (b) Future Population in Each River System (2015) B-35
Table 5.20 (c)Future Population in Each River System (2030) B-36
Table 5.21 Future Growth Rate of Industry B-38
Table 5.22 Future Pollution Load Generation (Without Project) B-38
Table 5.23 Future Pollution Load Generation (With Project) B-39
Table 5.24 Various Runoff Coefficient B-42

Table 5.25 Relation Between Flow Rate and Runoff Coefficient B-42
Table 5.26 Estimated Unit Self-purification Rate B-43
Table 5.27 Case Study of River Flow Velocity... B-44
Table 5.28 River Flow Velocity Measured by CPCB... B-44
Table 5.29 Adopted Runoff Coefficient B-45
Table 5.30 Existing Pollution Load Runoff... B-46
Table 5.31 Density of Pollution Load Runoff B-46
Table 5.32 Future Pollution Load Runoff (Without Project).. B-47
Table 5.33 Future Pollution Load Runoff (With Project)... B-48
Table 5.34 Objective River Station.. B-48
Table 5.35 Standard River Flow at Each Station... B-49
Table 5.36 Simulated Water Quality for the year 2001 (1).. B-49
Table 5.37 Simulated Water Quality for the year 2001 (2).. B-50
Table 5.38 Simulated Future Water Quality for Years 2015 and 2030 (1) B-50
Table 5.39 Simulated Future Water Quality for Years 2015 and 2030 (2) B-50
Table 5.40 Simulated Future Water Quality (1)... B-50
Table 5.41 Simulated Future Water Quality (2)... B-51
Table 5.42 Sewerage Development by GAP Phase I and YAP.. B-51
Table 5.43 GAP Phase-II and Works in Tributaries... B-52
Table 6.1 Components of QUAL2E Model.. B-57
Table 6.2 Urban Populations in 4 Cities... B-60
Table 6.3 Sampling Location of Water Quality Monitoring... B-61
Table 6.4 Simulated Future River Quality.. B-62
Table 7.1 Pollution Load Balance (2030)... B-64
Table 7.2 Impact of Domestic Pollution Load.. B-65
Table 7.3 Estimated Future BOD Values in Various Scenarios B-66
Table 7.4 Aerobic Bacteria in Human Faeces B-71
Table 7.5 Japanese Regulation/Guideline for the Hygiene Condition.. B-75
Table 7.6 Unsatisfactory Ratios for Coliform Criteria in Japan (1997) B-75
Table 7.7 Existing Faecal Coliform Number of Major Tributaries B-79
Table 7.8 Simulated Existing Water Quality (Ganga) B-79
Table 7.9 Simulated Existing Water Quality (Yamuna).. B-79
Table 7.10 Simulated Existing Water Quality (Gomati).. B-79
Table 7.11 Future Faecal Coliform Number of Major Tributaries B-81
Table 7.12 Simulated Future Water Quality in Case of Without Project (Ganga).......................... B-81
Table 7.13 Simulated Future Water Quality in Case of Without Project (Yamuna) B-81
Table 7.14 Simulated Future Water Quality in Case of Without Project (Gomati) B-82
Table 7.15 Simulated Future Faecal Coliform Number in Case of With Project (Ganga) B-82

Table 7.16 Simulated Future Faecal Coliform Number in Case of With Project (Yamuna)........... B-82
Table 7.17 Simulated Future Faecal Coliform Number in Case of With Project (Gomati)............ B-82
Table 7.18 Relation between Future Faecal Coliform and Various Scenarios (1).......................... B-83
Table 7.19 Relation between Faecal Coliform and Simulation Cases B-83
Table 7.20 Relation between Future Faecal Coliform and Various Scenarios (2).......................... B-84
Table 8.1 Staff Line-up for each Laboratory B-90
Table 8.2 Distribution of Water Quality Monitoring Stations in Ganga Basin............................... B-91
Table 8.3 Procurement Cost B-98
Table 8.4 Additional Annual O&M Cost... B-98
Table B.3.1(1) The Study on Water Quality Management Plan for Ganga River in the Republic of India.. B-103
Table B.4.1 Performance Evaluation of CETP and STPs at Kanpur(Oct-Nov 2002) B-106
Table B.4.2 Characteristics of Untreated and Treated Sewage of Dinapur Sewage Treatment Plant B-107
Table B.4.3 Available Sewerage Wastewater Quality in 4 Cities B-108
Table B.4.4 General Standards for Discharge of Pollutants Part-A: Effluents (The Environment (Protection) Rules, 1986) B-110
Table B.4.4 Waste Water Generation Standards Part-B...B-111
Table B.5.1 Basic Information of Each Sub-basin B-112
Table B.5.2 Total Georaphical Area of Various State Covered under Each Sub-basin..................B-113
Table B.5.3 Sub-basin Wise Population in Ganga Basin..B-114
Table B.5.4 Land Use Area in Sub-basins..B-119
Table B.5.5 Sub-basin Wise Livestock Head Number B-120
Table B.5.6 Livestock Pollution Load of Each Sub-Basin(Generated Pollution Load) B-121
Table B.5.7 Sub-basin Wise Existing Pollution Load Generation..B-122
Table B.5.8 Past and Future Population in Each State B-123
Table B.5.9 2015 Without Project Pollution Load Generation...B-124
Table B.5.10 2030 Without Project Pollution Load Generation...B-125
Table B.5.11 2015 With Project Pollution Load Generation..B-126
Table B.5.12 2030 With Project Pollution Load Generation..B-127
Table B.5.13 Sub-basin Wise Existing Pollution Load Runoff B-128
Table B.5.14 2015 Without Project Pollution Load Runoff B-129
Table B.5.15 2030 Without Project Pollution Load Runoff B-130
Table B.5.16 2010 With Project Pollution Load Runoff B-131
Table B.5.17 2030 With Project Pollution Load Runoff B-132
Table B.5.18 Density of Population, Pollution Load Generation and Runoff of Each Sub-basin........... ....B-133
Table B.6.1 Input Data of Kanpur for Detail Simulation(QUAL2E)Model.................................B-134

Table B.6.2 Input Data of Allahabad for Detail Simulation(QUAL2E)Model B-137
Table B.6.3 Input Data of Varanasi for Detail Simulation(QUAL2E)Model B-140
Table B.6.4 Input Data of Lucknow for Detail Simulation(QUAL2E)Model B-143
Table B.6.5 Simulated Existing River Water Quality..B-145
Table B.6.6 Simulated Future River Water Quality...B-146
Table B.6.7 Estimation of Flow Rate of Nalas at Kanpur B-151
Table B.6.8 Estimation of Flow Rate of Nalas at Allahabad...B-154
Table B.6.9 Estimation of Flow Rate of Nalas at Varanasi B-156
Table B.6.10 Estimation of Flow Rate of Nalas at Lucknow..B-158
Table B.7.1 Future Population and Reaching Pollution Load B-160
Table B.7.2 Monitoring Station Wise Relation between Pollution Reduction and Future Water Quality B-162
Table B.7.3 Necessary Pollution Reduction for Objective 4 Cities..B-163
Table B.8.1 Relevant Laboratories Involved in Water Quality Monitoring B-164
Table B.8.2 Coverage Area and Resposibility of each Laboratory...B-165
Table B.8.3 Existing/Required Analytical Equipment and Sampling Tools in the CPCB's Laboratory B-166
Table B.8.4 Existing Equipments & Sampling Tools in the U.P.PCB's Laboratories B-168
Table B.8.5 Procurement of Additional Equipment for Water Quality Analysis(for CPCB) B-170
Table B.8.6 Procurement of Additional Equipment for Water Quality Analysis (for U.P.PCB) B-171
Table B.8.7 Existing/Additional Water Quality Monitoring Stations in 4 Cities B-172
Table B.8.8 Necessary Water Quality Monitoring Stations in the Entire Ganga Basin.................B-173

LIST OF FIGURES

Figure 5.1 Linkage with GIS B-20
Figure 5.2 Population Density B-28
Figure 5.3 Ratio of Each Category Pollution Load Generation B-34
Figure 5.4 Density of Pollution Load Generation B-34
Figure 5.5 Industrial Growth Rates During Last Eight Years B-37
Figure 5.6 Basic Concept for Basin Runoff Model B-40
Figure 5.7 Skeleton of Basin Runoff Model B-41
Figure 5.8 River Flow Rate and Runoff Coefficient Curve B-43
Figure 5.9 Ratio of Each Pollution Load Runoff B-46
Figure 5.10 Density of Pollution Load Runoff B-47
Figure 5.11 City-wise Reaching Domestic Pollution Load to Trighat B-53
Figure 7.1 Descending Order of Urban Population in 2030 (Ganga Basin) B-66
Figure 7.2 City Wise Reaching Pollution Load to Kanpur (Ganga) B-67
Figure 7.3 City Wise Reaching Pollution Load to Allahabad (Ganga) B-67
Figure 7.4 City Wise Reaching Pollution Load to Allahabad (Yamuna) B-68
Figure 7.5 City Wise Reaching Pollution Load to Varanasi (Ganga) B-68
Figure 7.6 Death-rate Curves of Coliform Organisms B-72
Figure 7.7 Total Coliform Number and BOD Curve in Ganga Basin B-73
Figure 7.8 Total Coliform Number and BOD Curve in Tama River B-74
Figure 7.9 Longitudinal Profile of Coliform (Ganga Main) B-76
Figure 7.10 Longitudinal Profile of Coliform (Yamuna Main) B-77
Figure 7.11 Longitudinal Profile of Coliform (Gomati River) B-77
Figure 7.12 Faecal Coliform Number after Sewerage Treatment B-80
Figure 7.13 BOD and Faecal Coliform Curve B-81
Figure 7.14 Simulated Longitudinal Profile of Faecal Coliform (Using 2.5% Ratio) B-85
Figure 7.15 Pollution Load Reductions in Japan B-88
Figure 7.16 Historical Industrial Pollution Load Reduction B-88
Figure B.2.1 Seasonal Variation of Temperature, Relative Humidity and Rainfall(1) B-174
Figure B.2.1 Seasonal Variation of Temperature, Relative Humidity and Rainfall(2) B-175
Figure B.2.2 Divided 6 Major Sub-basins(River System)and 38 Sub-basins B-176
Figure B.2.3 CWC RIVER FLOW MONITORING SITES B-177
Figure B.2.4 Seasonal Variation of River Flow Rate B-178
Figure B.3.1 CPCB RIVER WATER QUALYTY MONITORING LOCATIONS B-179
Figure B.3.2 Longitudinal Profile of River Water Quality(Ganga River) B-180

Figure B.3.3 Longitudinal Profile of River Water Quality(Yamuna River) B-181
Figure B.3.4 Longitudinal Profile of River Water Quality(Gomati River) B-182
Figure B.3.5 Seasonal Variation of River Water Quality..B-183
Figure B.3.6 River Water Quality Trend(1)..B-184
Figure B.3.6 River Water Quality Trend(2)..B-185
Figure B.3.6 River Water Quality Trend(3)..B-186
Figure B.3.6 River Water Quality Trend(4)..B-187
Figure B.5.1 Sub-basin Wise Population Distribution B-188
Figure B.5.2 Sub-basin Wise Population Density B-189
Figure B.5.3 Sub-basin Wise Pollution Load Generation B-190
Figure B.5.4 Schematic Diagram of the Simulation of Pollution Load Runoff and Water Quality B-191
Figure B.5.5 Existing Pollution Runoff of Each Sub-basin B-192
Figure B.5.6 Density Pollution Load Runoff of Each Sub-basin B-193
Figure B.5.7 UNIT AREA POLLUTION LOAD RUNOFF(2003) B-194
Figure B.6.1 Location of Objective 4 Cities for Detail Simulation..B-195
Figure B.6.2 Schematic Diagram for Kanpur...B-196
Figure B.6.2 Schematic Diagram for Allahabad B-197
Figure B.6.2 Schematic Diagram for Varanasi B-198
Figure B.6.2 Schematic Diagram for Lucknow...B-199
Figure B.7.1 Pollution Impact against Ganga River(Domestic Pollution Load)...........................B-200
Figure B.7.2 City Location of Upstream Area of Ganga Basin..B-201
Figure B.7.3 Schematic Diagram for Simulation of Faecal Coliform(QUAL2E Model) B-202
Figure B.7.4 Simulated Longitudinal Projile of Coliform Number(2001)...................................B-203
Figure B.7.5 Simulated Longitudinal Profle of Coliform Number(Existing & 2030 Without).....B-204
Figure B.7.6 Location of CPCB Monitoring Stations on River Ganga B-205
Figure B.7.7 Location of CPCB Monitoring Stations on River Yamuna & Ganga B-206
Figure B.7.8 Location of CPCB Monitoring Stations on River Ganga B-207
Figure B.7.9 Location of CPCB Monitoring Stations on River Gomati B-208
Figure B.7.10 Pollution Control Scheme in Japan B-209
Figure B.8.1 Organization Chart of CPCB...B-210
Figure B.8.2 Organization Chart of UPPCB B-211

APPENDIX B RIVER WATER POLLUTION CONTROL PLANNING

CHAPTER 1 INTRODUCTION

1.1 GENERAL

The Ganga River, being a lifeline for millions of people, is aptly called "River of India" or "Mother of India". The river runs through a distance of about 2500 km, draining an area of approximately 840,000 km^2 in India and supporting life throughout its basin. The Ganga Basin covers slightly more than 25% of the country's total geographical area, and is the largest river basin in India. The Ganga basin stretches through the whole Uttar Pradesh, Delhi and parts of Haryana, Himachal Pradesh, Uttaranchal, Rajasthan, Madhya Pradesh, Bihar, Jharkhand, West Bengal and Chhatisgarh. The main river, starting in the northernmost part of Uttar Pradesh, flows through the states (provinces) of Uttar Pradesh, Bihar, and West Bengal and finally drains into the Bay of Bengal.

The Ganga River has a large number of tributaries, some of which have their origin in the Himalayas and have considerably large water wealth. The important tributaries within India are the Ramganga, the Yamuna, the Gomati, the Ghaghra, the Gandak, Kosi, etc. The Yamuna although a tributary of the Ganga, is virtually a river by itself. The major tributaries of River Yamuna include the Chambal, the Sind, the Betwa and the Ken. The main plateau tributaries of the Ganga are the Tons, the Son, the Damodar and the Haldi.

The water quality of Ganga Main River worsens during drought time due to the decrease of dilution and self-purification effects of the river water. It already exceeds the criteria in the middle reach of Ganga Main River, and the river water is much more polluted at immediately downstream of Kanpur City, Allahabad and Varanasi due to the large quantity of untreated domestic and industrial wastewater effluent it receives from these cities. The water of Yamuna River is also much affected by the untreated industrial and domestic wastewater discharged into this river from Delhi and Agra.

Moreover, the Gomati River is also much polluted because the river flow rate is inadequate and very low during the dry season and hence has less dilution effect. In addition, these river systems receive pollution load from the entire basin. Varanasi, a holy area famous for ablutions, is located in the middle reaches of the Ganga Main River, where water pollution control is also necessary to preserve the hygienic condition of river water.

The major point pollution sources of various rivers in the Ganga Basin are the sewerage and industrial wastewater from the numerous urban centers. The contributing urban centers whose population is more than one million are shown in Table 1.1.

Table1.1 Main Large Cities in the Ganga Basin

Receiving Water	Urban Centers (Point Pollution Sources)
Ganga Main River	Kanpur, Allahabad, Varanasi, Patna, Kolkata
Yamuna River	Delhi, Agra, Jaipur, Indore, Bhopal
Gomati River	Lucknow

The pollution mechanism of rivers is complicated. Not all of the pollution loads generated from the basins run off into the rivers. Especially, most of the non-point pollution load infiltrates into the ground or is self-purified in the lands/ditches/channels before it enters the river. Even the pollution load entering the rivers gradually decrease toward downstream due to the self-purification effects of river water. Hence, an elaborate analysis of the pollution mechanism in the river basins is essential to assess the river water quality at the objective river sections.

1.2 SCOPE OF THE STUDY

This Appendix B covers the following major scopes of the Study:

(1) The identification of existing river systems in the Study Area and the analysis of river flow rates at the principal stations in order to obtain the bases for the analysis of pollution mechanism of the river water and for the evaluation of the river water quality;
(2) The analysis of existing river water quality based on data collected as well as those actually observed in the course of the Study in order to evaluate the level of river water quality;
(3) The analysis of existing industrial and sewerage wastewater qualities based on the data collected and actually observed in the course of the Study in order to evaluate the point pollution load generation in the basin;
(4) The estimation of existing and future pollution loads generated in the basin, including point sources (industrial and sewerage wastewater) and non-point sources (wastewater of rural households, livestock, lands and so on);
(5) The construction of an integrated basin runoff simulation model covering pollution load runoffs from the basins to the rivers and the dilution/self-purification effects of the river water in order to analyze the existing pollution mechanism of the river water and to predict the future water quality at the principal river sections;
(6) The construction of detail simulation model covering 4 cities in order to estimate the existing river water pollution and predict the future river water quality at the objective points; and
(7) The estimation of pollution reduction effects of proposed sewerage wastewater treatment schemes.

CHAPTER 2 CLIMATE AND RIVER FLOW

2.1 CLIMATE

2.1.1 Available Data

The meteorological conditions in the Study Area are observed by the Indian Meteorological Department. The observation data of 10 stations as shown in Table 2.1 are employed in the Study to establish the existing climatic conditions of the Study Area, since 10 stations represent entire part of the whole basin, respectively [1)].

Table 2.1 Available Data for Climatic Information

No.	Station Name	Location (State)	Period
1	Shimla	Himachal Pradesh	1978-1987
2	Dehradun	Uttaranchal	1981-1998
3	New Delhi	New Delhi	1991-2001
4	Jaipur	Rajasthan	1990-2000
5	Lucknow	Uttar Pradesh	1989-2000
6	Patna	Bihar	1985-2000
7	Bhopal	Madhya Pradesh	1986-1995
8	Ranchi	Jharkhand	1980-2000
9	Kolkata	West Bengal	1987-1999
10	Raipur	Chhattisgarh	1985-1994

2.1.2 Climatic Characteristics of the Study Area

(1) Temperature

The temperature of the Study Area widely changes throughout the year, recording the highest in May and lowest in January. The monthly mean temperature is in the range of 20.0 ℃ to 39.9 ℃ at New Delhi, 9.3 ℃ to 24.3 ℃ at Shimla, 22.3 ℃ to 40.4 ℃ at Lucknow and 28.7 ℃ to 42.4 ℃ at Raipur. As for the seasonal variation of monthly average temperature, see Figure B.2.1.

(2) Humidity

The annual average humidity of the Study Area is 57.8% at New Delhi, 58.2% at Shimla, 63.8% at Lucknow and 55.7% at Raipur. As for the seasonal variation of monthly average relative humidity, see Figure B.2.1.

(3) Rainfall

The average annual rainfall is tabulated in Table 2.2.

Table 2.2 Annual Rainfall in Ganga Basin

No.	Station Name	Location (State)	Annual Rainfall (mm)
1	Shimla	Himachal Pradesh	1,491
2	Dehradun	Uttaranchal	1,880
3	New Delhi	New Delhi	758
4	Jaipur	Rajasthan	529
5	Lucknow	Uttar Pradesh	881
6	Patna	Bihar	1,175
7	Bhopal	Madhya Pradesh	1,153
8	Ranchi	Jharkhand	1,518
9	Kolkata	West Bengal	1,894
10	Raipur	Chhattisgarh	1,308

Rainfall in the Study Area concentrates in the monsoon season (July- September). The lowest monthly rainfall is recorded in November and December. As for the seasonal variation of monthly rainfall, see Figure B.2.1.

2.2 RIVER SYSTEM

The Ganga drainage area within India is divided into three (3) main basins; namely, Upper Ganga River Basin, Middle Ganga River Basin and Lower Ganga River Basin, which are further subdivided into 38 sub-basins. The subdivided drainage basins in the Study Area are shown in Figure B.2.2. As for the area of each sub-basin (within the Study Area), see, Table B.5.1.

On the other hand, taking the main tributaries of the Ganga River in India into consideration, the Ganga drainage area can be divided into the following six (6) river systems

(1) Upper Ganga Main River System

The Upper Ganga Main River and its tributaries, namely, Ramganga and Kalinadi, drain the upper part of the Ganga Main Basin. Starting from the country boundary between China and India, the Upper Ganga Main River flows through Haridwar City down to the principal river station named Kannauj for a distance of 63 km. At Haridwar, huge quantity of river water is withdrawn into Ganga Canal for irrigation and domestic use. This river system has four (4) sub-basins: Upper Ganga I (17,170 km^2), Upper Ganga II (19,799 km^2), Ramganga (30,841 km^2) and Kalinadi (12,775 km^2).

None of the major tributaries discharge into this 58 km stretch until Kannauj; the flood plains drain directly into this Upper Ganga Main River, which has a total drainage area of 36,969 km^2. The Kalinadi drains an area of 12,775 km^2 into the Ganga Main River at Kannauj Town. The Ramganga River, with a basin area of 30,841 km^2, joins the Ganga River also at Kannauj Town from the north.

After the confluence of these rivers, the water flows down the middle stretch of the Ganga Main River. Hence, the Upper Ganga Main River along with its tributaries drains a total area of 80,585 km^2 (Basin upstream of Kannauj: Upper Ganga Main River Basin).

(2) Middle Ganga Main River System

The Middle Ganga Main River is defined as the stretch from the downstream of Kannauj City up to the downstream of the confluence point of the Gomati River at Ghazipur (Basin upstream of Ghazipur: Middle Ganga Main River Basin). In this stretch, Ganga Main River is joined by Yamuna River at Allahabad City, Tons River before Mirzapur Town and Gomati River before Ghazipur Town. In addition to this, many drainage channels with sewage and factory effluent flow into this stretch, especially from cities like Kanpur, Allahabad and Varanasi.

The Middle Ganga Basin can be divided into five (5) sub basins: Middle Ganga I (3,686 km^2), Middle Ganga II (4,918 km^2), Middle Ganga III (2,623 km^2), Middle Ganga IV (7,608 km^2) and Tons (17,530 km^2).

A total of 36,365 km^2 is drained by this lower 1000 km stretch of the river (Basin downstream of Kannauj: Middle Ganga Main River Basin).

(3) Lower Ganga Main River System

In the lower part of the Study Area (downstream of Ghazipur), the Ganga River is joined by the flow from rivers such as Sone, Punpun, Falgu, Ghaghra, Gandak, Burhi Gandak and Kosi until the country boundary between India and Bangladesh. Shortly before the country boundary, the Ganga River bifurcates and flows down in West Bengal with some extent of river flow. In this river stretch, Ganga River is joined by many tributaries; namely, the rivers of Dwarka, Jalangi, Ajay, Damodar, Rupnarayan and Haldi from the drainage basin. The Lower Ganga Main River can be divided into seventeen (17) sub-basins: Karmanasa (2,612 km^2), Ghaghra (68,378 km^2), Sone (81,955 km^2), Punpun (5,786 km^2), Kiul (2,881 km^2), Falgu (15,117 km^2), Gandak (7,079 km^2), Burhi Gandak (17,798 km^2), Kosi (17,838 km^2), Dwarka (10,515 km^2), Jalangi (4,234 km^2), Ajay (14,150 km^2), Damodar (22,432 km^2), Rupnarayan (6,800 km^2), Haldi (18,222 km^2), Lower Ganga I (22,873 km^2) and Lower Ganga II (6,552 km^2). A total of 319,729 km^2 is drained by this lower 1000 km stretch of the river (Basin downstream of Ghazipur: Lower Ganga Main River Basin).

(4) Upper Yamuna River System

Yamuna River originates from the Yamunotri glacier near Badar Punch in the Mussoori Range of the Himalayas. Further flowing down, at Hathnikund, huge quantity of river water is withdrawn into East and West Yamuna Canals for irrigation and domestic use.

The Upper Yamuna River drains four (4) sub-basins: Upper Yamuna I (11,757 km^2), Upper Yamuna II (33,660 km^2), Upper Yamuna III (56,126 km^2) and Hindon (7,121 km^2). The upper part of Yamuna River (upstream of Etawah) is joined by the Hindon River after Delhi. Stretching through a distance of 76 km, this upper part of Yamuna River drains a total of 108,664 km^2 (Basin upstream of Etawah: Upper Yamuna River Basin).

(5) Lower Yamuna River System

The Lower Yamuna River drains five (5) sub-basins: Lower Yamuna (18,173 km2), Chambal (136,014 km2), Sind (31,372 km2), Betwa (43,432 km2) and Ken (30,396 km2).

The main tributaries joining the lower part of Yamuna River, between Etawah and Allahabad, are the Chambal, Sind, Betwa and Ken. Covering a distance of 146 km, the lower part of Yamuna River drains a total of 259,387 km2 (Basin downstream of Etawah: Lower Yamuna River Basin).

(6) Gomati River System

Gomati River, originating from a natural reservoir near Village Chanderpur in District Pilibhit, meanders for 715 km through the heart of Uttar Pradesh and merges with Ganga River near Village Audiar in the District of Ghazipur. In the initial reaches, the river remains more or less like a small stream; however, in due course, it joins with other streams and drains. After traversing about 100 km, it begins to take the shape of a well-defined river from Mohammadi, District of Kheri. Further, Gomati River is joined by a significant seasonal river, Saryu, approximately 30 km south of Sitapur at Bhatpur Ghat. After traversing 40 km more towards south, it enters Lucknow, capital city of Uttar Pradesh State. Gomati River, while meandering for about 12 km through the heart of the city, is joined by 25 city drains, which shed their pollution discharges into the river. On further traversing almost 300 km after passing through Sultanpur and Jaunpur, the river is joined by Sai River (C.A.: 9,721 km2), which has a catchment up to Unnao District. Ultimately, after traversing 715 km from the origin, it merges with the Middle Ganga Main River at a place near Audiar in Ghazipur District.

Gomati River can be divided into 3 sub-basins: Upper Gomati (10,762 km2), Lower Gomati (13,370 km2) and Sai (9,721 km2). Gomati River drains an area of 33,403 km2 in the central part of the Study Area.

2.3 RIVER FLOW RATE

2.3.1 Available Data

The Central Water Commission (CWC) of India is the principal agency responsible for the water level and flow rate measurement in the rivers of the Study Area. There are more than 300 water level and flow rate measurement stations that are operated by CWC in the Study Area..

Among all the gauging stations, 25 stations are selected for this Study, taking into account their location and observation periods as shown in Table 2.3. For location, see Figure B.2.3.

Table 2.3 Available Gauging Stations for Flow Data

No.	River/Station	Observation Period *	No.	River/Station	Observation Period *
1	Ganga/Fatehgarh		14	Kalinadi/Bewar	
2	Ganga/Ankinghat		15	Ramganga/Dabri	
3	Ganga/Kanpur		16	Tons/Mezaroad	
4	Ganga/Bhitaura		17	Gomati/Lucknow	
5	Ganga/Shahzadpur		18	Gomati/Maighat	
6	Ganga/Allahabad		19	Sai/Jalapur	
7	Ganga/Mirzapur		20	Karmanasa/Karmanasa Rly. St	
8	Ganga/Varanasi		21	Hindon/Galeta	
9	Ganga/Buxar		22	Chambal/Udi	
10	Yamuna/Delhi		23	Sind/Seondha	
11	Yamuna/Mohana		24	Betwa/Sahijna	
12	Yamuna/Etawah		25	Ken/Banda	
13	Yamuna/Pratappur				

Note: * Restricted data.

All the available flow rate data are used for the simulation study. Among the above available data, the data of the latest 5 years are used for the hydrological analysis.

2.3.2 Seasonal Variation of River Flow Rate

The river flow seasonally varies independently of the seasonal change of rainfall. The monthly average river flow lowers during March to May and rises during July to September. The variation of monthly average flow rate (indicative) at the major five (5) principal stations is shown in Figure B.2.4.

CHAPTER 3 EXISTING RIVER WATER QUALITY

3.1 AVAILABLE WATER QUALITY DATA

3.1.1 Sampling Location and Frequency

The Central Pollution Control Board (CPCB) has been periodically analyzing the river water quality in the Study Area since 1976. The water quality-monitoring program has been gradually extended based on the availability of resources and need. The CPCB has taken up the exercise in coordination with SPCBs and PCCs through a series of meetings and analysis of data.

The sampling locations are given in Table B.3.1(1). These sampling locations are also shown in Figure B.3.1.

Apart from the activities of CPCB, there are several periodical monitoring plans conducted by SPCB and NRCD, as shown in Table 3.1.

Table 3.1 Available River Water Quality Data

Objective Monitoring Area and Sampling Points	Name of Institute	Parameter	Monitoring Period
10 sampling points in Ganga at Kanpur, Allahabad and Varanasi	CPCB North Zonal Office, Kanpur	W. Temp, EC, DO, Cl, BOD, COD, T/F-coliform	1999-2001
12 sampling points in Ganga and Yamuna at Allahabad	U.P. PCB Allahabad Office	pH, DO, BOD, COD, T/F-coliform	1999-2001
3 points in Ganga at Varanasi	U.P. PCB Varanasi Office	pH, DO, BOD	-2001
68 points in Ganga, Yamuna and Gomati	NRCD	pH, DO, BOD, COD, T/F-coliform	1998-at present

As shown in above table, NRCD also conducts the periodical water quality monitoring entrusting the sampling and analyzing works to laboratories officially registered by Government for the purpose of evaluating the pollution abatement effects of STPs. For instance, in case of the Ganga Main Stem, 5 laboratories have been undertaking the monitoring work as shown in Table 3.2.

Table 3.2 Relevant Agency for NRCD's Monitoring of Ganga

Stretch	Agency
Rishikesh - Garhmukteshwar	PCRI – BHEL
Kannauj - Kanpur	IIT Kanpur
Allahabad - Terighat	CPCB Zonal office Kanpur
Bihar	Patna University
West Bengal	Bidhan Chandra Agricultural University

Moreover, Central Water Commission (CWC) has been also monitoring the river water quality, covering totally 118 sampling points as shown in Table B.3.1(2).

3.1.2 Water Quality in the Past

The periodically analyzed water quality parameters are as follows:

Water Temperature, EC, Turbidity, pH, DO (Dissolved O_2), BOD, COD, TOC, TSS, TDS, TFDS, T-S, Fe, Mn, Ca, Mg, K, Na, B, Cl^-, SO_4^{2-}, Oil, T-N, T-Kje-N, NH_3, NO_2, NO_3, PO_4, T-P, Anionic Detergent, Mineral Oils, Hardness ($CaCO_3$), Total Coliform Number, Faecal Coliform Number, etc.

For the evaluation of water quality in the Study Area, 12 of the 101 sampling locations are essential. These stations include those that are located on Ganga River (at Kannauj D/s, Kanpur D/s, Allahabad U/s, Allahabad D/s, Varanasi D/s, Ghazipur and Patna D/s), on Yamuna River (location being Okhla Bridge, Agra D/s and at Allahabad) and on Gomati River (at the locations of Lucknow D/s and the lowest point of Gomati).

The average and 90% values of water quality in major parameters are summarized in Table 3.3 and 3.4 (for period 1997-2001).

Table 3.3 Average River Water Quality

Location	Unit	Ganga at Kannauj D/S	Ganga at Kanpur D/S	Ganga at Aallahabad U/S	Ganga at Allahabad D/S	Ganga at Varanasi D/S	Ganga at Trighat (Ghazipur)
Water Temperature	℃	24.8	24.8	23.9	24.1	26.8	26.9
PH	(-)	8.09	7.95	8.21	8.40	8.20	7.96
Electro Conductivity	mS/m	389	386	-	-	-	-
Alkalinity	Ca mg/l	162	176	208	281	215	186
DO	mg/l	7.6	6.6	8.1	8.3	5.5	7.0
BOD	mg/l	3.3	6.5	3.3	3.4	13.6	4.6
COD	mg/l	16.6	25.2	16.8	20.6	-	17.7
Chloride	mg/l	22.7	27.9	14.2	17.4	38.5	29.5
Sulphate	mg/l	16.8	21.4	22.8	26.8	17.0	14.4
Na	mg/l	17.7	25.3	29.8	37.5	-	-
Ca	mg/l	82.7	94.5	105.0	117.5	165.5	141.4
Magnecium	mg/l	40.5	47.3	63.9	68.5	39.8	31.0
Faecal coloform	MPN/100ml	$1.3*10^5$	$8.4*10^5$	$1.7*10^3$	$3.1*10^3$	$1.4*10^5$	$1.7*10^3$
Turbidity	degree	37.6	43.2	180.0	129.9	80.4	62.4
T-KN	mg/l	4.9	23.0	2.5	3.5	-	1.5
Hardness	Ca mg/l	123.1	141.8	168.7	181.6	205.2	147.8
Total coliform	MPN/100ml	$3.8*10^5$	$7.2*10^6$	$4.7*10^3$	$7.0*10^3$	$2.3*10^5$	$3.2*10^4$
TDS	mg/l	163.2	192.4	171.5	206.0	520.3	422.1
TFDS	mg/l	118.5	189.7	97.4	116.0	-	-

Location	Unit	Ganga at at Patna D/S	Yamuna at Nizamuddin Bridge, Delhi	Yamuna at Etawah	Yamuna at Allahabad	Gomati at Lucknow D/S	Gomati at Lowest
Water Temperature	℃	24.4	26.9	26.6	25.2	27.1	26.2
PH	(-)	8.09	7.57	7.56	7.88	7.83	7.99
Electro Conductivity	mS/m	424	1,029	1,030	378	423	-
Alkalinity	Ca mg/l	143	-	-	168	218	184
DO	mg/l	8.4	3.4	9.6	7.8	3.6	7.2
BOD	mg/l	0.7	13.9	17.0	1.6	6.4	3.7
COD	mg/l	16.4	48.3	58.3	12.5	39.0	15.4
Chloride	mg/l	16.7	-	-	26.1	18.6	25.2
Sulphate	mg/l	16.5	-	-	26.8	23.0	9.9
Na	mg/l	19.8	-	-	35.4	33.5	-
Ca	mg/l	86.8	-	-	85.8	120.0	148.4
Magnecium	mg/l	44.8	-	-	38.9	79.7	35.3
Faecal coloform	MPN/100ml	$1.8*10^3$	$1.1*10^6$	$1.8*10^4$	$6.4*10^5$	$2.3*10^5$	$6.3*10^3$
Turbidity	degree	-	-	-	-	22.7	57.5
T-KN	mg/l	0.5	18.9	2.7	2.0	6.6	-
Hardness	Ca mg/l	133	-	-	131	200	183
Total coliform	MPN/100ml	$1.5*10^4$	$6.6*10^6$	$2.1*10^5$	$9.5*10^4$	$3.4*10^5$	$1.5*10^4$
TDS	mg/l	-	-	-	233.3	337.3	377.6
TFDS	mg/l	-	-	-	96.9	251.1	-

Table 3.4 90 Percentile River Water Quality

Parameter	Ganga Main Kannauj D/s	Ganga Main Kanpur D/s	Ganga Main Allahabad U/s	Ganga Main Allahabad D/s	Ganga Main Varanasi D/s	Ganga Main Ghazipur
DO (O_2) (mg/l)	6.0	5.0	6.9	7.0	3.0	6.0
BOD (mg/l)	4.3	8.2	3.4	4.1	22.5	6.0
Total coliform (MPN/100ml)	$9.3*10^5$	$2.3*10^7$	$1.4*10^3$	$1.7*10^4$	-	-
Parameter	**Ganga Main Patna D/s**	**Yamuna River Okhla Bridge**	**Yamuna River Agra D/s**	**Yamuna River At Allahabad**	**Gomati River Lucknow D/s**	**Gomati River Lowest**
DO (O_2) (mg/l)	8.4	0.0	2.0	6.2	2.4	6.0
BOD (mg/l)	1.0	33.0	30.0	2.6	7.4	5.0
Total coliform (MPN/100ml)	$2.4*10^4$	$1.9*10^7$	$5.8*10^6$	-	$5.0*10^5$	$1.9*10^4$

As shown in the above table, river water quality has the following characteristics:

(1) The river water temperature changes between 15°C and 34°C throughout the year, and especially becomes highest from April to June. The yearly average river water temperature is 23°C to 26°C.
(2) pH value is in normal range, referring to the standards of river water quality.
(3) BOD and COD show high values on the Ganga Main River after Kanpur, Allahabad, and Varanasi and on the Yamuna River after Delhi.
(4) The number of faecal coliform is extremely high on Ganga Main River after Kanpur and Yamuna River after Delhi. It is considered mainly due to the large quantity of domestic wastewater effluent contribution from the cities and towns, respectively.
(5) Electro-conductivity (EC), hardness, TDS and inorganic salts such as Na, Ca, Mg indicates high concentrations.
(6) The 90% value of DO on Gomati River at Lucknow is very low. It is considered to be due to the oxygen consumption by excessive organic pollution loads.
(7) Gomati River at Lucknow is also highly polluted. Most of the water quality parameters exceed the desired criteria for the riverwater.

3.2 EVALUATION OF PRESENT WATER QUALITY

For various rivers, the identified polluted-stretches are Yamuna (Delhi to Mathura), the Chambal (D/s of Nagda to D/s of Kota), the Kali (D/s of Modinagar to its confluence with Ganga), the Hindon (Saharanpur to its confluence with Yamuna), the Khan (Indore and D/s of Ganga), the Kshipra (city limits of Ujjain and D/s of Ujjain), the Damodar (D/s of Dhanbad to Haldia), the Gomati (Lucknow to its confluence with Ganga) and the Betwa (along Mandideep and Vidisha).

The longitudinal profile of river water quality in the Ganga basin with respect to BOD, DO and Total-coliform for the period 1997 to 2001 is given in Figure B.3.2 to B.3.4, respectively. All figures indicate that river water quality deteriorates immediately downstream of large cities such as Kanpur, Allahabad, Varanasi, Lucknow, Delhi and so on.

3.2.1 Ganga Main River

The results obtained by physico-chemical analysis of water quality monitoring data for a period of 60 months, i.e., from 1997 to 2001, are applicable to this Study. The river water quality in each river system is described as below

(1) Upper Ganga Main River System

The water quality in the upstream reach from Rishikesh to Haridwar is satisfactory. The annual average BOD value varies between 1-2.5 mg/l with an average value of 1.3-2.0 mg/l. BOD and DO values in this river reach are within the desired water quality criteria limits; however, total coliform exceeds the criteria limit slightly. In this river reach, although the impact of contamination is rather small compared to river flow, untreated domestic wastewater affects the total and faecal coliform value. Further, river water quality in the downstream reach from Haridwar to Kannauj becomes worse due to the small flow in the river caused by the huge quantity of intake at Haridwar.

On the other hand, much polluted tributaries such as Kalinadi and Ramganga join the Ganga Main at Kannauj City. These tributaries transport and add pollution load into Ganga Main and thus affect the river water quality slightly at Kannauj D/s.

(2) Middle Ganga Main River System

BOD rises sharply up to 8.2 mg/l downstream of Kanpur. In this river reach, BOD exceeds the desired water quality criteria limit at D/s Kanpur, D/s Varanasi and Trighat. Total coliform is much higher than the criteria limit in the river stretch up to Rajmahal, and thereafter, it is well within the criteria limit of desired class. On the other hand, DO level meets the desired level at all the monitoring stations except Varanasi D/s. Monthly river water quality monitoring of the river stretch from Allahabad to Trighat has been conducted by NRCD sponsored activities and the results are shown in Table 3.5. The results show that river water quality from Allahabad to Varanasi can be classified as below the C category under designated best use classification indicating that this stretch is not suitable for drinking and bathing.

Table 3.5 Existing River Water Quality at Allahabad and Varanasi

Monitoring Station*	Status of Critical Parameters			
	BOD	**DO**	**T-coliform**	**Overall Water Quality**
GA-u/s	Below C	A	Below C	Below C
YA-b/c	Below C	B	-ditto-	-ditto-
RS	CA	-ditto-	-ditto-	
GA-d/s-1/4	Below C	A	-ditto-	-ditto-
GA-d/s-1/2	CA	-ditto-	-ditto-	
VC	CA	-ditto-	-ditto-	
GV-u/s	Below C	B	-ditto-	-ditto-
DG	Below C	C	-ditto-	-ditto-
GV-d/s-1/4	C	B	-ditto-	-ditto-
GV-d/s-1/2	Below C	B	-ditto-	-ditto-
GM	C	B	B	
GT	C	B	B	

Note*: GA-u/s: Ganga at Allahabad u/s, YA-b/c: Yamuna at Allahabad b/c, RS: Ganga at Sangam Ghat in Allahabad, GA-d/s-1/4: Ganga at Allahabad d/s at 1/4 width, GA-d/s-1/2: Ganga at Allahabad d/s at 1/2 width, VC: Ganga at Vindhyachal Ghat, GV-u/s: Ganga at Varanasi u/s, DG: Ganga at Dashashwamedh Ghat, Varanasi, GV-d/s-1/4: Ganga at Varanasi d/s 1/4 width, GV-d/s-1/2: Ganga at Varanasi d/s 1/2 width, GM: Gomati at Kaithi, Varanasi, GT: Ganga at Trighat

(3) Lower Ganga Main River System

According to Figure B.3.2, the BOD concentration drops sharply after Varanasi D/s and low concentration of BOD continues until Rajmahal due to the sufficient dilution effect owing to its confluence with many large tributaries such as Son, Ghaghra and Gandak. Further, after bifurcating at the country border between India and Bangladesh, Ganga River is joined by large tributaries such as Ajay, Damodar and Rupnarayan. Kolkata is located at the lowest point of Ganga River and is the second largest city in India where more than 10 million people live. Although the City of Kolkata discharges a huge quantity of wastewater into Ganga River, the river water still remains not so polluted due to the dilution capacity of river caused by the abundant river flow.

(4) Specific Water Quality Problem

Ganga River is observed to be colored in the stretch from Kachlaghat to Kanpur, while before Kachlaghat River is found colorless. The study was conducted by UPPCB Kanpur for physical verification of all the tributaries merging Ganga River at Mahoba River, Ramganga River and Kalinadi River. According to the study results, the value of color ranges 25 – 50 in the stretch from Ganga River after confluence of Mahoba River to Kanpur. On the other hand, the extremely high values of color (50 –500) were found in the Mahoba River and Kalinadi River. The main contributors of color was pointed out in the study report as follows:

(a) Mahoba River and Kalinadi River significantly affect color of Ganga River, however, the contribution from Ramganga River is relatively lower.
(b) According to the further investigation of small tributaries discharging to Mahoba River, Bagat Nala is the single largest contributor of not only color but also BOD and COD. The other major specific contributors are Rampur drain and Siddha drain.
(c) The main contributors discharging to Kalinadi River are Meerut drain and Modinagar drain. These drains contribute BOD and COD also alongwith color.
(d) The specific pollution sources on investigation were notices as around 10 distilleries of Central and Western UP.

3.2.2 Yamuna River

The water quality monitoring data in the form of physio-chemical analysis results for the period of 60 months, i.e., from 1997 to 2001, is applicable for this Study. The annual averages of important water quality parameters are shown in Figure B.3.3.

(1) Upper Yamuna River System

Yamuna River maintains good condition of water quality in upstream reach i.e. Hathnikund to Palla. However, there is a gradual increase of BOD value between Hathnikund and Delhi, mainly caused by the inflow of untreated domestic and industrial wastewater from Panipat and Sonepat through drains in the state of Haryana.

DO drops after Wazirabad Barrage in Delhi due to addition of large amount of wastewater in Yamuna River through various drains. Whatever water flows in the downstream of Wazirabad barrage is the untreated or partially treated domestic and industrial wastewater contributed through 16 drains along with the water being transported by Haryana irrigation Department from Western Yamuna Canal to Agra Canal via Najafgarh Drain and the Yamuna. The annual average BOD value increases from 1.1 mg/l at Hathnikund to 14.4 mg/l at Nizamuddin Bridge. This high value of BOD beyond permissible limit prevails over the entire stretch of the Yamuna River in the downstream up to Delhi until the Chambal River provides dilution effect.

BOD in Yamuna River at Mazawali varies between 3-34 mg/l, with an average of 10.6 mg/l, which improves by the time it reaches to Mathura. BOD level at Mathura downstream D/s varies between 2-17 mg/l with an average of 7.5 mg/l and it remains consistent up to Agra upstream. However, downstream of Agra, the water quality is degraded to a very high extent due to the discharge of untreated wastewater inflow from Agra City and non-availability of considerable dilution effect. The stretch of Yamuna River between Agra and Etawah continues to remain in degraded condition with BOD varying between 1-15.6 mg/l with an average of 14.2-15.3 mg/l. The longitudinal profile of DO, BOD, total and faecal coliform reflects that the water quality of river is in deteriorated condition between Delhi and Etawah.

(2) Lower Yamuna River System

After the confluence of Chambal River shortly downstream of Etawah City, water quality in Yamuna River again becomes normal as is evident from the annual average BOD value (see Tables 3.3 and 3.4). The Yamuna River water quality recovers after joining of the Chambal River at Juhika, which provides significant dilution effect with fairly clean water to the extent of 5-10 times. Due to this dilution, Yamuna River regains its water quality with its BOD concentration at Allahabad ranging between 1-3 mg/l with an annual BOD average of 1.6 mg/l.

3.2.3 Gomati River System and Other Major Tributaries

(1) Gomati River

Gomati River is highly contaminated by domestic and industrial wastewater inflow. Especially, river flow becomes very low in drought season and in monsoon it swells with considerably high flow. Sitapur District is located in the upstream reach, and highly contaminated wastewater effluent from distilleries and sugar factories in the area is discharged into the upper reach of Gomati River. On the other hand, Lucknow City is located in the middle reach of Gomati River and is presently inhabited by approximately 2.39 million people. Just at the entrance to the city, almost 300 MLD of water is lifted from the river at Gaughat Intake Works for domestic use in the city.

The water quality of Gomati River before its confluence with Ganga River and Ganga River at Trighat was found to be in a relatively better condition complying with the B category, which implies that the river water is suitable for bathing, swimming and water related sports.

(2) Main Tributaries

Ganga River consists of many tributaries and CPCB has periodically monitored river water quality, as shown in Table 3.6. According to this table, BOD and Total Coliform values are high in the Kalinadi, Hindon and Ramganga rivers located in the Upper Ganga and Yamuna River stretches due to the domestic wastewater inflow from riverside cities. On the other hand, BOD values of the Chambal, Sind and Betwa rivers located in the Lower Yamuna stretch are moderate, and those of Sone, Ghaghra and Gandak rivers located in Lower Ganga stretch are low.

3.2.4 Seasonal Variation of River Water Quality

The seasonal variations of DO (dissolved oxygen), BOD and Total coliform at the representative monitoring stations using the monthly average data monitored in the past five years are illustrated in Figure B.3.5. The seasonal variation indicates that BOD is high in the dry season and low in the monsoon season; however, DO and Total coliform values do not show any significant change corresponding to the season.

Table 3.6 Average and 90% Water Quality of Main Tributary at Lowest Point

Grouping	Parameter	Ramganga	Kalinadi	Tons	Sone	Ghaghra	Gandak
Average	DO (O_2) (mg/l)	7.3	7.9	7.3	7.4	8.2	8.4
	BOD (mg/l)	3.3	4.0	2.6	0.5	0.5	0.5
	Total coliform (MPN/100ml)	$3.9*10^5$	$5.4*10^5$	$2.4*10^3$	8.9*10	$9.3*10^3$	$5.4*10^3$
Grouping	Parameter	Damodar	Rupnarayan	Hindon	Chambal	Sind	Betwa
Average	DO (O_2) (mg/l)	6.8	7.0	3.6	8.9	4.9	7.8
	BOD (mg/l)	3.4	1.4	8.5	1.6	2.4	3.1
	Total coliform (MPN/100ml)	$2.2*10^5$	$1.1*10^5$	-	$1.2*10^5$	-	$2.1*10^5$
Grouping	Parameter	Ramganga	Kalinadi	Tons	Sone	Ghagra	Gandak
90%	DO (O_2) (mg/l)	6.2	6.4	6.7	6.5	7.5	8.0
	BOD (mg/l)	4.0	6.2	4.1	2.7	1.0	1.0
	Total coliform (MPN/100ml)	$1.0*10^6$	$1.4*10^6$	-	$3.0*10^2$	$2.4*10^4$	$2.4*10^4$
Grouping	Parameter	Damodar	Rupnarayan	Hindon	Chambal	Sind	Betwa
90%	DO (O_2) (mg/l)	5.9	5.7	2.4	6.5	-	6.7
	BOD (mg/l)	8.5	2.1	11.8	2.0	3.0	4.0
	Total coliform (MPN/100ml)	--	-		$1.8*10^5$	-	$8.2*10^5$

3.2.5 Past River Water Quality Trend of Ganga

The trend of river water quality (annual summer average, March to June) of the Ganga River with respect to BOD, DO and Total Coliform for the period 1985 to 2001 is illustrated in Figure B.3.6. Based on Figure B.3.6, BOD at the stations considered in all the cities, namely, Kannauj, Kanpur, Allahabad and Varanasi, show the decreasing trend until 1993 and then observed to increase. On the other hand, DO values were completely different, i.e., it had an increasing trend although slightly in the early 1990s.

Hence, it can be assumed that pollution load generation from the Ganga Basin had decreased due to the GAP activities; however, the continuous rapid urbanization and natural increase in pollution load generation surpassed the abatement efforts of GAP. This is substantiated by the fact that pollution has increased throughout, i.e., even in the upstream of cities.

3.3 RIVER WATER QUALITY STANDARDS

River water is classified into five (5) categories in the provision of Water (Prevention and Control of Pollution) Act, 1974. The basic objective of this Act is to maintain and restore the wholesomeness of national aquatic resources by prevention and control of pollution. The five categories correspond to the following water uses. The Act prescribes the standard water quality of each category. The major water quality parameters are shown in Table 3.7.

Table 3.7 River Water Quality Standard

Quality Class	Designated Best Use	Primary Quality Criteria	Designated River Stretch	
			Ganga River	**Yamuna River**
A	Drinking water source without conventional treatment, but with chlorination	BOD: <2mg/l, DO:>6mg/l, Total Coliform: <50MPN/100ml	From origin to Rishikesh (0-250km)	From origin to Tajewala (0-178km)
B	Outdoor bathing (organized)	BOD: <3mg/l, DO: >5mg/l, Total Coliform: <500MPN/100ml	250-2450km	Mathura to Allahabad
C	Drinking water source with conventional treatment	BOD: <3mg/l, DO: >4mg/l, Total Coliform: <5000MPN/100ml	-	All remaining stretches
D	Propagation of wildlife and fisheries	DO: >4mg/l	Downstream of 2450km	-
E	Irrigation, Industrial cooling, and controlled waste disposal	pH: 6.0-8.5	-	-

Recently, primary quality for class B regarding coliform number has been revised as follows; faecal coliform: <500 MPN/100ml (Desirable), <2,500 MPN/100ml (Maximum permissible).

On the other hand, the Water Act has not set the standard river flow rate to evaluate the river water quality. Hence, the standard river flow rate corresponding to dry season should be adopted. Additionally, designated water quality criteria and present corresponding criteria for four (4) major cities located along the Ganga Main River are as given in Table 3.8.

Table 3.8 Desired Water Quality Criteria of 4 Cities

Location	Target Water Quality (Designated Criteria)	Present Corresponding Criteria	Questionable Parameter
Kanpur U/s	B	D	Coliform Number
Kanpur D/s	B	D	BOD, Coliform Number
Allahabad U/s	B	E	Coliform Number, NH_3
Allahabad D/s	B	E	Coliform Number, NH_3
Varanasi U/s	B	D	BOD
Varanasi D/s	B	E	DO, BOD
Lucknow U/s	C	C	
Lucknow D/s	C	E	DO, BOD, Coliform Number

CHAPTER 4 EXISTING WASTEWATER QUALITY IN THE STUDY AREA

4.1 WASTEWATER QUALITY

Sewerage wastewater quality has been analyzed by U.P. Jal Nigam on the ad-hoc basis and some of the results are available for this present Study. The sewerage wastewater quality is summarized below according to the analyzed data.

4.1.1 Sewerage Wastewater Quality after Treatment

Sewerage wastewater quality after treatment analyzed in STP of Kanpur and Varanasi is available for this Study as shown in Tables B.4.1 and B.4.2. These analyzed data are also used in the detail simulation model.

4.1.2 Wastewater Quality of Nala

It is found that the sewerage effluent is discharged through Nalas into various river courses. BOD value ranges widely from 30 to 500 mg/l due to the evaporation of the wastewater during flowing down in the Nalas. These Nalas causes unhygienic condition of the urban areas and spells offensive odor. Wastewater quality of Nalas in 4 cities, namely, Kanpur, Allahabad, Varanasi and Lucknow is available for this Study as shown in Table B.4.3 that indicate the wastewater quality. The wastewater quality is used in the detail simulation model as input data mentioned in Chapter 6.

4.2 STANDARD OF WASTEWATER QUALITY

The permissible limits of industrial wastewater discharged into rivers and public sewerage systems and effluent which is discharged into rivers from sewage treatment plants are prescribed in the Pollution Control Acts, Rules and Notifications, CPCB, September, 2001. The values of major parameters are shown in Table B.4.4.

CHAPTER 5 INVENTORY OF POLLUTION LOAD GENERATION IN THE ENTIRE GANGA BASIN

5.1 GENERAL

The former inventory of pollution load generation in the entire Ganga Basin was prepared in the year 1984 and some parts of the information provided are still available for this present Study. However, it is essentially necessary to update the former inventory using the latest data, e.g., river water quality, river flow, population, sewerage service area and so on, in order to analyze the status of water quality in the basin.

Adequate knowledge of the existing nature, magnitude and sources of various pollution loads in water bodies is much needed for any rational formulation of water pollution control policies and measures. As for the Ganga, being the largest river basin in the country, it is very important that reconnaissance is urgently carried out to assess the water quality in the basin.
The need and importance of basin-wise study of water quality and the various factors that determine the pollution load generation and its runoff is required as the basic information for the river water pollution control. Based on the analysis of collected data, it is observed that water pollution arising from industrial and urban wastewater is very significant. At the same time the rural surroundings and agricultural fields are also found to be the potential sources of pollution.

In the formulation of water pollution control programs, it has been emphasized that on account of the present trend of rapid industrialization, modernization of farming practices, fast urbanization, introduction of sewer systems in many towns, and supply of potable water to a number of villages, the pollution load in the Ganga Basin is also undergoing rapid changes. In other words, assessment of the current situation is not sufficient in the formulation of pollution control programmes, especially for such a vast drainage network as the Ganga Basin.

The main objectives of the inventory study may be briefly stated as follows:

(1) To collect detailed data relevant to water pollution for the entire Ganga Basin including information on the hydrology, climate, demography, land use, agriculture, wastewater disposal, etc.
(2) To analyze the data with a view to finding out possible relationship between human activities and the different aspects relating to water quality in the Ganga Basin.
(3) To present the data through maps, charts, tables, and texts in the form of a technical report, so that it may be useful for the control and prevention of water pollution in the Ganga Basin.
(4) To assess the impact of the various development programs on the use and quality of water in the basin.

In this report, the basic policy of the inventory study is that sub-basin wise totality of the pollution load generation as well as city or state wise pollution load generation has been adopted.

5.2 METHODOLOGY OF INVENTORY

Collection of data and information has been carried out on sub-basin basis for the purpose of the estimation of water pollution load generation and its runoff.

In this inventory study, sub-basin wise pollution load generation and pollution load runoff at the confluence point with the main river stem such as Ganga and Yamuna are calculated.

When estimation of pollution load generation is carried out city wise, the influence of only riverside cities on the river water quality can be taken into account. However, the pollution load generated from cities located far from the tributaries or main river stem, reduces significantly until the confluence with the main river stem due to the self-purification effect. Accordingly, it is essential to consider the sub-basin wise pollution load generation and runoff to the main river stem in order to estimate the pollution load exactly. In this Study, the pollution load generation from the entire Ganga Basin and pollution load runoff into the main river stem are estimated using the latest data and information considering the following assumptions:

(1) Class I cities and Class II towns located nearby the riverside of the main river stem and primary/secondary tributaries were selected as the point pollution sources. The point pollution load consists of the domestic and industrial wastewater effluent. However, the cities located at a distance of 30 km or more from the rivers are assumed to be non-point pollution sources.
(2) Among the above-mentioned cities designated as the point pollution sources, the population in the urban centers is treated as the point pollution sources and the remaining rural population is considered as the non-point pollution sources.
(3) The whole of livestock is treated as the non-point pollution sources, and total sub-basin wise urban heads of cattle, buffaloes, goats and sheep based on projected values for 2001 is considered for the pollution load estimation.
(4) The pollution load from land under different uses is assumed to be non-point pollution sources.
(5) Effluent from solid waste dumping site, throwing of unburnt/half-burnt human bodies and animal carcasses, laundry (dhobi) Ghats, cattle wallowing, etc., are not taken into consideration because the pollution load generation from these categories regarding the actual magnitude and unit pollution loads generation is not available for this Study.
(6) Non-point pollution load from human population has been allocated using district wise census data; however, in case a particular district is shared by several sub-basins, the population is divided based on the proportional area of the relevant sub-basins.

5.2.1 Data Collection Related to River Water Pollution

(1) Collected Data and Information

Information relating to physical aspects such as, hydrology, river water quality, climate, land use, population and industry, etc. has been collected from the various Government agencies.
The data supplied by the State Pollution Control Boards of Uttar Pradesh in prescribed format has been utilized.

(2) Limitation of the Inventory

Much of data of this report have been collected from secondary sources. Hence, the database presented here should be taken as indicative. However, it is sufficient for presenting a reasonably correct picture of the situation regarding water pollution in the Ganga Basin.

This inventory study aims at the entire Ganga Basin that covers 840,000 km^2 of catchment area (more than twice as large as the total area of Japan); hence, information on certain aspects, like water quality and hydrological characteristics of streams in the basin, has been rather inadequate and incomplete at several places. On the basis of the available data it has been sometimes difficult to draw accurate conclusion of quantitative nature. However, certain patterns of the river pollution have emerged from the findings of this Study by application of statistical techniques and coverage of whole area in Ganga Basin.

5.2.2 Objective River Sub-basin

For the grasp of river water quality, the pollution load generation needs to be calculated for the entire Ganga Basin , which has a total area of 840,000 km^2. The objective Ganga River Basin is divided into six (6) major sub-basins and further subdivided into 38 sub-basins, as shown in Table 5.1, for the estimation of existing and future pollution load generation. For location of the above six (6) major sub-basins and 38 sub-basins, see Figure B.2.1. Main features of the 38 sub-basins are shown in Table B.5.1.

Table 5.1 Objective River System and Sub-basins

River System	Sub-basin
Upper Ganga Main	(1) Upper Ganga I, (2) Upper Ganga II, (3) Ramganga and (4) Kalinadi
Middle Ganga Main	(5) Middle Ganga I, (6) Middle Ganga II, (7) Middle Ganga III, (8) Middle Ganga IV and (9) Tons
Lower Ganga Main	(22) Karmanasa, (23) Ghaghra, (24) Son, (25) Gandak, (26) Punpun, (27) Falgu, (28) Kiul, (29) Burhi Gandak, (30) Kosi and (31) Dwarka, (32) Jalangi, (33) Ajay, (34) Damodar, (35) Rupnarayan, (36) Haldi, (37) Lower Ganga I, (38) Lower Ganga II
Upper Yamuna River	(10) Upper Yamuna I, (11) Hindon, (12) Upper Yamuna II, (13) Upper Yamuna III
Lower Yamuna River	(14) Chambal, (15) Sind, (16) Betawa, (17) Ken, (18) Lower Yamuna
Gomati River	(19) Upper Gomati, (20) Lower Gomati, and (21) Sai

Note: Number in bracket is sub-basin number in Figure B.5.4.

The Ganga River Basin extends through the territories of eleven (11) states, either covering the whole state or only part of it. The area of each state covered by different river sub-basins in each river system can be seen in Table 5.2. Further, for the detailed relation between different state areas and each sub-basin, see Table B.5.2.

Table 5.2 Area of Each State Covered in Each River System

Unit: (km^2)

No.	Related States	1 Upper Ganga	2 Middle Ganga	3 Lower Ganga	4 Upper Yamuna	5 Lower Yamuna	6 Gomati	Sub-total
1	Himachal Pradesh	290			5,913			6,203
2	Haryana				34,759			34,759
3	Rajasthan				31,975	78,047		110,022
4	Uttaranchal	33,762		12,269	6,438			52,469
5	Uttar Pradesh	46,456	25,537	64,564	27,866	43,293	33,853	241,569
6	Madhya Pradesh		10,827	30,015		138,005		178,847
7	Bihar	2,910		78,450				81,360
8	Jharkhand			50,097				50,097
9	Delhi				1,493			1,493
10	West Bengal			52,118				52,118
11	Chhattisgarh			17,503				17,053
	Total	80,583	36,365	319,729	108,664	259,387	33,853	838,583

The above table shows that out of the 11 states in the Ganga River Basin, Uttar Pradesh shares the largest portion (28%) compared to the other states.

5.2.3 Modeling of Entire Ganga Basin

In order to estimate the influence of water quality deterioration in the entire Ganga Basin, it is necessary to formulate a basin runoff model for easier understanding of water quality trend. In this Study, the basin runoff model targeting the entire Ganga Basin was formulated for the purpose of rough estimation of pollution load generation and runoff on the sub-basin basis under the following assumptions:

(1) Pollution load generated in each sub-basin is discharged into small ditches, drainage channels and secondary tributaries, and is never excreted into canals for irrigation or domestic water supply.
(2) Non-point loads are not controlled and are constant even in future except for rural population.

