Monitoring of Indian Aquatic Resources
Series: MINARS/31/2009–2010

GANGA

WATER QUALITY TREND

Central Pollution Control Board
Ministry of Environment and Forests
Website: www.cpcb.nic.in • e-mail: cpcb@nic.in

DECEMBER 2009

USE BASED CLASSIFICATION OF SURFACE WATERS IN INDIA

Designated-Best-Use	Class of water	Criteria
Drinking water source without conventional treatment but after disinfection	A	1. Total Coliforms Organism MPN/100 ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6 mg/l or more 4. Biochemical Oxygen Demand 5 days 20 °C 2 mg/l or less
Outdoor bathing (organised)	B	1. Total Coliforms Organism MPN/100 ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5 mg/l or more 4. Biochemical Oxygen Demand 5 days 20 °C 3 mg/l or less
Drinking water source after conventional treatment and disinfection	C	1. Total Coliforms Organism MPN/100 ml shall be 5000 or less 2. pH between 6 and 9 3. Dissolved Oxygen 4 mg/l or more 4. Biochemical Oxygen Demand 5 days 20 °C 3 mg/l or less
Propagation of wild life and fisheries	D	1. pH between 6.5 and 8.5 2. Dissolved Oxygen 4 mg/l or more 3. Free Ammonia (as N) 1.2 mg/l or less
Irrigation, industrial cooling, controlled waste disposal	E	1. pH between 6.0 and 8.5 2. Electrical Conductivity at 25 °C micro mhos/cm maximum 2250 3. Sodium absorption ratio maximum 26 4. Boron maximum 2 mg/l

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FOREWORD

Since time immemorial, the River Ganga has been revered by Indians, who have conferred the status of goddess to it. It draws millions of people world over, who come with a belief that taking a dip in the holy water of Ganga will rid them of their all sins. The water of Ganga was perceived as holy, but not any more. With time and because of increased human intervention, sacred Ganga has become impure. The pristine water of Ganga has been replaced by polluted water. All forms of pollutants including mortal remains of human beings are released into the river. Thus, water of Ganga is overloaded with pollutants. In fact, according to a study, it is feared that a dip in Ganga might lead to some skin disease.

It is of utmost importance that the River Ganga be restored to its past glory. There is an urgent need to improve its water quality, through regular monitoring and assessment of water quality. A conscious effort towards reversing the current trends of deterioration of water quality of Ganga is the need of the hour. Central Pollution Control Board, in association with the state pollution control boards of Uttarakhand, Uttar Pradesh, Bihar, and West Bengal, has established a monitoring network to quantify water quality of the Ganga and recommend measures based on the assessment of the data generated for improving the quality.

This publication presents water quality of the Ganga for a decade spanning between 1999–2008. It is believed that this report will be of immense use to the agencies responsible for restoring and preserving water quality of the River Ganga and would serve as a model for conducting similar studies in other major rivers in India.

The CPCB acknowledges the cooperation of state pollution control boards of Uttarakhand, Uttar Pradesh, Bihar, and West Bengal in collecting and collating the data.

The data presented in this report has been assessed, processed, and compiled by Ms Garima Dublish, Mr R M Bhardwaj, and Dr D D Basu under the supervision of Shri J S Kamyotra, Member Secretary. Appreciation is also due to Dr S P Chakrabarti, former Member Secretary, CPCB, for his association and to The Energy and Resources Institute (TERI), New Delhi, for editing, designing, and printing of the report.

Prof. S P Gautam
Chairman, CPCB

GANGA
WATER QUALITY TREND

BACKGROUND

Rivers are the raisin d'être of India. The country is blessed with so many river systems that have a history of sustaining civilizations as old as Harappa and Indus Valley civilizations. That is why rivers are held in awe and revered in our country. But we have taken an unfair advantage of these lifelines of our country by polluting them. A case in point is the River Ganga. The River Ganga is a perennial river originating from the Himalayas and flowing through many states before its confluence with Bay of Bengal. The Ganga has been worshipped by Indians from time immemorial and the practice still continues. The water of the Ganga was considered to be holy, having powers to rid us from all our sins. But now the water has become contaminated to such an extent that it has the potential to cause many life threatening diseases.

To cleanse the rivers and restore them to their natural and pristine conditions, the Indian government has taken several initiatives. One such initiative was the setting up of the Central Pollution Control Board (CPCB) under the Water (Prevention and Control of Pollution) Act, 1974. One of the objectives of the Act are maintaining and restoring the aquatic resources by preventing and controlling pollution. The CPCB is mandated to make sure that all surface waterbodies are pollution-free by preventing or abating water pollution. It also advises the central government on issues related to water quality. It assists the government in executing nationwide programmes on controlling water pollution. The Board coordinates the pollution prevention activities of the states and resolves water-related disputes. Not only this, the Board is also actively involved in research programmes related to water quality of various waterbodies by providing financial and technical assistance. Further, it

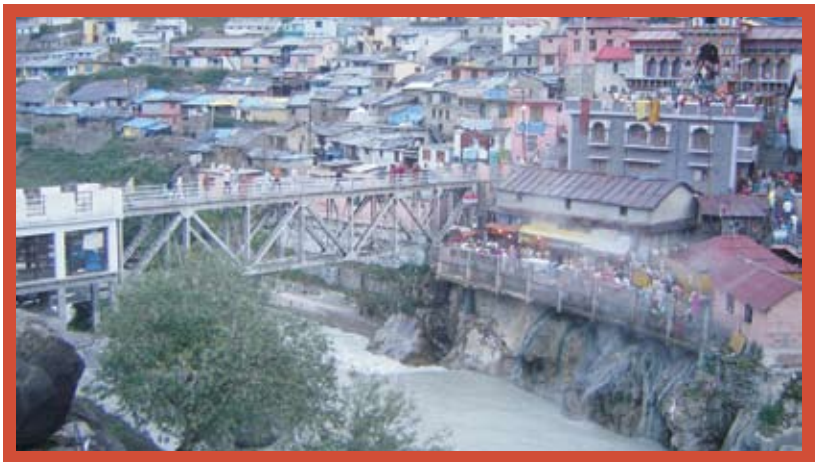
collects, compiles, and publishes data generated and disseminates this information for wider use and analyses. It also provides recommendations based on these research analyses.

The most important function of the Board is setting water quality standards and benchmarks in a bid to improve the water quality of various surface waterbodies. It also ensures that these standards are adhered to by various agencies concerned. As a monitoring agency, the Board evaluates the nature and extent of pollution, along with the effectiveness of pollution control measures. The Board has established various water quality monitoring stations across the country under the National Water Quality Monitoring Programme.

Widening its ambit, the Board undertook the assessment of water quality of the River Ganga, which is increasingly bearing the brunt of pollution from all corners. This role of the Board assumes more significance due to the fact that the Ganga river has been declared the national river of India. As a part of its initiative in cleaning up the river, the Board carried out a comprehensive study of the river and prepared a document the Basin Sub-basin Inventory of Water Pollution – the Ganga Basin. The comprehensive study identified the point and non-point sources responsible for the pollution of the river. The water quality monitoring results obtained by the Board formed the basis of the Ganga Action Plan (GAP) that was launched in 1985 for cleaning the river. This programme comprised several schemes that were implemented in the cities located along the river. These schemes included setting up sewage treatment plants, along with sewage pumping stations, and laying down of sewer lines. These schemes had resource recovery component attached to them. Under this component, digested sludge is sold as manure, digester biogas is used for heat and power generation, and the effluent released is used for irrigation and pisciculture. These sewage treatment schemes were complemented with low-cost sanitation schemes, electric crematoria, and ghat development schemes along the bank of the river.

All these schemes have been carefully chosen on the basis of site-specific needs dictated by the extent of pollution and river quality vis-à-vis the status and need for sanitary facilities and sewerage systems. Though these schemes have largely been successful as witnessed by the changed demographic and economic scenario, a lot still needs to be done to narrow the huge gap between the actual requirements and facilities extended under the Ganga Action Plan.

The present study involved regular monitoring of the River Ganga over a period of time. The water quality trends revealed that most of the parameters studied do not conform to criteria defined for drinking, bathing, and so on. Thus, there is an urgent need to reverse this trend. Thus, it is not enough to have several schemes and programmes in place. It is important that these are implemented diligently so that the natural conditions of the river are restored and the river regains its lost status of the 'Holy River of India'.



River Alakananda at Badrinath Shrine

INTRODUCTION

The Ganga basin accounts for a little more than one-fourth (26.3%) of the country's total geographical area and is the biggest river basin in India, covering the entire states of Uttarakhand, Uttar Pradesh (UP), Bihar, Delhi, and parts of Punjab, Haryana, Himachal Pradesh, Rajasthan, Madhya Pradesh, and West Bengal. The Ganga basin is bound in the north by the Himalayas and in the south by the Vindhyas. The main river stream originates in the northern-most part of Uttarakhand, flows through Uttar Pradesh, Bihar, and West Bengal, and finally drains into the Bay of Bengal. The river traverses a length of 1450 km in Uttarakhand and UP while touching the boundary between UP and Bihar for a stretch of 110 km. It then flows through Bihar, more or less covering a distance of 445 km. The length of the river measured along the Bhagirathi and Hugli rivers during its course in West Bengal is about 520 km. The River Ganga has a large number of tributaries, namely, Kali, Ramganga, Yamuna, Gomti, Ghaghara, Gandak, and Kosi. The River Yamuna, although a tributary of Ganga, is a river in itself. Its major tributaries are Chambal, Sind, Betwa, and Ken. The main plateau tributaries of the Ganga river are Tons, Son, Damodar, and Kangsabati-Haldi. The salient features of the Ganga river are summarized in Annexure I.

POPULATION STATUS

The total population residing in the Ganga basin is about 33.78 crore, of which 6.78 crore forms the urban population. Table 1 provides the details of state-wise population inhabiting the basin, as of 2001.

Table 1 Population statistics pertaining to the Ganga basin

State	Total population	Urban population	Total (%)
Uttarakhand	8 489 349	2 179 074	25.66
Uttar Pradesh	166 197 921	34 539 582	20.78
Bihar	82 998 509	8 681 800	10.46
West Bengal	80 176 197	22 427 251	27.97
Total	**337 861 976**	**67 827 707**	**20.07**

WATER QUALITY ASSESSMENT STUDIES

To study the water quality of River Ganga, the Central Pollution Control Board (CPCB) has set up 39 water quality monitoring stations on the main river and 102 stations on its various tributaries in 2008/09. Detailed monitoring station locations are presented in Table 2 and Annexure II. The locations are also depicted pictorially in Figure 1.

Table 2 Water quality monitoring stations in different states

States	Number of locations
Uttarakhand	9
Uttar Pradesh	13
Bihar	9
West Bengal	8

The core water quality parameters studied are temperature, pH, conductivity, dissolved oxygen (DO), biochemical oxygen demand (BOD), nitrate, nitrite, total coliforms (TC), and faecal coliforms (FC). Besides, several other location-specific parameters are also studied. The list of parameters assessed in the study of water quality is presented in Annexure III. Generally, state pollution control boards assist in sampling and analysis of water quality data, while the CPCB undertakes scrutiny, processing, and storage of data, along with the analysis of data for interpretation and preparation of action plans. The monitoring is undertaken either on monthly or quarterly basis.

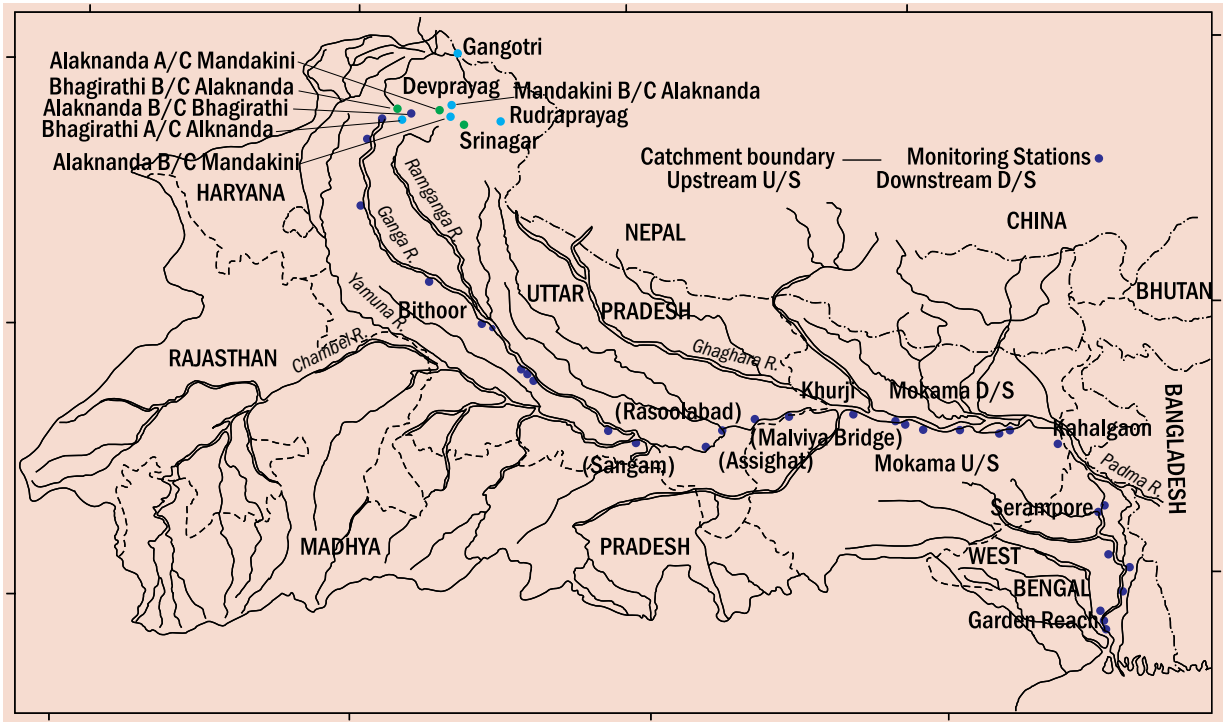


Figure 1 Location of water quality monitoring stations

WATER QUALITY TREND

BOD, DO, and FC normally indicate the biological health of a river. Therefore, these parameters were selected to study the water quality trend in the River Ganga for the period 1999–2008 in

different states (graphs are depicted for the period 2002–08). The water quality criteria for bathing, notified under the Environment (Protection) Act, 1986, are depicted in Annexure IV.

WATER QUALITY ASSESSMENT STUDIES IN UTTARAKHAND

The location of the monitoring stations in the Ganga riverine system in Uttarakhand is shown in Figure 2. Water quality status of River Ganga in Uttarakhand in terms of DO, BOD, and FC is shown in Table 3. A close examination clearly indicates that DO and BOD comply with the standards (standards are notified under EPA 1986 and given in Annexure IV). However, FC conforms with the standard in only few places and also shows a decreasing trend in some places, that is, the Bhagirathi at Gangotri and the Ganga at Rishikesh and Haridwar, the major pilgrimage centres. BOD in Bhagirathi at Gangotri, the Mandakini at Rudraprayag, and the Alaknanda after confluence with the Mandakni at Rudraprayag shows no trend. It shows a marginally increasing trend in the Alaknanda before confluence at Rudraprayag and Devprayag, and in the rest of the locations, it shows an increasing trend. Except the Bhagirathi at Gangotri and the Mandakini before confluence with Alaknanda at Rudraprayag, wherein DO shows marginally increasing and increasing trends, respectively, DO at all locations shows either decreasing or marginally decreasing trend. The trend analysis for the period 2002–08 with respect to individual location is summarized in Annexure V, and an overall summary of the trend in BOD, DO, and FC at various locations is presented in Figures 3–5. In overall analysis, the River Ganga in Uttarakhand is relatively clean and complying with the criteria, except for FC which is higher.

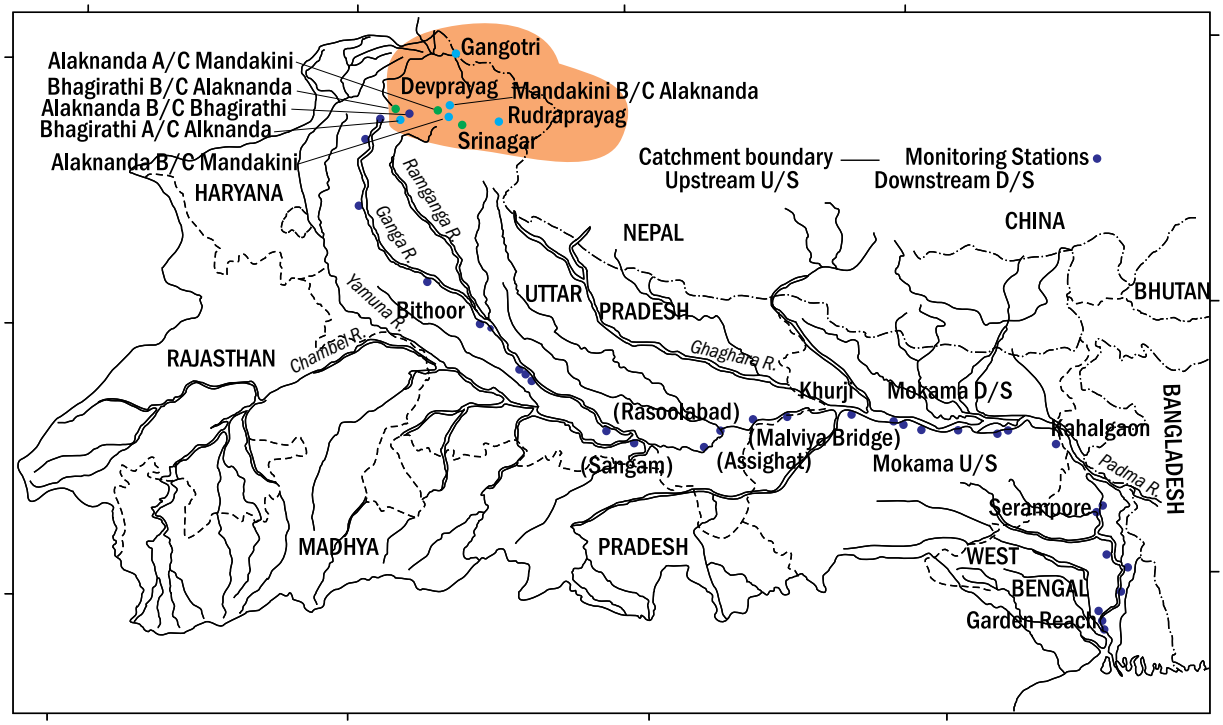


Figure 2 Location of monitoring stations in the River Ganga in Uttarakhand

Table 3 Biochemical oxygen demand, dissolved oxygen, and faecal coliform compliance with the standard, and trends in the River Ganga in Uttarakhand

Location	Biochemical oxygen demand		Dissolved oxygen		Faecal coliforms	
	Compliance with standard	Trend	Compliance with standard	Trend	Compliance with standard	Trend
Bhagirathi at Gangotri	Yes	No trend	Yes	Marginally increasing	Yes	Decreasing
Alaknanda B/C Mandakini at Rudraprayag	Yes	Marginally increasing	Yes	Marginally decreasing	No	Increasing
Mandakini B/C Alaklnanda at Rudraprayag	Yes	No trend	Yes	Increasing	No	Increasing
Alaknanda A/C Mandakini at Rudraprayag	Yes	No trend	Yes	Marginally decreasing	No	Increasing
Alaknanda b/C to Bhagirathi at Devprayag	Yes	Marginally increasing	Yes	Marginally decreasing	No	Increasing
Bhagirathi B/C with Alaknanda at Devprayag	Yes	Increasing	Yes	Marginally decreasing	Yes	Increasing
Alaknanda A/C with Bhagirathi at Devprayag	Yes	Increasing	Yes	Marginally decreasing	No	Increasing
Ganga at Rishikesh U/S	Yes	Increasing	Yes	Marginally decreasing	Yes	Decreasing
Ganga at Haridwar D/S	No	Increasing	Yes	Decreasing	Yes	Decreasing

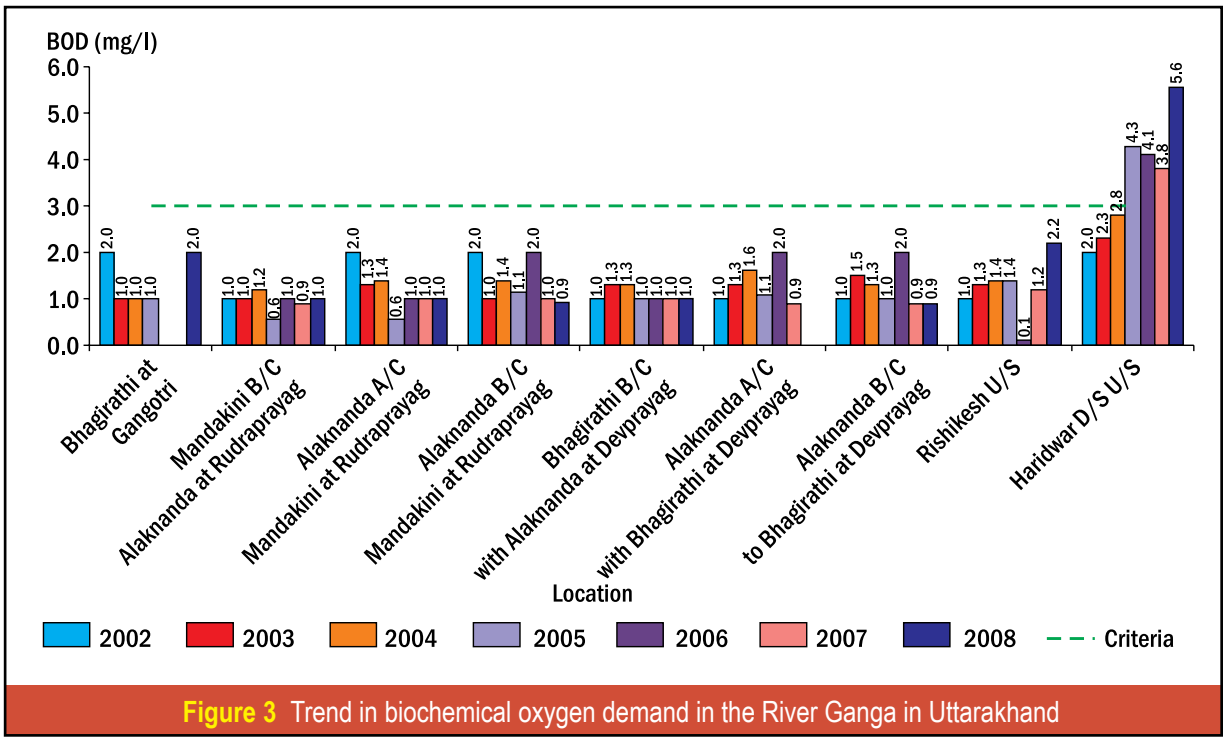


Figure 3 Trend in biochemical oxygen demand in the River Ganga in Uttarakhand

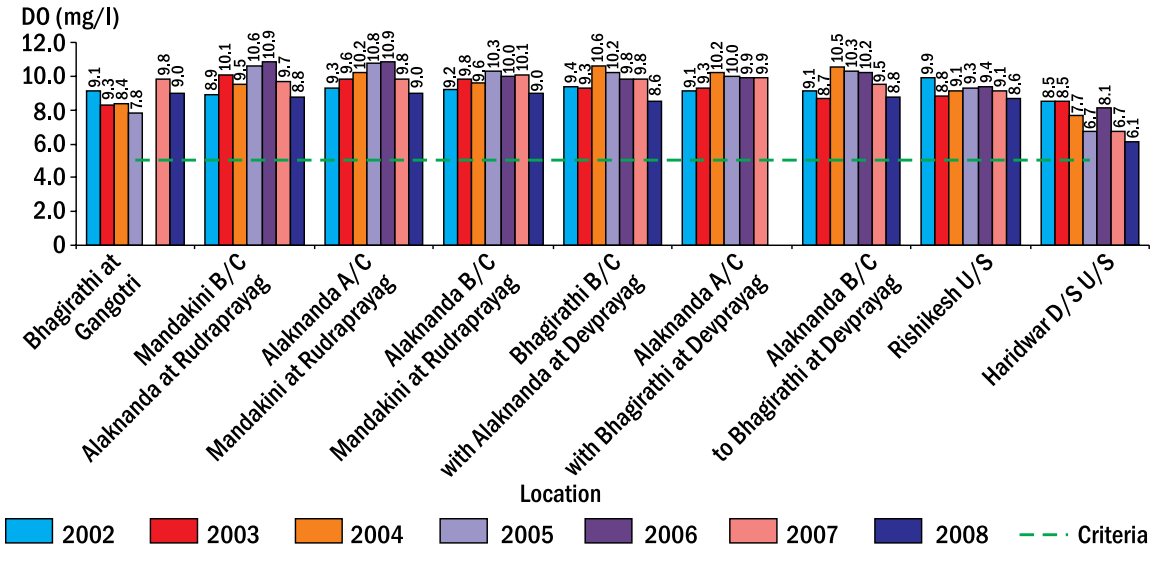


Figure 4 Trend in dissolved oxygen in the River Ganga in Uttarakhand

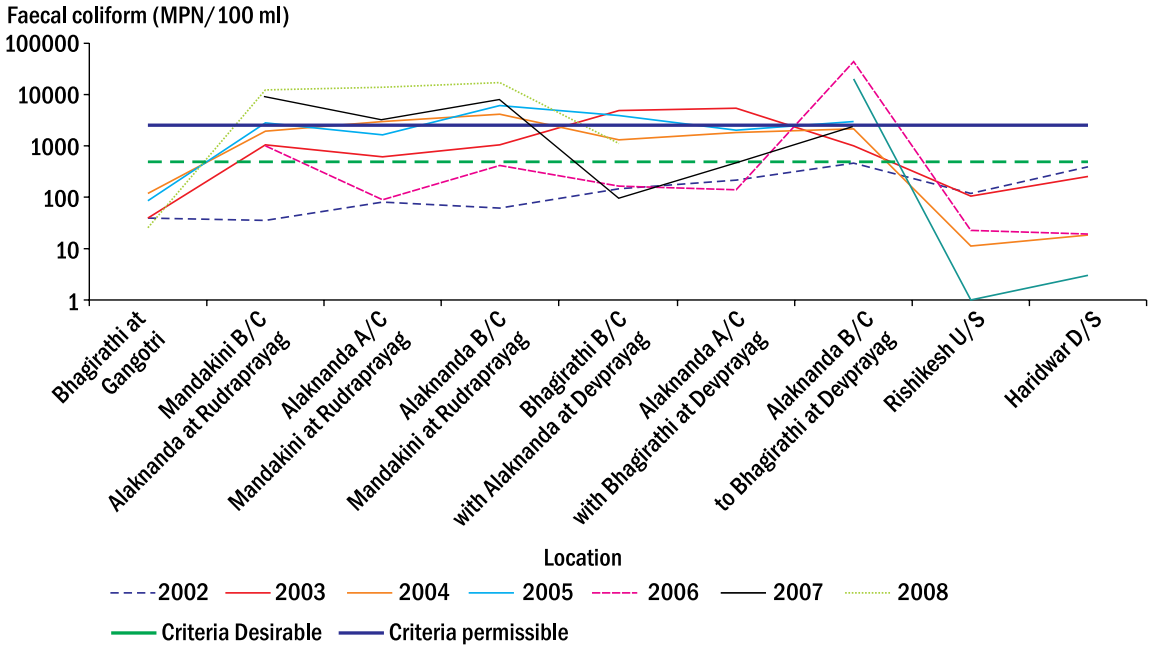


Figure 5 Trend in faecal coliforms in the River Ganga in Uttarakhand

WATER QUALITY ASSESSMENT STUDIES IN UTTAR PRADESH

The locations monitored in the Ganga and important towns/cities in Uttar Pradesh are shown in Figure 6. The status of water quality of the Ganga in Uttar Pradesh is presented in Table 4.


