Status of Grossly Polluting Industries Discharging Effluent in River Ganga and its Impact on Water Quality

(A thesis submitted in partial fulfillment of the requirements for the award of degree of Master of Civil Engineering in the faculty of Engineering and Technology of Jadavpur University)

Submitted by

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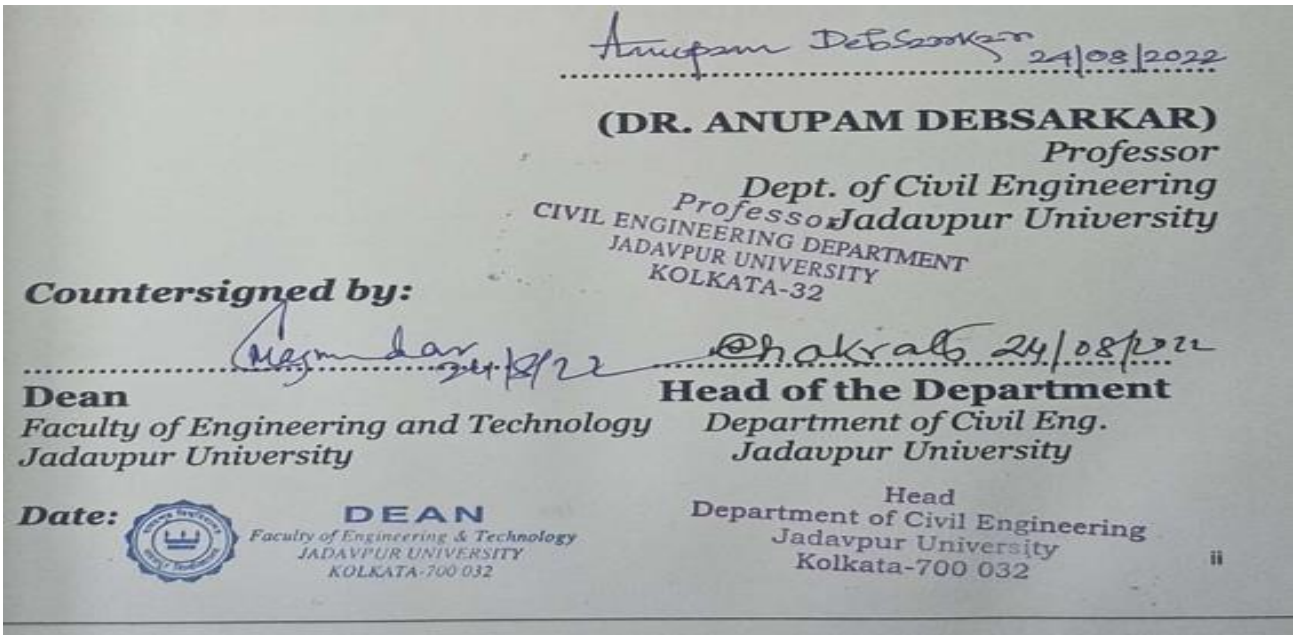
CERTIFICATE OF RECOMMENDATION

This is to certify that **Sourav Bhunia**, student of **M.C.E (2nd Year, 2nd Semester)** bearing Exam Roll No:**M4CIV22011** has prepared this thesis entitled **"Status of Grossly Polluting Industries Discharging Effluent in River Ganga and it Impact on Water Quality"** entirely by himself under my supervision as a part of his M.C.E (Environmental Engineering), 2nd Year curriculum of Department of Civil Engineering. It is also certified that no part of this thesis has been presented or published elsewhere.



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This is to certify that this thesis is hereby approved as an original work conducted and presented in a manner satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is implied that by this approval the undersigned do not necessarily endorse or approve any statement made, opinion expressed or conclusion drawn therein, but approved the thesis only for the purpose for which it is submitted.

Final Examination for evaluation of thesis

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Place

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I am using the opportunity to express my gratitude to everyone who supported me throughout the course of this thesis. I am thankful for their aspiring guidance, constructive criticism, and friendly advice during the project work. I am sincerely grateful to them for sharing their illuminating ideas on this project.

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I perceive this as an opportunity to hone my presentation skills and improve my knowledge base in this field in the best way possible.

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Chapter-1

1. Introduction:

1.1 General

Ganga is a major important river of India which originates from Gangotri, Uttarakhand in the Himalayas and runs through almost 52 populated cities and 48 towns to meet the Bay of Bengal. It is one of the longest rivers in India and also third largest river in the world in terms of water discharged in the sea. Ganga plays an important role in the life of Indian people as the genetic is highly fertile and ideal for cultivation of many crops. The river water are used for irrigation, transportation and fishing. The river Ganga is covering the entire state of Uttrakhand, Uttar Pradesh, Bihar, Delhi and parts of Punjab, Haryana, Himachal Pradesh, Rajasthan, Madhya Pradesh and west Bengal. The river cuts its path through the Himalayas and flow a distance of about 205 km from Gurumukhi and traverses through two districts of Uttarkashi and Tehri to reach Devprayag where another head stream, Alaknanda, joins it to form Holy Ganga. The river Alaknanda is a major tributary of the river Ganga at Uttrakhand and it travels approximately190 km before meeting Bhagirathi.

After flowing through the northern most part of Utttrakhand, the river flows through Uttar Pradesh, Bihar, Jharkhand, West Bengal and finally drains into the Bay of Bengal. The river traverses a length of 1450 km in Uttrakhand and Uttar Pradesh while touching the boundary between UP and Bihar for a stretch of 110 km. It then flow through Bihar covering a distance of 405 km. The river Ganga has a large number of tributaries namely kali, Ramaganga,Yamuna, Gomti, Ghaghara, Gandak and Kosi.

1.2 Salient Features of River Ganga

The main features of the river Ganga are given underneath:

- ✓ **Total Length : 2525 km**
  Uttarakhand : 450 km
  Uttar Pradesh : 1000 km
  UP and Bihar : 110 km
  Bihar` : 405 km
  Jharkhand : 40 km
  West Bengal : 520 km