(3) Population in urban centers of Class I and Class II towns and other major cities is assumed to be point pollution sources, and population in remaining rural area and small towns is considered to be non-point pollution sources.

5.2.4 Linkage with GIS

Calculation of sub-basin wise pollution load generation is ambitious, extremely extensive and complex; therefore, efficient data management, accumulation and assembly are necessary. In this circumstance, linkage with GIS is useful for the basin runoff model as shown in Figure 5.1. For detail, refer to the contents of GIS.

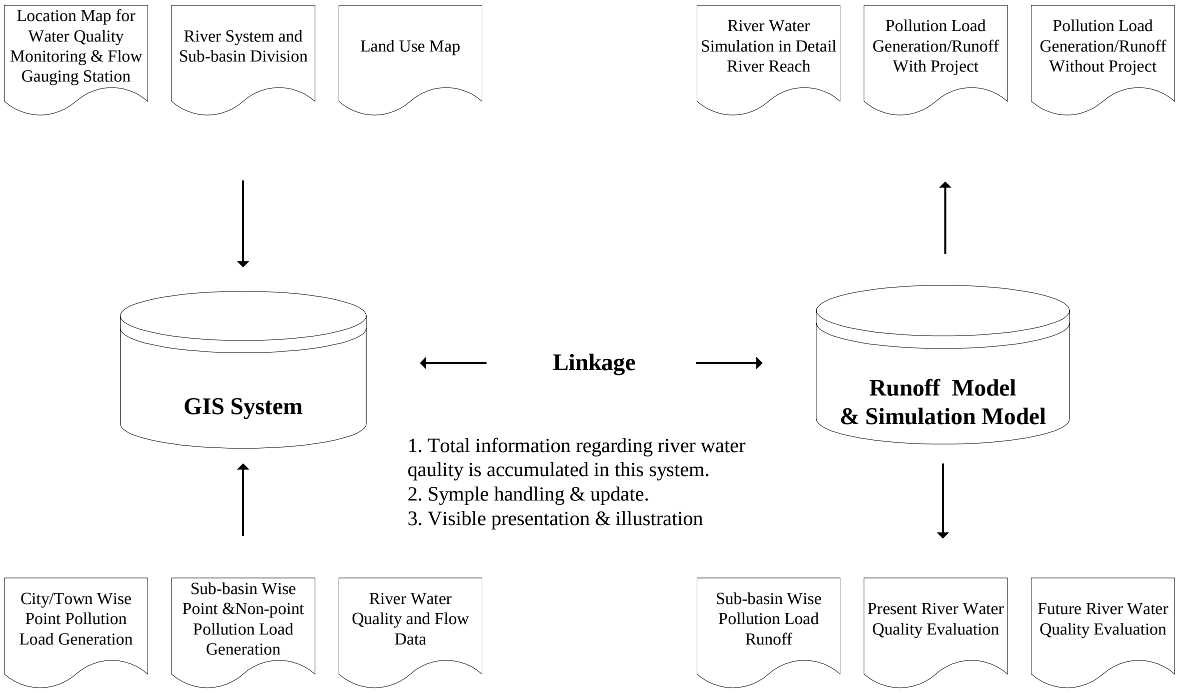


Figure 5.1 Linkage with GIS

5.3 EXISTING POLLUTION LOAD GENERATION

In this Study, pollution load is classified into point and non-point loads. The point load includes: (i) municipal wastewater discharged into rivers from sewerage system; (ii) industrial wastewater discharged into rivers from sewerage system; and, (iii) industrial wastewater directly discharged into rivers. However, domestic wastewater not covered by the sewerage system is dealt as non-point load. Hence, the non-point load includes wastewater from households (not covered by sewerage system), livestock and lands (agricultural land, pasture and shrub/forest). Wastewater from urban lands is disregarded because the urban area is small and negligible.

5.3.1 Point Pollution Load Generation

There are 101 Class I cities and 122 Class II towns in the Ganga Basin. In this basin where nearly 50% of the Class I cities and Class II towns are located on the riverbanks, the mode of discharge of municipal wastewater is mainly into the river systems. The recent survey of Class I and Class II cities indicated that about 8,250 MLD of wastewater is generated in the Ganga Basin, out of which treatment facilities are available only for 3,500 MLD of wastewater. Out of the 3,500 MLD treatment capacities, 880 MLD is to be created under the Ganga Action Plan, 720 MLD under the Yamuna Action Plan, and about 1,927 MLD by Government of Delhi for the restoration of water quality in the Yamuna River.

The Ganga River basin report indicated that Uttar Pradesh contributed the major share of more than 55% of the total urban industrial pollution load to the basin. It is observed that sugar and distilleries industries are the major pollutants in Uttar Pradesh followed by paper mills, textiles, engineering and pharmaceutical companies.

(1) Objective Point Pollution Sources

In this Study, objective point pollution sources are defined to be domestic and industrial wastewater effluent. There are 101 Class I cities and 122 Class II towns, and total population in these urban centers amount to approximately 91 million. BOD load is used as a representative index of organic substances. In this Study, objective point pollution sources are defined to be domestic and industrial wastewater.

(2) Domestic Pollution Sources

The domestic pollution sources mainly consist of effluents from human population and settlements located in urban areas.

(a) Population Calculation

As mentioned before, the entire area is subdivided into the 38 major sub-basins, which together form the Ganga Basin. Cities in each sub-basin are identified based on the population and categorized as Class I, Class II and small towns. Population in each city is classified into three (3) basic categories: Total, Urban and Rural. The Census of India is considered as the source of population information on cities.

Class I and Class II Towns: Total, urban and rural populations have been separately collected and compiled for the towns in the various sub-basins, and documented sub-basin wise for the pollution load calculation.

Small Towns: The available population for the small towns present in a particular sub-basin has been identified. The average population per unit town was estimated and then multiplied with the total number of towns in the basin. The populations of all the small towns were then summed up to estimate the population of the sub-basin.

(b) Unit BOD Pollution Load Generation of Domestic Wastewater

There are several reports on the unit BOD load of domestic wastewater stemming from field investigations, as shown in Table 5.3.

Table 5.3 Various BOD Unit Pollution Load

Country	BOD (g/c/d)	Data Source
Japan	58	Guideline for Basin-wide Water Pollution Control Master Plan
India	45	Manual on Sewerage and Sewage Treatment
Southeast Asia	43	D. Mara
India	30 – 45	-Ditto-
Rural France	23 – 34	
United Kingdom	50 – 59	
USA	45 – 78	
Developing Countries	40	WHO

The unit generated BOD load reported by previous studies ranges between 30 and 60 g/capita/day.

(c) Pollution Load Calculation

The pollution load calculation is based on the water supply and wastewater generation of the various towns. The sewage treatment plant capacities in all the towns were located and documented *(Source: CPCB)*. Data on total quantity of wastewater generation of the towns were also collected. In the case of towns where such information could not be gathered, the following assumptions were considered *(Water Manual CPHEEO):*

(1) Rural areas water supply: 70 lpcd (liter per capita per day)
(2) Towns provided with piped water supply and sewerage system: 135 lpcd
(3) Metropolis and Mega cities with water supply: 150 lpcd

As per assumption, 80% of the supplied water is generated as wastewater. The total wastewater generated is further divided into the category of treated and untreated wastewater. The untreated wastewater is assigned a BOD load of 200 mg/l and the treated wastewater is assigned a BOD load of 30 mg/l. The load calculation can be explained in the following equations:

Wastewater Generated = Water Supplied (lpcd) × Population × 0 .8

BOD load (kg/d) = (Total Wastewater - Treated Wastewater) MLD × 200 mg/l + Treated Wastewater MLD × 30 mg/l

Much of the data in this report have been collected from secondary sources. Hence, the database presented here should be taken as indicative. However, it is sufficient for presenting a reasonably correct picture of the situation regarding water pollution in the Ganga Basin.

(3) Industrial Pollution Load Generation

(a) Objective Industries

Pollution load from industrial activities has, no doubt, serious deleterious effects on the river water quality in the Ganga Basin. In this inventory study, objective industries are focused on the organic products. Therefore, following types were selected for the objective industries: Abattoir, Carpets, Chemicals & Caustic Soda, Dairy, Distillery, Cluster of Dyeing & Printing, Dyes, Engineering, Fertilizer, Cluster of Jute Processing, Pesticides, Pharmaceutical, Pulp & Paper, Sugar, Tannery, Textile, Thermal Power Plant and Vegetable oil & Vanaspati. The total targeting industries amounts to 1,289 in the entire Ganga Basin in the representing 234 districts. Out of these, there are 30 that represent clusters of Small Scale Industries (SSIs).

(b) Calculation Method

Sources of information

Background information on grossly polluting industries is available from respective SPCB and the Central Pollution Control Board, there is no single source which provides updated and recent information on quantum of industrial wastewater discharges specific to Ganga river.

Two of the starting documents for development of the database were the CPCB publications entitled "Status of the industrial pollution control programme along the river Ganga (Phase-I)" Probes/64/1994-95 and "An inventory of major polluting industries in the Ganga basin and their pollution control status" Probes/65/1995-96, respectively. This list was further augmented and updated with the help of the information available from association of industries, e.g., sugar, distillery, pulp and paper, vanaspati and vegetable oils, fertilizer, etc.

Additional relevant information was received from NRCD, Central Pollution Control Board, Ministry of Agriculture, etc. NRCD provided an updated list of grossly polluting industries including the BOD loads, receiving water bodies etc. This has been selectively cross- checked with communication and / or visits to the State Pollution Control Boards of UP, Uttaranchal, Bihar and West Bengal. Field visits were made to Kanpur and Varanasi to get first hand information. The visit to Kanpur and interaction with UPJN and IIT Kanpur enabled a realistic assessment of the pollution loads discharged by the tannery complex and the CETP at Jajmau.

Assessment of Industrial Wastewater Loads

Wherever the discharge data is not available, estimates of wastewater loads are based on the installed production capacity and corresponding unit wastewater loads recommended by the Central Pollution Control Board for various categories of industries. These unit loads are presented in Table 5.4. Installed capacity values have been taken from published industry association directories. Ideally the current production figures should be taken, however these are not available as widely and uniformly as the capacity figures. Productions have been assumed to be equal to the installed capacity, however, this is subjective since there could be significant variations in the level of capacity utilization among the industries.

However, in several cases it has been possible to get the flow and BOD data as recorded by the respective State Pollution Control Boards. The Industrial Pollution Monitoring Cell of the NRCD has provided this data. This data has been appropriately incorporated in the database and it has also served as a cross check for the long list of polluting industries developed as a base frame for the study. Before incorporating these values, they have also been cross checked with respect to the generally expected pattern along the lines of unit loads / typical BOD concentrations.
In most cases the treated effluent BOD concentration has been considered to be 30 mg/l (i.e., industry complying unless otherwise stated). However, in case of highly polluting industries, e.g., distillery, agro-residue (small without chemical recovery) and waste paper based pulp and paper industries, the treated effluent BOD concentrations have been taken as 1000 mg/l, 300 mg/ and 30 mg/l, respectively. In case of a combination of pulp and agro-residue or pulp and waste paper, an average of discharge and BOD values has been adopted. Similarly, in case of tanneries, the BOD of raw effluent is considered as 2500 mg/l. The wastewater generation Standards is shown in Table 5.4.

Approach for assessment of wastewater loads from SSI sector

Information on wastewater loads from individual small scale industries is not available with state or central boards. These industries are not registered with state pollution control boards and neither do they have representative industry or trade associations that collate and provide the relevant information.

In order to assess wastewater loads from SSI sector, a cluster of SSIs has been taken as an area source representing cumulative production capacity. For instance in Panipat there are 469 textile dyeing industries with total wastewater generation of 8 MLD and average BOD value of 400 mg/l. The strength of the source is considered as 3200 kg/d of BOD. (Ref. Pre-feasibility study on YAP-II, TEC, Paramount, MOEF, August 2000). In case of cluster of dyeing and printing units in Mathura, the combined strength of all SSI units is represented by the flow of the CETP.

Due to inherent limitations in the scheme and severe power cuts in the Jajmau area, the total effluent does not get complete treatment. Power cuts are reported to be typically for over 10 hr/d. Under such conditions, part of the effluent does not reach the CETP and that part which reaches there also receives only partial treatment. A part of the effluent is discharged through the existing surface drains directly into the river. The BOD of raw effluent is estimated to be 2500 mg/l while that of the combined treated effluent from the CETP is reported to be around 150 mg/l. The analysis report for one sample of treated effluent collected by UP Jal Nigam gives a value of 192 mg/l.

Table 5.4 Wastewater Generation Standards

No.	Industry	Quantity	Remarks
1	Integrated iron and steel	16 m^3/t of finished steel	
2	Sugar	0.4 m^3/t of cane crushed	Applied extensively
3	Large pulp and paper		
	Pulp and paper	174 m^3/t of paper produced	--do--
	Viscose staple fibre	150 m^3/t of product	
	Viscose filament Yarn	500 m^3/t of product	
4	Small pulp and paper		
	Agro residue based	150 m^3/t of paper produced	--do--
	Waste paper based	50 m^3/t of paper produced	--do--
5	Distilleries	12 m^3/KL of alcohol produced	--do--
7	Dairy	3 m^3/KL of milk	
6	Tanneries	28 m^3/t of raw hide	
	Vegetable oil and vanaspati industry		
	Solvent extraction	2 m^3/t of product	Effluent BOD @ 100 mg/l
	Refinery/ Vanaspati	2 m^3/t of product	--do--
	Integrated unit of extraction and refinery / vanaspati	4 m^3/t of product	--do--

(Source: Pollution control acts, rules and notifications issued hereunder, CPCB, September 2001, pp. 372)

As per the monitoring study carried out by IIT Kanpur, the entire Jajmau tannery complex, with its numerous surface drains and the CETP can be represented by an area source stretched over 3-5 km along the right bank of the Ganga river. As per this study the strength of the area source exclusively representing the tanneries is estimated to be 12.82 MLD carrying organic load of 9.39 tonnes of BOD/d. This comprises of 9.52 MLD reaching the CETP and 3.3 MLD which is draining directly into the river. The calculated values as per this procedure have been used in the database and for the mathematical modeling of the river water quality.

Assessment of the wastewater loads from slaughterhouses across the basin

A large number of municipal slaughterhouses are located in the Ganga basin. These are not registered as industries but considered as one of the essential services and therefore operated by the urban local bodies. However, their pollution loads are significant and therefore this sector has been considered as a quasi-industrial source of water pollution for the purpose of the water quality modeling study. Private sector abattoirs are not included in this analysis. Unit wastewater loads for discharges from slaughterhouse is given in Table 5.5.

Table 5.5 Unit Wastewater Loads for Discharges from Slaughterhouse

Category of SH	Size of SH	Specific wastewater generation (m^3/TLWK)	Specific BOD load (kg/TLWK)
Bovine	Large	1.4	5.5
	Medium	0.5	5.0
	Small	1.0	6.6
Sheep & Goat	All	3.0	8.1

Source: Comprehensive industry document on slaughterhouse, meat and seafood processing, CPCB, 1992.

(c) Estimated Industrial Pollution Load Generation

Category-wise distribution

Tanneries are concentrated at Kanpur, Mokemaghat, Kolkata and few units in Agra. The three main clusters together represent over 900 small and medium sized tanneries. The category as a whole accounts for almost 33% total industrial BOD load in the basin. This figure includes the potential load that will be discharged once the tanneries in Kolkata are relocated and commissioned and the proposed CETP there is made operational.

Table 5.6 Predominant Categories of Water Polluting Industries

Category	No. of operational units	No. of closed units	Total entries in the category	Remarks
Abattoir	NA	NA	196	Non-point source. Numbers correspond to erstwhile districts in various states except Uttaranchal and Jharkhand for which state level meat production data are not available
Distillery	95	5	100	
Pulp & Paper	158	91	249	Comprises all sub-categories e.g., pulp, agriculture residue and waste paper as the feed stock
Tannery	38	7	45	The operational units also include 3 clusters of Kanpur, Kolkata and Mokemaghat (Bihar) which together represent 903 SSIs
Sugar	178	16	194	
Vegetable oil & Vanaspati	69	41	110	Comprises all categories e.g., solvent extraction, refining, vanaspati (margarine) etc
			894	The six categories put together account for almost 70% of the total entries in the database.

Geographical Distribution

In terms of geographical distribution of BOD generation, the top ten districts in descending order are listed in Table 5.7. Largest generation is in South 24 Parganas district. Saharanpur is the second largest generator and it is way above Kanpur Nagar (primarily the city-based industries), which is normally considered to be a large source of industrial pollution. The two adjacent districts of Saharanpur and Muzaffarnagar put together generate 26 ton of BOD/d and their combined load is discharged into river Hindon (a tributary of Yamuna). The top 10 districts put together account for almost 43% of the total industrial BOD load generation.

State-wise BOD generation in descending order is presented in Table 5.8. As expected, UP is the largest generator accounting for 38% of the total, followed by West Bengal at 30% as shown in Table 5.8.

Table 5.7 Top ten districts in terms of BOD load generation in the Ganga basin

No.	Dis	State	BOD Generation (t/d)	Sub-basin
1	South 24 Parganas	WB	18.25	Lower Ganga II
2	Saharanpur	UP	17.02	Hindon
3	Kolkata	WB	16.60	Lower Ganga II
4	North 24 Parganas	WB	15.72	Lower Ganga II
5	Delhi	Delhi	14.00	Upper Yamuna II
6	Jaipur	Rajasthan	12.67	Chambal
7	Barddhaman	WB	11.08	Ajay
8	Kanpur Nagar	UP	10.59	Middle Ganga II
9	Muzaffarnagar	UP	8.80	Hindon
10	Ghaziabad	UP	7.79	Kalinadi
	Total		132.52 = 43% of total	

Table 5.8 Statewise Industrial BOD Load Distribution

No.	State	BOD (t/d)	% of total
1	UP	116.50	38
2	WB	91.52	30
3	Rajasthan	20.31	7
4	Bihar	18.04	6
5	MP	17.61	6
6	Haryana	14.76	5
7	Delhi	14.00	5
8	UTA	13.30	4
9	HP	2.79	1
10	Jharkhand	0.01	0
	Total	**308.84**	**100**

(4) Other Pollution Sources

Pollution caused by in-stream use of river water is as follows: Cattle wading, Bathing, Open defecation, Washing of clothes and so on. The rural population resides in areas located on both banks of the entire stretch of Ganga River Basin. The main activities in these areas are agricultural and cattle farming. The cattle from local farms frequently visit the river for various activities especially for wading in the river water. This activity affects the river water quality through many ways. The faecal matter of the cattle contributed during wading may directly increase the BOD and coliform load of the river water.

In the Hindi mythology, bathing in the rivers and other water bodies are considered sacred and great significance is assigned to it on some auspicious day or moment. It is believed that it is one of the ways to wash out the sins. Therefore, in the entire country mass bathing in river is a very common phenomenon. The water quality may deteriorate further through activities related to bathing, e.g., offering of flowers, milk, sweets, etc., into the river water.

Some parts of the river course in Ganga Basin are highly populated and sanitary facilities in rural and urban centers are either not existing or not developed. Therefore, a large part of the population uses the river catchment area for open defecation. Moreover, dumping of dead animals and human dead bodies in the river may also affect the water quality of the river.

Washing of clothes along the bank of the river is a common feature both in rural and urban centers. This may not only cause inorganic, organic and biological contamination but also increase the detergent contents.

However, pollution load generation from the above-mentioned sources is unaccountable; hence, in this Study; these sources should be excluded from the pollution load estimation.

(5) Sub-basin Wise Point Pollution Load Generation

(a) Population Distribution in Ganga Basin

Class I cities and Class II towns in each sub-basin are given in Table B.5.3. Further, the sub-basin wise total population including small towns classified as Class III and Class IV is shown in Figure B.5.1. According to the 2001 census data, the total population in the entire Ganga Basin amounts to 397 million, and approximately 22% of the people is living in the Class I cities and Class II towns.

Based on Figure B.5.1, the Upper Yamuna II and Lower Ganga II sub-basins are the most congested areas and large quantities of domestic wastewater are generated from these sub-basins.

The population density of each sub-basin is shown in Figure B.5.2, and it is obvious that the Middle Ganga II, III and IV sub-basins, as well as the Upper Yamuna II and Lower Ganga II sub-basins, have high population densities.

Further, river system wise population and its density is summarized in Table 5.9 and Figure 5.2.

Table 5.9 River System Wise Population and Its Density

No.	River System	Population	Total Area (km^2)	Population Density ($person/km^2$)	Main Cities
1	Upper Ganga	34,352,486	80,585	426	
2	Middle Ganga	30,883,036	36,365	849	Kanpur, Allahabad, Varanasi
3	Lower Ganga	152,530,853	319,729	477	Patna, Culcatta
4	Upper Yamuna	72,826,333	108,664	670	Delhi, Agra
5	Lower Yamuna	80,114,263	259,387	309	Jaipur, Indore, Bhopal
6	Gomati	26,951,239	33,403	807	Lucknow
	Total	397,658,210	838,583	474	

The Figure 5.2 shows that population density ranges from 309 to 849 person/km^2 and those of Upper Ganga, Middle Ganga, Upper Yamuna and Gomati are slightly higher than those of other river systems.

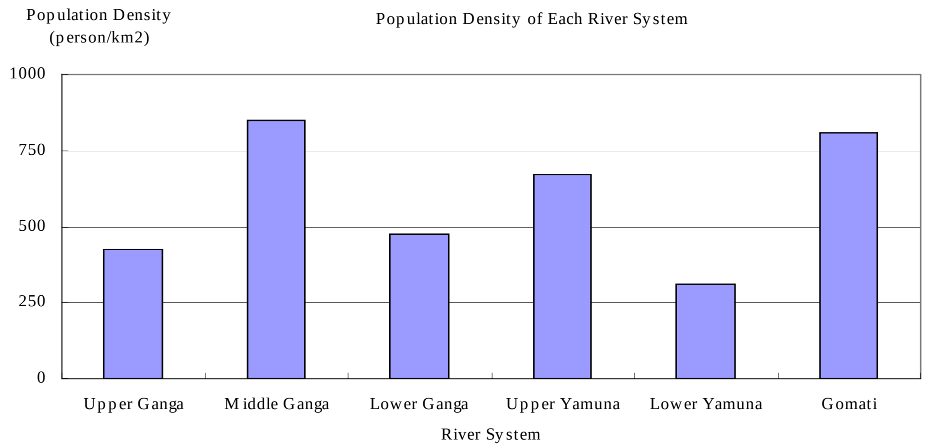


Figure 5.2 Population Density

(b) Sub-basin Wise Industrial Pollution Load Generation

Pollution from industrial and urban wastes has, no doubt, serious deleterious effects on the water quality in the Ganga Basin. Sub-basin wise industrial BOD load generation is presented in Table 5.10. Sub-basins with significant load generation are Lower Ganga II, Upper Yamuna II, Chambal, Ramganga and Hindon. The corresponding districts draining into these sub-basins are also listed in Table 5.10. The top five sub-basins account for 57% of the total load generation. The Top ten sub-basins account for 83% of the total load generation and the remaining 26 sub-basins with individual share of 0-3% account for the rest 17%.

Table 5.10 Basin/ Sub-basin wise Industrial BOD Load Distribution in the Study Area

No.	Sub basin	BOD (t/d)	% of total	Remarks
1	Lower Ganga II	65.23	21.1	Five industrialized districts of Haora, Hugli, Kolkata, North and South 24 Parganas contribute to this sub-basin.
2	Upper Yamuna II	30.14	9.8	Intensively industrialized districts of Delhi, Karnal, Kurukshetra, Panipat, Sonipat and Yamunanagar drain into this sub-basin.
3	Chambal	28.01	9.1	Entire western MP and most of Rajasthan drain into this sub-basin
4	Ramganga	27.48	8.9	The sub-basin drain districts with concentration of agro based industries, i.e., sugar, distillery and pulp & paper. The districts are Bareilly, Bijnor, Moradabad, Nainital, Pilibhit, Shahjahanpur and Udhamsingh Nagar
5	Hindon	25.82	8.4	Muzaffarnagar and Saharanpur, two industrially developed districts in western UP drain into this sub-basin.
6	Upper Yamuna III	20.15	6.5	Main districts draining in this sub-basin are Noida, Mathura, Agra, Faridabad, Gurgaon, and Alwar
7	Middle Ganga II	17.38	5.6	Industries in Kanpur Nagar and Unnao districts drain into this sub-basin
8	Kalinadi	15.85	5.1	Top eight sub-basins carry 75% of the total industrial BOD load generated in the Ganga basin.
9	Ghaghra	15.68	5.1	Districts in north-eastern UP
10	Ajay	11.30	3.7	Barddhaman district (WB)
11	Others	51.81	16.8	Remaining 26 sub-basins with industrial BOD loads in the range of 0 to 3% of the total
	Total	308.84	100	

On the other hand, from operational individual units and 30 clusters of SSIs, the quantum of BOD load entering into the river system is estimated to be 308,838 kg/d. With respect to the estimated BOD load from the domestic sector (approximately 2,225 tonnes/day for 2001 population) this comes out to be around 14 %.

5.3.2 Non-point Pollution Load Generation

Water runoff from rural settlements, cattle pens, agricultural farms, etc., in the basin is likely to be toxic enough to pollute the prevailing water bodies and drainage systems and the heavy silt load brought down by the runoff also affects the water quality and causes navigational problems and other environmental hazards in the Ganga Basin. The generation of pollution load from agricultural land, livestock and rural households would be more or less uniformly spread over large areas.

After land disposal of the wastewater, the pollutants do not reach the water bodies directly but get decomposed by microorganisms present in the soil or are consumed by other living beings. Some parts of wastewater may also percolate into the soil. Thus, there is feeble chance for these sources to directly deteriorate river water quality through such a phenomenon.

During the onset of the monsoon, with the first showers of the season, the flushing of the whole catchment area takes place. As a result, the pollution load from land surface present in small or large quantities may find its way to recipient water bodies such as rural drains, along with storm water. However, in the course of flow downstream, these pollutants may undergo physical, chemical and biological changes and a considerable portion of particular substances settles down by the time the flow joins the main river course. Thus, the pollution load in rural areas regarded as non-point sources does not cause a serious problem to river water quality during the dry season.

(1) Objective Non-point Pollution Sources

In this Study, non-point pollution load is assumed to be generated from livestock, lands (agricultural land, pastureland, shrubs/forests) and households in the rural area. The number of livestock, rural population and land use area in each sub basin has been estimated, as shown in Table B.5.1.

The Ganga basin survey reported that the tonnage consumption of fertilizers in the basin accounted for almost 33.8 percent of Indian annual consumption. The application of fertilizer per hectare of land varies tremendously, and is higher in the alluvial plains of the basin. The area between Ganga and Yamuna basins has a conspicuous feature.

BOD unit pollution load generation of each non-point source category is assumed, as shown in Table 5.11, based on previous studies and reports.

Table 5.11 Unit BOD Pollution Load Generation from Non-point Sources

Sources		Unit Load of BOD	Reference
Livestock	Bovine	600 g/head/day	Guideline for Basin-wide Water Pollution Control Master Plan, Japan Sewage Works Association, 1996, p41
	Sheep and Goats	60 g/head/day	Guideline for Basin-wide Water Pollution Control Master Plan, Japan Sewage Works Association, 1996, p41
	Others	200 g/head/day	Guideline for Basin-wide Water Pollution Control Master Plan, Japan Sewage Works Association, 1996, p41
Agricultural Land		8.57 kg/km^2/day	Preparation of Unit Pollutant Load for Environmental Assessment, Nomura Synthetic Institute Japan
Pastureland		1.00 kg/km^2/day	Assumed by the Study Team
Shrub/Forest		0.75 kg/km^2/day	Preparation of Unit Pollutant Load for Environmental Assessment, Japan Sewage Society
Household (After Septic Tank Treatment)		14.0 g/person/day	Preparation of Unit Pollutant Load for Environmental Assessment, Japan Sewage Society

In the table above, unit population load generation from households is the pollution load generated after septic tank treatment. Further, non-point pollution load from cattle is considered to reduce by about 80% of the unit pollution load (600g/head) because of its use as manure and fuel.

(2) Sub-basin Wise Non-point Pollution Load Generation

(a) Land Use in Ganga Basin

Land use data for the study area is based on the map prepared by the Indian Institute of Remote Sensing, Dehradun, using the satellite imagery of the region. A large part of Ganga River Basin is extensively cultivated to support self-sufficiency with respect to food production for around 40% of the Indian human population living in the basin area. The climate and soil conditions in the region also favor agricultural production. Therefore, agriculture is the largest sector of economic activity in Ganga River Basin and hence, in all the six river systems included in the Ganga River Basin, share of the agriculture land use is significant. Table 5.12 shows the land use area of each river system, for sub-basin wise land use area, see Table B.5.4. Approximately, around 74% of the total basin area (approximately 840,000 km^2) lie under agricultural land use. Forests and shrubs occupy around 18% of the total area. Pasture and Grassland spreads over an area of 2% of the total basin area. Areas that are not cultivated, e.g., Barren land, Desert, Wasteland, Rock, Snow and Water bodies, have been categorized as “Others” and contribute around 6% of the total basin area.

Table 5.12 Area of Each Land Use Category

No.	River System	Shrub/Forest (km^2)	Agricultural Land (km^2)	Pasture Land (km^2)	Others (km^2)	Total (km^2)
1	Upper Ganga	15,079	51,626	8,516	5,364	80,585
2	Middle Ganga	4,881	29,590	1	1,893	36,365
3	Lower Ganga	48,584	231,341	4,276	35,528	319,729
4	Upper Yamuna	8,102	95,395	1,153	4,014	108,664
5	Lower Yamuna	71,988	177,891	0	9,508	259,387
6	Gomati	556	32,629	45	623	33,853
	Grand Total	149,190	618,472	13,991	56,930	838,583

<u>Area under Forests/Shrubs in Different River Systems</u>

The areas that are covered by different kinds of forest, bushes and shrubs are classified under forests and shrubs land use category. These forests include various kinds of vegetation like coniferous, deciduous, temperate broadleaved trees, tropical and subtropical evergreen forests, etc. For Upper Ganga, Middle Ganga and Lower Ganga river systems, the area covered under forests and shrubs are around 19%, 13% and 15% of the total area in these river systems. In the case of Upper Yamuna and Gomati, the percentage area under forests is much lower at 7% and 2%, respectively. In Lower Yamuna, forests cover river systems by around 28% of area. The reason for Lower Yamuna consisting of high percentage of forest is attributed to the fact that in Chambal, Sind, Betwa and Ken sub-basins of this river system a large proportion of area falls under forests. There has been extensive deforestation and overexploitation of forest resources in these regions in the past few decades. To maintain sustainable and better quality soil, water and air environment, it is important to emphasize on afforestation. Planting of trees could be extended to such areas as wastelands, uncultivated lands, along the roads and canals in order to increase the degree of forestation.

Agricultural Land in River Systems

With the increase of population, the demand of food grains is also increasing. This has led to the practice of intensive agriculture throughout the region. In this study, agricultural land in different river systems includes those areas that are being used as irrigated and intensive agricultural lands and also include the cultivable land on slopes. It can be observed from Table 5.12 that in various river systems, the area covered by agricultural land is more than 60%, and for Middle Ganga, Upper Yamuna and Gomati river systems, agricultural lands extend through an area of more than 80% of the total area under these river systems. The sub-basins of Gomati river systems (Upper Gomati, Lower Gomati and Sai sub-basins) lie in the core of the fertile region of Indo-Gangetic plains and almost 96% of area is under the agricultural practices. In the case of Upper Yamuna river systems, also a large part of the basin is under cultivation covering almost 88% of the total area under this river system. Rice, wheat, beans, oilseeds and coarse food grains such as Maize, Bajra and Jowar are the major crops grown in the various regions of river systems of the basin. On an average, two crops are taken in a year with an average cropping intensity of around 1.3. Intensive agriculture is making use of high quantities of fertilizers and pesticides along with manures from compost.

Area under Grasslands in River Systems

Grasslands present in the study area consist of various kinds of grasslands. This category also includes the area used as pastures. In most of the river systems, area covered under this category is around one percent or less except Upper Ganga river system. In Upper Ganga river system, 10% of area is covered by Pastures and Grasslands mainly because of the presence of grasslands in a large part of Upper Ganga I sub-basin (situated in the states of Uttaranchal and Himachal Pradesh).

Table 5.13 Percentage of Total Area under Each Land Use Category

No.	River System	Shrub/Forest	Agricultural Land	Pasture Land	Others	Total Area (km^2)
1	Upper Ganga	18.7	64.1	10.6	6.7	80,585
2	Middle Ganga	13.4	81.4	0.0	5.2	36,365
3	Lower Ganga	15.2	72.4	1.3	11.1	319,729
4	Upper Yamuna	7.5	87.8	1.1	3.7	108,664
5	Lower Yamuna	27.8	68.6	0.0	3.7	259,387
6	Gomati	1.6	96.4	0.1	1.8	33,853
	Total	17.8	73.8	1.7	6.8	838,583

Area under Category Others in River Systems

The areas occupied by barren land, desert, wasteland, rock, snow and water bodies are categorized as “Others” in this study. It also includes the area used as human settlements. All the river systems have only 2-7 percent area lying under this category except the Lower Ganga river systems. In Lower Ganga river system, sub-basins like Haldi and Damodar consist of a large area covered by open water bodies and hence categorized as Others.

<u>Non- point Source Pollution Load Generation from Different Land Use Category</u>

Among all the land uses, the area being used as agricultural land contributes maximum non-point sources pollution load to the rivers. Based on the previous studies, it is assumed that from agricultural land around 8.57 kg/km2/day of BOD load is contributed as non-point sources pollution (see Table 5.11). The unit BOD load from pastureland is considered as 1.0 kg/km2/day and the corresponding value for shrubs and forests are taken as 0.75 kg/km2/day. Using these values, total BOD load contribution as non-point sources load from each category of land use is estimated. However, these rivers receive the pollutant loads along with the runoff mainly during the wet season and only little pollution load is able to reach the river in the dry season.

(b) Livestock Number

The livestock data for the year 2001 considered in this study has been estimated by the projection of data of livestock from the 14th Livestock Census (1987). Growth rate for each type of livestock has been considered using 10-year Cumulative Annual Growth Rate (CAGR, 1987-1997) of data on the national level. Five years of CAGR is observed to be varying too much in nature, so it has not been possible to arrive at any conclusive growth rate based on 5-year CAGR. Therefore, 10-year CAGR has been considered while deciding the value of growth rate for the livestock population projection purposes.

There has been no census of livestock in the states of Bihar and Jharkhand in the year 1987. Therefore, the livestock population of these states for the base year (1987) has been estimated using the average livestock population density of Uttar Pradesh (a neighboring state) and area of each district of Bihar and Jharkhand. In Table 5.14, data on bovine includes the total number of crossbred and indigenous cattle and buffaloes. The number of goats and sheep have been added together and the category “Others” include the total number of horses, ponies, mules, etc. The number of bovine contributes a major share (more than two-thirds) to the total number of livestock.

In the rural areas, the livestock population load is widely distributed over a large area. Moreover, the disposal of wastes occurs normally on land instead of their direct disposal into water bodies. Livestock excreta in rural areas are mostly used as either fuel or manure and hence add very little to the pollutant load into river streams. On the other hand, in urban areas, a large number of dairies, slaughterhouses, feed lots, and tanneries are located which drain their wastes directly into rivers, streams or sewerage systems thus posing a great threat to organic load into the river systems. Therefore, for the calculation of BOD load contribution into the river streams, only urban livestock population under each category has been considered.

Table 5.14 Total Number of Livestock in Each River System

Unit: million heads

No.	River System	Bovine	Sheep & Goats	Others	Sub-total
1	Upper Ganga	10.893	2.575	0.168	13.636
2	Middle Ganga	6.258	2.018	0.052	8.328
3	Lower Ganga	43.758	18.097	0.408	62.263
4	Upper Yamuna	14.006	5.174	0.197	19.377
5	Lower Yamuna	22.499	11.593	0.139	34.231
6	Gomati	6.782	1.968	0.071	8.821
	Total	104.196	41.425	1.035	

The number of urban livestock in each category present in different river systems is shown in Table 5.15. The number of various kinds of total and urban livestock in each sub-basin is given in Table B.5.5. Among the urban livestock population also, the contribution of bovine (cattle and buffaloes) is significant followed by the number of sheep and goats.

Table 5.15 Total Number of Urban Livestock in River Systems

Unit: 1000 heads

No.	River System	Bovine	Sheep & Goats	Others	Sub-total
1	Upper Ganga	470.6	137.2	24.3	632.1
2	Middle Ganga	242.3	75.5	6.6	324.4
3	Lower Ganga	1,777	795.8	60.1	2,632.9
4	Upper Yamuna	1138.6	385.1	24.4	1548.1
5	Lower Yamuna	1756.1	782.5	43.9	2582.5
6	Gomati	140.7	87.5	19.8	248
	Total	5,525.3	2263.6	179.1	-

Further, using the unit pollution load of livestock, non-point pollution load generation was estimated as shown in Table B.5.6.

5.3.3 Total Existing Pollution Load Generation

The existing total pollution load generation of BOD in the entire Ganga River Basin (estimation objective area: approximately 840,000 km^2) is broken down by pollution source, as shown in Table 5.16.

Table 5.16 Pollution Load Generation from Each River System

(Unit: kg/day)

Source	Upper Ganga	Middle Ganga	Lower Ganga	Upper Yamuna	Lower Yamuna	Gomati	Total	(%)
Point (sewerage)	188,346	89,423	498,260	364,618	303,497	71,960	1,516,103	13
Point (industry)	37,864	19,337	123,208	84,270	39,969	6,941	311,589	3
Sub-total	226,210	108,760	621,468	448,888	343,466	78,901	1,827,692	16
Non-point (households)	284,061	269,041	1,406,795	515,587	731,247	260,689	3,467,421	30
Non-point (livestock)	69,578	34,927	273,010	164,609	266,467	26,084	834,675	7
Non-point (land)	462,262	257,250	2,023,308	824,766	1,578,516	280,092	5,426,194	47
Sub-total	815,901	561,218	3,703,113	1,504,962	2,576,230	566,865	9,728,290	84
Total	1,042,111	669,978	4,324,581	1,953,850	2,919,696	645,766	11,555,982	100.0

The existing pollution load generation of BOD by source and in each sub-basin is illustrated in Figure B.5.3. Further, it is broken down by source and by sub-basin, as shown in Table B.5.7.

The ratio of existing pollution load generation of each source in the objective Ganga River Basin is shown in Figure 5.3. Of the total pollution load generation, non-point pollution load generation of BOD shares 84%. However, the runoff of the non point pollution load is very small during the dry season and does not affect the river water quality.

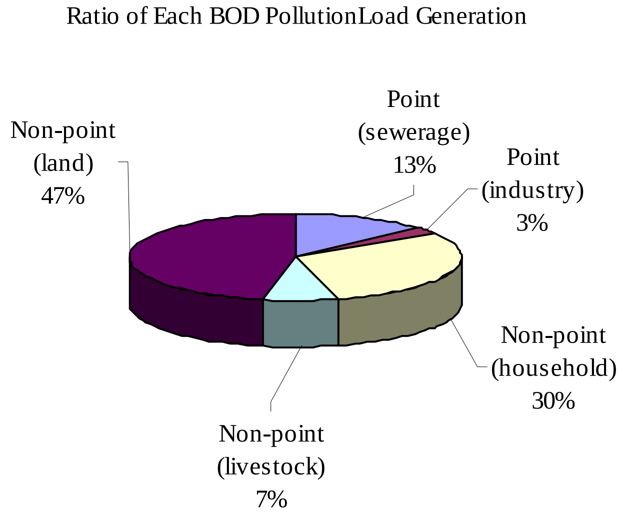


Figure 5.3 Ratio of Each Category Pollution Load Generation

Further, the density of existing BOD pollution load generation in each river system is shown in Table 5.17 and Figure 5.4.

Table 5.17 Density of Pollution Load Generation in Each River System

No.	River System	Pollution Load Generation (kg/d)	Total Area (km^2)	Pollution Density ($kg/d/km^2$)	Main Cities
1	Upper Ganga	1,042,111	80,585	12.93	
2	Middle Ganga	669,978	36,365	18.42	Kanpur, Allahabad, Varanasi
3	Lower Ganga	4,324,581	319,729	13.53	Patna, Calcutta
4	Upper Yamuna	1,953,850	108,664	17.98	Delhi, Agra
5	Lower Yamuna	2,919,696	259,387	11.26	Jaipur, Indore, Bhopal
6	Gomati	645,766	33,403	19.33	Lucknow
	Total	11,555,982	838,583	13.78	

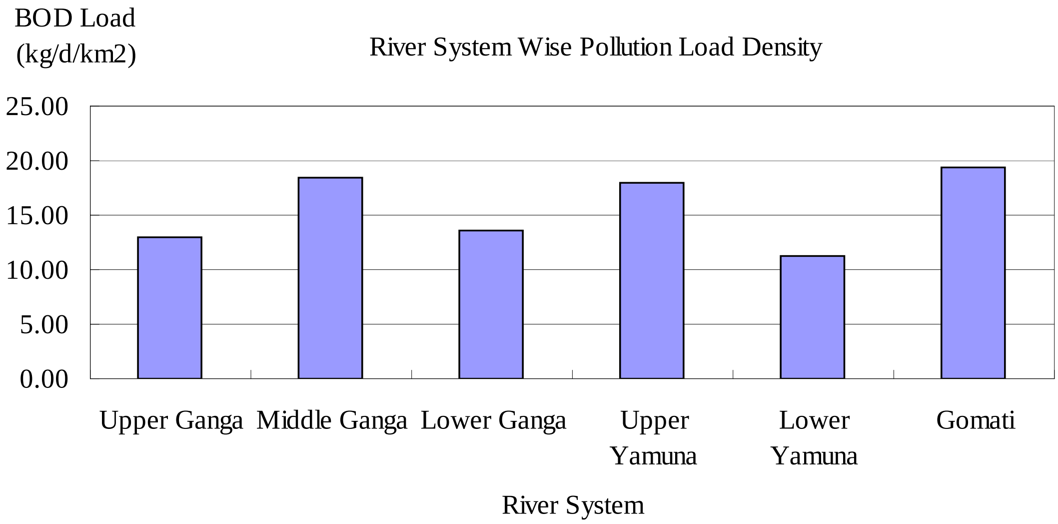


Figure 5.4 Density of Pollution Load Generation

According to the figure above, pollution load generation density of Gomati, Middle Ganga and Upper Yamuna is relatively high compared to other river systems. However, in all the river systems, pollution load generation density ranges from 10 to 20 kg/day/km^2. In order to estimate the exact impact on the river water quality, it is essential that sub-basin-wise pollution load runoff be considered as mentioned in a later part of this report.

5.4 FUTURE POLLUTION LOAD GENERATION WITHOUT PROJECT

5.4.1 Basis for Future Frame of Population / Economic Growth

Municipal wastewater will increase according to the growth of sewerage served population and per capita wastewater quantity, while industrial wastewater will increase according to the growth of industrial production.

(1) Future Population

The future population in the objective basin has been estimated based on the projection study on the actual past census data and state-wise future projection. The target years for the future projection are 2010, 2015 (F/S) and 2030 (M/P).

To project sub-basin-wise population, firstly, the population is projected based on the census data of 1971, 1981, 1991 and 2001. The projection values were obtained for the year 2010, 2015 and 2030. A table has been prepared which provides particulars of the state-wise area in each sub-basin as shown in Table B.5.8. The ratio of area in each sub-basin and the total geographical area of the state is obtained. It is assumed that the population is evenly distributed over the entire geographical area of the state. The population of the state is multiplied with the ratio obtained to give the average population in the basin. The river system wise future projected population is tabulated as given in Table 5.18 (a) to 5.18 (c).

Table 5.18 (a) Future Population in Each River System (2010)

No.	River System	Population	Area (km^2)	Population Density (person/km^2)	Main Cities
1	Upper Ganga	41,500,189	80,585	515	
2	Middle Ganga	37,596,538	36,365	1034	Kanpur, Allahabad, Varanasi
3	Lower Ganga	178,468,210	319,729	558	Patna, Culcatta
4	Upper Yamuna	90,373,580	108,664	832	Delhi, Agra
5	Lower Yamuna	97,243,451	259,387	375	Jaipur, Indore, Bhopal
6	Gomati	38,653,948	33,403	1157	Lucknow
Total		483,835,916	838,583	577	

Table 5.19 (b) Future Population in Each River System (2015)

No.	River System	Population	Area (km^2)	Population Density (person/km^2)	Main Cities
1	Upper Ganga	46,036,308	80,585	571	
2	Middle Ganga	41,839,398	36,365	1151	Kanpur, Allahabad, Varanasi
3	Lower Ganga	197,231,125	319,729	617	Patna, Culcatta
4	Upper Yamuna	103,495,500	108,664	952	Delhi, Agra
5	Lower Yamuna	107,934,932	259,387	416	Jaipur, Indore, Bhopal
6	Gomati	43,089,647	33,403	1290	Lucknow
Total		539,626,910	838,583	643	

(2) Future Economic Growth

The future economic growth in the objective basin was estimated based on the projection study on the actual information published by the industrial sectors. The target years for the future projection are 2010, 2015 (F/S) and 2030 (M/P).

Table 5.20 (c)Future Population in Each River System (2030)

No.	River System	Population	Area (km^2)	Population Density ($person/km^2$)	Main Cities
1	Upper Ganga	60,240,639	80,585	748	
2	Middle Ganga	55,104,871	36,365	1515	Kanpur, Allahabad, Varanasi
3	Lower Ganga	256,987,502	319,729	804	Patna, Culcatta
4	Upper Yamuna	145,231,321	108,664	1337	Delhi, Agra
5	Lower Yamuna	140,764,011	259,387	543	Jaipur, Indore, Bhopal
6	Gomati	57,030,415	33,403	1707	Lucknow
Total		715,358,759	838,583	853	

Considering the wide geographical and category spread of the future industrial products it is rather difficult to arrive at a uniform or singular number indicating the growth rate in industrial pollution for next decade or beyond. However, an attempt was made to develop a representative scenario considering the following aspects:

(a) Generally, the growth of point pollution load from industrial sector is correlated to the growth of industrial sector. The latter is indicated in “Index of Industrial Production” which is calculated annually by the Central Statistical Organization (CSO) based on a sample survey of a wide spectrum of industry across the country. This study can use the index corresponding to the category of “manufacturing industry” provided separately by the CSO.

(b) While the Tenth Five-Year Plan targets an annual growth of 10% in the industrial production, the trend in the recent past has not been anywhere close to this figure. It was only in the year 1995-96 that the country recorded an overall growth rate of 13%. Since then the growth rate has been between 5 to 6% and during the year 2001-2002 it declined to 2.7 % representing global slow down. A plot of growth rates in manufacturing sector and the overall industrial sector is shown in Figure 5.5. As per the Indian Economic Survey of 2002-03, the first six months of the year showed an up trend and the two indices are recorded at 5.4 and 5.3, respectively. It is expected that in the near future the growth rate for the manufacturing sector will continue to be around 5%.

(c) However, if the individual industry categories are considered, the situation can be quite complex. The sugar industry is expected to be stagnant due to excess production capacity. Similarly the pulp and paper industry has been struggling to come out of recession and is growing at a flat rate. There is high level of sickness in the vegetable oil and vanaspati industry. Almost 40% of the units from the latter category included in the database have been closed down.

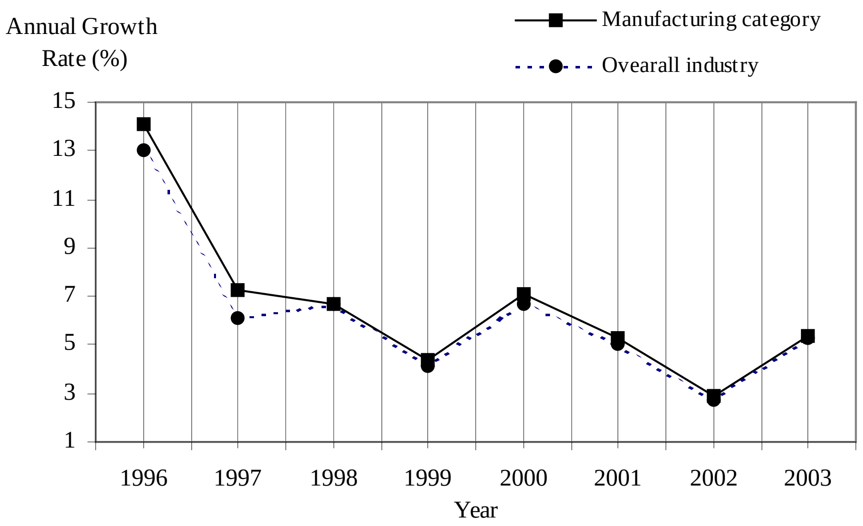


Figure 5.5 Industrial Growth Rates During Last Eight Years

(d) Tannery industry has been at a receiving end due to environmental pressures both from the domestic and international markets. It has been forced to install pollution control systems and thus discharges from this industry are not expected to grow dramatically.

(e) Among the top polluting categories of industries, those that are expected to grow are abattoir and distillery. Production in registered and unregistered abattoirs is correlated to the growing population of consumers of meat products and the discharges from this sector are completely unregulated. On the other hand, in case of distilleries, it is expected that the recent trend of bio-composting and achieving zero discharge will pick up and thereby the net release of organic load into the river system will decline.

(f) Moreover, it is expected that in coming years implementation of pollution control laws will be more stringent and effective and industry will tend to comply with discharge norms under the emerging international quality and environmental systems. Besides this, the increasingly critical situation on water availability is compelling industries to adopt higher levels of treatment and recycling of effluents. Under this overall scenario a conservative estimate of growth of around 4% in the BOD load is considered for the next 7 years i.e., up to 2010 from the industrial sector in the Ganga basin.

(g) In subsequent years, while the overall infrastructure is expected to improve, it is very difficult to forecast the rate of industrial growth. While the Tenth Five Year Plan aims to achieve an average of 10% growth per annum, the prediction would be subjected to uncertainties associated with the international industrial scenario, liberalizing trade regime, cycles of economic growth and recession and last but not the least the vicissitudes of climate change. While keeping an ambitious growth target, the Tenth Plan document itself states that “unless India is proactive in responding to the imperatives of the changing environment, there is a very serious danger that it would be left far behind in today’s race for the ‘survival of the fittest’. In short, Indian industry has to discard its inward looking approach and become outward-oriented and learn to operate in an unprotected, internationally competitive environment” (Tenth Five Year Plan, 2002-2007, Vol. II pp. 664).

(h) A high rate of growth witnessed in some of the South Asian countries during the last decade has turned out to be unsustainable. On the other hand, in the case of developed and stable economies of Western Europe, USA and Japan, the typical annual growth rate is between 2-4%. Indian economy (especially the manufacturing or the secondary sector) could well be entering into that territory of growth by the turn of the current decade. In this context, a rather flat growth rate of 2% for the industrial pollution load is assumed for the period between 2010 to 2030. As a result, the aggregate basin-wide BOD loads for year 2010 and 2030 are estimated as shown in Table 5.21.

Table 5.21 Future Growth Rate of Industry

Year	2003	2010	2015	2030
Annual Growth Rate (%)	-	4.0	3.6	2.0
BOD (ton/d)	308.8	406.4	475.6	603.8
Constant	1.00	1.31	1.54	1.95

5.4.2 Future Point Pollution Load Generation

The future point pollution load generation without project in the objective Ganga River Basin in the target years of the F/S (2015) and Master Plan (2030) are estimated in the same manner as in existing case.

5.4.3 Future Non-point Pollution Load Generation

In this Study, non-point pollution load from livestock, lands (agricultural land, pastureland, shrubs/forests) is assumed to be in the same condition as in existing one because non-point pollution loads are not controlled and predicted. However, households in the rural area are only taken into account as a future condition based on the future projection.

5.4.4 Total Future Pollution Load Generation

The future pollution load generation in the objective Ganga River Basin in the target years of the F/S (2015) and Master Plan (2030) are estimated, as shown in Table B.5.9 to B.5.12. The total future pollution load generation of BOD in the objective Ganga River Basin (estimated objective area: 840,000 km^2) is summarized in Tables 5.22 and 5.23. In case of the future condition with project, it is assumed that 80% of domestic pollution load generation is cut down.

Table 5.22 Future Pollution Load Generation (Without Project)

(Unit: kg/d)

Target Year	Source	Lower Ganga	Upper Ganga	Middle Ganga	Upper Yamuna	Lower Yamuna	Gomati	Total	(%)
2010	Point	757,819	277,983	147,207	535,562	422,205	98,518	2,239,295	18.0
	Non-Point	3,942,649	875,196	619,582	1,624,859	2,732,536	688,879	10,483,701	82.0
	Total	4,700,468	1,153,179	766,789	2,160,421	3,154,741	787,398	12,722,996	100
2015	Point	848,179	312,087	172,252	598,512	473,434	111,229	2,515,693	19.0
	Non-Point	4,120,596	912,833	656,422	1,710,095	2,829,760	732,796	10,962,502	81.0
	Total	4,968,775	1,224,920	828,674	2,308,608	3,303,194	844,025	13,478,195	100
2030	Point	1,091,818	407,085	244,781	787,828	620,233	149,006	3,300,751	21.0
	Non-Point	4,689,614	1,030,713	771,498	1,977,476	3,127,548	870,820	12,467,670	79.0
	Total	5,781,432	1,437,798	1,016,280	2,765,304	3,747,782	1,019,826	15,768,420	100

Table 5.23 Future Pollution Load Generation (With Project)

(Unit: kg/d)

Target Year	Source	Lower Ganga	Upper Ganga	Middle Ganga	Upper Yamuna	Lower Yamuna	Gomati	Total	(%)
2010	Point	280,686	95,278	49,707	195,427	126,329	26,978	774,404	7.0
	Non-Point	3,942,649	875,196	619,582	1,624,859	2,732,536	688,879	10,483,701	93.0
	Total	4,223,335	970,474	669,288	1,820,286	2,858,865	715,857	11,258,105	100
2015	Point	321,428	109,066	58,273	223,523	143,929	30,797	887,016	7.0
	Non-Point	4,120,596	912,833	656,422	1,710,095	2,829,760	732,796	10,962,502	93.0
	Total	4,442,024	1,021,899	714,695	1,933,618	2,973,688	763,593	11,849,518	100
2030	Point	410,568	140,485	79,122	289,027	186,398	40,629	1,146,229	8.0
	Non-Point	4,689,614	1,030,713	771,498	1,977,476	3,127,548	870,820	12,467,670	92.0
	Total	5,100,182	1,171,197	850,620	2,266,503	3,313,947	911,450	13,613,899	100

5.5 FORMULATION OF BASIN RUNOFF MODEL

The non-point pollution load flows on lands or through small channels/ditches to a tributary. On the other hand, the point pollution load is directly discharged into a tributary or main river with or without treatment. Thereafter, both point and non-point pollution loads run off through the tributaries to enter the main river. Finally, they flow down the main river.

In the first runoff stage, the non-point pollution load is decreased to a large extent by the natural purification effects on lands and in small channels. In the second runoff stage, the self-purification effects in the tributaries reduce the point and non-point pollution loads until they enter the main river. The self-purification effects in the main river further reduce the pollution loads entering the main river while they flow down to the objective station of river water quality simulation. The river water quality at the objective station of the main river is simulated by combining (i) runoff model from basin, and (ii) self-purification model of Main River. In this Study, the term “pollution load runoff” is defined as the pollution load that enters the main river through the above-mentioned first and second runoff stages. The concept of the basin runoff model is illustrated in Figure 5.6.

In order to evaluate the priority of the sewerage development of each city, it is necessary to estimate not only the total pollution load generation but also pollution load runoff. The objective drainage basin for simulation (840,000 km^2) is divided into 38 sub-basins with a representative tributary each. The pollution load runoff is simulated at the downstream end of the representative tributary of each sub-basin. The above-mentioned main river covers the following river courses: Ganga Main River (Haridwar after Ganga Canal withdrawal – Rajmahal), Yamuna River (Tajewala – Confluence with Ganga Main at Allahabad), and Gomati River (Sitapur – Confluence with Ganga Main at Varanasi).

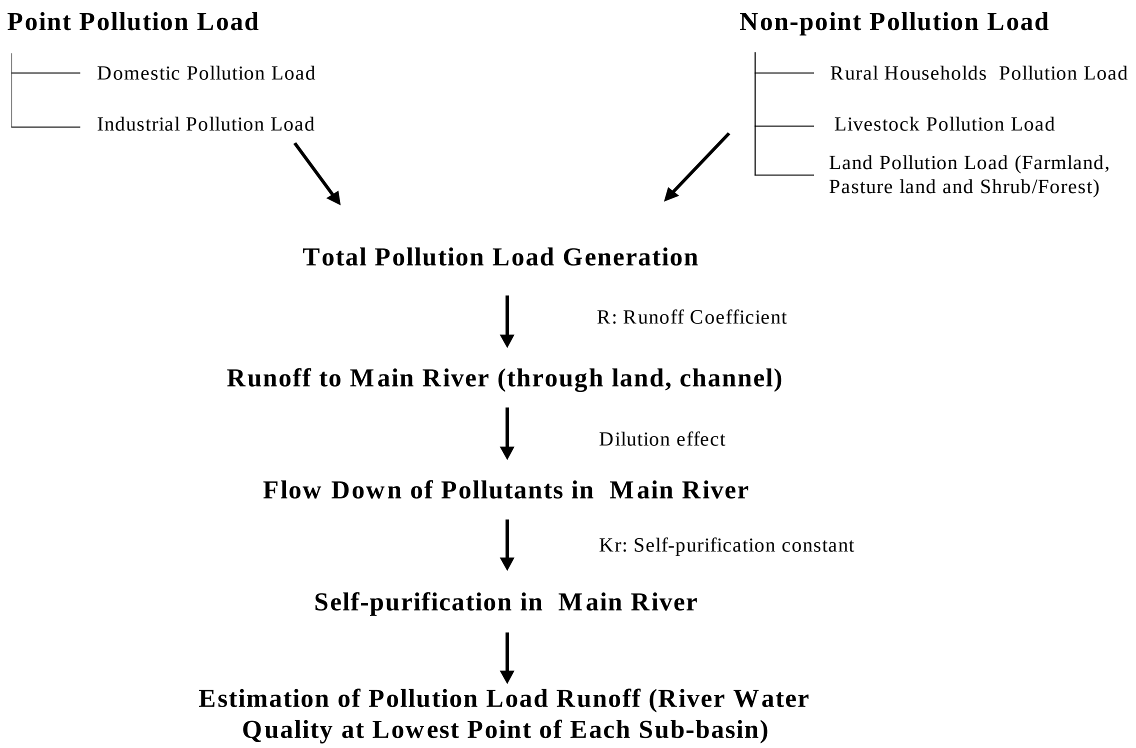


Figure 5.6 Basic Concept for Basin Runoff Model

In order to evaluate the priority of the sewerage development of each city, it is necessary to estimate not only the total pollution load generation but also pollution load runoff.

5.5.1 Skeleton of Basin Runoff Model

The pollution load runoff from basin to the main river is estimated for each of the 38 sub-basins by multiplying the generated pollution load by coefficients of R_1 and R_2 as follows:

Pollution Load Runoff (L_R) = *Generated Pollution Load* $(L_G) \times R_1 \times R_2$

Here, R_1 is the runoff coefficient of pollution load generated from each sub-basin to its representative tributary. R_2 is the self-purification rate of pollution load in the representative tributary of each sub-basin.
Figure 5.7 shows the above-mentioned calculation process of pollution load runoff in one of the sub-basin.