River Ganga at Bithoor

It is observed from the table that BOD complies with the standard only at Garhmukteshwar and Narora, and also shows decreasing trends in these locations. Except in Kanpur d/s, where BOD shows a marginally decreasing trend, BOD in rest of the locations shows increasing or marginally increasing trends. DO complies with the standard at all locations. However, no trend is observed at Kannauj u/s, Bithoor, Kanpur u/s, Allahabad (Rasoolabad), and Allahabad d/s. At Kannauj d/s, marginally decreasing and at Kanpur d/s, decreasing trends in DO are observed. DO in rest of the locations showed a marginal increasing trend. FC complied with the standard at only one location, that is, Narora. From Garhmukteshwar

Table 4 Biochemical oxygen demand, dissolved oxygen, and faecal coliform compliance with the standard, and trends in the River Ganga in Uttar Pradesh

Location	Biochemical oxygen demand		Dissolved oxygen		Faecal coliforms	
	Compliance with standard	Trend	Compliance with standard	Trend	Compliance with standard	Trend
Garhmukteshwar	Yes	Decreasing	Yes	Marginally increasing	No	Increasing
Narora (Bulandshar)	Yes	Decreasing	Yes	Marginally increasing	Yes	Increasing
Kannauj u/s (Rajghat)	No	Increasing	Yes	No trend	No	Increasing
Kannauj d/s	No	Increasing	Yes	Marginally decreasing	No	Increasing
Bithoor (kanpur)	No	Increasing	Yes	No trend	No	Increasing
Kanpur u/s (Ranighat)	No	Increasing	Yes	No trend	No	Increasing
Kanpur d/s (jajmau pumping station)	No	Marginally decreasing	Yes	Decreasing	No	Increasing
Dalmau (Rai Bareilly)	No	Increasing	Yes	Marginally increasing	No	Increasing
Allahabad (Rasoolabad)	No	Increasing	Yes	No trend	No	Increasing
Allahabad d/s (Sangam)	No	Increasing	Yes	No trend	No	Increasing
Varanasi u/s (Assighat)	No	Marginally increasing	Yes	Marginally increasing	No	Decreasing
Varanasi d/s (Malviya Bridge)	No	Increasing	Yes	Marginally increasing	No	Decreasing
Trighat (wGhazipur)	No	Increasing	Yes	Marginally increasing	No	Marginally decreasing

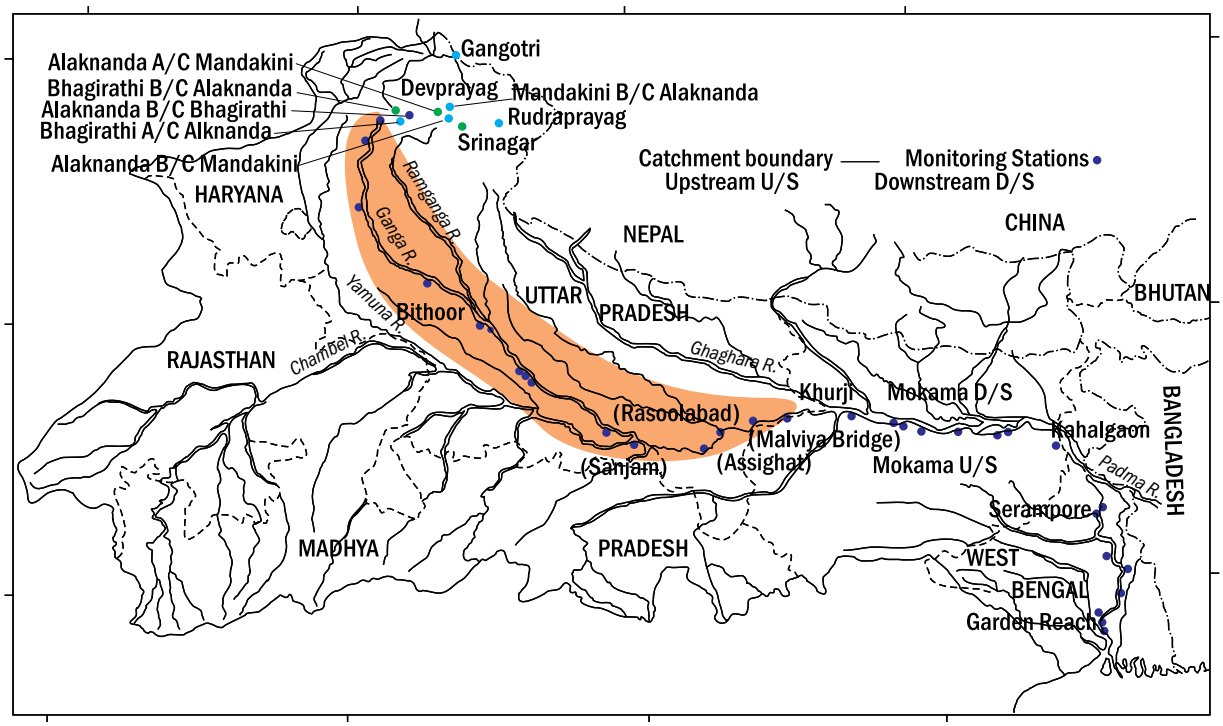


Figure 6 Location of monitoring stations in the River Ganga in Uttar Pradesh

to Allahabad d/s, a continuous increasing trend is observed with respect to FC. At Varanasi u/s and d/s, decreasing trends in FC are observed, whereas a marginal decreasing trend is noticed at Trighat. The graphical representation with respect to water quality parameters at individual location is given in Annexure V. An overall picture of trends of BOD, DO, and FC at various locations is presented in Figures 7–12.

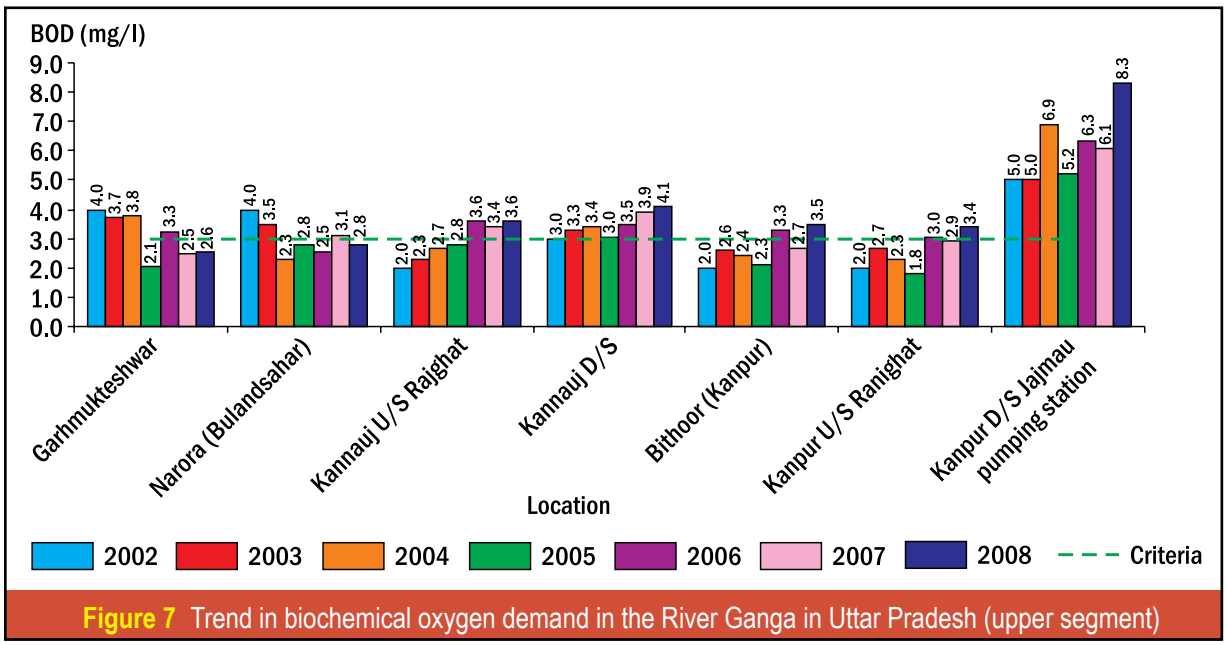


Figure 7 Trend in biochemical oxygen demand in the River Ganga in Uttar Pradesh (upper segment)

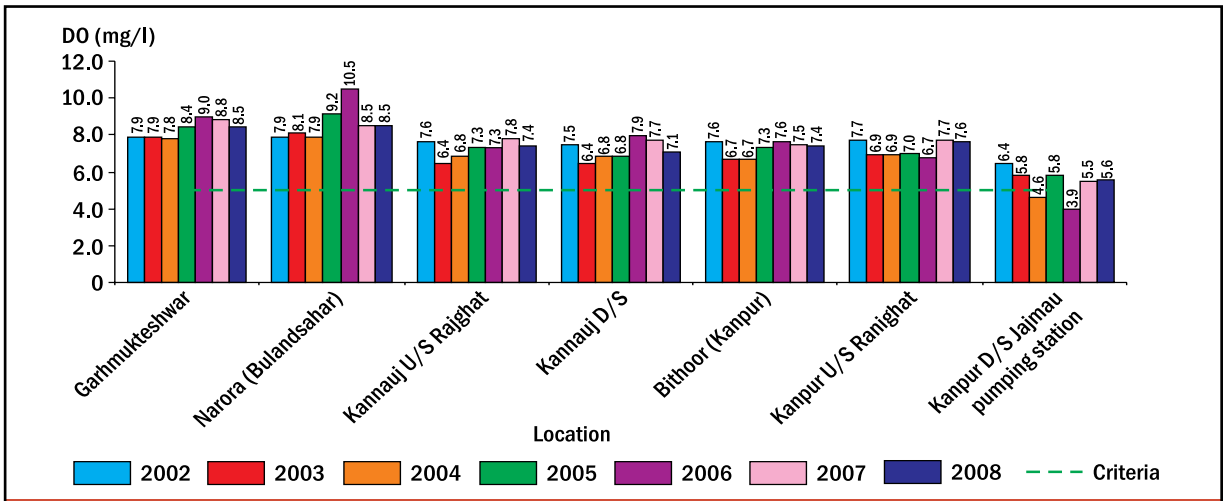


Figure 8 Trend in dissolved oxygen in the River Ganga in Uttar Pradesh (upper segment)

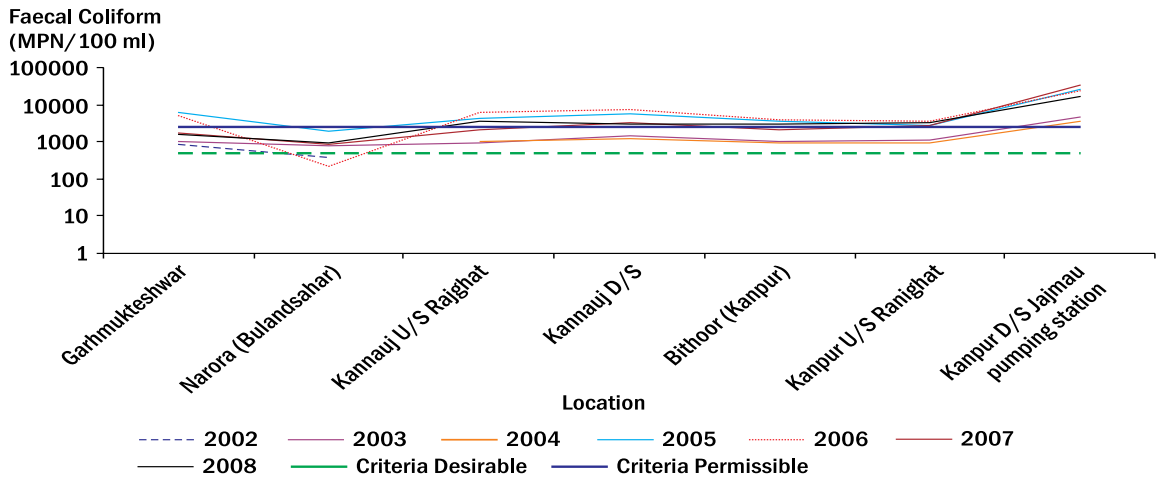


Figure 9 Trend in faecal coliforms in the River Ganga in Uttar Pradesh (upper segment)

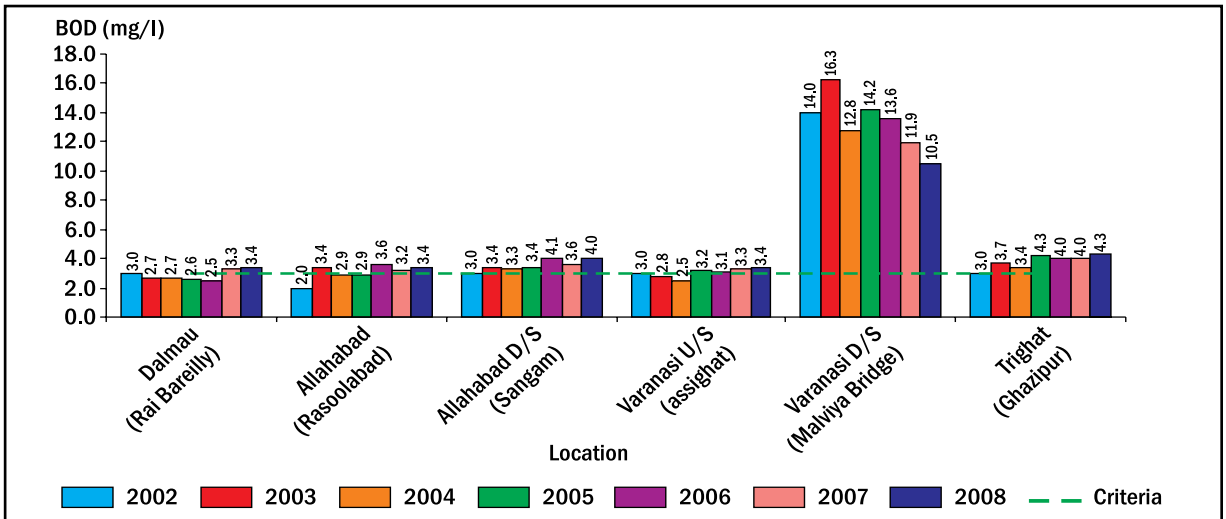


Figure 10 Trend in biochemical oxygen demand in the River Ganga in Uttar Pradesh (lower segment)

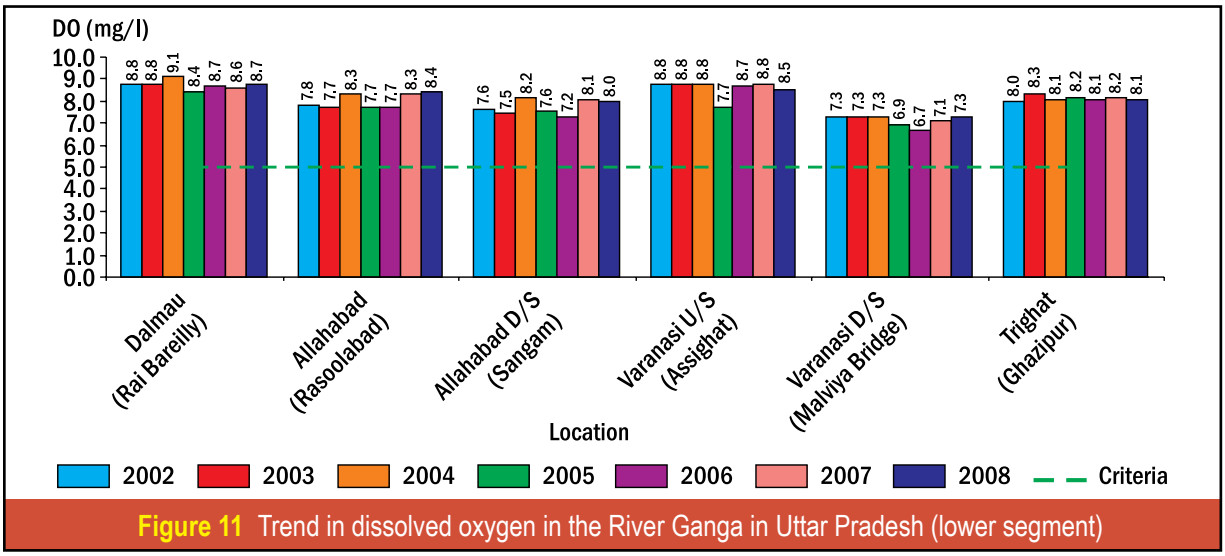


Figure 11 Trend in dissolved oxygen in the River Ganga in Uttar Pradesh (lower segment)

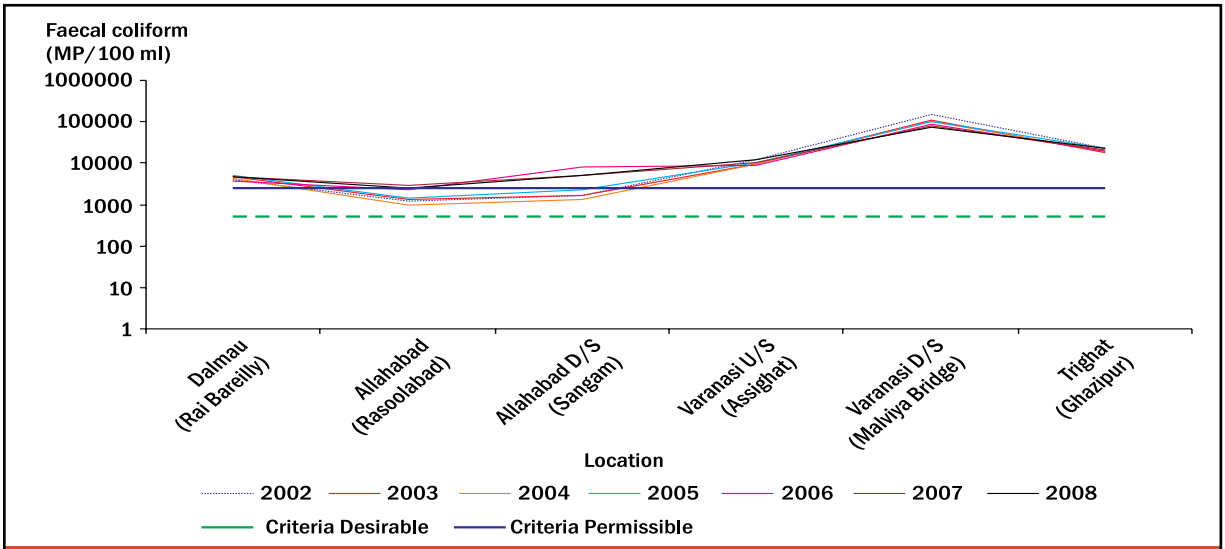


Figure 12 Trend in faecal coliforms in the River Ganga in Uttar Pradesh (lower segment)

WATER QUALITY ASSESSMENT STUDIES IN BIHAR

The stretch of the River Ganga and the locations of water quality monitoring stations in Bihar are depicted in Figure 13. Table 5 gives the status of water quality (in terms of BOD, DO, and FC) of the Ganga in Bihar. It is observed that BOD and DO comply with the standard at all the locations, while FC does not conform to the standard at any of the locations. BOD shows an increasing or a marginally increasing trend at all the locations. No trend is observed with respect to DO in Buxar, Khurji, Patna d/s, and Mokama d/s stretches. Except at Rajmahal, where a marginally decreasing trend is observed, DO shows an increasing or a marginally increasing trend. The trends at individual locations are graphically depicted in Annexure V. An overall picture of trends for BOD, DO, and FC at various locations is presented in Figures 14–16.

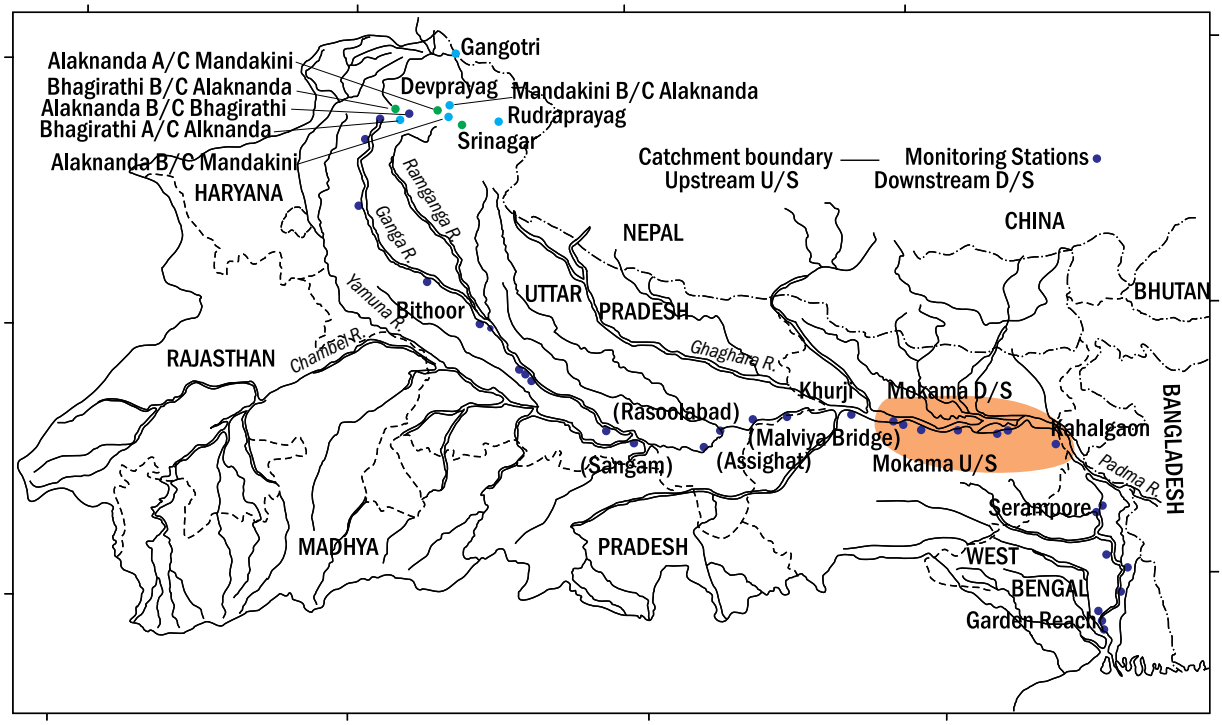


Figure 13 Location of monitoring stations in the River Ganga in Bihar

Table 5 Biochemical oxygen demand, dissolved oxygen, and faecal coliform compliance with the standard, and trends in the River Ganga in Bihar

Location	Biochemical oxygen demand		Dissolved oxygen		Faecal coliforms	
	Compliance with standard	Trend	Compliance with standard	Trend	Compliance with standard	Trend
Ganga at Buxar	Yes	Increasing	Yes	No trend	No	Increasing
Ganga at Khurji, Patna u/s	Yes	Increasing	Yes	No trend	No	Increasing
Ganga at Patna d/s (Ganga Bridge)	Yes	Increasing	Yes	No trend	No	Increasing
Ganga at Mokama (u/s)	Yes	Marginally increasing	Yes	Marginally increasing	No	No trend
Ganga at Mokama (d/s)	Yes	Increasing	Yes	No trend	No	Increasing
Ganga at Munger	Yes	Marginally increasing	Yes	Marginally increasing	No	Decreasing
Ganga at Bhagalpur	Yes	Increasing	Yes	Increasing	No	Decreasing
Rajmahal	—	Increasing	—	Marginally decreasing	—	Marginally increasing
Ganga at Kahalgaon	Yes	Marginally increasing	Yes	Increasing	No	Decreasing