- ✓ **Catchment Area : 8,61,405 sq. km**

- ✓ **Avg. annual discharge : 4,93,400 million m^3**

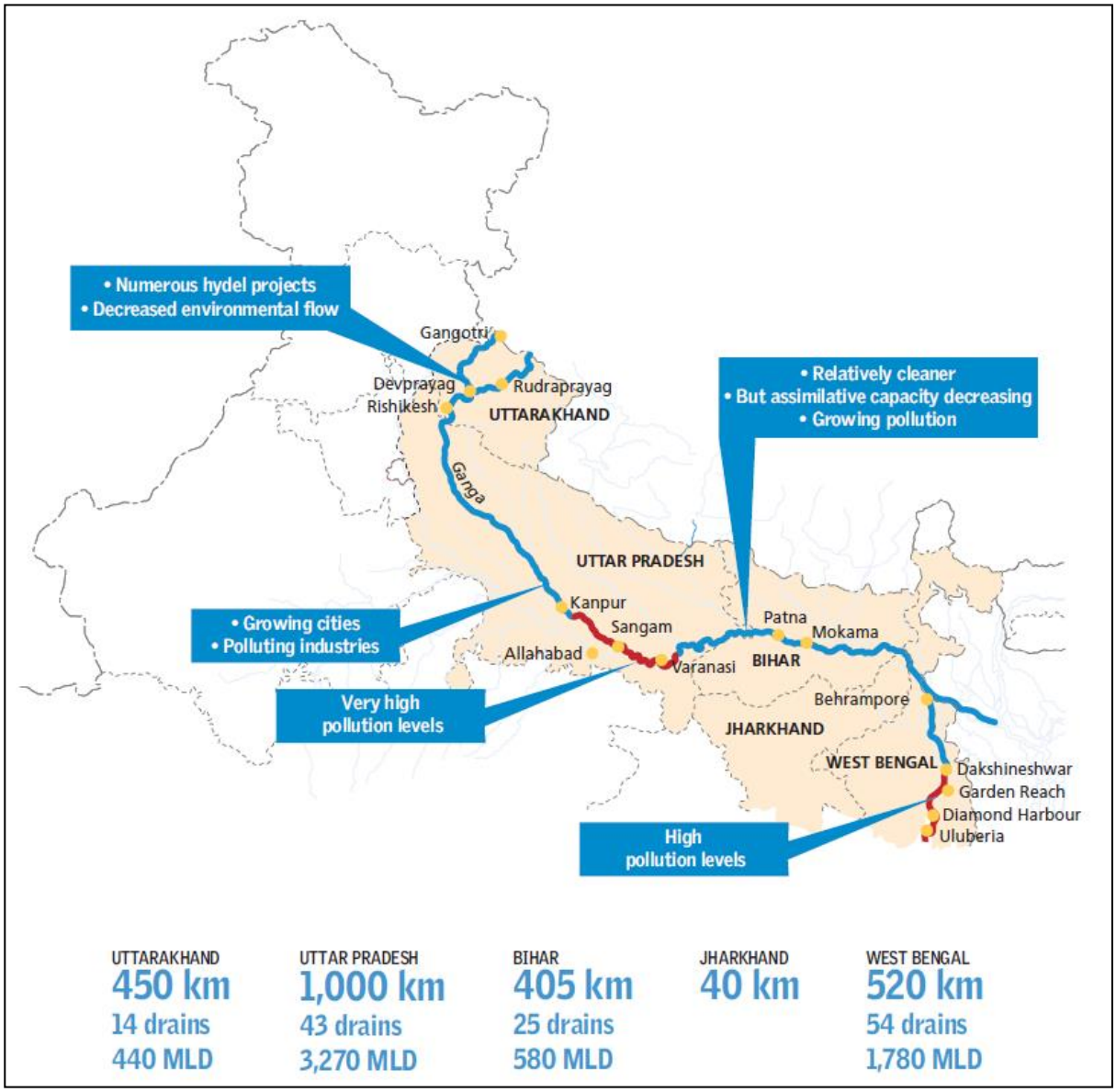

Fig-1.1: River Ganga- At a Stretch

1.3 Grossly Polluting Industries (GPI)

One of the functions entrusted to Central Pollution Control Board under National Ganga River Basin Authority Project is inventorization, monitoring and surveillance of pollution load discharging into river Ganga. While assessing the industrial pollution load it is understood that the assessment of pollution load in the tributaries namely Rāmgangā and Kali (E) is an imperative prerequisite. Thus the assessment of pollution load of Kali and Rāmgangā is added along with main stem of Ganga. An attempt has been made in this publication is to collect, collate and disseminate the information from the data of concerned State Pollution Control Boards which are located on the banks of main stem of River Ganga. These are: **Uttarakhand, Uttar Pradesh, Bihar, Jharkhand** and **West Bengal.**

Grossly Polluting Industries (GPI) are defined *as the industry which is discharging wastewater more than 100 KLD and/or hazardous chemicals used by the industry as*

specified under the Schedule-I, Part-II of The Manufacture, Storage and Import of Hazardous Chemical Rules of 1989 under Environment (Protection) Act, 1986.

1.4 Classification of Industrial Units with respect to products

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Industrial units are classified in following sectors.

- **Chemicals:** which mainly include *fertilizer, petro-chemical, pesticides and pharmaceuticals.*
- **Distillery**
- **Dairy, Food & Beverage**
- **Pulp and Paper**
- **Sugar**
- **Tannery**
- **Textile, Bleaching & Dyeing**
- **Other** *(Cement, Slaughter house, Ordinance, Packaging & printing, Paint, Electronics & Electrical, Thermal, Electroplating, Metallurgical, automobile etc.)*

Chapter-2:

2.Literature Review

Status of Grossly Polluting Industries (GPI)

2.1. General

There are 764 industries in the main stem of Ganga. Out of which 687 industrial units are in Uttar Pradesh followed by 42 in Uttarakhand. Sector wise distribution of industrial units is given in figure-8.1. It is observed from the Fig. 2.1 that number wise tanneries are dominant industries followed by sugar, pulp & paper and Textile, dyeing and bleach.

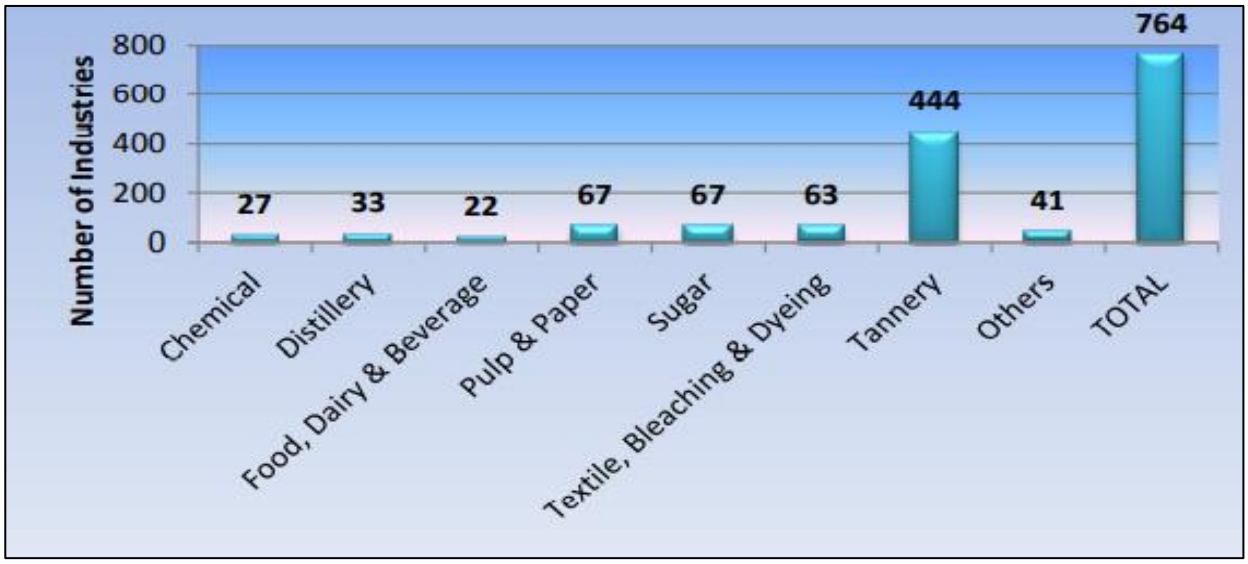


Fig-2.1: Sector wise Distribution of Industrial Units in Uttar Pradesh, Uttarkhand, Bihar and West Bengal

Total water consumption in the industries is 1123 MLD and waste water generation is 501 MLD. Uttar Pradesh is the dominating states with respect to water consumption (62 % of total water consumed) and wastewater generation (45% of total wastewater generated) followed by Uttarakhand. This is summarized in table-2.1 and percentage wise consumption and generation is depicted in Fig-2.2.

Table-2.1: State wise Status of Industrial unit, Water Consumption and Wastewater Generation

State	Number of Industry	Water Consumption (MLD)	Wastewater Generation (MLD)
Uttarakhand	42	224	127
Uttar Pradesh	687	693	269
Bihar	13	91	17
Jharkhand	0	00	00
West Bengal	22	116	87
TOTAL	**764**	**1123**	**501**

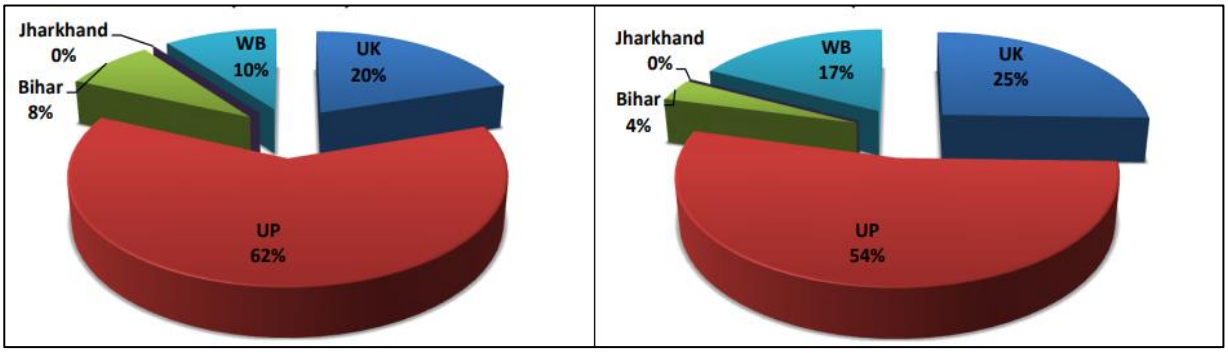


Fig-2.2: State wise water consumption and wastewater generation

From Fig. 2.2 it is observed that

- Wastewater generation is nearly 45% in terms of total water consumption.
- In terms of water consumption industries in Uttar Pradesh consumes maximum water followed by Uttarakhand and West Bengal.
- But wastewater generation with respect to water consumption is enhanced in Uttarakhand and West Bengal.