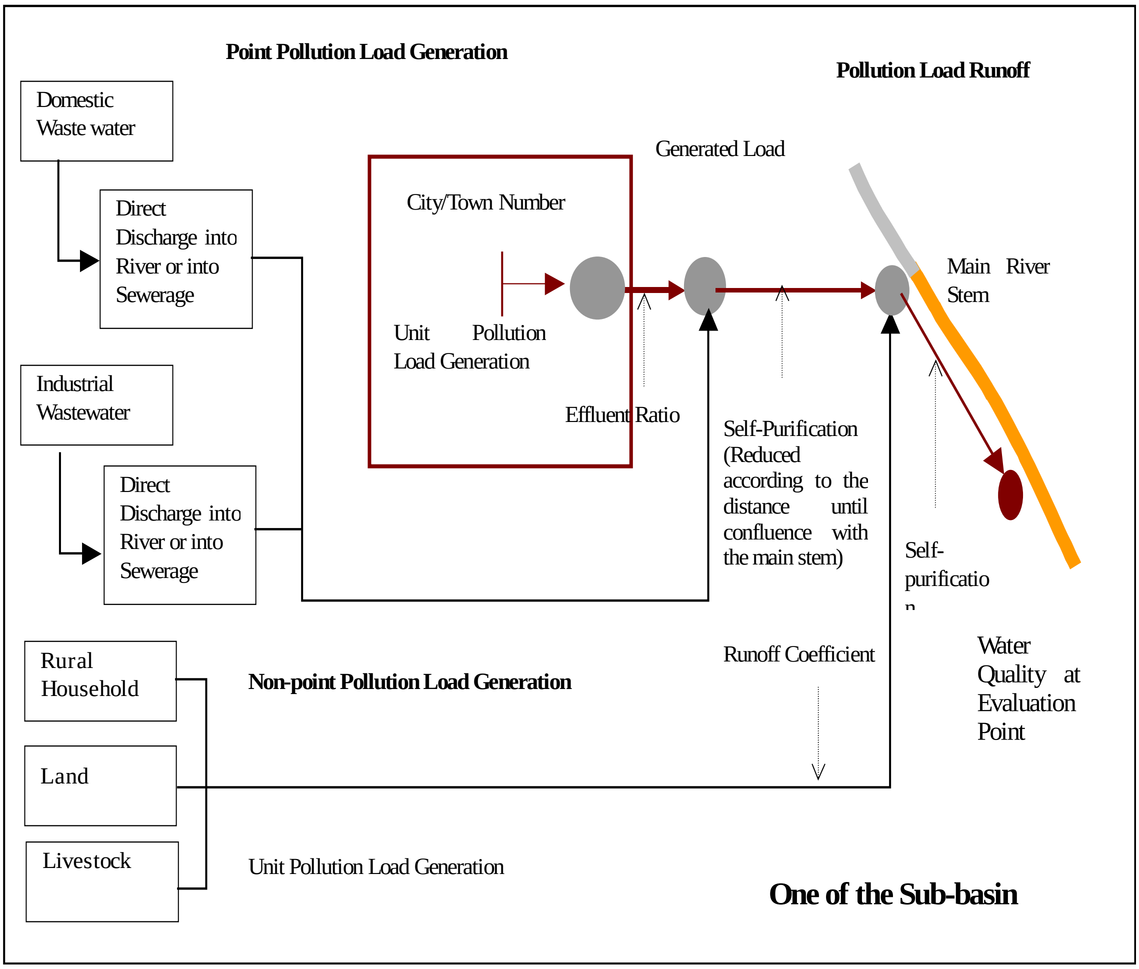


Figure 5.7 Skeleton of Basin Runoff Model

Further, total sub-basin wise pollution load runoff is calculated by $T\text{-}L_R = \Sigma L_{R1\text{-}i}$, and it means the reaching pollution load at the lowest point of each sub-basin. Hence, the river water quality at the lowest point of each sub-basin can be roughly obtained by the total pollution load runoff divided by the river flow.

The city/town source is then assigned to a particular sub-basin/tributary and the corresponding tributary/channel distance from district headquarter is considered as the length over which the wastewater will travel before joining the main stem of Ganga or Yamuna rivers.

5.5.2 Schematic Diagram for Entire Ganga Basin

The simulation of pollution load runoff and river water quality is shown schematically in Figure B.5.4. In this Study, the pollution load runoff is estimated in terms of the parameter BOD.

5.5.3 Runoff Coefficient

Generally, a large portion of the non-point pollution load runs off from the basin in rainy time and the runoff decreases during drought time. Then, the runoff coefficient of non-point load varies according to the variation of river flow rate. The runoff coefficient of pollution load also varies depending on the topographical, geological and other environmental conditions of the objective sub-basin.

(1) Case Study of Runoff Coefficient Value

Similar studies for such a BOD runoff coefficient of non-point pollution load have been conducted in not only Ganga Basin but also in other river basins, as shown in Table 5.24.

Table 5.24 Various Runoff Coefficient

River	Country	Runoff Coefficient	Season	Data Source
Ubate	Colombia	0.03	Dry Season	JICA Study Report (2000)
Sava	Croatia	0.07	Dry Season (95 % River Flow)	JICA Study Report (2001)
Ganga	India	0.05 to 0.42*	Dry Season	Previous Inventory of Ganga

* Previous inventory report does not mention about contents of the pollution load in detail.

Moreover, BOD unit runoff is considered as 0.5 to 1.0 kg/km^2 from watershed in Japan for the sewerage development planning.

(2) Estimation of Runoff Coefficient for this Study

In this Study, the runoff coefficient (R_1) from the sub-basins is obtained through comparison of the calculated pollution load runoff with the observed one at the representative water quality observation point. In this comparison, the pollution load reduction by the self-purification effect in the tributary is duly considered.

As mentioned before, there is a certain relationship between runoff coefficient (R_1) of non-point pollution load (BOD) and river flow rate. Such a relationship is analyzed at the monitoring station Hamirpur (Lowest Point) of the Betwa River where necessary data for the analysis are available.

The relationships between river-flow rate and BOD runoff coefficient at Hamirpur (Lowest Point) is established as shown in Table 5.25, based on the existing available data (water quality data and river flow rate data; past 5 years). The relationships are also illustrated in Figure 5.8.

Table 5.25 Relation Between Flow Rate and Runoff Coefficient

Probability (%)	Flow Rate (m^3/s)	Runoff Coefficient	BOD Calculated (mg/l)	BOD Actual (mg/l)
90	24	0.010	3.9	4.0
75	30	0.015	3.2	3.2
50	54	0.080	2.8	2.8
40	156	0.180	2.5	2.6
30	219	0.270	2.4	2.4

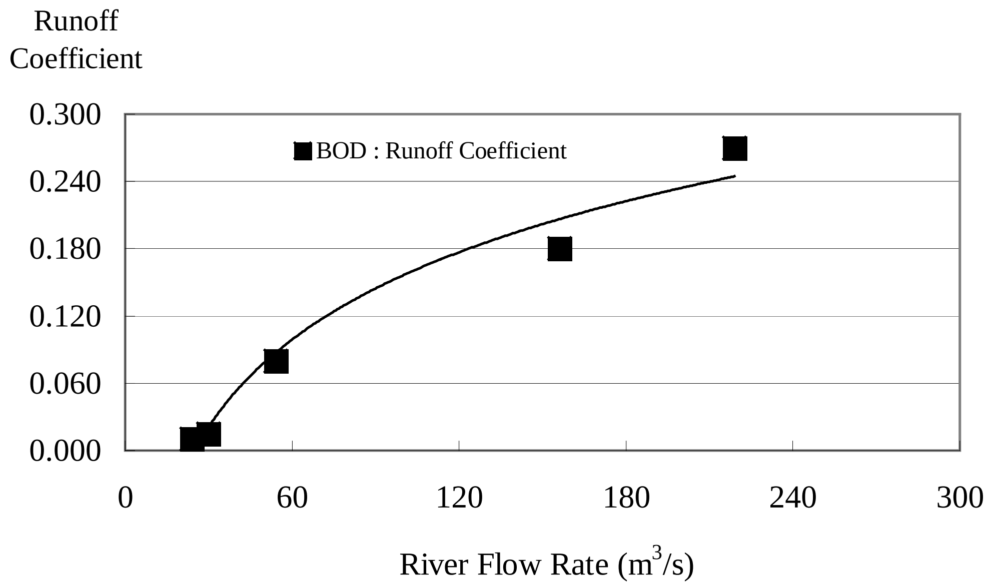


Figure 5.8 River Flow Rate and Runoff Coefficient Curve

In this Study, the runoff coefficients for 90% river flow rate are employed as a condition of the river water quality during dry season. From the above discussions, the BOD runoff coefficient of non-point load for 90% river flow rate is assumed to be 0.01 (1/d).

(3) Estimation of Self-purification Rate of Tributary (R_2)

The pollution load reduction rate in a certain river distance varies mainly depending on the flowing time of river water. The unit pollution load reduction rate (reduction rate per river distance) of the slowly flowing river is larger than that of the fast flowing river.

In this Study, the self-purification rate of the tributary of each sub-basin is estimated by assuming the unit self-purification rate (pollution load reduction rate per river distance).

The unit self-purification rate of the Ganga Main River (Kanpur D/s to Allahabad U/s) is estimated based on the water quality data at Kanpur D/s and Allahabad U/s. There is no major lateral pollution load inflow between these river stretches. The distance between Kanpur D/s to Allahabad U/s is approximately 185 km. The river water quality for 90% river flow rate at the two (2) stations is shown below. From these data, the unit self-purification rate is also calculated as shown in Table 5.26.

Table 5.26 Estimated Unit Self-purification Rate

Parameter	Kanpur D/s	Allahabad U/s	Unit Self-purification Rate (1/km)
BOD	8.2 mg/l	3.4 mg/l	0.004

The unit self-purification rate of tributaries is estimated from that of the Ganga Main River, considering the difference of river flow velocity since the available water quality and hydrological data are limited in the tributaries. In this estimation, the unit self-purification rate is assumed to be in inversely proportion to the river flow velocity.

The average flow velocity in the tributaries of the Yamuna River Basin is considered almost the same as that of the Ganga Main River. However, the flow velocity in the tributaries of the Gomati River Basin is very slow compared to that of the Ganga Main River.

From the above discussions, the unit self-purification rates of BOD for the tributaries of the Ganga Main River and Yamuna are estimated to be approximately 0.4% per km. Consequently, the unit self–purification rate of 0.4% per km (BOD) is applied for the tributaries in all the sub-basins of the Ganga Basin.

The actual data for river flow velocity that were measured in Yamuna River stretch and tributaries in August 2002 are as shown in Table 5.27.

Table 5.27 Case Study of River Flow Velocity

Measuring Points	Width (m)	Max. Depth (m)	Flow Velocity (m)	Water Level (m)
1) Okhla (35km)	116	2.5	0.22	195
2) Mazawali (55km)	120	1.1	0.49	181
3) Mathura upstream (160km)	45	0.5	0.38	169
4) Mathura downstream (175km)	60	1.4	0.19	160
5) Agra upstream (204km)	50	0.6	0.33	146
6) Agra downstream (214km)	66	0.6	0.24	135
7) Bateshwar (274km)	60	4.5	0.07	129
8) Etawah downstream (300km)	61	2.6	0.15	115
9) Chambal River	375	3.1	0.14	-
10) Juhika (414km)	320	8.9	0.06	100
11) Allahabad (600km)	-		-	90

Also CPCB has been measuring the river flow velocity using the current meter in Ganga Main stem, as shown in Table 5.28.

Table 5.28 River Flow Velocity Measured by CPCB

No.	Measuring Points	Flow Velocity (m/s)	No.	Measuring Points	Flow Velocity (m/s)
1	Ganga at Hardwar	0.5 – 1.2	8	Ramganga at Kannauj	0.4 – 0.6
2	Ganga at Kannauj U/s	0.2 – 0.6	9	Kalinadi at Kannauj	0.5 – 0.6
3	Ganga at Kanpur U/s	0.3 – 0.7	10	Ghaghra at near Chapra	0.3 – 0.8
4	Ganga at Allahabad	0.3 – 0.6	11	Hindon at Ghazipur	0.2 –0.4
5	Ganga at Allahabad D/s	0.3 – 0.6	12	Gomati at Jaunpur	0.3 –1.4
6	Ganga at Varanasi U/s	0.3 – 1.0	13	Betwa at Lowest	0.4 – 0.8
7	Ganga at Trighat	0.4 –1.0	14	Sind at Dabra.M.P.	0.2 –0.4

In this study, velocity of river flow is determined referring above values.

(4) Adopted Runoff Coefficient (R_1) and Tributary Self-purification Rate (R_2)

Table 5.29 shows runoff coefficient of sub-basin (R_1) and self-purification rate of tributary (R_2) for point and non-point loads that were adopted for the pollution load runoff simulation of the 38 sub-basins.

Table 5.29 Adopted Runoff Coefficient

Pollution Load	BOD
Point Load	
R_1	0.8
R_2	0.4 % reduction/km
Non-Point Load	
R_1	0.01
R_2	0.4 % reduction/km

5.5.4 Self-purification Model of Main River Water

The Streeter-Phelps Model is widely applied to estimate the self-purification effect of river water with regard to BOD. In this Study, this model is used to estimate the self-purification effect of the main rivers only with regard to BOD. The objective main river covers the following river courses: Ganga Main River (Kannauj - Ghazipur), Yamuna River (Tajewala - Confluence with Ganga Main), and Gomati River (Lucknow U/s - Confluence with Ganga Main River).

BOD concentrations at the objective points were simulated based on the following equations:

Variation rate of BOD concentration: $dC/dt = -K \bullet C$

BOD concentration at objective point (i): $Ci = Li/Qi$
Where,

C: BOD concentration (mg/l)
Ci: BOD concentration at objective point (i) (mg/l)
K: Variation speed coefficient (1/day)
Li: Pollution load at objective point (i) (kg/day)
Qi: River flow rate at objective point (i) (m^3/s)

The self-purification constant K of BOD in the Ganga Main River is estimated to be 0.123 (1/day) based on the water quality data at the Kanpur D/s and Allahabad U/s monitoring stations. These constants were also applied for the Yamuna River and Gomati River.

5.6 EXISTING POLLUTION LOAD RUNOFF

The existing total pollution load runoff of BOD in the entire Ganga River Basin (simulation objective area: 840,000 km^2) is broken down by pollution source, as shown in Table 5.30 (for detail, see Table B.5.13) and Figure B.5.5.

Table 5.30 Existing Pollution Load Runoff

(Unit: kg/day)

Source	Upper Ganga	Middle Ganga	Lower Ganga	Upper Yamuna	Lower Yamuna	Gomati	Total	(%)
Point (sewerage)	51,164	56,794	75,948	149,748	19,522	42,950	396,126	79.4
Point (industry)	11,291	12,078	18,727	25,749	2,215	3,248	73,308	14.7
Sub-total	62,455	68,873	94,674	175,498	21,736	46,198	469,434	94.1
Non-point (household)	964	2,188	3,323	2,138	1,239	1,002	10,854	2.2
Non-point (livestock)	201	285	730	713	474	114	2,517	0.5
Non-point (land)	1,493	2,120	5,122	3,549	2,781	1,193	16,258	3.3
Sub-total	2,659	4,592	9,175	6,400	4,494	2,309	29,629	5.9
Total	65,113	73,465	103,849	181,898	26,231	48,507	499,063	100.0

The ratio of pollution load runoff at each source in the objective Ganga River Basin is shown in Figure 5.9. On the runoff basis, point pollution load shares a large ratio different from that on generation basis and consists of sewerage effluent: 79% and Industrial effluent: 15%.

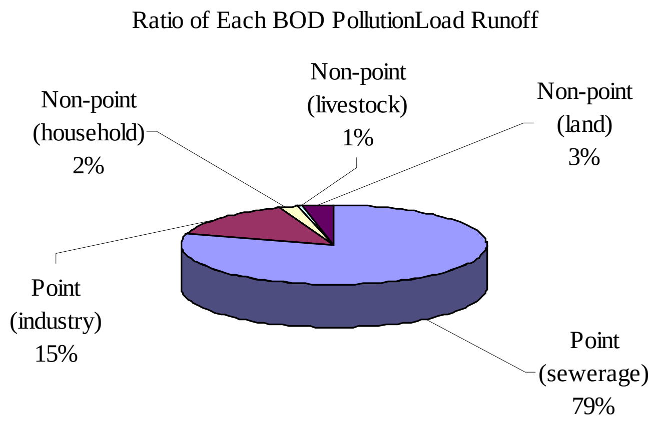


Figure 5.9 Ratio of Each Pollution Load Runoff

Further, the density of sub-basin wise pollution load runoff is illustrated in Figure B.5.6. Among them, Middle Ganga II (Kanpur), Middle Ganga III (Allahabad), and Middle Ganga IV (Varanasi) sub-basins indicate very high density of pollution load runoff. Subsequently Hindon, Upper Yamuna II (Delhi), Lower Ganga I (Patna) and Lower Ganga II (Kolkata) also have high density. Using these results, the density of each river system is calculated as presented in Table 5.31 and Figure 5.10.

Table 5.31 Density of Pollution Load Runoff

No.	River System	Pollution Load Runoff (kg/d)	Total Area (km^2)	Pollution Density ($kg/d/km^2$)	Main Cities
1	Upper Ganga	65,113	80,585	0.81	
2	Middle Ganga	73,465	36,365	2.02	Kanpur, Allahabad, Varanasi
3	Lower Ganga	103,849	319,729	0.32	Patna, Culcatta
4	Upper Yamuna	181,898	108,664	1.67	Delhi, Agra
5	Lower Yamuna	26,231	259,387	0.10	Jaipur, Indore, Bhopal
6	Gomati	48,507	33,403	1.45	Lucknow
	Total	499,063	838,583	0.60	

Based on the Figure 5.10, the pollution load runoff density of Upper Yamuna, Middle Ganga and Gomati is much higher than that of the other river systems. Hence, it may be concluded that the river water quality in these river stretches is much affected by the excessive pollution load discharged into the river.

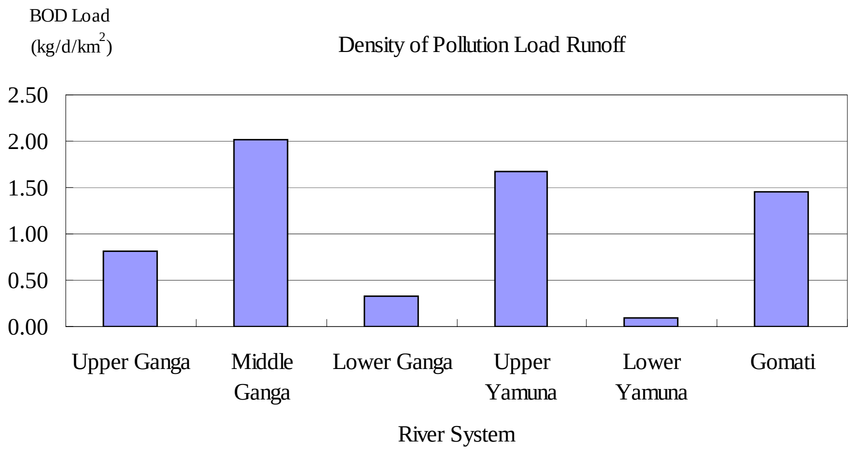


Figure 5.10 Density of Pollution Load Runoff

5.7 FUTURE POLLUTION LOAD RUNOFF WITHOUT PROJECT

5.7.1 Point Pollution Load Runoff

The future point pollution load runoffs without project in the objective Ganga River Basin in the target years of the Master Plan (2030) and F/S (2015) have been estimated.

5.7.2 Non-point Pollution Load Runoff

The future non-point pollution load runoff of BOD in each sub-basin is calculated as products of values in Table B.5.14 and Table B.5.15.

5.7.3 Total Future Pollution Load Runoff

The total future pollution load runoff of BOD in the objective Ganga River Basin (estimated objective area: 840,000 km^2) is summarized in Tables 5.32 and 5.33.

Table 5.32 Future Pollution Load Runoff (Without Project)

(Unit: kg/d)

Target Year	Source	Lower Ganga	Upper Ganga	Middle Ganga	Upper Yamuna	Lower Yamuna	Gomati	Total	(%)
2010	Point	115,930	76,349	93,308	204,574	26,675	57,869	574,705	94.7
	Non-Point	9,744	2,844	5,066	6,875	4,763	2,924	32,216	5.3
	Total	125,674	79,194	98,374	211,449	31,438	60,792	606,921	100.0
2015	Point	130,223	85,504	109,217	225,529	29,902	65,402	645,777	95.0
	Non-Point	10,153	2,962	5,365	7,209	4,929	3,109	33,727	5.0
	Total	140,376	88,466	114,582	232,738	34,831	68,511	679,505	100.0
2030	Point	169,291	110,509	155,354	287,386	39,278	88,061	849,880	95.7
	Non-Point	11,457	3,328	6,299	8,259	5,436	3,692	38,470	4.3
	Total	180,748	113,836	161,653	295,645	44,714	91,753	888,350	100.0

Table 5.33 Future Pollution Load Runoff (With Project)

(Unit: kg/d)

Target Year	Source	Lower Ganga	Upper Ganga	Middle Ganga	Upper Yamuna	Lower Yamuna	Gomati	Total	(%)
2010	Point	42,655	27,103	31,320	67,900	7,656	14,978	191,611	85.6
	Non-Point	9,744	2,844	5,066	6,875	4,763	2,924	32,216	14.4
	Total	52,398	29,947	36,386	74,775	12,419	17,901	223,827	100.0
2015	Point	48,931	31,012	36,724	76,829	8,709	17,082	219,287	86.7
	Non-Point	10,153	2,962	5,365	7,209	4,929	3,109	33,727	13.3
	Total	59,084	33,973	42,089	84,038	13,638	20,191	253,014	100.0
2030	Point	62,838	39,716	49,913	97,646	11,310	22,679	284,103	88.1
	Non-Point	11,457	3,328	6,299	8,259	5,436	3,692	38,470	11.9
	Total	74,295	43,044	56,212	105,905	16,746	26,371	322,574	100.0

The future pollution load runoff of BOD (without project) is broken down into different components of point and non-point sources, as shown in Table B.5.14 (2015) and B.5.15 (2030).

5.8 OBJECTIVE RIVER STATION AND STANDARD FLOW RATE

5.8.1 Objective River Station

The river water quality has been simulated at 11 objective locations: Ganga Main River at Kannauj D/s (A), Kanpur D/s (B), Allahabad U/s (C), Allahabad D/s (D) and Varanasi D/s (E), Yamuna River at Delhi D/s (F), Etawah D/s (G), and At Allahabad (H), Gomati River at Lucknow D/s (I) and Lowest (J). Table 5.34 shows objective river stations for the simulation.

Table 5.34 Objective River Station

River	Code	Objective Station	Remarks
Ganga	A	Kannauj D/s	
	B	Kanpur D/s	
	C	Allahabad U/s	
	D	Allahabad D/s	After confluence with Yamuna
	E	Varanasi D/.s	
Yamuna	F	Delhi D/s	
	G	Etawah	
	H	At Allahabad	
Gomati	I	Lucknow D/s	
	J	Lowest	

5.8.2 Standard River Flow Rate

In this Study, 90% is applied as river flow rate for the evaluation of river water quality and 75% is also used for the supplementary simulation studies on the Gomati River. These standard river flow rates are shown in Table 5.35.

Table 5.35 Standard River Flow at Each Station

River	Objective Station	90% Flow Rate (m^3/s)	75% Flow Rate (m^3/s)	Remarks
Ganga	Ankinghat	117	177	
	Kanpur	103	166	
	Shahzadpur	113	183	Before Allahabad
	Allahabad	304	495	After c/o Yamuna
	Varanasi	360	467	
Yamuna	Delhi (Rly-Bridge)	30	34	
	Etawah	27	44	
	Pratapur	219	273	Yamuna Lowest
Gomati	Lucknow	12	15	
	Mighat	55	80	Gomati Lowest

5.9 DISTRIBUTION OF RIVER WATER POLLUTION IN GANGA BASIN

5.9.1 Distribution of Pollution Load Runoff

Distribution of pollution load runoff is in proportion to the actual river water quality. In other words, density of pollution load runoff considerably affects the river water quality. Sub-basin wise distribution of Pollution Load Runoff is illustrated in Figure B.5.7. According to Figure B.5.7, high density of pollution load runoff can been seen in Upper Yamuna II, III sub-basins, Middle Ganga II, III, and IV sub-basins and Upper Gomati sub-basin. These extremely polluted sub-basins affect the river water quality and there is a need to treat and thereby improve the domestic wastewater quality before being discharged into water bodies.

5.9.2 Simulated Existing/Future River Water Quality

(1) Existing River Water Quality

The existing water quality of the Ganga Main River and Yamuna River at the time of 90% river flow rate has been estimated, as given in Table 5.36.

Table 5.36 Simulated Water Quality for the year 2001 (1)

Item	Ganga Main River					Yamuna River		
	A	B	C	D	E	F	G	H
BOD (mg/l)	5.2 (4.3)	8.0 (8.2)	3.4 (3.4)	4.2 (4.1)	3.5 *(3.1)	38.2 (33.0)	31.9 (30.0)	3.4 (3.3)

Note: Figures in parentheses of lower column indicate observed water quality. Further, evaluation points are as follows: A: Kannauj D/s, B: Kanpur D/s, C: Allahabad U/s, D: Allahabad D/s, E: Varanasi D/s, F: Okhla Bridge, G: Etawah and H: At Allahabad. *: Observed Data by SPCB (CPCB's Data indicate E: 22.5 mg/l that supposes to be doubtful)

The existing water quality of the Gomati River at the time of 90% river flow rate has also been simulated, as given in Table 5.37.

Table 5.37 Simulated Water Quality for the year 2001 (2)

Item	Gomati River	
	I (Lucknow D/s)	J (Lowest)
BOD (mg/l)	7.4 (7.4)	4.7 (5.0)

Note: Figures in parentheses in the lower row indicate the observed water quality.

As shown in the table above, the estimated river water quality is well in agreement with the observed one. Hence, the basin runoff model established in this Section is considered applicable for the prediction of future river water quality.

(2) Future River Water Quality Without Project

The future water quality of the Ganga Main River and the Yamuna River without project in 2015 and 2030 at the time of 90% river flow rate has been simulated, as given in Table 5.38.

Table 5.38 Simulated Future Water Quality for Years 2015 and 2030 (1)

Item	Ganga Main River					Yamuna River		
	A	B	C	D	E	F	G	H
BOD (mg/l)	7.2	12.3	5.3	6.1	5.1	41.2	58.4	4.7
	9.4	16.5	7.1	8.2	7.0	44.4	78.8	6.2

Note: Figures in upper row indicate the future BOD value at 2015 and in lower row indicate the future BOD value in 2030 Evaluation points are as follows: A: Kannauj D/s, B: Kanpur D/s, C: Allahabad U/s, D: Allahabad D/s, E: Varanasi D/s, F: Okhla Bridge, G: Etawah and H: At Allahabad.

Similarly, the future water quality of the Gomati River without project in 2015 and 2030 at the time of 90% river flow rate has been simulated, as given in Table 5.39.

Table 5.39 Simulated Future Water Quality for Years 2015 and 2030 (2)

Item	Gomati River	
	I (Lucknow D/s)	J (Lowest)
BOD (mg/l)	9.9 13.4	6.6 8.8

Note: Figures in the upper row indicate the future BOD value in 2015 and those in the lower row indicate the future BOD value in 2030 without project

(3) Future River Water Quality With Project

The future water quality of the Ganga Main River and the Yamuna River with project in 2015 and 2030 at the time of 90% river flow rate has been simulated, as given in Table 5.40.

Table 5.40 Simulated Future Water Quality (1)

Item	Ganga Main River					Yamuna River		
	A	B	C	D	E	F	G	H
BOD (mg/l)	3.0	5.1	2.2	2.3	1.8	12.6	21.5	1.7
	3.8	6.3	2.7	2.9	2.4	14.4	27.9	2.2

Note: Figures in upper row indicate the future BOD value at 2015 with project and in lower row indicate the future BOD value at 2030 with project Further, evaluation points are as follows: A: Kannauj D/s, B: Kanpur D/s, C: Allahabad U/s, D: Allahabad D/s, E: Varanasi D/s, F: Okhla Bridge, G: Etawah and H: At Allahabad.

Similarly, the future water quality of the Gomati River with project in 2015 and 2030 at the time of 90% river flow rate has been simulated, as given in Table 5.41.

Table 5.41 Simulated Future Water Quality (2)

Item	Gomati River	
	I (Lucknow D/s)	J (Lowest)
BOD (mg/l)	2.6	2.1
	3.5	2.7

Note: Figures in the upper row indicate the future BOD value in 2015 with project and those in the lower row indicate the future BOD value in 2030 with project

As reflected in the above table, the improvement effects of sewerage development are large especially in Allahabad and Varanasi and able to satisfy with water quality category B (BOD 3 mg/l).

5.9.3 On-going/Planned Project for Pollution Abatement

(1) GAP Phase-1

The Ganga Action Plan (GAP) was started in 1985 as a centrally sponsored project. The Ganga Action Plan, which is now referred to as GAP Phase-I, was basically launched as a five-year action plan (1985-1990) with the main aim of restoring water quality up to the bathing standard by integrated actions of pollution control and abatement.

The GAP was basically a city-based program. The main basis of the plan was the CPCB study, the findings of which indicate that nearly 80% of the total pollution load generation is due to municipal sewage from Class I cities located along the riverbanks. Accordingly, the main measures undertaken were to intercept and treat and/or divert the municipal sewage away from the river. Industrial pollution was yet to be controlled under existing environmental laws, and GAP envisaged only monitoring of pollution from identified grossly polluting industries. The aim was to compel them to adopt adequate pollution control measures.

The works related to control of point pollution sources such as sewage interception and diversion schemes and construction of sewage treatment plants (STPs) were core schemes, as shown below.

GAP Phase-I was implemented in 25 Class I category cities located along the banks of the main stems of Ganga as shown in Table 5.42. Regarding wastewater collection and treatment, the target of GAP was fixed to develop necessary treatment facilities for 873 MLD (65%) out of the total estimated 1,340 MLD wastewater generated in 25 cities at the time.

Table 5.42 Sewerage Development by GAP Phase I and YAP

Schemes	GAP Phase-I		YAP (Initial 15 Cities only)
	Total Number Sanctioned	Completed as of 1998	
Capacity build up for domestic wastewater interception and treatment (MLD)	882 MLD (Existing: 151 MLD; New facilities: 731 MLD)	728	704
Pollution control in grossly polluting industries (total wastewater discharge 260 MLD)	68	68	

Source: MOEF 1999, NRCD 1996

(2) GAP Phase-II and Works in Tributaries

Although the works under GAP-I could not be fully completed within the scheduled time of 1991 due to various reasons, a significant reduction in pollution load generation manifested by marked improvement in water quality of Ganga River was observed. This boosted the confidence upon the success of the program. Consequently, the Central Ganga Authority decided to take up Phase-II of Ganga in order to include more cities and schemes in the program and also to extend the works on tributaries such as the Yamuna, Damodar and Gomati rivers. The GAP-II was formally announced on 1991 as a 10-year program; however, the actual implementation was moved on different dates, as shown in Table 5.43.

NRCD reports that a total of nearly 5,044 MLD of sewage, 50/50 in the main stem and tributaries, is generated in the towns along the main stem and tributaries of Ganga. Combining both Phase I and Phase-II, GAP aims to tackle a total of 2,804 MLD, i.e., 55% of sewage throughout the Ganga Basin and GAP-I. Approximately 60% of sewage is expected to be tackled with the timely completion of GAP Phases I and II along the main stem of Ganga River.

(3) Yamuna Action Plan (YAP)

The Yamuna Action Plan (YAP) was initiated in April 1996 (but sanctioned in 1993) with external funding assistance from the Government of Japan. It was originally planned to cover 15 cities (U.P.: 8, Haryana: 6, and Delhi); however, 6 or more cities of Haryana were added later by order of the Supreme Court of India. While the schemes to be implemented were basically on the same lines as those of GAP Phase-I, some modifications were made in the program policies based on previous experience in GAP-I and recent technological innovation.

Table 5.43 GAP Phase-II and Works in Tributaries

Ganga Action Plans		Sanction Date	Target of Sewage Treatment (MLD)	No. of Cities/Towns
GAP Phase-I		Jun. 1985	882 (revised)	25 class-I cities (U.P.; Bihar and WB)
GAP Phase-II	GAP Phase-II (main stem)	Jul. 1995	618	29 (U.P.: 10; Bihar: 11; WB: 8)
	GAP (supreme court cases)	Oct. 1996	162	30 (U.P.: 12; Bihar: 3; WB: 15)
	Yamuna Action Plan (YAP)	Apr. 1996	744	21 (Haryana-12; U.P-8; Delhi)
	Gomati Action Plan	Apr. 1993	330	3 (U.P.)
Damodar Action Plan		Oct. 1996	68	12 (Bihar-8; WB-4)

On the other hand, in the downstream of Ganga River where large cities such as Patna and Kolkata are located along the riverside, there is no serious problem regarding river water quality owing to the huge quantity of river water derived from several large tributaries such as Sone, Ghaghra, Burhi Gandak and so on. Accordingly, apart from the river reach of Yamuna from Delhi to Agra where the Yamuna Action Plan is ongoing for the improvement of river water quality, the urgent improvement of river water quality is highly necessary in the middle river reach where Kanpur, Allahabad and Varanasi are located, and Gomati River where Lucknow is located. Further, apart from the Yamuna river system, the estimated density of pollution load runoff is very large in the Middle Ganga and Gomati river systems compared to others. Hence, a detailed river water quality simulation for the area of four (4) cities is necessary for the estimation of existing/future river water quality and urgent development of the sewerage treatment system.

The overall size of schemes under YAP consists of 44 sewage interception and diversion works, 28 sewage treatment plant construction (total capacity: 704 MLD) and others.

5.9.4 Main Target Area for Detail Study

All the tributaries that flow through cities in the Ganga Basin accept treated or untreated wastewater. Small-scale tributaries are used for wastewater drainage; therefore, river water lacks dissolved oxygen and is blackish in color. Large quantities of river water are withdrawn for irrigation and domestic use at mainly the upper reaches of Ganga and Yamuna; therefore, the shortage of river flow especially occurs in the downstream. Among the specified river stretches, river water quality becomes much worse after intake due to the influence of a huge quantity of wastewater during drought time.

In the Ganga Basin, the irrigation canals and wastewater drainages are much entangled; however, looking at the color of river water, it is very easy to distinguish one from the other because water in irrigation canals are green in color, while water in drainage channels is blackish. Except for some river stretches, Ganga River has a high self-purification effect on itself; i.e., organic pollutants are easily decomposed biologically while flowing down some extent of the river stretch and river water quality will thus revert to its original condition. Further, the river water quality in the downstream is low, clean and stable due to the abundant dilution effect caused by the influence of large tributaries. Currently, there is no major issue related to river water quality in the upper reach, e.g., Rishikesh and Hardwar. However, the reach of Yamuna from Delhi to Agra in Yamuna River, middle reach of Ganga from Kanpur to Varanasi and the reach downstream of Lucknow are too much polluted due to the high density of pollution load runoff.

Further, reaching domestic pollution loads discharged from Varanasi, Lucknow, Allahabad and Kanpur is dominant at the confluence point of Ganga Main and Gomati River (Trighat) as shown in Figure 5.11.

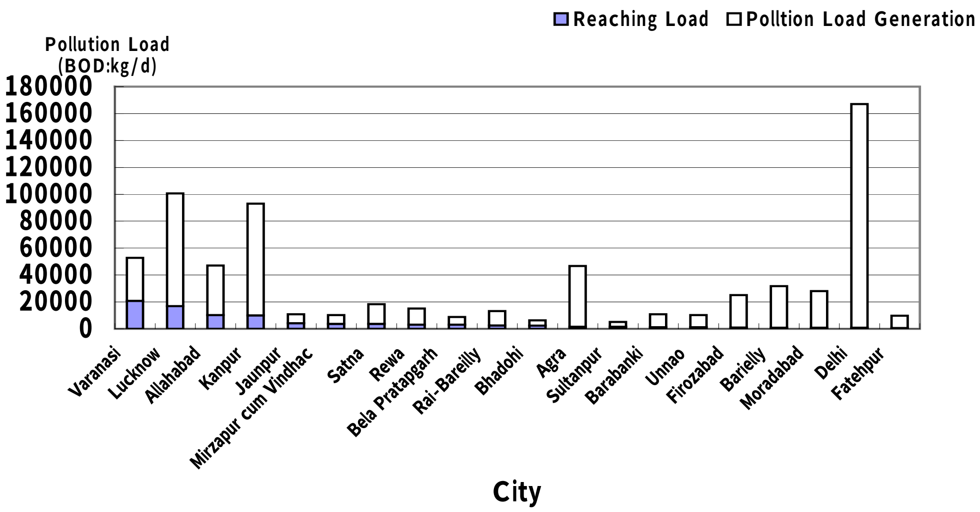


Figure 5.11 City-wise Reaching Domestic Pollution Load to Trighat

Hence, pollution loads reduction of above-mentioned 4 cities is effective and rational to improve the river water quality of middle stretch of Ganga Main.

CHAPTER 6 SIMULATION OF RIVER WATER QUALITY FOR DETAILED STUDY ON THE OBJECTIVE BASIN

6.1 FORMULATION OF DETAILED SIMULATION MODEL

6.1.1 Objective Basin for Water Quality Simulation

The objective basin for water quality simulation involved four (4) cities; namely, Kanpur, Allahabad, Varanasi and Lucknow, as shown in Figure B.6.1. A detailed simulation model was constructed individually for each of the four cities in consideration of accuracy and easier handling. Moreover, the detail simulation model has a special linkage with the basin runoff model set up in the previous section, i.e., the future condition of river water quality of the upstream can be simulated by the basin runoff model and used for the detailed simulation model.

6.1.2 Selection of Water Quality Parameter

The Ganga River is highly polluted by organic material of domestic and industrial origin. This has resulted in a high concentration of organic material, low dissolved oxygen and high concentration of bacteria in the river water. This Study has focused on the most obvious water quality parameter affected by the type of pollution. BOD, DO and Coliform number are used as an indicator of water quality of the Ganga River.

6.1.3 Basis of Detail Simulation for Selected Parameters

The equations for BOD, DO and Coliform Number used in the detail simulation model are as follows:

The objective main river courses are the Ganga Main River (Kanpur - Varanasi) and the Gomati River (Lucknow - Confluence with Ganga Main).

The equations used for simulation of BOD, DO and Coliform Number in the QUAL2E are as follows:

(1) BOD

Streeter and Phelps advocated the equation below for BOD simulation.

$$L_L = \left(L_u - \frac{L_a}{2.31k_r} \right) \times 10^{-k_r t} + \frac{L_a}{2.31k_r}$$

$$D_L = \frac{k_1}{k_2 - k_r} \left(L_u - \frac{L_a}{2.31k_r} \right) \times \left(10^{-k_r t} - 10^{-k_2 t} \right) + \frac{k_1}{2.31k_2} \times \left(\frac{L_a}{k_r} + \frac{D_B}{k_1} \right) \bullet \left(1 - 10^{-k_2 t} \right) + D_u 10^{-k_2 t}$$

···(6-1)

where,

L	:	BOD (ultimate BOD)
D	:	DO concentration（mg/λ）
u	:	Upstream point　*L* :Downstream point
kr	:	reduction coefficient（=*k1* + *k2*）（λ/day）
k1	:	Deoxygenation coefficient（λ/day）
k2	:	Reaeration coefficient
k3	:	Reduction coefficient of sedimentation
La	:	BOD load supplied from river bed（mg/λ/day）
DB	:	Supply or consumption quantity except for reaeration（mg/λ/day）
t	:	Flowing time from A point to B point（day）or current velocity (m/s)

BOD concentrations at the objective points were simulated based on the following simplified equations:

Variation speed of BOD concentration: $dC/dt = -K \bullet C$
BOD concentration at objective point (i): $Ci = Li/Qi$

Where,

- C: BOD concentration (mg/l)
- Ci: BOD concentration at objective point (i) (mg/l)
- K: Variation speed coefficient (1/day)
- Li: Pollution load at objective point (i) (kg/day)
- Qi: River flow rate at objective point (i) (m^3/s)

Based on the water quality data at Kanpur D/s and Allahabad monitoring stations, the self-purification constant K for BOD in the Ganga Main River is estimated to be 0.123 (1/day). The constants are also applied to the Gomati River.

The bacterial number changes in accordance with the decay of bacteria as a function of retention time in the environment and the factors of water temperature, light intensity and salinity. However, salinity does not play any significant role in the case of Ganga Main River; whereas, changes in water temperature and light intensity can highly influence the decay rate.

(2) DO

The oxygen balance in a stream system depends on the capacity of the stream to reiterate itself. This capacity is a function of the advection and diffusion processes occurring within the system and the internal sources and sinks of oxygen. The major sources of oxygen, in addition to atmospheric reaeration, are the oxygen produced by photosynthesis and the oxygen contained in the incoming flow. The sinks of dissolved oxygen include biochemical oxidation of carbonation and nitrogenous organic matter, benthic oxygen demand and the oxygen utilized by algae respiration.

The differential equation used in QUAL2E to describe the rate of change of oxygen is shown below.

$$\frac{dO}{dt} = K_2(0^* + 0) - K_1 L - K_4 / d \qquad \text{.....(6-2)}$$

where,
o = the concentration of dissolved, mg/l
o*= the saturation concentration of dissolved oxygen at the local temperature and pressure, mg/l
$\alpha\,\alpha_5$= the rate of uptake per unit of ammonia nitrogen oxidation, mg-/mg-0
α_6= the rate of oxygen uptake per unit of nitrite nitrogen oxidation, mg-0/mg-N
L = concentration of ultimate carbonaceous BOD, mg/l
d = mean stream depth, m
K_1 = carbonaceous BOD deoxygenation rate, temperature dependent, day^{-1}
K_2 = the reaeration rate in accordance with the Fickian diffusion analogy, temperature dependent, day^{-1}
K_4 = sediment oxygen demand rate, temperature dependent, g/ft^2-day

(3) Coliform Number

The coliform mortality rate is expressed as follows:

$$Kd = K_{do} \,.\, \theta_s^{(sal)} \theta_{I}{}' \,.\, \theta_T^{(T-20)} \qquad \text{...... (6-3)}$$

Kd = *decay rate of coliforms (1/day)*
K_{do} =*decay rate at 20 ^oC, a salinity of 0 promille and darkness*

θ_s =*salinity coefficient for decay rate*
Where,
sal: salinity (promille)
θ_1 : light coefficient for decay rate
I : light intensity integrated over depth (kW/m^2)
θ_T: temperature coefficient for decay rate
T : water temperature (℃)

6.1.4 QUAL2E Simulation Model

It is widely known that the Enhanced Stream Water Quality Model (QUAL2E) is a comprehensive and versatile stream water quality model. It can simulate DO, BOD, Coliform Number and other parameters. The model is applicable to dendritic streams that are well mixed. It uses a finite-difference solution of the advective depressive mass transport and reaction equations. The model is intended for use in water quality planning.

The Streeter-Phelps Model is widely applied to estimate the self-purification effect of river water on BOD. In this Study, this model was used to estimate the self-purification effect of the main rivers.

The stream water quality model QUAL2E is widely used for waste load allocations, discharge permits determinations and other conventional pollutant evaluations in the United States. Since the introduction of QUAL-II in 1970, several different versions of the model have evolved. The most recent modifications in the form of enhanced models called QUAL2E and QUAL2E-UNCAS. Both models have been developed through cooperative agreements between the National Council for Air and Stream Improvement (NCASI), the Department of Civil Engineering at Tufts University, and EPA.

The Enhanced Stream Water Quality Model (QUAL2E) is a comprehensive and versatile one-dimensional stream water quality model. This model is intended as a water quality planning tool for developing total maximum daily loads (TMDLs) and can also be used in conjunction with field sampling for identifying the magnitude and quality characteristics of non-point sources. QUAL2E has been explicitly developed for steady flow and steady waste load conditions and is therefore a "steady state model" although temperature and algae functions can vary on a diurnal basis.

QUAL2E-UNCAS is an enhancement to QUAL2E that allows the user to perform uncertainty analysis. Three uncertainty options are

- Sensitivity analysis
- First order error analysis
- Monte Carlo Simulation

QUAL2E simulates up to 15 water quality constituents in branching stream systems. It divides the stream into three parts as under

- Headwater
- Reaches
- Junction

The reason to subdividing sections of a stream into reaches is that it assumes that some 26 physical, chemical, and biological parameters are constant along a reach.

QUAL2E software requires input data, which can be grouped into three categories as under:

- Stream/river system
- Global Variables
- Forcing Functions

Stream/river system: stream system divides into reaches, which have hydraulic characteristics, after that each reaches is sub divided into computational element of equal length. Thus, all reaches must consist of an integer number. River reaches are the basic of the most input data.

Global Variables: It includes simulation variables, such as units and simulation type, water quality constituents, and some physical characteristics of the basin.

Forcing Variables: This should be specified in terms of flow, water quality characteristics, local climatology, headwater inputs, point sources or withdrawals, incremental inflow/outflow along a reach and the downstream boundary concentration.

In forcing variables category Load climatic data is required for the simulation of algae and temperature. Temperature simulation uses a heat balance across the air water interface and thus it requires values of wet and dry bulb air temperature, atmospheric pressure, wind velocity and cloud cover. Algal simulation requires values of net solar radiation.

All the input parameters and information needed to simulate all 15 state variables for steady state and dynamic conditions are listed in Table underneath.

Table 6.1 Components of QUAL2E Model

Geographic information and temporal information	**Number of reaches, reach length, junction locations, headwater or not, latitude, longitude, standard meridian, basin elevation, period of simulation within the year calendar**
General variables	steady state or quasi-dynamic simulations, units, type of simulation to be performed (regular simulation, uncertainty analysis, type of uncertainty analysis), state variables to be modeled, maximum iteration number, in case of dynamic simulations: time step, total simulation length, time increment for intermediate summary reports of concentration profiles,
Compartment and flow characteristics	compartment size and flow type, dispersion coefficient, coefficient and exponent of the velocity for flow calculation, coefficient and exponent of the flow for stream depth calculation, Manning's coefficient, incremental inflow per reach, headwater flows, water quality characteristics of point sources
Climatic data for light limitation	Dust attenuation coefficient, solar radiation factor, light averaging factor, criteria for light average from solar radiation, fraction of cloud cover, absolute solar radiation
Climatic data for temperature calculations	Two evaporation coefficients, dry and wet bulb temperatures, barometric pressure, wind speed
Temperature	Temperature coefficient for: BOD decay, BOD settling, reaeration, SOD uptake, organic N decay, organic N settling, ammonia decay, ammonia source, nitrite decay, organic P decay, organic P settling, Dissolved P source, algal growth, algal respiration, algal settling, Coliform decay and three arbitrary non-conservative constituents, initial temperature per reach
Nitrogen cycle (values per reach)	Ammonia oxidation coefficient, nitrite oxidation coefficient, nitrogen content in algae coefficient, benthos source rate for ammonia nitrogen, organic nitrogen settling rate, rate constant for the hydrolysis of organic nitrogen to ammonia, nitrification inhibition coefficient, initial values per reach for the four components of the nitrogen cycle and at the headwater
Phosphorus cycle (values per reach)	Organic phosphorus settling rate, benthos source rate for dissolved phosphorus, rate constant for the decay of organic phosphorus to dissolved phosphorus, initial values per reach for the four components of the phosphorus cycle
Algae	Maximum specific algae growth rate, respiration rate, Michaelis-Menten nitrogen half saturation constant, Michaelis-Menten phosphorus half saturation constant, Michaelis-Menten half-saturation constant for light, non-algal light extinction coefficient, linear algal self-shading coefficient, non-linear algal self-shading coefficient, algal preference factor for ammonia, algal settling rate, ratio of chlorophyll-a to algal biomass, fraction of algal biomass that is nitrogen, fraction of algal biomass that is phosphorus, light saturation coefficient, initial Chl. A values per reach and at the headwaters, types of nutrient and light limitation functions
Dissolved Oxygen	O2 production per unit of algal growth coefficient, O2 uptake per unit of algae respired, benthic oxygen demand, carbonaceous deoxygenation rate constant, criteria for the type of reaeration,

	type of reaeration calculations, reaeration coefficient and associated coefficient and exponent, initial DO value per reach and at the headwater
BOD	Rate loss of BOD due to settling, initial BOD values per reach and at the headwater, type of BOD: BOD-5 or ultimate BOD
Arbitrary non-conservative constituent	Arbitrary non-conservative settling rate, benthal source rate for arbitrary non-conservative settling rate, arbitrary non-conservative decay coefficient
Coliforms	Coliform die-off rate

The interface of QUAL2E consists of 24 screens. The first 20 screens symbolize the data for QUAL2E and the last four screens are for QUAL2E-UNCAS.

The screen input for QUAL2E is divided into 6 data components as under:

1. QUAL2E simulation control
2. Stream system
3. Global variables
4. Functional data
5. Climatologic data
6. Uncertainty analysis

- ***QUAL2E simulation control*** describes simulation control variables and number of reaches in the reach system.
- ***Stream system*** is described by the reach connection, element type and computational length.
- ***Global variables*** include number of consistent to be simulated, geographical and climatological information, option for plotting DO/BOD, and Kinetics and temperature correction factors.
- ***Functional data*** provide flow data, reaction coefficients and forcing functions. Initial conditions, boundary conditions and point source loads are input as forcing functions.
- ***Climatologic data*** are required only for diurnal DO simulations.
- ***Uncertainty analyses*** data consist of types of uncertainty analyses, input and Output conditions and input variables with perturbations.

In 24 screens, the first 3 screens describe the complete stream system, which are described by reach name, beginning and ending reach in terms of river miles or kilometer and an indication of the headwater. Sequence of reaches given on screen 2, each reach is then subdivided into computational elements of equal length. The reach names are entered with beginning and ending river miles or kilometers for each reach. The sequence of the reaches should always be entered from the most upstream reach to the most downstream reach. Once this information has been provided, the interface will automatically link all reaches to a stream system and assign the element type as under:

1. Headwater
2. Standard
3. Upstream elements
4. Junction element
5. Downstream element
6. Point source
7. Withdrawal element

- ***Headwater*** element begins every tributary as well as the river system and therefore must always be the first element in a headwater reach
- ***Standard*** element is one that does not qualify as one of the remaining six elements
- ***Upstream*** element is on the mainstream, which is just upstream of a junction.
- ***Junction*** element has a simulated tributary entering it.

- ***Downstream*** element is defined as the last element in a stream system.
- ***Point sources*** and ***withdrawals*** represent elements that have inputs (waste loads and un-simulated tributaries)

6.1.5 Lateral Distribution Analysis

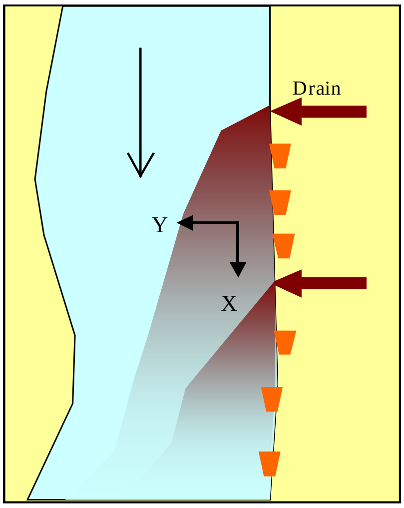
Untreated sewerage wastewater flows into the river through the drainage, however, in case of the large river like the Ganga River, it does not completely mix immediately after confluence with receiving river. Therefore, a lateral distribution of river water quality will be formed until over several km downstream.

The river water pollution at the bank side is much worse than that of the river flow center. There are bathing Ghats in each city along the rivers. Among them especially in Varanasi, more than 80 bathing Ghats are located at the bank side of Ganga and these polluted stretch of river water may affect the people's health. However, it is assumed that pollution load effluent is completely mixed with the river water immediately after inflow according to above-mentioned one dimension model such as QUAL2E. In order to precisely grasp the river pollution, it is required to make a lateral distribution analysis of the river water quality.

To assist in the design and planning of the lateral distribution analysis, following equation is proposed.

$$C(x,y) = \frac{M}{du(4\pi D_y x/u)^{1/2}} \exp\left[\frac{-y^2 u}{4D^y x}\right] \qquad \cdots \text{(6-4)}$$

where,
M = point source mass discharging rate (kg/d)
u = average river velocity (m/s)
D_y = lateral dispersion coefficient (m^2/s)
x = distance across the river (m)
d = average river depth (m)



6.1.6 Basic Condition of Objective Area

All the selected 4 cities are located in Uttar Pradesh and middle part of the Ganga Basin. Since 4 cities has a mutual points that they are very congested and untreated wastewater generates from urban centers are discharged into water body, the water quality of Ganga and Gomati rivers has been extremely deteriorated. Hence, the urgent sewerage development projects are necessary for the improvement of the river water quality. Existing and future condition of urban and rural population of 4 cities is estimated as in following table using the 2001 census data and future projection.

The population projection for the 4 cities, i.e., Allahabad, Kanpur, Varanasi and Lucknow has been made based on the census data for the past 4 decades. The past population has been used to project a graph displaying the trend in the population growth in the past decade. To get a view of the future growth the graph was fitted with three different trend lines, i.e., linear, exponential and parabolic. The best-fitted curve selected based on the value of regression coefficient was used to give the value of the projected population. The census data consisted of an integrated value of rural and urban population for the 4 decades. Hence the projected values also represented the integrated population. To obtain the urban future population the ratio of urban population to total population for 2001 was obtained and an assumption was made that the ratio would be valid for future also. The future urban population was obtained by multiplying the ratio to the total future population.

Table 6.2 Urban Populations in 4 Cities

City	2001 $(*10^3)$	2010 $(*10^3)$	2015 $(*10^3)$	2030 $(*10^3)$
Kanpur	2,880	3,513	3,916	5,183
Allahabad	1,214	1,481	1,651	2,185
Varanasi	1,269	1,548	1,725	2,283
Lucknow	2,342	2,857	3,185	4,216

The basic conditions of the objective areas are summarized below.

(1) Kanpur

Kanpur is the biggest city of Uttar Pradesh and famous for the industrial activities. It is situated on the right bank of Ganga River, which enters the city from the western side and flows out in the eastern direction. Currently, there are 26 drains in Kanpur that have polluted the Ganga River as shown in Figure B.6.2, as a schematic diagram for detailed simulation.

(2) Allahabad

Allahabad is a major urban agglomeration located in the southeastern region of Uttar Pradesh. Allahabad being located at the confluence of two major rivers, namely, Ganga and Yamuna has navigational importance and potential. An industrial zone was created in Naini area and major industrial establishments started operation within this zone. Currently, altogether 11 of existing nalas (drains) tapping arrangements collect sewage from various nalas and discharge them into the present system of sewerage. Nala-wise breakdown of these tapping points are shown in Figure B.6.2, as a schematic diagram for detail simulation.

(3) Varanasi

The city of Varanasi has grown on the holy river Ganga. This holy river traverses a distance of around 10 km along the city. The pollution of river Ganga in this region has been derived from the rapid urbanization, industrialization, tourism activities, throwing of unburned and partly burnt dead bodies, discharge of excreta along banks, dumping of animal carcasses, agricultural runoff and similar activities. Although a sewerage system had already been laid in Varanasi during 1917 from Assi to Rajghat (Trunk Sewer) for the disposal of domestic sewage and drainage of storm water in the river Ganga, sewage started flowing through these drains and pollution of the river started as a result of unplanned and haphazard growth of population. The current condition of sewerage disposal is shown in Figure B.6.2 as a schematic diagram for detail simulation.

Further, there are many river water quality-monitoring stations in Varanasi, which are tabulated in Table 6.3. The data of these stations have been used for the calibration of the simulation results. However, at some stations among them, the sampling has not been carried out along the center of river cross-section, hence the monitoring location should be confirmed in detail.

Table 6.3 Sampling Location of Water Quality Monitoring

Name of Monitoring Station	Sampling Location	BOD Value (mg/l)		Source of Data
		90%	Average	
Varanasi U/s	Assi Ghat	4.1	3.4	CPCB
Varanasi U/s	Pantoon Bridge	3.3	2.2	SPCB (U.P.)
Varanasi D/s	Malavia Bridge	22.5	13.6	CPCB
Dashashwamedh Ghat	-	17.0	6.9	SPCB (U.P.)
Varanasi D/s at Kaithy 1/4	At 1/4 width	3.2	2.2	SPCB (U.P.)
Varanasi D/s at Kaithy 1/2	At 1/2 width	3.2	2.2	SPCB (U.P.)

In the above table, BOD values of Varanasi D/s monitored by CPCB and Dashashwamedh Ghat monitored by SPCB (U.P.) are much higher than that of other monitoring stations. This means that sampling locations are either along the riverbank or located near Ghat and thus they are very polluted by sewerage effluent and human activities.

(4) Lucknow

The urban area of Lucknow is located on both banks of Gomati River called CIS side and TRANS side, respectively. Currently, there are 26 drains in Lucknow, which have extremely polluted Gomati River. Out of the 26 drains, 14 are in the CIS side of the river and 12 are in the TRANS side. The existing condition of the 26 drains is shown in Figure B.6.2 as a schematic diagram for detail simulation.

On the other hand, it should be appropriate to mention here that the sampling station of river water quality named “Lucknow D/s is located before confluence of large sewerage effluent that shares more than 75 % of total domestic wastewater generation.

6.2 INPUT DATA FOR SIMULATION

The river water quality with existing condition, feasibility study (F/S 2010) and master plan (M/P 2030) project was simulated under the following procedures:

6.2.1 Objective Main River Station and River Flow

The river water quality is simulated at the 4 objective locations: Ganga Main River at Kanpur D/s, Allahabad D/s and Varanasi D/s, and Gomati River at Lucknow D/s. River flow data of these 4 objective stations used for the detail simulation as headwater conditions are the same as mentioned in Chapter 5, Sub-section 5.8.2.

6.2.2 Simulation Constant and Coefficient

In order to conduct a simulation study using QUAL2E Model, many constants and coefficients are to be employed and utilized. These values are given in Table B.6.1 to B.6.4. These constants and coefficients were estimated through many calibrations and are based on EPA’s recommendation.

6.2.3 Existing Condition of Pollution Load Generation

For the actual simulation study, existing pollution load and river water quality should be prepared as input data. The existing condition of 4 cities regarding water quality and flow of each drain are also given in Table B.6.1 to B.6.4.

6.2.4 Future Condition of Pollution Load Generation

Municipal wastewater will increase according to the growth of sewerage served population and per capita wastewater quantity, while industrial wastewater will increase according to the growth of industrial production. The future pollution load generation without project in the objective 4 cities in the target years of the F/S (2010) and M/P (2030) are estimated, as shown in Table B.6.1 to B.6.4. Using these data regarding future condition, future river water quality has been simulated in detail.

6.3 SIMULATED RIVER WATER QUALITY

6.3.1 Simulated Existing River Water Quality

(1) One Dimension Analysis (QUAL2E)

In order to grasp the change of the river water quality along the river section, the actual monitoring data are utilized and compared with the simulated river water quality.

The longitudinal profile of existing water quality simulated by QUAL2E Model for each city is shown in Figure B.6.5.

(2) Lateral Distribution Analysis

In order to analyze the lateral distribution of river water quality, many hydrological information is necessary such as two dimension river flow rate, exact river cross section of target river stretch and so on. Especially, cross sectional river flow rate is very important for the simulation of the lateral distribution analysis. Unfortunately, such kinds of information were not thoroughly available for this study, hence, it is impossible to conduct the lateral distribution of the river water quality targeting 4 cities.

As mentioned above, the simulated river water quality (QUAL2E) is well in agreement with the observed one. Hence, the established simulation model in this Chapter is considered applicable for the prediction of future river water quality.

6.3.2 Simulated Future River Water Quality

Results of simulated future river water quality are shown in Table B.6.6. The summary of the results is tabulated in Table 6.4.

Table 6.4 Simulated Future River Quality

S. No	City Name	Present Condition 2003 BOD mg/l	Future Condition 2030 BOD mg/l			
			Without Project	With Project Reduction Rate=80%	With Project Reduction Rate=95%	With Project Reduction Rate=99%
1	Kanpur	8.2	19.3	5.1		1.6
2	Allahabad	3.6	7.3	2.4		1.9
3	Varanasi	2.7	4.9	1.7		1.4
4	Lucknow	14.9	30.0	8.0		1.5

The following assumption/conclusion have been made while generation simulation for the future.

<u>*Kanpur*</u>:

(1) In order to achieve the standards set for the river water quality, interception of 95% sewage is important at Kanpur D/S.

(2) Complete treatment of the effluent from Jajmau treatment

Plant is necessary.

(3) It has been assumed that the treated domestic wastewater shall be utilized completely for irrigation purposes hence shall not contribute to River pollution.

Allahabad

(1) In order to achieve the standards set for the river water quality, interception of 80% sewage is important at Allahabad D/S.

(2) It has been assumed that the treated domestic wastewater shall be utilized completely for irrigation purposes hence shall not contribute to River pollution.

Varanasi

(1) In order to achieve the standards set for the river water quality, interception of 80% sewage is important at Kaithy D/S.

(2) It has been assumed that the treated domestic wastewater shall be utilized completely for irrigation purposes hence shall not contribute to River pollution.

Lucknow

(1) In order to achieve the standards set for the river water quality, interception of 99% sewage is important at Lucknow D/S.

(2) It has been assumed that the treated domestic wastewater shall be utilized completely for irrigation purposes hence shall not contribute to River pollution.

(3) It is necessary to divert the effluent point of the intercepted untreated sewage from the discharge point located upstream of the river to a downstream location.

Apart from the above four cities it is necessary to reduce the pollution load generation by overall sewerage development in all the cities/towns located in the river basin to achieve the goal.

In case of Kanpur and Lucknow, though some amount of sewerage developments has taken place but to achieve the river water standards, almost the entire domestic wastewater generated needs to be treated. Further, in case of Allahabad and Varanasi the effects of sewerage developments are not so visible due to the increased flow in the river.

CHAPTER 7 SCENARIO FOR POLLUTION LOAD REDUCTION

7.1 POLLUTION LOAD BALANCE IN 2030

The river water quality is affected both by river flow and pollution load runoff, the lower river flow and higher level of pollution load runoff leads to the river water pollution. Therefore, it is very important to reduce the inflowing pollution load. The future domestic pollution load balance at the each point estimated in previous Chapter 5 is tabulated in Table 7.1.