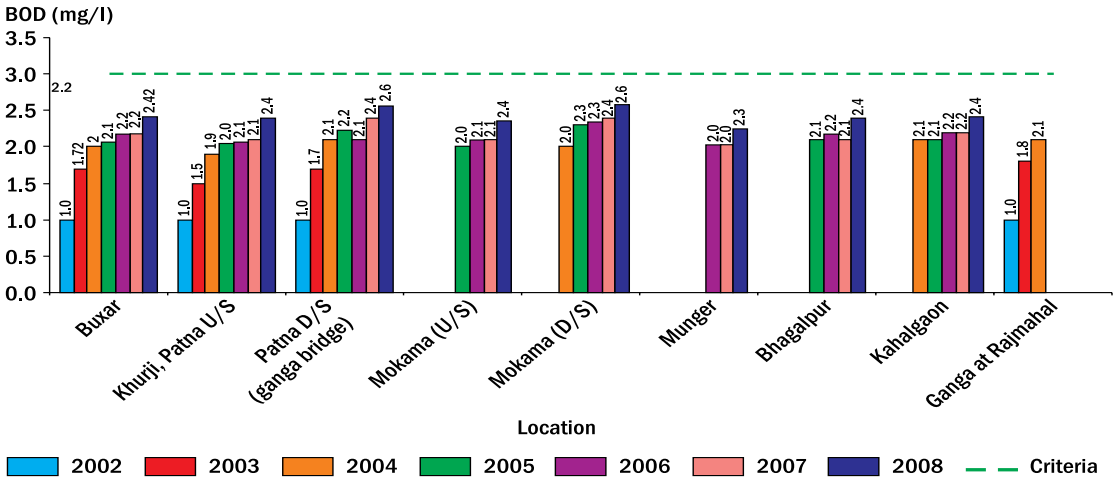


Figure 14 Trend in biochemical oxygen demand in the River Ganga in Bihar

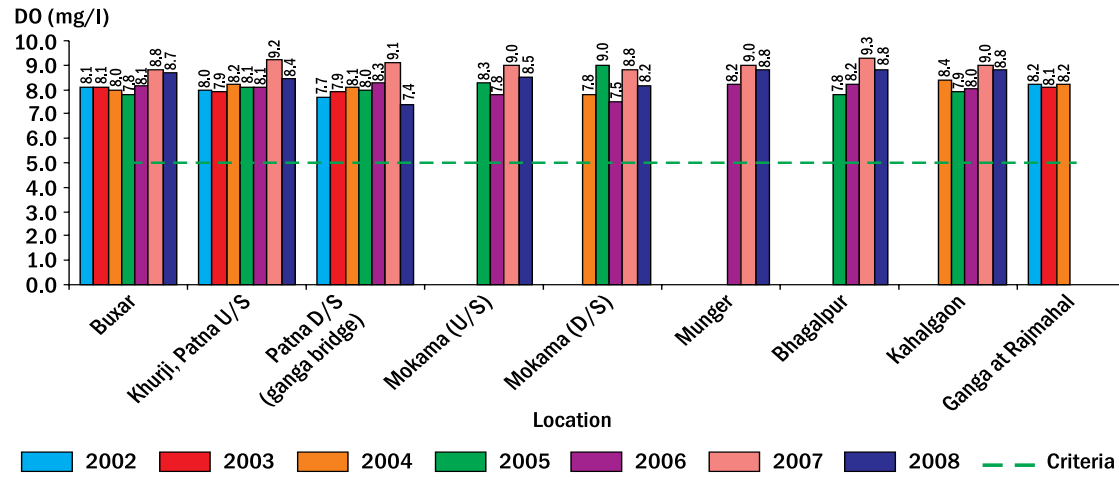


Figure 15 Trend in dissolved oxygen in the River Ganga in Bihar

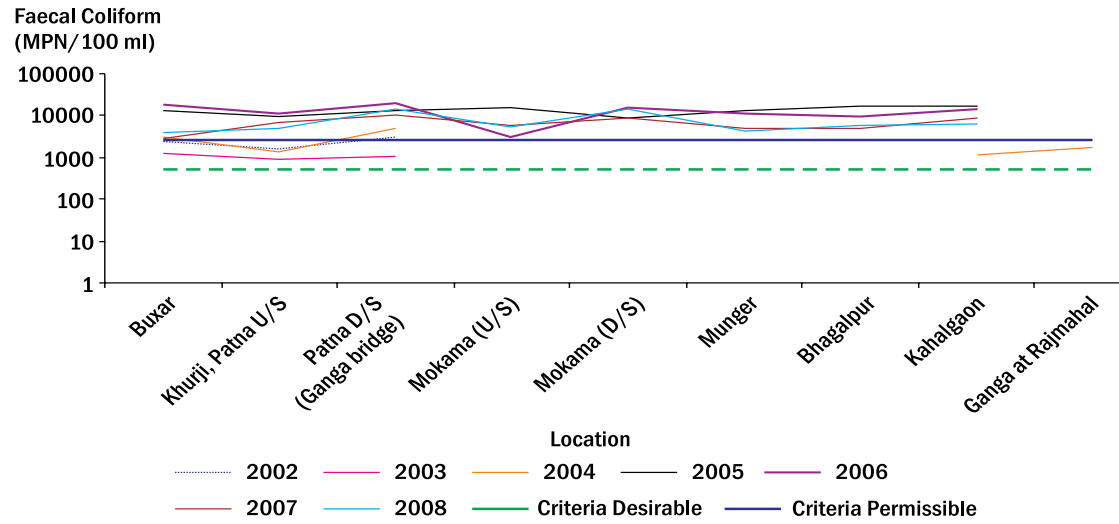


Figure 16 Trend in faecal coliforms in the River Ganga in Bihar

WATER QUALITY ASSESSMENT STUDIES IN WEST BENGAL

The location of monitoring stations in West Bengal is shown in Figure 17. The water quality of the River Ganga in West Bengal, in terms of BOD, DO, and FC, is presented in Table 6. Analysis of the data shows that DO complies with the standard at all locations, while BOD complies with the criteria at all monitoring locations except Dakshineshwar. Also, FC exceeds the standard at all the monitoring locations. An increasing trend with respect to BOD is observed at Dakshineshwar and Garden Reach, whereas marginally increasing trend is observed at Uluberia. BOD shows no trend at Diamond Harbour, but depicts a decreasing trend at rest of the locations, that is, at Beharampore, Serampore, Howrah-Shivpur, and Palta. A marginally decreasing trend with respect to DO is observed at Beharampore and at Uluberia to Diamond Harbour stretch. A marginally increasing

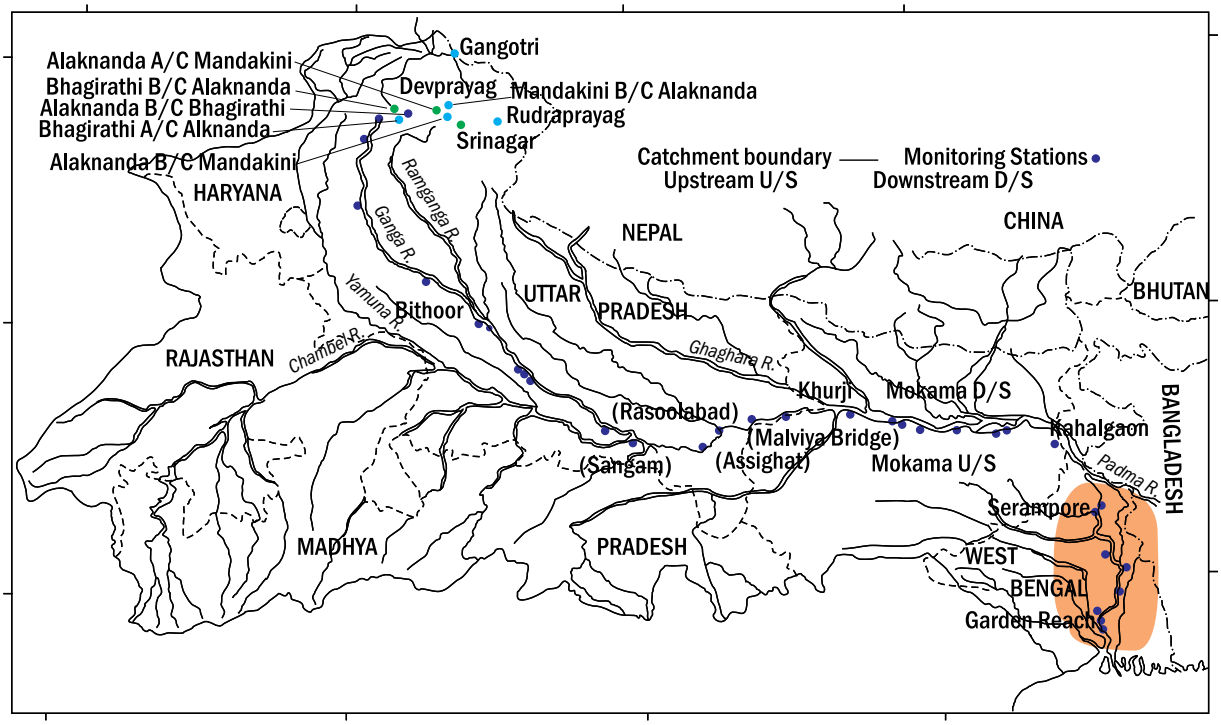


Figure 17 Location of monitoring stations in the River Ganga in West Bengal

Table 6 Biochemical oxygen demand, dissolved oxygen, and faecal coliform compliance with the standard, and trends in the River Ganga in West Bengal

Location	Biochemical oxygen demand		Dissolved oxygen		Faecal coliforms	
	Compliance with standard	Trend	Compliance with standard	Trend	Compliance with standard	Trend
Baharampore	Yes	Decreasing	Yes	Marginally decreasing	No	Decreasing
Serampore	Yes	Decreasing	Yes	No trend	No	Decreasing
Dakshin- eshwar	No	Increasing	Yes	Marginally increasing	No	No trend
Howrah-Shivpur	Yes	Decreasing	Yes	No trend	No	No trend
Garden Reach	Yes	Increasing	Yes	No trend	No	Marginally Increasing
Uluberia	Yes	Marginally increasing	Yes	Marginally decreasing	No	Marginally decreasing
Palta	Yes	Decreasing	Yes	Marginally decreasing	No	Decreasing
Diamond Harbour	Yes	No trend	Yes	Marginally decreasing	No	Decreasing

trend is observed at Dakshineshwer, but at rest of the locations, that is, Serampore, Howrah-Shivpur, and Garden Reach, DO shows no trend. FC shows a decreasing trend at Baharampore, Serampore, Palta, and Diamond Harbour.

A marginal upward trend is observed at Garden Reach and FC decreases marginally at Uluberia. A graphical representation of the trends in water quality parameters for individual location is given in Annexure V, while an overall summary of the trends of these parameters for all the locations is presented in Figures 18–20.

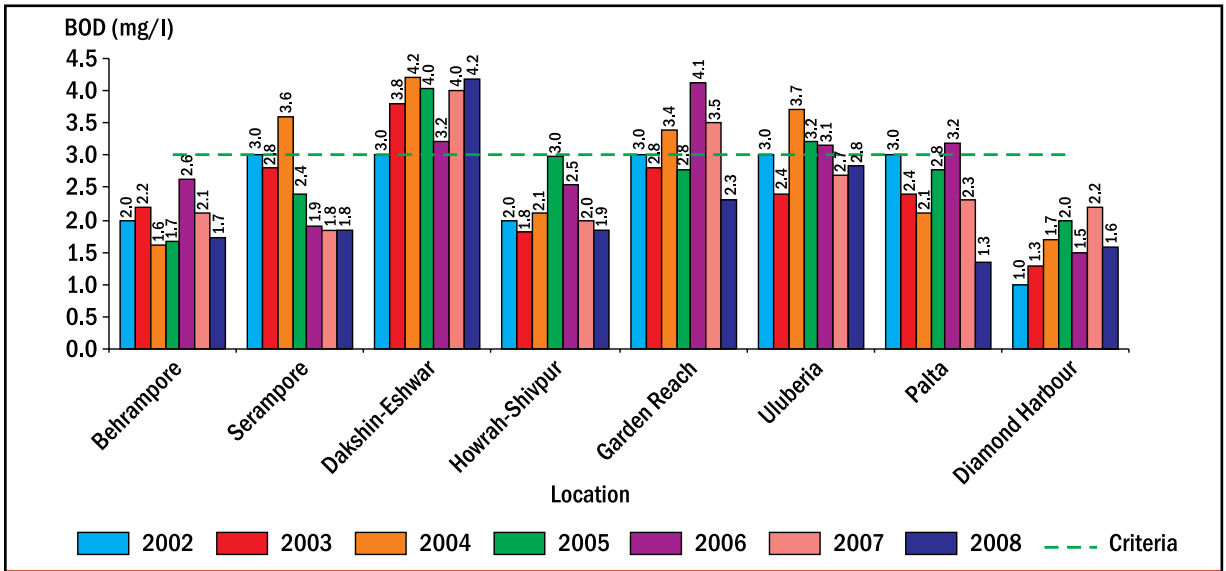


Figure 18 Trend in biochemical oxygen demand in the River Ganga in West Bengal

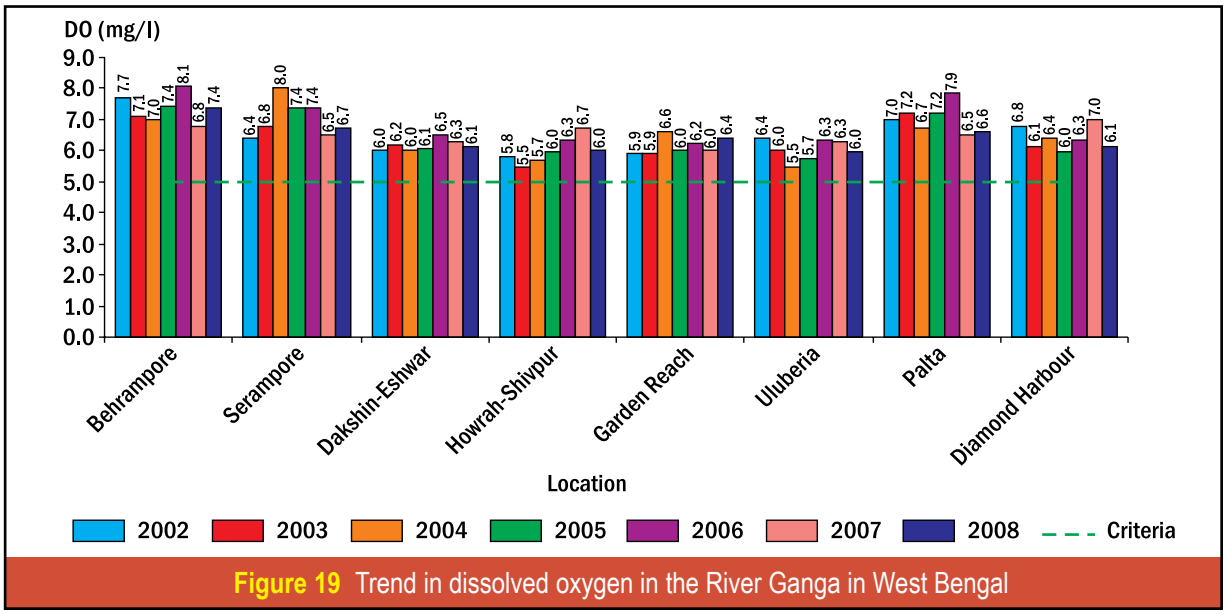


Figure 19 Trend in dissolved oxygen in the River Ganga in West Bengal

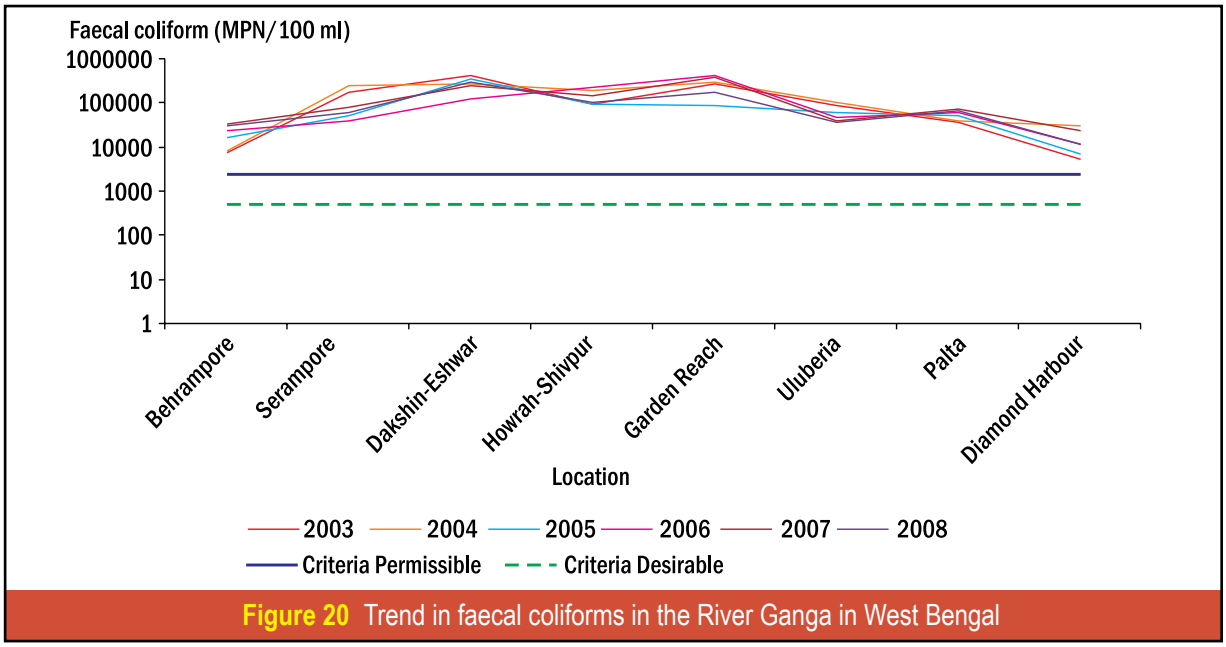


Figure 20 Trend in faecal coliforms in the River Ganga in West Bengal

OVERALL WATER QUALITY STATUS OF THE RIVER GANGA

It is observed that FC does not meet the criteria in almost all the locations except Rishikesh, Haridwar and Narora. The water quality is found to be deteriorating with respect to BOD, which is an indicator of organic pollution, especially in the stretch that spans from Kannauj to Trighat.

A combinatorial analysis was carried out to classify the river quality on a scale of good, satisfactory, not satisfactory, and bad. There are two factors that govern the combinatorial analysis: compliance to the standard and the trend. This analysis is schematically shown in Figure 21.

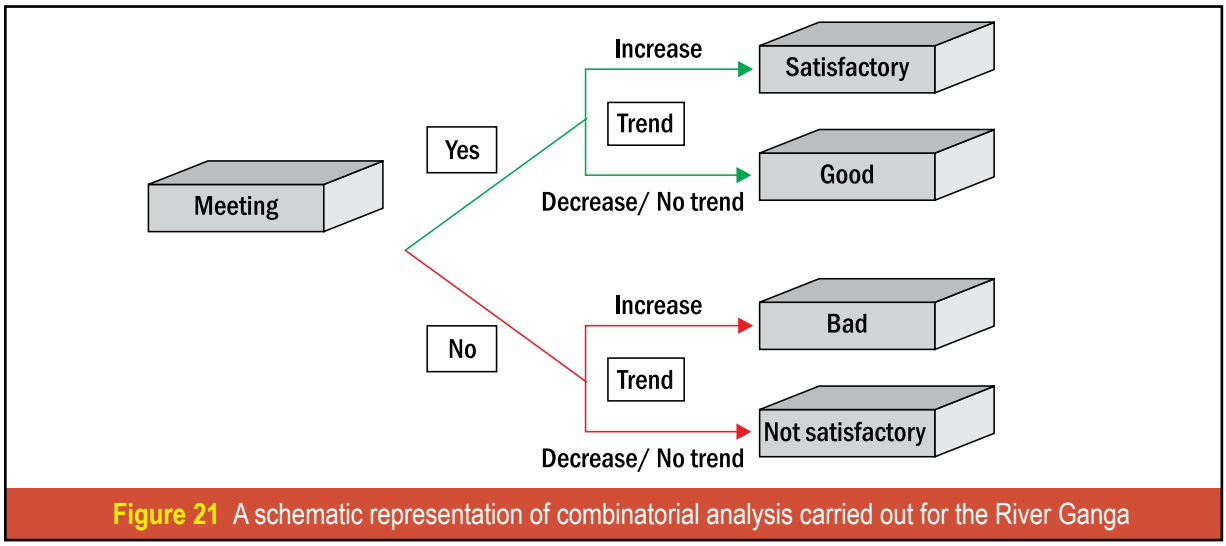


Figure 21 A schematic representation of combinatorial analysis carried out for the River Ganga

The classification, as deduced from the combinatorial analysis of the water quality monitoring data with respect to BOD, for the River Ganga is summarized in Table 7. It is observed that all the stations in Uttarakhand have the least satisfactory level. However, except Garhmukteshwar and Narora, all the stations in Uttar Pradesh show that the BOD values in River Ganga are increasing and in exceedence with the criteria. The situation, however, improved in Bihar where most of the observation at all the monitoring stations in the State show satisfactory compliance level. This is achieved due to enhanced flow by the tributaries. In West Bengal, except Dakshineshwar, the situation is in the category of good, however water quality at Garden Reach and Uluberia is

Flow in River Ganga at Ganga Bridge – Shuklaganj u/s Kanpur (Upstream River)

Table 7 Classification of water quality monitoring locations with respect to biochemical oxygen demand

Locations	Good	Satisfactory	Not satisfactory	Bad
Uttrankhand				
Bhagirathi at Gangotri	√	—	—	—
Alaknanda b/c Mandakini at Rudraprayag	—	√	—	—
Mandakini b/c Alaknanda at Rudraprayag	√	—	—	—
Alaknanda a/c Mandakini at Rudraprayag	√	—	—	—
Alaknanda b/c to Bhagirathi at Devprayag	—	√	—	—
Bhagirathi b/c with Alaknanda at Devprayag	—	√	—	—
Alaknanda a/c with Bhagirathi at Devprayag	—	√	—	—
Ganga at Rishikesh u/s	—	√	—	—
Ganga at Haridwar d/s	—	√	—	—
Uttar Pradesh				
Garhmukteshwar	√	—	—	—
Narora (Bulandsahar)	√	—	—	—
Kannauj u/s (Rajghat)	—	—	—	√
Kannauj d/s	—	—	—	√
Bithoor (Kanpur)	—	—	—	√
Kanpur u/s (Ranighat)	—	—	—	√
Kanpur d/s (Jajmau pumping station)	—	—	√	—
Dalmau (Rai Bareilly)	—	—	—	√
Allahabad (Rasoolabad)	—	—	—	√
Allahabad d/s (Sangam)	—	—	—	√
Varanasi u/s (Assighat)	—	—	—	√
Varanasi d/s (Malviya bridge)	—	—	—	√
Tarighat (Ghazipur)	—	—	—	√
Bihar				
Ganga at Buxar	—	—	√	—
Ganga at Khurji, Patna u/s	—	√	—	—
Ganga at Patna d/s (Ganga Bridge)	—	√	—	—
Ganga at Mokama (u/s)	—	√	—	—
Ganga at Mokama (d/s)	—	√	—	—
Ganga at Munger	—	√	—	—
Ganga at Bhagalpur	—	√	—	—
Ganga at Kahalgaon	—	√	—	—
West Bengal				
Baharampore	√	—	—	—
Serampore	√	—	—	—
Dakshineshwar	—	—	—	√
Howrah-Shivpur	√	—	—	—
Garden Reach	—	√	—	—
Uluberia		√		
Palta	√	—	—	—
Damond Harbour	√	—	—	—

satisfactory. These results indicate that the stretch in Uttar Pradesh from Kannauj to Trighat is due to discharge of wastewater either from municipality/industry or scanty flow during lean period. Hence, an assessment of flow and wastewater load is necessary. The water quality trends in the states are shown in Figure 22 through 25.

STATUS OF RIVER FLOW IN UTTAR PRADESH

The data pertaining to dependable flow of the River Ganga at Kanpur (1959–2008), is depicted in Figure 22. The data indicates that the average flow is less than 1000 m^3/s during lean period November to May and 10%, 50%, 90%, and average dependable flow tends to be the same. However, during July to October, a higher value due to monsoon discharge is observed, along with a sharp variation on 10%, 50%, 90%, and average dependable value. This also indicates a higher degree of flow during certain periods of monsoon, while the flow during rest of the time is around 90–386 m^3/s.

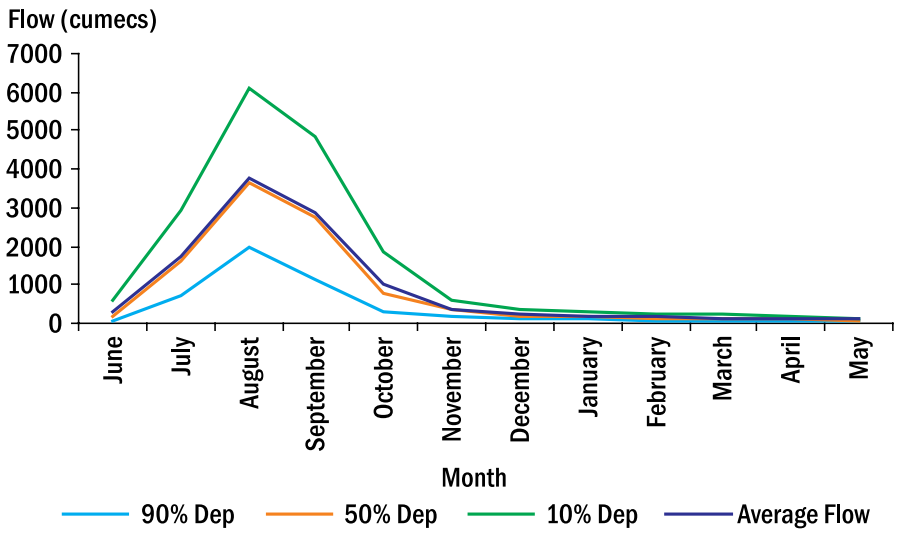


Figure 22 Trend of dependable flow of River Ganga at Kanpur

The data on the dependable flow of the River Ganga at Allahabad (1970–2008) is depicted in Figure 23.