Table-2.2: Status of sector specific industrial water consumption and waste generation

Type of industry	Total No. of unit	Water Consumption (MLD)	Wastewater Generation (MLD)
Chemical	27	210.9	97
Distillery	33	78.8	37
Food, Dairy	22	11.2	6.5
Pulp and paper	67	306.3	201.4

Sugar	67	304.8	96
Textile, Bleaching	63	14.1	11.4
Tannery	444	28.7	22.1
Others	41	168.3	28.6
Total	**764**	**1123**	**501**

2.2 Status of State wise Water Consumption and Wastewater Generation from Grossly Polluting Industries:

(a) Uttarakhand

Number of grossly polluting industries located in Uttarakhand is 42. Out of which, 7 industries are discharging in the main stem of Ganga and located in the region of Dehradun and rest are located in the sub-basin of Ramganga in the region of Kashipur and Udham Singh Nagar. In Uttarakhand category wise only three types of industries are located; these are pulp and paper, sugar and distillery.

Table-2.3: Status of Water Consumption and Wastewater Generation in Uttarakhand

Category of Industry	Number of Industry	Water Consumption (MLD)	Wastewater Generation (MLD)
Distillery	3	5.6	2.2
Pulp and Paper	30	193.1	115.5
Sugar	9	25.3	9.8
Total	**42**	**224**	**127.5**

(b) Uttar Pradesh

The category wise and water body wise wastewater generation in the state of Uttar Pradesh is depicted in table. It is observed from the table that there are 687 industries of grossly polluting status discharging 269 MLD wastewater. The Sugar, Pulp and Paper and Chemical are the major industrial sector which discharged 70% of total wastewater generated in the state. Out of 688 industries 594 are located in the main stem of Ganga River. It is also observed that 442 industries are tannery. Volume wise highest wastewater 85.7 MLD is coming from sugar industry. This indicates that the tannery although have a higher number of industries but discharging less volume of wastewater, which concludes that tanneries are basically small scale industry.

With respect to River Kali-East sugar, distillery and pulp and paper are the major industrial sectors which are discharging in to the river. In comparison to the number of the industries with respect to Ganga is small (53) but discharging 71.4 MLD

wastewater. Pulp and paper industry is discharging 36.8 MLD wastewater, which is 52% of the total wastewater discharged into the river Kali-East by grossly polluting industries. Next to Pulp and paper industry is Sugar industry (15) and discharging 14.8 MLD.

It is pertinent to mention that Ramganga which houses 44 industries but discharging 106 MLD wastewater and major of them are sugar industries which are discharging 50% of total wastewater discharged into the river Ramganga in Uttar Pradesh.

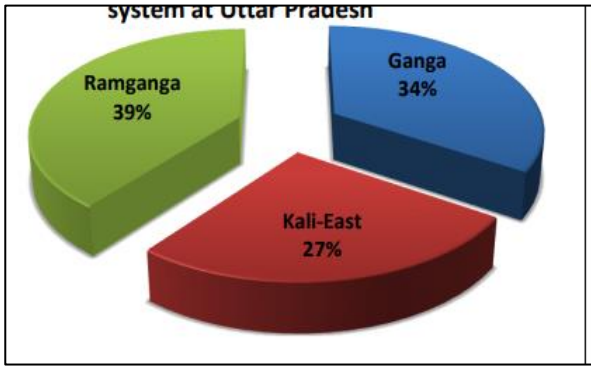


Fig-2.4: Percentage wise wastewater discharge in Uttar Pradesh

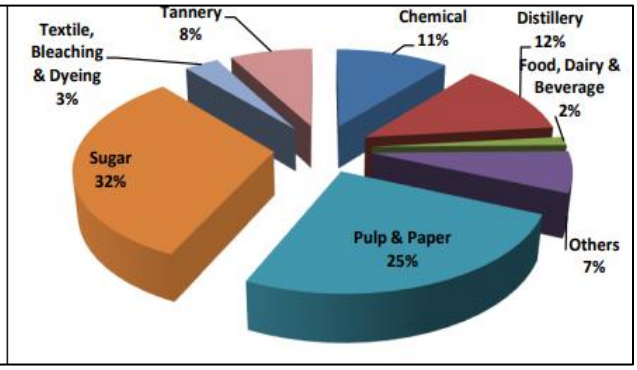


Fig 2.5 Sector wise wastewater generation (% basis) in Uttar Pradesh

Table-2.4: Status of Water Consumption and Wastewater Generation in Uttar Pradesh

Category of the industry	Number of industry	Water consumption (MLD)	Wastewater generation (MLD)
Chemical	20	113.0	29.6
Distillery	27	69.2	33.0
Food and Dairy	15	6.3	3.8
Others	35	90.7	18.1
Pulp and Paper	33	96.3	68.1
Sugar	56	278.4	85.7
Textile and Bleaching	59	11.4	9.0
Tannery	442	27.4	21.6
Total	687	693	269

(c) Bihar

In the state of Bihar, discharge from grossly polluting industries is not so prominent in comparison to other states with respect to river Ganga. The total discharge from industries is 17.3 MLD, out of which 7 MLD is from Barauni refinery.

Table-2.5: Status of water consumption and wastewater generation in Bihar

Category of industry	Number of industry	Water consumption (MLD)	Wastewater generation (MLD)
Chemical	1	122	7.2
Distillery	1	0.6	0.1
Food, Dairy	2	0.8	0.4
Pulp and paper	1	1.1	0.5
Tannery	2	1.3	0.5
Textile, Bleach	3	0.0	0.0
Others	3	75.1	8.7
Total	**13**	**90.9**	**17.3**

(d) Jharkhand

There is no information regarding industrial discharge in river Ganga at Jharkhand.

(e) West Bengal

In the stretch of West Bengal the river Hooghly (Ganga is named as Hoogly here) receives 87 MLD wastewater from 22 grossly polluting industries. It is pertinent to note that various categories of industries are housed on the banks of Hooghly, this is summarized in table-2.6. It is observed that chemical industry discharges 70% of total wastewater generated, followed by Pulp and paper which is 20%. This is a deviation from the trend in Upper and middle Ganga.

Table-2.6: Status of Wastewater Generation and Water Consumption in West Bengal:

Category of industry	Number of industry	Water consumption (MLD)	Wastewater generation (MLD)
Chemical	6	85.9	61
Distillery	2	3.3	1.8
Food, Dairy and Beverage	5	4.2	2.3
Others	3	2.5	1.8
Pulp and paper	3	15.9	17.3
Sugar	2	1.1	0.6
Textile, Bleaching	1	2.6	2.4
Total	**22**	**115.5**	**87.2**

Distribution of wastewater generated from different types of industry in West Bengal is depicted in the following Fig. 2.6.