Table 7.1 Pollution Load Balance (2030)

Calculation Cases	Population	Before Kanpur, Allahabad and Varanasi			Before Varanasi (Ganga)	After Varanasi (Ganga)	Meeting Point with Ganga & Gomati
		Upper Allahabad (Yamuna)	Upper Kanpur (Ganga)	Total			
Domestic Pollution Load Generation							
Objective 4 Cities	11,682,626	-	-	-	152,066	120,052	235,992
Largest 20 Cities	75,404,082	-	-	-	-	-	1,009,135
Largest 40 Cities	91,310,701	-	-	-	-	-	1,289,364
Largest 60 Cities	100,930,003	-	-	-	-	-	1,488,967
All the Cities	117,048,374	1,141,237	337,106	1,478,343	1,547,308	1,515,294	1,682,779
Ratio of 4 Cities	9.981	-	-	-	9.8%	7.9%	14.0%
Pollution Load Runoff							
Objective 4 Cities (Domestic)		-	-	-	78,525	48,979	105,873
All the Cities		114,713	54,508	169,221	210,377	186,706	240,838
Ratio of 4 Cities		-	-	-	37.3	26.2	44.0%

On the other hand, the domestic pollution loads generated from objective 4 cities obviously affect the river water quality significantly at immediately downstream of each city. Comparing the reaching pollution load of upstream area and that of each city, the impacts against the river water quality can be estimated as shown in Table 7.2. In the meantime, Figure B.7.1 shows the pollution impact against upper and middle stretch of Ganga River (domestic pollution load). As shown in Table 7.2 and Figure B.7.1, the domestic pollution load generation discharged from above mentioned 4 cities amounts to a large quantity and influences a severe impact on the river water quality in the middle stretch of the Ganga Basin. Especially, the impact against Kanpur and Lucknow is very serious so that reduction of domestic pollution load is indispensable for the abatement of the river water quality.

Table 7.2 Impact of Domestic Pollution Load

Objective Cities	A. Domestic Pollution Load Discharged from each City (BOD: kg/d)	B. Reaching Pollution Runoff to each City (BOD: kg/d)	Ratio (%) B/A*100
Kanpur	83,058	54,508	152
Allahabad	36,994	169,221	22
Varanasi	21,104	186,706	17
Lucknow	64,530	2,323	2,780

7.2 CITY WISE POLLUTION LOAD REDUCTION

7.2.1 General

In the entire Ganga Basin, more than 200 large cities categorized into class I and II are widely scattered and discharging a huge quantity of wastewater into the river courses. Many of them are situated along the riverbanks or close to the water body due to the convenience to use the water resources and the inland waterway transportation. Figure B.7.2 shows the city distribution in the upstream area of objective four cities. Figure 7.1 explains a descending order of each city's population covered by the upstream area of the meeting point of Ganga and Gomati Rivers. According to Figure 7.1, there are many large cities, but no significant difference is shown among them except for Delhi. As for the population rank of the objective 4 cities, Kanpur is the second largest city, and following 3 cities: Lucknow, Varanasi and Allahabad are fourth, 9th and 11th, respectively. Total urban population corresponding to upstream areas from the meeting point of Ganga and Gomati Rivers amounts to 117 million. Meanwhile, total urban population of objective 4 cities (Kanpur, Allahabad, Varanasi and Lucknow) runs up to 11.6 million and shares approximately 10% of total urban population of the upstream area of the meeting point of Ganga and Gomati Rivers, and its ratio is too small to obviously improve the river water quality. Needless to say, all the cities located upstream area of objective 4 cities should be planned to possess appropriate sewerage treatment system for the abatement of river water pollution in addition to the existing planning for GAP II and YAP II. Otherwise, installation of sewerage treatment system for objective 4 cities will not be beneficial and its effect will be limited because remaining population and pollution loads share approximately 90% and are too much excessive to control and affect the serious water pollution. In order to meet the water quality standard, efficient countermeasures is indispensable to give full play to its ability of the necessary reduction of the pollution loads. Originally, huge amount of pollution loads generation are discharged into the Ganga Basin, hence, the river water quality is already extremely polluted before reaching at the objective 4 cities even if the self-purification and dilution effects are considered. If the reduction of pollution loads is only taken into consideration in the objective 4 cities, future river water quality is estimated as shown in Table 7.3.

According to results below, reduction of pollution load in the objective 4 cities does not indicate sufficient effect on the recovery of river water quality. Huge amounts of pollution loads discharged into upstream area of the objective 4 cities already affect the river water quality in the middle stretch of Ganga River. In order to apparently improve the river water quality in the middle stretch of Ganga River, pollution loads have to be drastically reduced in all the cities located upstream of the objective 4 cities. As for the reduction ratio suitable for meeting the standard, 65% of reduction ratio is at least required. Further, the pollution load reduction in the largest 60 cities can satisfy the desired standard of the river water.

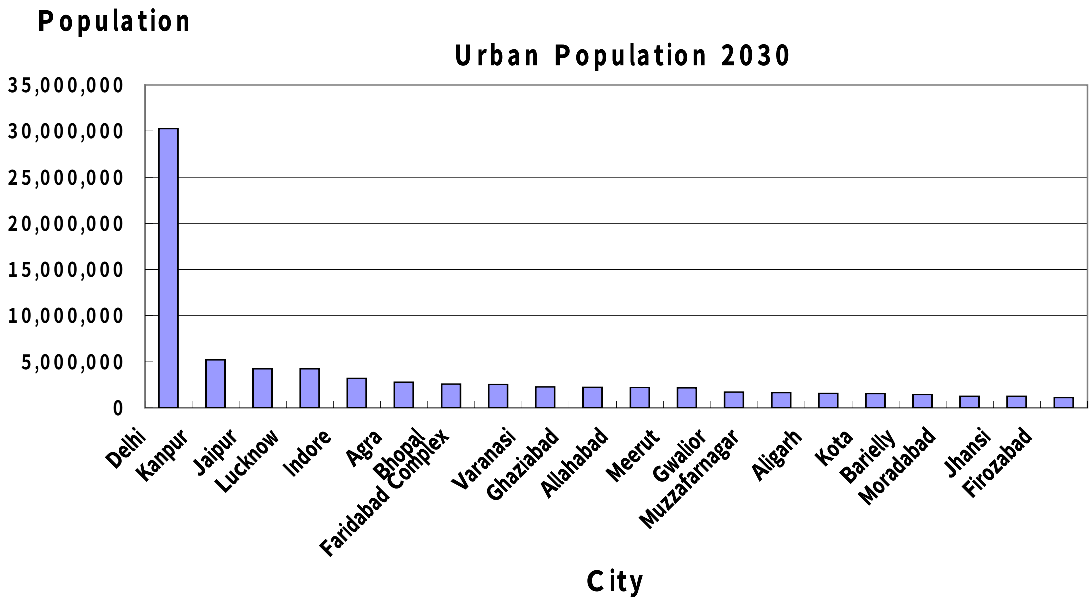


Figure 7.1 Descending Order of Urban Population in 2030 (Ganga Basin)

Table 7.3 Estimated Future BOD Values in Various Scenarios

Case	Kanpur U/s	Allahabad U/s (Ganga)	Allahabad U/s (Yamuna)	Varanasi U/s	Remarks
Without Project	5.1	6.2	5.8	5.9	
Objective 4 Cities (80%)	5.1	3.7	5.8	4.7	
Largest 20 Cities (80%)	4.1	3.3	3.6	3.5	Including 4 cities
Largest 40 Cities (80%)	3.9	3.2	3.1	3.1	Including 4 cities
Largest 60 Cities (80%)	2.9	2.8	2.7	2.5	Including 4 cities
All the Cities (65%)	2.7	2.0	3.0	2.8	
All the Cities (80%)	2.0	2.4	2.1	2.1	

Note: [shaded box] means the satisfactory condition of BOD

7.2.2 Breakdown of Cities

Large cities obviously influence the river water quality due to the huge quantity of the point pollution loads. However, the impact against the river water quality caused by each city is different because the distance from each city to the middle stretch of Ganga River is widely spreading over and their self-purification effect is extensively ranged. Table B.7.1 explains the reaching domestic pollution loads discharged from each city to the final point where the Ganga Main and Gomati River meets. According to Table B.7.1, 95% of the domestic pollution load generation discharged from Delhi ranked as the largest city in Ganga Basin is reduced at the meeting point of Ganga and Gomati, meanwhile only 35% of the pollution load generation discharged from Kanpur ranked as the second largest city is reduced at the objective point. In this Study, the first priority of the project is to mitigate the river pollution especially in the middle stretch of the Ganga River; hence, the efficiency for the reduction of the domestic pollution loads is important.
Figure 7.2 to 7.4 explains the descending order of the reaching pollution load to Kanpur (Ganga), Allahabad (Ganga) and Allahabad (Yamuna), respectively.

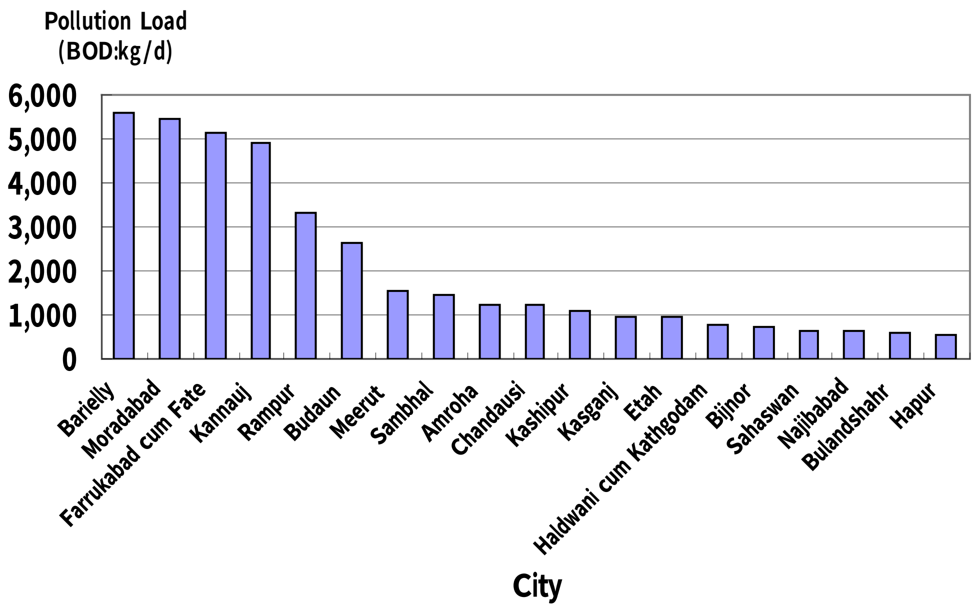


Figure 7.2 City Wise Reaching Pollution Load to Kanpur (Ganga)

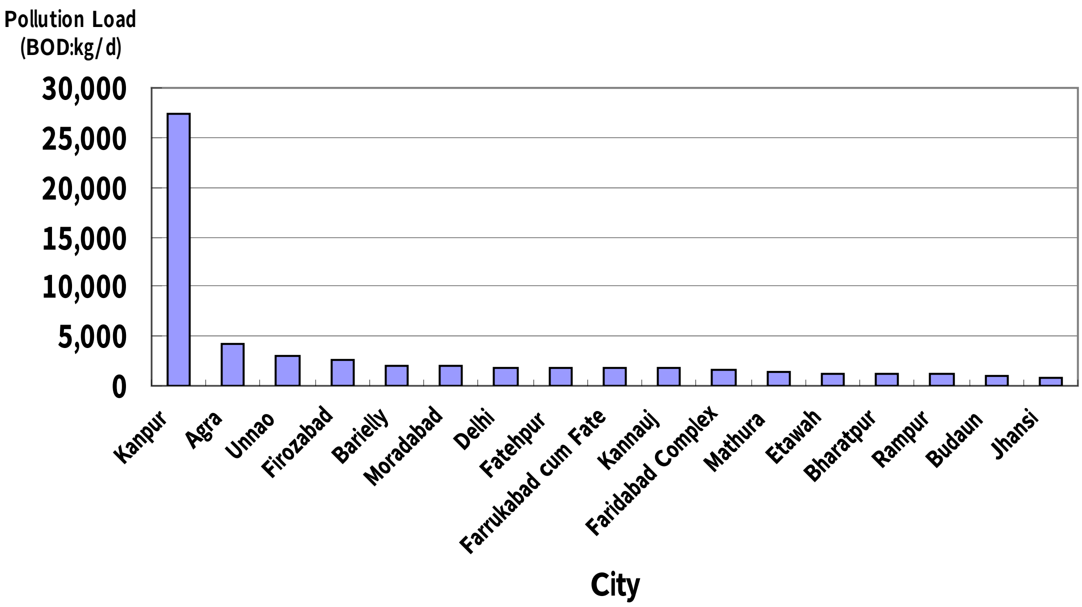


Figure 7.3 City Wise Reaching Pollution Load to Allahabad (Ganga)

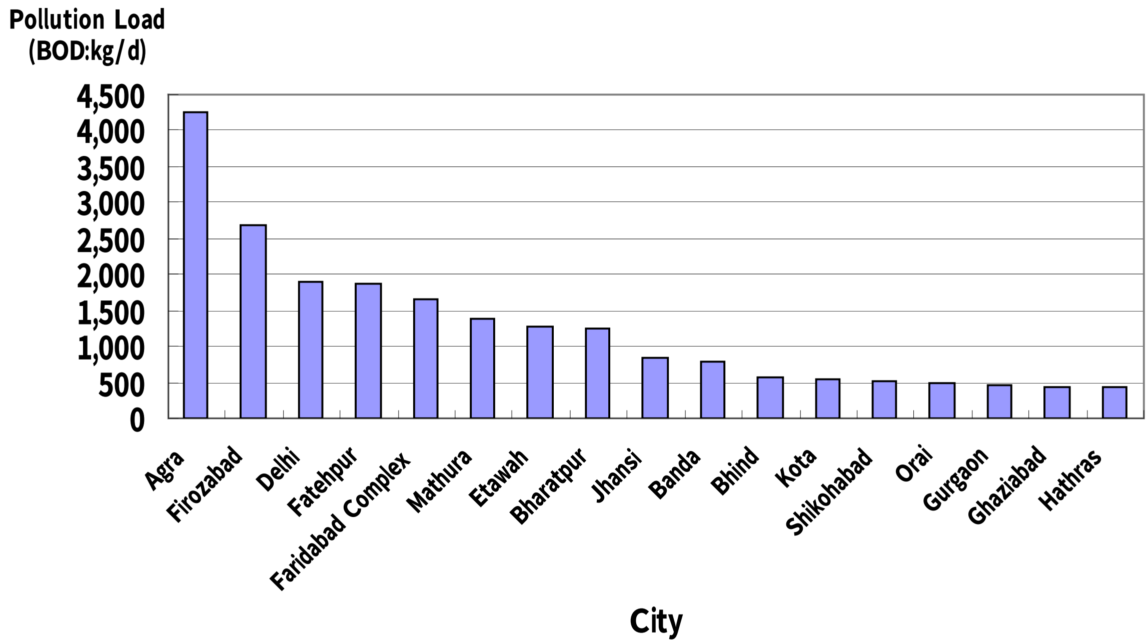


Figure 7.4 City Wise Reaching Pollution Load to Allahabad (Yamuna)

On the other hand, in case of Varanasi located in downstream of Allahabad, city wise reaching pollution load of Kanpur and Allahabad is dominant compared to that of other cities as shown in Figure 7.5. Subsequent large reaching pollution loads are discharged from Satna and Rewa located along Tons River.

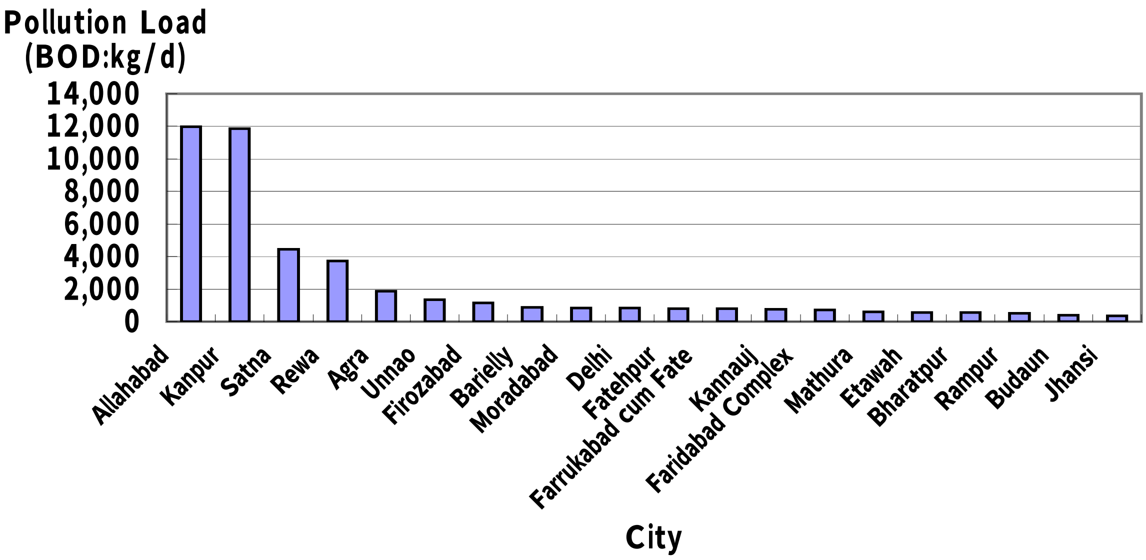


Figure 7.5 City Wise Reaching Pollution Load to Varanasi (Ganga)

Finally, in case of Lucknow, reaching pollution loads from upstream cities are estimated to be small.

7.3 RECOMMENDATION FOR THE SEWERAGE DEVELOPMENT IN THE UPSTREAM AREA

Table B.7.2 explains the monitoring station wise (Kanpur U/s, Allahabad U/s of Ganga and Yamuna and Varanasi U/s) relation between pollution load reduction and future water quality.

There may be a few cities located in the upstream area of objective 4 cities among the selected priority cities with less contribution to river pollution, which means that, it is difficult to identify the recipient river that accepts the wastewater discharged from urban centres located on the sub-basin boundary during dry season due to the long distance from the recipient river or irrigation use. Typical case is obviously taking place in Aligarh City, where wastewater effluent is flowing into a small lake at first and then most of the wastewater is used for irrigation purposes. Another case is reported in case of Jaipur where all the wastewater infiltrates into the sandy riverbed before confluence with Chambal River. In addition to Aligarh and Jaipur, towns like Jhunjhunun, Alwar and Pilibhit are located very far from the Yamuna/Ganga main stems or primary tributaries, therefore, wastewater discharged from these cities are unlikely to reach final recipient rivers during dry season. Accordingly, these five large cities should be omitted from necessary future sewerage development explained in Figure 7.3 to 7.4 and Table B.7.1.

On the other hand, most cities are located in the vicinity of the riverbanks or rather far from the river. In order to select the priority cities for future sewerage development for the purpose of the river water quality improvement of the middle stretch of Ganga including the existing YAP and GAP, contribution for the reaching pollution load to the target 4 cities should be considered instead of the pollution load generation discharged from each city. Table B.7.3 shows the necessity of the sewerage development in the upstream area for the purpose of the abatement of reaching pollution load to the 4 cities. However, in this study, main Study Area for formulation of Master Plan is focused on the target 4 cities. Therefore, information on selected 35 cities shown in Table B.7.3, like reaching process of domestic pollution load to primary tributary or Ganga/Yamuna main stem, is partially inaccurate because selected cities are widely scattered in upstream area of Ganga/Yamuna Basin. Hence, in order to improve the accuracy of above said information, it is necessary to conduct supplementary studies on each selected city. According to the results based on the city wise pollution load reduction scenarios, priority sewerage development is summarized as follows:

(1) Kanpur

In order to meet the water quality standard at Kanpur U/s, 70% of domestic pollution load discharged from 9 cities shown below should be at least reduced in 2030. Among them only in Farrukabad cum Fate a sewerage treatment under GAP has been developed and in the remaining 9 cities no sewerage development have been considered so far. Hence, in addition to GAP activities, sewerage development planning for the remaining 9 cities is also considered to be necessary.

Barielly, Moradabad, Farrukabad cum Fate, Kannauj, Rampur, Budaun, Meerut, Sambhal, Amroha and Chandausi.

(2) Allahabad

Pollution loads reach to Allahabad from upstream cities located along Ganga and Yamuna rivers. In order to meet the water quality standard at Allahabad U/s of both two main stem, Ganga and Yamuna, 70 to 80 % of domestic pollution load discharged from 27 cities shown below should be at least reduced in 2030. Among them in Farrukabad cum Fate and Kanpur sewerage treatment systems under GAP have been developed. On the other hand, Agra, Delhi, Faridabad Complex, Mathura, Etawah, Gurgaon and Ghaziabad have had sewerage network under YAP. The remaining cities have not had any STP so far. Hence, sewerage development for these cities should be considered for the river water improvement at Allahabad U/s.

Ganga: Kanpur, Unnao, Barielly, Moradabad, Farrukabad cum Fate, Kannauj, Rampur, Budaun, Meerut and Sambhal Yamuna: Agra, Firozabad, Delhi, Fatehpur, Faridabad Complex, Mathura, Etawah, Bharatpur, Jhansi, Banda, Bhind, Kota, Shikohabad, Orai, Gurgaon, Ghaziabad, and Hathras

(3) Varanasi

Varanasi is located in lower part of middle stretch of Ganga main stem. Estimated reaching pollution loads are dominant in adjacent cities, namely: Allahabad, Satna, Rewa, Bhadehi and Mirzapur cum Vindhac as well as above mentioned 27 cities. 70% of pollution loads reduction in 27 cities can meet the water quality standard at Varanasi U/s. Hence, sewerage development for these cities is indispensable for the improvement of river water quality.

(4) Lucknow

In case of Gomati River, no major city is located in upstream area of Lucknow. Further, the most critical reach is defined to be from Lucknow to downstream of Gomati River. The river water quality exceeds the water quality standard in these stretch. Accordingly, capacity development of sewerage treatment in Lucknow is essential to satisfy the water quality standard of class C in this river stretch.

7.4 STUDY ON IMPROVEMENT OF HYGIENIC CONDITION

7.4.1 General

(1) Basic Information on Unit Pollution Load of Coliform Number

Coliform bacteria are used as the index of the hygienic quality of water for several beneficial uses and for many foods. About one-quarter of the 100 to 150 grams of faeces produced per person per day is bacterial cells. There are many kinds of aerobic bacteria in human faeces as shown in Table 7.4. These circumstances are thought same in case of livestock such as cattle, pigs and sheep. It is reported that coliform organisms are at an output of 300 billion per capita per day. About $100*10^9$ MPN/100ml of coliform bacteria are contained in a fresh domestic wastewater in Japan. There are huge numbers of point and non-point pollution sources in the entire Ganga Basin, and the influence of bacterial organisms from various sources is unavoidable.

The river water quality will tend to deteriorate more rapidly in future than that of the present one due to the enormous population increase. In order to diminish the impact on the river pollution, sewerage system should be introduced to the growing urban centres such as the objective 4 cities. For the purpose of mitigation of river water quality, various kinds of measures can be studied. Among them, elaborate decision is necessary for the selection of the counter measures that are efficient to solve the river pollution of Ganga Basin. Especially, mitigation of bacterial contamination such as coliform number is important with respect to bathing in the River Ganga.

Table 7.4 Aerobic Bacteria in Human Faeces

Genus	Species frequently detected	Species sometimes detected
Pseudomonas		P. aeruginosa, P. faecalis
Escherichia	E.coli ($10^{6\text{-}9}$/g)	Escherichia sp.
Klebsiella		K. pneumoniae
Enterobacter		E. aerogenes, E. cloaca, E. liquefaciens
Proteus		P. mirabilis, P. Morganii, P. rettgerii, etc.
Streptococcus	S. faecalis ($10^{6\text{-}9}$/g), S. faecium($10^{6\text{-}9}$/g)	S.sanguis, S.durans, S. mitis, S, bovis, S. cremoris, etc.
Staphylococcus		S.albus, S. epidermidis.
Micrococcus		Micrococcus spp.
Lactobacillus	L. acidophilus ($10^{6\text{-}9}$/g) L. salivarius ($10^{6\text{-}9}$/g) L. fermentum ($10^{6\text{-}9}$/g)	L. casei, L. plantarum, L. brevis, L. lactis
Corynebacterium		Corynebacterium spp.
Bacillus		B. cereus, B. Subtilus
Candida		C. albicans, Candida sp.

Note: Figures in parentheses indicate bacterial number detected in human faeces.

(2) Fate of Intestinal Bacteria in a Stream

The intestinal bacteria dies according to flowing process in a stream. Figure 7.6 shows one of the patterns related to the death-rate curves for cool and warm weather condition, which is investigated in Ohio River water, United State of America. Such death rate curves indicate different pattern influenced by light intensity, water temperature and salinity (for detail, see previous Chapter 6, Sub-section 6.1.3). According to Figure 7.6, in case of warm-weather condition, 90% of coliform organisms die within two days, and 99% of them die within five days.

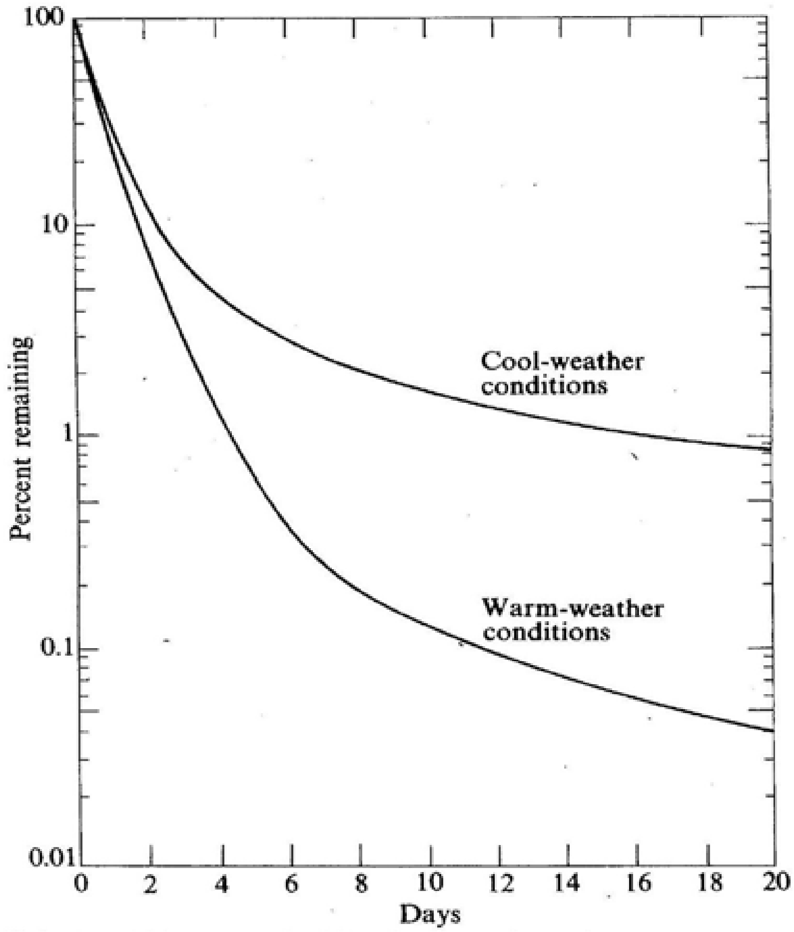


Figure 7.6 Death-rate Curves of Coliform Organisms

(3) Relationship between BOD and Coliform Number

The relationship between BOD and Total coliform number is illustrated in Figure 7.7 using the data of 2001 targeting dry season (April-June). As shown in figure below, Total coliform number varies widely with BOD value, however, certain relationship can be found in the figure and estimated for future condition of coliform number.

According to the monitoring data analysed by CPCB, coliform number indicates the extremely high value in the middle reach of Ganga River due to not only the point sources but also due to non-point sources such as cattle excreta. It is essential to reduce the coliform number for maintaining the hygienic condition along the riverine area. For the purpose of mitigating the hygienic condition, sewerage treatment system should be constructed in the major cities.

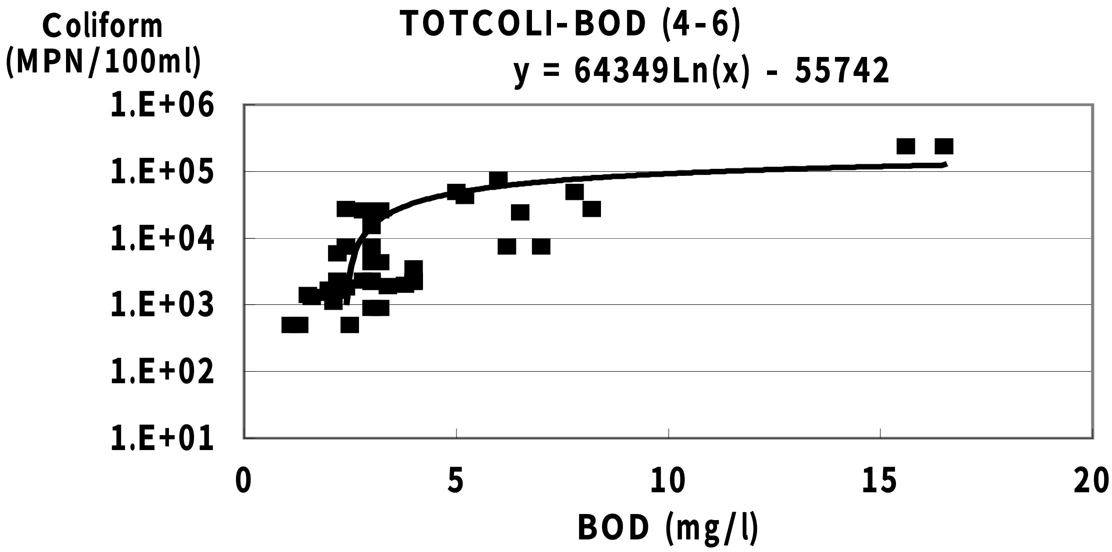


Figure 7.7 Total Coliform Number and BOD Curve in Ganga Basin

However, the effect of reduction of coliform number is limited because sewerage system cannot completely treat bacteria and cattle excreta also degrade the hygienic condition of the riverine area. In order to drastically cope with the standard of river water quality, non-sewerage scheme is necessary besides the sewerage scheme. The Ganga Basin shows a distinguished feature that coliform number exceeds the desired criteria at all the river courses. Especially, hygienic condition worsens just downstream of large cities due to the influence of untreated wastewater.

7.4.2 Japanese Case Study on Bacterial River Water Quality

Figure 7.8 show the relationship between BOD and Total coliform number in case of Tama River located in the vicinity of Tokyo in Japan. Recently, sewerage system has been widely covered in Tama River Basin, and the river water quality (BOD) has been much improved compared to the condition before. However, even though secondary treatment wastewater is disinfected so as to meet the regulation of wastewater quality, detected coliform number in the river water still indicates high value due to the influence of non-point sources.

Accordingly, as shown in Figure 7.8, the lowest value of total coliform number exceeds the criteria regulated in India, 500 MPN/100ml even at the sampling points located at the upstream area where small point pollution sources are distributed. It is very difficult to reduce the coliform number in river water, and its number is easily affected by contaminants such as agricultural soils and livestock excreta. Hence, it is unavoidable to be lower than criteria because pollution source of coliform is derived from not only human activities but also non-point sources such as agricultural soils and livestock excreta.

During the passage through the catchment area, the stream becomes significantly contaminated by faecal bacteria, suggesting the existence of a semi-permanent store of faecal bacteria in catchment soils, combined with hydrological transport mechanisms capable of moving bacteria from land to the stream channel. Thus, agricultural soils may be the serious pollution sources of faecal bacteria.
In case of Japan, hygiene condition of surface water and various water uses is regulated as shown in Table 7.5. As shown in table below, total coliform number is employed as criteria for the national regulation of the surface water, category AA type is designated as the cleanest water area, hence, the criteria of total coliform number is very strictly regulated (50 MPN/100ml). On the other hand, faecal coliform number is regulated in bathing water, and its criterion is 100MPN/100ml.

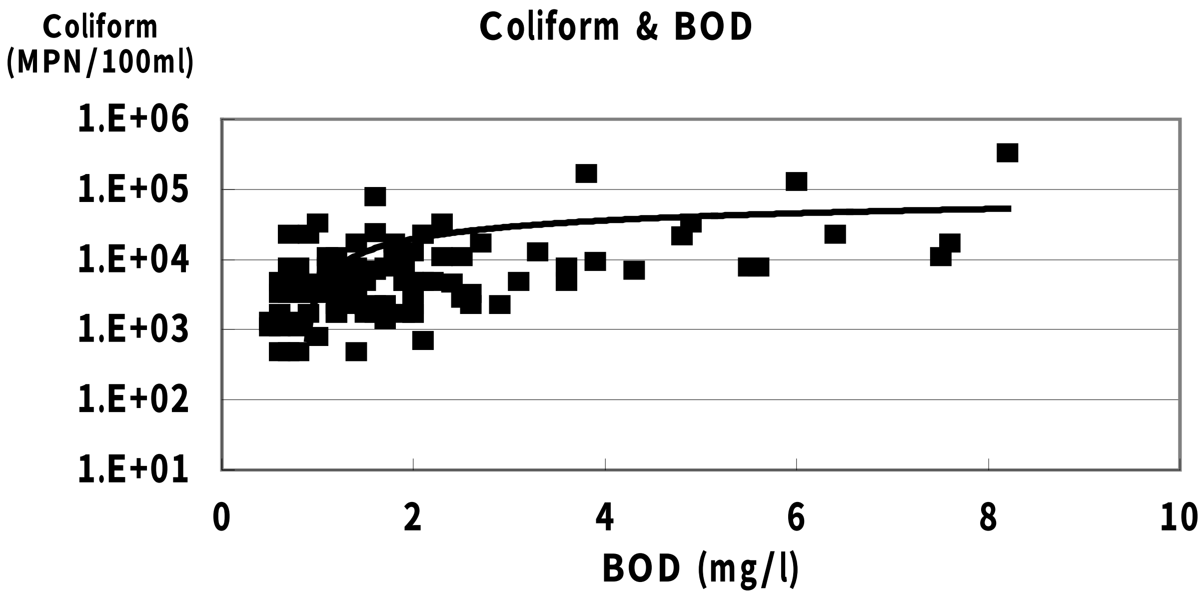


Figure 7.8 Total Coliform Number and BOD Curve in Tama River

Table 7.5 Japanese Regulation/Guideline for the Hygiene Condition

Grouping	Standard	Parameter	Criteria
Surface Water	River/Lake/Sea Water	Total Coliform Number	AA Type: 50MPN/100ml
			A Type: 1,000MPN/100ml
			B Type: 5,000MPN/100ml
	Bathing Water	Faecal Coliform	100MPN/100ml
			Temporary 100MPN/100ml
Tap Water		Total Coliform Number	Non-detected
		General Bacteria Number	1,000 colony/100ml
Wastewater	Factory Effluent	Total Coliform Number	300,000MPN/100ml
	Sewerage Treatment Effluent	Total Coliform Number	300,000MPN/100ml
	Night Soil Treatment Effluent	Total Coliform Number	300,000MPN/100ml
Recycle Water Use	Flush Toilet	Total Coliform Number	1,000MPN/100ml
	Sprinkle Water	Total Coliform Number	Non-detected
	Landscape Irrigation Use	Total Coliform Number	1,000MPN/100ml
	Amenity Use	Total Coliform Number	50MPN/100ml
Specified Water Use	Public Bath	Total Coliform Number	100MPN/100ml
	Swimming Pool	Total Coliform Number	5MPN/100ml
	School Pool	Total Coliform Number	Non-detected
		General Bacterial Number	2,000 colony/100ml

On the other hand, Table 7.6 shows the unsatisfactory ratio for coliform criteria based on the annual data monitored in 1997 covered by all the first-class rivers in Japan.

Table 7.6 Unsatisfactory Ratios for Coliform Criteria in Japan (1997)

Category	Monitoring station number that exceeds criteria of coliform	Total monitoring station number	Unsatisfactory Ratio (%)
AA	3,286	4,049	81.2
A	15,574	22,769	68.4
B	5,715	11,044	51.7
Total	24,575	37,862	64.9

As reflected from above results, monitoring station number that exceeds criteria of coliform totally amounts to 24,575 all over the country and shares 64.9% of all the monitoring stations. Especially, category AA that is required the cleanest condition of river water quality indicates a high unsatisfactory ratio for coliform criteria (Total coliform number: 50 MPN/100ml). The reason for the high unsatisfactory ratio is considered that not only faecal coliform but also the bacteria number derived from soils and another non-point sources is simultaneously analysed.

The high unsatisfactory ratio extracted from above results suggests the difficulty to improve the hygiene condition of surface water.

7.4.3 Longitudinal Profile of Coliform Number

CPCB has periodically monitored both total-coliform and faecal coliform in the entire Ganga Basin since 1976. Using the data monitored during 1997 to 2001, longitudinal profiles of faecal coliform number in three rivers are summarized as below:

(1) Ganga Main Stem

Figure 7.9 shows the longitudinal profile of coliform numbers in the Ganga main stem, and it is easily recognized that middle stretch from Kannauj to Varanasi is the most contaminated by coliform due to the huge quantity of wastewater inflow into the river. Further, the two tributaries of Ramganga and Kalinadi are very polluted by untreated wastewater, meeting with Ganga main stem at the upstream of Kannauj. Therefore, the bacterial water quality worsens significantly and highly exceeds the water quality of faecal coliform for bathing in the river water until influx of Buxar. In addition to the wastewater inflow, non-point pollution sources such as cattle wallowing and agricultural activities significantly influence the bacterial water quality of the polluted stretch of Ganga.

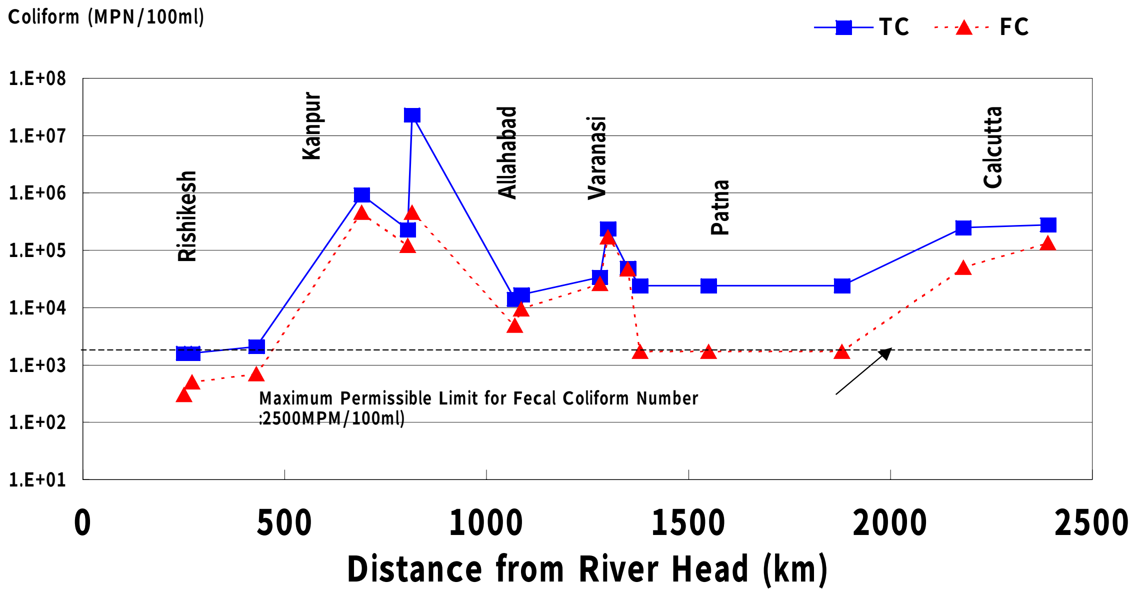


Figure 7.9 Longitudinal Profile of Coliform (Ganga Main)

(2) Yamuna Main Stem

Before influx of the large tributaries like Chambal, Sind, Betwa and Ken, river flow of Yamuna main stem during dry season continues to be low and the river stretch from Delhi to Etawah is playing the role as almost wastewater drainage.

Figure 7.10 explains longitudinal profile of coliform in the Yamuna main stem. According to this figure, faecal coliform number changes in the range of 10^4 to 10^6 in the polluted river stretch from Delhi to Etawah because of the large quantity of wastewater inflow. Moreover, faecal coliform number lowers in the river stretch from the confluence point with Chambal to Allahabad due to the dilution and decay effect.

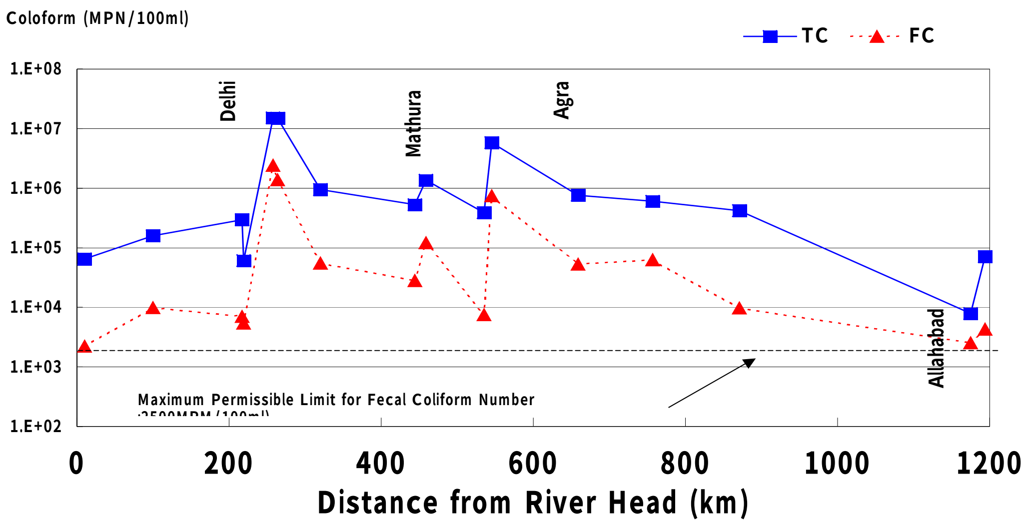


Figure 7.10 Longitudinal Profile of Coliform (Yamuna Main)

(3) Gomati River

Lucknow is located on the riverbanks of Gomati River, and untreated and treated sewerage wastewater severely affects the hygiene condition of this river stretch. Figure 7.11 indicates the longitudinal profile of coliform number, and high values are obviously shown after Lucknow. Hence, it is essential to improve the bacterial water quality at Lucknow.

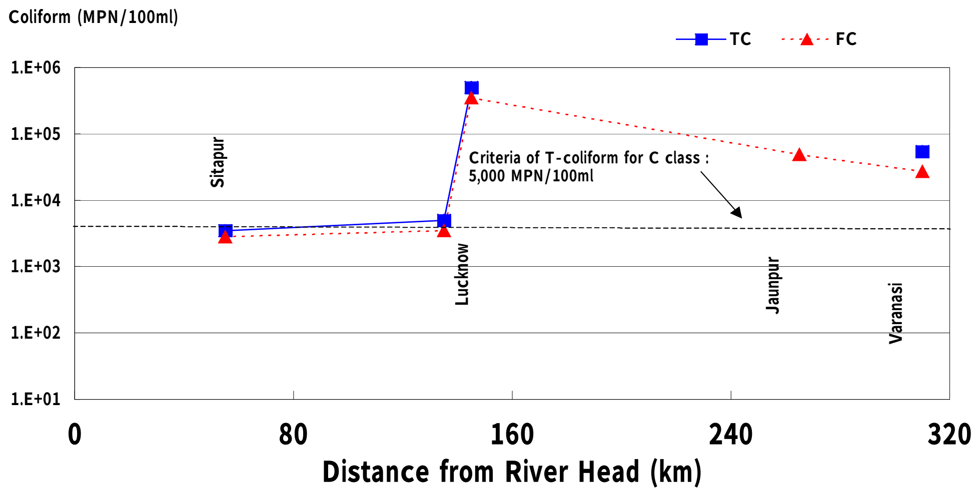


Figure 7.11 Longitudinal Profile of Coliform (Gomati River)

7.4.4 Simulation Study for Faecal Coliform Number

In this Study, detail simulation study targeting each objective city was already conducted using 3 parameters (BOD, DO and Total-coliform number) and mentioned in previous Chapter 6. Apart from the detail simulation model, another QUAL2E simulation model was formulated in order to evaluate the future hygiene condition in the upstream area of the objective four cities as described below:

(1) Objective Basin for Simulation Study

The objective basin for simulation covers both two main river stems, namely; Ganga and Yamuna focused on the upstream area of the objective four cities as shown in Figure B.7.3 (schematic diagram). Moreover, QUAL2E simulation model has a special linkage with the basin runoff model set up in Chapter 5, i.e., the future BOD values of the target area can be used for the estimation of the faecal coliform number of the each point source.

(2) Selection of Water Quality Parameter

In this sub-section 7.4, faecal coliform number was selected as the evaluation of the existing and future hygiene condition in the upstream area of objective four cities. Because faecal coliform number has been newly designated as the criteria of class B.

(3) Basis of Simulation Study

Equation for faecal coliform used in this QUAL2E simulation model is the same as detail simulation model set up in the previous Chapter 6.

(4) Input Data for Simulation

The river water quality with existing condition and master plan (M/P 2030) project was simulated under the following procedures:

(a) The river water quality is simulated at the five points of Ganga Main River and four points of Yamuna Main River. River flow data of these objective stations used for this simulation study are same as mentioned in Chapter 5, Sub-section 5.8.2.
(b) Simulation constants and coefficient are having the same condition as the detail simulation set up in the previous Chapter 6.
(c) Existing condition of faecal coliform regarding each point pollution source has been determined through the calibration study. Because no faecal coliform data regarding city wise domestic wastewater is available for this simulation study. In this Study, city wise current condition of faecal coliform was determined through a trial-and-error method considering the average faecal coliform number analyzed in untreated wastewater inflow into Dinapur STP, Varanasi as shown in Appendix B, Table B.4.2. Analyzed data of faecal coliform widely fluctuate in the range of 10^6 to 10^9 MPN/100ml. Further, the city wise future condition of faecal coliform number is assumed to be in the same condition as in existing one.
(d) On the other hand, future domestic wastewater generation is assumed to increase in proportion to the future population growth.
(e) Existing condition of faecal coliform at each lowest point of major tributaries is used as shown in Table 7.7.
(f) Non-point pollution sources are considered in this QUAL2E Model. Input data for faecal coliform number was also determined through a trial-and-error method.

Table 7.7 Existing Faecal Coliform Number of Major Tributaries

Item	Ramganga	Kalinadi	*Hindon	Chambal	*Sind	Betwa	*Ken	Sai	*Tons	*Karmanasa
Faecal Coliform (MPN/100ml)	1..5*10^5	4.3*10^5	3.9*10^5	2.8*10^3	1.6*10^5	9.8*10^4	2.3*10^5	5.0*10^4	3.6*10^5	1.0*10^3

Note: There is no monitoring station at the lowest point of Hindon, Sind, Ken, Tons and Karmanasa. Therefore, existing faecal coliform number of these tributaries was determined by BOD values simulated by Basin Runoff Model using the relation between BOD and Faecal coliform number as shown in Figure 7.5

(5) Simulated Existing Water Quality

Each longitudinal profile of existing faecal coliform number simulated by QUAL2E Model is shown in Figure B.7.4. Further, comparison between actual monitoring data and simulated values is tabulated in Table 7.8 (Ganga), Table 7.9 (Yamuna) and Table 7.10 (Gomati).

Table 7.8 Simulated Existing Water Quality (Ganga)

Item	A	B	C	D	E	F	G	H
Faecal Coliform (MPN/100ml)	4.9*10^2 (5.0*10^2)	1.6*10^5 (4.3*10^5)	2.6*10^4 (1.2*10^5)	5.2*10^5 (4.6*10^5)	3.8*10^3 (4.9*10^3)	9.6*10^3 (9.4*10^3)	1.5*10^4 (2.6*10^4)	1.9*10^5 (1.7*10^5)

Note: Figures in parentheses of lower column indicate observed water quality. Further, evaluation points are as follows: A: Hardwar, B: Kannauj D/s, C: Kanpur U/s, D: Kanpur D/s, E: Allahabad U/s, F: Allahabad D/s, G: Varanasi U/s, H: Varanasi D/s

Table 7.9 Simulated Existing Water Quality (Yamuna)

Item	I	J	K	L	M	N
Faecal Coliform (MPN/100ml)	3.3*10^6 (2.4*10^6)	1.7*10^5 (1.2*10^5)	9.8*10^5 (7.4*10^5)	2.4*10^4 (6.2*10^4)	1.3*10^3 (2.5*10^3)	3.8*10^3 (4.3*10^3)

Note: Figures in parentheses of lower column indicate observed water quality. Further, evaluation points are as follows: I: Delhi (Nizamuddin Bridge), J: Mathura D/s, K: Agra D/s, L: Etawah D/s, M: at Allahabad U/s, N: at Allahabad

Table 7.10 Simulated Existing Water Quality (Gomati)

Item	O (Lucknow U/s)	P (Lucknow D/s)	Q (Lowest)
Faecal Coliform (MPN/100ml)	3.2*10^3 (3.5*10^3)	3.7*10^5 (3.5*10^5)	2.2*10^4 (2.7*10^4)

Note: Figures in parentheses in the lower row indicate the observed water quality.

As shown in the table above, the estimated river water quality of faecal coliform number is almost in agreement with the observed one except for few monitoring stations. Hence, the QUAL2E Model established in this Section is considered applicable for the prediction of future river water quality for faecal coliform.

(6) Simulation Case for Future Prediction

A number of assumptions have been considered for this QUAL2E Simulation Model in order to predict the future condition of faecal coliform. The various simulation cases are without project and with project. In case of with project, 80% and 100% of the future population is assumed to be covered by sewerage network. Further, there are two cases in the with project scenario as follows: without disinfection and with disinfection.

(7) Assumption and Input Data for Future Prediction

(a) Future Assumption for Without Project

Future faecal coliform number of city wise domestic wastewater in case of without project is assumed to be in the same condition as the existing one. On the other hand, domestic wastewater generation is assumed to increase in proportion to population growth in 2030. In the year 2030, future population of the objective upstream area is estimated to increase 1.87 times as current condition, hence, the future domestic wastewater generation of each city is assumed to simultaneously increase at the same ratio as the population growth. These input data are shown in Table B.7.3.

(b) Future Assumption for With Project Without Disinfection

In India, seldom case of disinfection has been found so far in sewerage treatment in India due to the difficulty of operation and maintenance for the chlorination facility. In case of with project without disinfection, the change of faecal coliform number after the ordinary sewerage treatment without disinfection can be estimated through the actual monitoring case analysed at the STP of Dinapur, Varanasi as shown in Figure 7.12. According to Figure 7.12, treated sewerage discharge decreases at the ratio of 31%. In this study, faecal coliform number is assumed to decrease at 30% in convenience.

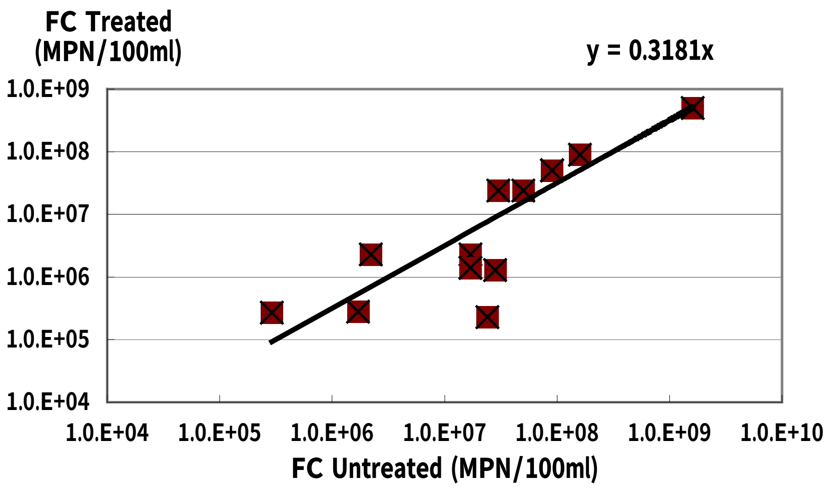


Figure 7.12 Faecal Coliform Number after Sewerage Treatment

(c) Future Assumption for With Project With Disinfection

In case of with disinfection, the future condition (faecal coliform number) of the effluent from the sewerage treatment plant is assumed to be 1,000 MPN/100ml (Desirable) and 10,000 MPN/100ml (Maximum permissible) referring the UPSPCB guideline for treated sewerage discharge.

(d) Future Condition of Main Tributaries

It is very difficult to predict the future faecal coliform number of each major tributary because its simulation is not included in this QUAL2E Model. Therefore, the future faecal coliform number of each tributary can be determined through the future BOD value predicted by Basin Runoff Model using the relation between faecal coliform number and BOD value as shown in Figure 7.13. Estimated future condition of BOD and faecal coliform number at the each lowest point of major tributaries is tabulated in Table 7.11.

Table 7.11 Future Faecal Coliform Number of Major Tributaries

Item	Ramganga	Kalinadi	*Hindon	Chambal	*Sind	Betwa	*Ken	Sai	*Tons	*Karmanasa
BOD (mgl)	7.1	14.4	37.0	2.8	8.0	4.1	9.3	11.2	16.6	0.2
Faecal Coliform (MPN/100ml)	$2.8*10^5$	$4.3*10^5$	$6.0*10^5$	$8.0*10^4$	$3.0*10^5$	$1.6*10^5$	$3.4*10^5$	$3.8*10^5$	$4.6*10^5$	$2.0*10^3$

Note: There is no monitoring station at the lowest point of Hindon, Sind, Ken, Tons and Karmanasa.

(8) Simulated Future Water Quality in Case of Without Project

The longitudinal profile of existing and future faecal coliform number in case of without project simulated by QUAL2E Model is shown in Figure B.7.5. Further, simulated values at the main monitoring stations are tabulated in Table 7.12 (Ganga), Table 7.13 (Yamuna) and Table 7.14 (Gomati).

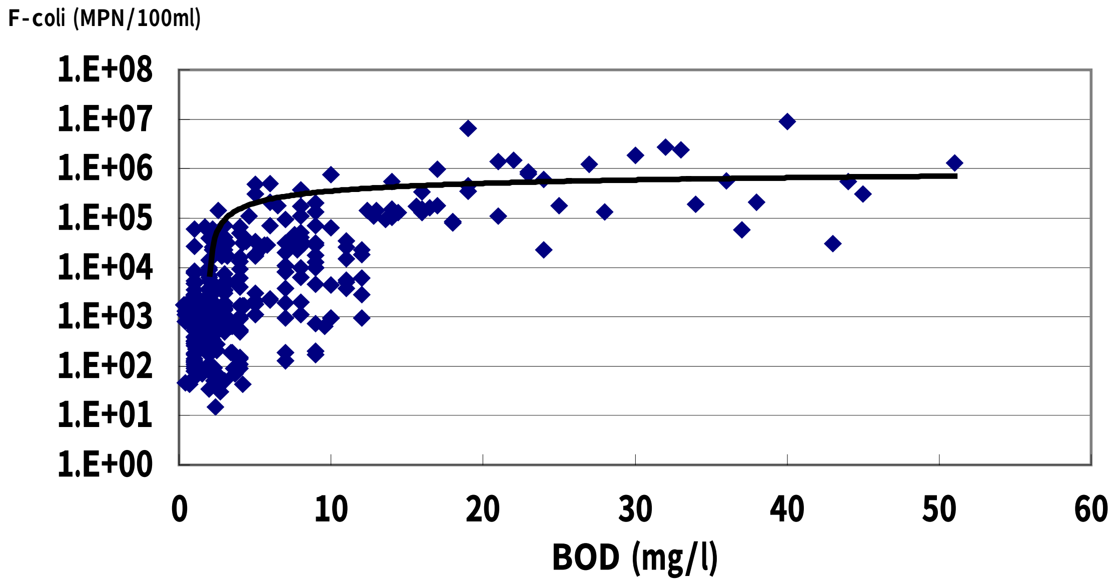


Figure 7.13 BOD and Faecal Coliform Curve

Table 7.12 Simulated Future Water Quality in Case of Without Project (Ganga)

Item	A	B	C	D	E	F	G	H
Faecal Coliform (MPN/100ml)	$5.0*10^2$	$2.8*10^5$	$2.6*10^4$	$9.2*10^5$	$3.6*10^3$	$1.5*10^4$	$1.6*10^4$	$3.4*10^5$

Note: Evaluation points are as follows: A: Haridwar, B: Kannauj D/s, C: Kanpur U/s, D: Kanpur D/s, E: Allahabad U/s, F: Allahabad D/s, G: Varanasi U/s, H: Varanasi D/s

Table 7.13 Simulated Future Water Quality in Case of Without Project (Yamuna)

Item	I	J	K	L	M	N
Faecal Coliform (MPN/100ml)	$4.1*10^6$	$1.8*10^5$	$1.0*10^6$	$2.9*10^5$	$9.5*10^2$	$7.4*10^3$

Note: Evaluation points are as follows: I: Delhi (Nizamuddin Bridge), J: Mathura D/s, K: Agra D/s, L: Etawah D/s, M: at Allahabad U/s, N: at Allahabad

Table 7.14 Simulated Future Water Quality in Case of Without Project (Gomati)

Item	O (Lucknow U/s)	P (Lucknow D/s)	Q (Lowest)
Faecal Coliform (MPN/100ml)	$3.2*10^3$	$6.1*10^5$	$3.1*10^4$

As shown in above tables, predicted future river water quality of faecal coliform slightly becomes worse than that of existing condition at each monitoring station.

(9) Simulated Future Water Quality in Case of With Project

The longitudinal profile of future faecal coliform number in case of with project simulated by QUAL2E Model is shown in Figure B.7.5. Further, comparison between without/with disinfection cases is tabulated in Table 7.15 (Ganga), Table 7.16 (Yamuna) and Table 7.17 (Gomati).

Table 7.15 Simulated Future Faecal Coliform Number in Case of With Project (Ganga)

Item	A	B	C	D	E	F	G	H
Faecal Coliform (MPN/100ml)	$5.0*10^2$	$1.6*10^5$	$2.5*10^4$	$4.1*10^5$	$3.5*10^3$	$8.0*10^3$	$1.5*10^4$	$1.6*10^5$
	$5.0*10^2$	$1.2*10^5$	$2.5*10^4$	$2.0*10^5$	$3.5*10^3$	$5.0*10^3$	$1.5*10^4$	$8.0*10^4$

Note: Figures in upper row indicates without disinfection and lower row indicates with disinfection. Further, evaluation points are as follows: A: Haridwar, B: Kannauj D/s, C: Kanpur U/s, D: Kanpur D/s, E: Allahabad U/s, F: Allahabad D/s, G: Varanasi U/s, H: Varanasi D/s

Table 7.16 Simulated Future Faecal Coliform Number in Case of With Project (Yamuna)

Item	I	J	K	L	M	N
Faecal Coliform (MPN/100ml)	$1.8*10^6$	$8.0*10^4$	$4.5*10^5$	$2.7*10^4$	$9.5*10^2$	$3.8*10^3$
	$8.3*10^5$	$3.7*10^4$	$2.1*10^5$	$1.3*10^4$	$9.5*10^2$	2.210^3

Note: Figures in upper row indicates without disinfection and lower row indicates with disinfection. Further, evaluation points are as follows: I: Delhi (Nizamuddin Bridge), J: Mathura D/s, K: Agra D/s, L: Etawah D/s, M: at Allahabad U/s, N: at Allahabad.

Table 7.17 Simulated Future Faecal Coliform Number in Case of With Project (Gomati)

Item	O (Lucknow U/s)	P (Lucknow D/s)	Q (Lowest)
Faecal Coliform (MPN/100ml)	$3.2*10^3$	$2.7*10^5$	$1.5*10^4$
	$3.1*10^3$	$1.2*10^5$	$1.5*10^4$

Note: Figures in upper row indicates without disinfection and lower row indicates with disinfection.

As shown in the table above, estimated future water quality of faecal coliform number in case of with project without/with disinfection indicates slightly lower values than that of without project cases. However, 80% of sewerage coverage area does not meet the river water quality standard for faecal coliform because remaining 20% of untreated domestic wastewater containing extremely large number of faecal coliform directly affects the river water quality at the downstream area of each city.

(10) Future Trend of Hygiene Condition

Future trend of hygiene condition will change depending on the presence of sterilization process in the STP. Table 7.18 shows a relation between future bacterial water quality of faecal coliform targeting objective 4 cities and various scenarios simulated by QUAL2E Model. Further, in case of

Lucknow, water quality standard of Gomati is designated as class C and T-coliform is employed in the standard (desirable limit: 5,000MPN/100ml). In consideration of the relation between total and faecal coliform number, 2,500 MPN/100ml can be adopted as the class C criteria of faecal coliform. Table 7.18 explains that it is very difficult to meet the water quality of faecal coliform except for Allahabad D/s. The main reason for the unsatisfactory condition is summarized as below:

(a) Ratio of Non-point Sources

In this simulation study, faecal coliform caused by non-point sources is considered to share approximately 25% of point pollution sources. Especially a high ratio of non-point pollution sources are given in the upstream reaches of Kanpur, Varanasi and Lucknow. On the other hand, in case of organic pollution, BOD runoff coefficient of non-point sources was estimated to be only 1% of total pollution generation.