The data indicates that the average flow is less than 1000 m^3/s during lean periods, and 10%, 50%, 90%, and average dependable flows tend to be the same. However, during July and October, a higher value due to monsoon discharge is observed, and a sharp variation on 10%, 50%, 90%, and average dependable value is also observed. This indicates that certain periods of monsoon show higher degree of peak flow, while during the rest of the time, the peak flow is around 279–997 m^3/s.

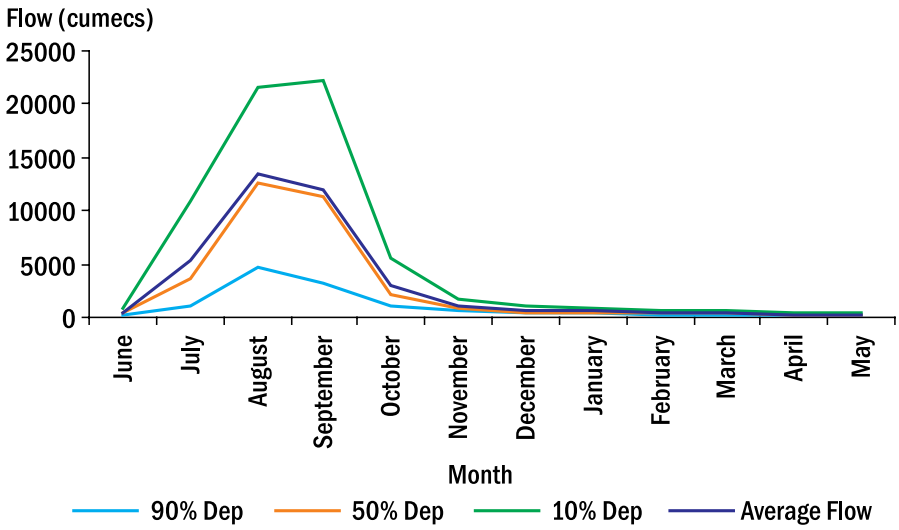


Figure 23 Trend of dependable flow of River Ganga at Allahabad

Data on the dependable flow of the River Ganga at Varanasi (1959–2008), is depicted in Figure 24. It is observed from the dependable flow data of the Ganga at Varanasi (1959–2008) that the average flow is less than 1200 m^3/s during lean periods, and 10%, 50%, 90%, and average dependable flow tends to be the same. However, during July and October, a higher value due to monsoon discharge is observed, and a sharp variation on 10%, 50%, 90%, and average dependable value is also observed. This indicates that certain periods of monsoon show higher degree of peak flow, which is around 278–1160 m^3/s during the rest of the time.

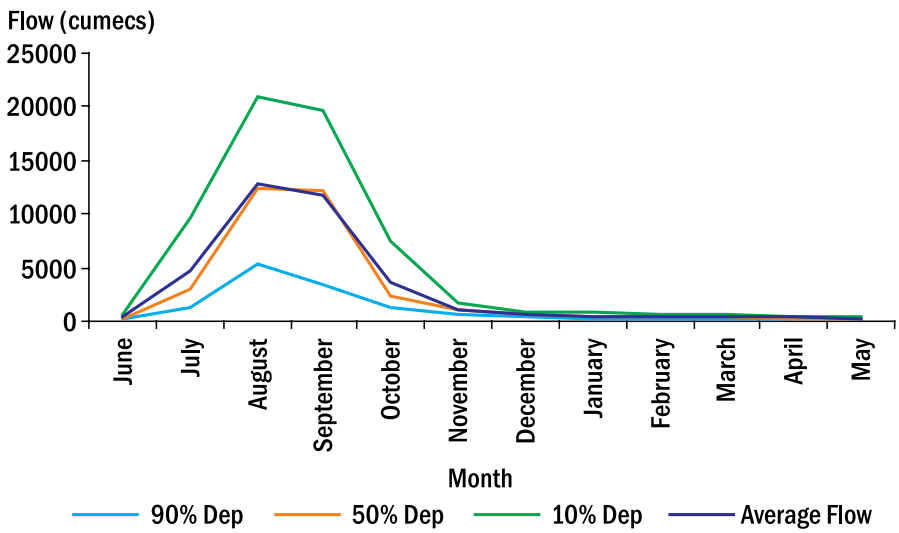


Figure 24 Trend of dependable flow of River Ganga at Varanasi

A comparison of the flow data in Kanpur, Allahabad, and Varanasi reveals a similar trend in the flow. However, the flow in Kanpur during the lean period is almost half of that in Allahabad and Varanasi, thus conferring a critical status on Kanpur with respect to water quality management.

STATUS OF WASTE WATER DISCHARGE INTO THE RIVER GANGA

- Municipal waste water discharge into the Ganga from Class I cities is 2561.7 million litres per day (MLD), and 1174.4 MLD waste water treatment capacity (45.8% of the discharge) exists. This information is summarized in Table 8.
- The sewage generated in the cities like Patna (249.2 MLD), Kanpur (339.3 MLD), Allahabad (208.0 MLD), Varanasi (187.1 MLD), Kolkata (618.4 MLD), and Howrah (136.2 MLD) is much more than the existing capacity for sewage treatment plants in these major cities—Patna (43.7%), Kanpur (50.4%), Allahabad (42.8%), Varanasi (75.3%), Kolkata (27.8%) and Howrah (46.9%). It is pertinent to mention that waste water in Kolkata and Howrah is discharged into the estuarine part of the river.
- About 121.9 MLD of waste water is generated in Class II cities, and treatment capacity available is only 16.4 MLD, which is 13.5% of the total waste water generated. The contribution of Class II cities to sewage generation is as low as 4.76% (comparative values compared to big cities) compared to sewage generated by Class I cities (Table 9).
- The industrial effluent generated and municipal sewage discharged into the Ganga, by state, is given in Table 10. It is observed that the industrial effluent generated is 10.65% of the municipal sewage generated (data of West Bengal is not included).

River Ganga at Shuklaganj

Table 8 Sewage pollution load of Class I cities (sewage disposed of in the River Ganga)

S. No.	City/Town	Population	States/UTs	Total Sewage (Mld)	Capacity of STP (Mld)	Capacity Gap (Mld)	Percent Treatment Capacity
1	Hardwar	175010	Uttarakhand	39.6	18.0	21.6	45.5
2	Kanpur	2532138	Uttar Pradesh	339.3	171.1	168.2	50.4
3	Varanasi	1100748	Uttar Pradesh	187.1	141.0	46.1	75.3
4	Allahabad	990298	Uttar Pradesh	208.0	89.0	119.0	42.8
5	Farrukhabad-cum-Fatehgarh	227876	Uttar Pradesh	30.5	8.3	22.2	27.0
6	Mirzapur-Vindhyachal	205264	Uttar Pradesh	27.5	14.0	13.5	50.9
7	Unnao	144917	Uttar Pradesh	23.9	19.4	4.5	81.2
8	Ballia	102226	Uttar Pradesh	18.0	—	18.0	—
9	Bhagalpur	340349	Bihar	61.6	11.0	50.6	17.9
10	Patna	1376950	Bihar	249.2	109.0	140.2	43.7
11	Munger	187311	Bihar	34.0	13.5	20.5	39.7
12	Katihar	175169	Bihar	31.7	31.7	0.0	100.0
13	Kolkata	4580544	West Bengal	618.4	172.0	446.4	27.8
14	Haldia	170695	West Bengal	24.5	24.5	0.0	100.0
15	Santipur	138195	West Bengal	18.7	18.7	0.0	100.0
16	Nabadwip	115036	West Bengal	15.5	10.0	5.5	64.4
17	Basirhat	113120	West Bengal	15.3	—	15.3	—
18	Bangaon	102115	West Bengal	13.8	—	13.8	—
19	South Dumdum	392150	West Bengal	53.0	52.9	0.1	99.8
20	Rajpur Sonarpur	336390	West Bengal	33.6	45.4	0.0	100.0
21	Kamarhati	314334	West Bengal	48.8	40.0	8.8	82.0
22	North Dumdum	220032	West Bengal	29.7	—	29.7	—
23	Naihati	215432	West Bengal	20.5	—	20.5	—
24	Ulberia	202095	West Bengal	27.3	—	27.3	—
25	Kanchrapara	126118	West Bengal	17.0	—	17	—
26	Halisahar	124479	West Bengal	16.8	—	16.8	—
27	North Barrackpur	123523	West Bengal	19.2	16.7	2.5	87.0
28	Rishra	113259	West Bengal	13.5	15.3	0.0	100.0
29	Ashoknagar Kalyangarh	111475	West Bengal	17.3	15.0	2.3	86.7
30	Haora	1008704	West Bengal	136.2	63.9	72.3	46.9
31	Bhatpara	441956	West Bengal	59.7	28.5	31.2	47.7
32	Maheshtala	389214	West Bengal	52.5	3.9	48.6	7.4
33	Serampore	197955	West Bengal	26.7	18.9	7.8	70.8
34	Chandannagar	162166	West Bengal	16.1	22.7	0.0	100.0
35	Habra	127695	West Bengal	17.2	—	17.2	—
	Total	17384938		2561.7	1174.4	1407.5	45.8

Table 9 Sewage pollution load of Class II cities (sewage disposed of into the River Ganga)

S. No.	City/Town	Population	States/UTs	Total Sewage (Mld)	Capacity of STP (Mld)	Capacity Gap (Mld)	Percent Treatment Capacity
1	Rishikesh	59671	Uttarakhand	10.7	6.3	4.4	58.9
2	Roorkee	97064	Uttarakhand	11.0	—	11	—
3	Deoband	81706	Uttar Pradesh	7.8	—	7.8	—
4	Najibabad	79087	Uttar Pradesh	7.6	—	7.6	—
5	Bijnor	79368	Uttar Pradesh	7.6	8.1	0.0	100.0
6	Kannauj	71530	Uttar Pradesh	7.0	—	7.0	—
7	Gangaghat	70817	Uttar Pradesh	6.8	—	6.8	—
8	Mughalsarai	88386	Uttar Pradesh	16.0	—	16.0	—
9	Ghazipur	95243	Uttar Pradesh	10.7	—	10.7	—
10	Buxar	82975	Bihar	7.6	2.0	5.6	26.3
11	Sitamarhi	56769	Bihar	6.5	—	6.5	—
12	Begusarai	93378	Bihar	8.6	—	8.6	—
13	Mokameh	56400	Bihar	8.0	—	8.0	—
14	Ranaghat	68754	West Bengal	6.0	—	6.0	—
	Total	1081148		121.9	16.4	106.0	13.5

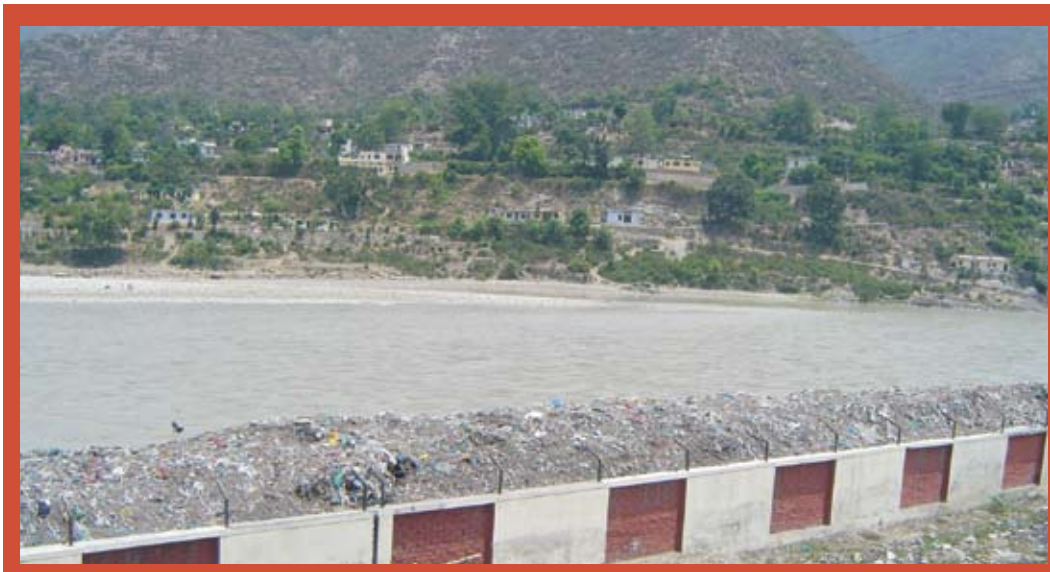
Table 10 Industrial effluent generated and municipal sewage discharged into the River Ganga, by state

State	Industrial Effluent (in Mld)	Municipal Sewage (in Mld)
Uttrakhand	3.5	61.3
Uttar Pradesh	152.3	897.8
Bihar	56.2	407.2
West Bengal	73.9	1317.3
Total	285.9	2683.6

CONCLUSION

The River Ganga suffers from myriad problems, most significant ones being the lean flow during dry season and dumping of nearly 50% untreated and/or partially treated sewage into the river. River flow in the Ganga is low because of diversion through Upper and Lower Ganga canals, leaving virtually very little flow in the main river, which makes it impossible for fair weather dilution even with the treated sewage.

Ganga in Uttar Pradesh demands treatment of sewage and minimum ecological flow for its survival as a river. Since a river is a living eco-system and therefore ultimate goal should be to protect the functioning of the river eco-system. The increasing trend of Faecal Coliform in Uttarakhand in Alakananda, Mandakini and Bhagirathi downstream of Gangotri is observed. In



River Ganga at Srinagar

Uttar Pradesh increasing trend of BOD and Faecal Coliform is observed from Garhmukteshwar to Tarighat reflecting entire length in the state. In Bihar stretch of the river level of BOD is although confirming to standard but increasing trend is clearly seen. Whereas, Faecal Coliform is not confirming to standard and show increasing trend. In West Bengal although decreasing trend is observed with respect to Faecal Coliform however exceeding the standard at all locations. The water quality needs improvement in Uttrakhand from downstream of Rudrapryag, in Uttar Pradesh from Garhmukteshwar to Tarighat, in Bihar from Buxar to Kahalgaon and in West Bengal from Behrampore to Diamond Harbour on priority basis. An assessment of flow and wastewater is necessary.

It is to be borne in mind that unabated discharge of treated sewage, even if after 100% treatment, with BOD level of 30 mg/l, cannot bring the water to bathing quality level in lean season river flow. In order to achieve the goal it is important that minimum flow throughout the year is maintained to support eco-system in general and all forms of aquatic life in particular and ultimately maintain the wholesomeness of water bodies. Hence, it would be prudent to create more water storage facility in the upper stretches of the Ganga riverine system for release in the lean period to effectively maintain minimum flow in the river which support hydel power generation and also thereby reduce chances of flood in the monsoon season.

ANNEXURE I

Salient Features of River Ganga

Total length	2,525 km
Uttar Pradesh and Uttarakhand	1,450 km
Boundary between Uttar Pradesh and Bihar	110 km
Bihar	445 km
West Bengal	520 km
Geographical area of India	3.28 million sq km
Reported area – river basins	3.05 million sq km
Catchment area – Ganga basin	8,61,404 sq km (26.4%)
Average annual discharge	4,93,400 million cubic metre
Tributaries	Yamuna, Ramganga, Gomti, Ghaghara, Gandak, Kosi and Kali
Main sub tributaries	Chambal, Sindh, Betwa, Ken, Tons, Sone, Damodar and Kangsabati Haldi

ANNEXURE II

River-wise water quality monitoring network in River Ganga basin

Ganga (Including Alaknanda and Mandakini) (39)	Daha (1)
Yamuna (23)	Dhous (1)
Betwa (10)	Farmer (1)
Chambal (8)	Gandak (1)
Damodar (5)	Gohad (1)
Gomti (5)	Johila (1)
Sone (5)	Kali sot(1)
Ghaghra (3)	Kolar (1)
Hindon (3)	Mahananda (1)
Khan (3)	Mandakini (Madhya Pradesh) (1)
Kshipra (3)	Ramganga (1)
Churni (2)	Rapti (1)
Kali (2)	Rupanarayan (1)
Kali (West) (2)	Sai (1)
Parvati (2)	Sankh(1)
Rihand (2)	Sikrana (1)
Tons (Madhya Pradesh) (2)	Sindh (1)
Barakar (1)	Sirsa (1)
Bichia(1)	Tons (Himachal Pradesh) (1)
Bihar(1)	

ANNEXURE III

List of parameters – River Ganga water quality monitoring programme

Core parameters (9)	**Field observations (7)**
PH	Weather
Temperature	Depth of main stream/depth of water table
Conductivity	Colour and intensity
Dissolved Oxygen	Odour
Bio-chemical Oxygen Demand	Visible effluent discharge
Nitrate – N	Human activities around station
Nitrite – N	Station detail
Faecal Coliform	**Trace Metals (9)**
Total Coliform	Arsenic, µg/L
General Parameters (19)	Cadmium, µg/L
Turbidity, NTU	Copper, µg/L
Phenolphthalein Alkalinity, as $CaCO_3$	Lead, µg/L
Total Alkalinity, as $CaCO_3$	Chromium (Total), µg/L
Chlorides, mg/L	Nickel, µg/L
Chemical Oxygen Demand, mg/L	Zinc, µg/L
Total Kjeldahl – N, as N mg/L	Mercury, µg/L
Ammonia – N, as N mg/L	Iron (Total), µg/L
Hardness, as $CaCO_3$	**Pesticides (15)**
Calcium, as $CaCO_3$	Alpha BHC
Sulphate, mg/L	Beta BHC
Sodium, mg/L	Gama BHC (Lindane)
Total dissolved solids, mg/L	O P DDT
Total fixed dissolved solids, mg/L	P P DDT
Total suspended Solid, mg/L	Alpha Endosulphan
Phosphate	Beta Endosulphan
Boron, mg/L	Aldrin
Magnesium, as $CaCO_3$	Dieldrin
Potassium, mg/L	Carboryl (carbamate)
Fluoride, mg/L	2-4 D
Bio-monitoring (3)	Malathian
Saprobity index	Methyl parathian
Diversity index	Anilophos
P/R Ratio	Chloropyriphos

ANNEXURE IV

Primary water quality criteria for bathing water

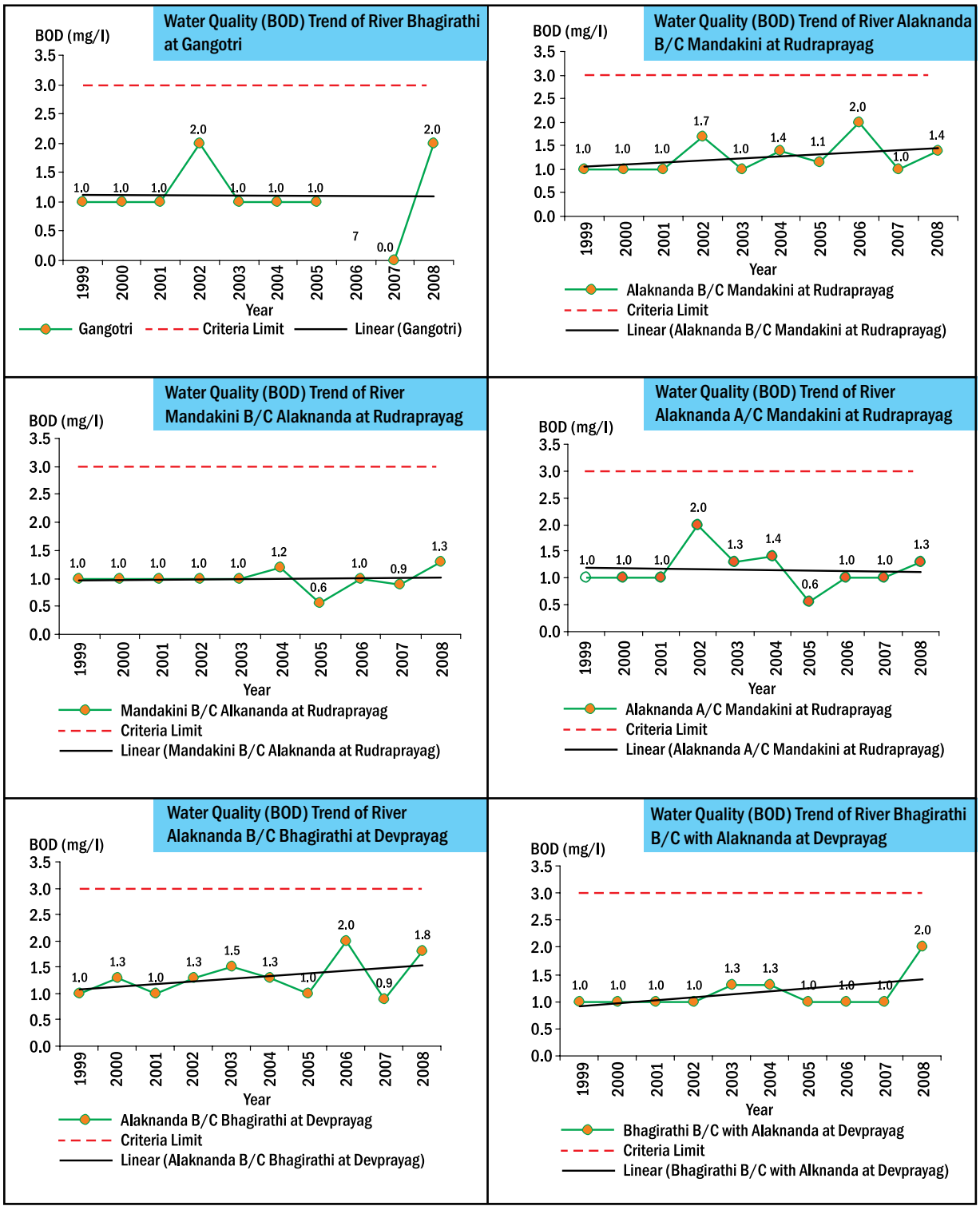
In a water body or its part, water is subject to several types of uses. Depending on the type of use and activity, water quality criteria have been specified to determine its suitability for a particular purpose. Among the various types of uses there is one use that demands highest level of water quality or purity and that is termed as 'designated best use' in that stretch of water body. Based on this, water quality requirements have been specified for different uses in terms of primary water quality criteria. The primary water quality criteria for bathing water are specified along with the rationale in Table A1.

Table A1 Primary water quality criteria for bathing water (water used for organized outdoor bathing)

Criteria	Rationale
Faecal Coliform : 500 (desirable) MPN/100ml : 2500 (maximum permissible) Faecal Streptococci : 100 (desirable) MPN/100ml : 500 (maximum permissible)	To ensure low sewage contamination, faecal coliform and faecal streptococci are considered as they reflect the bacterial pathogenicity. The desirable and permissible limits are suggested to allow for fluctuation in environmental conditions such as seasonal changes, changes in flow conditions, and so on.
pH : between 6.5 and 8.5	The range provides protection of the skin and delicate organs like eyes, nose, ears, and so on, which are directly exposed during outdoor bathing.
Dissolved oxygen : 5 mg/l or more	The minimum dissolved oxygen concentration of 5 mg/l ensures reasonable freedom from oxygen consuming organic pollution immediately U/s which is necessary for preventing production of anaerobic gases (obnoxious gases) from sediments.
Biochemical oxygen : 3 mg/l or less Demand 3 day, 27 °C	The biochemical oxygen demand of 3 mg/l or less of the water ensures reasonable freedom from oxygen demanding pollutants and prevent production of obnoxious gases.