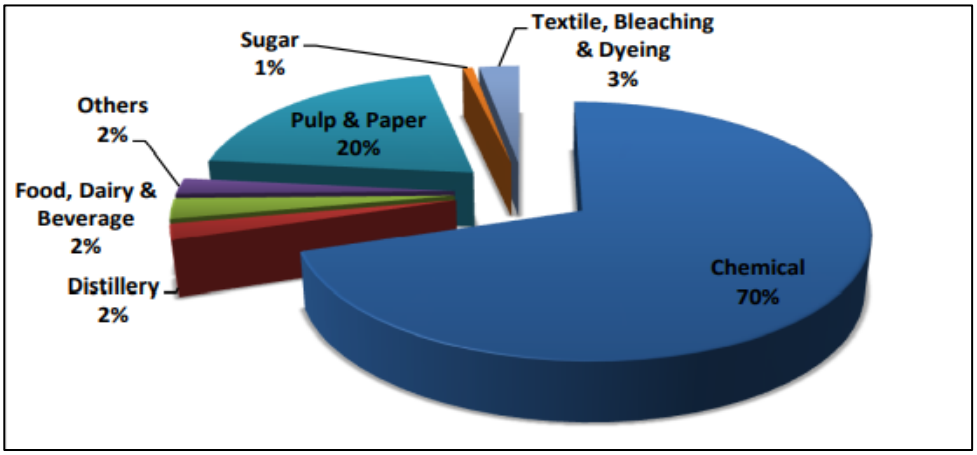


Fig-2.6: Sector wise Wastewater Generation (% basis) in West Bengal

- **Sector specific wastewater generation in terms of water consumption:**

In Uttarakhand, Uttar Pradesh, Bihar and West Bengal all together it is observed that average wastewater generation by grossly polluting industries is approx 45% of water consumed by these industries.

Table-2.7: Percentage of sector specific wastewater generation with respect to consumption

Industrial sector	Chemical	Distillery	Food and Dairy	Pulp and Paper	Sugar	Textile and Bleaching	Tannery	Others
% of wastewater generation with respect to consump-tion	46.4	47	58	65.8	31.5	80.9	77	17

Chapter - 3:

Literature Review(Part- 2)

3. Status of Water Quality of River Ganga

3.1. General

In order to assess water quality of river Ganga, the Central Pollution Control Board has set up 57 water quality monitoring stations on the main stem of river Ganga, in association with State Pollution Control Boards of Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal. The salient features of monitoring locations is presented in Table-3.1

Table-3.1: Water quality monitoring stations on main stem of River Ganga in different states

State	No. of Monitoring Locations	Frequency	Monitoring Agency
Uttarakhand	11	Yearly/Monthly	UEPPCB/CPCB
Uttar Pradesh	20	Monthly	UPPCB
Bihar	15	Monthly	BPCB
Jharkhand	1	Monthly	JPCB
West Bengal	10	Monthly	WBPCB

The monitoring results obtained during 2011 under National Water Quality Monitoring Programme reflect that organic matter and bacterial population of faecal origin continue to dominate the pollution problem in River Ganga. The major water quality concerns as revealed from the monitoring results are pathogenic pollution as reflected through indicators i.e. Total Coliforms (TC) and Faecal Coliform (FC), organic matter as reflected through Biochemical Oxygen Demand (BOD) and salinity as reflected through conductivity. The observed range of water quality parameters river Ganga for the year 2011 along with summary for the year 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009 and 2010 is given in Table 3.2 for comparative assessment of water quality trends over the years.

Table-3.2: Range of Water Quality Parameters during the Years – 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010 and 2011 in river Ganga

Table 3.2: Range of water quality parameters during the years – 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010 and 2011 in river Ganga								
Year	No of Monitoring locations	Observed Range of Water Quality Parameters						
		Temp. (^{0}C)	pH	Conductivity (µmhos/cm)	DO (mg/l)	BOD (mg/l)	Total Coliform (MPN/100 ml)	Faecal Coliform (MPN/100 ml)
2002	34	3-34	6.4-9.0	19-2720	2.7-11.5	0.5–16.8	300-25x10^5	20-11x10^5
2003	34	4-34	6.8-8.9	49-1323	4-11	0.8-27	47-45x10^5	26-12x10^5
2004	34	5-35	7-8.8	72-4080	0.3-13.2	0.7-14.4	11-45x10^5	11-7x10^5
2005	39	4-39	6.1-9	23-1696	3.2-12.8	0.1-15.2	13-45x10^5	13-11x10^5
2006	39	9-33	7.0-8.9	97-5620	2.2-11.9	0.1-16.4	1-25x10^5	17-11x10^5
2007	39	4-33	6.1-8.8	23-5040	1.4-11	0-14	0-28x10^5	0-7 x10^5
2008	39	2.5-35.5	6.1-8.9	39-6320	1.2 - 11.6	0.5-21.0	0- 101x10^5	0 - 85 x10^4
2009	57	4-37	6.5-8.9	68-4460	4.3-11.2	0.2-16	2-65 x10^4	0-4 x10^5
2010	57	4-35	6.7-9.0	21-5250	3.6-12	0.2-15	3-14x10^5	2-4 x10^5
2011	57	3-37	6.7-9.1	49-10240	4-14.3	0.2-11	5-25 x10^5	5-11 x10^5

3.2 Water Quality Assessment for River Ganga:

3.2.1 Water Quality Assessment in Uttarakhand:

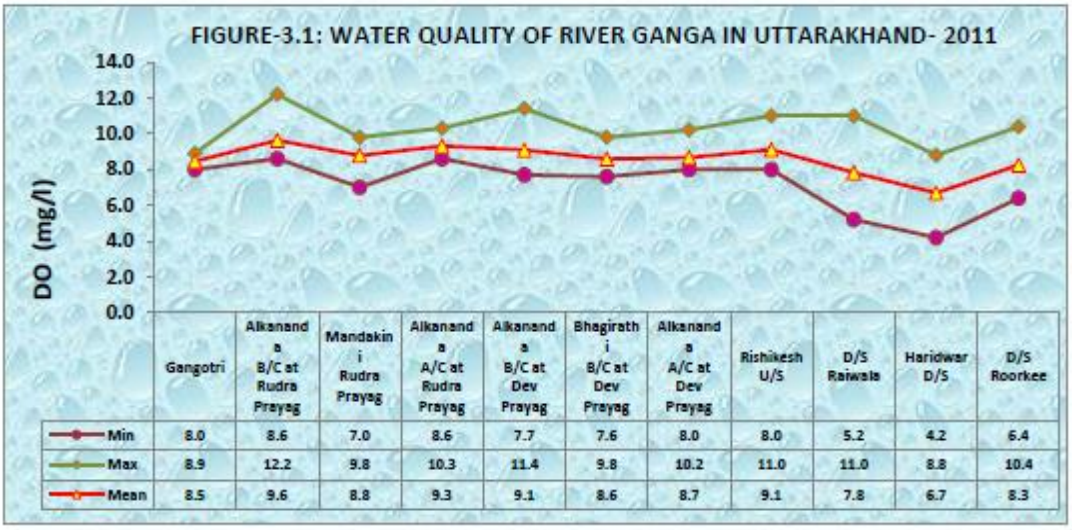
The spatial distribution of water quality data is illustrated in Fig-3.1 to 3.5 with respect to Dissolved Oxygen (DO), Bio-chemical Oxygen Demand (BOD), Total Coliform (TC), Faecal Coliform (FC) and conductivity. The examination of the figures indicates following observations:

- pH - meeting the water quality criteria for bathing, notified under the Environment (Protection) Act, 1986, depicted in **Annexure I** at all the monitoring locations.
- Conductivity meeting the primary water criteria based on designated best use depicted in **Annexure II**.
- DO varies from 4.2-12.2 mg/l. The average value of DO is meeting the criteria at all monitoring locations. In some periods of the year the DO is not meeting the criteria in river Ganga at Haridwar downstream (D/s).
- BOD ranges from 0.2-11.0 mg/l. The highest value 11.0 mg/l is observed at D/s Haridwar. River Ganga at D/s of Raiwala and D/s of Rishikesh is not meeting the water quality criteria for bathing with respect to BOD.
- Faecal Coliform value ranges from 5-46000 MPN/100ml and not meeting the water quality criteria for bathing in river Alaknanada at Rudraprayag before

confluence (B/c) & after confluence (A/c) river Mandakini and at Devraprayag B/c and A/c River Bhagirathi