Table 7.18 Relation between Future Faecal Coliform and Various Scenarios (1)

Scenarios	Kanpur d/s	Allahabad d/s	Varanasi d/s	Lucknow d/s	Remarks
Existing 2001	$4.6*10^5$	$9.4*10^3$	$1.7*10^5$	$3.5*10^5$	Actual monitoring data (90%)
Future Without Project	$9.2*10^5$	$1.5*10^4$	$3.4*10^5$	$6.1*10^5$	
Future With Project Without Disinfection	$4.1*10^5$	$8.0*10^3$	$1.6*10^5$	$2.7*10^5$	80% STP coverage
A. Future With Project With Disinfection	$2.0*10^5$	$5.1*10^3$	$8.0*10^4$	$1.3*10^5$	80% STP coverage & Treatment at 10,000MPN/100ml
B. Future With Project With Disinfection (Targeted only 4 cities)	$1.9*10^4$	$2.5*10^3$	$1.5*10^4$	$3.5*10^3$	100% STP coverage & Treatment at 1,000MPN/100ml
C. Future With Project With Diversion (Targeted only 4 cities)	$1.9*10^4$	$2.5*10^3$	$1.5*10^4$	$3.2*10^3$	100% STP coverage & diverted into irrigation channel

Note[ ] : Satisfactory with maximum permissible criteria for faecal coliform number (2,500 MPN/100ml),
Non-coloured: Exceeds criteria. Unit: Faecal coliform MPN/100ml

Compared to BOD runoff, the ratio of faecal coliform, the values of 25% may be too much higher than expected. However, if a low ratio of non-point pollution sources such as 2.5% is given to QUAL2E Model, although simulated faecal coliform number at downstream monitoring points of Kanpur, Varanasi and Lucknow is well in agreement with the observed one, simulated faecal coliform number at upstream monitoring points becomes much lower than actual monitoring data as shown in Table 7.19.

Table 7.19 Relation between Faecal Coliform and Simulation Cases

Simulation Cases	Kanpur U/s	Allahabad U/s	Varanasi U/s	Lucknow U/s	Remarks
Actual Data	$1.2*10^5$	$4.9*10^3$	$2.6*10^4$	$3.5*10^3$	
Non-point Ratio: 25%	$2.6*10^4$	$3.6*10^3$	$1.5*10^4$	$3.2*10^3$	
Non-point Ratio: 2.5%	$1.2*10^3$	$5.8*10^2$	$1.3*10^3$	$6.5*10^2$	

(b) Influence of Non-point Pollution Sources

The mechanism and unit pollution load of contamination caused by coliform has been rarely reported in India as well as worldwide and is not available for this study. Particularly, it is very hard to know the influence of non-point pollution sources such as cattle wallowing and open defecation taking place along the riverbanks and in the river. However, these activities have been often observed in the entire Ganga Basin, for instance, thousands of buffaloes were seen wallowing at the Sangam located in the confluence point of Ganga and Yamuna through the monitoring survey of this Study. Hence, the actual influence of non-point pollution sources is supposed to be probably significant.

(c) Monitoring Data of Faecal Coliform

Monitoring data and sampling location should be representative of each monitoring station. However, extremely high values are frequently seen in CPCB's monitoring data. If the actual data of faecal coliform is much lower at the upstream monitoring stations of the objective 4 cities than that of observed one, influence of non-point pollution sources can be estimated to be much less.

Figures B.7.6 to B.7.9 show the detail sampling location of existing monitoring station of 4 cities. All the upstream and downstream monitoring stations are located in the city area, hence, the water quality of upstream monitoring stations might be much affected by point pollution load. These monitoring stations should be replaced or newly stationed at further upstream of each city.

(11) Additional Future Simulation Cases

Using the lower ratio of non-point pollution loads (2.5%), future trend of hygiene condition was additionally simulated as shown in Table 7.20. As shown in Figure 7.14, the ultimate simulation cases, namely: 100% STP coverage and treatment at 1,000MPN/100ml or diverted into irrigation channel, indicate that the future river water quality at the downstream monitoring station of each city can meet the standard. Further, considering various reasons regarding the high value of faecal coliform number at the upstream monitoring stations of the four cities, the lower ratio of non-point pollution loads (2.5%) is likely to be suitable for the simulation of bacterial pollution.

Table 7.20 Relation between Future Faecal Coliform and Various Scenarios (2)

Scenarios	Kanpur d/s	Allahabad d/s	Varanasi d/s	Lucknow d/s	Remarks
Existing 2001	$4.6*10^5$	$9.4*10^3$	$1.7*10^5$	$3.5*10^5$	Actual monitoring data (90%)
Future Without Project	$9.0*10^5$	$1.7*10^4$	$3.3*10^5$	$6.0*10^5$	
Future With Project Without Disinfection	$4.0*10^5$	$7.8*10^3$	$1.5*10^5$	$2.7*10^5$	80% STP coverage
A. Future With Project With Disinfection	$1.8*10^5$	$3.8*10^3$	$6.6*10^4$	$1.2*10^5$	80% STP coverage & Treatment at 10,000MPN/100ml
B. Future With Project With Disinfection (Targeted only 4 cities)	$1.2*10^3$	$4.4*10^2$	$1.7*10^3$	$4.1*10^2$	100% STP coverage & Treatment at 1,000MPN/100ml
C. Future With Project With Diversion (Targeted only 4 cities)	$1.2*10^3$	$4.3*10^2$	$1.7*10^3$	$2.0*10^2$	100% STP coverage & diverted into irrigation channel

Note: [yellow box] : Satisfactory with desirable criteria for faecal coliform number (500 MPN/100ml), [light yellow box] : Satisfactory with maximum permissible criteria for faecal coliform number (2,500 MPN/100ml), Non-coloured :Exceeds criteria. Unit: Faecal coliform MPN/100ml

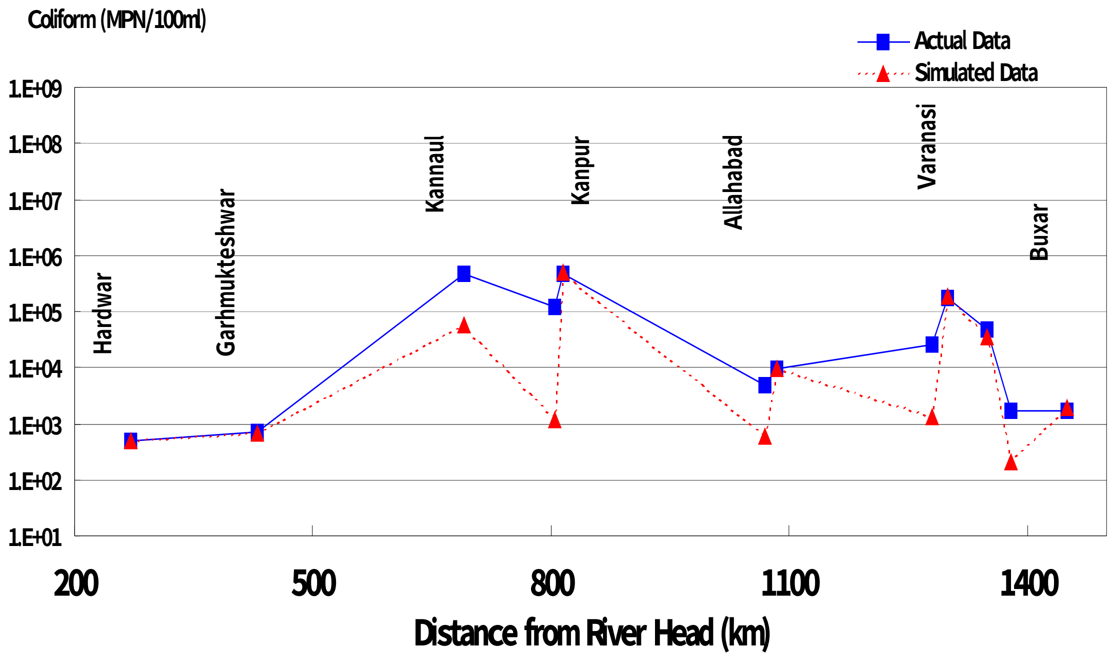


Figure 7.14 Simulated Longitudinal Profile of Faecal Coliform (Using 2.5% Ratio)

7.5 JAPANESE SCHEME OF POLLUTION CONTROL AND WATER QUALITY MANAGEMENT

Japan is regarded as one of the most highly developed countries to have suffered and made significant recovery from severe pollution problems. The recovery was based largely on environmental management policies, standards and regulatory procedures adopted specifically to the situation in Japan. These experiences are very much helpful to the critical situation of river water pollution in developing management plans and recovering water quality. However, it is important to keep in mind that successful procedure in Japan might not be fully transferable to Indian situation due to differences in environmental settings, proposed water use and cultural perspectives. Apart from the question of differences, some part of Japanese scheme for pollution control and water quality management is meaningful and useful to solve the critical situation of river pollution as mentioned below:

7.5.1 Current Situation of River Pollution in India

As discussed in previous Chapter, the circumstances regarding the water pollution of Ganga River is quite severe and somehow irretrievable unless the sound countermeasures are taken against the indiscriminate pollution load discharge. Especially, reaching pollution load from the upstream area of 4 cities will amount to huge quantity in near future due to the enormous increase of population and economic growth. Unless the suitable countermeasure are adopted, level of river water quality indicators will highly exceed the water quality standard. Hence, it is indispensable to consider not only the sewerage development but also multiple pollution control measures such as enforcement of relevant institution and regulation for improvement of river water quality.

7.5.2 Regulation of Total Maximum Daily Loading

In order that pollution load runoff does not exceed the environmental allowable capacity of each river basin, it is necessary to regulate not only the water quality of the pollutants but also the total maximum daily loading as follows:

(1) Limitation of Regulations for Effluent Water Quality

In Japan, the Water Pollution Control Law legislated in 1970 defined Environmental Water Quality Standards (EWQS) as targets for water quality management and regulated effluent quality from industry to comply with the targets. In addition to these regulations, prefectural governments legislated more stringent effluent standards.
The regulation for effluent water quality have been effective in Japan, whereas the following legal limitation have been pointed out:

(a) Although the decrease in total loading is necessary to comply with the Environmental Water Quality Standards (EWQS), loading from inland area are difficult to control. This is because more stringent prefectural effluent standards are legislated by each prefectural government and not necessary based on water quality in estuaries.
(b) The loading from industries decreased significantly due to the effluent regulations. However, domestic wastewater has not been controlled effectively except for sewerage effluent, but their contribution to the total loading has increased considerably. Especially, little effort has been made to control gray waters.
(c) The effluent quality regulations could not prevent the increase in total loading associated with the increase in productivity nor the dilution of effluent to comply with the regulation.

(2) Regulation of Total Maximum Daily Loading

Thus, improved effluent quality was not enough to restore water quality in large-scale closed waters. Regulations for the total amount of loading not only from industrial and domestic sources but also non-point sources are necessary. The regulation of total maximum daily loading (TMDL) started in 1978 in order to comply with the EWQS as amendments of “Water Pollution Control Law (WPCL) and “the Law Concerning Special Measures for Conservation of the Environment of the Seto Inland Sea” in 1973.

(3) Regulatory System of TMDL in Japan

The purpose of TMDL is to reduce the TMDL into large and closed water bodies faced with serious pollution. The pollution load reduction must be uniform and effective for all the activities in the basin including the inland area. The governmental ordinance defines specific water bodies and parameters to be regulated for the regulation of TMDL. Specified waters are highly polluted and enclosed water bodies with a drainage basin having concentrated human activities and high potential of pollution load generation, like Ganga Basin in India.
The Prime Minister is responsible for the basic TMDL policy. The governor of each prefecture is responsible for making the TMDL plan based on the basic policy for TMDL and necessary countermeasures to attain TMDL as follows:

(a) Reduction of Large Domestic Pollution Load

- Increase in the percentile service by public owned sewerage system and domestic wastewater treatment systems (Gappei-Jyokaso, Sewerage systems for farming villages and community plants).
- Advanced treatment processes and improved maintenance.
- Environmental education to reduce domestic loading.

(b) Reduction of Loading with Equality among Industries

- Regulation of industrial effluent according to TMDL standards.
- Guidelines for small-scale and non-controlled industries, and increases in the number of industries to be regulated.

(c) Reduction of Non-point Pollution Load

- Management of livestock wastewater.
- Improvement of systems for the control of combined sewerage overflow.
- Dredging of riverbed sediment.
- Ecosystem management to restore and maintain natural purification capacity.

Contemporary regulation controlled the concentration of effluent at the discharging point. The TMDL regulations, however, controls the maximum permissible daily loading from industries located in the specified basin and having a daily discharge quantity of more than 50 m^3, calculated as follows:

$$L = C \bullet Q \times 10^{-3}$$

Where,

L: Maximum permissible pollution load (kg/d)
C: COD value specified by the governor (mg/l)
Q: Volume of specified effluent (m^3/day)

Specified effluents are discharged from specified industries except for waters without pollution load such as cooling water. Further, the latest TMDL regulation requires more stringent control of pollution load from new and expanded plants built after 1980.

The above-mentioned COD value is so called “C-value”. Each governor decides C-value for each industrial category based on the permissible upper and lower limits specified by Environmental Ministry. There were totally 217 industrial categories in the first TMDL regulation and finally it increased up to 232 in the latest TMDL regulation.

(4) Outcome of TMDL Regulation

Tokyo Bay, Ise Bay and Seto Bay are regarded as the representative enclosed water bodies and accept a large quantity of pollution load discharged from megalopolis. Figure 7.15 explains the reduction of TMDL into specific water zones from the beginning of the 1st to the end of 3rd TMDL regulations. The pollution load reduction from domestic sources in Tokyo was significant, whereas that of industrial sources was insufficient. Both domestic and industrial sources decreased in the Seto Inland Sea. Implementation of various measures to control domestic loads effected decreasing its contribution in recent years.

(5) Pollution Load Reduction form Industries

Industries have carried out various measures to reduce pollution load generation. They tried to save water, improved production process and maintenance of wastewater treatment plants. Improvement in production process such as proper use of chemicals and additives, and better process control seem to be effective for reduction of pollution load generation.

Figure 7.16 explains the historical pollution load reduction per unit production in recent years and clearly shows significant improvement on pollution load reduction among all the industrial categories.

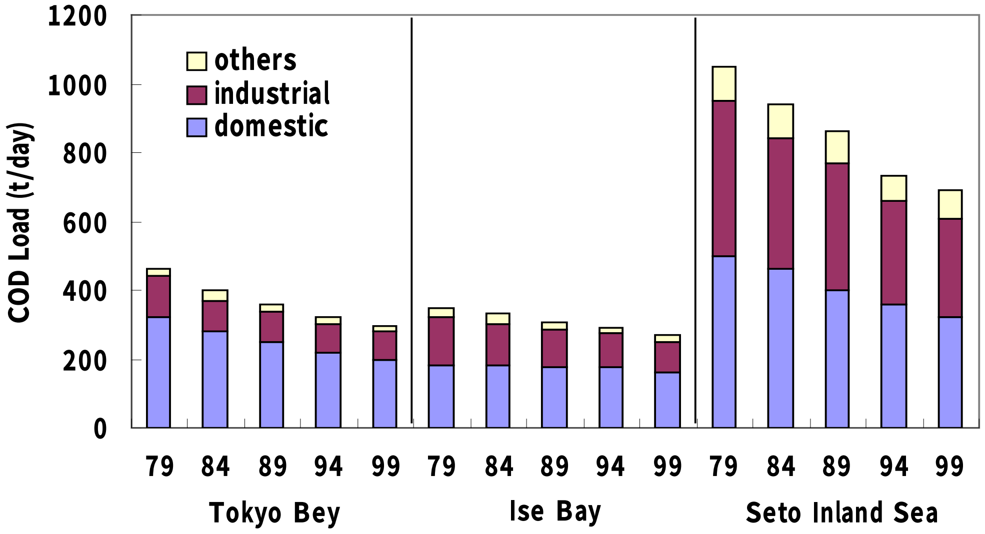


Figure 7.15 Pollution Load Reductions in Japan

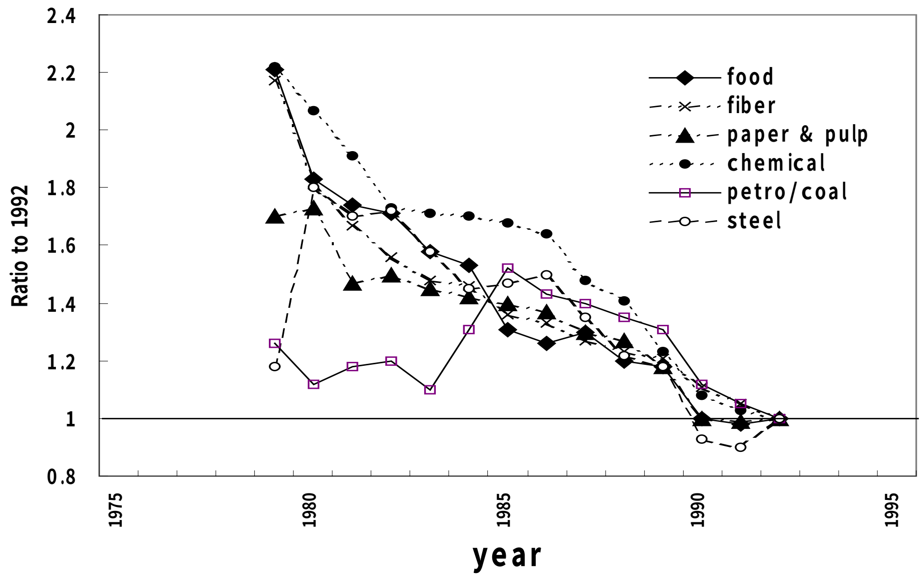


Figure 7.16 Historical Industrial Pollution Load Reduction

7.5.3 Case Study of Comprehensive Pollution Control in Japan

Biwa Lake that is the largest in Japan and the most symbolic lake for the country. However, Biwa Lake has been polluted due to the increasing pollution load inflow discharged from lake shore and exceeded the water quality standards at the several monitoring stations almost 20 years ago. Figure B.7.10 shows the comprehensive pollution control in Japan and explains various measures for water quality improvement undertaken in Biwa Lake.

In order to recover the severe pollution of water quality, it is important to consider the comprehensive measures not only the sewerage development but also another measures such as reinforcement of regulation for industrial pollution load reduction, various measures for non-point pollution load reduction, reinforcement of water quality monitoring, environmental education and set-up of financing system for projects. Biwa Lake has gradually recovered the lake water quality under the various measures so far.

CHAPTER 8 IMPROVEMENT OF WATER QUALITY MONITORING

8.1 RELEVANT ORGANIZATION FOR WATER QUALITY MONITORING

Surface water quality must periodically be observed to manage river water quality in compliance with the standards and, for this purpose, the existing monitoring network system must be reconsidered due to the various problems. The improvement plan of the existing monitoring plan is strongly recommended, as discussed below.

8.1.1 Organization

There are several existing water quality monitoring system in the Study Area at present, many of them are conducted by CPCB, SPCBs and PCCs, which cover the entire Ganga Basin and periodically monitor the surface water quality of rivers/lakes/drainages and ground water.

Relevant organizational charts are given in Figures B.8.1 (CPCB) and B.8.2 (UPPCB). Monitoring Division of Pollution Assessment wing shown in chart is responsible for water quality monitoring. The water laboratories of State Pollution Control Board of respective States in the Ganga are associated with this program of CPCB.

8.1.2 Laboratories and Staff Involved in Water Quality Monitoring

(1) Laboratories

The laboratories involved in water quality monitoring are listed in Table B.8.1. There are three CPCB's laboratories (Delhi, Kanpur and Kolkata) and 44 SPCB's laboratories in the entire Ganga Basin.

(2) Staff

The staff working in each laboratory is tabulated in Table 8.1. Among them, totally 26 persons are affiliated with CPCB Central Laboratory. There is acute shortage of manpower for field monitoring as well as for laboratory analysis due to restriction on recruitment. In the laboratories of regional offices of SPCBs, same laboratory personnel are engaged in the activities of water quality and air quality monitoring. Hence they are overloaded.

(3) Responsibility of CPCB and SPCB

The programmes of CPCB/SPCB on National Water Monitoring Programme including the coverage of Ganga Basin is indicated in Table B.8.2

Table 8.1 Staff Line-up for each Laboratory

Name	Laboratory Work (Person)	Sampling Work (Person)	Remarks
CPCB Central Laboratory	18	8	
UPSPCB Kanpur Laboratory	34	22	
Bihar SPCB Laboratory	14	9	
West Bengal SPCB Laboratory	20	15	
Rajasthan SPCB Laboratory	8	6	
Madhya Pradesh SPCB Laboratory	36	20	
Haryana SPCB Laboratory	6	5	
Himachal Pradesh SPCB Laboratory	5	3	

(4) Mandate of Pollution Control Boards for Water Quality Monitoring

The Pollution Control Boards in India are responsible for restoring and maintaining the wholesomeness of aquatic resources. To ensure that the water quality is being maintained or restored at desired level it is important that the pollution control boards regularly monitor the water quality. The water quality monitoring is performed with following main objectives in mind:

- Rational planning of pollution control strategies and their prioritization;
- To assess nature and extent of pollution control needed in different water bodies or their part;
- To evaluate effectiveness of pollution control measures already in existence;
- To evaluate water quality trend over a period of time;
- To assess assimilative capacity of a water body thereby reducing cost on pollution control;
- To understand the environmental fate of different pollutants.
- To assess the fitness of water for different uses.

On the other hand, the State Pollution Control Boards are taking action on the polluted water bodies identified by Central Pollution Control Board to contain the level of pollution and restoration of water quality in accordance with the desired water quality class for different stretches of water bodies. National River Conservation Directorate is preparing plan for restoration of water quality based on the identified polluted water bodies in the country.

8.2 EXISTING MONITORING SYSTEM

8.2.1 Water Quality Monitoring Network

The Central Pollution Control Board has been monitoring water quality of national aquatic resources in collaboration with concerned State Pollution Control Boards at 784 stations. Out of which 710 stations are under MINARS (Monitoring of Indian National Aquatic Resources), 50 stations are under GEMS (Global Environmental Monitoring Systems) and 24 stations are under YAP (Yamuna Action Plan) programs. Out of 784 stations, 514 stations are on rivers, 181 stations are on ground water, 57 stations are on lakes and 32 stations are on canals, creeks, drains, ponds and tanks.

8.2.2 Sampling Locations for Water Quality Monitoring

Many sampling locations are scattered in the entire Ganga Basin for evaluation of current situation of river water quality. In order to grasp the exact condition of river water pollution, sampling points must represent the average location of the river flow condition. Moreover, lowest sampling points of each major tributary are very important for estimation of pollution load. In Ganga Basin, totally 117 sampling locations are stationed as shown in Table 8.2. According to the existing sampling locations, in the case of several major tributaries such as Sind, Ken, Tons, Karmanasa, Kiul and Jalangi, monitoring stations have not been stationed at the lowest point. Hence, information for pollution load generated from major tributaries is not available, and to be estimated at these major tributaries.

Table 8.2 Distribution of Water Quality Monitoring Stations in Ganga Basin

River (main stream), Tributaries and Sub-Tributaries	Total Stations
Ganga Main (34) **Tributaries**-Barakar (1), Betwa (3), Chambal (7), Damodar (5), Gandak (1), Saryu-Ghaghra (3), Gomti (5), Hindon (3), Kali (West) (2), Kali Nadi (2), Khan (1), Kshipra (3), Mandakini (Madhya Pradesh) (1), Parvati (2), Ramganga (1), Rapti (1), Rihand (2), Rupanarayan (1), Sai (1), Sone (5), Tons (Madhya Pradesh) (2), Yamuna (23), Sind (1), Johila (1), Sankh (1), Gohad (1), Kolar (1), Sai (1), Churni (1), Tons (Himachal Pradesh) (1)	117

8.2.3 Water Quality Sampling Covered by each Organization

Monitoring under YAP is being carried by CPCB, Head Office and Monitoring at Daman Diu and Dadra Nagar Haveli is being carried out by Zonal Office Vadodara, CPCB. For remaining stations, the monitoring is being carried out by respective SPCB's/PCC's. The monitoring of water quality at 254 stations is being done on monthly basis, 178 stations on half yearly basis, 349 stations on quarterly basis and at 3 stations on yearly basis.

8.2.4 Wastewater Quality Monitoring of Sewerage Effluent

Under the current monitoring system, U.P. Jal Nigam was managing the water quality monitoring performance of STP and CETP. As per analysis conducted by the JICA Study Team, the Jal Nigam has no adequate expertise and laboratory infrastructure for ensuring smooth reporting and smooth analysis of water quality monitoring programme. The Parameters reported by the Jal Nigam authorities were not including the microbiological parameters like E. Coli, which is very important parameter and cannot be neglected during routine monitoring reporting. The labs at STP needs up gradation in terms of manpower as well as analytical capability. It is strongly recommended that the monitoring work of STP and CETP should be either handed to CPCB regional office or it should be entrusted to UPPCB. A separate team lead by private entrepreneur could also be established and funds could be provided for up gradation of laboratories as these were lacking necessary equipment.

8.2.5 Parameters to be monitored

Many parameters are to be periodically monitored. CPCB is analysing 29 parameters consisting of physio-chemical and bacteriological parameters for ambient water samples. Besides this, 9 trace metals and 7 pesticides are analysed in site- specific samples. Bio monitoring is also carried out in specific locations. However, CPCB mainly monitors organic substances rather than toxic ones because current river pollution is attributed to domestic and non-point organic pollution loads. Needless to say, toxic substances must be periodically observed due to the necessity of the confirmation on the health damage of the residents.

8.2.6 Existing Monitoring Equipment

(1) CPCB's Central Laboratory

The Central Laboratory in CPCB is equipped with analytical equipments and sampling tools for general parameters as shown in Table B.8.3. Space of laboratory is rather sufficient, however, most of the equipment is either out-of-date or not functioned. Hence, procurement of additional equipment is necessary to improve the capacity of the current water quality monitoring.

(2) Laboratories of UPPCB and STPs

The equipment installed in laboratories of UPPCB and STPs is tabulated in Table B.8.4. Currently, the four laboratories of UPPCB are well equipped, however, some of equipment is out-of-date. On the other hand, laboratories of STPs are less equipped because the number of parameters to be monitored is less than that of the river water quality monitoring.

8.2.7 Analytical Data Management

The water quality monitoring data is transmitted through hard copies by post from SPCBs to CPCB. Data is entered in d-base format and processed for determining the ranges, i.e., minimum and maximum and mean values for annual averages. The data is published as annual report for each year.

The data is also used for preparing trend reports, replying VIP queries, Parliament Questions and for formulation of river action plans to control pollution and to achieve the desired water quality.

8.3 CURRENT ISSUES ENCOUNTERED IN WATER QUALITY MONITORING

CPCB published the report " Rationalization and Optimization of Water Quality Monitoring Network" in July 2001, in which it has been cited that many problems were encountered during execution of the water quality monitoring program and that have impeded the wholesome monitoring activities. CPCB covers wide area of whole country for monitoring network, therefore, it is still difficult to conduct the sufficient water quality monitoring due to the technical and administrative problems. To achieve the satisfactory water quality monitoring, it is worth considering some of these persisting problems as mentioned below:

8.3.1 Technical Problems

Main technical problems are broken down as follows; sampling station, sampling procedures, preservation of samples, transportation of samples from sampling sites to the laboratory and availability of competent persons involved in sampling, analysis and reporting of data. Some of them are summarized below:

- Location of sampling site is very important to represent the water quality, however, the right samples have not been taken in some monitoring stations. If wrong sample is collected, the precision and accuracy used in analysis becomes futile. These problems have occurred due to the following reasons: difficulty of approach to exact sampling sites, unrepresentative samples, lack of availability of boat for sampling and no flow in the river during dry season.
- After sampling, adequate storage and preservation of samples is essential for accurate water quality analysis. However, many times these necessary measures have been neglected during water quality sampling.
- Many times field parameters like temperature and dissolved oxygen are not analyzed in the field.
- Data reporting has been often hindered by various problems such as lack of information regarding climatic and hydraulic condition, deficiency of all the parameters to be analyzed, abnormal results, inadequate procedure of data format and data transmission etc.

Among the above items, optimum location of sampling site is considered to be one of the important issues for solving the sound water quality monitoring. Moreover, new additional monitoring stations should be set up in the entire Ganga Basin considering the necessity of monitoring. Because in some major tributaries the river water quality have not been monitored up to now.

8.3.2 Administrative Problems

A number of administrative problems such as scarcity of fund and trained manpower, facilities, delayed in repairing of instrument low priority towards monitoring are noticed. The major administrative problems are given below:

- Many times due to inadequate fund the monitoring is not being done as per schedule.
- Due to the pressure of some other urgent work, water quality monitoring does not get priority.
- In some cases untrained manpower is engaged in water quality monitoring.
- Delayed transmission of data is reported in many cases.
- Delayed response of CPCB's communication is many cases.
- It is also reported that majority attendance of repair work has been hindered due to

administrative problems.
- Freedom to the monitoring staff according to work schedule is not observed in many cases.
- To assess the fitness of water for different uses.

8.3.3 Scarcity of Capacity of Optimum Monitoring Activities

(1) Laboratory and Field Equipment

The existing laboratories involved in water quality monitoring are widely positioned in the entire Ganga Basin and narrowly functioned for water quality monitoring activities. Moreover, laboratory and field equipment for monitoring are not enough at present due to the increasing coverage area and number of samples. To achieve the satisfactory water quality monitoring, laboratory and field equipment should be provided.

(2) Staff Training

The staff training is indispensable for precious water quality analysis and to be periodically executed. However, it is reported that satisfactory staff training has not been conducted so far due to the various reasons. To obtain accurate analytical results, laboratory staff must be periodically trained. There is need to design refresher training programs for water quality monitoring and upgrade analytical capability.
Likewise, the staff present at the state pollution control board laboratories are not updated on issues related to water quality monitoring aspects from the samples collection to its result dissemination. They are engaged in variety of works other than water quality monitoring. No scientific journals or manuals are present in the laboratories, which prescribe the guidelines with respect to sampling point allocations, inference of non- point sources with sampling results and other issues. The general perception of water quality monitoring staff is that the water sampling work is among the routine jobs they are engaged in. This aspect of water quality monitoring activity should be dealt with increased interest generation among staff engaged in water quality monitoring equipments.

(3) Analytical Capability

The comparative list of combined instrument inventory shows that the list of instruments seems adequate with normal water monitoring exercise, but it is not supportive to exhaustive sampling exercises, which includes more sensitive parameters like organic residues and other carcinogenic parameters, which are of more environmental concern, in addition to routine parameters monitored. This analytical capability should be compensated with adequate and sophisticated instrumentation provision with respect to organic compounds analysis.

(4) Availability of Sufficient Funds

The present monitoring program for river Ganga has suffered a lot due to paucity of funds. Though the water quality monitoring has been a CPCB funded scheme, the monitoring scheme at normal riverine system was very smooth as compared to the monitoring of Sewerage Treatment Plant (STP) as well as Combined Effluent Treatment plant (CETP). Comparative analysis of the system present for water quality monitoring at UPPCB and STP facilities shows clear disfunctioning and irregularities during the visit. Funds were not managed at the STP monitoring sites as the monitoring agency U.P. Jal Nigam were not quiet capable of monitoring adequately with respect to the water quality objectives and standards. Additional Funds should be provided exclusively by CPCB to UPSPCB for the monitoring of STP and CETP functioning.

8.3.4 Analytical Quality Control (AQC)

In order to conduct accurate monitoring, analytical quality control is necessary for all the laboratory staff. CPCB and SPCBs/PCCs are doing AQC activities as follows:

- There should be a habit of preparing control charts and conducting regular intra-lab AQC in all the laboratories in water quality monitoring program.
- It is necessary for CPCB to visit the SPCBs/PCCs laboratories more frequently and interact with Laboratory officials for ventilating their problems.
- Internal communication and joint monitoring of CPCB and SPCBs/PCCs is required for the improvement of AQC.
- Concerned laboratories are doing various precision controls such as control by duplicate analysis, using pooled and certified reference material, use of control chart and Inter-laboratory analytical quality control.

In addition to the existing AQC, crosscheck analysis between CPCB and SPCBs/PCCs using the standard solution is recommendable for the improvement of the accuracy control.

8.4 MONITORING PROGRAM FOR GANGA RIVER BY UPPCB

8.4.1 Existing Laboratory Conditions in 4 Cities

The water quality monitoring programs at all four places are commonly consisting of monitoring of rivers as well as lakes and other surface water bodies. CPCB sponsors the Ganga water quality-monitoring program and the entire funding is provided to SPCB for these monitoring activities. The normal steam structure of these state laboratories consists of:

Assistant Scientific Officer

Monitoring Assistant	Laboratory Assistant	Scientific Assistant
3	1	3

The above-mentioned staff is deployed at Kanpur, Allahabad and Varanasi, but at Lucknow the total staff dedicated to water quality monitoring is 25. The above mentioned team is normally deployed being responsible for following tasks:

a. Collection of Sample
b. Transportation of sample
c. Storage and Analysis of Samples
d. Reporting of Results

The results are then send to CPCB as per the prescribed format by the CPCB. The comparative laboratory analytical capability are addressed below as attachment:

The above comparative analysis of laboratories shows that the laboratory set up is comparatively better at Lucknow, as it is the headquarter of the UPPCB. The laboratories at STP were not functioning well with respect to their capacity of functioning, manpower as well as data reliability.

The Jal Nigam department, who were not competent at par with the UPPCB laboratories and CPCB, managed these laboratories. The list of common analytical equipments is satisfactory with respect to inorganic analysis and general laboratory equipments in UPPCB laboratories, but it was not up to the mark in case of STP and CETP laboratories. The water quality monitoring equipments are also adequate as far as the lists of equipments specifically used for water quality monitoring are concerned.

8.4.2 Issues Related To Laboratory Performance Improvement

The laboratory conditions are good at all the four places, but still they need some improvement with respect to the following issues:

(1) Monitoring up gradation at STP and CETP laboratories: under the current monitoring system, U.P. Jal Nigam was managing the water quality monitoring performance of STP and CETP. As per our visit and analysis the Jal Nigam has no adequate expertise and laboratory infrastructure for ensuring smooth reporting and smooth analysis of water quality monitoring programme. The Parameters reported by the Jal Nigam authorities were not including the Microbiological parameters like E.Coli, which is very important parameter and cannot be neglected during routine monitoring reporting. The laboratories at STP needs up gradation in terms of manpower as well as analytical capability. It is strongly recommended that the monitoring work of STP and CETP should be either handed to CPCB regional office or it should be entrusted to UPPCB. A separate team lead by private entrepreneur could also be established and funds could be provided for up gradation of laboratories as these were lacking necessary equipment.

(2) Staff Capability Improvement**:** The staff present at the state pollution control board laboratories are not updated on issues related to water quality monitoring aspects from the samples collection to its result dissemination. They are engaged in variety of works other than water quality monitoring. No scientific journals or manuals are present in the laboratories, which prescribe the guidelines with respect to sampling point allocations, inference of non-point sources with sampling results and other issues. The general perception of water quality monitoring staff is that the water sampling work is among the routine jobs they are engaged in. This aspect of water quality monitoring activity should be dealt with increased interest generation among staff engaged in water quality monitoring equipment.

(3) Analytical Capability**:** The comparative list of combined instrument inventory shows that the list of instruments seems adequate with normal water monitoring exercise, but it is not supportive to exhaustive sampling exercises, which includes more sensitive parameters like organic residues and other carcinogenic parameters, which are of more environmental concern, in addition to routine parameters monitored. This analytical capability should be compensated with adequate and sophisticated instrumentation provision with respect to organic compound analysis.

(4) Capacity building measures: Normally the capacity building measures are not adequate with respect to training component for the staff engaged in the water quality monitoring exercise. The training programmes are organized with resource mobilization and support from CPCB. This needs additional support and resource persons should be taken up from other educational institutes like India Institute of Technology, Kanpur, Banaras Hindu University, Varanasi, National Environmental Engineering Research Institute (NEERI) and other related institutions. The frequency of these training programmes should be maximized after every 4 months. The staff at ground level instead of policy level should be encouraged to attend these training programs. This shall increase the competency level of staff engaged in analysis and supervision of work of water quality monitoring.

(5) Application of Quality Assurance procedures For Data**:** It was felt that the staffs engaged in the water quality monitoring were not aware of the quality assurance tools used in water quality monitoring. The staff in data analysis did not use the statistical tools like Chi square test, ANOVA, and correlation and regression analysis and it's reporting. These deficiencies should be taken care of as this shall minimize the prevailing discrepancy of corrupt data, reporting impression of SPCB laboratory results and increase their credibility with respect to reputation between CPCB and other related agencies using their information.

(6) Easy Administration**:** The set up of state pollution control board laboratories was analyzed and it was found that the administration set up was not transparent and flexible with respect to various decision making exercises ranging from purchase of equipment to sanctioning of grant for equipments. This lead to the delay in operation and maintenance of various advance instruments. The present bidding based purchase policy encouraged the purchase of low cost equipments, which leads to drop in quality of analytical results as well as data produced. The purchase of various advanced analytical instruments should be made with respect to quality assurance of instrument provider. These instruments should be purchased from a specified equipment provider, which could be referred by the leading research and development institutions.

(7) Availability of Sufficient Funds**:** The present monitoring program for river Ganga has suffered a lot due to paucity of funds. Though the water quality monitoring has been a CPCB funded scheme, the monitoring scheme at normal riverine system was very smooth as compared to the monitoring of Sewerage Treatment Plant (STP) as well as Combined Effluent Treatment plant (CETP). Comparative analysis of the system present for water quality monitoring at UPPCB and at STP facilities shows clear disfunctioning and irregularities during the visit. Funds were not managed at the STP monitoring sites as the monitoring agency U.P. Jal Nigam were not quiet capable of monitoring adequately with respect to the water quality objectives and standards. Additional Funds should be provided exclusively by CPCB to UPSPCB for the monitoring of STP and CETP functioning.

(8) Wide Publicity of water Quality Monitoring Date**: N**ormally the common public conceives the publicity of water quality monitoring data as irrational thing. This vital information, which is crucial with respect to finalizing different environmental projects and other important decisions, related to future planning of water resources. The information should be widely disseminated among various public groups through regular publishing in various newspapers as well as other public target groups. The water quality monitoring data should not be conceived as scientific information and it should be conveyed to public as important as other environmental issues.

8.5 RECOMMENDATIONS

8.5.1 Capacity Building for Optimum Monitoring

(1) Improvement of Laboratory

In case of CPCB's Central Laboratory in Delhi and UPPCB's laboratories in 4 cities, existing equipment for water quality analysis is out-of-date and inefficient. Besides, trained manpower for field and in-house work for water quality monitoring is in short. Hence, it is necessary to build up the capacity for optimization of water quality monitoring.
To monitor water quality under the recommended basis, laboratory equipment must be improved. The required equipment is given in Table B.8.5 (CPCB's Central Laboratory) and Table B.8.6 (UPPCB's laboratories in 4 cities), respectively. The required equipment was selected according to the following aspects:

(a) Field equipment like pH, DO and conductivity meter is very useful for water quality sampling. Currently, such kinds of handy- type meter are deficient in each laboratory.
(b) Originally, laboratories of CPCB and SPCB inspect the industrial effluent and have a role of water quality monitoring. However, it is reported that wastewater from relevant laboratories is untreated. Hence, the equipment for the wastewater treatment is indispensable in each laboratory.
(c) Gas chromatography, Atomic Absorption Spectrophotometer and UV/VIS Spectrophotometer are basic equipment, however many of them are not functioning, especially in CPCB's Central Laboratory. Therefore, additional equipment is necessary.

(2) Cost Estimate

(a) Procurement Cost

Procurement and construction costs related to the improvement of the monitoring system are laboratory equipment. These costs are estimated based on the market prices prevailing in March 2004 (for detail, see Table B.8.5). The procurement cost for laboratory equipment is estimated to be Rs. 46,261 thousand (US$1,020 thousand). The total procurement costs related to the laboratory are summarized below.

Table 8.3 Procurement Cost

Item	Cost (in thousand Rs)
CPCB's Central Laboratory	13,151
SPCB' laboratories in 4 cities	16,237
Total	29,388
Total (in thousand US$)	(648)

Exchange Rate: US$1.00 = ¥109 = Rs 45.33

(b) Annual Monitoring Cost

The O&M cost related to additional equipment is composed of consumable material cost such as spare parts and chemical reagent. The annual O&M cost is currently allocated 35,000 Rs per one unit in case of sophisticated equipment such as Gas- chromatography, Atomic Absorption Spectrophotometer and so on. Except for these sophisticated equipment, the annual O&M cost of remaining equipment like field equipment is assumed to be 0.25% of procurement cost. Using these assumptions, the annual O&M cost related to the new additional equipment installed in CPCB's/SPCB's laboratories is estimated as below.

Table 8.4 Additional Annual O&M Cost

Item	Additional Equipment (Unit)	O&M Cost (1,000 Rs/year)	Remarks (Nos of Sophisticated Equipment)
CPCB's Central Laboratory	13	143	4
SPCB's laboratories in 4 cities	56	154	4
Total	69	297	
Total (US$1,000)	-	(7)	

Exchange Rate: US$1.00 = ¥109 = Rs. 45.33

8.5.2 Current Monitoring Station

(1) Basic Concept for Selection of Monitoring Stations

Sampling locations should be selected based on the following aspects; (i) the location of water use, (ii) the location where polluted water is sufficiently diluted after it has been discharged to the river and the location upstream of such wastewater discharge, (iii) the location where the water from a tributary is sufficiently mixed with water of main stream, and before confluence point of the main stream and tributary, (iv) the location adjacent to the intake points of public water and irrigation uses, and (v) any other location to be established as required. Reference monitoring stations for quality standards should be always included in the water quality monitoring survey.

(2) Reconsideration of Current Sampling Site

Exact sampling location leads to the representative monitoring data, however some of current sampling points stationed in Ganga Basin have to be reconsidered as explained below:

(a) General Condition of Monitoring Stations

- Upstream sampling points of each city should be stationed at the front area where the river water quality is not affected by any point pollution loads inflow.
- Faecal coliform number exceeds the water quality standards (desirable: 500 MPN/100ml and maximum permissible: 2,500 MPN) significantly at the existing upstream monitoring stations, especially, Kanpur, Varanasi and Lucknow. The reasons of bacterial contamination at the upstream monitoring stations might be as follows; (i) contamination due to non-point pollution sources such as cattle wallowing, open defecation, etc. along the river banks, (ii) inappropriate location of upstream monitoring station which does not take into account the inflow of point pollution load. Hence, additional monitoring station should be established at appropriate distance further upstream from existing one of each city.
- Downstream sampling points of each city should be stationed at the central area where all the pollution loads are well mixed and river water quality can be represented.
- The sampling points where the river flow is stagnant should be avoided and replaced to the well flowing points.
- The most convenient way is to take samples on the bridge because the foothold is stable and well-mixed points can be easily found.
- An edge of river is not suitable to take samples because river water quality is not generally well mixed. If any bridges are not located in vicinity of the sampling point, usage of boat is recommendable for sampling at the well-mixed points of river water.

(b) Sampling Site of the 4 Cities

The monitoring stations located in the 4 cities conducted by CPCB/UPPCB are follows:

- There are three CPCB's monitoring stations located in Kanpur. Upstream sampling point is located at Bithoor, middle sampling point is stationed at Dhondighat, and water quality samples are taken at Jajmau Pumping Station. Among the three sampling points, downstream sampling point is located in the city area and is not well-mixed all the pollution load discharged from Kanpur. Hence, it is recommendable to set up an additional new monitoring station at further downstream of Kanpur.
- In case of Lucknow, 2 sampling points are located at "Water Intake Point" where is regarded as upstream of Lucknow and at "Gomati Barrage" where is regarded as downstream of Lucknow. Apart from these 2 sampling points stationed by CPCB, 6 another sampling points conducted by UPPCB are located in the Lucknow city area. All

the sampling locations are located within the city area of Lucknow. Therefore, it is recommendable to set up 2 additional new monitoring stations at further upstream and downstream of Lucknow.

- There are 4 sampling points stationed by CPCB located in Allahabad. Apart from CPCB's sampling points, there are another 5 sampling points taken by UPPCB. It is necessary to station 2 additional new sampling points at further upstream of Allahabad in Yamuna and at further downstream of Allahabad on Ganga. Because existing upstream sampling point of Yamuna is located in city area, therefore, river water is probably affected by point pollution inflow. On the other hand, existing downstream sampling point of Ganga is located immediately after confluence with Ganga and Yamuna, hence, river water seemed not to be well mixed.
- Sampling locations in Varanasi is controversial because actual sampling points of upstream and downstream is very much affected by domestic pollution inflow. Therefore, apart from these 2 existing sampling points, it is essential to set up two additional monitoring stations at further upstream and further downstream of Varanasi.

As mentioned earlier, upstream and downstream monitoring stations in 4 cities are mostly located in city area and their locations seemed to be already affected by point pollution inflow. Hence, above sampling points stationed at upstream and downstream of Kanpur, Allahabad, Varanasi and Lucknow need to be minutely investigated to adjust the correct sites.

(3) Additional Monitoring Stations to be selected

Tables B.8.7 and B.8.8 show recommended additional monitoring station for Ganga Basin along with the existing monitoring stations. Necessary monitoring stations were selected based on the following aspects:

- There are few major tributaries for which monitoring locations were not included in current water quality monitoring plan. Therefore, additional monitoring stations should be selected at the lowest point and confluence points of tributaries to take into account pollution load balance in the entire Ganga basin.
- In case of Varanasi City, there are two different monitoring stations at the downstream area in Ganga Main River. However, one new monitoring station should be set up at lower point in addition because these existing monitoring stations are much affected by Varuna River and not well mixed. Further, there has not been any water quality monitoring in Varuna River, hence it is necessary to set up a new monitoring station at the lowest point of Varuna River.

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Table B.3.1(1) The Study on Water Quality Management Plan for Ganga River in the Republic of India

S.No.	ST_CODE	LOCATION (From CPCB data)	RIVER	LAT	LONG	Remarks
1	**1046**	GANGA AT ALLAHABAD (RASOOLABAD), U.P.	GANGA	25 27'	81 49'	
2	**1049**	GANGA AT ALLAHABAD D/S (SANGAM), U.P.	GANGA	25 19'	81 59'	
3	**1052**	GANGA AT ULUBERIA, WEST BENGAL	GANGA	22 25'	88 8'	
4	**1053**	GANGA AT DAKSHINESHWAR, WEST BENGAL	GANGA			
5	**1054**	GANGA AT PALTA, WEST BENGAL	GANGA	22 16'	88 23'	
6	**1059**	GANGA AT RAJMAHAL, BIHAR	GANGA	25 20'	87 46'	
7	**1060**	GANGA AT RISHIKESH U/S, UTTARANCHAL	GANGA	30 6'	78 16'	
8	**1061**	GANGA AT HARIDWAR D/S, UTTARANCHAL	GANGA	29 49'	78 8'	
9	**1062**	GANGA AT GARHMUKTESHWAR, U.P	GANGA	28 57'	78 7'	
10	**1063**	GANGA AT KANNAUJ U/S (RAJGHAT), U.P	GANGA	27 7'	79 51'	
11	**1064**	RAMGANGA AT KANNAUJ (BEFORE CONF.),U.P	RAMGANGA	27 3'	79 50'	
12	**1065**	KALINADI AT KANNAUJ (BEFORE CONF.),U.P	KALINADI	27 12'	79 47'	
13	**1066**	GANGA AT KANNAUJ D/S, U.P	GANGA	27 3'	79 59'	
14	**1067**	GANGA AT KANPUR U/S (RANIGHAT), U.P	GANGA	26 29'	80 19'	
15	**1068**	GANGA AT KANPUR D/S (JAJMAU PUMPING STATION), U.P	GANGA	26 22'	80 26'	
16	**1069**	YAMUNA AT ALLAHABAD D/S (BALUA GHAT), U.P	YAMUNA	25 19'	81 38'	
17	**1070**	GANGA AT VARANASI U/S (ASSIGHAT), U.P	GANGA	25 16'	83 1'	
18	**1071**	GANGA AT VARANASI D/S (MALVIYA BRIDGE), U.P	GANGA	25 18'	83 7'	
19	**1072**	GOMTI AT VARANASI, U.P	GOMATI	25 26'	83 1'	
20	**1073**	GANGA AT TRIGHAT (GHAZIPUR), U.P	GANGA	25 29'	83 35'	
21	**1074**	GANGA AT BUXAR,BIHAR	GANGA	25 38'	84 4'	
22	**1075**	SONE AT KOELWAR, BIHAR	SONE	25 33'	84 50'	
23	**1076**	GHAGHARA NEAR CHAPRA, BIHAR	GHAGHARA	25 46'	84 41'	
24	**1077**	GANGA AT KHURJI, PATNA U/S, BIHAR	GANGA	25 44'	85 14'	
25	**1078**	GANDAK AT SONEPUR, PATNA (BEFORE CONFL.),BIHAR	GANDAK	25 38'	85 10'	
26	**1079**	GANGA AT PATNA D/S (GANGA BRIDGE),BIHAR	GANGA	25 34'	85 17'	
27	**1080**	GANGA AT BAHARAMPORE, WEST BENGAL	GANGA	24 13'	88 23'	
28	**1117**	YAMUNA AT HATHNIKUND, HARYANA	YAMUNA	30 13'	77 31'	
	1118		YAMUNA	29 22'	77 11'	
29	**1119**	YAMUNA AT SONEPAT, HARYANA	YAMUNA			
30	**1120**	YAMUNA AT WAZIRABAD U/S (PALLA), DELHI, CPCB	YAMUNA	28 43'	77 15'	
31	**1121**	YAMUNA AT NIZAMUDDIN BRIDGE, DELHI	YAMUNA			
32	**1123**	YAMUNA AT MATHURA U/S, UTTAR PRADESH	YAMUNA	27 29'	77 41'	
33	**1124**	YAMUNA AT MATHURA D/S, UTTAR PRADESH	YAMUNA			
34	**1125**	YAMUNA AT AGRA U/S, UTTAR PRADESH	YAMUNA	27 13'	77 56'	
35	**1126**	YAMUNA AT AGRA D/S, UTTAR PRADESH	YAMUNA	27 8'	78 4'	
36	**1127**	YAMUNA AT ETAWAH, U.P.	YAMUNA	26 46'	78 59'	
37	**1129**	YAMUNA AT ALLAHABAD. U.P.	YAMUNA	25 19'	81 46'	
38	**1142**	SONE AT CHACHAI, M.P.	SONE	24 4'	81 13'	
39	**1143**	TONS AT CHAKGHAT, M.P.	TONS (MP)	24 57'	81 40'	
40	**1144**	TONS AT MADHAVGARH, M.P.	TONS (MP)	24 37'	81 00'	
41	**1145**	GANGA AT NARORA (BULANDSAHAR), U.P.	GANGA	28 18'	78 16'	
42	**1146**	GANGA AT BITHOOR (KANPUR), U.P.	GANGA	26 34'	80 18'	
43	**1147**	GANGA AT DALMAU (RAI BAREILLY), U.P.	GANGA	26 00'	80 46'	
44	**1288**	CHAMBAL AT KOTA U/S (INTAKE PT. NEAR BARRAGE), RAJASTHAN	CHAMBAL	25 8'	75 46'	
45	**1289**	CHAMBAL AT KOTA D/S (2 KM. FROM CITY),RAJASTHAN	CHAMBAL	25 15'	75 46'	
46	**1331**	DAMODAR AT DISHERGARH VILL.(NR.BIHAR-WEST BENGAL BORDER),WEST BENGAL	DAMODAR	23 43'	86 59'	
47	**1332**	DAMODAR AT D/S OF IISCO AFTER 3RD OUTFALL AT DHENNA VILLAGE, WEST BENGAL (BARNPUR)	DAMODAR	23 45'	86 49'	
48	**1333**	DAMODAR AT NARAINPUR AFTER CONFL. OF NUNIA NALLAH, WEST BENGAL (DURGAPUR)	DAMODAR	23 31'	87 18'	
49	**1334**	DAMODAR NEAR MUJHER MANA VILLAGE AFTER CONF. OF TAMLA NALLAH, WEST BENGAL (DURGAPUR)	DAMODAR	23 24'	87 31'	
50	**1335**	DAMODAR AT HALDIA D/S (2 KM AWAY FROM HALDIA TOWN), WEST BENGAL	DAMODAR	22 5'	88 26'	
51	**1336**	BARAKAR AT ASANSOL (WATER INTAKE POINT), WEST BENGAL	BARAKAR	23 43'	87 9'	
52	**1337**	RUPNARAYAN BEFORE CONFL. TO RIVER GANGA NEAR GEONKHALI, WEST BENGAL	RUPNARAYAN	22 17'	88 11'	
53	**1350**	GOMTI AT SITAPUR U/S AT WATER INTAKE, U.P.	GOMATI	27 33'	80 38'	
54	**1351**	GOMTI AT LUCKNOW U/S AT WATER INTAKE POINT,U.P.	GOMATI	26 53'	80 52'	
55	**1352**	GOMTI AT LUCKNOW D/S, U.P.	GOMATI	26 46'	80 58'	
56	**1353**	GOMTI AT JAUNPUR D/S, U.P.	GOMATI	25 38'	82 43'	

Table B.3.1(1) The Study on Water Quality Management Plan for Ganga River in the Republic of India

S.No.	ST_CODE	LOCATION (From CPCB data)	RIVER	LAT	LONG	Remarks
57	**1354**	SARYU AT AYODHYA AT MAIN BATHING GHAT, U.P. (GHAGHRA) FAIZABAD	Saryu(GHAGHA	26 39'	82 16'	
58	**1355**	GHAGHARA AT DEORIA D/S, U.P.	GHAGHARA	26 7'	83 56'	
59	**1356**	BETWA BEFORE CONF. YAMUNA AT HAMIRPUR, U.P.	BETWA	25 52'	80 4'	
60	**1357**	HINDON AT SAHARANPUR D/S, U.P.	HINDON	29 47'	77 34'	
61	**1358**	HINDON AT GHAZIABAD D/S, U.P.	HINDON	28 38'	77 23'	
62	**1359**	RIHAND AT RENUKUT U/S, U.P.	RIHAND	24 10'	83 5'	
63	**1360**	RIHAND AT RENUKUT D/S, U.P.	RIHAND	24 21'	83 5'	
64	**1361**	SAI AT UNNAO AFTER DRAIN OUTFALL, U.P.	SAI	27 6'	80 16'	
65	**1363**	RAPTI AFTER CONFL. OF R. HONIN NR. DOMINGARH RLY BRIDGE, GORAKHPUR, U.P.	RAPTI			
	1364	RAMGARH LAKE , U.P.		26 33'	83 20'	
66	**1365**	CHAMBAL AT NAGDA U/S (WATER INTAKE POINT) M.P.	CHAMBAL	23 26'	75 21'	
67	**1366**	CHAMBAL AT NAGDA D/S, M.P.	CHAMBAL	23 34'	75 13'	
68	**1367**	KHAN AT KABIT KHEDI (NEAR INDORE) M.P.	KHAN	22 43'	75 43'	
	1368		KSHIPRA	23 14'	75 35'	
69	**1369**	KSHIPRA AT RAMGHAT AT UJJAIN, M.P.	KSHIPRA	23 10'	75 37'	
70	**1370**	KSHIPRA AT TRIVENISANGAM (1 KM. D/S OF SANGAM), M.P.	KSHIPRA	23 17'	75 44'	
71	**1371**	SONE AT AMLAI, M.P.	SONE	24 10'	81 19'	
72	**1372**	MANDAKINI AT CHITRAKUT, M.P.	MANDAKINI (MI	25 17'	80 52'	
73	**1376**	CHAMBAL AT ETAWAH BEFORE CONFL. TO R. YAMUNA, U.P.	CHAMBAL	26 31'	79 7'	
74	**1413**	CHAMBAL AT RAMESHWARGHAT NR. SAWAIMADHOPUR, RAJASTHAN	CHAMBAL	25 58'	76 45'	
75	**1418**	CHAMBAL AT GANDHI SAGAR DAM, RAMPURA, MP	CHAMBAL	24 36'	75 26'	
76	**1432**	PARVATI NEAR VILLAGE BATAODAPAR, M.P.	PARVATI	24 31'	77 1'	
	1460		CHAMBAL	25 52'	75 25'	
77	**1468**	KSHIPRA AT SIDDHAWAT (D/S) OF UJJAIN.,M.P. (REALLOCATED FROM ST. 1368 FROM 2/94).	KSHIPRA			
78	**1469**	GANGA AT DIAMOND HARBOUR, WEST BENGAL	GANGA			
79	**1470**	GANGA AT GARDEN REACH, WEST BENGAL	GANGA			
80	**1471**	GANGA AT HOWRAH-SHIVPUR, WEST BENGAL	GANGA			
81	**1472**	GANGA AT SERAMPORE, WEST BENGAL	GANGA			
82	**1477**	KALINADI AT U/S OF MUZAFFAR NAGAR U.P.	KALI (WEST)			
83	**1478**	KALINADI AT D/S OF MUZAFFAR NAGAR, U.P.	KALI (WEST)			
84	**1480**	KALINADI AT U/S OF GULAOTHI TOWN IN BULANDSAHAR, U.P.	KALINADI			
85	**1483**	HINDON AFTER CONFL. WITH R. KRISHNA & KALI NEAR BINAULI TOWN, MEERUT,U.P.	HINDON			
86	**1484**	ALAKANANDA B/C MANDAKINI AT RUDRA PRAYAG, UTTARANCAL	ALKANANDA			
87	**1485**	MANDAKINI B/C ALKALNADA AT RUDRAPRAYAG, UTTARANCHAL	MANDAKINI (UTT)			
88	**1486**	ALAKANANDA A/C MANDAKINI AT RUDRAPRAYAG, UTTARANCHAL	ALKANANDA			
89	**1487**	ALAKANANDA B/C WITH BHAGIRATHI AT DEVPRAYAG, UTTARANCHAL	ALKANANDA			
90	**1488**	BHAGIRATHI B/C WITH ALAKNANDA AT DEVPRAYAG, UTTARANCHAL	BHAGIRATHI			
91	**1489**	ALAKANANDA A/C WITH BHAGIRATHI AT DEVPRAYAG, UTTARANCHAL	ALKANANDA			
92	**1490**	YAMUNA AT U/S DAK PATTHAR, UTTARANCHAL	YAMUNA			
93	**1491**	BHAGIRATHI AT GANGOTRI, UTTARANCHAL	BHAGIRATHI			
94	**1492**	YAMUNA AT YAMUNOTRI, UTTARANCHAL	YAMUNA			
95	**1493**	YAMUNA AT HANUMANCHATTI, UTTARANCHAL	YAMUNA			
96	**1494**	YAMUNA AT U/S OF LAKHWAR DAM, UTTARANCHAL	YAMUNA			
97	**1495**	YAMUNA AT D/S OF LAKHWAR DAM, UTTARANCHAL	YAMUNA			
98	**1496**	YAMUNA AT KALANAUR, YAMUNA NAGAR, HARYANA	YAMUNA			
99	**1497**	YAMUNA AT MAZAWALI, UTTAR PRADESH	YAMUNA			
100	**1498**	YAMUNA AT BATESWAR, UTTAR PRADESH	YAMUNA			
101	**1499**	YAMUNA AT JUHIKA B/C WITH CHANBAL, ETAWAH, UTTAR PRADESH	YAMUNA			
102	**1375**	YAMUNA AT OKHLA BRIDGE (INLET OF AGRA CANAL), DELHI	YAMUNA	28 31'	77 19'	
103	**1433**	SANKH AT TIGRA RESERVOIR, M.P.	SANKH	26 10'	77 46'	

Table B.3.1(1) The Study on Water Quality Management Plan for Ganga River in the Republic of India

S.No.	ST_CODE	LOCATION (From CPCB data)	RIVER	LAT	LONG	Remarks
104	**1510**	TONS AT D/S Dakpathar, Uttaranchal	TONS (UTT)			
105	**1553**	RIVER YAMUNA , U/S PAONTA SAHIB, H.P	YAMUNA			
106	**1554**	RIVER YAMUNA , D/S PAONTA SAHIB, H.P	YAMUNA			
107	**1607**	GOHAD DAM, GOHAD, M.P	*			
108	**1608**	R. SINDH AT DABRA, M.P	SINDH			
109	**1609**	R. CHAMBAL AT DHOLPUR, M.P	CHAMBAL			
110	**1610**	R.SONE AT ORIGINE AMARKANTAK, M.P	SONE			
111	**1611**	R.JOHILA NEAR NAROJABAD NEAR UMARIA ROAD BRIDGE, M.P	JOHILA			
112	**1612**	R.SONE AT DEVLOAD OUT LET OF BANSAGAR DAM, M.P	SONE			
113	**1613**	KOLAR DAM WATER SUPPLY INTAKE WELL, DISTT. SEHORE, M.P	*			
114	**1614**	R.BETWA NEAR INTAKE POINT, VIDISHA, M.P	BETWA			
115	**1615**	R.PARVATI NEAR INTAKE POINT PILLUKHEDI DISTT. RAJGARH, M.P	PARVATI			
116	**1735**	GOVIND SAGAR, U.P	BETWA			
117	**1763**	CHURNI AT GADE BORDER (BANGLADESH - INDIA BORDER), WEST BENGAL	CHURNI			
118	**1764**	CHURNI D/S OF SANTIPUR TOWN, WEST BENGAL	CHURNI			
119	**1812**	RIVER YAMUNA AT OKHLA AFTER MEETING OF SHAHDARA DRAIN, DELHI	YAMUNA			
120	**1785**	MANTHRALAYAM , KURNOOL DIST., A.P	*			

Table B.4.1 Performance Evaluation of CETP and STPs at Kanpur (Oct- Nov 2002)

Sampling Points	pH	Colour	Alk.	Cl- (mg/l)	Sulphide (mg/l)		TSS (mg/l)	VSS (mg/l)	MLSS (mg/l)	MLVSS (mg/l)	COD (mg/l)	BOD (mg/l)	SAR (mg/l)	Boron (mg/l)	T. Coli. (MPN/100ml)	F. Coli. (MPN/100ml)
					Day	Night										
5 mld Inlet	7.9	50	492	326	17	10.2	661	387	-	-	673	216	7.39	0.28	$5 X 10^7$	$1.1 X 10^7$
5 mld Outlet	8.4	50	532	308	16.9	14.6	41	37	-	-	104	59	9.46	ND	$2.3 X 10^6$	$8 X 10^5$
130 mld Inlet	8	50	484	308	15.3	10.8	507	325	-	-	672	194	6.88	0.35	$5 X 10^7$	$5 X 10^6$
Aeration tank-1,130mld	-	-	-	-	-	-	-	-	1991	1030	-	-	-	-	-	-
Aeration tank-2,130mld	-	-	-	-	-	-	-	-	1987	1008	-	-	-	-	-	-
Aeration tank-3,130mld	-	-	-	-	-	-	-	-	2236	1102	-	-	-	-	-	-
130 mld Outlet	8.1	50	388	326	ND	ND	65	40	-	-	80	40	9.67	ND	$8 X 10^6$	$1.3 X 10^6$
36 mld Inlet (Tannery)	9.1	100	472	2050	59.7	14.8	1724	1009	-	-	1504	388	33.10	2.20	-	-
36 mld Inlet (Sewage)	8	50	520	335	13.5	0.18	480	112	-	-	590	187	7.04	0.73	$1.6 X 10^8$	$3 X 10^6$
36 mld Collection chamber	8.4	50	676	1089	-	-	1125	554	-	-	1077	416	17.00	0.94	-	-
36 mld after Reactor no. 1	8.2	50	1416	1561	-	-	281	174	-	-	750	226	20.20	1.47	-	-
36 mld after Reactor no. 2	8.3	50	1428	1542	-	-	284	171	-	-	757	250	19.60	0.97	-	-
36 mld after Clariflocculator n	8.4	50	1336	1561	-	-	117	73	-	-	643	274	20.20	1.26	-	-
36 mld after Clariflocculator n	8.5	50	1288	1588	-	-	125	71	-	-	613	219	23.05	0.70	-	-
36 mld Final Outlet	8.4	50	1112	1470	88.3	73.7	99	66	-	-	644	163	15.90	0.45	$3 X 10^6$	$1.3 X 10^6$

All the units are in mg/l except pH, Colour (Hazen), Coliform (MPN/100ml).