ANNEXURE V

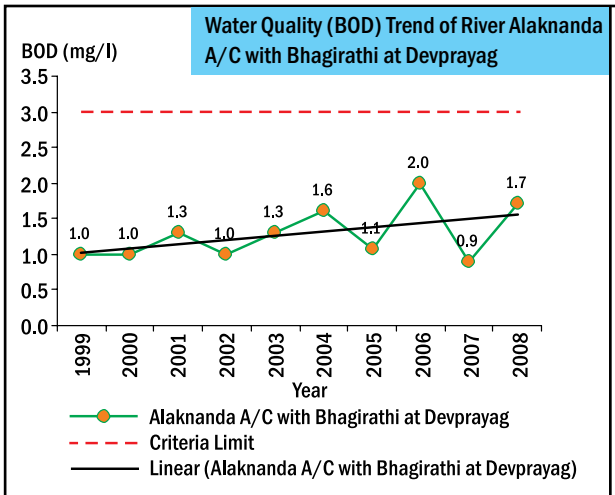
Water Quality (BOD) Trend of River Ganga in Uttarakhand

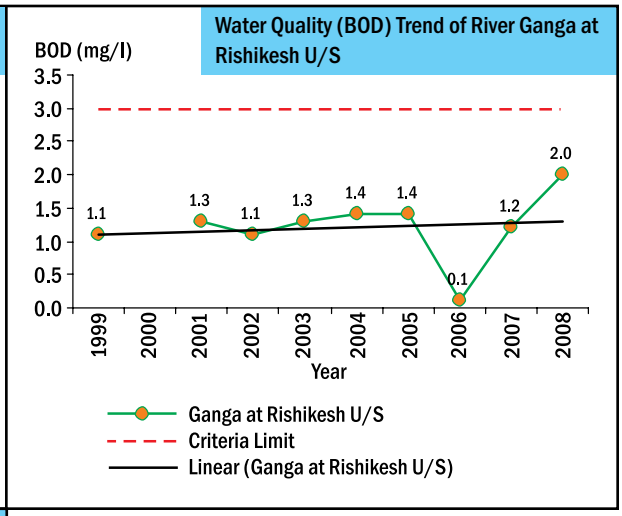


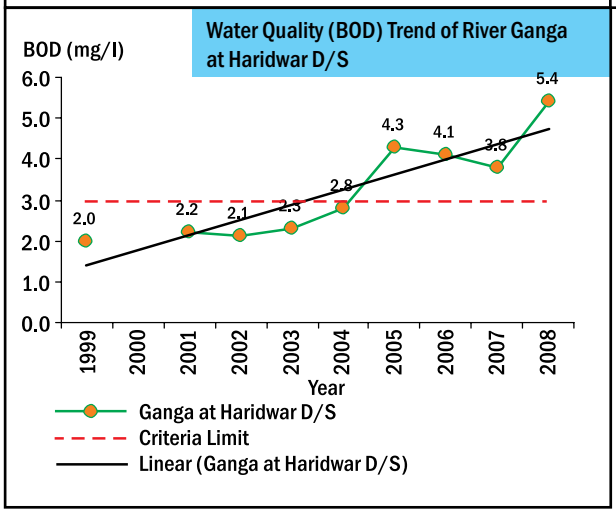
BOD – bio-chemical oxygen demand

ANNEXURE V

Water Quality (BOD) Trend of River Ganga in Uttarakhand



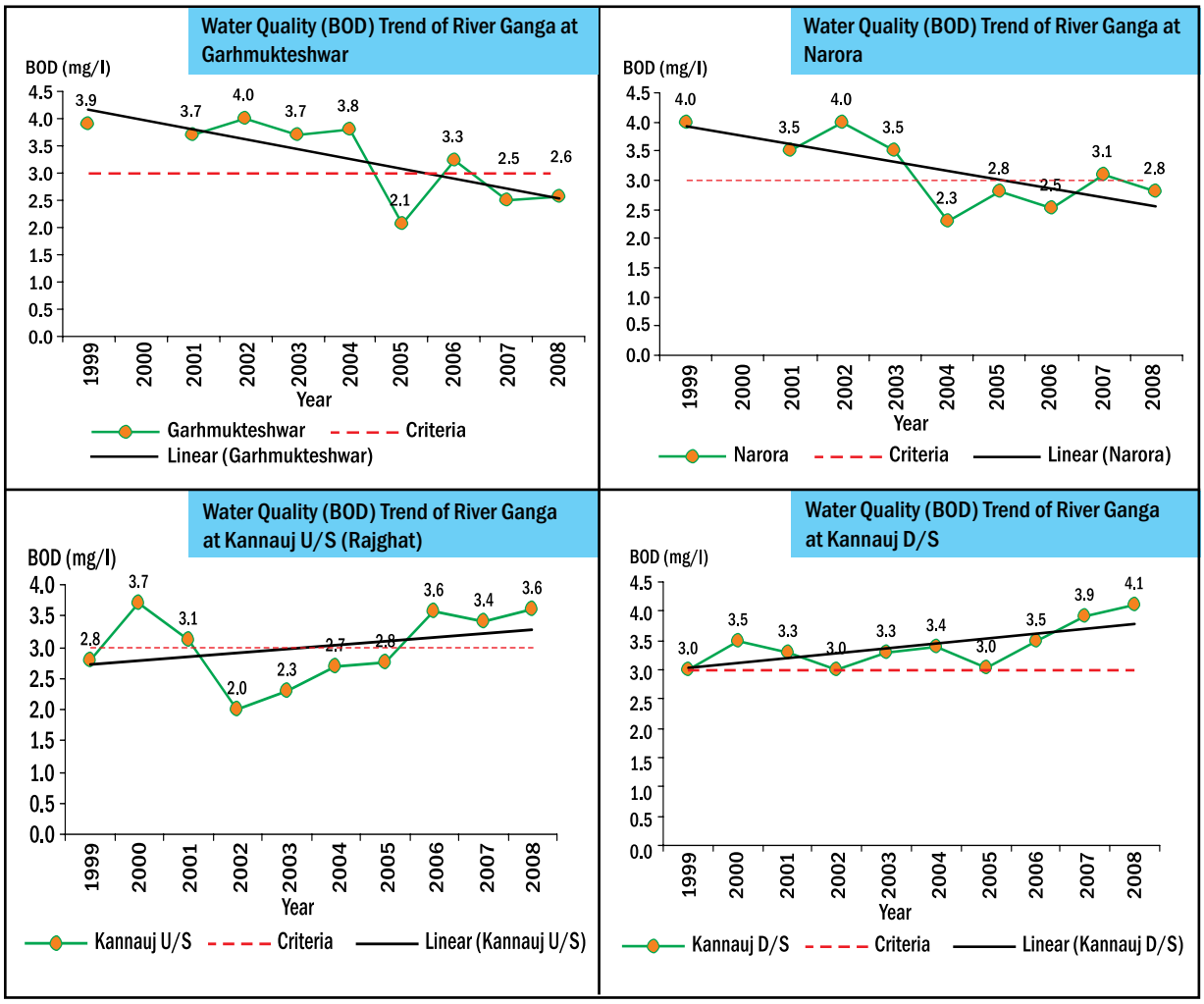




D/S – down stream; U/S – up-stream

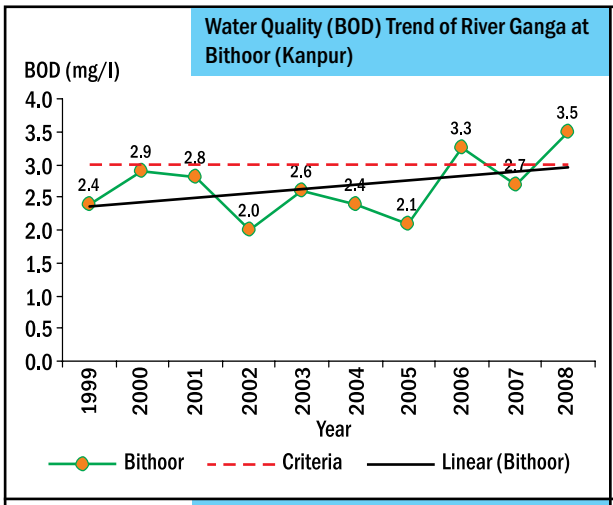
ANNEXURE V

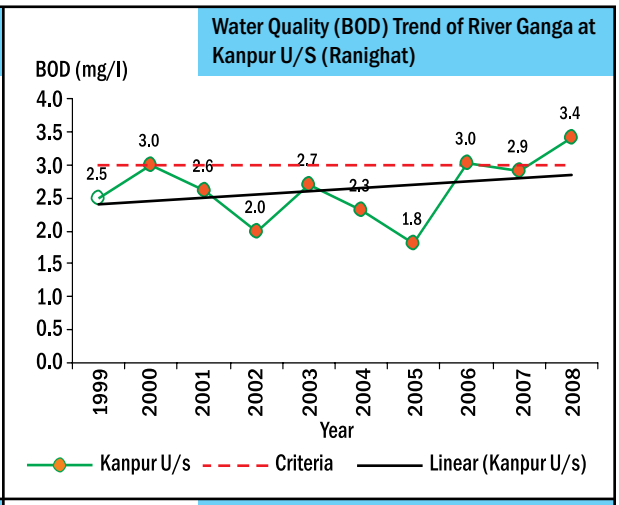
Water Quality (BOD) Trend of River Ganga in Uttar Pradesh

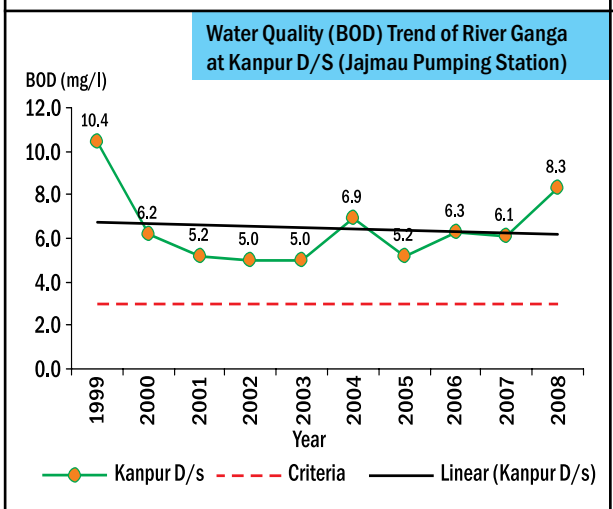


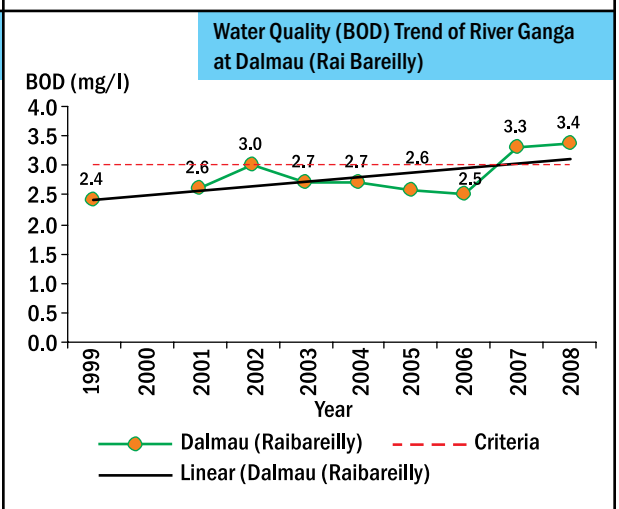
ANNEXURE V

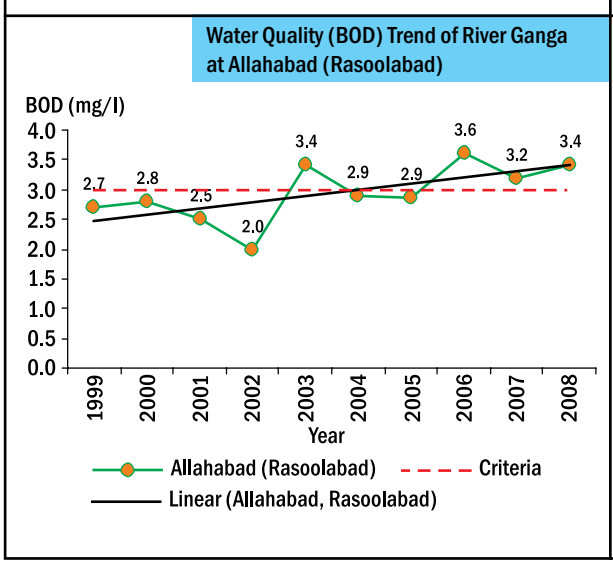
Water Quality (BOD) Trend of River Ganga in Uttar Pradesh

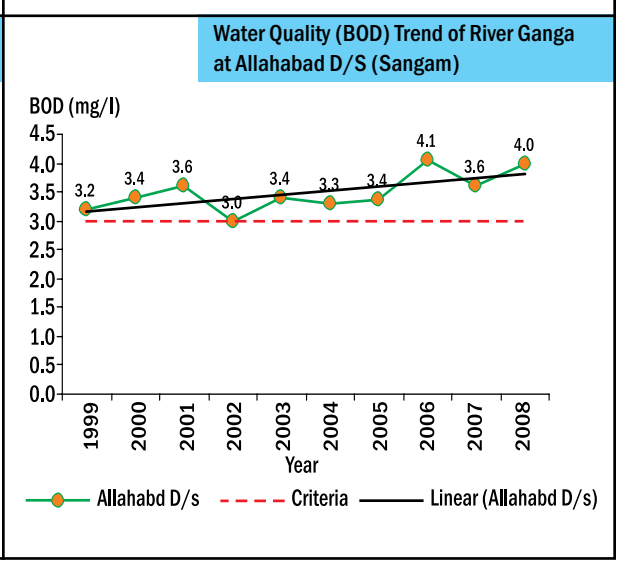






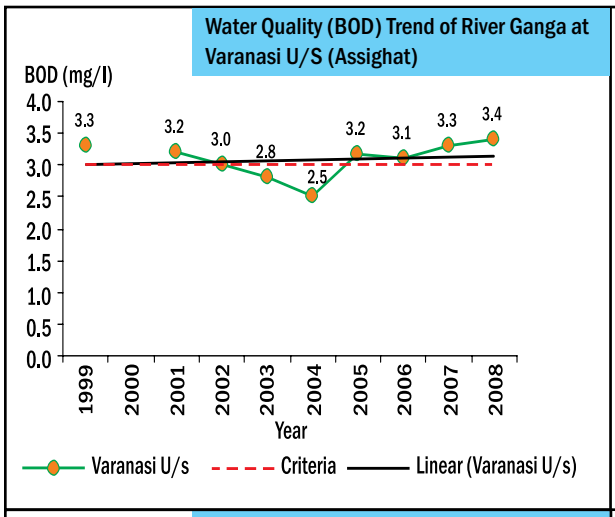


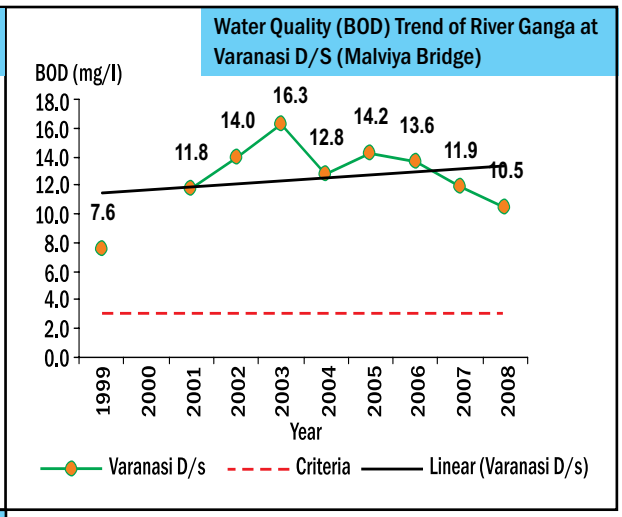


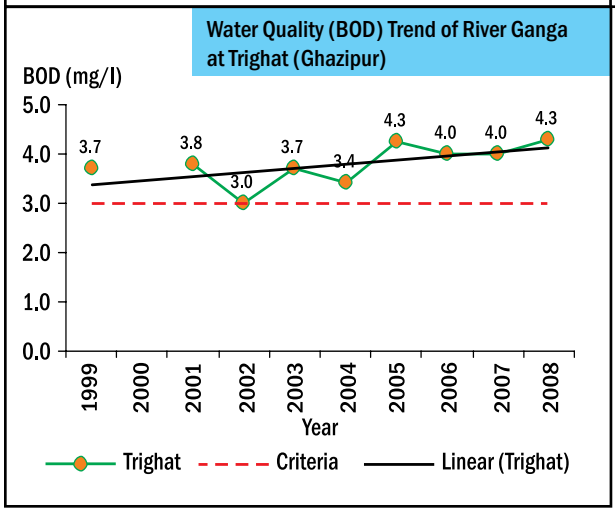


ANNEXURE V

Water Quality (BOD) Trend of River Ganga in Uttar Pradesh

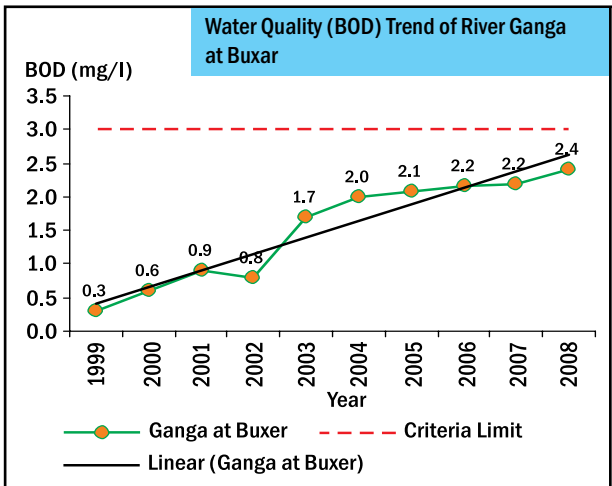


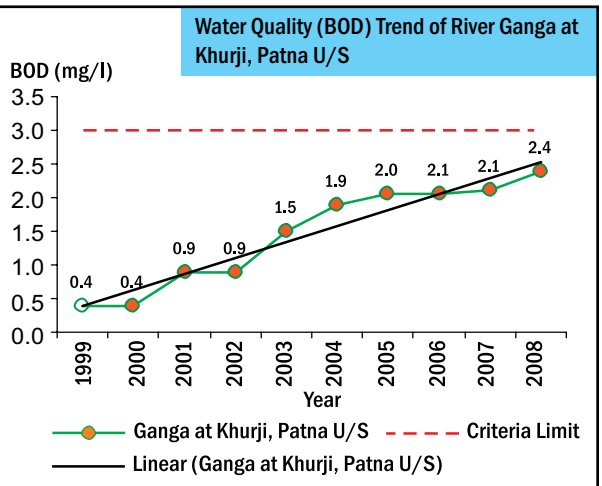


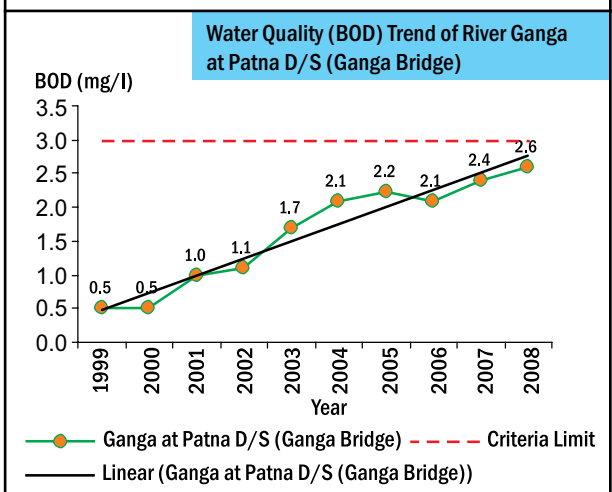


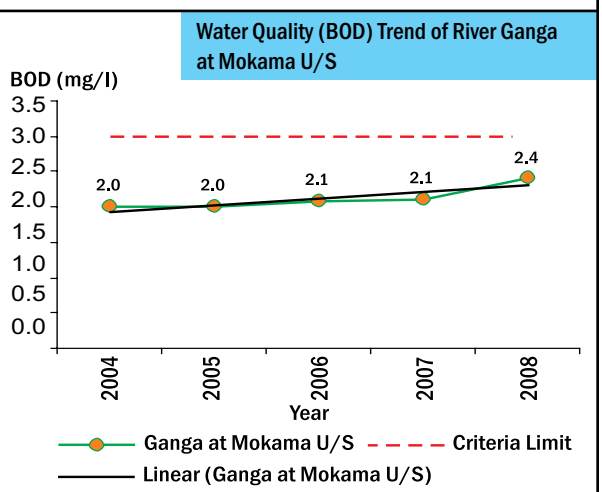
ANNEXURE V

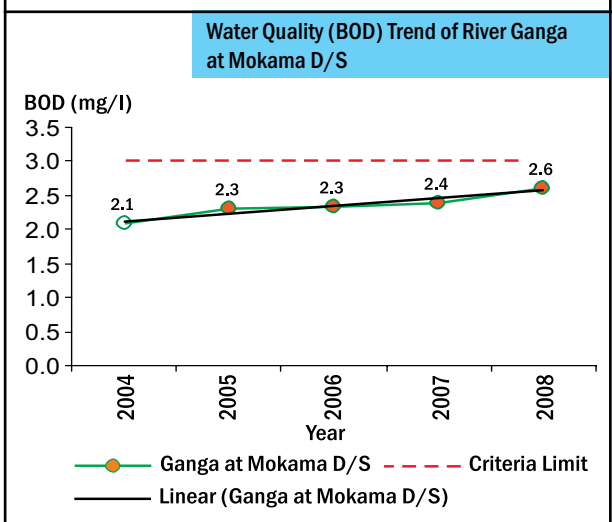
Water Quality (BOD) Trend of River Ganga in Bihar

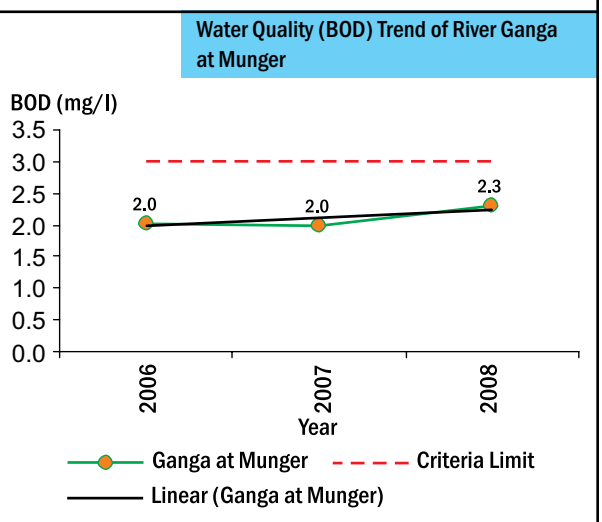






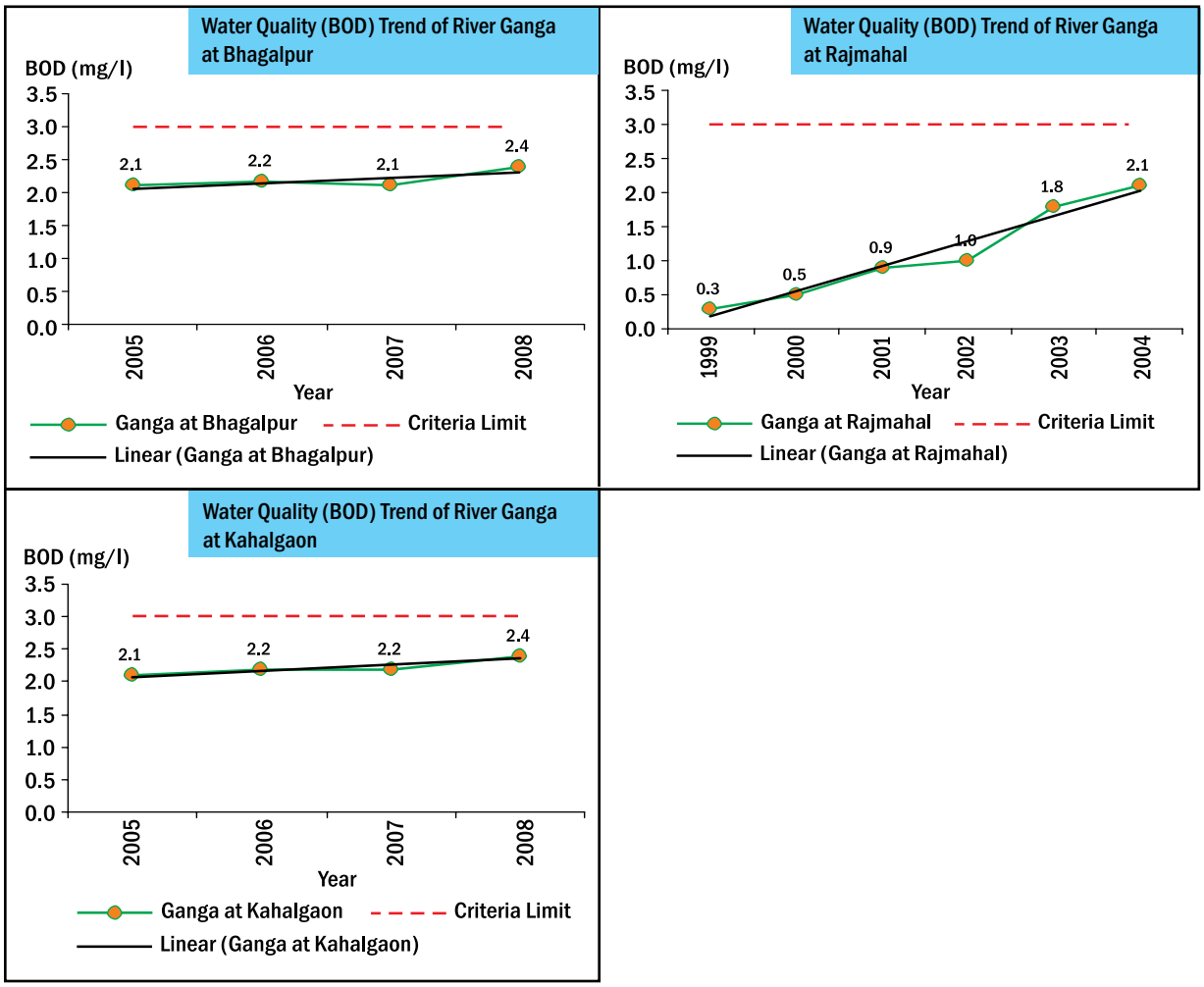






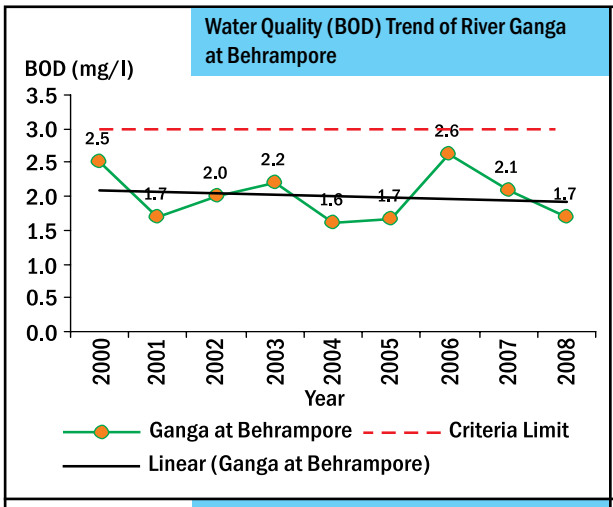
ANNEXURE V

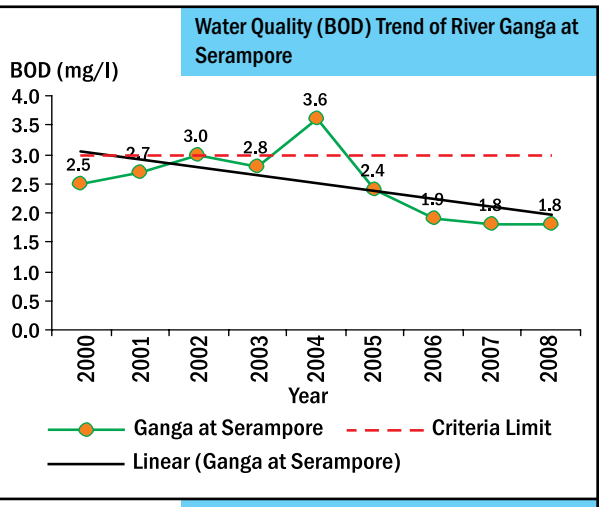
Water Quality (BOD) Trend of River Ganga in Bihar