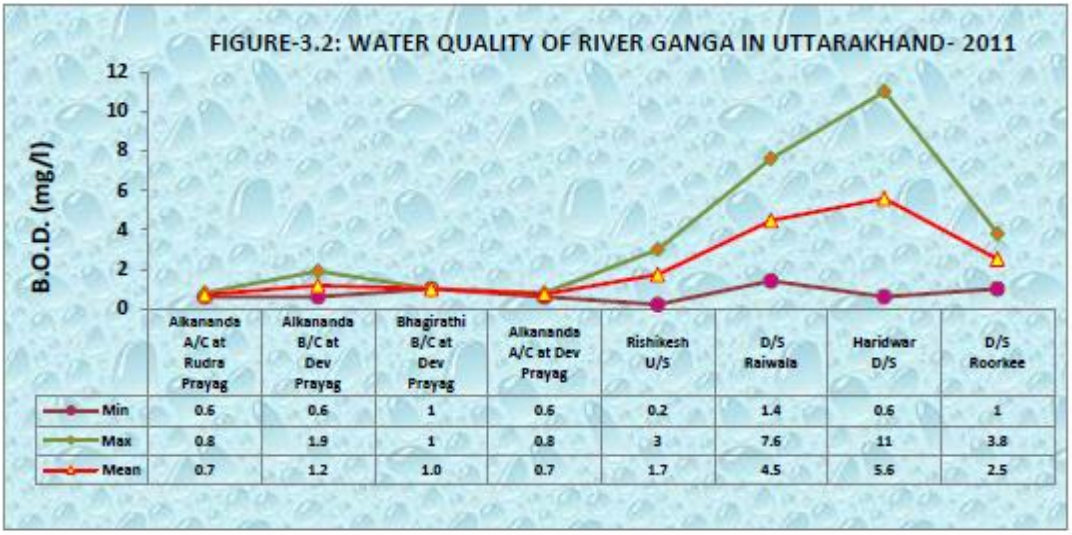
- While the Total Coliform value ranges 5- 580000 and not meeting the primary water criteria based on designated best use for category 'C' at all monitored locations of river Alaknanda and Mandakini; and in river Ganga at D/s Raiwala and D/s Haridwar.
- The higher value of coliform bacteria and organic pollution is observed in Upper Ganga due to open defecation and discharge of waste water directly through small drains into the river.

FIGURE-3.1: WATER QUALITY OF RIVER GANGA IN UTTARAKHAND- 2011

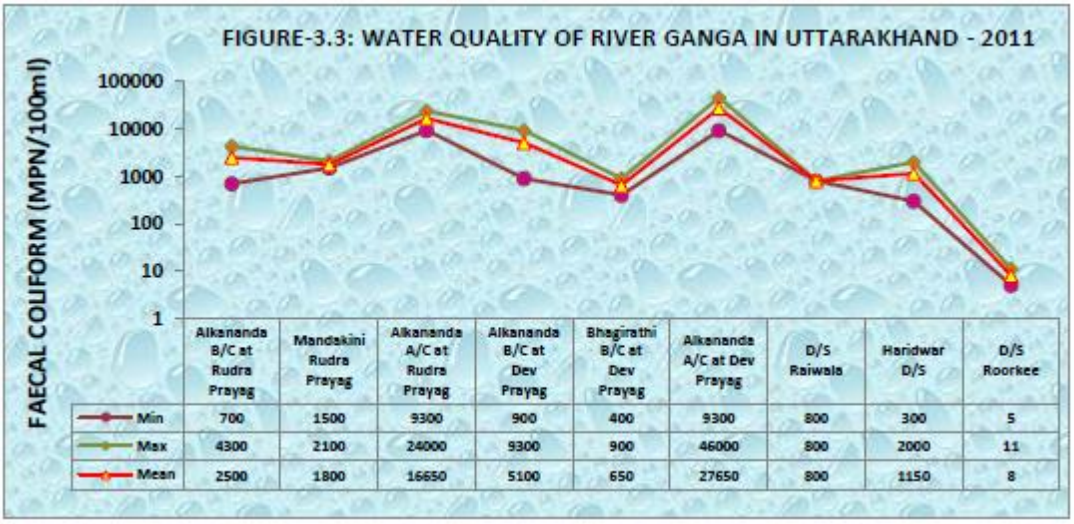


	Gangotri	Alkananda B/C at Rudra Prayag	Mandakini Rudra Prayag	Alkananda A/C at Rudra Prayag	Alkananda B/C at Dev Prayag	Bhagirathi B/C at Dev Prayag	Alkananda A/C at Dev Prayag	Rishikesh U/S	D/S Raiwala	Haridwar D/S	D/S Roorkee
Min	8.0	8.6	7.0	8.6	7.7	7.6	8.0	8.0	5.2	4.2	6.4
Max	8.9	12.2	9.8	10.3	11.4	9.8	10.2	11.0	11.0	8.8	10.4
Mean	8.5	9.6	8.8	9.3	9.1	8.6	8.7	9.1	7.8	6.7	8.3

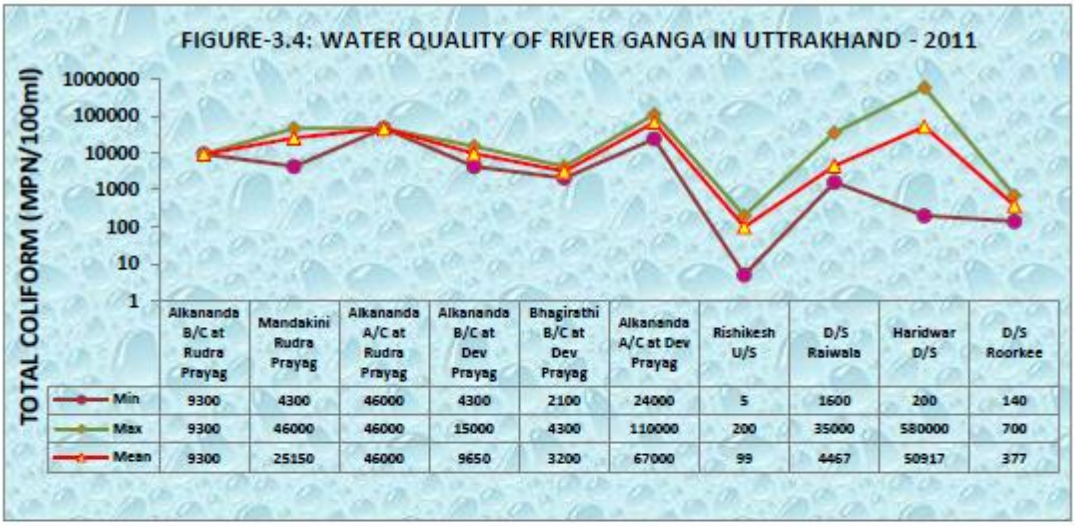
FIGURE-3.2: WATER QUALITY OF RIVER GANGA IN UTTARAKHAND- 2011



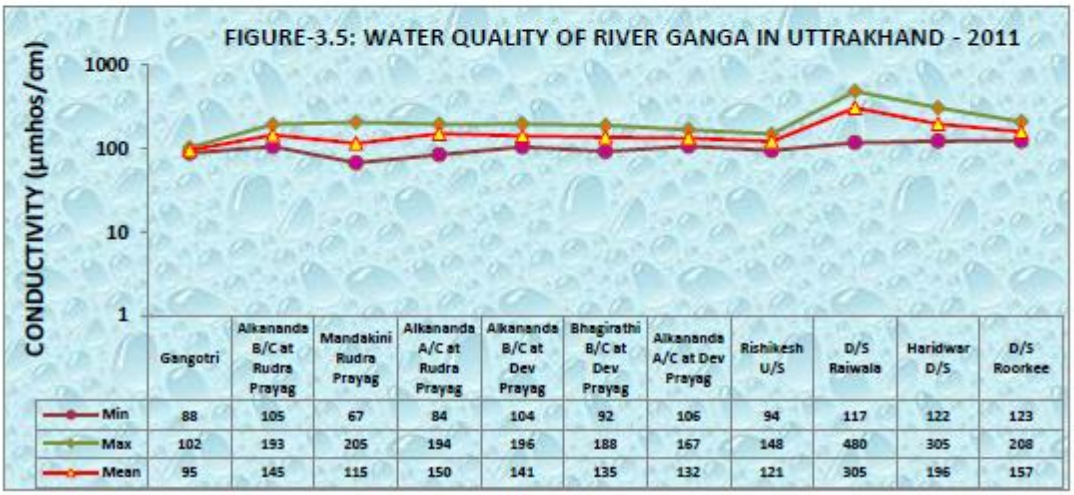
	Alkananda A/C at Rudra Prayag	Alkananda B/C at Dev Prayag	Bhagirathi B/C at Dev Prayag	Alkananda A/C at Dev Prayag	Rishikesh U/S	D/S Raiwala	Haridwar D/S	D/S Roorkee
Min	0.6	0.6	1	0.6	0.2	1.4	0.6	1
Max	0.8	1.9	1	0.8	3	7.6	11	3.8
Mean	0.7	1.2	1.0	0.7	1.7	4.5	5.6	2.5