Table B.4.2 Characteristics of Untreated and Treated Sewage of Dinapur Sewage Treatment Plant

Sampling Period	Sampling Point	Parameters									
		pH	TSS (mg/l)	BOD (mg/l)	VSS (mg/l)	COD (mg/l)	NO_3-N (mg/l)	NH_3-N (mg/l)	PO_4-P (mg/l)	Total Coliform (MPN/100ml)	Fecal Coliform (MPN/100ml)
Dec. '98	Untreated	8.15	448.0	145.0		398.0	12.0	12.0	1.6	1.6×10^8	9×10^7
	Treated	7.88	89.0	33.0		173.0	13.0	16.0	0.2	9×10^6	5×10^7
Jan. '99	Untreated	7.77	381.0	152.0		531.0	0.7	21.0	0.8	1.6×10^9	1.6×10^9
	Treated	7.82	96.0	39.0		221.0	0.6	27.0	1.47	9×10^8	5×10^8
Feb. '99	Untreated	7.44	472.0	155.0	224.0	630.0	2.1			2.2×10^6	1.7×10^6
	Treated	7.69	99.0	33.0	81.0	193.0	1.0			1.6×10^7	2.8×10^6
Mar. '99	Untreated	7.71	338.0	115.0	295.0	380.0	1.1	24.0	0.8	2.2×10^7	1.7×10^7
	*Treated	8.12	575.0	105.0	309.0	356.0	1.3	30.0	0.6	8×10^6	1.4×10^6
Apr. '99	Untreated	7.68	285.0	134.0		400.0	NT	30.0	1.7	1.6×10^8	1.6×10^8
	Treated	8.04	121.0	68.0		216.0	NT	43.0	0.8	9×10^7	9×10^7
May '99	Untreated	7.75	253.0	109.0	188.0	335.0	1.2	22.0	1.4	1.7×10^7	1.7×10^7
	Treated	7.85	75.0	19.0	71.0	181.0	0.8	26.0	1.0	2.3×10^6	2.3×10^6
June '99	Untreated	7.81	360.0	208.0	210.0	522.0	3.3	25.0	6.1	5×10^7	2.4×10^7
	Treated	7.86	40.0	77.0	27.0	100.0	10.0	21.0	3.5	3×10^5	2.3×10^5
July '99	Untreated	7.61	253.0	185.0	108.0	236.0	9.0	11.0	1.1	5×10^6	22×10^5
	Treated	8.10	71.0	30.0	64.0	62.0	2.0	8.0	0.7	3×10^6	23×10^5
Aug. '99	Untreated	7.86	792.0	95.0	512.0	598.0	NT	35.0	3.7		
	Treated	8.38	25.0	13.0	19.0	81.0	NT	33.0	2.9		
Sep. '99	Untreated	8.59	374.0	55.0	226.0	146.0	1.6	2.7	2.8	35×10^6	28×10^6
	Treated	8.55	29.0	24.0	19.0	51.0	1.2	4.9	2.8	22×10^6	13×10^5
Oct. '99	Untreated	8.58	440.0	105.0	256.0	400.0	3.6	9.9	2.8	1.1×10^6	2.9×10^5
	Treated	8.39	56.0	27.0	42.0	84.0	1.6	7.3	3.2	2.4×10^6	2.7×10^5
Nov. '99	Untreated	7.53	315.0	179.0	240.0	397.0	7.7	20.7	2.1	9×10^7	1.7×10^7
	Treated	7.91	34.8	36.0	28.4	105.0	4.1	21.9	2.5	1.6×10^8	1.4×10^6
Dec. '99	Untreated	7.68	402.0	172.0		476.0	2.0	33.3	3.9	9×10^7	5×10^7
	Treated	8.09	50.0	42.0		113.0	2.8	32.9	3.2	9×10^2	5×10^2
Jan. 2K	Untreated	8.24	332.0	129.0		349.0	1.0	24.5	0.6	5×10^7	5×10^7
	Treated	8.29	77.0	53.3		177.0	0.6	35.9	0.5	5×10^7	24×10^6
Feb. 2K	Untreated	7.86	429.0	215.0	305.0	466.0	3.1	27.3	2.0	5×10^7	3×10^7
	Treated	8.25	103.0	54.0	94.0	154.0	3.1	29.1	1.2	3×10^7	2.4×10^7
Mar. 2K	Untreated	8.00	356.0	226.0	269.0	481.0	0.9	42.4	4.4	2.8×10^7	2.2×10^6
	Treated	8.42	56.0	70.0	51.0	150.0	NT	35.0	1.0	1.7×10^7	1.7×10^7

* Remark - Due to overloading of STP at the time of Holi Festival

Note: All the parameters except pH are expressed in mg/l and Total & Fecal Coliform are expressed in numbers/100 ml

Table B.4.3 Available Sewerage Wastewater Quality in 4 Cities

City	Name of Drains	Sampling Date	Flow (MLD)	pH	DO (mg/l)	BOD (mg/l)	COD (mg/l)	TSS (mg/l)	T-N (mg/l)	TS (mg/l)
Kanpur	Bazidpur	2002.6.3	-	8.5	-	217	796	650	-	-
	Budiya	2002.6.3	-	8.0	-	260	815	695	-	-
	Bangali Ghat Nala	2002.6.3	-	9.0	-	326	1335	836	-	-
	Dubka Nala	2002.6.3	-	9.0	-	273	863	735	-	-
	Golf Club-2 Nala	2002.6.3	0.47	7.5	-	173	403	360	-	-
	Golf Club-1 Nala	2002.6.6	0.08	7.5	-	180	528	430	-	-
	Guptar Ghat Nala	2002.6.6	13.74	8.0	-	246	640	580	-	-
	Jail Nala	2002.6.6	0.48	8.0	-	286	753	890	-	-
	Police Line Nala	2002.6.6	0.40	7.5	-	162	476	475	-	-
	Muir Mill Nala	2002.6.6	4.54	7.5	-	172	489	315	-	-
	Parmat Ghat Nala	2002.6.6	0.49	7.5	-	210	568	345	-	-
	TAFCO Nala (PARMAT)	2002.6.10	0.42	7.5	-	170	482	525	-	-
	Sisamau Nala	2002.6.10	117.19	8.0	-	228	586	545	-	-
	Rani Ghat Nala	2002.6.10	1.42	7.5	-	154	428	475	-	-
	Nawabganj Nala	2002.6.10	4.34	7.5	-	193	510	470	-	-
	Jewra Nala	2002.6.13	1.46	7.5	-	189	460	340	-	-
	Jageswar Nala	2002.6.13	3.88	7.5	-	209	530	565	-	-
	Khewra Nala	2002.6.13	0.19	7.5	-	176	568	540	-	-
	Roadways Coloney Nala	2002.6.13	0.10	7.5	-	232	605	570	-	-
	KESA Coloney Nala	2002.6.13	1.71	7.5	-	211	562	535	-	-
	Halwa Khanda Nala	2002.6.15	2.50	7.5	-	225	510	560	-	-
	Ganda Nala	2002.6.15	56.0	8.0	-	274	628	635	-	-
	C.O.D. Nala	2002.6.15	3.84	7.5	-	241	548	550	-	-
Allahabad	Main Ghaghar Nala		31.3	-	-	102 - 144	-	263 - 324	-	-
	Ghaghar 1A		4.0	-	-	380 - 560	-	659 - 1120	-	-
	Ghaghar 1A1		0.2	-	-	450 - 704	-	718 -1215	-	-
	Ghaghar 1B		0.8	-	-	229 - 300	-	400 - 520	-	-
	Dariabad - Kathaghat Drain		1.0	-	-	136 - 359	-	240 - 600	-	-
	Dariabad - Peepalght Drain		0.03	-	-	81 - 206	-	120 - 230	-	-
	Dariabad - Jogighat Drain		0.05	-	-	130 - 260	-	180 - 640	-	-
	Morigate Nala		13.5	-	-	118 - 138	-	216 - 265	-	-
	Salori Nala/Allenganj Nala		27.1	-	-	72 - 340	-	112 - 575	-	-
	Jondhwal Nala		2.5	-	-	48 - 96	-	185 - 234	-	-
	Shankarghat Nala		0.2	-	-	36 - 54	-	115 - 145	-	-
	Rasulabad Paccaghat Drain		0.04	-	-	36 - 203	-	90 - 300	-	-
	A.D.A. Colony Nala		1.6	-	-	42 - 66	-	113 - 215	-	-
	Jondhwar Rasulabad Drain		0.07	-	-	62 - 78	-	10 - 160	-	-
	Shankarghat Colony Drain		0.01	-	-	44 - 124	-	50 - 190	-	-
	Jondhwalghat Drain		0.07	-	-	56 - 97	-	70 - 200	-	-
	Rajapur Nala		7.0	-	-	42 - 52	-	124 - 138	-	-
	T.V. Tower Nala		2.0	-	-	33 - 52	-	108 - 142	-	-
	Sadar Bazar Nala		3.0	-	-	39 - 66	-	109 - 135	-	-
	Unchawagarhi Drain-I		0.70	-	-	33 - 145	-	60 - 150	-	-
	Unchawagarhi Drain-II		0.25	-	-	62 - 137	-	100 - 190	-	-
	Beligaun Drain		0.25	-	-	75 - 158	-	90- 240	-	-
	Mumfordganj Drain		0.40	-	-	96 - 124	-	246 - 275	-	-
	Muirabad Nala		1.00	-	-	27 - 62	-	101 - 165	-	-
	Nayapurwa Drain		0.06	-	-	86 - 245	-	90 - 250	-	-
	Mehdauri Gaon Drain		0.20	-	-	46 - 138	-	20 - 150	-	-
	Mawaiya Nala		9.00	-	-	44 - 78	-	95 - 178	-	-
	Shivkuti Drain-1		0.02	-	-	27 - 263	-	30 - 250	-	-
Allahabad	Shivkuti Drain-2		0.01	-	-	37 - 123	-	50 - 130	-	-
	Shivkuti Drain-3 (North)		1.60	-	-	25 - 36	-	84 - 136	-	-
	Shivkuti Drain-4		0.10	-	-	17 - 180	-	20 - 190	-	-
	Shivkuti Drain-5		0.03	-	-	21 - 173	-	30 - 180	-	-

Table B.4.3 Available Sewerage Wastewater Quality in 4 Cities

City	Name of Drains	Sampling Date	Flow (MLD)	pH	DO (mg/l)	BOD (mg/l)	COD (mg/l)	TSS (mg/l)	T-N (mg/l)	TS (mg/l)
	Shivkuti Drain-6		0.02	-	-	30- 200	-	30 -220	-	-
	Shivkuti Drain-7 (East)		0.72	-	-	45 - 72	-	115 - 175	-	-
	Indra Awas Drain		0.23	-	-	18 - 113	-	20 - 260	-	-
	Lotey Haren Nala		2.00	-	-	30-70	-	103 - 145	-	-
	shastri Bridge Nala		0.02	-	-	13 - 138	-	20 - 140	-	-
	Kodara Nala		6.75	-	-	108 - 126	-	240- 430	-	-
	Nehru Park Nala		0.50	-	-	36 - 84	-	50 - 130	-	-
	Ponghat Nala		1.75	-	-	33 - 103	-	40 - 120	-	-
Varanasi	Ram Nagar Industrial Drain	1998.12.24-27	6.25	1.7	-	149	359	147	9.4	-
	Makhiya Drain	1998.12.24-27	6.00	-	-	12	77	120	14.0	-
	Ram Nagar City Sewage Discharge	1998.12.24-27	4.00	-	-	80	-	120	-	-
	Treated Effluent of Bhagwanpur STP	1998.12.24-27	14.4	8.0	0.3	16	42	65	13.1	-
	Nagua Drain	1998.12.24-27	40.0	7.7	-	60	198	138	18.3	-
	Shivala Drain	1998.12.24-27	2.30	7.9	-	62	462	307	7.9	-
	Rajghat Drain	1998.12.24-27	8.50	7.8	-	176	196	388	26.6	-
	Varuna Drain	1998.12.24-27	175	8.3	0.5	58	563	769	7.7	-
	Weeping Points along Ganga	1998.12.24-27	10.0	-	-	145	-	448	-	-
	Treated Effluent of Dinapur STP	1998.12.24-27	90.0	7.9	5.6	33	173	89	28.0	-
Lucknow	GH CANAL		73	7.6	-	257	480	-	56	922
	LAMATENIR		0.5	8.1	-	78	128	-	22	112
	GAUGHAT		1.0	8.3	-	185	263	-	50	912
	SARKAT		18.0	7.8	-	225	405	-	55	550
	PATA		18.0	7.7	-	195	312	-	38	506
	WAZIRGANJ		43.0	7.8		245	335	-	52	782
	GASIYARIMANDI		10.0	7.7	-	220	3398	-	48	744
	NER U S		0.5	7.8	-	85	162	-	40	166
	NER D S		0.5	7.8	-	128	210	-	52	124
	CHINA BAZAR		2.0	7.5	-	181	268	-	46	317
	LAPALACE		1.0	7.7	-	198	322	-	60	300
	JOPLIN ROAD		1.0	6.0	-	180	841	-	61	430
	ROOPPUR KHADRA		0.5	7.6	-	238	866	-	80	1791
	TG HOSTEL		1.0	7.4	-	150	358	-	53	170
	DYRE MEKIAN		2.0	6.6	-	420	960	-	43	433
	DALIGANJ No.1		8.0	8.2	-	215	479	-	54	156
	DALIGANJ No.2		1.0	7.6	-	114	486	-	27	130
	ARTS COLLEGE		0.5	8.0	-	207	828	-	50	135
	HANUMAN SETU		0.5	8.0	-	207	828	-	42	135
	TGPS		1.0	7.5	-	77	200	-	42	122
	KEDARNATH		2.0	7.6	-	227	470	-	50	114
	NISHAT GANJ		1.0	7.3	-	100	218	-	45	166
	KUKRAIL		29.0	8.1	-	144	269	-	41	150

Table B. 4.4 General Standards for Discharge of Pollutants Part-A: Effluents (The Environment (Protection) Rules, 1986)

Sl. No.	Parameter	Standards			
		Inland Surface Water	Public Sewers	Land for irrigation	Marine coastal areas
1	2	3 (a)	3 (b)	3 (c)	3 (d)
1	Colour and odour	See 6 of Annexure-I	---	---	---
2	Suspended Solids mg/l, Max.	50	600	200	(a) For process waste water-100 (b) For cooling water effluent 10% above total suspended matter of influent
3	Particular size of suspended solids	Shall pass 850 micron IS Sieve	---		(a) Floatable solids, max. 3mm (b) Settleable solids, max 850 microns
[2]4	---	---	---	---	---
5	pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
6	Temperature	shall not exceed 5°C above the receiving water temperature	---	---	shall not exceed 5°C above the receiving water temperature
7	Oil and grease mg/l Max.	10	20	10	20
8	Total Residual Chlorin mg/l max.	10	---	---	1.0
9	Ammonical nitrogen (as N), mg/l Max.	50	50	---	50
10	Total Kjeldahl nitrogen (as NH3): mg/l, Max.	100	---	---	100
11	Free ammonia (as NH3) mg/l, Max		---	---	5.0
12	Biochemical Oxygen Demand (5 days at 20°C), mg/l max.	30	350	100	100
13	Chemical Oxygen Demand, mg/l max.	250			250
14	Arsenic (as As), mg/l max.	0.20	0.20	0.20	0.20
15	Mercury (As Hg), mg/l Max.	0.01	0.01		0.01
16	Lead (as Pb) mg/l, Max.	0.10	0.10		2.0
17	Cadmium (as Cd) mg/l, Max.	2.0	1.0		2.0
18	Hexavalent Chromium. (as Cr+6), mg/l, Max.	0.1	2.0		1.0
19	Total chromium (as Cr) mg/l, Max	2.0	2.0		2.0
20	Copper (as Cu) mg/l, Max.	3.0	3.0		3.0
21	Zine (as Zn) mg/l, Max.	5.0	15.0		15.0
22	Selenium (as Sc.) mg/l, Max.	0.05	0.05		0.05
23	Nickel (as Ni) mg/l Max.	3.0	3.0		5.0
[2]24	***	*	*	*	*
[2]25	***	*	*	*	*
[2]26	***	*	*	*	*
27	Cyanide (as CN), mg/l Max.	0.2	2.0	0.2	0.2
[2]28	***	*	*	*	*
29	Fluoride (as F) mg/l Max.	2.0	15.0		15.0
30	Dissolved phosphates (as P), mg/l Max.	5.0			
31	***	*	*	*	*
32	Sulphide (as S) mg/l Max.	2.0			5.0
33	Phenoile compounds (as C_6H_5OH) mg/l Max.	1.0	5.0		5.0
34	Radioactive materials:				
	(a) Alpha emitter micro curie/ml	10^{-7}	10^{-7}	10^{-8}	10^{-7}
	(b) Beta emitter micro curie/ml	10^{-6}	10^{-6}	10^{-7}	10^{-6}
35	Bio-assay test	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in	90% survival of fish after 96	90% survival of fish after 96 hours in 100% effluent
36	Manganese (as Mn)	2mg/l	2mg/l		2mg/l
37	Iron (as Fe)	3mg/l	3mg/l		3mg/l
38	Vanadium (as V)	0.2mg/l	0.2mg/l		0.2mg/l
39	Nitrate Nitrogen	10mg/l			20mg/l
[2]40	***	*	*	*	*

1. Schedule VI inserted by Rule 2(d) of the Environment (Protection) Second Ammendment Rules, 1993 notified vide G.S.R. 422 (E) dated 19.05.1993, published in the Gazette No. 174 dated 19.05.1993.

2. Omitted by Rule 2(d)(i) of the Environment (Protection) Third Amendment Rules, 1993 vide Notification No. G.S.R. 801 (E) dated 31.12.1993.

Table B.4.4 Waste Water Generation Standards Part-B

Sl. No.	Industry	Quantum
1	Integrated Iron & Steel	16m^3/tonne of finished steel
2	Sugar	0.4m^3/tonne of cane crushed
3	Pulp & Paper Industries	
	(a) Larger pulp & paper	
	(i) Pulp & Paper	175m^3/tonne of paper produced.
	(ii) Viscose Staple Fibre	150m^3/tonne of product
	(iii) Viscose Filament Yarn	500m^3/tonne of product
	(b) Small Pulp & Paper:	
	(i) Agro-residue based	150m^3/tonne of paper produced
	(ii) Waste paper based	50m^3/tonne of paper produced
4	Fermentation Industries:	
	(a) Maltry	3.5m^3/tonne of grain produced
	(b) Brewery	0.25m^3/KL of beer produced
	(c) Distillery	12m^3/KL of alchol produced
5	Caustic Soda	
	(a) Membrane cell process	1m^3/tonne of caustic soda produced excluding cooling rtower blowdown
	(b) Mercury cell process	4m^3/tonne of caustic soda produced (Mercury bearing) 10% blow down permitted for cooling tower.
6	Textile Industries:	120m^3/tonne of fibre produced
7		150m^3/tonne of product
8		28m^3/tonne of raw hide
9		8m^3/tonne of maize crushed
		3m^3/KL Milk
10	Natural rubber processing industry	4m^3/tonne of rubber
11	Fertilizer	
	(a) Straight nitrogenous fertilizer	5m^3/tonne of urea of equivalent produced
	(b) Straight phosphatic fertilizer (SSP & TSP) excluding manufacture of any acid	0.5m^3/tonne of of SSP/TSP
	(c) Complex fertilizer	Standards of nitrogenous and phosphatic fertilizers are applicable depending on the primary product

Load baded standards Part-C

1 Oil Refinery Industry:

Parameter Processed	Quantum in kg/1000 tonnes of crube
Oil & grease	
Phenol	
BOD	
Suspended Solids	
Sulphide	

2 Large Pulp & Paper, News Print/Rayon grade palnts of capacity above 24000 tonne/Annum

Parameter	Quantum
Total Organic Chloride (TOCI)	2 kg/tonne of product

Table B.5.1 Basic Information of Each Sub-basin

Basin No.	River System*	Sub-Basin Name	Sub-basin Information		Land Use and Livestock Number							Rural Population
			Tributary or Main Stretch Length (km)	Sub-Basin Area (km^2)	Livestock (mn. Heads)			Agricultural Land Area (km^2)	Pasture Land Area (km^2)	Shrub/ Forest Area (km^2)	Others	
					Cattle	Sheep & Goats	Others					
1	Upper Ganga Main	Upper Ganga-I	195	17,170	1.028	0.479	0.016	2,431	7,222	4,082	3,435	1,829,358
2	ditto	Upper Ganga-II	490	19,799	2.897	0.995	0.194	15,940	363	2,528	968	5,889,299
3	ditto	Ramganga	399	30,841	4.049	1.427	0.254	21,208	930	8,467	236	9,178,993
4	ditto	Kalinadi	411	12,775	2.248	0.743	0.164	12,047	1	2	725	7,358,616
5	Middle Ganga Main	Middle Ganga I	79	3,686	0.649	0.214	0.047	3,444	0	0	242	1,494,699
6	ditto	Middle Ganga II	120	4,918	0.866	0.286	0.063	4,550	1	14	353	3,184,680
7	ditto	Middle Ganga III	99	2,623	0.462	0.152	0.034	2,577	0	33	13	3,955,712
8	ditto	Middle Ganga IV	411	7,608	1.339	0.442	0.098	6,831	0	106	671	3,634,176
9	ditto	Tons	224	17,530	2.826	0.784	0.114	12,188	0	4,728	614	5,531,628
10	Upper Yamuna	Upper Yamuna I	133	11,757	0.728	0.526	0.013	3,654	1,090	6,872	141	591,535
11	ditto	Upper Yamuna	218	33,660	5.931	1.449	0.508	31,615	35	840	1,170	13,002,601
12	ditto	Upper Yamuna	411	56,126	7.025	4.156	0.514	53,286	28	205	2,607	22,606,372
13	ditto	Hindon	178	7,121	1.183	0.395	0.084	6,840	0	185	96	6,090,917
14	Lower Yamuna	Chambal	804	136,014	14.829	9.545	0.545	100,181	0	29,799	6,034	38,482,857
15	ditto	Sind	384	31,372	4.895	1.257	0.135	19,123	0	10,996	1,253	9,027,007
16	ditto	Betwa	514	43,432	6.914	1.871	0.249	23,281	0	19,201	950	9,716,517
17	ditto	Ken	378	30,396	4.765	1.238	0.140	18,464	0	11,529	403	4,448,799
18	ditto	Lower Yamuna	386	18,173	3.180	1.040	0.225	16,842	0	463	868	3,753,279
19	Gomati	Upper Gomati	229	10,762	1.894	0.626	0.138	10,178	44	512	28	3,992,499
20	ditto	Lower Gomati	278	13,370	2.353	0.777	0.171	12,948	1	20	401	5,231,534
21	ditto	Sai	427	9,721	1.711	0.565	0.125	9,503	0	24	194	8,268,463
22	Lower Ganga Main	Karmanasa	149	2,612	0.278	0.097	0.011	1,611	0	883	118	509,585
23	ditto	Ghaghra	796	68,378	10.352	3.625	0.703	51,220	4,050	8,098	5,010	23,650,040
24	ditto	Sone	703	79,343	8.434	2.959	0.321	48,942	0	26,820	3,581	15,479,316
25	ditto	Gandak	255	7,079	1.158	0.634	0.064	5,768	88	848	375	726,497
26	ditto	Punpun	186	5,786	0.957	0.540	0.052	5,244	0	226	316	971,526
27	ditto	Falgu	292	14,922	2.469	1.393	0.133	12,273	0	1,195	1,454	5,339,237
28	ditto	Kiul	103	2,881	0.518	0.273	0.024	2,259	0	248	374	817,713
29	ditto	Burhi Gandak	398	17,798	2.913	1.644	0.157	16,469	107	1,091	131	9,069,888
30	ditto	Kosi	216	17,838	2.907	1.641	0.157	16,985	31	154	668	10,876,840
31	ditto	Dwarka	202	10,030	1.845	0.967	0.080	8,794	0	812	424	2,557,910
32	ditto	Jalangi	140	4,234	0.812	0.384	0.024	3,330	0	12	892	1,043,105
33	ditto	Ajay	254	12,485	2.269	1.199	0.101	9,078	0	1,279	2,127	2,150,871
34	ditto	Damodar	457	22,432	3.981	2.142	0.188	12,086	0	5,422	4,924	9,515,903
35	ditto	Rupnarayan	252	6,800	1.455	0.687	0.044	5,807	0	95	898	2,540,792
36	ditto	Haldi	334	18,222	3.447	1.634	0.105	8,002	0	453	9,767	13,008,645
37	ditto	Lower Ganga I	836	13,574	2.387	1.213	0.119	11,713	0	573	1,288	8,550,957
38	ditto	Lower Ganga II	200	15,315	2.919	1.434	0.118	11,761	0	375	3,180	16,789,046
Total			-	838,583	120.87	51.43	6.23	618,472	13,991	149,190	56,930	290,867,410

Table. B.5.2 Total Georaphical Area of Various State Covered under Each Sub-basin

River System	Sub-Basin Names	Area under states (sq. km.)											Total area of each subbasin
		Himachal Pradesh	*Haryana*	*Rajsthan*	*Uttaranchal*	*Uttar Pradesh*	*Madhya Pradesh*	*Bihar*	*Jharkhand*	*Delhi*	*West Bengal*	Chattis-garh	
Upper Ganga	Upper Ganga-I	290			16,803								**17,170**
	Upper Ganga-II				5,063	14,735							**19,799**
	Ramganga				11,896	18,946							**30,841**
	Kalinadi					12,775							**12,775**
	Sub-total	290			33,762	46,456							**80,585**
Middle Ganga	Middle Ganga I					3,686							**3,686**
	Middle Ganga II					4,918							**4,918**
	Middle Ganga III					2,623							**2,623**
	Middle Ganga IV					7,608							**7,608**
	Tons					6,703	10,827						**17,530**
	Sub-total					25,537	10,827						**36,365**
Upper Yamuna	Upper Yamuna I	5,913	152		5,509								**11,757**
	Upper Yamuna II		26,156	2,551	324	3,256				1,337			**33,660**
	Upper Yamuna III		8,451	29,425		18,094				156			**56,126**
	Hindon				605	6,516							**7,121**
	Sub-total	5,913	34,759	31,975	5,834	21,350				1,493			**101,543**
Lower Yamuna	Chambal			78,044		1,224	56,777						**136,014**
	Sind			4		5,249	26,120						**31,372**
	Betwa					13,413	29,948						**43,432**
	Ken					6,006	24,390						**30,396**
	Lower Yamuna					17,402	770						**18,173**
	Sub-total			78,047		43,293	138,005						**259,387**
Gomati	Upper Gomati					10,762							**10,762**
	Lower Gomati					13,370							**13,370**
	Sai					9,721							**9,721**
	Sub-total					33,853							**33,853**
Lower Ganga	Karmanasa												
	Ghaghra				12,269	51,899		2,910					**68,378**
	Sone					9,186	30,015	2,221	13,030			17,503	**81,955**
	Gandak					480		6,496					**7,079**
	Punpun							4,714	1,072				**5,786**
	Falgu							12,316	2,801				**15,117**
	Kiul												
	Burhi Gandak							17,620					**17,798**
	Kosi							17,589					**17,838**
	Dwarka							1,533	5,043		3,939		**10,515**
	Jalangi										3,797		**4,234**
	Ajay							3,632	5,821		4,697		**14,150**
	Damodar								17,109		5,323		**22,432**
	Rupnarayan										6,800		**6,800**
	Haldi								319		15,867		**18,222**
	Lower Ganga I					3,000		9,419	4,902		5,254		**22,873**
	Lower Ganga II										6,441		**6,552**
	Sub-total				12,269	64,564	30,015	78,450	50,097		52,118	17,503	**319,729**
Total Georaphical area of each state		**6,203**	**34,759**	**110,022**	**51,865**	**235,055**	**178,848**	**78,450**	**50,097**	**1,493**	**52,118**	**17,503**	**831,462**

Table B.5.3 Sub-basin Wise Population in Ganga Basin

Sub-basin No.	Sub-Basin Name	City/Town	Population 2001 Total	Urban Population 2001	Rural Population 2001
		Dehra Dun	1,279,083	677,118	601,965
		Rishikesh	189,512	86,669	102,843
		Haridwar	1,444,213	445,663	998,550
		Small Towns	1,182,146	148,096	1,034,050
1	Upper Ganga I		4,094,954	1,357,546	2,737,408
		Sambhal	794,112	204,275	589,837
		Budaun	840,086	227,468	612,618
		Bijnor	535,047	153,018	382,029
		Chandpur	605,012	101,939	503,073
		Chandausi	545,870	150,432	395,438
		Sahaswan	349,511	58,194	291,317
		Najibabad	605,457	175,256	430,201
		Farrukabad cum Fate	864,699	277,721	586,978
		Small Towns	2,097,808		2,097,808
2	Upper Ganga II		7,237,602	1,348,303	5,889,299
		Haldwani cum Kathgodam	458,860	171,670	287,190
		Amroha	640,362	205,305	435,057
		Moradabad	1,433,066	704,508	728,558
		Rampur	1,922,450	480,064	1,442,386
		Pilibhit	685,920	162,793	523,127
		Barielly	1,259,522	801,244	458,278
		Shahjahanpur	838,161	354,966	483,195
		Nagina	625,696	117,127	508,569
		Kashipur	473,692	188,472	285,220
		Rudrapur (Nain)	378,951	28,324	350,627
		Shahabad	430,136	63,606	366,530
		Small Towns	3,310,256		3,310,256
3	Ramganga		12,457,072	3,278,079	9,178,993
		Meerut	1,812,897	1,208,655	604,242
		Hapur	774,007	285,116	488,891
		Bulandshahr	735,177	239,200	495,977
		Aligarh	2,990,388	863,385	2,127,003
		Mawana	686,743	159,117	527,626
		Pilkhua	50,162		50,162
		Khurja	400,932	98,403	302,529
		Kasganj	750,423	160,900	589,523
		Etah	807,601	139,304	668,297
		Small Towns	1,554,528		1,554,528
4	Kalinadi		10,562,858	3,154,080	7,408,778
		Kannauj	1,385,227	231,912	1,153,315
		Mainpuri	602,078	139,740	462,338
		Small Towns	341,384		341,384
5	Middle Ganga I		2,328,689	371,652	1,957,037
		Kanpur	5,721,526	2,879,587	2,841,939
		Unnao	741,801	232,542	509,259
		Small Towns	342,741		342,741
6	Middle Ganga II		6,806,068	3,112,129	3,693,939
		Allahabad	4,941,510	1,213,828	3,727,682
		Small Towns	228,030		228,030
7	Middle Ganga III		5,169,540	1,213,828	3,955,712
		Mirzapur cum Vindhac	978,359	225,710	752,649
		Varanasi	3,147,927	1,268,522	1,879,405
		Bhadohi	562,978	103,340	459,638
		Small Towns	4,414,987	511,059	3,903,927
8	Middle Ganga IV		9,104,251	2,108,631	6,995,619
		Satna	1,868,648	385,590	1,483,058

Table B.5.3 Sub-basin Wise Population in Ganga Basin

Sub-basin No.	Sub-Basin Name	City/Town	Population 2001 Total	Urban Population 2001	Rural Population 2001
		Rewa	1,972,333	320,475	1,651,858
		Small Towns	4,235,585	572,282	3,671,540
9	Tons		8,076,566	1,278,347	6,806,456
		Shimla	721,745	166,833	554,912
		Small Towns	1,009,114	111,509	897,605
10	Upper Yamuna I		1,730,859	278,342	1,452,517
		Yamunanagar	982,369	392,921	589,448
		Karnal	927,482	285,629	641,853
		Panipat	967,338	391,903	575,435
		Sirsa	862,297	239,062	623,235
		Hisar	1,536,417	397,980	1,138,437
		Bhiwani	949,605	219,860	729,745
		Rohtak	940,036	329,550	610,486
		Sonipat	941,037	273,292	667,745
		Delhi	**13,782,976**	**12,819,761**	**963,215**
		Kaithal	945,631	183,121	762,510
		Jind	806,355	189,060	617,295
		Kairana	491,432	145,432	346,000
		Bahadurgarh	370,014	139,931	230,083
		Baraut	650,007	130,307	519,700
		Small Towns	5,727,076	1,150,310	4,576,766
11	Upper Yamuna II		30,880,071	17,288,118	13,591,953
		Gurgaon	1,657,669	369,304	1,288,365
		Noida	1,191,263	438,212	753,051
		Faridabad Complex	2,193,276	1,220,194	973,082
		Alwar	2,990,862	434,493	2,556,369
		Hathras	462,279	149,903	312,376
		Mathura	2,069,578	582,387	1,487,191
		Agra	3,611,301	1,557,345	2,053,956
		Firozabad	2,045,737	621,063	1,424,674
		Bharatpur	2,098,323	408,540	1,689,783
		Jhunjhunun	1,913,099	394,925	1,518,174
		Nawalgarh	291,866	74,272	217,594
		Narnaul	459,846	75,130	384,716
		Rewari	764,727	136,305	628,422
		Palwal	404,130	100,528	303,602
		Khurja	400,932	98,403	302,529
		Shikohabad	572,621	116,287	456,334
		Hindaun	346,570	84,784	261,786
		Etawah	1,340,031	309,037	1,030,994
		Small Towns	5,532,030		5,532,030
12	Upper Yamuna III		30,346,140	7,171,112	23,175,028
		Saharanpur	946,310	462,649	483,661
		Muzzafarnagar	3,541,952	903,829	2,638,123
		Modinagar	555,054	255,396	299,658
		Ghaziabad	1,629,357	1,242,037	387,320
		Deoband	730,355	123,509	606,846
		Shamli	682,293	188,848	493,445
		Small Towns	1,181,864		1,181,864
13	Hindon		9,267,185	3,176,268	6,090,917
		Indore	2,585,321	1,850,311	735,010
		Dewas	420,710	230,658	190,052
		Ujjain	563,636	430,669	132,967
		Guna	446,723	137,132	309,591
		Kota	1,568,580	837,913	730,667
		Bhilwara	2,009,516	414,726	1,594,790

Table B.5.3 Sub-basin Wise Population in Ganga Basin

Sub-basin No.	Sub-Basin Name	City/Town	Population 2001 Total	Urban Population 2001	Rural Population 2001
		Tonk	1,211,343	253,113	958,230
		Jaipur	2,413,279	2,324,319	88,960
		Nagda	215,300	110,480	104,820
		Jaora (Ratlam)	210,230	72,642	137,588
		Mandsaur	396,868	124,097	272,771
		Bundi	961,269	178,931	782,338
		Sawai Madhopur	1,116,031	212,575	903,456
		Baran	1,022,568	173,199	849,369
		Chittaurgarh	1,802,656	289,083	1,513,573
		Dholpur	982,815	176,433	806,382
		Sehore	355,625	93,115	262,510
		Small Towns	28,109,783		28,109,783
14	Chambal		46,392,253	7,909,396	38,482,857
		Shivpuri	1,440,666	239,672	1,200,994
		Gwalior	1,629,881	983,331	646,550
		Morena	474,181	176,112	298,069
		Bhind	1,426,951	338,153	1,088,798
		Datia	627,818	137,545	490,273
		Small Towns	4,271,329		4,271,329
15	Sind		9,870,826	1,874,813	7,996,013
		Bhopal	1,836,784	1,479,119	357,665
		Sagar	2,021,783	591,362	1,430,421
		Jhansi	1,746,715	717,551	1,029,164
		Vidisha	1,214,759	260,279	954,480
		Bina Etawah	55,443		55,443
		Lalitpur	977,447	141,831	835,616
		Tikamgarh	1,203,160	212,375	990,785
		Orai	324,674	147,522	177,152
		Small Towns	3,941,234		3,941,234
16	Betwa		13,321,999	3,550,039	9,771,960
		Damoh	310,476	147,397	163,079
		Chattarpur	289,346	109,021	180,325
		Mahoba	708,831	154,787	554,044
		Banda	1,500,253	244,023	1,256,230
		Small Towns	3,132,147	454,480	2,683,281
17	Ken		5,941,053	1,109,708	4,836,959
		Auraiya	597,574	135,693	461,881
		Fatehpur	2,305,847	237,279	2,068,568
		Small Towns	1,684,711		1,684,711
18	Lower Yamuna River		4,588,132	372,972	4,215,160
		Sitapur	719,832	208,163	511,669
		Lakhimpur	889,325	65,129	824,196
		Lucknow	3,681,416	2,342,239	1,339,177
		Small Towns	4,486,532	596,553	3,889,980
19	Upper Gomati		9,777,105	3,212,084	6,565,022
		Jaunpur	927,816	168,797	759,019
		Barabanki	2,673,394	247,859	2,425,535
		Sultanpur	933,895	100,085	833,810
		Small Towns	1,213,170		1,213,170
20	Lower Gomati		5,748,275	516,741	5,231,534
		Rai-Bareilly	2,872,204	273,745	2,598,459
		Hardoi	975,147	125,078	850,069
		Bela Pratapgarh	2,727,156	144,313	2,582,843
		Small Towns	4,851,352	476,998	4,382,590
21	Sai		11,425,859	1,020,134	10,413,961
		Small Towns	443,923		443,923

Table B.5.3 Sub-basin Wise Population in Ganga Basin

Sub-basin No.	Sub-Basin Name	City/Town	Population 2001 Total	Urban Population 2001	Rural Population 2001
22	Karmnasa		443,923		443,923
		Gonda	2,765,754	196,159	2,569,595
		Faizabad	2,087,914	281,314	1,806,600
		Gorakhpur	3,784,720	740,565	3,044,155
		Maunath Bhanjan	736,734	264,848	471,886
		Balrampur	1,684,567	135,274	1,549,293
		Basti	2,068,922	115,318	1,953,604
		Tanda	512,406	117,139	395,267
		Deoria	2,730,376	270,120	2,460,256
		Siwan	2,708,840	147,746	2,561,094
		Small Towns	6,665,423		6,665,423
23	Ghaghra		25,745,656	2,268,483	23,477,173
		Murwara	569,654	197,661	371,993
		Arrah	369,648	203,395	166,253
		Chapra	361,404	178,835	182,569
		Shahdol	1,572,748	398,135	1,174,613
		Sasaram	295,841	131,042	164,799
		Small Towns	13,484,751		13,484,751
24	Son		16,654,046	1,109,068	15,544,978
		Bagaha	316,454	91,383	225,071
		Bettiah	184,910	116,692	68,218
		Small Towns	1,369,011		1,369,011
25	Gandak		1,870,375	208,075	1,662,300
		Dehri	233,147	119,007	114,140
		Small Towns	857,386		857,386
26	Punpun		1,090,533	119,007	971,526
		Gaya	3,464,983	475,041	2,989,942
		Bihar Sharif	213,225		213,225
		Jehanabad	1,511,406	111,893	1,399,513
		Mokameh	167,224	56,400	110,824
		Nawada	257,439	82,291	175,148
		Small Towns	49,355		49,355
27	Falgue		5,663,632	725,625	4,938,007
		Lakhisarai	801,173	117,585	683,588
		Small Towns	442,681		442,681
28	Kiul		1,243,854	117,585	1,126,269
		Muzaffarpur	3,743,836	348,271	3,395,565
		Darbhanga	495,768	266,834	228,934
		Motihari	291,054	109,250	181,804
		Sitamarhi	2,669,887	153,251	2,516,636
		Barauni	225,879		225,879
		Small Towns	2,746,949		2,746,949
29	Burhi Gandak		10,173,373	877,606	9,295,767
		Purnia	2,540,788	221,940	2,318,848
		Madhubani	3,570,651	124,403	3,446,248
		Saharsa	1,506,418	124,015	1,382,403
		Small Towns	3,729,341		3,729,341
30	Kosi		11,347,198	470,358	10,876,840
		Nawadwip	121,793	16,875	104,918
		Suri	54,298		54,298
		Deoghar	256,031	112,501	143,530
		Small Towns	2,320,915		2,320,915
31	Dwarka		2,753,037	129,376	2,623,661
		Krishnanagar	404,381	9,575	394,806
		Small Towns	648,299		648,299
32	Jalangi		1,052,680	9,575	1,043,105

Table B.5.3 Sub-basin Wise Population in Ganga Basin

Sub-basin No.	Sub-Basin Name	City/Town	Population 2001 Total	Urban Population 2001	Rural Population 2001
		Bolpur	175,490		175,490
		Small Towns	1,760,713		1,760,713
33	Ajay		1,936,203		1,936,203
		Phatratu	234,771	152,624	82,147
		Bokaro Steel City	1,775,961	804,741	971,220
		Dhanbad	2,394,434	1,254,330	1,140,104
		Ondal	168,807	127,394	41,413
		Raniganj	101,678	77,306	24,372
		Durgapur	425,836		425,836
		Barddhaman	6,919,698	2,572,423	4,347,275
		Small Towns	2,909,372		2,909,372
34	Damodar		14,930,557	4,988,818	9,941,739
		Bankura	219,128		219,128
		Bishnupur	396,892	27,982	368,910
		Small Towns	1,952,754		1,952,754
35	Rupnarayan		2,568,774	27,982	2,540,792
		Medinipur	9,638,473	1,010,954	8,627,519
		Kharagpur	181,008	26,910	154,098
		Haldia	100,347		100,347
		Puruliya	2,535,233	255,239	2,279,994
		Contai	53,484		53,484
		Small Towns	1,947,034		1,947,034
36	Haldi		14,455,579	1,293,103	13,162,476
		Ghazipur	701,685	114,383	587,302
		Patna	4,709,851	1,968,924	2,740,927
		Munger	1,135,499	316,586	818,913
		Bhagalpur	2,430,331	451,919	1,978,412
		Katihar	2,389,533	218,246	2,171,287
		Buxar	1,403,462	128,771	1,274,691
		Ballia	818,118	122,437	695,681
		Jamalpur	181,571	96,659	84,912
		Small Towns	3,961,757		3,961,757
37	Lower Ganga I		17,731,807	3,417,925	14,313,882
		Santipur	217,289	50,254	167,035
		Ranaghat	537,612	91,170	446,442
		Calcutta	10,643,211	10,643,211	
		Baharampur	378,830	22,890	355,940
		Aurangabad	2,004,960	168,833	1,836,127
		Jangipur	200,936		200,936
		Rajpur	113,546		113,546
		Katwa	272,380	5,665	266,715
		Small Towns	8,148,491		8,148,491
38	Lower Ganga II		22,517,255	10,982,023	11,535,232

Table B.5.4 Land Use Area in Sub-basins

No.	Repre_basin_Name	Each Land Use Area (km^2)					Each Pollution Load of BOD (kg/d)			
		Shrub/Forest	Agri_land	Pasture /Grassland	Others	Sub-basin Total	Shrub/Forest	Agri_land	Pasture /Grassland	Sub-basin Total
1	Upper Ganga-I	4,082	2,431	7,222	3,435	17,170	3,062	20,834	7,222	31,117
2	Upper Ganga-II	2,528	15,940	363	968	19,799	1,896	136,606	363	138,865
3	Ramganga	8,467	21,208	930	236	30,841	6,350	181,753	930	189,033
4	Kalinadi	2	12,047	1	725	12,775	2	103,243	1	103,245
5	Middle Ganga I	0	3,444	0	242	3,686	0	29,515	0	29,515
6	Middle Ganga II	14	4,550	1	353	4,918	11	38,994	1	39,005
7	Middle Ganga III	33	2,577	0	13	2,623	25	22,085	0	22,110
8	Middle Ganga IV	106	6,831	0	671	7,608	80	58,542	0	58,621
9	Tons	4,728	12,188	0	614	17,530	3,546	104,451	0	107,997
10	Upper Yamuna I	6,872	3,654	1,090	141	11,757	5,154	31,315	1,090	37,559
11	Upper Yamuna II	840	31,615	35	1,170	33,660	630	270,941	35	271,606
12	Upper Yamuna III	205	53,286	28	2,607	56,126	154	456,661	28	456,843
13	Hindon	185	6,840	0	96	7,121	139	58,619	0	58,758
14	Chambal	29,799	100,181	0	6,034	136,014	22,349	858,551	0	880,900
15	Sind	10,996	19,123	0	1,253	31,372	8,247	163,884	0	172,131
16	Betwa	19,201	23,281	0	950	43,432	14,401	199,518	0	213,919
17	Ken	11,529	18,464	0	403	30,396	8,647	158,236	0	166,883
18	Lower Yamuna	463	16,842	0	868	18,173	347	144,336	0	144,683
19	Upper Gomati	512	10,178	44	28	10,762	384	87,225	44	87,653
20	Lower Gomati	20	12,948	1	401	13,370	15	110,964	1	110,980
21	Sai	24	9,503	0	194	9,721	18	81,441	0	81,459
22	Karamanasa	883	1,611	0	118	2,612	662	13,808	0	14,470
23	Ghaghra	8,098	51,220	4,050	5,010	68,378	6,074	438,955	4,050	449,079
24	Sone	26,820	48,942	0	3,581	79,343	20,115	419,431	0	439,546
26	Punpun	226	5,244	0	316	5,786	170	44,941	0	45,111
27	Falgu	1,195	12,273	0	1,454	14,922	897	105,176	0	106,073
25	Gandak	848	5,768	88	375	7,079	636	49,432	88	50,156
28	Kiul	248	2,259	0	374	2,881	186	19,356	0	19,542
29	Burhi Gandak	1,091	16,469	107	131	17,798	818	141,139	107	142,065
30	Kosi	154	16,985	31	668	17,838	116	145,561	31	145,708
31	Dwarka	812	8,794	0	424	10,030	609	75,365	0	75,973
32	Jalangi	12	3,330	0	892	4,234	9	28,538	0	28,547
33	Ajay	1,279	9,078	0	2,127	12,485	960	77,798	0	78,758
34	Damodar	5,422	12,086	0	4,924	22,432	4,067	103,577	0	107,644
35	Rupnarayan	95	5,807	0	898	6,800	71	49,766	0	49,837
36	Haldi	453	8,002	0	9,767	18,222	340	68,577	0	68,917
37	Lower Ganga I	573	11,713	0	1,288	13,574	430	100,380	0	100,809
38	Lower Ganga II	375	11,761	0	3,180	15,315	281	100,791	0	101,072
	Total	149,190	618,472	13,991	56,930	838,583	1,527,976	2,437,480	4,860,969	9,665,008

Table B. 5.5 Sub-basin Wise Livestock Head Number

Name of Subbasin	Total Cross-bred	Urban Cross-bred	Total Indigenous	Urban Indigenous	Total Buffaloes	Urban Buffaloes	Total Sheep	Urban Sheep	Total Goats	Urban Goats	Total Horse+Ponies	Urban Horse+Ponies	Total Mules	Urban Mules	Total Donkeys	Urban Donkeys
Upper Ganga-I	19,356	819	337,321	4,951	192,803	1,235	188,871	1,357	195,217	1,691	3,089	43	9,653	202	47	7
Upper Ganga-II	60,286	4,555	1,022,398	45,015	1,644,364	87,341	97,646	4,887	510,958	37,514	15,119	2,494	8,526	1,639	12,173	2,357
Ramganga	110,927	8,689	1,897,323	68,233	2,589,425	130,410	138,255	8,609	808,612	47,847	26,979	5,805	16,861	1,726	5,592	1,648
Kalinadi	46,679	3,659	759,492	31,596	2,212,183	84,136	80,248	4,442	554,840	30,888	16,104	2,015	17,790	2,392	36,036	4,011
Middle Ganga I	16,223	483	210,926	7,157	210,128	8,576	32,770	1,136	121,770	6,016	1,387	224	1,054	204	1,447	321
Middle Ganga II	32,929	1,429	485,452	17,574	394,904	21,967	82,557	3,252	205,918	12,228	4,597	761	2,227	410	3,243	551
Middle Ganga III	19,857	1,566	312,848	5,040	181,191	4,191	65,914	1,079	125,889	3,272	2,699	219	390	14	2,974	134
Middle Ganga IV	110,315	4,065	1,187,786	63,213	660,070	17,519	269,341	4,619	413,718	19,718	5,670	473	1,702	274	10,179	1,127
Tons	39,790	5,938	1,746,412	58,490	649,147	25,141	202,811	5,671	496,903	18,553	6,905	803	1,246	178	5,796	865
Upper Yamuna I	7,696	971	149,383	4,343	114,069	4,805	72,541	298	84,623	1,078	2,405	146	4,400	237	98	21
Hindon	18,859	3,980	443,265	24,671	1,195,406	70,884	39,039	4,083	80,146	11,165	11,227	1,209	7,773	961	11,173	1,403
Upper Yamuna II	132,568	20,948	1,676,611	93,846	3,430,815	253,531	987,421	29,687	528,543	26,447	25,462	2,142	18,720	804	5,670	861
Upper Yamuna III	42,671	9,457	1,818,069	205,717	4,977,060	445,418	1,062,366	52,016	2,318,971	260,289	21,103	3,289	29,930	4,750	59,023	8,559
Chambal	42,565	11,549	6,308,587	302,489	4,453,481	251,688	3,058,615	49,427	4,657,058	259,222	23,257	2,562	3,611	1,144	37,604	7,037
Sind	6,332	5,224	1,839,353	127,725	1,298,149	123,068	302,921	47,821	892,741	153,864	6,716	4,135	10,036	8,652	12,057	7,571
Betwa	6,312	2,094	2,620,086	398,650	1,070,779	158,863	271,439	10,297	811,044	102,453	6,992	2,357	2,802	1,550	4,927	2,190
Ken	2,561	807	1,866,050	77,677	721,343	33,019	117,944	2,623	560,313	33,339	4,216	537	2,769	1,367	3,008	1,184
Lower Yamuna	15,438	3,049	1,114,364	93,121	1,133,926	167,093	209,471	13,948	711,682	109,541	6,623	870	5,724	1,626	8,369	1,117
Upper Gomati	145,765	1,883	831,929	17,294	682,661	19,843	46,686	1,328	457,232	27,025	5,122	834	4,095	2,093	3,005	888
Lower Gomati	364,584	7,999	1,817,506	26,540	998,854	21,320	199,242	1,774	635,398	32,785	10,754	1,503	14,616	7,372	12,976	3,409
Sai	109,880	1,580	1,118,399	22,784	712,686	21,461	175,747	2,852	453,224	21,715	8,896	1,024	3,794	1,591	7,688	1,041
Ghaghra	940,021	19,991	5,708,076	99,655	3,399,863	82,473	451,622	4,921	2,668,531	117,606	31,058	3,520	33,065	6,479	47,634	5,211
Son	156,103	7,659	3,992,785	170,861	2,242,964	116,453	289,341	11,120	1,497,739	83,629	22,377	2,340	12,532	2,545	17,416	2,566
Punpun	41,942	1,550	426,744	16,782	419,808	24,580	57,579	2,201	204,005	15,823	3,667	508	3,422	693	4,567	656
Falgu	109,000	4,025	1,109,032	43,615	1,091,006	63,876	149,636	5,720	530,175	41,121	9,528	1,320	8,892	1,798	11,867	1,705
Gandak	45,077	1,664	458,636	18,037	451,182	26,416	61,881	2,364	219,252	17,006	3,940	546	3,678	744	4,907	705
Burhi Gandak	125,883	4,648	1,280,807	50,369	1,259,989	73,770	172,811	6,603	612,292	47,491	11,003	1,525	10,268	2,072	13,705	1,967
Kosi	123,306	4,552	1,254,571	49,338	1,234,180	72,260	169,274	6,468	599,751	46,517	10,776	1,493	10,056	2,028	13,423	1,927
Mor	70,340	5,617	1,102,799	40,449	549,533	30,437	226,150	3,893	792,571	36,145	5,357	631	3,992	809	5,349	793
Jalangi	98,594	5,383	572,869	22,220	69,296	641	95,153	379	705,831	17,928	3,093	106	0	0	0	0
Ajay	100,908	11,687	1,523,484	65,343	753,534	47,383	238,759	7,015	859,318	56,029	6,410	875	5,445	1,099	7,286	1,089
Damodar	145,913	11,070	2,017,623	73,522	1,258,511	76,038	338,678	8,052	1,122,035	65,138	10,307	1,436	9,365	1,894	12,514	1,824
Rupnarayan	50,945	8,058	1,140,271	32,170	119,219	7,198	174,513	961	771,650	22,941	134	42	3	0	32	27
Haldi	43,394	5,765	2,600,023	49,504	200,053	6,550	427,241	1,751	1,438,428	28,475	194	22	143	31	207	41
Lower Ganga I	180,633	10,665	2,386,792	95,703	1,451,794	76,327	398,162	8,123	1,618,074	72,939	14,961	1,609	13,655	2,303	20,355	2,385
Lower Ganga II	128,031	29,899	1,227,697	75,553	94,593	37,215	115,173	5,031	1,091,214	52,450	1,740	716	9	2	87	30

Table B 5.6 Livestock Pollution Load of Each Sub-Basin (Generated Pollution Load)

No.	Sub-Basin Name	Livestock (Heads)			BOD (kg/day)			
		Bovine	Sheeps & Goats	Others	Bovine	Sheeps & Goats	Others	Sub-Total
1	Upper Ganga-I	7,005	3,048	252	841	183	50	1,074
2	Upper Ganga-II	136,911	42,401	6,490	16,429	2,544	1,298	20,271
3	Ramganga	207,332	56,456	9,179	24,880	3,387	1,836	30,103
4	Kalinadi	119,391	35,330	8,418	14,327	2,120	1,684	18,130
5	Middle Ganga I	16,216	7,152	749	1,946	429	150	2,525
6	Middle Ganga II	40,970	15,480	1,722	4,916	929	344	6,190
7	Middle Ganga III	10,797	4,351	367	1,296	261	73	1,630
8	Middle Ganga IV	84,797	24,337	1,874	10,176	1,460	375	12,011
9	Tons	89,569	24,224	1,846	10,748	1,453	369	12,571
10	Upper Yamuna I	10,119	1,376	404	1,214	83	81	1,378
11	Hindon	99,535	15,248	3,573	11,944	915	715	13,574
12	Upper Yamuna II	368,325	56,134	3,807	44,199	3,368	761	48,328
13	Upper Yamuna III	660,592	312,305	16,598	79,271	18,738	3,320	101,329
14	Chambal	565,726	308,649	10,743	67,887	18,519	2,149	88,555
15	Sind	256,017	201,685	20,358	30,722	12,101	4,072	46,895
16	Betwa	559,607	112,750	6,097	67,153	6,765	1,219	75,137
17	Ken	111,503	35,962	3,088	13,380	2,158	618	16,156
18	Lower Yamuna	263,263	123,489	3,613	31,592	7,409	723	39,724
19	Upper Gomati	39,020	28,353	3,815	4,682	1,701	763	7,147
20	Lower Gomati	55,859	34,559	12,284	6,703	2,074	2,457	11,233
21	Sai	45,825	24,567	3,656	5,499	1,474	731	7,704
22	Ghaghra	202,119	122,527	15,210	24,254	7,352	3,042	34,648
23	Sone	294,973	94,749	7,451	35,397	5,685	1,490	42,572
24	Punpun	42,912	18,024	1,857	5,149	1,081	371	6,602
25	Falgu	111,516	46,841	4,823	13,382	2,810	965	17,157
26	Gandak	46,117	19,370	1,995	5,534	1,162	399	7,095
27	Burhi Gandak	128,787	54,094	5,564	15,454	3,246	1,113	19,813
28	Kosi	126,150	52,985	5,448	15,138	3,179	1,090	19,407
29	Mor	76,503	40,038	2,233	9,180	2,402	447	12,029
30	Jalangi	28,244	18,307	106	3,389	1,098	21	4,509
31	Ajay	124,413	63,044	3,063	14,930	3,783	613	19,325
32	Damodar	160,630	73,190	5,154	19,276	4,391	1,031	24,698
33	Rupnarayan	47,426	23,902	69	5,691	1,434	14	7,139
34	Haldi	61,819	30,226	94	7,418	1,814	19	9,251
35	Lower Ganga I	182,695	81,062	6,297	21,923	4,864	1,259	28,047
36	Lower Ganga II	142,667	57,481	748	17,120	3,449	150	20,719
Total		5,525,350	2,263,696	179,045	663,042	135,822	35,809	834,673

Table B.5.7 Sub-basin Wise Existing Pollution Load Generation

Ganga-1

Sub-Basin Name	Upper Ganga I	Upper Ganga II	Ramganga	Kalinadi	Middle Ganga I	Middle Ganga II	Middle Ganga III	Midle Ganga IV	Tons	Karmanasa	Ghaghra	Son	Punpun	Falgu	Kiul	Gandak	Burhi Gandak	Kosi
BOD (Sewerage)	20,968	28,443	70,806	68,128	5,009	38,322	16,019	14,822	15,251	0	52,877	23,616	2,571	15,674	2,540	4,494	18,956	10,160
BOD (Industry)	1,506	3,077	26,100	7,181	76	17,470	398	1,384	9	111	11,627	2,711	0	1,923	200	362	9,132	763
BOD (Livestock)	1,074	20,271	30,103	18,130	2,525	6,190	1,630	12,011	12,571	1,357	34,648	41,215	6,602	16,936	3,707	7,095	19,813	19,407
BOD (Land)	31,118	138,865	189,033	103,246	29,515	39,006	22,110	58,622	107,997	14,470	449,079	439,546	45,111	106,073	19,542	50,156	142,064	145,708
BOD (Household)	32,318	65,960	102,805	82,978	16,741	41,372	44,304	84,075	82,550	4,972	264,880	174,104	10,881	55,306	12,614	18,618	104,113	121,821
Total	86,984	256,616	418,847	279,663	53,866	142,360	84,461	170,913	218,378	20,910	813,111	681,192	65,165	195,911	38,603	80,725	294,078	297,858

Ganga-2 (Unit :kg/day)

Sub-Basin Name	Dwarka	Jalangi	Ajay	Damodar	Rupnarayan	Haldi	Lowe Ganga I	Lower Ganga II	Total
BOD (Sewerage)	2,795	207	0	107,758	604	27,931	53,427	174,651	776,029
BOD (Industry)	801	5,810	0	11,090	723	7,102	4,676	66,177	180,409
BOD (Livestock)	11,475	4,509	17,050	24,698	7,139	9,251	16,644	31,464	377,515
BOD (Land)	75,974	28,547	78,758	107,644	49,837	68,917	100,810	101,072	2,742,820
BOD (Household)	29,385	11,683	21,685	111,347	28,457	147,420	160,315	129,195	1,959,897
Total	120,430	50,756	117,493	362,538	86,760	260,621	335,873	502,558	6,036,670

Yamuna (Unit :kg/day)

Sub-Basin Name	Upper Yamuna I	Hindon	Upper Yamuna II	Upper Yamuna III	Chambal	Sind	Betwa	Ken	Lower Yamuna	Total
BOD (Sewerage)	3,604	34,692	219,237	107,085	164,570	40,445	76,273	14,153	8,056	668,115
BOD (Industry)	2,789	33,606	27,424	20,451	33,274	1,515	4,710	282	188	124,239
BOD (Livestock)	1,378	13,574	48,328	101,329	88,555	46,895	75,137	16,156	39,724	431,076
BOD (Land)	37,559	58,758	271,606	456,843	880,900	172,131	213,919	166,883	144,683	2,403,282
BOD (Household)	17,517	68,218	165,113	264,738	431,008	89,555	109,446	59,201	42,037	1,246,834
Total	62,847	208,849	731,709	950,446	1,598,307	350,541	479,485	256,675	234,688	4,873,546