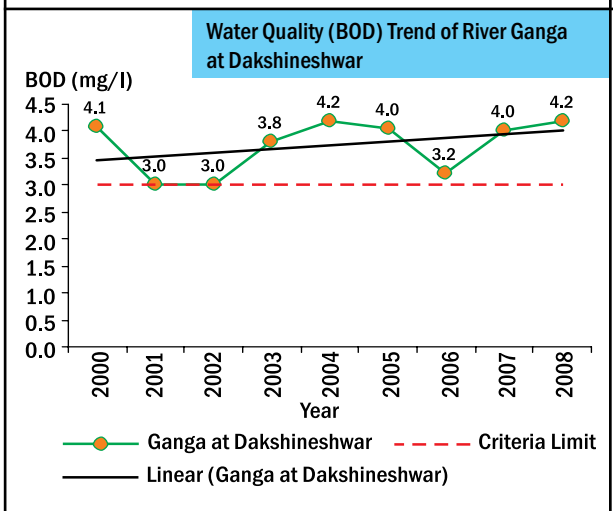


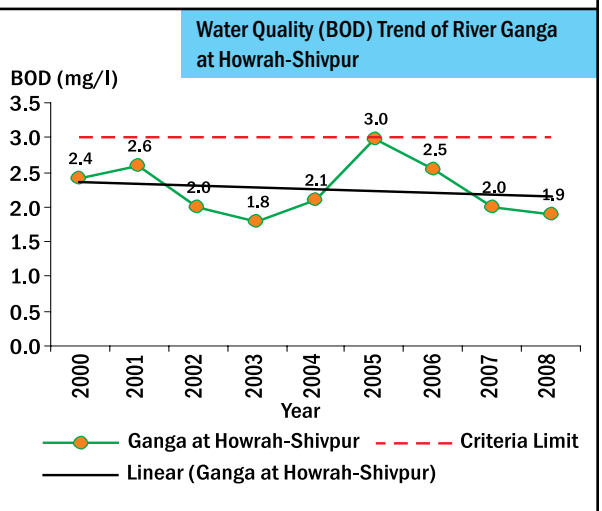
ANNEXURE V

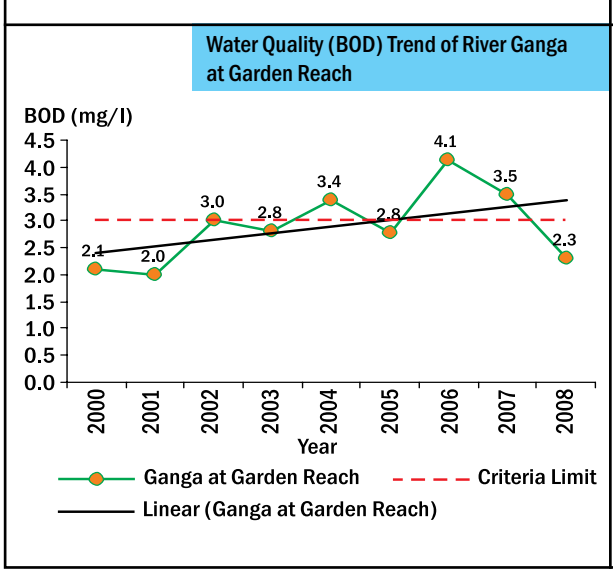
Water Quality (BOD) Trend of River Ganga in West Bengal

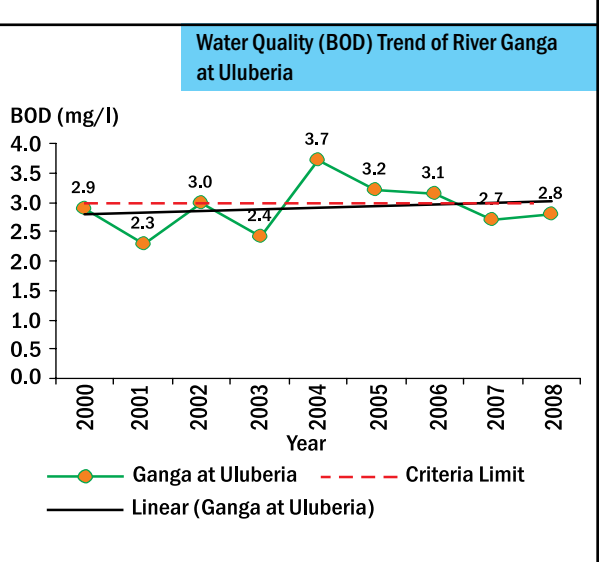






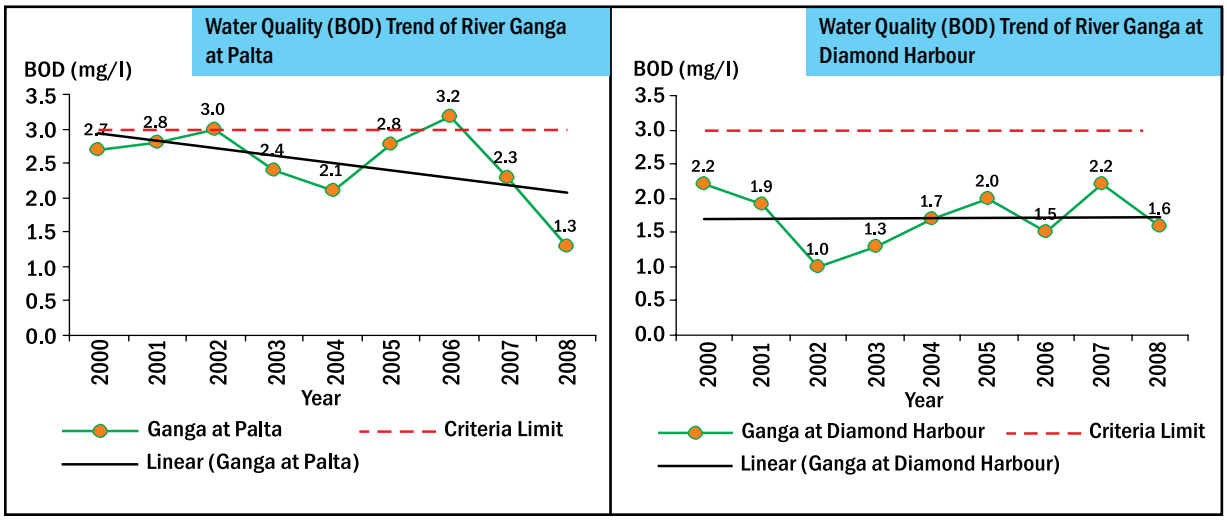






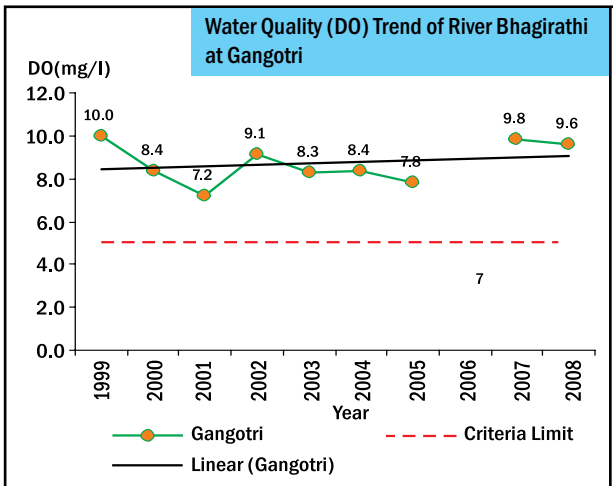
ANNEXURE V

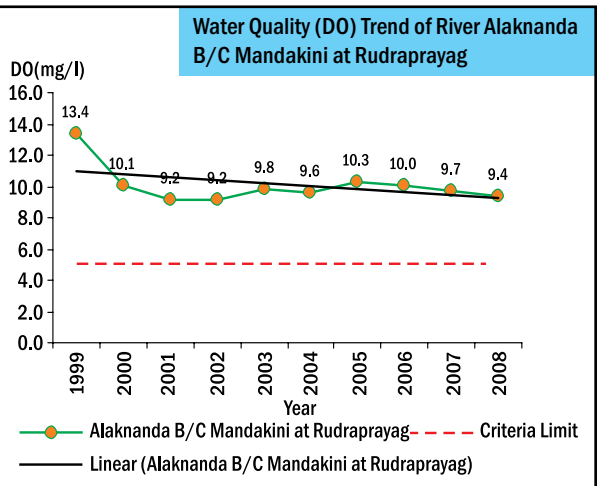
Water Quality (BOD) Trend of River Ganga in West Bengal

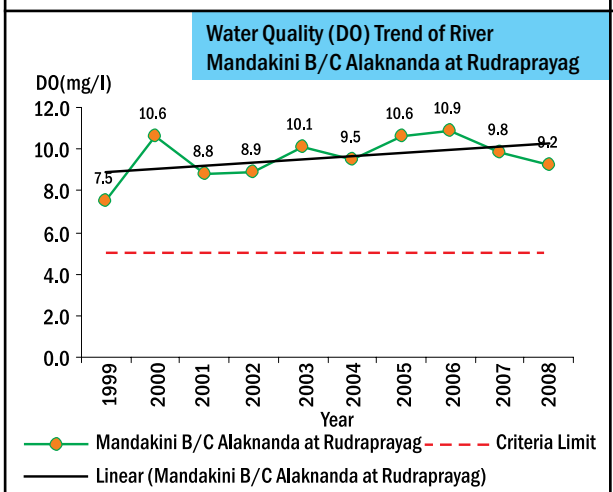


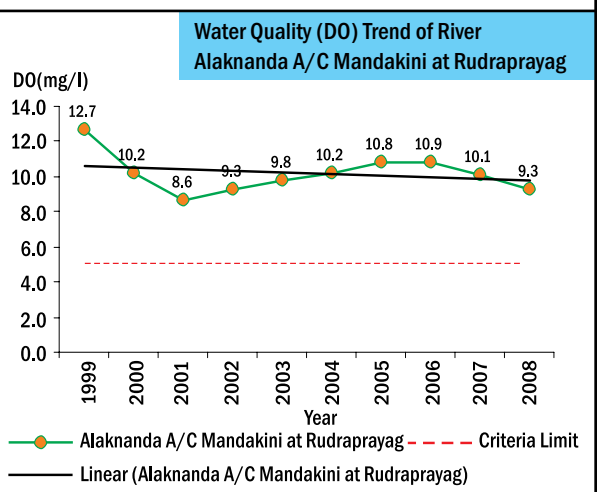
ANNEXURE V

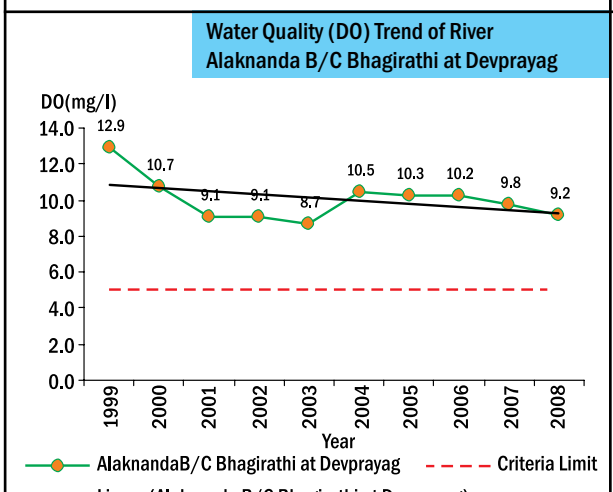
Water Quality (Dissolved Oxygen) Trend of River Ganga in Uttarakhand

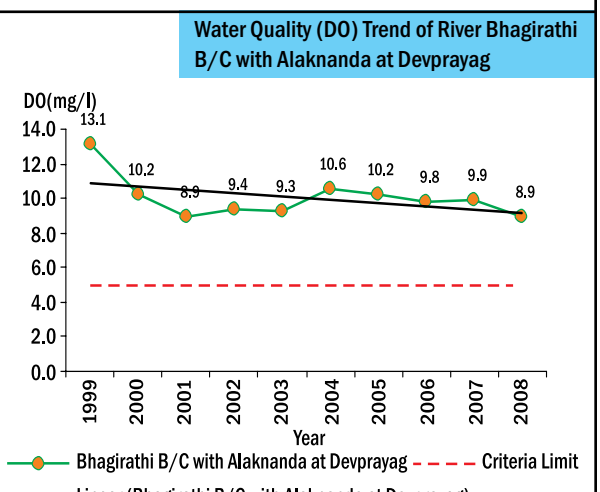






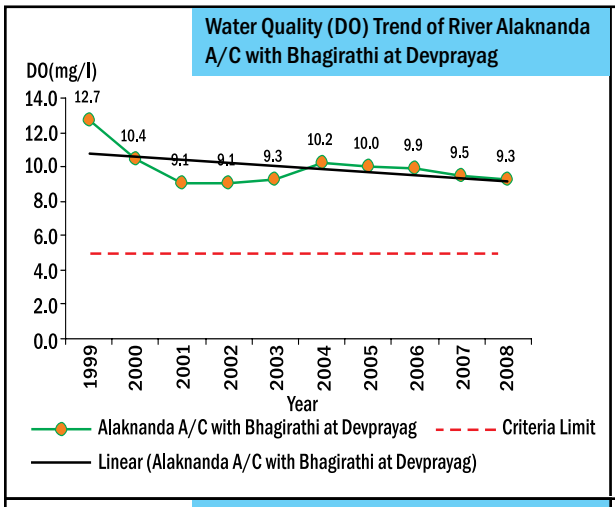


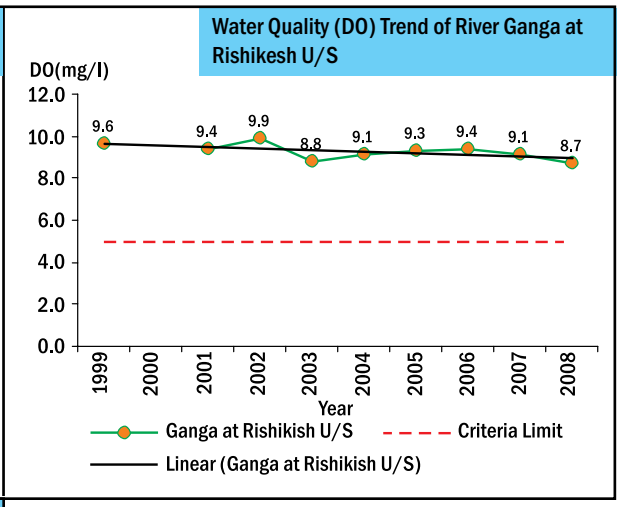


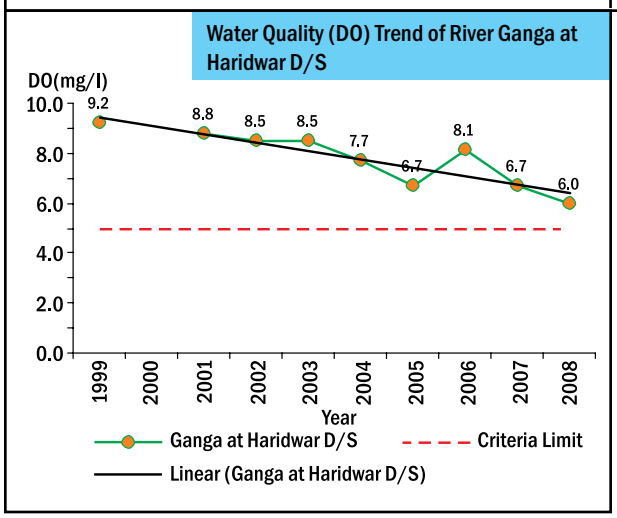


ANNEXURE V

Water Quality (Dissolved Oxygen) Trend of River Ganga in Uttarakhand

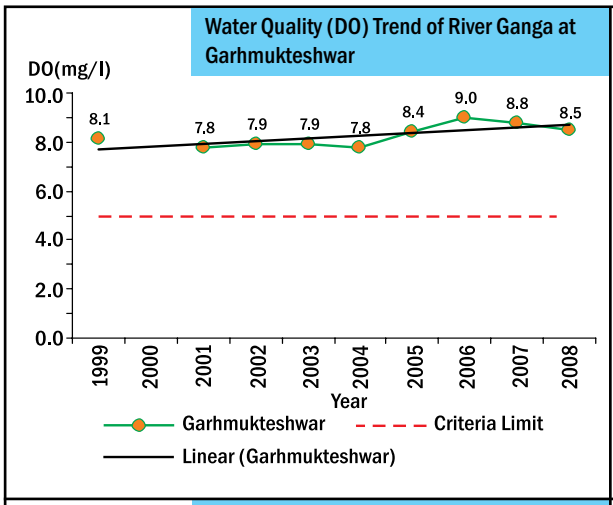


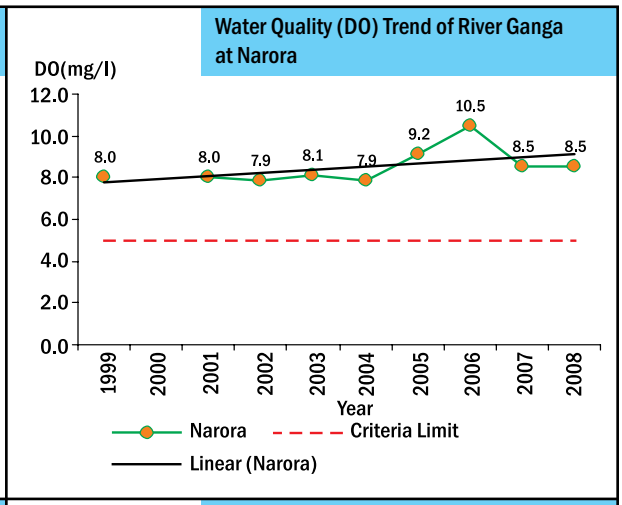


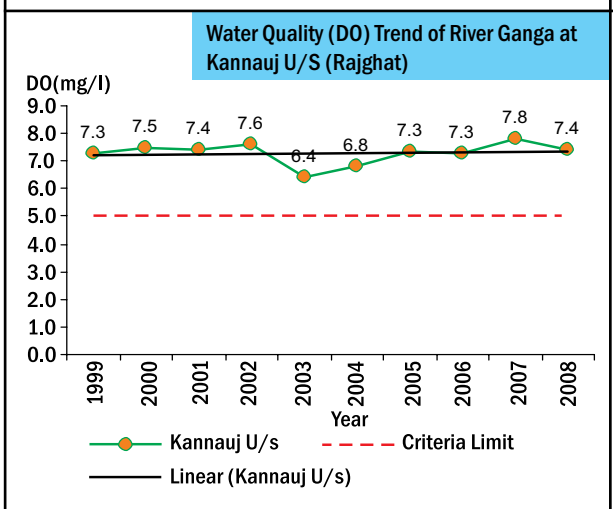


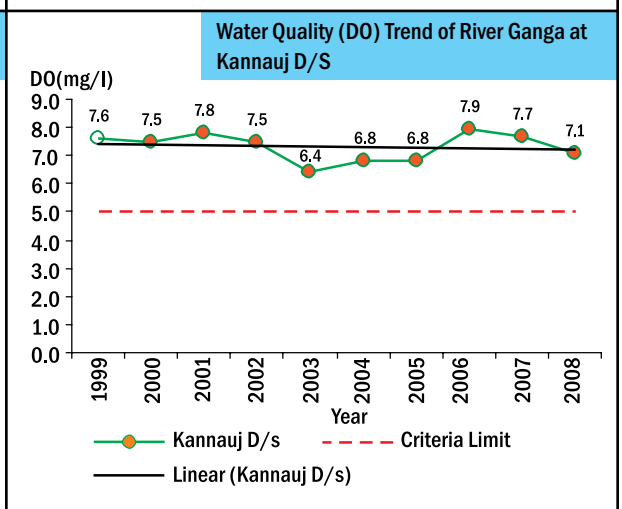
ANNEXURE V

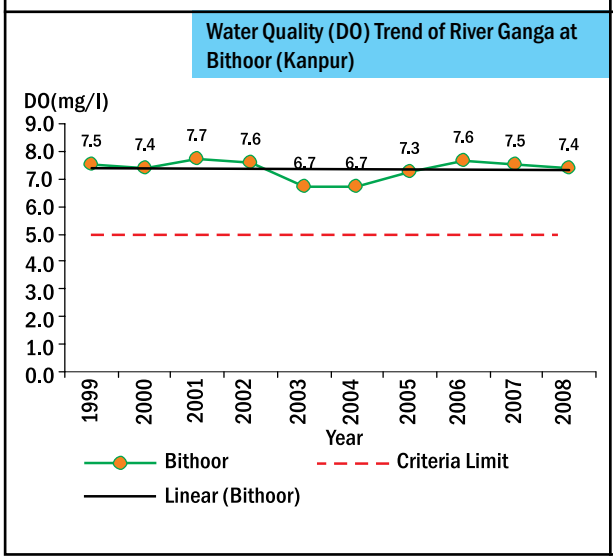
Water Quality (Dissolved Oxygen) Trend of River Ganga in Uttar Pradesh