	Alkananda B/C at Rudra Prayag	Mandakini Rudra Prayag	Alkananda A/C at Rudra Prayag	Alkananda B/C at Dev Prayag	Bhagirathi B/C at Dev Prayag	Alkananda A/C at Dev Prayag	D/S Raiwala	Haridwar D/S	D/S Roorkee
Min	700	1500	9300	900	400	9300	800	300	5
Max	4300	2100	24000	9300	900	46000	800	2000	11
Mean	2500	1800	16650	5100	650	27650	800	1150	8



	Alkananda B/C at Rudra Prayag	Mandakini Rudra Prayag	Alkananda A/C at Rudra Prayag	Alkananda B/C at Dev Prayag	Bhagirathi B/C at Dev Prayag	Alkananda A/C at Dev Prayag	Rishikesh U/S	D/S Raiwala	Haridwar D/S	D/S Roorkee
Min	9300	4300	46000	4300	2100	24000	5	1600	200	140
Max	9300	46000	46000	15000	4300	110000	200	35000	580000	700
Mean	9300	25150	46000	9650	3200	67000	99	4467	50917	377



	Gangotri	Alkananda B/C at Rudra Prayag	Mandakini Rudra Prayag	Alkananda A/C at Rudra Prayag	Alkananda B/C at Dev Prayag	Bhagirathi B/C at Dev Prayag	Alkananda A/C at Dev Prayag	Rishikesh U/S	D/S Raiwala	Haridwar D/S	D/S Roorkee
Min	88	105	67	84	104	92	106	94	117	122	123
Max	102	193	205	194	196	188	167	148	480	305	208
Mean	95	145	115	150	141	135	132	121	305	196	157

Fig3.1Water quality of river ganga in Uttarakhand(total coliform,DO,BOD,conductivity)

3.2.2 Spatial and temporal trend of water quality in Uttarakhand :

To study the water quality trend in the River Ganga BOD, DO, FC and TC parameters were considered. Average value of aforementioned parameters is used for the period 2006–2011 and depicted in figure 3.6-3.8.

- From a close examination it is observed that average value of DO comply with the standards for the period of 2006-2011 at all monitoring locations in Uttrakhand. A decreasing trend in DO is observed at most of the monitoring locations.
- BOD also complies with the standard at all locations except Haridwar D/s for the period 2006-2011 and an increasing trend at this location is observed, while most of the locations are showing a decreasing trend.
- However, TC and FC conforms to the standard in only a few places, i.e, the Bhagirathi at Gangotri and the Ganga at Rishikesh and Haridwar, the major pilgrimage centres. A mixed trend in TC and FC is observed.
- In overall analysis, the River Ganga in Uttarakhand is relatively clean and complying with the criteria, except for TC and FC which is higher. However the location Haridwar D/s appears as a critical location.

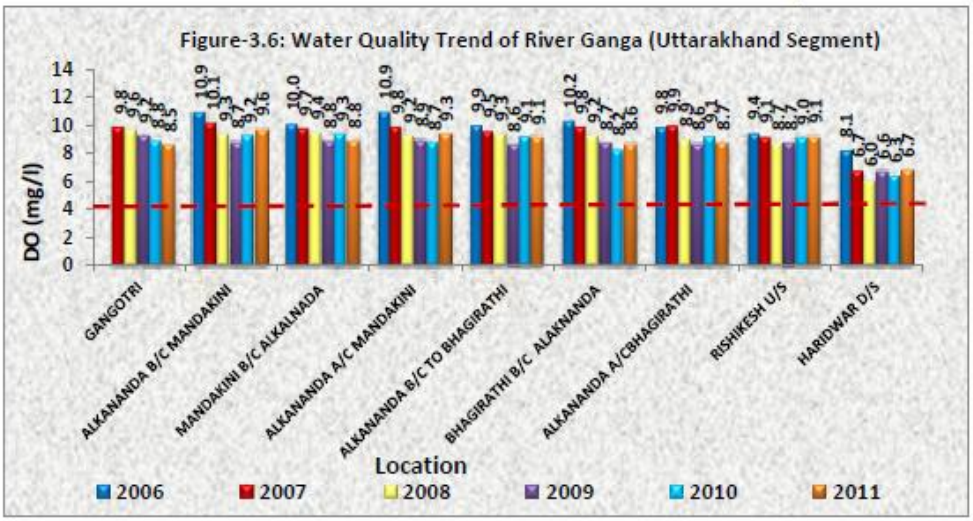


Figure-3.6: Water Quality Trend of River Ganga (Uttarakhand Segment)
DO (mg/l)
Location
GANGOTRI
ALKANANDA B/C MANDAKINI
MANDAKINI B/C ALKALNADA
ALKANANDA A/C MANDAKINI
ALKANANDA B/C TO BHAGIRATHI
BHAGIRATHI B/C ALAKNANDA
ALKANANDA A/CBHAGIRATHI
RISHIKESH U/S
HARIDWAR D/S
2006
2007
2008
2009
2010
2011

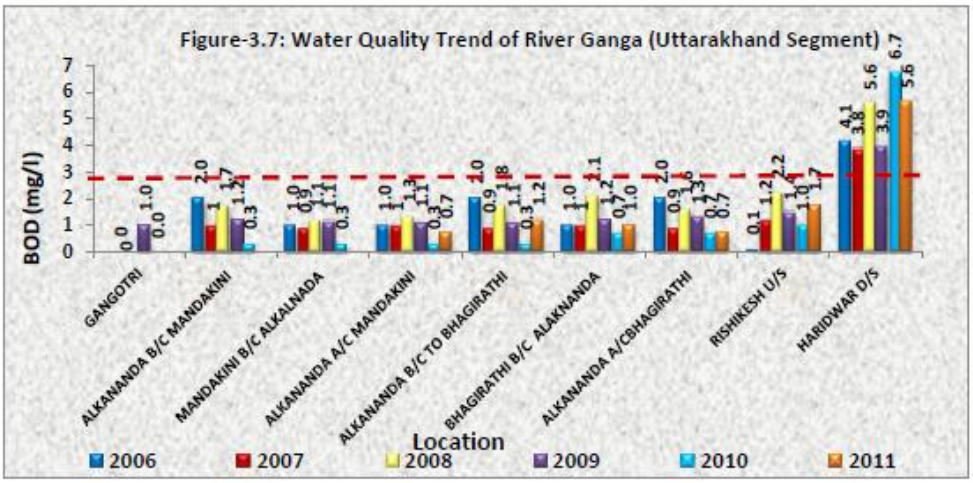
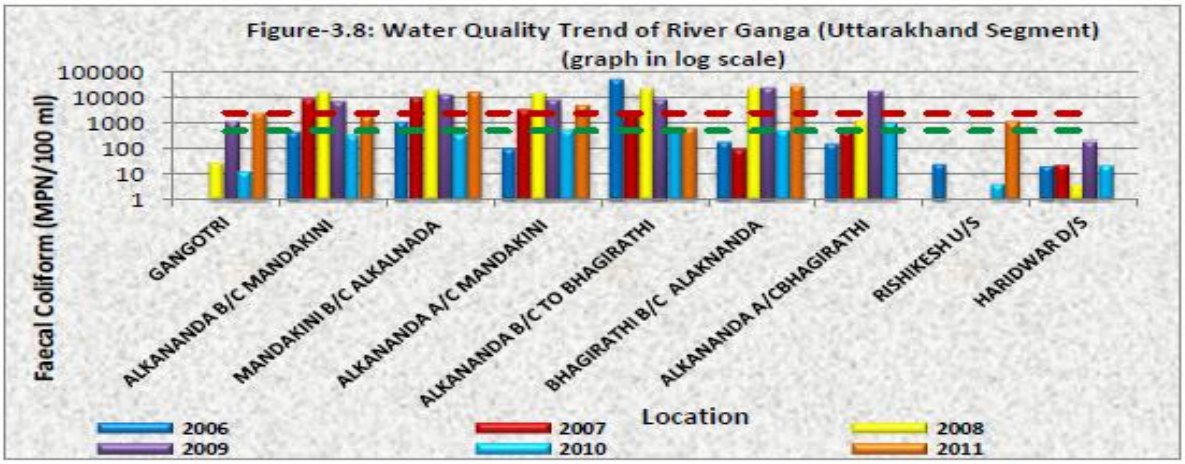