Gomati (Unit :kg/day)

Sub-bain Name	Upper Gomati	Lower Gomati	Sai	Total
BOD (Sewerage)	49,355	10,873	11,732	71,960
BOD (Industry)	5,346	915	680	6,941
BOD (Livestock)	7,147	11,233	7,704	26,084
BOD (Land)	87,653	110,980	81,459	280,092
BOD (Household)	80,210	58,593	121,886	260,689
Total	229,711	192,594	223,461	645,766

Table B.5.8 Past and Future Population in Each State

Decade	1,971	1,981	1,991	2,001	2,010	2,030	Decade growth	% decadal growth	Growth factor
Bihar	42,126,236	52,302,665	64,530,554	82,878,796	101,949,814	156,631,087	19,071,018	23	0.230
Chhatisgarh	11,637,494	14,010,337	17,614,928	20,795,956	24,385,094	33,348,911	3,589,138	17	0.170
Haryana	10,036,431	12,922,119	16,463,648	21,082,989	26,747,969	13,554,052	5,664,980	27	0.269
Himachal Pradesh	3,460,434	4,280,818	5,170,877	6,077,248	6,942,019	8,982,481	864,771	14	0.142
Jharkhand	14,227,133	17,612,069	21,843,911	26,909,428	32,189,877	32,189,877	5,280,449	20	0.196
Madhya Pradesh	30,016,625	38,168,507	48,566,242	60,385,118	72,779,430	105,547,852	12,394,312	21	0.205
Rajasthan	25,765,806	34,261,862	44,005,990	56,473,122	69,051,943	102,926,818	12,578,821	22	0.223
Uttar Pradesh	83,848,797	105,136,540	131,998,804	166,052,859	201,787,135	299,887,486	35,734,276	22	0.215
Uttaranchal	4,492,724	5,725,972	7,113,483	8,479,562	9,656,461	12,326,066	1,176,899	14	0.139
West Bengal	44,312,011	54,580,647	68,077,965	80,221,171	90,891,900	115,136,860	10,670,729	13	0.133
Delhi	4,065,698	6,220,406	9,420,644	13,782,976	18,626,023	32,602,359	4,843,047	35	0.351

Table B.5.9 2015 Without Project Pollution Load Generation

Ganga-1

Sub-Basin Name	Upper Ganga I	Upper Ganga II	Ramganga	Kalinadi	Middle Ganga I	Middle Ganga II	Middle Ganga III	Midle Ganga IV	Tons	Karmanasa	Ghaghra	Son	Punpun	Falgu	Kiul	Gandak	Burhi Gandak	Kosi
BOD (Sewerage)	26,454	38,928	95,741	92,654	6,813	62,522	25,457	27,244	20,436	0	71,992	31,978	3,560	21,708	3,518	6,225	26,254	14,071
BOD (Industry)	2,319	4,739	40,194	11,059	117	26,904	613	2,131	14	171	17,906	4,175	0	2,961	308	557	14,063	1,175
BOD (Livestock)	1,074	20,271	30,103	18,130	2,525	6,190	1,630	12,011	12,571	1,357	34,648	41,215	6,602	16,936	3,707	7,095	19,813	19,407
BOD (Land)	31,118	138,865	189,033	103,246	29,515	39,006	22,110	58,622	107,997	14,470	449,079	439,546	45,111	106,073	19,542	50,156	142,064	145,708
BOD (Household)	39,104	89,706	139,332	112,851	22,767	56,266	60,253	114,342	110,616	6,762	360,955	224,067	15,070	76,598	17,471	7,766	144,196	168,722
Total	100,070	292,508	494,403	337,940	61,737	190,888	110,064	214,350	251,635	22,760	934,579	740,981	70,344	224,277	44,545	71,799	346,391	349,083

Ganga-2 (Unit :kg/day)

Sub-Basin Name	Dwarka	Jalangi	Ajay	Damodar	Rupnarayan	Haldi	Lowe Ganga I	Lower Ganga II	Total
BOD (Sewerage)	3,659	249	0	135,912	728	33,657	81,851	223,077	1,054,688
BOD (Industry)	1,234	8,947	0	17,079	1,113	10,937	7,201	101,913	277,830
BOD (Livestock)	11,475	4,509	17,050	24,698	7,139	9,251	16,644	31,464	377,515
BOD (Land)	75,974	28,547	78,758	107,644	49,837	68,917	100,810	101,072	2,742,820
BOD (Household)	35,638	14,078	26,131	137,177	34,291	177,641	222,037	155,679	2,569,515
Total	127,980	56,330	121,939	422,510	93,108	300,403	428,543	613,205	7,022,368

Yamuna (Unit :kg/day)

Sub-Basin Name	Upper Yamuna I	Hindon	Upper Yamuna II	Upper Yamuna III	Chambal	Sind	Betwa	Ken	Lower Yamuna	Total
BOD (Sewerage)	4,396	59,391	245,859	159,090	225,186	54,214	102,561	18,965	10,956	880,618
BOD (Industry)	4,295	51,753	42,233	31,495	51,242	2,333	7,253	434	290	191,328
BOD (Livestock)	1,378	13,574	48,328	101,329	88,555	46,895	75,137	16,156	39,724	431,076
BOD (Land)	37,559	58,758	271,606	456,843	880,900	172,131	213,919	166,883	144,683	2,403,282
BOD (Household)	21,371	92,777	243,364	363,209	582,777	120,483	147,473	76,874	57,170	1,705,497
Total	68,999	276,253	851,390	1,111,965	1,828,660	396,055	546,344	279,312	252,823	5,611,801

Gomati (Unit :kg/day)

Sub-bain Name	Upper Gomati	Lower Gomati	Sai	Total
BOD (Sewerage)	69,694	14,891	15,955	100,540
BOD (Industry)	8,233	1,409	1,047	10,689
BOD (Livestock)	7,147	11,233	7,704	26,084
BOD (Land)	87,653	110,980	81,459	280,092
BOD (Household)	109,085	151,770	165,766	426,620
Total	281,812	290,282	271,931	844,025

Table B.5.10 2030 Without Project Pollution Load Generation

Ganga-1

Sub-Basin Name	Upper Ganga I	Upper Ganga II	Ramganga	Kalinadi	Middle Ganga I	Middle Ganga II	Middle Ganga III	Midle Ganga IV	Tons	Karmanasa	Ghaghra	Son	Punpun	Falgu	Kiul	Gandak	Burhi Gandak	Kosi
BOD (Sewerage)	32,724	51,742	126,154	122,631	9,017	92,100	36,994	42,428	26,537	0	95,433	44,697	4,833	29,466	4,775	8,450	35,638	19,100
BOD (Industry)	2,937	6,000	50,895	14,003	148	34,067	776	2,699	18	216	22,673	5,286	0	3,750	390	706	17,807	1,488
BOD (Livestock)	1,074	20,271	30,103	18,130	2,525	6,190	1,630	12,011	12,571	1,357	34,648	41,215	6,602	16,936	3,707	7,095	19,813	19,407
BOD (Land)	31,118	138,865	189,033	103,246	29,515	39,006	22,110	58,622	107,997	14,470	449,079	439,546	45,111	106,073	19,542	50,156	142,064	145,708
BOD (Household)	46,861	118,728	183,923	149,361	30,133	74,470	79,747	151,335	143,636	8,949	479,080	327,315	20,456	103,975	23,715	10,541	195,732	229,023
Total	114,713	335,606	580,108	407,371	71,338	245,832	141,257	267,094	290,759	24,993	1,080,912	858,060	77,002	260,200	52,129	76,947	411,054	414,726

Ganga-2 (Unit :kg/day)

Sub-Basin Name	Dwarka	Jalangi	Ajay	Damodar	Rupnarayan	Haldi	Lowe Ganga I	Lower Ganga II	Total
BOD (Sewerage)	4,701	296	0	168,747	864	39,941	118,395	276,227	1,391,887
BOD (Industry)	1,562	11,330	0	21,626	1,410	13,849	9,118	129,045	351,798
BOD (Livestock)	11,475	4,509	17,050	24,698	7,139	9,251	16,644	31,464	377,515
BOD (Land)	75,974	28,547	78,758	107,644	49,837	68,917	100,810	101,072	2,742,820
BOD (Household)	42,663	16,706	31,010	166,486	40,693	210,810	301,393	184,748	3,371,489
Total	136,375	61,388	126,818	489,200	99,943	342,768	546,360	722,556	8,235,509

Yamuna (Unit :kg/day)

Sub-Basin Name	Upper Yamuna I	Hindon	Upper Yamuna II	Upper Yamuna III	Chambal	Sind	Betwa	Ken	Lower Yamuna	Total
BOD (Sewerage)	5,297	89,578	289,233	239,393	299,087	70,412	133,667	24,626	14,501	1,165,795
BOD (Industry)	5,439	65,532	53,477	39,879	64,884	2,954	9,185	550	367	242,266
BOD (Livestock)	1,378	13,574	48,328	101,329	88,555	46,895	75,137	16,156	39,724	431,076
BOD (Land)	37,559	58,758	271,606	456,843	880,900	172,131	213,919	166,883	144,683	2,403,282
BOD (Household)	25,750	122,793	348,000	491,559	756,603	155,826	191,459	103,010	75,666	2,270,667
Total	75,423	350,235	1,010,643	1,329,003	2,090,030	448,219	623,367	311,225	274,941	6,513,085

Gomati (Unit :kg/day)

Sub-bain Name	Upper Gomati	Lower Gomati	Sai	Total
BOD (Sewerage)	94,552	19,802	21,117	135,471
BOD (Industry)	10,425	1,784	1,326	13,535
BOD (Livestock)	7,147	11,233	7,704	26,084
BOD (Land)	87,653	110,980	81,459	280,092
BOD (Household)	144,377	200,871	219,396	564,644
Total	344,154	344,671	331,002	1,019,826

Table B.5.11 2015 With Project Pollution Load Generation

Ganga-1

Sub-Basin Name	Upper Ganga I	Upper Ganga II	Ramganga	Kalinadi	Middle Ganga I	Middle Ganga II	Middle Ganga III	Midle Ganga IV	Tons	Karmanasa	Ghaghra	Son	Punpun	Falgu	Kiul	Gandak	Burhi Gandak	Kosi
BOD (Sewerage)	5,291	7,786	19,148	18,531	1,363	12,504	5,091	5,449	4,087	0	14,398	6,396	712	4,342	704	1,245	5,251	2,814
BOD (Industry)	2,319	4,739	40,194	11,059	117	26,904	613	2,131	14	171	17,906	4,175	0	2,961	308	557	14,063	1,175
BOD (Livestock)	1,074	20,271	30,103	18,130	2,525	6,190	1,630	12,011	12,571	1,357	34,648	41,215	6,602	16,936	3,707	7,095	19,813	19,407
BOD (Land)	31,118	138,865	189,033	103,246	29,515	39,006	22,110	58,622	107,997	14,470	449,079	439,546	45,111	106,073	19,542	50,156	142,064	145,708
BOD (Household)	39,104	89,706	139,332	112,851	22,767	56,266	60,253	114,342	110,616	6,762	360,955	224,067	15,070	76,598	17,471	7,766	144,196	168,722
Total	78,906	261,366	417,810	263,816	56,287	140,870	89,698	192,555	235,286	22,760	876,985	715,399	67,495	206,910	41,731	66,819	325,387	337,826

Ganga-2 (Unit :kg/day)

Sub-Basin Name	Dwarka	Jalangi	Ajay	Damodar	Rupnarayan	Haldi	Lowe Ganga I	Lower Ganga II	Total
BOD (Sewerage)	732	50	0	27,182	146	6,731	16,370	44,615	210,938
BOD (Industry)	1,234	8,947	0	17,079	1,113	10,937	7,201	101,913	277,830
BOD (Livestock)	11,475	4,509	17,050	24,698	7,139	9,251	16,644	31,464	377,515
BOD (Land)	75,974	28,547	78,758	107,644	49,837	68,917	100,810	101,072	2,742,820
BOD (Household)	35,638	14,078	26,131	137,177	34,291	177,641	222,037	155,679	2,569,515
Total	125,053	56,131	121,939	313,780	92,526	273,477	363,062	434,743	6,178,618

Yamuna (Unit :kg/day)

Sub-Basin Name	Upper Yamuna I	Hindon	Upper Yamuna II	Upper Yamuna III	Chambal	Sind	Betwa	Ken	Lower Yamuna	Total
BOD (Sewerage)	879	11,878	49,172	31,818	45,037	10,843	20,512	3,793	2,191	176,124
BOD (Industry)	4,295	51,753	42,233	31,495	51,242	2,333	7,253	434	290	191,328
BOD (Livestock)	1,378	13,574	48,328	101,329	88,555	46,895	75,137	16,156	39,724	431,076
BOD (Land)	37,559	58,758	271,606	456,843	880,900	172,131	213,919	166,883	144,683	2,403,282
BOD (Household)	21,371	92,777	243,364	363,209	582,777	120,483	147,473	76,874	57,170	1,705,497
Total	65,482	228,740	654,703	984,693	1,648,511	352,684	464,295	264,140	244,058	4,907,307

Gomati (Unit :kg/day)

Sub-bain Name	Upper Gomati	Lower Gomati	Sai	Total
BOD (Sewerage)	13,939	2,978	3,191	20,108
BOD (Industry)	8,233	1,409	1,047	10,689
BOD (Livestock)	7,147	11,233	7,704	26,084
BOD (Land)	87,653	110,980	81,459	280,092
BOD (Household)	109,085	151,770	165,766	426,620
Total	226,057	278,370	259,167	763,593

Table B.5.12 2030 With Project Pollution Load Generation

Ganga-1

Sub-Basin Name	Upper Ganga I	Upper Ganga II	Ramganga	Kalinadi	Middle Ganga I	Middle Ganga II	Middle Ganga III	Midle Ganga IV	Tons	Karmanasa	Ghaghra	Son	Punpun	Falgu	Kiul	Gandak	Burhi Gandak	Kosi
BOD (Sewerage)	6,545	10,348	25,231	24,526	1,803	18,420	7,399	8,486	5,307	0	19,087	8,939	967	5,893	955	1,690	7,128	3,820
BOD (Industry)	2,937	6,000	50,895	14,003	148	34,067	776	2,699	18	216	22,673	5,286	0	3,750	390	706	17,807	1,488
BOD (Livestock)	1,074	20,271	30,103	18,130	2,525	6,190	1,630	12,011	12,571	1,357	34,648	41,215	6,602	16,936	3,707	7,095	19,813	19,407
BOD (Land)	31,118	138,865	189,033	103,246	29,515	39,006	22,110	58,622	107,997	14,470	449,079	439,546	45,111	106,073	19,542	50,156	142,064	145,708
BOD (Household)	46,861	118,728	183,923	149,361	30,133	74,470	79,747	151,335	143,636	8,949	479,080	327,315	20,456	103,975	23,715	10,541	195,732	229,023
Total	88,534	294,213	479,184	309,266	64,125	172,152	111,662	233,152	269,529	24,993	1,004,566	822,302	73,136	236,627	48,309	70,188	382,544	399,446

Ganga-2

(Unit :kg/day)

Sub-Basin Name	Dwarka	Jalangi	Ajay	Damodar	Rupnarayan	Haldi	Lowe Ganga I	Lower Ganga II	Total
BOD (Sewerage)	940	59	0	33,749	173	7,988	23,679	55,245	278,377
BOD (Industry)	1,562	11,330	0	21,626	1,410	13,849	9,118	129,045	351,798
BOD (Livestock)	11,475	4,509	17,050	24,698	7,139	9,251	16,644	31,464	377,515
BOD (Land)	75,974	28,547	78,758	107,644	49,837	68,917	100,810	101,072	2,742,820
BOD (Household)	42,663	16,706	31,010	166,486	40,693	210,810	301,393	184,748	3,371,489
Total	132,614	61,151	126,818	354,203	99,252	310,815	451,644	501,575	7,121,999

Yamuna

(Unit :kg/day)

Sub-Basin Name	Upper Yamuna I	Hindon	Upper Yamuna II	Upper Yamuna III	Chambal	Sind	Betwa	Ken	Lower Yamuna	Total
BOD (Sewerage)	1,059	17,916	57,847	47,879	59,817	14,082	26,733	4,925	2,900	233,159
BOD (Industry)	5,439	65,532	53,477	39,879	64,884	2,954	9,185	550	367	242,266
BOD (Livestock)	1,378	13,574	48,328	101,329	88,555	46,895	75,137	16,156	39,724	431,076
BOD (Land)	37,559	58,758	271,606	456,843	880,900	172,131	213,919	166,883	144,683	2,403,282
BOD (Household)	25,750	122,793	348,000	491,559	756,603	155,826	191,459	103,010	75,666	2,270,667
Total	71,185	278,572	779,257	1,137,489	1,850,760	391,889	516,433	291,524	263,340	5,580,450

Gomati

(Unit :kg/day)

Sub-bain Name	Upper Gomati	Lower Gomati	Sai	Total
BOD (Sewerage)	18,910	3,960	4,223	27,094
BOD (Industry)	10,425	1,784	1,326	13,535
BOD (Livestock)	7,147	11,233	7,704	26,084
BOD (Land)	87,653	110,980	81,459	280,092
BOD (Household)	144,377	200,871	219,396	564,644
Total	268,512	328,829	314,108	911,450

Table B.5.13 Sub-basin Wise Existing Pollution Load Runoff

Ganga-1

Sub-Basin Name	Upper Ganga I	Upper Ganga II	Ramganga	Kalinadi	Middle Ganga I	Middle Ganga II	Middle Ganga III	Midle Ganga IV	Tons	Karmanasa	Ghaghra	Son	Punpun	Falgu	Kiul	Gandak	Burhi Gandak	Kosi
BOD (Sewerage)	15,645	10,271	20,347	4,902	2,726	21,305	11,932	10,998	9,833	0	8,467	7,233	1,134	5,383	1,732	72	437	4,747
BOD (Industry)	1,131	1,243	8,589	328	41	10,728	296	1,007	6	48	1,862	425	0	756	119	113	307	321
BOD (Livestock)	9	63	96	32	21	47	13	94	110	9	20	77	42	85	29	11	12	116
BOD (Land)	272	433	604	185	244	293	178	459	945	101	262	824	290	530	153	81	83	872
BOD (Household)	282	206	328	148	138	311	358	658	723	35	155	326	70	276	98	30	61	729
Total	17,338	12,216	29,964	5,595	3,171	32,684	12,778	13,216	11,616	194	10,767	8,886	1,536	7,029	2,131	307	899	6,785

Ganga-2

(Unit :kg/day)

Sub-Basin Name	Dwarka	Jalangi	Ajay	Damodar	Rupnarayan	Haldi	Lowe Ganga I	Lower Ganga II	Total
BOD (Sewerage)	674	150	0	11,699	205	11,347	14,253	8,414	183,906
BOD (Industry)	367	819	0	2,188	222	2,859	1,122	7,198	42,096
BOD (Livestock)	71	32	93	9	39	42	23	18	1,216
BOD (Land)	470	205	430	41	274	311	138	58	8,735
BOD (Household)	182	84	119	42	156	666	219	74	6,475
Total	1,764	1,289	642	13,980	897	15,225	15,755	15,763	242,427

Yamuna

(Unit :kg/day)

Sub-Basin Name	Upper Yamuna I	Hindon	Upper Yamuna II	Upper Yamuna III	Chambal	Sind	Betwa	Ken	Lower Yamuna	Total
BOD (Sewerage)	1,366	8,641	89,488	50,253	11,037	801	4,150	1,377	2,156	169,270
BOD (Industry)	1,077	7,259	8,473	8,940	1,786	8	209	24	188	27,964
BOD (Livestock)	10	38	102	563	172	2	131	11	159	1,187
BOD (Land)	273	165	573	2,538	1,710	7	373	112	578	6,330
BOD (Household)	127	192	349	1,471	837	4	191	40	168	3,377
Total	2,854	16,295	98,985	63,764	15,542	822	5,054	1,565	3,248	208,128

Gomati

(Unit :kg/day)

Sub-bain Name	Upper Gomati	Lower Gomati	Sai	Total
BOD (Sewerage)	33,458	5,445	4,047	42,950
BOD (Industry)	2,617	460	171	3,248
BOD (Livestock)	18	68	28	114
BOD (Land)	223	676	294	1,193
BOD (Household)	204	357	440	1,002
Total	36,521	7,006	4,980	48,507

Table B.5.14 2015 Without Project Pollution Load Runoff

Ganga-1

Sub-Basin Name	Upper Ganga I	Upper Ganga II	Ramganga	Kalinadi	Middle Ganga I	Middle Ganga II	Middle Ganga III	Midle Ganga IV	Tons	Karmanasa	Ghaghra	Son	Punpun	Falgu	Kiul	Gandak	Burhi Gandak	Kosi
BOD (Sewerage)	19778	14,149	27,523	6,666	3,707	34,451	18,963	20,319	13,176	0	11,551	10,044	1,571	7,455	2,399	100	605	6,575
BOD (Industry)	1741	1,915	13,228	505	64	16,521	457	1,550	9	74	2,868	655	0	1,164	184	174	473	495
BOD (Livestock)	9	63	96	32	21	47	13	94	110	9	20	77	42	85	29	11	12	116
BOD (Land)	272	433	604	185	244	293	178	459	945	101	262	824	290	530	153	81	83	872
BOD (Household)	341	280	445	202	188	423	486	895	968	47	211	420	97	382	136	12	84	1,009
Total	22142	16,839	41,895	7,590	4,224	51,735	20,098	23,317	15,208	232	14,912	12,020	2,000	9,615	2,900	379	1,257	9,066

Ganga-2 (Unit :kg/day)

Sub-Basin Name	Dwarka	Jalangi	Ajay	Damodar	Rupnarayan	Haldi	Lowe Ganga I	Lower Ganga II	Total
BOD (Sewerage)	882	180	0	14,174	247	13,674	21,195	10,782	260,166
BOD (Industry)	566	1,211	0	3,370	342	4,402	1,727	11,084	64,778
BOD (Livestock)	71	32	93	9	39	42	23	18	1,216
BOD (Land)	470	205	430	41	274	311	138	58	8,735
BOD (Household)	220	101	143	52	188	803	304	90	8,530
Total	2,209	1,729	666	17,646	1,091	19,232	23,387	22,032	343,424

Yamuna (Unit :kg/day)

Sub-Basin Name	Upper Yamuna I	Hindon	Upper Yamuna II	Upper Yamuna III	Chambal	Sind	Betwa	Ken	Lower Yamuna	Total
BOD (Sewerage)	1,667	17,462	92,431	74,316	15,047	1,074	5,593	1,846	2,932	212,367
BOD (Industry)	1,659	11,179	13,049	13,768	2,751	12	322	37	290	43,065
BOD (Livestock)	10	38	102	563	172	2	131	11	159	1,187
BOD (Land)	273	165	573	2,538	1,710	7	373	112	578	6,330
BOD (Household)	155	261	514	2,017	1,131	5	257	52	228	4,621
Total	3,764	29,104	106,668	93,202	20,811	1,099	6,676	2,058	4,187	267,569

Gomati (Unit :kg/day)

Sub-bain Name	Upper Gomati	Lower Gomati	Sai	Total
BOD (Sewerage)	47,441	7,455	5,504	60,400
BOD (Industry)	4,031	709	263	5,002
BOD (Livestock)	18	68	28	114
BOD (Land)	223	676	294	1,193
BOD (Household)	278	924	599	1,801
Total	51,991	9,832	6,688	68,511

Table B.5.15 2030 Without Project Pollution Load Runoff

Ganga-1

Sub-Basin Name	Upper Ganga I	Upper Ganga II	Ramganga	Kalinadi	Middle Ganga I	Middle Ganga II	Middle Ganga III	Midle Ganga IV	Tons	Karmanasa	Ghaghra	Son	Punpun	Falgu	Kiul	Gandak	Burhi Gandak	Kosi
BOD (Sewerage)	24502	18,888	36,277	8,823	4,907	50,519	27,557	31,710	17,109	0	15,355	13,824	2,132	10,120	3,256	136	821	8,925
BOD (Industry)	2205	2,424	16,749	639	81	20,920	578	1,963	11	94	3,632	829	0	1,473	232	220	599	626
BOD (Livestock)	9	63	96	32	21	47	13	94	110	9	20	77	42	85	29	11	12	116
BOD (Land)	272	433	604	185	244	293	178	459	945	101	262	824	290	530	153	81	83	872
BOD (Household)	409	370	587	267	249	560	644	1,185	1,257	63	280	613	131	519	185	17	114	1,370
Total	27397	22,179	54,314	9,947	5,501	72,338	28,970	35,411	19,433	268	19,549	16,167	2,596	12,726	3,855	465	1,629	11,909

Ganga-2 (Unit :kg/day)

Sub-Basin Name	Dwarka	Jalangi	Ajay	Damodar	Rupnarayan	Haldi	Lowe Ganga I	Lower Ganga II	Total
BOD (Sewerage)	1,133	214	0	16,915	294	16,227	30,121	13,381	353,144
BOD (Industry)	716	1,519	0	4,267	434	5,574	2,187	14,035	82,009
BOD (Livestock)	71	32	93	9	39	42	23	18	1,216
BOD (Land)	470	205	430	41	274	311	138	58	8,735
BOD (Household)	264	120	169	63	223	953	413	106	11,133
Total	2,654	2,090	693	21,296	1,264	23,107	32,881	27,599	456,238

Yamuna (Unit :kg/day)

Sub-Basin Name	Upper Yamuna I	Hindon	Upper Yamuna II	Upper Yamuna III	Chambal	Sind	Betwa	Ken	Lower Yamuna	Total
BOD (Sewerage)	2,008	28,243	97,132	109,791	19,972	1,394	7,316	2,397	3,881	272,135
BOD (Industry)	2,100	14,155	16,522	17,434	3,483	15	407	47	367	54,530
BOD (Livestock)	10	38	102	563	172	2	131	11	159	1,187
BOD (Land)	273	165	573	2,538	1,710	7	373	112	578	6,330
BOD (Household)	187	345	735	2,730	1,469	6	334	69	302	6,178
Total	4,579	42,946	115,065	133,056	26,806	1,424	8,561	2,636	5,286	340,360

Gomati (Unit :kg/day)

Sub-bain Name	Upper Gomati	Lower Gomati	Sai	Total
BOD (Sewerage)	64,530	9,912	7,285	81,727
BOD (Industry)	5,104	897	333	6,334
BOD (Livestock)	18	68	28	114
BOD (Land)	223	676	294	1,193
BOD (Household)	368	1,223	793	2,384
Total	70,244	12,777	8,732	91,753

Table B.5.16 2015 With Project Pollution Load Runoff

Ganga-1

Sub-Basin Name	Upper Ganga I	Upper Ganga II	Ramganga	Kalinadi	Middle Ganga I	Middle Ganga II	Middle Ganga III	Midle Ganga IV	Tons	Karmanasa	Ghaghra	Son	Punpun	Falgu	Kiul	Gandak	Burhi Gandak	Kosi
BOD (Sewerage)	3956	2,830	5,505	1,333	741	6,890	3,793	4,064	2,635	0	2,310	2,009	314	1,491	480	20	121	1,315
BOD (Industry)	1741	1,915	13,228	505	64	16,521	457	1,550	9	74	2,868	655	0	1,164	184	174	473	495
BOD (Livestock)	9	63	96	32	21	47	13	94	110	9	20	77	42	85	29	11	12	116
BOD (Land)	272	433	604	185	244	293	178	459	945	101	262	824	290	530	153	81	83	872
BOD (Household)	341	280	445	202	188	423	486	895	968	47	211	420	97	382	136	12	84	1,009
Total	6319	5,520	19,877	2,257	1,258	24,174	4,927	7,062	4,668	232	5,672	3,985	743	3,651	981	299	773	3,807

Ganga-2 (Unit :kg/day)

Sub-Basin Name	Dwarka	Jalangi	Ajay	Damodar	Rupnarayan	Haldi	Lowe Ganga I	Lower Ganga II	Total
BOD (Sewerage)	176	36	0	2,835	49	2,735	4,239	2,156	52,033
BOD (Industry)	566	1,066	0	3,370	342	4,402	1,727	11,084	64,633
BOD (Livestock)	71	32	93	9	39	42	23	18	1,216
BOD (Land)	470	205	430	41	274	311	138	58	8,735
BOD (Household)	220	101	143	52	188	803	304	90	8,530
Total	1,503	1,440	666	6,308	893	8,293	6,431	13,407	135,147

Yamuna (Unit :kg/day)

Sub-Basin Name	Upper Yamuna I	Hindon	Upper Yamuna II	Upper Yamuna III	Chambal	Sind	Betwa	Ken	Lower Yamuna	Total
BOD (Sewerage)	333	3,492	18,486	14,863	3,009	215	1,119	369	586	42,473
BOD (Industry)	1,659	11,179	13,049	13,768	2,751	12	322	37	290	43,065
BOD (Livestock)	10	38	102	563	172	2	131	11	159	1,187
BOD (Land)	273	165	573	2,538	1,710	7	373	112	578	6,330
BOD (Household)	155	261	514	2,017	1,131	5	257	52	228	4,621
Total	2,430	15,135	32,724	33,749	8,774	240	2,202	581	1,841	97,676

Gomati (Unit :kg/day)

Sub-bain Name	Upper Gomati	Lower Gomati	Sai	Total
BOD (Sewerage)	9,488	1,491	1,101	12,080
BOD (Industry)	4,031	709	263	5,002
BOD (Livestock)	18	68	28	114
BOD (Land)	223	676	294	1,193
BOD (Household)	278	924	599	1,801
Total	14,038	3,868	2,285	20,191

Table B.5.17 2030 With Project Pollution Load Runoff

Ganga-1

Sub-Basin Name	Upper Ganga I	Upper Ganga II	Ramganga	Kalinadi	Middle Ganga I	Middle Ganga II	Middle Ganga III	Midle Ganga IV	Tons	Karmanasa	Ghaghra	Son	Punpun	Falgu	Kiul	Gandak	Burhi Gandak
BOD (Sewerage)	4900	3,778	7,255	1,765	981	10,104	5,511	6,342	3,422	0	3,071	2,765	426	2,024	651	27	164
BOD (Industry)	2205	2,424	16,749	639	81	20,920	578	1,963	11	94	3,632	829	0	1,473	232	220	599
BOD (Livestock)	9	63	96	32	21	47	13	94	110	9	20	77	42	85	29	11	12
BOD (Land)	272	433	604	185	244	293	178	459	945	101	262	824	290	530	153	81	83
BOD (Household)	409	370	587	267	249	560	644	1,185	1,257	63	280	613	131	519	185	17	114
Total	7795	7,068	25,292	2,888	1,576	31,923	6,925	10,042	5,746	268	7,265	5,108	890	4,631	1,250	356	972

Ganga-2 (Unit :kg/day)

Sub-Basin Name	Dwarka	Jalangi	Ajay	Damodar	Rupnarayan	Haldi	Lowe Ganga I	Lower Ganga II	Total
BOD (Sewerage)	227	43	0	3,383	59	3,245	6,024	2,676	70,629
BOD (Industry)	716	1,348	0	4,267	434	5,574	2,187	14,035	81,838
BOD (Livestock)	71	32	93	9	39	42	23	18	1,216
BOD (Land)	470	205	430	41	274	311	138	58	8,735
BOD (Household)	264	120	169	63	223	953	413	106	11,133
Total	1,748	1,747	693	7,764	1,029	10,126	8,785	16,894	173,551

Yamuna (Unit :kg/day)

Sub-Basin Name	Upper Yamuna I	Hindon	Upper Yamuna II	Upper Yamuna III	Chambal	Sind	Betwa	Ken	Lower Yamuna	Total
BOD (Sewerage)	402	5,649	19,426	21,958	3,994	279	1,463	479	776	54,427
BOD (Industry)	2,100	14,155	16,522	17,434	3,483	15	407	47	367	54,530
BOD (Livestock)	10	38	102	563	172	2	131	11	159	1,187
BOD (Land)	273	165	573	2,538	1,710	7	373	112	578	6,330
BOD (Household)	187	345	735	2,730	1,469	6	334	69	302	6,178
Total	2,972	20,352	37,359	45,223	10,829	309	2,709	719	2,181	122,652

Gomati (Ur

Sub-bain Name	Upper Gomati	Lower Gomati	Sai
BOD (Sewerage)	12,906	1,982	1,457
BOD (Industry)	5,104	897	333
BOD (Livestock)	18	68	28
BOD (Land)	223	676	294
BOD (Household)	368	1,223	793
Total	18,619	4,847	2,904

Table B.5.18 Density of Population, Pollution Load Generation and Runoff of Each Sub-basin

No.	Sub-basin Name	Populaion (person/km^2)		Pollution Load Genaration (BOD kg/d/km^2)		Pollution Load Runoff (BOD kg/d/km^2)		Remarks (Large City)
		Value	Ranking	Value	Ranking	Value	Ranking	
1	Upper Ganga-I	238	32	5.1	37	0.86	11	
2	Upper Ganga-II	366	24	13.0	21	0.61	20	
3	Ramganga	404	20	13.6	18	0.83	14	
4	Kalinadi	827	10	21.9	8	0.46	21	
5	Middle Ganga I	468	16	14.6	15	0.83	14	
6	Middle Ganga II	1384	3	26.5	4	4.84	2	Kanpur
7	Middle Ganga III	1971	1	32.2	2	5.15	1	Allahabad
8	Middle Ganga IV	1197	6	22.5	7	1.80	7	Varanasi
9	Tons	461	17	12.5	23	0.67	19	
10	Upper Yamuna I	147	38	5.3	36	0.28	24	
11	Upper Yamuna II	1301	5	29.3	3	1.98	6	Delhi
12	Upper Yamuna III	917	8	21.6	9	2.70	4	Agra
13	Hindon	551	15	16.9	11	0.84	12	
14	Chambal	341	25	11.8	27	0.15	31	
15	Sind	315	26	11.2	30	0.04	37	Jaipur, Indore
16	Betwa	307	27	11.1	31	0.19	28	Bhopal
17	Ken	195	34	8.4	34	0.07	36	
18	Lower Yamuna	252	30	0.5	38	0.20	27	
19	Upper Gomati	908	9	21.3	10	3.53	3	Lucknow
20	Lower Gomati	430	19	14.4	16	0.68	18	
21	Sai	1175	7	23.0	6	1.16	9	
22	Karmanasa	170	36	8.0	35	0.08	35	
23	Ghaghra	377	23	11.9	26	0.17	30	
24	Sone	210	33	8.6	33	0.12	32	
25	Gandak	188	35	11.3	29	0.27	25	
26	Punpun	380	21	13.1	20	0.44	22	
27	Falgu	432	18	11.4	28	0.19	28	
28	Kiul	264	29	13.4	19	0.74	17	
29	Burhi Gandak	572	14	16.5	13	0.09	34	
30	Kosi	636	13	16.7	12	0.38	23	
31	Dwarka	274	28	12.0	24	0.20	26	
32	Jalangi	249	31	12.0	24	0.75	16	
33	Ajay	155	37	9.4	26	0.03	38	
34	Damodar	666	12	16.2	14	1.01	10	
35	Rupnarayan	378	22	12.8	22	0.11	33	
36	Haldi	793	11	14.3	17	0.84	13	
37	Lower Ganga I	1306	4	24.7	5	1.47	8	Patna
38	Lower Ganga II	1530	2	34.1	1	2.21	5	Culcatta

Table B.6.1 Input Data of Kanpur for Detail Simulation (QUAL2E) Model

1. Study area

The river stretch for which simulation has been carried out in this section of study is the part of Ganga River passing through Kanpur city and Kanpur Canal (a stream of River Ganga in Kanpur) flowing into Ganga River. Along the Ganga River, a point, 2 km upstream of the confluence of Kanpur Canal with Ganga River has been considered as the upstream boundary of simulation domain and downstream boundary has been taken near the water quality sampling station, Kanpur d/s, located 3.5 km downstream of Wazidpur Nala. Similarly, in the case of Kanpur Canal, the diversion point from the Ganga River is considered as upstream boundary of the domain and downstream boundary is the Canal's confluence point with Ganga River.

2. Reaches and elements

The domain of simulation has been segregated into discrete sets of elements each measuring 50 m in length in order to comprehensively analyze water quality change in Ganga River in Kanpur city. Summary of the stream system and its components is given in Table A. The schematic diagram of stream system is shown in Figure, which briefly explains about stream components used for QUAL2E simulation process.

Table A Summary of stream system and its components

	Chainage (km)	Number of Reach	Element Length (m)	Number of Elements	Remarks
Ganga River	12.9	13	50	258	
Kanpur Canal	9.0	9	50	180	
Total	21.9	22	-	438	

3. Hydraulic parameter of the rivers

It has been assumed that the cross section of the Ganga River and that of Kanpur Canal is trapezoidal and the side slope is assumed to be 1:1. The widths of both rivers are determined on the basis of satellite photograph taken on April 7, 2003. Average gradient between Allahabad and Farakka is considered as longitudinal slope. Hydraulic parameter of the river segments is given in Table B.

Table B Hydraulic parameter of river segment

	Width (m)	Roughness (Manning' N)	Side slope Left bank	Side slope Right bank	Longitudinal Section Slope
Ganga River	400	0.02	1:1	1:1	0.00007
Kanpur Canal	50	0.02	1:1	1:1	0.00007

4. Upstream boundary condition

The considered values of upstream boundary condition for the two stream system used in this simulation is given in Table C.1. The water quality parameters taken at the beginning of the calculation are that observed at water quality sampling station "Ganga at Bithoor (Kanpur)" and it is not influenced by sewage from Kanpur as the Bithoor sampling station is located about 10 km upstream of Kanpur. Kanpur Canal also branches out of Ganga River and therefore its upstream boundary condition is considered same as that of Ganga River.

Table C.1 Upstream boundary condition (Present condition)

	Flow Rate (m3/s)	Temp. (deg. C)	DO (mg/l)	BOD (mg/l)	Coliform (N/100ml)	Remarks
Headwater of Ganga River	93	28	6.0	3.6	1.5×10^4	WQSS Ganga at Bithoor
Headwater of Kanpur canal	10	28	6.0	3.6	1.5×10^4	

In case of the future simulation, following BOD value shown in Table C.2 is adopted as headwater BOD for without project and with project conditions instead of Table C.1.

Table C.2 Upstream boundary condition (in 2010 and 2030)

	Year	Condition	BOD (mg/l)	Remarks
Headwater of Ganga River	2010	Without project	3.8	Results of water quality simulation on entire Ganga basin
		With project	1.7	
Headwater of Kanpur canal		Without project	3.8	
		With project	1.7	
Headwater of Ganga River	2030	Without project	5.0	
		With project	1.8	
Headwater of Kanpur canal		Without project	5.0	
		With project	1.8	

5. Point source condition

The observed values of flow rate, water temperature and water quality parameters for various Nalas in the stream section is given in Table D. Some assumptions have been made wherever reliable data is not available. The detail on estimation of flow rate for Nalas in Kanpur has been given in Table B.6.7.

Table D Point source condition of Kanpur (without project)

Reach No.	Element No.	Name of Point Source	Name of Nala	Flow (m3/s) 2003	2010	2030	Temp (deg in C)	DO (mg/l)	BOD (mg/l)	Coliform (N/100ml)
6	7	Nala-1〜6	Kesa Colony Nala	0.165	0.295	0.801	28	0	201	1.0E+07
			Roadways Colony Nala							
			Khewra Nala							
			Jageswar Nala							
			Jewara Nala							
			Nawabganj Nala							
6	8	Nala-7	Rani Ghat Nala	0.020	0.036	0.097	28	0	154	1.0E+07
7	2	Nala-8	Sisamau Nala	1.660	1.924	2.969	28	0	228	1.0E+07
7	4	Nala-9	TAFCO Nala (Parmat)	0.006	0.011	0.029	28	0	170	1.0E+07
8	10	Nala-10	Parmat Ghat Nala	0.007	0.012	0.034	28	0	210	1.0E+07
9	17	Nala-11	Muir Mill Nala	0.064	0.114	0.312	28	0	172	1.0E+07
10	10	Nala-12	Police Line Nala	0.006	0.010	0.027	28	0	200	1.0E+07
10	15	Nala-13	Jail Nala	0.007	0.012	0.033	28	0	286	1.0E+07
11	7	Nala-14	Guptar Ghat Nala	0.195	0.346	0.943	28	0	286	1.0E+07
16	15	Nala-15&16	Golf Club - 1 Nala	0.008	0.014	0.037	28	0	173	1.0E+07
			Golf Club - 2 Nala							
17	2	Nala-17	Dubka Nala (Jaimau tannery complex)	0.038	0.084	0.179	28	0	2480	1.0E+07
17	7	Nala-18	Bangali Ghat Nala	0.000	0.000	0.000				
18	7	Nala-19	Budiya Ghat Nala	0.000	0.000	0.000				
19	8	Nala-20	Wazidpur Nala (Effluent of CETP)	0.110	0.110	0.110	28	5	125	1.0E+07

6. Reaction rate constants

In the simulation process, reaction rate constants have been determined so that calculated water quality of "Ganga at Kanpur d/s" may match well with observed value. Adopted value of reaction rate constants and equation representing reaeration rate are given in Table E.

Table E Reaction rate constants

	k1 (1/day)	k3 (1/day)	kd (1/day)	SOD (g/m2-day)	Equation for k2
Ganga River	0.20	0.01	3.0	2.5	O'Connor and Dobbins equation
Kanpur Canal	0.20	0.01	3.0	2.5	O'Connor and Dobbins equation

k1: Deoxygenation coefficient
k2: Reaeration coefficient
k3: Reduction coefficient of sedimentation
kd: Decay rate of coliform
SOD: Sediment Oxygen Demand rate

Table B.6.2 Input Data of Allahabad for Detail Simulation (QUAL2E) Model

1. Study area
The river stretch for which simulation has been carried out in this section of study is the part of Ganga River passing through Allahabad city and Yamuna River flowing into Ganga River. Along the Ganga River, a point near water quality sampling station "Ganga at Allahabad (Rasoolabad)" has been considered as the upstream boundary of simulation domain and downstream boundary is taken near water quality sampling station, "Ganga at d/s on Mawaiya". Similarly, in the case of Yamuna River, a point, 2 km upstream of Main Ghaghar Nala is considered as upstream boundary of simulation domain and downstream boundary is Yamuna River's confluence point with Ganga River.

2. Reaches and elements
The domain of simulation has been segregated into discrete sets of elements each measuring 50 m in length in order to comprehensively analyze water quality change in Ganga River and Yamuna River in Allahabad city. Summary of the stream system and its components is given in Table A. The schematic diagram of stream system is shown in Figure, which briefly explains about stream components used for QUAL2E simulation process.

Table A Summary of stream system

	Chainage (km)	No. of Reach	Element Length (m)	No. of Elements	Remarks
Ganga River	13.2	14	50	264	
Yamuna River	7.1	8	50	142	
Total	20.3	22	-	406	

3. Hydraulic parameter of the rivers
It has been assumed that the cross section of the Ganga River and that of Yamuna River is trapezoidal and the side slope is assumed to be 1:1. The widths of both rivers are determined on the basis of satellite photograph taken on April 7, 2003. Average gradient between Allahabad and Farakka is considered as longitudinal slope. Hydraulic parameter of the river segments is given in Table B.

Table B Hydraulic parameter of river segment

	Width (m)	Roughness (Manning' N)	Side slope Left bank	Side slope Right bank	Longitudinal Section Slope
Ganga River before the confluence	300	0.02	1:1	1:1	0.00007
Ganga River after the confluence	600	0.02	1:1	1:1	0.00007
Yamuna River	600	0.02	1:1	1:1	0.00007

4. Upstream boundary condition
The considered values of upstream boundary condition for the two stream system used in this simulation is given in Table C.1. The water quality parameters taken at the beginning of the calculation of Ganga River are that observed at water quality sampling station "Ganga at Allahabad (Rasoolabad)", and the water quality parameters taken at the beginning of the calculation of Yamuna River are that observed at "Yamuna at u/s on water intake Allahabad".

Table C.1 Upstream boundary condition

	Flow (m^3/s)	Temp. (deg. C)	DO (mg/l)	BOD (mg/l)	Coliform (N/100ml)	Water quality Sampling sta.
Headwater of Ganga River	113	28	7.2	2.7	1,700	at Allahabad (Rasoolabad)
Headwater of Yamuna River	219	28	7.2	3.3	3,500	at u/s on water intake Allahabad

In case of the future simulation, following BOD value shown in Table C.2 is adopted as headwater BOD for without project and with project conditions instead of Table C.1.

Table C.2 Upstream boundary condition (in 2010 and 2030)

	Year	Condition	BOD (mg/l)	Remarks
Headwater of Ganga River	2010	Without project	4.0	Results of water quality simulation on entire Ganga basin
		With project	1.6	
Headwater of Yamuna River		Without project	3.6	
		With project	1.3	
Headwater of Ganga River	2030	Without project	4.3	
		With project	1.9	
Headwater of Yamuna River		Without project	5.5	
		With project	1.9	

5. Point source condition

The observed values of flow rate, water temperature and water quality parameters for various Nalas in the stream section is given in Table D. Some assumptions have been made wherever reliable data is not available. The detail on estimation of flow rate for Nalas in Allahabad can be seen in Table B.6.8.

6. Reaction rate constants

In the simulation process, reaction rate constants have been determined so that calculated water quality of "Ganga at d/s of Mawaiya" may match well with observed value. Adopted value of reaction rate constants and equation representing reaeration rate are given in Table E

Table E Reaction rate constants

	k1 (1/day)	k3 (1/day)	kd (1/day)	SOD (g/m2-day)	Equation for k2
Ganga River	0.20	0.01	3.0	2.5	O'Connor and Dobbins equation
Yamuna River	0.20	0.01	3.0	2.5	O'Connor and Dobbins equation

k1: Deoxygenation coefficient
k2: Reaeration coefficient
k3: Reduction coefficient of sedimentation
kd: Decay rate of coliform
SOD: Sediment Oxygen Demand rate

Table D Point source condition of Allahabad (Without project)

(1) Ganga River Basin

Reach No.	Element No.	Name of Point Source	Name of Nala	Flow (m3/s) 2003	Flow (m3/s) 2010	Flow (m3/s) 2030	Temp (deg in C)	DO (mg/l)	BOD (mg/l)	Coliform (N/100ml)
1	2	Nala-11&17	Jondhwal Nala Shankarghat Nala Rasulabad Paccaghat Drain Ada Colony Nala Govindpur Purani Basti Drain Govindpur Drain No.2 Jondhwalghat Drain Basna Drain	0.060	0.070	0.118	28	0	84	1.0E+07
1	7	Nala-16	Co-Operative Drain	0.000	0.000	0.000				
2	8	Nala-14	Shivkuti Drain No.1 Shivkuti Drain No.2 Shivkuti Drain No.3 (North) Shivkuti Drain No.4 Shivkuti Drain No.5 Shivkuti Drain No.6 Shivkuti Drain No.7 (East)	0.031	0.036	0.063	28	0	52	1.0E+07
3	13	Nala-15	Chilla Drain Govindpur Purani Basti Drain Govindpur Drain No.1 Govindpur Drain No.2 Govindpur Drain No.3 Govindpur Drain No.4	0.000	0.000	0.000				
8	3	Nala-9&10	Alenganj Salori Nala	0.358	0.425	0.715	28	0	340	1.0E+07
9	7	Nala-7, 8	Morigate Nala	0.000	0.131	0.448	28	0	70	1.0E+07
20	13	Nala-20	Lotey Haran Nala	0.028	0.034	0.057	28	0	70	1.0E+07
22	3	Nala-13	Mawaiya Nala	0.119	0.141	0.238	28	0	78	1.0E+07

(2) Yamuna River Basin

Reach No.	Element No.	Name of Point Source	Name of Nala	Flow (m3/s) 2003	Flow (m3/s) 2010	Flow (m3/s) 2030	Temp (deg in C)	DO (mg/l)	BOD (mg/l)	Coliform (N/100ml)
12	20	Nala-1	Main Ghaghar Nala Ghaghar Nala 1'A' Ghaghar Nala 1'A'-1 Ghaghar Nala 1'B' Dariabad-Peepalghat Drain Dariabad-Katharaghat Drain Dariabad-Jogighat Drain	0.281	0.393	0.877	28	0	187	1.0E+07
13	18	Nala-2	Chachar Nala	0.226	0.310	0.675	28	0	187	1.0E+07
14	18	Nala-3	Emergency Outfall Drain (of Gau	0.241	0.286	0.482	28	0	187	1.0E+07
15	6	Nala-4	Drain at Gate No.9	0.026	0.031	0.053	28	0	187	1.0E+07
15	16	Nala-5	Drain at Gate No.13	0.053	0.063	0.106	28	0	187	1.0E+07
17	6	Nala-6A	Fort Drain No.2	0.000	0.000	0.000				
17	6	Nala-6	Fort Drain No.1	0.000	0.000	0.000				

Table B.6.3 Input Data of Varanasi for Detail Simulation (QUAL2E) Model

1. Study area

The river stretch for which simulation has been carried out in this section of study is the part of Ganga River passing through Varanasi city and Varuna River flowing into Ganga River. Along the Ganga River, a point near water quality sampling station, "Ganga River at Varanasi u/s (Assighat)" has been considered as upstream boundary of simulation domain and downstream boundary is taken near the water quality sampling station, "Ganga at Varanasi d/s (Kaithy)", located 37 km downstream of Varanasi city. Similarly, in the case of Varuna River, a point, 2 km upstream of Phulwaria Nala has been considered as upstream boundary of the domain and downstream boundary is the River's confluence point with River Ganga.

2. Reaches and elements

In case of Varanasi city, since the domain of simulation on River Ganga is very long (about 50 km), the domain has been divided into two as Ganga River-1 and Ganga River-2. The domain of Varuna River and that of Ganga River-1 has been segregated into discrete sets of elements each measuring 50 m in length in order to comprehensively analyze water quality change in Ganga River and Varuna River in Varanasi city. Whereas the domain of Ganga River-2 has been segregated into discrete sets of elements each measuring 1 km in length. Summary of the stream system and its components is given in Table A. The schematic diagram of stream system is shown in Figure, which briefly explains about stream components used for QUAL2E simulation process.

Table A Summary of stream system

	Chainage (km)	No. of Reach	Element Length (m)	No. of Elements	Remarks
Varuna River	14.7	15	50	294	
Ganga River -1	14.6	15	50	252	
Ganga River -2	35.0	2	1,000	35	
Total	64.3	32	-	621	

3. Hydraulic parameters of the river

It is assumed that the cross section of the Ganga River and that of Varuna River is trapezoidal and the side slope is assumed to be 1:1. The widths of both rivers are determined on the basis of satellite photograph taken on April 7, 2003. Average gradient between Varanasi and Farakka is considered as longitudinal slope. Hydraulic parameter of the river segments is given in Table B.

Table B Hydraulic parameters of the river

	Width (m)	Roughness (Manning' N)	Side slope Left bank	Side slope Right bank	Longitudinal Section Slope
Ganga River	15	0.02	1:1	1:1	0.00007
Varuna River	600	0.02	1:1	1:1	0.00007

4. Upstream boundary condition

The considered values of upstream boundary condition for the two stream system used in this simulation is given in Table C.1. The water quality parameters taken at the beginning of the calculation of Ganga River are that observed at water quality sampling station "Ganga at Varanasi u/s (Assighat)". The water quality parameters taken at the beginning of the calculation of Varuna River are assumed based on observation of study team.

Table C.1 Upstream boundary condition (Present condition)

	Flow (m3/s)	Temp. (deg. C)	DO (mg/l)	BOD (mg/l)	Coliform (N/100ml)	Water quality Sampling sta.
Headwater of Varuna River	0.8	28	5.0	5.0	8,000	Assumed by Study team
Headwater of Ganga River	359	28	5.8	3.3	30,000	Varanasi u/s

In case of the future simulation, following BOD value shown in Table C.2 is adopted as headwater BOD for without project and with project conditions instead of Table C.1.

Table C.2 Upstream boundary condition (in 2010 and 2030)

	Year	Condition	BOD (mg/l)	Remarks
Headwater of Ganga River	2010	Without project With project	3.8 1.4	Results of water quality simulation on entire Ganga basin
	2030	Without project With project	5.3 1.9	

5. Point source condition

The observed values of flow rate, water temperature and water quality parameters for various Nalas in the stream section is given in Table D. Some assumptions have been made wherever reliable data is not available. The detail on estimation of flow rate for Nalas in Varanasi has been explained in Table B.6.9.

Table D Point source condition of Varanasi (Without project)

(1) Ganga River Basin

Reach No.	Element No.	Name of Point Source	Name of Nala	Flow (m3/s)			Temp (deg in C)	DO (mg/l)	BOD (mg/l)	Coliform (N/100ml)
				2003	2010	2030				
1	2	Nala-2	Samne Ghat Drain	0.000	0.000	0.000				
2	6	Nala-3	Assi Nala	0.556	0.661	1.077	28	0	80	1.0E+08
3	10	Nala-4	Shiwala Drain	0.011	0.024	0.076	28	0	80	1.0E+08
3	16	Nala-5	Harishchandra Ghat Drain	0.005	0.011	0.034	28	0	80	1.0E+08
4	2	Nala-6	Mansarovar Drain	0.005	0.011	0.034	28	0	80	1.0E+08
4	16	Nala-7	Dr. R. P. Ghat Nala (Ghora Nala)	0.051	0.110	0.344	28	0	80	1.0E+08
5	4	Nala-8	Jalesan Drain	0.008	0.017	0.052	28	0	80	1.0E+08
5	13	Nala-9	Sankatha Ghat	0.001	0.001	0.004	28	0	80	1.0E+08
5	16	Nala-10	Trilochan Ghat Drain	0.007	0.015	0.048	28	0	80	1.0E+08
6	10	Nala-11	Telia Nala	0.006	0.013	0.041	28	0	80	1.0E+08
6	15	Nala-12	Bhainsasur Nala	0.005	0.006	0.010	28	0	80	1.0E+08
7	3	Nala-13	Rajghat Railway Nala	0.000	0.000	0.001				
8	8	Nala-14	Rajghat Outfall	0.181	0.392	1.224	28	0	80	1.0E+08

(2) Varuna River Basin

Reach No.	Element No.	Name of Point Source	Name of Nala	Flow (m3/s)			Temp (deg in C)	DO (mg/l)	BOD (mg/l)	Coliform (N/100ml)
				2003	2010	2030				
2	20	Nala-1(R)	Phulwaria Nala	0.095	0.113	0.184	28	0	80	1.0E+08
3	8	Nala-7(L)	Central Jail Nala	0.081	0.104	0.157	28	0	80	1.0E+08
4	10	Nala-2(R)	Sadar Bazar Nala	0.025	0.030	0.048	28	0	80	1.0E+08
4	15	Nala-3(R)	Drain Of Hotels	0.003	0.003	0.005	28	0	80	1.0E+08
5	10	Nala-8(L)	Orderly Bazar Nala	0.087	0.104	0.169	28	0	80	1.0E+08
5	19	Nala-9(L)	Chamrautia Nala	0.037	0.045	0.073	28	0	80	1.0E+08
6	2	Nala-4(R)	Raja Bazar Nala	0.001	0.001	0.002	28	0	80	1.0E+08
6	10	Nala-10(L)	Nala Of Khajurl Colony	0.019	0.022	0.036	28	0	80	1.0E+08
7	9	Nala-5(R)	Teliabagh Nala	0.225	0.267	0.436	28	0	80	1.0E+08
8	8	Nala-11(L)	Banaras Nala No.5	0.012	0.015	0.024	28	0	80	1.0E+08
8	12	Nala-12(L)	Hukulgang Nala	0.031	0.037	0.061	28	0	80	1.0E+08
9	17	Nala-13(L)	Nala Of Nai Basti	0.037	0.045	0.073	28	0	80	1.0E+08
10	4	Nala-6(R)	Nala Near Nakhi Ghta	0.001	0.001	0.002	28	0	80	1.0E+08
11	14	Nala-14(L)	Narokhar Nala	0.094	0.111	0.182	28	0	80	1.0E+08
13	20	Nala-15(R)	Konia SPS by-pass	0.486	0.486	0.486	28	0	150	1.0E+08

6. Reaction rate constants

In the simulation process, reaction rate constants have been determined so that calculated water quality of "Ganga at Varanasi d/s (Kaithy)" may match well with observed value. Adopted value of reaction rate constants and equation representing reaeration rate are given in Table E.

Table E Reaction rate constants

	k1 (1/day)	k3 (1/day)	kd (1/day)	SOD (g/m2-day)	Equation for k2
Varuna River	0.20	0.01	2.0	2.5	O'Connor and Dobbins equation
Ganga River	0.20	0.01	2.0	2.5	O'Connor and Dobbins equation

k1: Deoxygenation coefficient
k2: Reaeration coefficient
k3: Reduction coefficient of sedimentation
kd: Decay rate of coliform
SOD: Sediment Oxygen Demand rate

Table B.6.4 Input Data of Lucknow for Detail Simulation (QUAL2E) Model

1. Study area

The river stretch for which simulation has been carried out in this section of study is the part of Gomati River passing through Lucknow city. Along the Gomati River, a point near water quality sampling station, "Gomati River at Lucknow u/s (Water intake)", located 30 km upstream of Lucknow city has been considered as upstream boundary of simulation domain and downstream boundary is taken near the water quality sampling station, "Gomati at Lucknow d/s".

2. Reaches and elements

The domain of simulation has been segregated into discrete sets of elements each measuring 50 m in length in order to comprehensively analyze water quality change in Gomati River in Lucknow city. Summary of the stream system and its components is given in Table A. The schematic diagram of stream system is shown in Figure, which briefly explains about stream components used for QUAL2E simulation process.

Table A Summary of stream system

	Chainage (km)	No. of Reach	Element Length (m)	No. of Elements	Remarks
Gomati River	17.8	18	50	256	

3. Hydraulic condition of the river

It is assumed that the cross section of the Gomati River is trapezoidal and the side slope is assumed to be 1:0.01. The widths of both rivers are determined on the basis of satellite photograph taken on April 7, 2003. Longitudinal slope is assumed to be almost flat because the domain of simulation is as close as a ponded stream. Hydraulic parameter of the river segments is given in Table B.

Table B Hydraulic condition of the river

	Width (m)	Roughness (Manning' N)	Side slope Left bank	Side slope Right bank	Longitudinal Section Slope
Gomati River	100	0.02	1:0.01	1:0.01	0.000001

4. Upstream boundary condition

The considered values of upstream boundary condition for the system used in this simulation are given in Table C.1. The water quality parameters taken at the beginning of the calculation are that observed at water quality sampling station "Gomati at Lucknow u/s (Water intake)".

Table C.1 Boundary condition data (Present condition)

	Flow (m3/s)	Temp. (deg. C)	DO (mg/l)	BOD (mg/l)	Coliform (N/100ml)	Water quality Sampling sta.
Gomati River	12.0	28	7.0	3.0	5,000	Lucknow u/s

In case of the future simulation, following BOD value shown in Table C.2 is adopted as headwater BOD for without project and with project conditions instead of Table C.1.

Table C.2 Upstream boundary condition (in 2010 and 2030)

	Year	Condition	BOD (mg/l)	Remarks
Headwater of Gomati River	2010	Without project With project	3.5 1.8	Results of water

2030	Without project With project	5.0 2.6	on entire Ganga basin

5. Point source condition

The observed values of flow rate, water temperature and water quality parameters for various Nalas in the stream section is given in Table D. Some assumptions have been made wherever reliable data is not available. The detail on estimation of flow rate for Nalas in Lucknow has been described in Table B.6.10.

Table D Point source condition of Lucknow (Without project)

Reach No.	Element No.	Name of Point Source	Name of Nala	Flow (m3/s)			Temp (deg in C)	DO (mg/l)	BOD (mg/l)	Coliform (N/100ml)
				2001	2010	2030				
2	20	Nala-1,2	Nagaria Nala	0.000	0.006	0.030	28	0	193	
3	9	Nala-3	Sarkata Nala	0.000	0.057	0.305	28	0	193	
4	16	Nala-16	Mahesh Ganj Nala	0.000	0.000	0.000	28	0	193	1.0E+07
6	9	Nala-4&5	Pata Nala (Through Ips) Pata Nala (Through Sewer)	0.000	0.042	0.220	28	0	195	1.0E+07
6	11	Nala-17	Rooppur Khadra Nala	0.008	0.009	0.016	28	0	238	1.0E+07
7	8	Nala-6	Ner U/S Nala	0.008	0.009	0.016	28	0	193	1.0E+07
7	9	Nala-18	Mohan Meakin	0.046	0.055	0.097	28	0	285	1.0E+07
7	13	Nala-7	Ner D/S Nala	0.008	0.009	0.016	28	0	193	1.0E+07
7	14	Nala-19	Daliganj U/S Nala	0.122	0.148	0.258	28	0	215	1.0E+07
7	18	Nala-20	Daliganj D/S Nala	0.015	0.018	0.032	28	0	114	1.0E+07
7	20	Nala-8	Wazirganj Nala	0.000	0.137	0.729	28	0	193	1.0E+07
8	13	Nala-9	Ghasiyari Mandi Nala	0.000	0.032	0.169	28	0	193	1.0E+07
8	20	Nala-21	Arts College Nala	0.008	0.009	0.016	28	0	207	1.0E+07
9	9	Nala-10	China Bazar Nala	0.031	0.037	0.064	28	0	181	1.0E+07
9	19	Nala-22	Hanuman Setu Nala	0.008	0.009	0.016	28	0	207	1.0E+07
10	3	Nala-11	Laplace Nala	0.015	0.018	0.032	28	0	198	1.0E+07
11	1	Nala-23	T.G.P.S. Drain Nala	0.015	0.018	0.032	28	0	77	1.0E+07
11	7	Nala-24	Kedarnath Nala	0.031	0.037	0.064	28	0	227	1.0E+07
11	11	Nala-25	Nishatganj Nala	0.015	0.018	0.032	28	0	100	1.0E+07
12	4	Nala-12	Joplimg Road Nala	0.015	0.018	0.032	28	0	180	1.0E+07
12	5	Nala-26	Baba Ka Purwa Nala	0.000	0.000	0.000	28	0	193	1.0E+07

6. Reaction rate constants

In the simulation process, reaction rate constants have been determined so that calculated water quality of "Gomati at Lucknow d/s" may match well with observed value. Adopted value of reaction rate constants and equation representing reaeration rate are given in Table E.