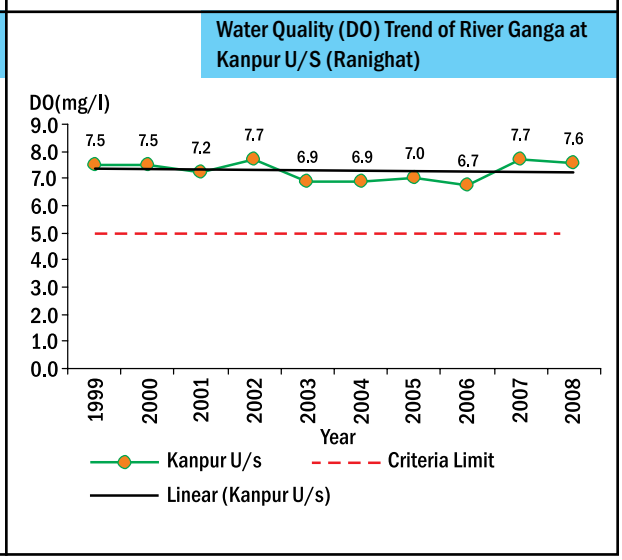






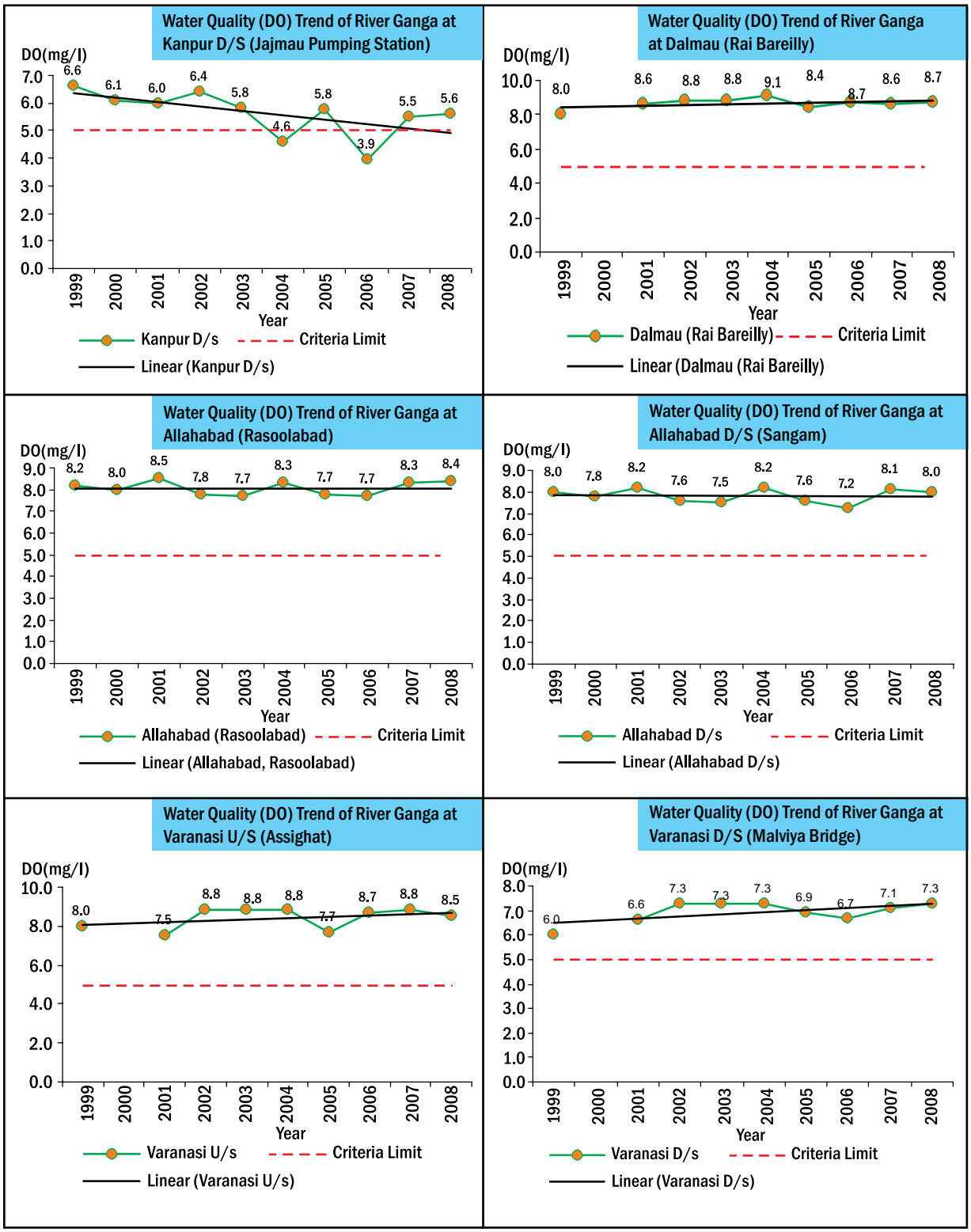






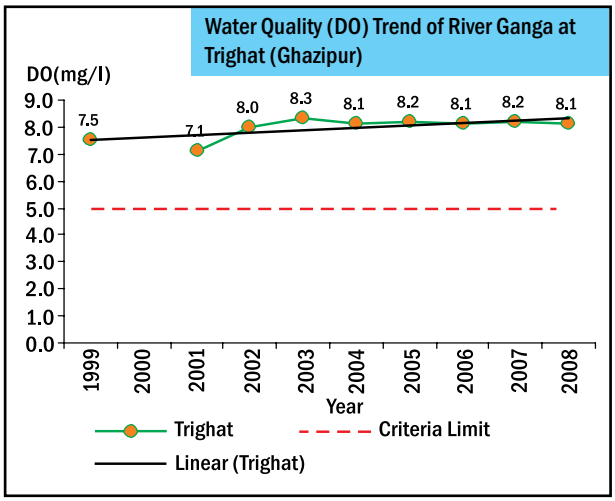
ANNEXURE V

Water Quality (Dissolved Oxygen) Trend of River Ganga in Uttar Pradesh



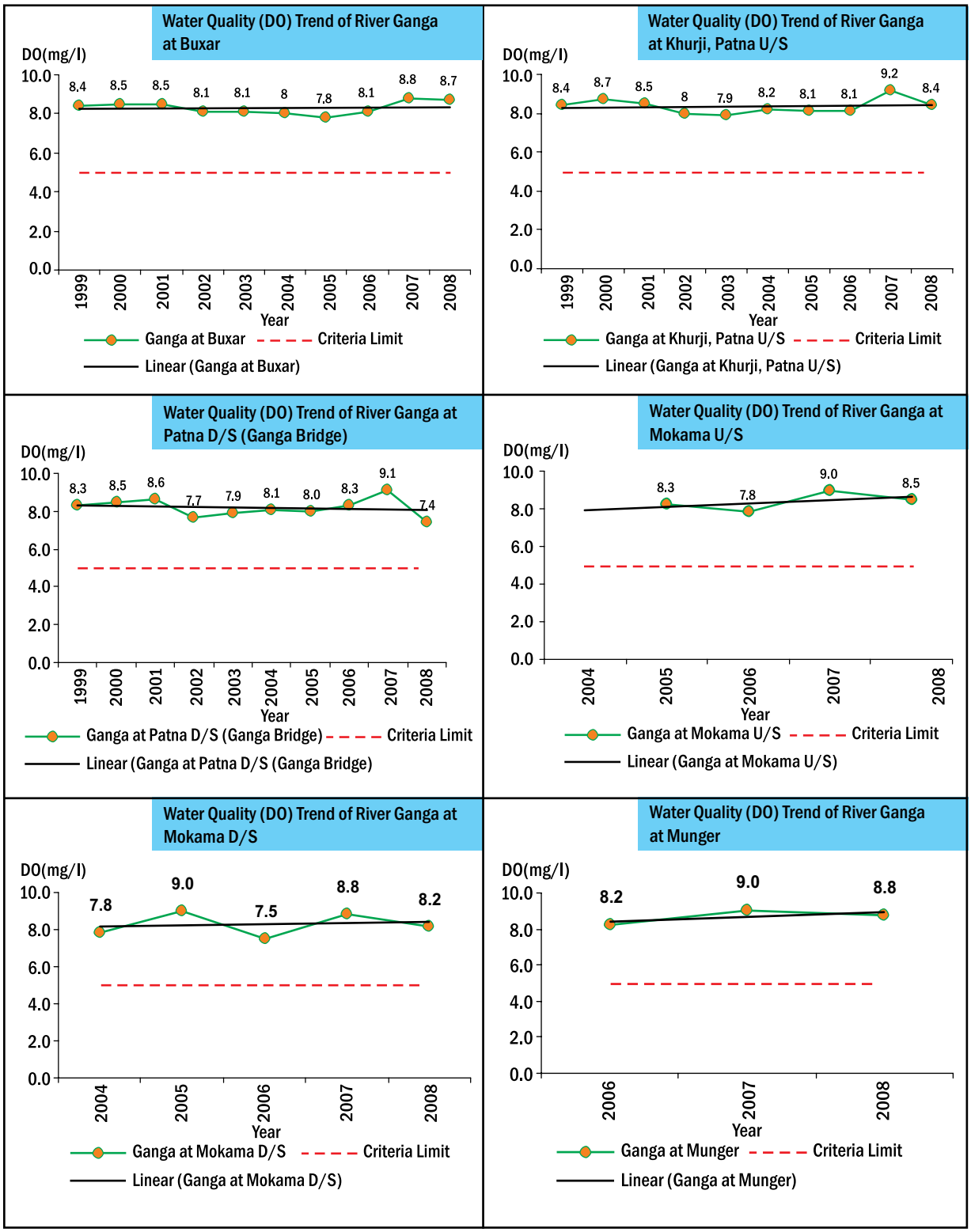
ANNEXURE V

Water Quality (Dissolved Oxygen) Trend of River Ganga in Uttar Pradesh



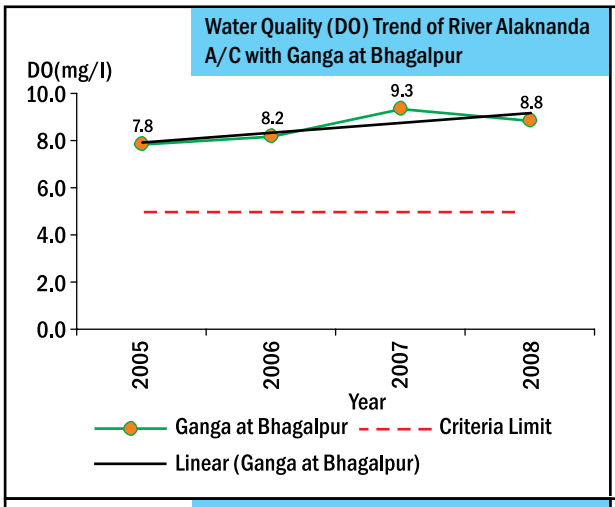
ANNEXURE V

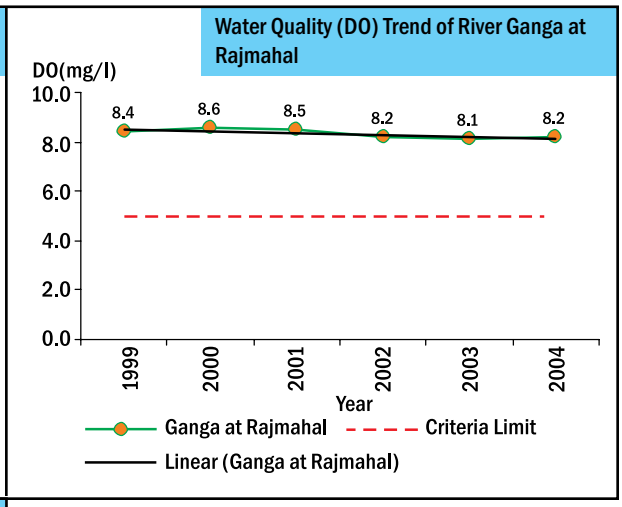
Water Quality (Dissolved Oxygen) Trend of River Ganga in Bihar

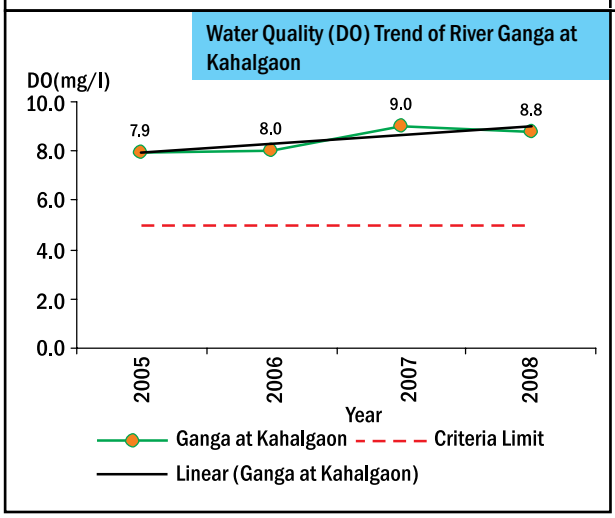


ANNEXURE V

Water Quality (Dissolved Oxygen) Trend of River Ganga in Bihar

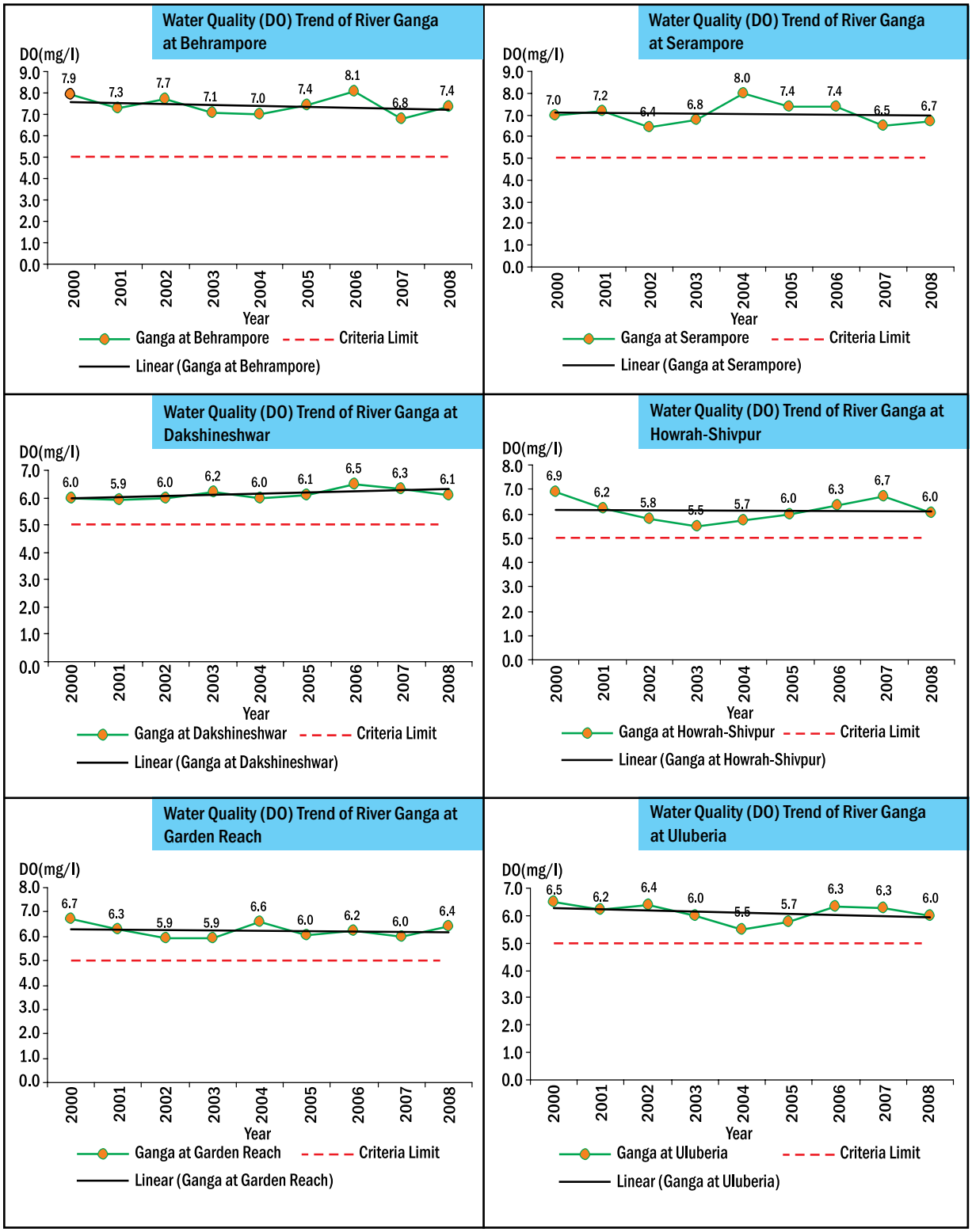






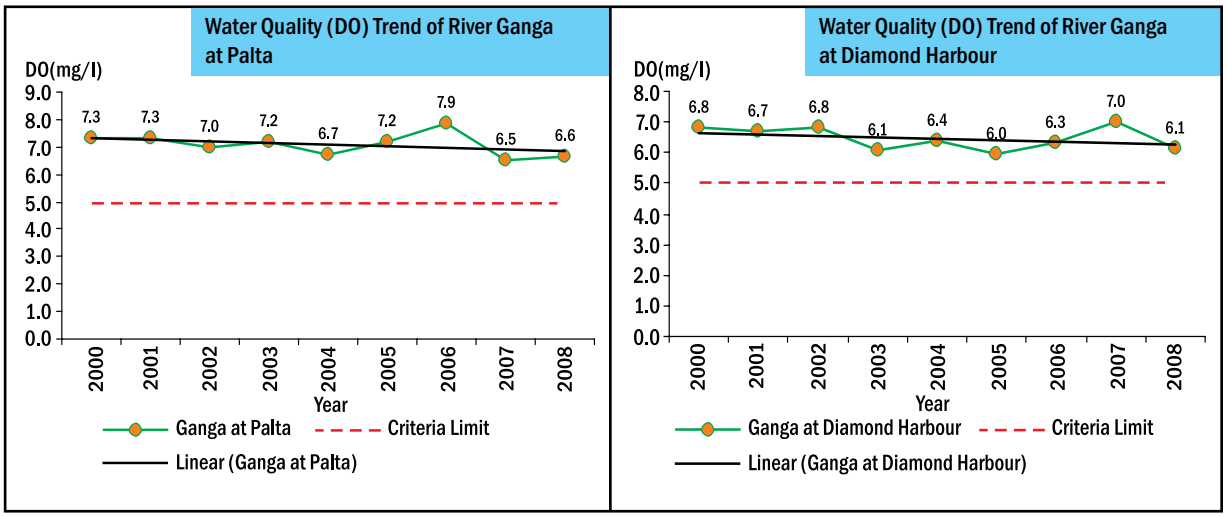
ANNEXURE V

Water Quality (Dissolved Oxygen) Trend of River Ganga in West Bengal



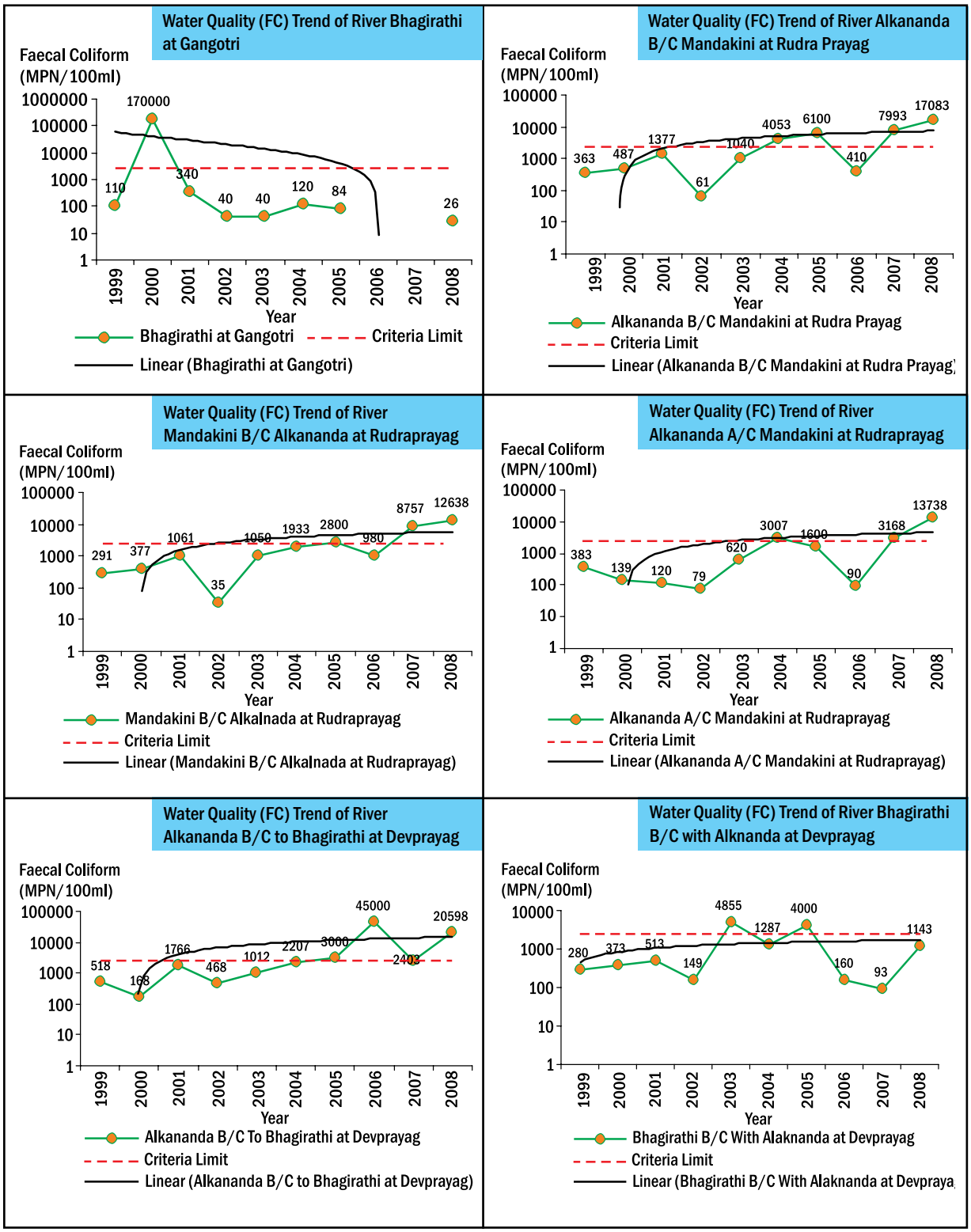
ANNEXURE V

Water Quality (Dissolved Oxygen) Trend of River Ganga in West Bengal



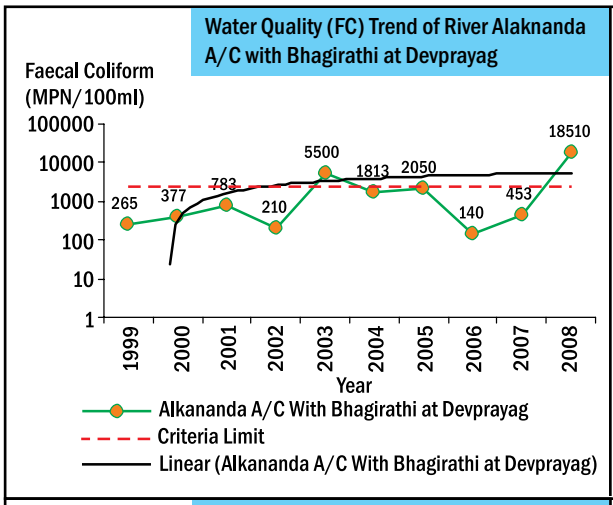
ANNEXURE V

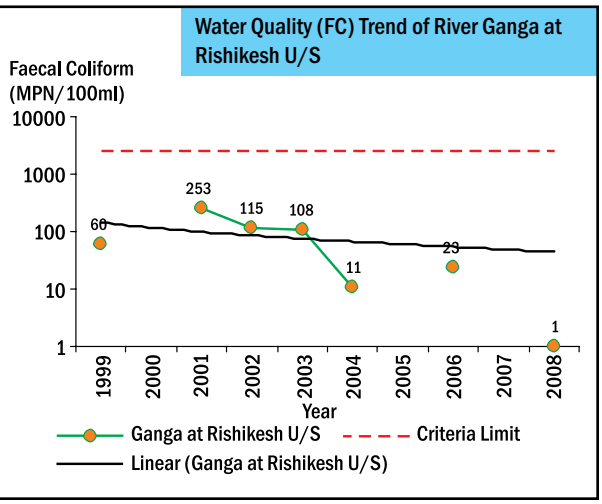
Water Quality (Faecal Coliform) Trend of River Ganga in Uttarakhand

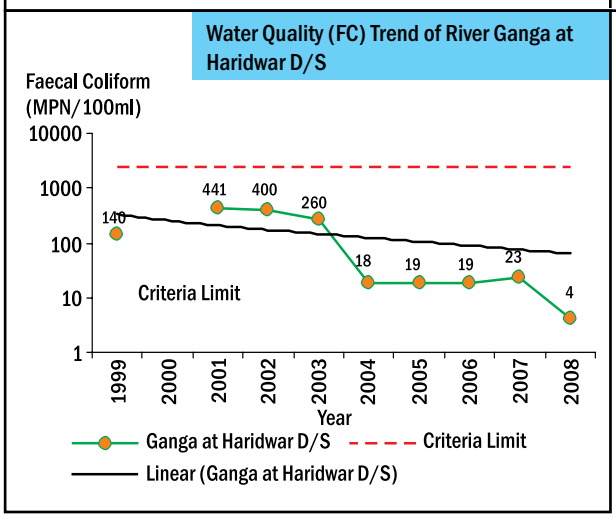


ANNEXURE V

Water Quality (Faecal Coliform) Trend of River Ganga in Uttarakhand

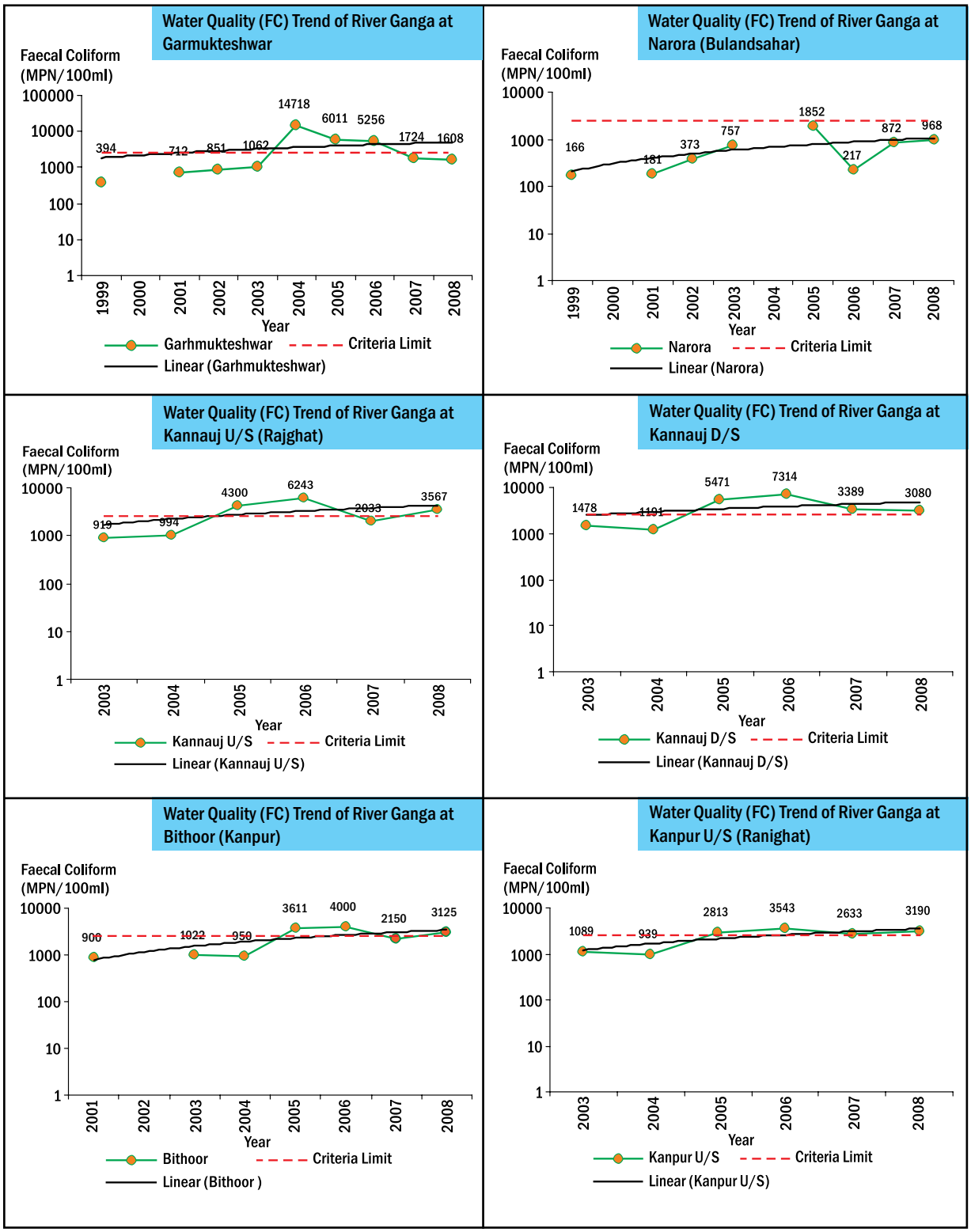






ANNEXURE V

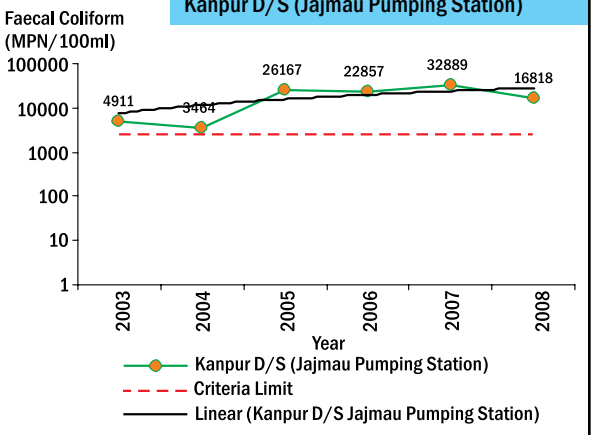
Water Quality (Faecal Coliform) Trend of River Ganga in Uttar Pradesh