Figure-3.7: Water Quality Trend of River Ganga (Uttarakhand Segment)
BOD (mg/l)
Location
GANGOTRI
ALKANANDA B/C MANDAKINI
MANDAKINI B/C ALKALNADA
ALKANANDA A/C MANDAKINI
ALKANANDA B/C TO BHAGIRATHI
BHAGIRATHI B/C ALAKNANDA
ALKANANDA A/CBHAGIRATHI
RISHIKESH U/S
HARIDWAR D/S
2006
2007
2008
2009
2010
2011



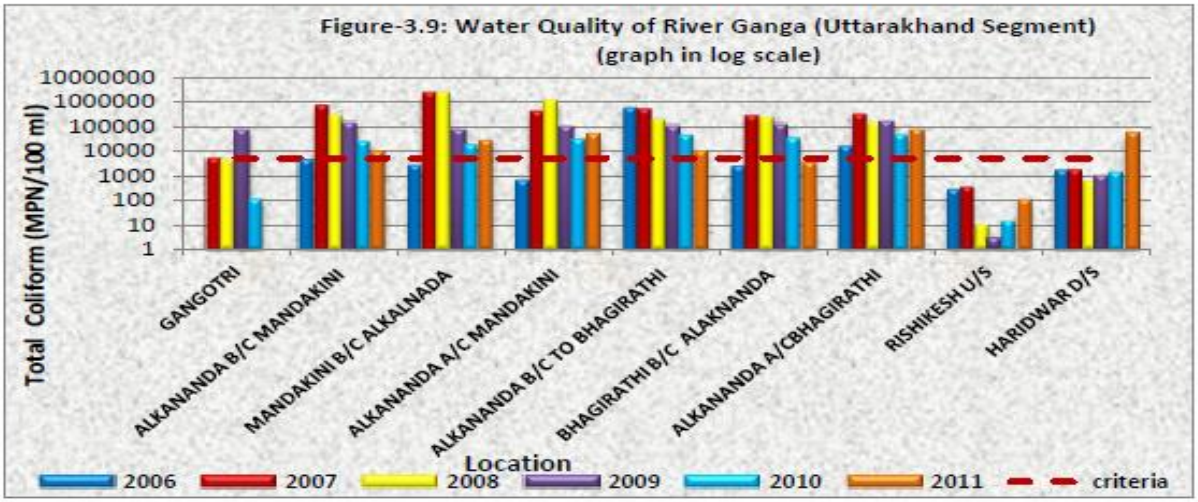


Fig 3.2 Water quality of river Ganga(Total coliform, Faecal coliform)

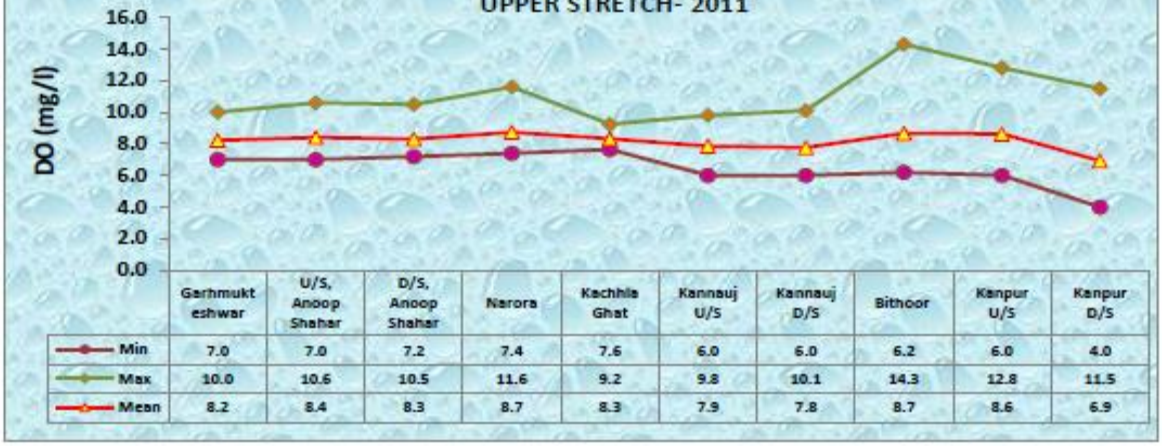
3.2.3 Water Quality Assessment in Uttar Pradesh Upper Stretch (from Garhmukteshwar to Kanpur D/s) :

In the upper stretch of Uttar Pradesh from Garhmukteshwar to Kanpur D/sthe results are depicted in figure 3.10 to 3.14. Following observations emerge from analysis of the data:

- pH is meeting the water quality criteria for bathing at all the monitoring locations.
- Conductivity is meeting the primary water quality criteria based on designated best use.
- DO varies from 4.0-14.3 mg/l. The average value of DO is meeting the criteria at all monitoring locations. At some periods of the year the value of DO observed in river Ganga at Kanpur D/s is not meeting the criteria and supersaturation at Bithoor is also observed.
- BOD ranges from 1.6-9.6 mg/l. The maximum value of BOD measured at all monitoring locations is exceeding the water quality criteria notified for bathing.

- Faecal Coliform value ranges from 70-93000 MPN/100ml and not meeting the water quality criteria for bathingat from Kannauj U/s to D/s Kanpur.
- While the Total Coliform value ranges 150- 240,000 not meeting the criteria for category 'C' of designated best use concept at all monitored locations.

FIGURE-3.10: WATER QUALITY OF RIVER GANGA IN UTTAR PRADESH
UPPER STRETCH- 2011

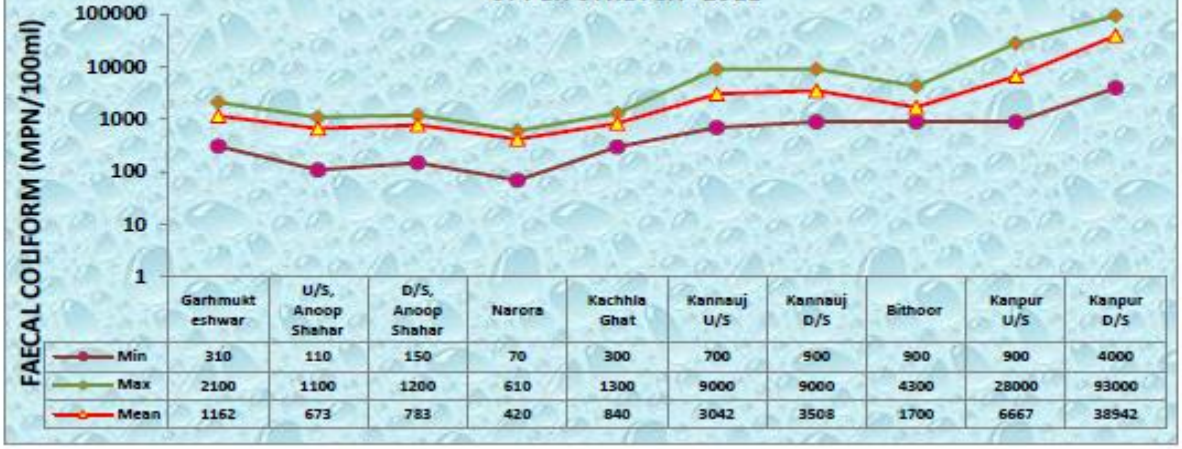


	Garhmukteshwar	U/S, Anoop Shahar	D/S, Anoop Shahar	Narora	Kachhla Ghat	Kannauj U/S	Kannauj D/S	Bithoor	Kanpur U/S	Kanpur D/S
Min	7.0	7.0	7.2	7.4	7.6	6.0	6.0	6.2	6.0	4.0
Max	10.0	10.6	10.5	11.6	9.2	9.8	10.1	14.3	12.8	11.5
Mean	8.2	8.4	8.3	8.7	8.3	7.9	7.8	8.7	8.6	6.9