Table E Reaction rate constants

	k1 (1/day)	k3 (1/day)	kd (1/day)	SOD (g/m2-day)	Equation for k2
Gomati River	0.20	0.01	2.5	3.0	O'Connor and Dobbins equation

k1: Deoxygenation coefficient
k2: Reaeration coefficient
k3: Reduction coefficient of sedimentation
kd: Decay rate of coliform
SOD: Sediment Oxygen Demand rate

Table B.6.5 Simulated Existing River Water Quality

Simulated existing river water quality at downstream boundary on each of the four cities based on the input data of Table A to D are as follows. The schematic of longitudinal change of flow rate and water quality along stretches for each of the four cities are shown in Figure A to D.

(1) Kanpur
Simulated existing river water quality for Kanpur is shown in Table A.

Table A Simulated existing water quality for Kanpur

Water quality sampling sta. on downstream boundary		DO (mg/l)	BOD (mg/l)	T. Coliform (N/100ml)
Ganga at Kanpur d/s	Observed	5.0	8.2	4.3 E+04
	Simulated	5.7	8.2	4.1 E+04

(2) Allahabad
Simulated existing river water quality for the case of Allahabad is shown in Table B.

Table B Simulated existing water quality for Allahabad

		DO (mg/l)	BOD (mg/l)	T. Coliform (N/100ml)
Ganga at d/s of Mawaiya,	Observed	7.1	3.4	3.5 E+03
Allahabad	Simulated	6.5	3.6	2.2 E+04

(3) Varanasi
Simulated existing river water quality in the case of Varanasi is shown in Table C.

Table C Simulated existing water quality in Varanasi

		DO (mg/l)	BOD (mg/l)	T. Coliform (N/100ml)
Ganga at Varanasi d/s	Observed	5.7	3.2	3.0 E+04
(Kaithy)	Simulated	5.9	2.7	2.6 E+04

(4) Lucknow
Simulated existing river water quality for the case of Lucknow is shown in Table D.

Table D Simulated existing water quality for Lucknow

		DO (mg/l)	BOD (mg/l)	T. Coliform (N/100ml)
Gomti at Lucknow d/s	Observed	0.0	16.0	5.0 E+05
	Simulated	1.9	14.9	6.4 E+05

TableB.6.6 Simulated Future River Water Quality

Results of detail future water quality analysis in the four main cities are summarized in Table 1 to 4 following this page. The simulated values of water quality in 2001, 2010 and 2030 for different cases including the cases of "without project" and "with project" is shown in Figure A to D.

Note:

Without project (1): not including on-going or sanctioned project
Without project (2): including on-going or sanctioned project
Interception rate is assumed to be as in the following table.

Interception rate of wastewater		
	In the case of "without project"	In the case of "with project"
Domestic wastewater of four main cities	Same as present condition	100 %
Industrial wastewater of four main city	Same as present condition	100 % Jajmau Tannery Complex at Kanpur
Domestic wastewater at all the cities/towns located in the basin	Same as present condition	80 %
Industrial wastewater at all the cities/towns located in the basin	0 %	0 %

Tabel 1 Kanpur

	Year	DO (mg/l)			BOD (mg/l)			T-Coliform (N/100ml)		
		Without Project (1)	Without Project (2)	With Project	Without Project (1)	Without Project (2)	With Project	Without Project (1)	Without Project (2)	With Project
Ganga River at upstream boundary	2003				3.5	-	-			
	2010	6.0	6.0	6.0	3.8	3.8	1.7	1.5 E+04	1.5 E+04	1.5 E+04
	2030				5.0	5.0	1.8			
Ganga River before confluence with Kanpur Canal	2003				3.5	-	-			
	2010	6.0	6.0	6.0	3.8	3.8	1.7	1.3 E+04	1.3 E+04	1.3 E+04
	2030				5.0	5.0	1.8			
Ganga River after confluence with Kanpur Canal	2003	5.8	-	-	8.1	-	-	1.2 E+05	-	-
	2010	5.7	5.9	6.2	10.3	7.3	1.7	1.7 E+05	1.1 E+05	1.0 E+04
	2030	5.3	5.5	6.2	17.0	14.2	1.8	3.3 E+05	2.7 E+05	1.0 E+04
Ganga River at downstream boundary (Kanpur d/s)	2003	5.4	-	-	8.2	-	-	4.1 E+04	-	-
	2010	5.2	5.8	6.4	11.3	8.6	1.5	5.8 E+04	4.1 E+04	2.0 E+03
	2030	4.6	5.0	6.4	19.3	16.9	1.6	1.1 E+05	9.1 E+04	2.0 E+03
Kanpur Canal at upstream boundary	2003				3.5	-	-			
	2010	6.0	6.0	6.0	3.8	3.8	1.7	1.5 E+04	1.5 E+04	1.5 E+04
	2030				5.0	5.0	1.8			
Kanpur Canal before confluence with Ganga River	2003	4.0	-	-	39	-	-	8.6 E+05	-	-
	2010	3.5	4.8	6.3	48	30	1.5	1.1 E+06	7.1 E+05	4.0 E+03
	2030	2.0	2.9	6.4	75	63	1.6	1.9 E+06	1.6 E+06	4.0 E+03

(Kanpur d/s): Water quality sampling station

With project (1): not including on-going project

With project (2): including on-going project, i.e. interception of wastewater in Sisamau Nala and a new 200 mld STP

Table 2 Allahabad

	Year	DO (mg/l)			BOD (mg/l)			T. Coliform (N/100ml)		
		Without Project (1)	Without Project (2)	With Project	Without Project (1)	Without Project (2)	With Project	Without Project (1)	Without Project (2)	With Project
Ganga River at upstream boundary (Ganga at Allahabad)	2003				2.7	-	-			
	2010	7.2	7.2	7.2	4.0	4.0	1.6	1.7 E+03	1.7 E+03	1.7 E+03
	2030				4.3	4.3	1.9			
Ganga River before confluence with Yamuna River	2003	6.5	-	-	3.6	-	-	2.5 E+04	-	-
	2010	6.4	6.5	6.6	5.1	3.8	1.5	3.8 E+04	7.7 E+03	5.0 E+02
	2030	6.1	6.1	6.6	8.3	7.1	2.1	8.3 E+04	5.4 E+04	5.0 E+02
Ganga River at Sangam	2003	6.6	-	-	3.7	-	-	2.2 E+04	-	-
	2010	6.5	6.5	6.6	4.5	4.1	1.3	3.0 E+04	2.0 E+04	9.0 E+02
	2030	6.2	6.3	6.7	7.4	7.0	1.9	6.7 E+04	5.6 E+04	1.1 E+03
Ganga River at downstream boundary (Ganga at d/s on Mawaiya)	2003	6.5	-	-	3.6	-	-	2.2 E+04	-	-
	2010	6.4	6.4	6.5	4.5	4.0	1.3	2.9 E+04	2.1 E+04	7.0 E+02
	2030	6.0	6.0	6.6	7.3	6.9	1.9	5.5 E+04	4.8 E+04	8.0 E+02
Yamuna River at upstream boundary	2003				3.3	-	-			
	2010	7.2	7.2	7.2	3.6	3.6	1.3	3.5 E+03	3.5 E+03	3.5 E+03
	2030				5.0	5.0	1.9			
Yamuna River before confluence with Ganga River	2003	6.6	-	-	3.8	-	-	2.4 E+04	-	-
	2010	6.6	6.6	6.7	4.3	4.2	1.2	3.1 E+04	3.0 E+04	1.4 E+03
	2030	6.4	6.3	6.8	6.9	6.9	1.8	5.9 E+04	5.8 E+04	1.4 E+03

(Ganga at Allahabad), (Ganga at d/s on Mawaiya): Name of water quality sampling station

With project (1): not including on-going project

With project (2): including on-going project, i.e. interception of wastewater in Salori Nala and Morigate Nala

Table 3 Varanasi

	Year	DO (mg/l)			BOD (mg/l)			T. Coliform (N/100ml)		
		Without Project (1)	Without Project (2)	With Project	Without Project (1)	Without Project (2)	With Project	Without Project (1)	Without Project (2)	*With Project
Ganga River	2003				3.3	-	-			
at upstream boundary	2010	5.8	5.8	5.8	3.8	3.8	1.4	3.0 E+04	3.0 E+04	3.0 E+04
(Ganga Varanasi u/s)	2030				5.3	5.3	1.9			
Ganga River	2003	5.8	-	-	3.3	-	-	1.6 E+05	-	-
near Dasashwamedh	2010	5.8	5.8	5.9	3.9	3.7	1.4	1.9 E+05	3.5 E+04	3.1 E+04
Ghat	2030	5.7	5.8	5.9	5.9	5.8	2.0	3.1 E+05	1.5 E+05	2.3 E+04
Ganga River	2003	5.8	-	-	3.3	-	-	1.7 E+05	-	-
before confluence	2010	5.8	5.8	6.0	3.8	3.7	1.4	2.6 E+05	1.6 E+05	1.0 E+05
with Varuna River	2030	5.6	5.6	6.0	6.0	5.9	1.9	6.0 E+05	5.0 E+05	1.5 E+04
Ganga River	2003	5.8	-	-	3.5	-	-	2.8 E+05	-	-
after confluence	2010	5.8	5.8	6.0	4.1	4.0	1.4	3.6 E+05	2.7 E+05	9.1 E+04
with Varuna River	2030	5.6	5.6	6.0	6.4	6.3	1.9	7.8 E+05	6.9 E+05	1.5 E+04
Ganga River	2003	5.9	-	-	2.7	-	-	2.6 E+04	-	-
at downstream boundary	2010	5.9	5.9	6.2	3.2	3.1	1.1	3.4 E+04	2.5 E+04	8.0 E+03
(Ganga at Kaithy)	2030	5.5	5.6	6.2	4.9	4.8	1.4	6.6 E+04	5.8 E+04	1.0 E+03
Varuna River	2003									
at upstream boundary	2010	5.0	5.0	5.0	5.0	5.0	5.0	8.0 E+03	8.0 E+03	8.0 E+03
	2030									
Varuna River	2003	3.1	-	-	62	-	-	3.0 E+07	-	-
before confluence	2010	2.9	2.9	6.6	63	63	1.4	3.1 E+07	3.1 E+07	1.0 E+03
with Ganga River	2030	2.2	2.2	6.6	65	65	1.4	3.2 E+07	3.2 E+07	1.0 E+03

(Ganga Varanasi u/s), (Ganga at Kaithy): Name of water quality sampling station

With project (1): not including on-going project
With project (2): including on-going project, i.e. interception of wastewater in Salori Nala and Morigate Nala

Table 4 Lucknow

	Year	DO (mg/l)			BOD (mg/l)			T. Coliform (N/100ml)		
		Without Project (1)	Without Project (2)	With Project	Without Project (1)	Without Project (2)	Without Project	Without Project (1)	Without Project (2)	With Project
Gomati River at upstream boundary	2003				3.0	-	-			
	2010	7.0	7.0	7.0	3.5	3.5	1.8	5.0 E+03	5.0 E+03	5.0 E+03
	2030				5.0	5.0	2.6			
Gomati River near Railway Bridge	2003	4.5	-	-	3.5	-	-	4.6 E+04	-	-
	2010	4.1	4.4	-	5.5	2.5	-	7.1 E+04	<1.0 E+02	-
	2030	3.6	3.7	4.7	9.3	7.3	1.9	1.8 E+05	1.2 E+05	<1.0 E+02
Gomati River at downstream Boundary (Lucknow d/s)	2003	1.9	-	-	14.9	-	-	4.0 E+05	-	-
	2010	0.6	3.5	-	18.7	2.0	-	4.1 E+05	<1.0 E+02	-
	2030	0.0	0.0	3.8	30.0	17.0	1.5	4.6 E+05	8.0 E+04	<1.0 E+02

(Lucknow d/s): Name of water quality sampling station

With project (1): not including on-going project
With project (2): including on-going project, i.e. Interception of wastewater in all Nalas that is located upstream of "Lucknow d/s"

Table B.6.7 Estimation of Flow Rate of Nalas at Kanpur

1. Flow of Nalas in 1997

(1) Wastewater generation

Total quantity of wastewater generated in 1997 was estimated at approximately 370 mld.

(2) Measured flow of Nalas

The observation of the flow rate of Nalas was carried out in 1997. According to observation, there are totally 23 Nalas in Kanpur. The total flow of 20 Nala in Ganga River basin was approximately 151 mld, and that of 3 Nalas in Pandu River basin was 62 mld, so total flow of Nalas in Kanpur was estimated to be 213 mld.

(3) Quantity of intercepted wastewater

Quantity of intercepted wastewater was estimated as approximately 160 mld. Intercepted wastewater was treated in STPs and the treated wastewater was used for agriculture. The sum of quantity of wastewater in Nalas and intercepted wastewater is 373 mld and it is almost same as generated wastewater that is 370mld.

2. Flow of Nalas in 2003

(1) Wastewater generation

The estimated urban district population of Kanpur in 2003 is approximately 2,990,000; it increased by approximately 14% in comparison to 2,630,000 in 1997. It is assumed that wastewater generation also increased proportionately during this period, and wastewater generation in 2003 is estimated to be 421 mld.

(2) Quantity of intercepted wastewater

It is assumed that the quantity of intercepted wastewater in 2003 is 160 mld that equals to that in 1997.

(3) Estimated flow of Nalas

The flow rate of Nala is assumed as the difference between the generated wastewater and intercepted wastewater. The flow rate of each Nala was obtained by proportional distributing at the flow rate of 1997.

(4) Industrial wastewater generation of Jajmau Tannery Complex

The quantity of wastewater generated at Jajmau Tannery Complex is estimated at 12.8 mld. Approximately, 3.3 mld of wastewater is discharged into Ganga River via Nalas without any treatment, and approximately 9.5 mld is treated at CETP then discharged into Ganga River.

3. Flow of Nalas in 2010 and 2030 (without project)

(1) Wastewater generation

Wastewater generation in 2010 and 2030 was calculated on the assumption that the wastewater generation corresponds to that of increased population between the target years and 2003. The wastewater generation in 2010 and 2030 is shown in Table A.

Table A Wastewater generation in 2010and 2030

	2003	2010	2030
Urban population	2,990,000	3,480,000	5,340,000
Wastewater generation (mld)	421	488	753
Ratio	1.00	1.16	1.79

(2) Quantity of intercepted wastewater

a) In the case of excluding on-going project

It is assumed that quantity of intercepted wastewater in 2010 and 2030 is 160 mld, which equals to that in 2003.

b) In the case of including on-going project

A new 200 mld-STP will be completed by 2010 and total capacity of STPs will become 371 mld. It is assumed that all wastewater in Pandu River basin that is approximately 89 mld will be intercepted because the new STP is located in Pandu River basin, and remainining capacity that is 111 mld will be made use for intercepting wastewater in Sisamau Nala that is the biggest un-intercepted Nala in Kanpur. In the case of 2030, it is assumed that quantity of intercepted wastewater is same as that of 2010.

(3) Estimated flow of Nalas

The flow rate of Nala is assumed as the difference between the generated wastewater and intercepted wastewater. The flow rate of each Nala was obtained by proportional distributing at the flow rate of 1997.

(4) Industrial wastewater generation

It is assumed that the increase rate of wastewater generation of Jajmau Tannery Complex would be 4% per year between 2003 and 2010, and 2% per year between 2010 and 2030. It is assumed that capacity of CETP in 2010 and 2030 is equal to that in 2003. Industrial wastewater generation of Jajmau Tannery Complex in 2010 and 2030 is shown in Table B.

Table B Industrial wastewater generation of Jajmau Tannery Complex

	2003	2010	2030
Discharge directly to Ganga River (mld)	3.30	7.27	15.48
Discharge via CETP (mld)	9.52	9.52	9.52
Total	12.82	16.79	25.00

Flow of Nalas in the case of “without project" is shown in Table C.

4. Flow of Nalas in 2010 and 2030 (with project)

(1) Wastewater generation

It is assumed that quantity of wastewater generated is same as in the case of “without project”.

(2) The interception rate in 2010 and 2030

A new 200 mld-STP will be completed by 2010 and total capacity of STPs will become 371 mld, so interception rate will be approximately 76%. But because of the un-intercepted wastewater, water quality at Kanpur d/s does not satisfy water quality standard. Therefore, almost complete interception is necessary to satisfy the standard, so it is assumed that interception rate in 2010 will be 100% in the case of “with project”. For the same reason, it is also assumed that interception rate in 2030 will be 100% in the case of “with project”.

(3) Industrial wastewater generation

It is assumed that untreated industrial wastewater discharge into Ganga River will become zero by 2010 by making full use of existing CETP and whole industrial wastewater will be treated in augmented CETP by 2030.

Flow of Nalas in the case of “with project” is shown in Table D.

Table B.6.8 Estimation of Flow Rate of Nalas at Allahabad

1. Flow of Nalas in 1998

(1) Wastewater generation

Total quantity of wastewater generated in 1998 was estimated as approximately 209 mld.

(2) Measured flow of Nalas

The observation of the flow rate of Nalas was carried out in 1998-99. According to observation, there are totally 61 Nalas in Allahabad. The total flow of 47 Nala in Ganga River basin was approximately 106 mld, and that of 14 Nalas in Yamuna River basin was 103 mld, so total flow of Nalas in Allahabad was estimated as 209 mld.

(3) Quantity of intercepted wastewater

Quantity of intercepted wastewater was almost zero in 1998.

2. Flow of Nalas in 2003

(1) Wastewater generation

The estimated urban district population of the Allahabad City in 2003 is approximately 1,290,000; it increases approximately by 14% in comparison to 1,130,000 in 1998. It is assumed that wastewater generation would also increase in same proportion in this period, and therefore wastewater generation in 2003 is estimated as 239 mld.

(2) Quantity of intercepted wastewater

It is assumed that the quantity of intercepted wastewater in 2003 is 90 mld.

(3) Estimated flow of Nalas

The flow rate of Nala is assumed as the difference between the generated wastewater and intercepted wastewater. The flow rate of each Nala was obtained by proportional distributing at the flow rate of 1998.

3. Flow of Nalas in 2010 and 2030 (without project)

(1) Wastewater generation

Wastewater generation in 2010 and 2030 was calculated on the assumption that the wastewater generation corresponds to that of increased population between the target years and 2003. The wastewater generation in 2010 and 2030 is shown in Table A.

Table A Wastewater generation in 2010and 2030

	2003	2010	2030
Urban population	1,290,000	1,540,000	2,580,000
Wastewater generation (mld)	239	284	478
Ratio	1.00	1.19	2.00

(2) Quantity of intercepted wastewater

a) In the case of excluding on-going project

It is assumed that quantity of intercepted wastewater in 2010 and 2030 is 90 mld, which is equal to that in 2003.

b) In the case of including on-going project

Wastewater in Salori Nala and Morigate Nala will be intercepted additionally by 2010. In the case of 2030, it is assumed that quantity of intercepted wastewater is same as that of 2010.

(3) Estimated flow of Nalas

The flow rate of Nala is assumed as the difference between the generated wastewater and intercepted wastewater. The flow rate of each Nala was obtained by proportional distributing at the flow rate of 1998.

Flow of Nalas in the case of “without project" is shown in Table B.

4. Flow of Nalas in 2010 and 2030 (with project)

(1) Wastewater generation

It is assumed that quantity of wastewater generated is same as in the case of “without project”.

(2) The interception rate in 2010 and 2030

Wastewater in two Nalas will be intercepted additionally by 2010 but water quality at Allahabad d/s does not satisfy desired water quality standard. So it is assumed that interception rate in 2010 would be 100% in the case of “with project”. Due to same reason, it is assumed that interception rate in 2030 would also be 100% in the case of “with project”.

Flow of Nalas in the case of “with project" is shown in Table C.

Table B.6.9 Estimation of Flow Rate of Nalas at Varanasi

1. Flow of Nalas in 2000

(1) Wastewater generation

Total quantity of wastewater generated in 2000 was estimated as approximately 240 mld.

(2) Measured flow of Nalas

The observation of the flow rate of Nalas was carried out in 2000. According to observation, there are totally 28 Nalas in Varanasi. The total flow of 14 Nala in Ganga River basin was approximately 180 mld, and that of 14 Nalas in Varuna River basin was 60 mld, so total flow of Nalas in Allahabad was estimated as 240 mld.

(3) Quantity of intercepted wastewater

Quantity of intercepted wastewater was almost zero in 2000.

2. Flow of Nalas in 2003

(1) Wastewater generation

The estimated urban district population of the Varanasi City in 2003 is approximately 1,340,000, and it increases approximately by 8% in comparison to 1,240,000 in 2000. It is assumed that wastewater generation also increased in same proportion in this period, and wastewater generation in 2003 is estimated as 259 mld.

(2) Quantity of intercepted wastewater

It is assumed that the quantity of intercepted wastewater in 2003 is 122 mld.

(3) Estimated flow of Nalas

The flow rate of Nala is assumed as the difference between the generated wastewater and intercepted wastewater. The flow rate of each Nala was obtained by proportional distributing at the flow rate of 2000.

3. Flow of Nalas in 2010 and 2030 (without project)

(1) Wastewater generation

Wastewater generation in 2010 and 2030 was calculated on the assumption that the wastewater generation corresponds to that of increased population between the target years and 2003. The wastewater generation in 2010 and 2030 is shown in Table A.

Table A Wastewater generation in 2010and 2030

	2003	2010	2030
Urban population	1,340,000	1,590,000	2,600,000
Wastewater generation (mld)	259	308	502
Ratio	1.00	1.19	1.94

(2) Quantity of intercepted wastewater

a) In the case of excluding on-going project

It is assumed that quantity of intercepted wastewater in 2010 and 2030 is 122 mld, which is equal to that in 2003.

b) In the case of including on-going project

Wastewater in Assi Nala will be intercepted additionally by 2010. In the case of 2030, it is assumed that quantity of intercepted wastewater is same as that of 2010.

(3) Estimated flow of Nalas

The flow rate of Nala is assumed as the difference between the generated wastewater and intercepted wastewater. The flow rate of each Nala was obtained by proportional distributing at the flow rate of 2000.

Flow of Nalas in the case of “without project" is shown in Table B.

4. Flow of Nalas in 2010 and 2030 (with project)

(1) Wastewater generation

It is assumed that quantity of wastewater generated is same as in the case of “without project”.

(2) The interception rate in 2010 and 2030

Wastewater in Assi Nalas will be intercepted additionally by 2010 but water quality at Allahabad d/s does not satisfy the desired water quality standard. Therefore, it is assumed that interception rate in 2010 would be 100% in the case of “with project”. For the same reason, it is assumed that interception rate in 2030 would also be 100% in the case of “with project”.

Flow of Nalas in the case of “with project" is shown in Table C.

Table B.6.10 Estimation of Flow Rate of Nalas at Lucknow

1. Flow of Nalas in 1993

(1) Wastewater generation

Total quantity of wastewater generated in 1993 was estimated as approximately 229 mld.

(2) Measured flow of Nalas

The observation of the flow rate of Nalas was carried out in 1993. According to observation, there are totally 28 Nalas in Lucknow. The total flow of all 28 Nalas in Gomati River basin was approximately 180 mld.

(3) Quantity of intercepted wastewater

Quantity of intercepted wastewater was almost zero in 1993.

2. Flow of Nalas in 2003

(1) Wastewater generation

The estimated urban district population of the Lucknow City in 2003 is approximately 2,450,000; it increases approximately by 32% in comparison to 1,850,000 in 1993. It is assumed that wastewater generation also increased in the same proportion in this period, and wastewater generation in 2003 is estimated as 302 mld.

(2) Quantity of intercepted wastewater

It is assumed that the quantity of intercepted wastewater in 2003 is 113 mld.

(3) Estimated flow of Nalas

The flow rate of Nala is assumed as the difference between the generated wastewater and intercepted wastewater. The flow rate of each Nala was obtained by proportional distributing at the flow rate of 1993.

3. Flow of Nalas in 2010 and 2030 (without project)

(1) Wastewater generation

Wastewater generation in 2010 and 2030 was calculated on the assumption that the wastewater generation corresponds to that of increased population between the target years and 2003. The wastewater generation in 2010 and 2030 is shown in Table A.

Table A Wastewater generation in 2010and 2030

	2003	2010	2030
Urban population	2,450,000	2,970,000	5,180,000
Wastewater generation (mld)	302	365	637
Ratio	1.00	1.21	2.11

(2) Quantity of intercepted wastewater

a) In the case of excluding on-going project

It is assumed that quantity of intercepted wastewater in 2010 and 2030 is 113 mld, which is equal to that in 2003.

b) In the case of including on-going project

A new 345 mld-STP will be completed by 2010 and total capacity of STPs will become 412 mld, which exceeds wastewater generation of 365 mld in 2010. Therefore, wastewater in all Nalas will be intercepted completely and be discharged into STPs.

(3) Estimated flow of Nalas

The flow rate of Nala is assumed as the difference between the generated wastewater and intercepted wastewater. The flow rate of each Nala was obtained by proportional distributing at the flow rate of 1993

Flow of Nalas in the case of "without project" is shown in Table B.

4. Flow of Nalas in 2010 and 2030 (with project)

(1) Wastewater generation

It is assumed that quantity of wastewater generated is same as in the case of "without project".

(2) The interception rate in 2010 and 2030

A new 345 mld-STP will be completed by 2010 and total capacity of STPs will become 412 mld, which exceeds wastewater generation of 365 mld in 2010. Therefore, wastewater in all Nalas will be intercepted completely and be discharged into STPs or there would not be any untreated wastewater that is discharged into Gomati River in 2010. So there is no additional proposal on intercepting wastewater in Nalas for 2010 "with project". In the case of 2030, wastewater generation will increase thereby un-intercepted wastewater will increase and therefore water quality at Lucknow d/s would not satisfy the desired standard. So it is assumed that interception rate in 2030 would be 100% in the case of "with project".

Flow of Nalas in the case of "with project" is shown in Table C.

Table B.7.1 Future Population and Reaching Pollution Load

No.	Sub-Basin Name	City/Town	Urban Population 2030	Reaching Pollution Load (BOD:kg/d)	
				To Allahabad	To Trighat
1	Upper Yamuna II	Delhi	30,254,636	1,902	700
2	Midle Ganga II	Kanpur	5,183,257	27,299	10,053
3	Upper Gomati	Lucknow	4,216,030	-	16,859
4	Chambal	Indore	3,219,541	214	79
5	Upper Yamuna III	Agra	2,803,221	4,261	1,569
6	Betwa	Bhopal	2,573,667	180	66
7	Upper Yamuna III	Faridabad Complex	2,550,205	1,651	608
8	Middle Ganga IV	Varanasi	2,283,340	-	20,725
9	Hindon	Ghaziabad	2,235,667	441	162
10	Middle Ganga III	Allahabad	2,184,890	-	10,148
11	Kalinadi	Meerut	2,175,579	548	202
12	Sind	Gwalior	1,710,996	334	123
13	Hindon	Muzzafarnagar	1,626,892	106	39
14	Chambal	Kota	1,525,002	531	196
15	Ramganga	Barielly	1,442,239	1,980	729
16	Ramganga	Moradabad	1,268,114	1,928	710
17	Betwa	Jhansi	1,248,539	847	312
18	Upper Yamuna III	Firozabad	1,117,913	2,678	986
19	Upper Yamuna III	Mathura	1,048,297	1,375	506
20	Betwa	Sagar	1,028,970	180	66
21	Upper Ganga I	Dehra Dun	981,821	-	-
22	Upper Yamuna III	Noida	915,863	305	112
23	Ramganga	Rampur	864,115	1,175	432
24	Hindon	Saharanpur	832,768	12	5
25	Upper Yamuna II	Hisar	831,778	7	3
26	Upper Yamuna II	Yamunanagar	821,205	12	4
27	Upper Yamuna II	Panipat	819,077	26	10
28	Upper Yamuna III	Gurgaon	771,845	457	168
29	Chambal	Bhilwara	754,801	112	41
30	Chambal	Ujjain	749,364	63	23
31	Upper Yamuna III	Bharatpur	735,372	1,258	463
32	Upper Yamuna II	Rohtak	688,760	50	18
33	Tons	Satna	670,927	-	3,764
34	Upper Ganga I	Haridwar	646,211	-	-
35	Ramganga	Shahjahanpur	638,939	74	27
36	Upper Yamuna II	Karnal	596,965	2	1
37	Sind	Bhind	588,386	556	205
38	Upper Yamuna II	Sonepat	571,179	40	17
39	Tons	Rewa	557,627	-	3,166
40	Upper Yamuna III	Etawah	556,267	1,274	469
41	Chambal	Chittaurgarh	526,131	74	27
42	Kalinadi	Hapur	513,209	187	69
43	Upper Ganga II	Farrukabad cum Fate	499,898	1,809	666
44	Upper Yamuna III	Sirsa	499,640	2	1
45	Sai	Rai-Bareilly	492,741	-	2,543
46	Chambal	Tonk	460,666	154	57
47	Hindon	Modinagar	459,713	102	38
48	Upper Yamuna II	Bhiwani	459,506	18	7
49	Betwa	Vidisha	452,885	52	19
50	Lower Gomati	Barabanki	446,146	-	1,150
51	Kalinadi	Bulandshahr	430,560	215	79
52	Lowe Yamuna	Fatehpur	427,102	1,818	684
53	Ken	Banda	424,600	781	287
54	Middle Ganga II	Unnao	418,576	3,116	1,148
55	Middle Ganga I	Kannauj	417,442	1,731	638
56	Sind	Shivpuri	417,029	15	6
57	Upper Ganga II	Budaun	409,442	937	345
58	Middle Ganga IV	Mirzapur cum Vindhac	406,278	-	3,744
59	Chambal	Dewas	401,345	38	14
60	Upper Yamuna II	Jind	395,135	8	3
61	Chambal	Sawai Madhopur	386,887	215	79
62	Upper Yamuna II	Kaithal	382,723	8	3
63	Betwa	Tikamgarh	382,275	145	54
64	Upper Gomati	Sitapur	374,693	-	293

Table B.7.1 Future Population and Reaching Pollution Load

No.	Sub-Basin Name	City/Town	Urban Population 2030	Reaching Pollution Load (BOD:kg/d)	
				To Allahabad	To Trighat
65	Ramganga	Amroha	369,549	434	160
66	Upper Ganga II	Sambhal	367,695	513	189
67	Hindon	Shamli	339,926	30	10
68	Ramganga	Kashipur	339,250	388	143
69	Chambal	Bundi	325,654	28	42
70	Upper Ganga II	Najibabad	315,461	222	82
71	Chambal	Baran	315,222	108	40
72	Chambal	Dholpur	306,993	365	134
73	Sind	Morena	306,435	74	27
74	Upper Yamuna II	Kairana	303,953	24	9
75	Lower Gomati	Jaunpur	303,835	-	4,139
76	Upper Yamuna II	Bahadurgarh	292,456	45	17
77	Kalinadi	Kasganj	289,620	341	143
78	Kalinadi	Mawana	286,411	-	-
79	Upper Yamuna II	Rewari	284,877	244	90
80	Upper Ganga II	Bijnor	275,432	254	94
81	Upper Yamuna II	Baraut	272,342	34	13
82	Upper Ganga II	Chandausi	270,778	428	157
83	Upper Yamuna III	Hathras	269,825	438	161
84	Ken	Mahoba	269,329	52	19
85	Betwa	Orai	265,540	496	183
86	Sai	Bela Pratapgarh	259,763	-	3,127
87	Ken	Damoh	256,471	7	2
88	Betwa	Lalitpur	255,296	79	29
89	Middle Ganga II	Mainpuri	251,532	597	220
90	Kalinadi	Etah	250,747	338	124
91	Ramganga	Haldwani cum Kathgodam	248,922	265	98
92	Upper Yamuna I	Shimla	245,245	-	-
93	Betwa	Auraiya	244,247	143	53
94	Sind	Datia	239,328	34	12
95	Chambal	Guna	238,610	50	19
96	Sai	Hardoi	225,140	-	352
97	Hindon	Deoband	222,316	11	4
98	Chambal	Mandsaur	215,929	38	14
99	Ramganga	Nagina	210,829	148	55
100	Upper Yamuna III	Palwal	210,104	156	58
101	Upper Yamuna III	Shikohabad	209,317	528	193
102	Chambal	Nagda	192,235	148	55
103	Ken	Chattarpur	189,697	21	8
104	Middle Ganga IV	Bhadohi	186,012	-	2,348
105	Lower Yamuna River	Chandpur	183,490	184	68
106	Lower Gomati	Sultanpur	180,153	-	1,474
107	Kalinadi	Khurja	177,125	211	78
108	Chambal	Sehore	162,020	9	3
109	Upper Yamuna III	Narnaul	157,022	140	52
110	Upper Yamuna III	Hindaun	152,611	211	78
111	Upper Gomati	Nawalgarh	135,175	-	33
112	Chambal	Jaora	126,397	18	7
113	Upper Ganga I	Rishikesh	125,670	-	-
114	Sai	Lakhimpur	117,232	-	44
115	Ramganga	Shahabad	114,490	99	36
116	Upper Ganga II	Sahaswan	104,749	231	85
117	Ramganga	Rudrapur	50,983	57	21
118	Ramganga	Shahabad	114,490	99	36
119	Upper Ganga II	Sahaswan	104,749	231	85
120	Ramganga	Rudrapur	50,983	57	21

Table B.7.2 Monitoring Station Wise Relation between Pollution Reduction and Future Water Quality

Case No.	Monitoring Point	Reduction Ratio BOD Pollution Load (%) and Predicted BOD Value (mg/l)				Target Cities for Pollution Load Reduction
		Without Project	65	70	80	
I	Kanpur U/s (Ganga)	5.4	3.2	3.0	2.7	10 cities located in apstream area of Kanpur (Ganga): Barielly, Moradabad, Farrukabad cum Fate, Kannauj, Rampur, Budaun Meerut, Sambhal, Amroha and Chandausi.
II	Kanpur U/s (Ganga)	5.4	2.7	2.5	2.1	18 cities located in apstream area of Kanpur (Ganga): Kashipur, Etah, Haldwani cum Kathgodam, Bijnor, Sahaswan, Najibabad, Bulandshahr and Hapur including above 10 cities.
III	Allahabad U/s (Ganga)	6.3	3.5	3.3	2.9	18 cities located in apstream area of Allahabad: Kanpur, Agra, Unnao, Firozabad, Brielly, Moradabad, Delhi, Fatehpur, Farrukabad cum Fate, Kannauj, Faridabad Complex, Mathura, Etawah, Bharatpur, Rampur, Budaun Jhansi, Banda.
	Allahabad U/s (Yamuna)	6.1	3.7	3.6	3.3	
IV	Allahabad U/s (Ganga)	6.3	3.4	3.2	2.8	28 cities located in apstream area of Allahabad: Bhind, Meerut, Kota, Shikohabad, Sambhal, Orai, Gurgaon, Ghaziabad and Hathras including above 18 cities.
	Allahabad U/s (Yamuna)	6.1	3.3	3.1	2.7	
V	Allahabad U/s (Ganga)	6.3	3.2	3.0	2.5	38 cities located in apstream area of Allahabad: Amroha, Chandausi, Kashipur, Dholpur, Kasganj, Etah, Gwalior, Noida and Haldwani cum Kathgodam including above 28 cities.
	Allahabad U/s (Yamuna)	6.1	3.2	3.0	2.6	
VI	Allahabad U/s (Ganga)	6.3	3.2	2.9	2.3	48 cities located in apstream area of Allahabad: Bijnor, Shahaswan, Najibabad, Sawai Madhopur, Indore, Khurja, Bulandshahr, Hindayn and Hapur including above 38 cities.
	Allahabad U/s (Yamuna)	6.1	3.2	2.9	2.5	
VII	Varanasi U/s (Ganga)	6.0	3.3	3.2	2.8	24 cities located in apstream area of Varanasi: Allahabad, Kanpur, Satna, Rewa, Bhadehi, Mirzapur cum Vindhac, Agra, Unnao, Firozabad, Brielly, Moradabad, Delhi, Fatehpur, Farrukabad cum Fate, Kannauj, Faridabad Complex, Mathura, Etawah, Bharatpur, Rampur, Budaun, Jhansi, Banda.
VIII	Varanasi U/s (Ganga)	6.0	3.1	2.9	2.5	33 cities located in apstream area of Varanasi: Bhind, Meerut, Kota, Shikohabad, Sambhal, Orai, Gurgaon and Ghaziabad and Hathras including above 24 cities.

Note: (shaded cells) : Satisactory for Criteria (BOD 3 mg/l)

Table B. 7.3 Necessary Pollution Reduction for Objective 4 Cities

No.	Sub-Basin Name	City/Town	Urban Population 2030	Reaching Pollution Load (BOD:kg/d)		Existing STP (2001)		*Necessity for Sewerage Development	Remarks
				To Allahabad	To Trighat	STP	Treatment Capacity (MLD)		
1	Upper Yamuna II	Delhi	30,254,636	1,902	700	○	1,927	B	YAP
2	Midle Ganga II	Kanpur	5,183,257	27,299	10,053	○	170	B	GAP
3	Upper Gomati	Lucknow	4,216,030	-	16,859	○	42	B	Gomati AP
4	Upper Yamuna III	Agra	2,803,221	4,261	1,569	○	90	B	YAP
5	Upper Yamuna III	Faridabad Complex	2,550,205	1,651	608	○	115	B	YAP
6	Middle Ganga IV	Varanasi	2,283,340	-	20,725	○	102	B	GAP
7	Hindon	Ghaziabad	2,235,667	441	162	○	129	B	YAP
8	Middle Ganga III	Allahabad	2,184,890	-	10,148	○	131	B	GAP
9	Kalinadi	Meerut	2,175,579	548	202			A	
10	Chambal	Kota	1,525,002	531	196			A	
11	Ramganga	Barielly	1,442,239	1,980	729			A	
12	Ramganga	Moradabad	1,268,114	1,928	710			A	
13	Betwa	Jhansi	1,248,539	847	312			A	
14	Upper Yamuna III	Firozabad	1,117,913	2,678	986			A	
15	Upper Yamuna III	Mathura	1,048,297	1,375	506	○	28	B	YAP
16	Ramganga	Rampur	864,115	1,175	432			A	
17	Upper Yamuna III	Gurgaon	771,845	457	168	○	30	B	YAP
18	Upper Yamuna III	Bharatpur	735,372	1,258	463			A	
19	Tons	Satna	670,927	-	3,764			A	
20	Sind	Bhind	588,386	556	205			A	
21	Tons	Rewa	557,627	-	3,166			A	
22	Upper Yamuna III	Etawah	556,267	1,274	469	○	10	A	YAP
23	Upper Ganga II	Farrukabad cum Fate	499,898	1,809	666	○	4	A	GAP
24	Lowe Yamuna	Fatehpur	427,102	1,818	684			A	
25	Ken	Banda	424,600	781	287			A	
26	Middle Ganga II	Unnao	418,576	3,116	1,148			A	
27	Middle Ganga I	Kannauj	417,442	1,731	638			A	
28	Upper Ganga II	Budaun	409,442	937	345			A	
29	Middle Ganga IV	Mirzapur cum Vindhac	406,278	-	3,744	○	14	B	
30	Upper Ganga II	Sambhal	367,695	513	189			A	
31	Upper Ganga II	Chandausi	270,778	428	157			A	
32	Upper Yamuna III	Hathras	269,825	438	161			A	
33	Betwa	Orai	265,540	496	183			A	
34	Upper Yamuna III	Shikohabad	209,317	528	193			A	
35	Middle Ganga IV	Bhadohi	186,012	-	2,348			A	

Note* A: First priority for sewerage development, B: Necessary to improve the current sewarage treatment capacity planned by GAP, YAP and this Study

Table B.8.1 Relevant Laboratories Involved in Water Quality Monitoring

Name	Institution	Location	Remarks
CPCB Central Laboratory	CPCB	New Delhi	
		Kanpur	
		Kolkata	
UP-SPCB Laboratory	U.P. SPCB	Kanpur	
		Allahabad	
		Varanasi	
		Lucknow	
		Agra	
		Aligarh	
		Bareilly	
		Faizabad	
		Gorakhpur	
		Ghaziabad	
		Jhansi	
		Moradabad	
		Meerut	
		Mathura	
		Noida	
		Raibareily	
		Saharanpur	
Bihar-SPCB Laboratory	Bihar SPCB	Patna	
		Bhagalpur	
		Begusarai	
		Muzaffarpur	
West Bengal-SPCB Laboratory	West Bengal SPCB	Kolkata	
		Hoogly	
		24 Pargana North	
		Durgapur	
		Midnapur	
		Siliguri	
Rajasthan SPCB Laboratory	Rajasthan SPCB	Jaipur	
		Udaipur	
		Alwar	
		Kota	
Madhya Pradesh SPCB Laboratory	Madhya Pradesh	Bhopal	
		Rewa	
		Satna	
		Indore	
		Ujjain	
		Gwalior	
		Guna	
Haryana SPCB Laboratory	Haryana	Panchkula	
		Yamunanagar	
		Panipat	
		Sonepat	
Himachal Pradesh SPCB Laboratory	Himachal Pradesh	Shimla	
		Parwanoo	

Table B.8.2 Coverage Area and Resposibility of each Laboratory

Name	Coverage Area	Responsible Activities
CPCB Central Laboratory	Uttaranchal, Uttar Pradesh,Bihar,West Bengal,Rajasthan,Madhya Pradesh,Haryana,Hmachal Pradesh	Sampling, Analysis, Data Processing, Report Preparation, Identification of polluted stretches, Preparation of action plan for restoration of water quality
U.P.SPCB Kanpur Laboratory	Kanpur,Allahabad,Varanasi,	Sampling, Analysis, Data Processing
	Lucknow,Agra,Aligarh,Bareilly,	
	Faizabad,Gorakhpur,Ghaziabad	
	Jhansi,Moradabad,Meerut,Mathura,	
	Noida,Raibareily,	
	Saharanpur	
Bihar SPCB Laboratory	Patna,Bhagalpur,Begusarai,	Sampling, Analysis, Data Processing
	Muzaffarpur	
West Bengal SPCB Laboratory	Kolkata,Hoogly,24 Pargana North,	Sampling, Analysis, Data Processing
	Durgapur,Midnapur,Siliguri	
Rajasthan SPCB Laboratory	Jaipur,Udaipur,Alwar,Kota	Sampling, Analysis, Data Processing
Madhya Pradesh SPCB Laboratory	Bhopal,Rewa,Satna,Indore,Ujjain,	Sampling, Analysis, Data Processing
	Gwalior,Guna,	
Haryana SPCB Laboratory	Panchkula,Yamunanagar,Panipat,	Sampling, Analysis, Data Processing
	Sonepat	
Himachal Pradesh SPCB Laboratory	Shimla	Sampling, Analysis, Data Processing
	Parwanoo	

Table B.8.3 Existing/Required Analytical Equipment and Sampling Tools in the CPCB's Laboratory

Code No.	Equipment Name	CPCB Central Laboratory			Necessuty of Additioal Equipment	Remarks
		Nos.		Period		
		Working	Not functioned			
C. Commom Analytical Equipment						
C-4	Atomic Absorption Spectrophotometer	2	1	Very old	1	Very important to analyze heavy metals
C-5	Flame Photometer	1				
C-6A	UV/VIS Spectrophotometer (Double Beam)	1		Very old	1	Basic Equipment
C-6B	VIS Spectrophotometer (Double Beam)	3		Very old		
C-7	GC-MS	1				
C-8	GC	1	1	Very old	1	Very important to analyze pesticides
C-9	AOX Meter	1				
C-12	Ion Chromatograph	1				
C-13	Stereoscopic Microscope	1				
C-14	Microscope	2				
C-15	Handy Type pH Meter	-			2	Basic Equipment
C-16	Laboratory pH Meter	1			1	Basic Equipment
C-18	Mercury Analyzer	1				
C-19	Glass Wares Set	Equiped				
C-20	Reagents (w/Standard Samples)	Equiped				
G. General Laboratory Equipment						
G-1	Semi-Micro Analysis Balance	1				
G-2	Macro Analysis Balance	1				
G-4	Centrifuge	1	1			
G-6	Muffle Furnace (for Organic)	1				
G-8	Constant Temperature Oven	1				
G-9	Middle Temperature Oven	2				
G-12	Autoclave (Vertical Type)	2				
G-13	Incubator	3				
G-15	Rotary Evaporator	2	2			
G-24	High Speed Homogenizer	1				
G-25	Hot Plate (Small)	3				
G-26	Magnetic Stirrer (w/Hop Plate)	9				
G-28	Constant Temperature Water Bath	1				
G-32	Water Bath	1				
G-38	Ion Exchanger	1				
G-40	Clean Bench	1				
G-42	Draft Chamber	2				
G-43	AC Stabilizer	2				

Table B.8.3 Existing/Required Analytical Equipment and Sampling Tools in the CPCB's Laboratory

Code No.	Equipment Name	CPCB Central Laboratory			Necessuty of Additioal Equipment	Remarks
		Nos.		Period		
G-46	Refrigerator	6				
G-49	Copy Machine	1				
G-57	Colony Counter	1				
W. Water Quality Monitoring Equipment						
W-1	Total Organic Carbon Analyzer	1		Very old		
W-2	Handy Type DO Meter		5		2	Basic Equipment for field survey
W-3	Laboratory Type DO Meter				1	Basic Equipment
W-4&5	Kjeldhal Decomposition Unit	1				
W-6&7	Tint Meter/Turbidity Meter	1			1	Basic Equipment
W-8	Handy Type Conductivity/Temp. Meter	2			2	Basic Equipment for field survey
W-9	Conductivity Meter	1				
W-11	Water Sampler(Bandon Type)	1				
W-13	Ekman Barge Grab Sampler	5				
W-14	Plankton Net	2				
W-15	Distillation Apparatus(for CN,NH4,F)	each 1				
W-18	BOD Analyzing Apparatus(Incubator)	2				
W-19	COD Analyzing Apparatus w/Closed Reflux (Cr)	1				
W-22	Wastewater Treatment Equipment				1	Wastewater from Laboratory sholde be treated.
W-26	Water Quality Analysis (Temp,pH,Conductivity,Turbidity, and	1				
W-30	Automatic Titrator	1				
W-31	Ion Analyzer (Electrode Set)	1				
W-32	Portable Water Quality Test Kit	1				
W-33	Vacuum Filter w/Manufold	2				

Table B.8.4 Existing Equipments & Sampling Tools in the U.P.PCB's Laboratories

Code No.	Equipment Name	SPCB's Laboratories				STP & CETP Lab
		Kanpur	Lucknow	Allahabad	Varanasi	
Common Analytical Equipments						
C-5	Atomic Absorption Spectrophotometer	1	2	1	1	-
C-6	UV/VIS Spectrophotometer (Double Beam)	2	2	2	2	-
C-7	Gas-chromatography	1	1	1	1	-
C-12	Ion Chromatograph	1	0	1	1	-
C-13	Stereoscopic Microscope	0	1	0	0	-
C-14	Microscope	0	2	0	0	-
C-15	Handy type pH Meter	0	3	0	0	-
C-16	Laboratory type pH Meter	1	3	2	2	Equiped
C-18	Mercury analyzer	0	1	1	1	-
C-19	Glass ware sets	Equiped	Equiped	Equiped	Equiped	Equiped
C-20	Reagents (W/standard samples)	Equiped	Equiped	Equiped	Equiped	Equiped
G. General Laboratory Equipment						
G-1	Semi-Micro analysis Balance	3	1	1	1	-
G-2	Macro-analysis Balance	0	2	1	1	-
G-4	Tabletop type Centrifuge	0	2	0	0	-
G-6	Muffle furnace (for Organic)	1	2	1	1	-
G-8	Constant temperature Oven	1	1	1	1	Equiped
G-9	Middle temperature Oven	1	1	1	1	-
G-12	Autoclave-Vertical type	1	2	1	1	-
G-13	Incubator	2	3	1	1	Equiped
G-14	Low temperature Incubator	0	1	0	0	-
G-15	Rotary Evaporator	0	2	0	0	-
G-20	Shaker (Middle)	0	2	0	0	-
G-23	Mixer	1	2	1	1	Equiped
G-24	High speed Homogenizer	0	1	0	0	-
G-25	Hot plate (small)	2	3	2	2	Equiped
G-26	Magnetic stirrer (w/hot plate)	1	3	1	1	-
G-27	Multi Magnetic stirrer (w/magnet plate)	1	3	1	1	-
G-32	Water Bath	1	3	1	1	Equiped
G-33	Cooling unit	0	3	0	0	-
G-38	Ion Exchanger	1	1	1	1	-

Table B.8.4 Existing Equipments & Sampling Tools in the U.P.PCB's Laboratories

Code No.	Equipment Name	SPCB's Laboratories				STP & CETP Lab
		Kanpur	Lucknow	Allahabad	Varanasi	
G-39	Water Distillation unit	1	2	1	1	Equiped
G-40	Clean Bench	0	0	0	0	-
G-41	Draft Chamber W/ Gas Cleaning device	0	0	0	0	-
g-42	Draft chamber	1	-	-	-	-
G-43	AC stabilizer	1	2	1	1	Equiped
G-44	Refrigerator	1	2	1	1	Equiped
G-45	Freezer	-	1	-	-	-
G-48	Copy Machine	-	1	-	-	-
G-57	Colony Counter	1	1	1	1	-
W.Water Quality Monitoring Equipment						
W-1	Total Organic Carbon analyzer	1	1	1	1	-
W-2	Handy type DO meter	1	2	1	1	-
W-3	Laboratory type DO meter	2	3	2	2	-
W-4&5	Total Nitrogen/total Phosphate analyzer	1	3	1	1	-
W-6$7	Tint Meter/ turbidity meter	0	1	0	0	Equiped
W-8	Handy type conductivity / Temp meter	0	2	0	0	-
W-9	Conductivity meter	1	3	1	1	Equiped
W-11A	Water sampler (hyroht type)	0	2	0	0	-
W-13	Ekman Barge grab sampler	0	3	0	0	-
W-14	Plankton Net	0	1	0	0	-
W-15	Distillation apparatus (for CN, NH4, F)	10	-	10	10	Equiped
W-18	BOD analyzing Apparatus / Incubator	1	2	1	1	Equiped
W-19	COD analyzing apparatus / Closed Reflux (Cr)	1	1	1	1	Equiped
W-22	Wastewater treatment equipment	0	0	0	0	-
W-26	Water quality Analysis (Temp, Cond, pH, turbidity & DO)	0	0	0	0	-
W-30	Automatic titrator	0	0	0	0	-
W-31	Ion analyzer	1	0	1	1	-
W-32	Portable water quality kit	1	2	1	1	-
W-33	Vacuum Filter w / Manifold)	0	1	0	0	-

Table B.8.5 Procurement of Additional Equipment for Water Quality Analysis (for CPCB)

Analysis Equipment	Analysis Parameter	Number	Unit cost (10^3*Rs)	Cost (10^3*Rs)	Remarks
Atomic Absorption Spectrophotometer	Pb,Cd,Zn,Cu,As,Fe,Mn	1	4,118	4,118	
UV/VIS Spectrophotometer (Double Beam)	Inorganic Substances	1	1,152	1,152	
GC	Pesticides	1	2,092	2,092	
Handy Type pH Meter	pH	2	29	58	
Laboratory pH Meter	pH	1	82	82	
Handy Type DO Meter	DO	2	62	125	
Laboratory Type DO Meter	DO	1	187	187	
Tint Meter/Turbidity Meter	Tubidity	1	428	428	
Handy Type Conductivity/Temp. Meter	Conductivity	2	50	100	
Wastewater Treatment Equipment		1	1,772	1,772	
Sub-total			9,975	10,116	
Tax, Customs duties, Exise duties, Transportation costs and Handling fee				3,035	30%
Total (10^3*Rs)				13,151	
*Total (10^3*US:$)				290	

* Exchange rate : 1US$ = 109￥ = 45.33 Rs March 2004.

Table B.8.6 Procurement of Additional Equipment for Water Quality Analysis (for U.P.PCB)

Analysis Equipment	Analysis Parameter	Number	Unit cost (10^3*Rs)	Cost (10^3*Rs)	Remarks
Handy Type pH Meter	pH	8	29	233	
Laboratory pH Meter	pH	8	82	659	
Handy Type DO Meter	DO	8	62	499	
Laboratory Type DO Meter	DO	8	187	1,498	
Tint Meter/Turbidity Meter	Tubidity	4	428	1,714	
Handy Type Conductivity/Temp. Meter	Conductivity	16	50	799	
Wastewater Treatment Equipment		4	1,772	7,089	
Sub-total			2,612	12,490	
Tax, Customs duties, Exise duties, Transportation costs and Handling fee				3,747	30%
Total (10^3*Rs)				16,237	
*Total (10^3*US:$)				358	

* Exchange rate : 1US$ = 109 ¥ = 45.33 Rs March 2004.

Table B.8.7 Existing/Additional Water Quality Monitoring Stations in 4 Cities

City	Existing/Recommended Additional	Sampling point of Name/Location	Water Quality (90% Value) BOD (mg/l)	DO (mg/l)	Fecal Coliform (MPN/100ml)	Sampling Frequency	Charasteristics	Nesessity of Reconsideration	Organization of Monitoring	Remarks (Data Sourse)
Kanpur	Existing Points	Ganga at BITHOOR (Kanpur), U.P.	3.5	6.0	$1.3*10^5$	Once a month	FC is already detected to be high	Necessary to consider the bacterial contamination	U.P.PCB	CPCB's Data
		Ganga at Dhondigaht	-	-	-	Once a month			U.P.PCB	Ditto
		Ganga at Kanpur D/S (JAJMAU PUMPING STATION), U.P	8.2	5.0	$4.6*10^5$	Once a month	Much polluted		U.P.PCB	Ditto
	Additional Points	Further downstream monitoring station from existing one	-	-	-			New monitoring station		
Allahabad	Existing Points	Yamuna at Allahabad. U.P.	2.6	6.0	$2.5*10^3$	Once a month	Normal		CPCB	CPCB's Data
		Yamuna at Allahabad D/S (BALUA GHAT), U.P	3.0	7.0	$4.3*10^3$	Once a month	Normal		CPCB	Ditto
		Ganga at Allahabad (RASOOLABAD), U.P.	3.4	6.9	$4.9*10^3$	Once a month	Normal		U.P.PCB	Ditto
		Ganga at Allahabad D/S (SANGAM), U.P.	4.1	7.0	$9.4*10^3$	Once a month	Normal		U.P.PCB	Ditto
		River Ganga u/s of Allahabad b/c to Yamuna.	-	-	-	Once a month			U.P.PCB	CPCB Kanpur Zonal
		River Yamuna b/c with Ganga.	-	-	-	Once a month			U.P.PCB	Ditto
		Bathing Ghat at Sangam, Allahabad	-	-	-	Once a month			U.P.PCB	Ditto
		River Ganga d/s of Allahabad at 1/4 width.	-	-	-	Once a month			U.P.PCB	Ditto
		River Ganga d/s of Allahabad at 1/2 width.	-	-	-	Once a month			U.P.PCB	Ditto
		River Ganga at Pakka ghat, Vindhyachal.	-	-	-	Once a month			U.P.PCB	Ditto
	Additional Points	Further upstream monitoring station from existing one in Yamuna	-	-	-			New monitoring station		
	Additional Points	Further downstream monitoring station from existing one in Ganga	-	-	-			New monitoring station		
Varanasi	Existing Points	Ganga at Varanasi U/S (ASSIGHAT), U.P	4.0	6.8	$2.6*10^4$	Once a month	FC is already detected to be high	Necessary to consider the sampling site	U.P.PCB	CPCB's Data
		Ganga at Varanasi D/S (MALVIYA BRIDGE), U.P	22.2	3.0	$1.7*10^5$	Once a month	Extremely polluted	Necessary to consider the sampling site	U.P.PCB	Ditto
		River Ganga u/s of Varanasi.	3.3	5.8	$1.4*10^4$	Once a month	Normal		U.P.PCB	CPCB Kanpur Zonal
		River Ganga at Dashashwamedh ghat, Varanasi.	-	-	-	Once a month			U.P.PCB	Ditto
		River Ganga d/s of Varanasi at 1/4 width (Kaithy)	3.1	5.4	$5.0*10^3$	Once a month	Normal		U.P.PCB	Ditto
		River Ganga d/s of Varanasi at 1/2 width (Kaithy)	3.1	5.7	$1.3*10^4$	Once a month	Normal		U.P.PCB	Ditto
	Additional Points	Lowest point of Varuna River	-	-	-			New monitoring station		
	Additional Points	Further upstream monitoring station from existing one	-	-	-			New monitoring station		
	Additional Points	Further downstream monitoring station from existing one	-	-	-			New monitoring station		
Lucknow	Existing Points	Gomati at Lucknow U/S AT WATER INTAKE POINT,U.P.	3.0	7.0	$3.5*10^3$ $(5.0*10^3)$	Once a month	Coliform is detected to be high	Necessary to consider the bacterial pollution source	U.P.PCB	CPCB's Data
		Gomati at Lucknow D/S, U.P.	7.4	2.4	$3.5*10^5$ $(5.0*10^5)$	Once a month	Actual quality is expected to be much higher	Necessary to consider the sampling site	U.P.PCB	Ditto
		Gomti at Lucknow D/S at Mohan Mekins	-	-	-	Once a month			U.P.PCB	Ditto
		Gomti at Lucknow D/S at Nishatganj	-	-	-	Once a month			U.P.PCB	Ditto
		Gomti at Upstream Barriage at Lucknow	-	-	-	Once a month			U.P.PCB	Ditto
		Gomti at pipra Ghat	-	-	-	Once a month			U.P.PCB	Ditto
	Additional Points	Further upstream monitoring station from existing one	-	-	-			New monitoring station		
		Further downstream monitoring station from existing one	-	-	-			New monitoring station		

Note: the figures in parenthesis indicate Total coliform number

Table B.8.8 Necessary Water Quality Monitoring Stations in the Entire Ganga Basin

Basin No.	River System*	Sub-Basin Name	Existing Monitoring Stations		Necessary Monitoring Station		Remarks
			Total Number	Lowest Point	Nos.	Location	
1	Upper Ganga Main	Upper Ganga-I	7	○	-	-	
2	ditto	Upper Ganga-II	2	○	-	-	
3	ditto	Ramganga	1	○	-	-	
4	ditto	Kalinadi	3	○	-	-	
5	Middle Ganga Main	Middle Ganga I	2	○	-	-	
6	ditto	Middle Ganga II	3	○	-	-	
7	ditto	Middle Ganga III	2	○	-	-	
8	ditto	Middle Ganga IV	2	○	-	-	
9	ditto	Tons	2	None	1	Lowest	Urgent
10	Upper Yamuna	Upper Yamuna I	9	○	-	-	
11	ditto	Upper Yamuna II	6	○	-	-	
12	ditto	Upper Yamuna III	8	○	-	-	
13	ditto	Hindon	2	○	-	-	
14	Lower Yamuna	Chambal	22	○	-	-	
15	ditto	Sind	3	None	1	Lowest	Urgent
16	ditto	Betwa	4	○	-	-	
17	ditto	Ken	None	None	2 to 3	Including Lowest	Urgent
18	ditto	Lower Yamuna	2	○	-	-	
19	Gomati	Upper Gomati	3	○	-	-	
20	ditto	Lower Gomati	2	○	-	-	
21	ditto	Sai	1	○	-	-	
22	Lower Ganag Main	Karmanasa	None	None	1	Lowest	
23	ditto	Ghaghra	4	○	-	-	
24	ditto	Sone	8	○	-	-	
25	ditto	Gandak	1	○	1	Middle Stetch	
26	ditto	Punpun	None	None	1	Lowest	
27	ditto	Falgu	None	None	2 to 3	Including Lowest	
28	ditto	Kiul	None	None	1	Lowest	
29	ditto	Burhi Gandak	None	None	2 to 3	Including Lowest	
30	ditto	Kosi	None	None	2 to 3	Including Lowest	
31	ditto	Dwarka	None	None	2 to 3	Including Lowest	
32	ditto	Jalangi	None	None	2 to 3	Including Lowest	
33	ditto	Ajay	None	None	2 to 3	Including Lowest	
34	ditto	Damodar	5	None	1	Lowest	
35	ditto	Rupnarayan	1	○	1	Middle Stetch	
36	ditto	Haldi	None	None	2 to 3	Including Lowest	
37	ditto	Lower Ganga I	5	○	-	-	
38	ditto	Lower Ganga II	7	○	-	-	