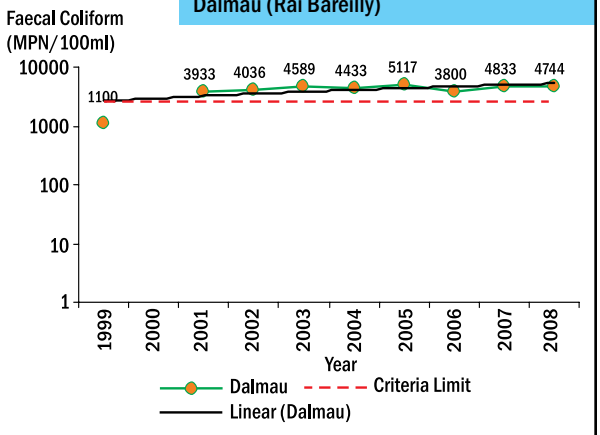
ANNEXURE V

Water Quality (Faecal Coliform) Trend of River Ganga in Uttar Pradesh

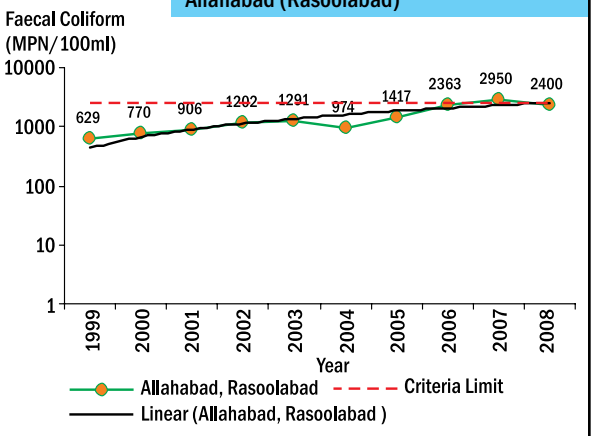
Water Quality (FC) Trend of River Ganga at Kanpur D/S (Jajmau Pumping Station)



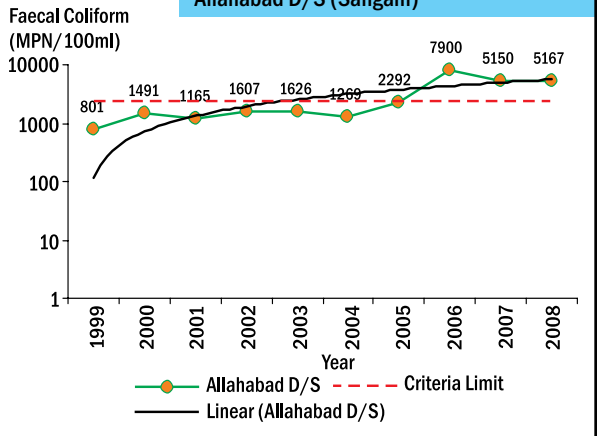
Water Quality (FC) Trend of River Ganga at Dalmau (Rai Bareilly)



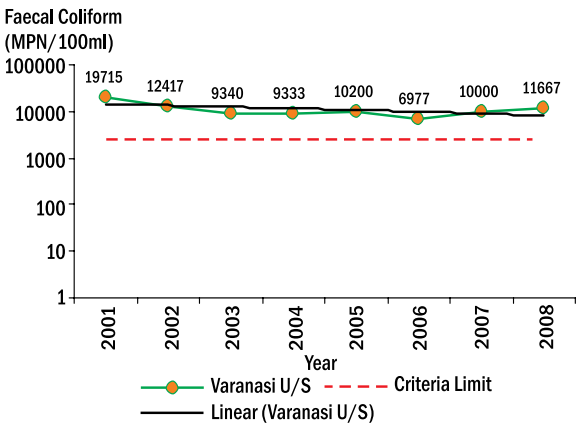
Water Quality (FC) Trend of River Ganga at Allahabad (Rasoolabad)



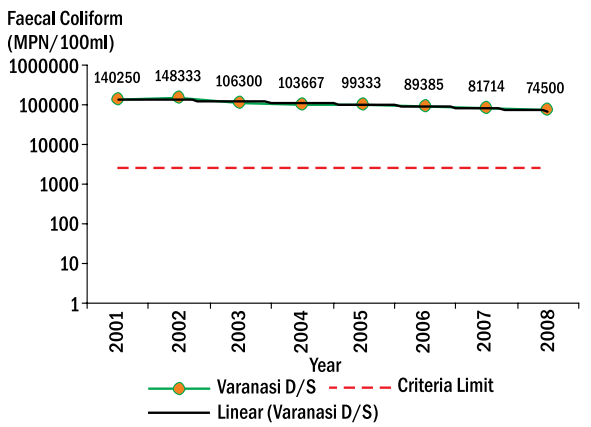
Water Quality (FC) Trend of River Ganga at Allahabad D/S (Sangam)



Water Quality (FC) Trend of River Ganga at Varanasi U/S (Assighat)

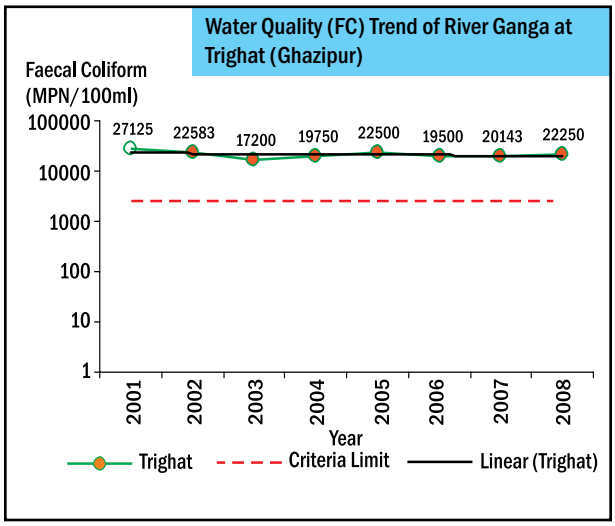


Water Quality (FC) Trend of River Ganga at Varanasi D/S (Malviya Bridge)



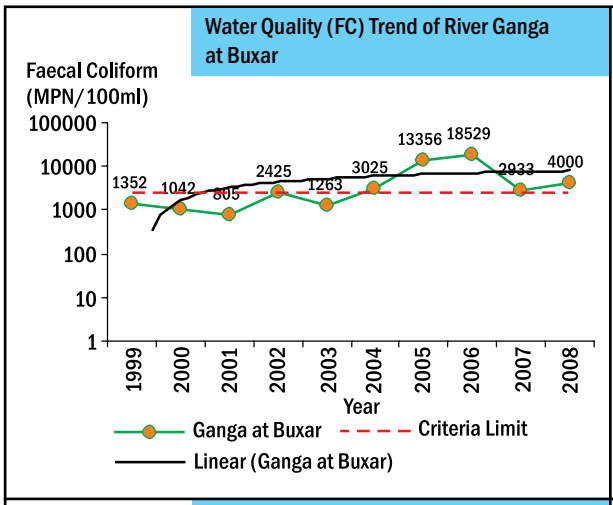
ANNEXURE V

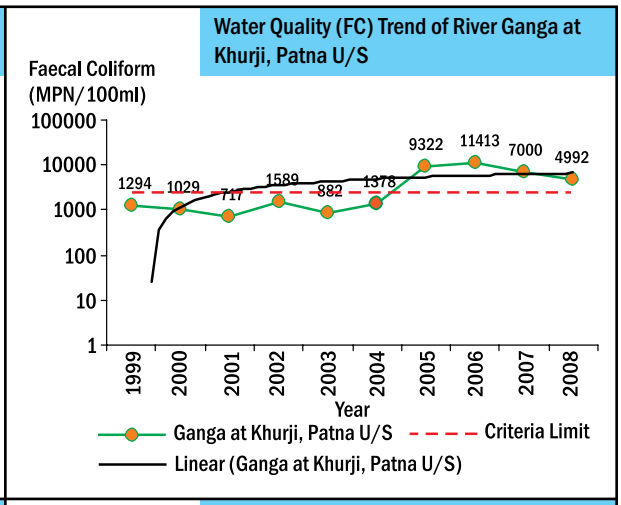
Water Quality (Faecal Coliform) Trend of River Ganga in Uttar Pradesh

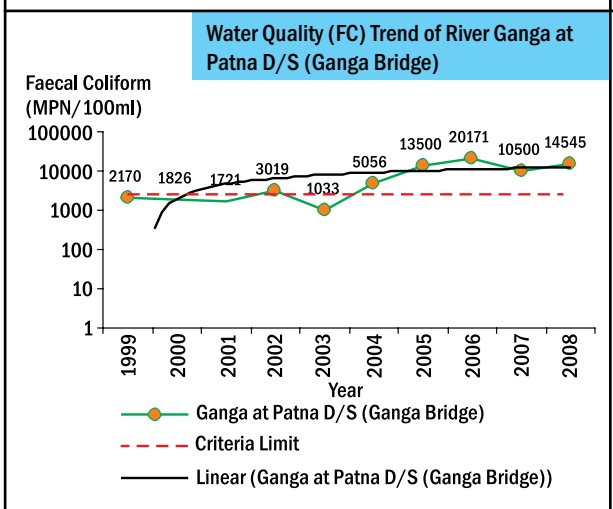


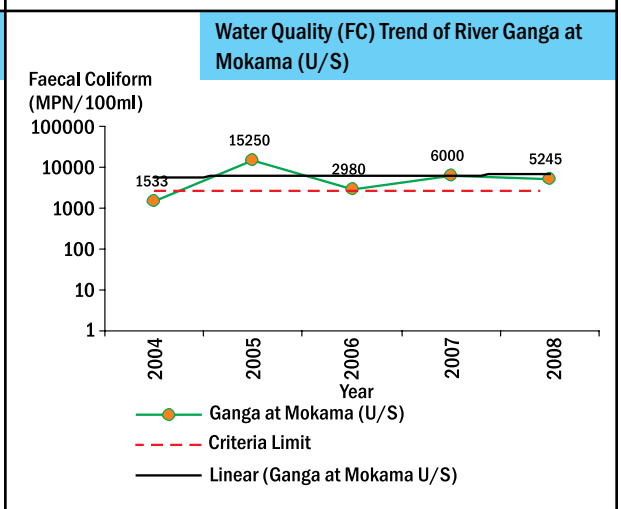
ANNEXURE V

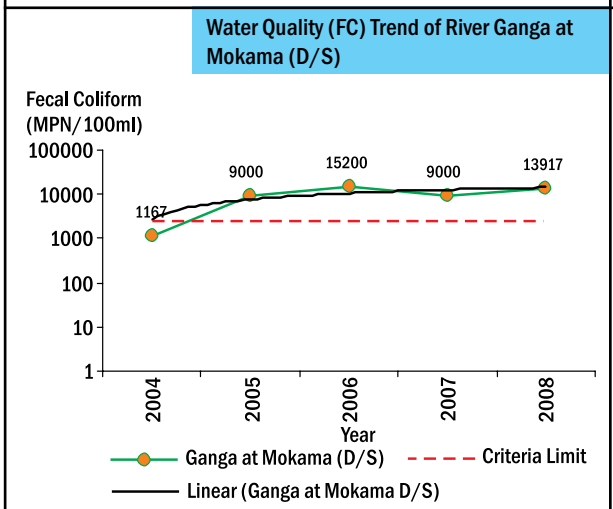
Water Quality (Faecal Coliform) Trend of River Ganga in Bihar

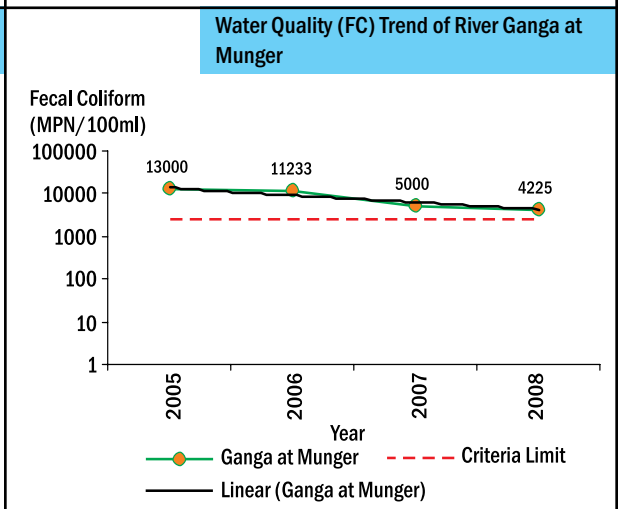












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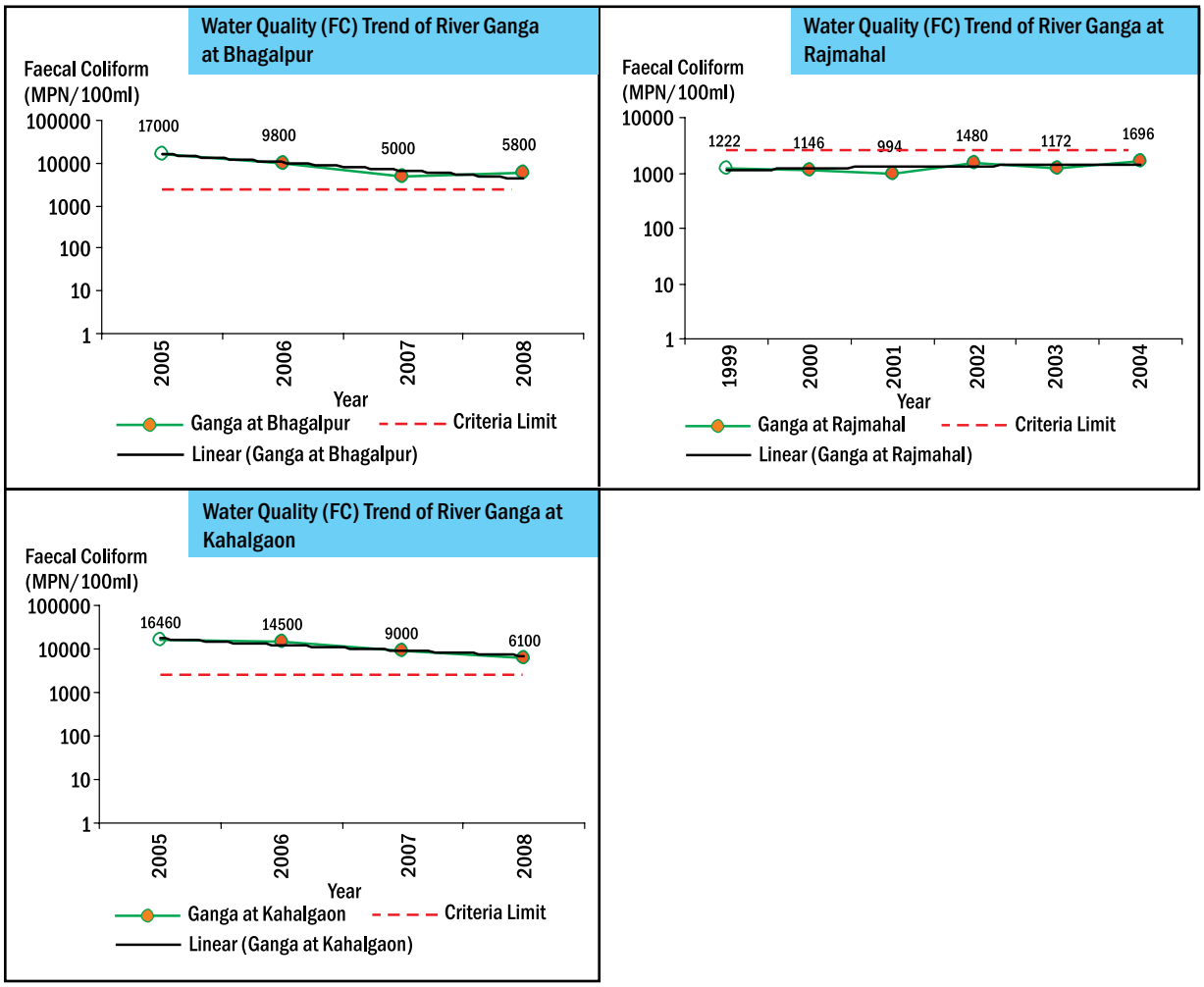
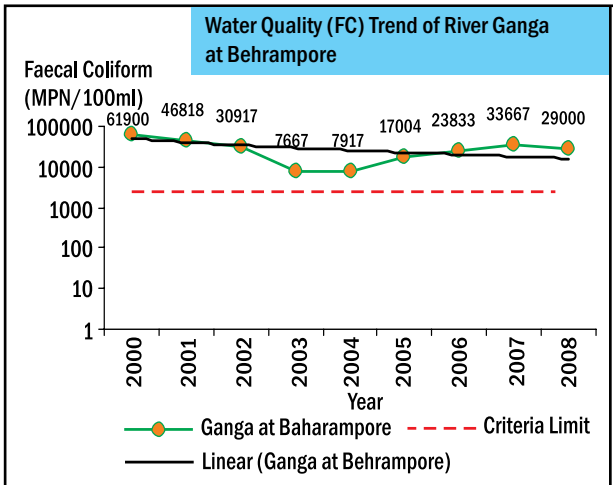
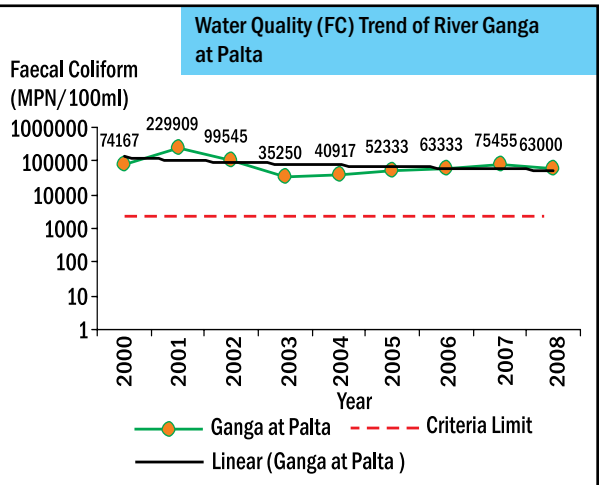
Water Quality (Faecal Coliform) Trend of River Ganga in Bihar

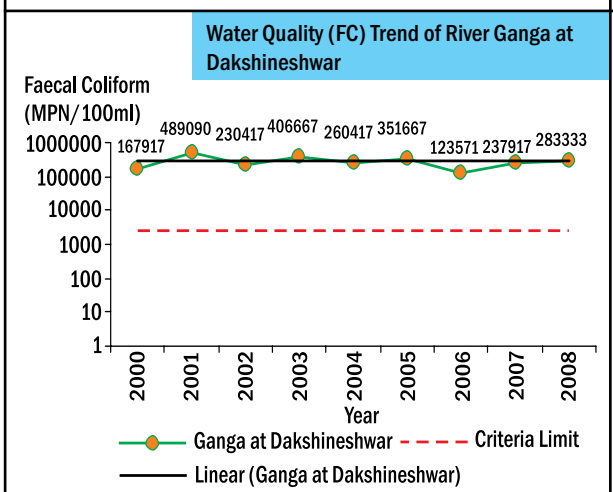


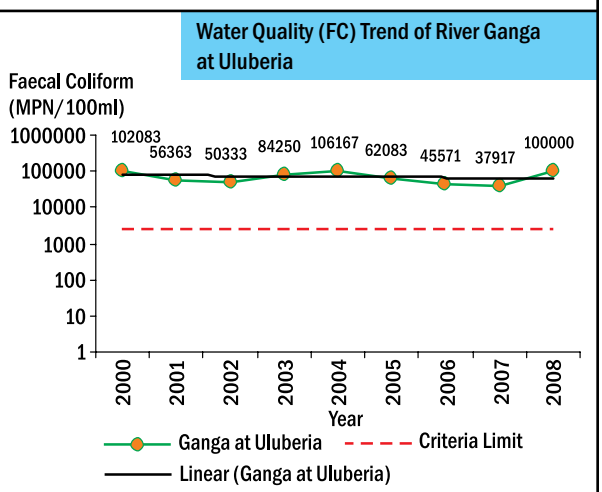
ANNEXURE V

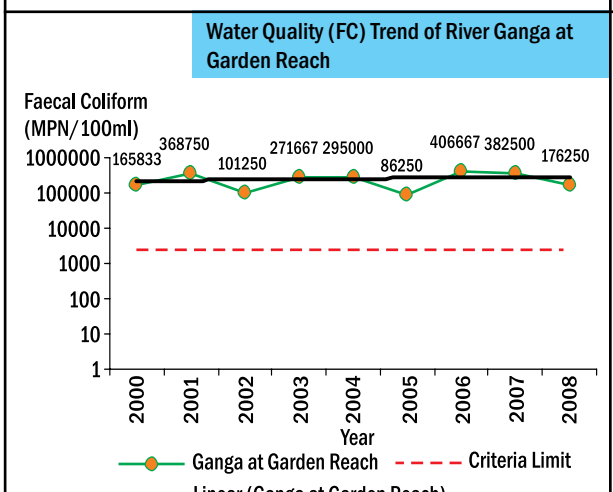
Water Quality (Faecal Coliform) Trend of River Ganga in West Bengal

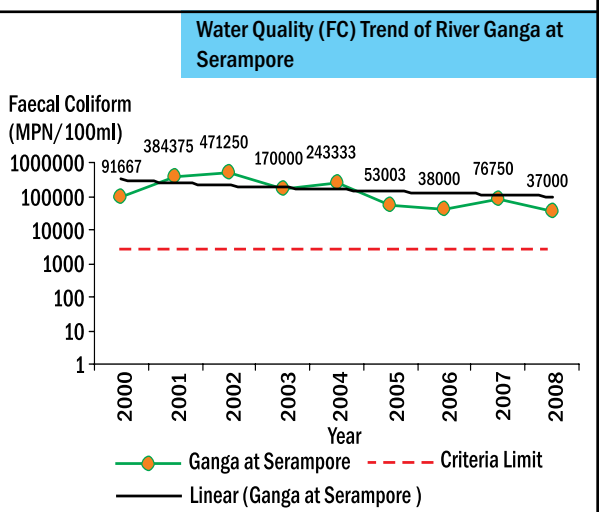






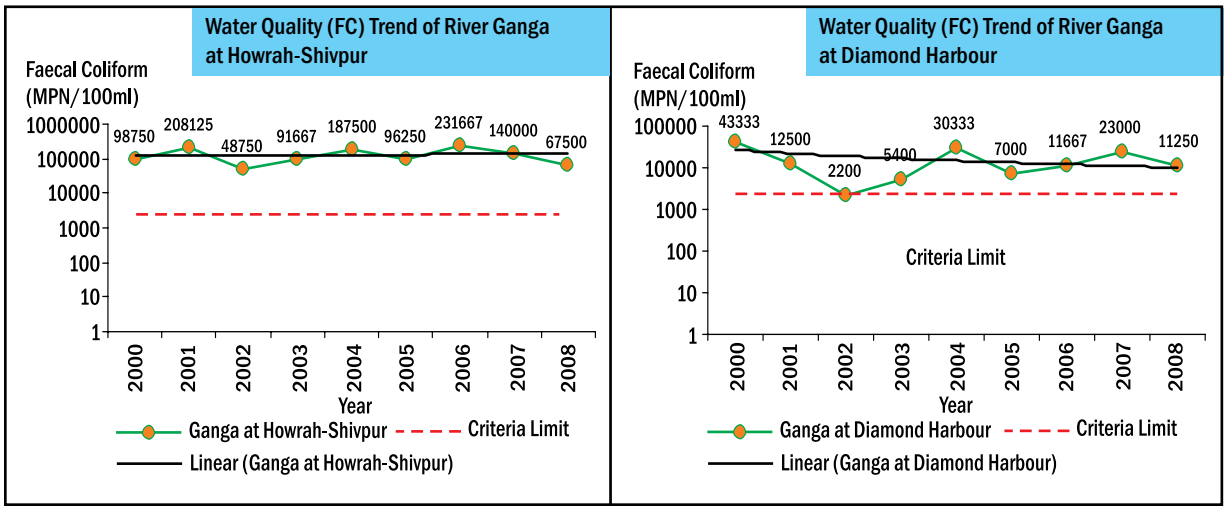






ANNEXURE V

Water Quality (Faecal Coliform) Trend of River Ganga in West Bengal



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