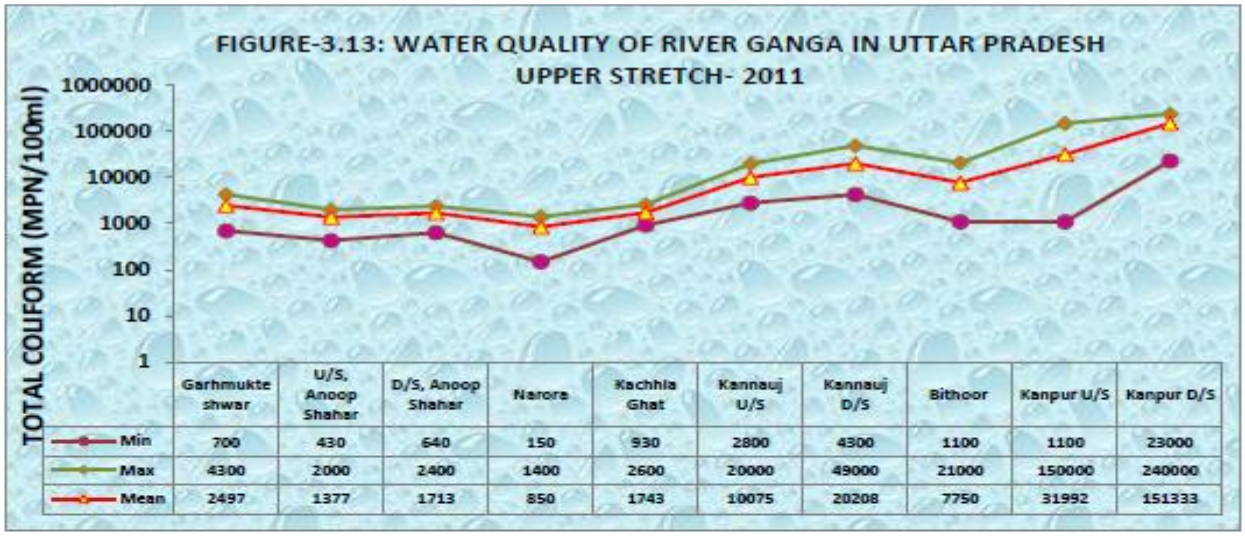
FIGURE-3.11: WATER QUALITY OF RIVER GANGA IN UTTAR PRADESH
UPPER STRETCH- 2011

	Garhmukteshwar	U/S, Anoop Shahar	D/S, Anoop Shahar	Narora	Kachhla Ghat	Kannauj U/S	Kannauj D/S	Bithoor	Kanpur U/S	Kanpur D/S
Min	2.8	1.6	2.2	1.9	2.2	3.4	4.2	2.6	3	6.6
Max	4.5	3.8	6.1	6.6	6.8	6.2	9	5.6	5.5	9.6
Mean	3.4	2.8	3.6	3.1	3.7	4.5	5.5	4.0	4.3	8.4

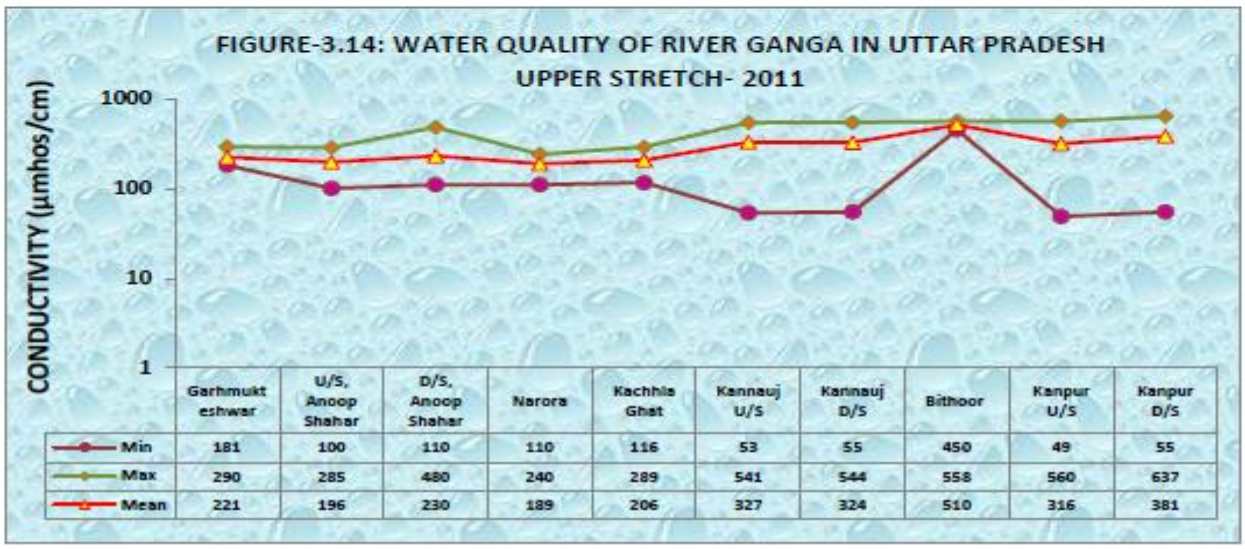
FIGURE-3.12: WATER QUALITY OF RIVER GANGA IN UTTAR PRADESH
UPPER STRETCH- 2011



	Garhmukteshwar	U/S, Anoop Shahar	D/S, Anoop Shahar	Narora	Kachhla Ghat	Kannauj U/S	Kannauj D/S	Bithoor	Kanpur U/S	Kanpur D/S
Min	310	110	150	70	300	700	900	900	900	4000
Max	2100	1100	1200	610	1300	9000	9000	4300	28000	93000
Mean	1162	673	783	420	840	3042	3508	1700	6667	38942



	Garhmukteshwar	U/S, Anoop Shahar	D/S, Anoop Shahar	Narora	Kachhla Ghat	Kannauj U/S	Kannauj D/S	Bithoor	Kanpur U/S	Kanpur D/S
Min	700	430	640	150	930	2800	4300	1100	1100	23000
Max	4300	2000	2400	1400	2600	20000	49000	21000	150000	240000
Mean	2497	1377	1713	850	1743	10075	20208	7750	31992	151333



	Garhmukteshwar	U/S, Anoop Shahar	D/S, Anoop Shahar	Narora	Kachhla Ghat	Kannauj U/S	Kannauj D/S	Bithoor	Kanpur U/S	Kanpur D/S
Min	181	100	110	110	116	53	55	450	49	55
Max	290	285	480	240	289	541	544	558	560	637
Mean	221	196	230	189	206	327	324	510	316	381

Fig 3.3 Water quality of river ganga in Uttar Pradesh(conductivity, Total coliform,BOD,DO, Faecal coliform)

3.2.4 Spatial and temporal of water quality in Uttar Pradesh upper stretch

The results from 2006 to 2011 for DO, BOD, FC and TC are summarised and illustrated in figure 3.15 to 3.18. A close examination indicates that-

- Average values of DO comply with the standards for the period of 2006-2011 at most of the locations.
- BOD does not comply with the standards at most of the locations for the period of 2006-2011. An increasing trend of BOD is observed.
- A decreasing trend is observed in faecal coliform count.
- A decreasing trend is also observed in Total Coliform count.
- In overall analysis, the River Ganga in upper stretch of Uttar Pradesh is polluted.

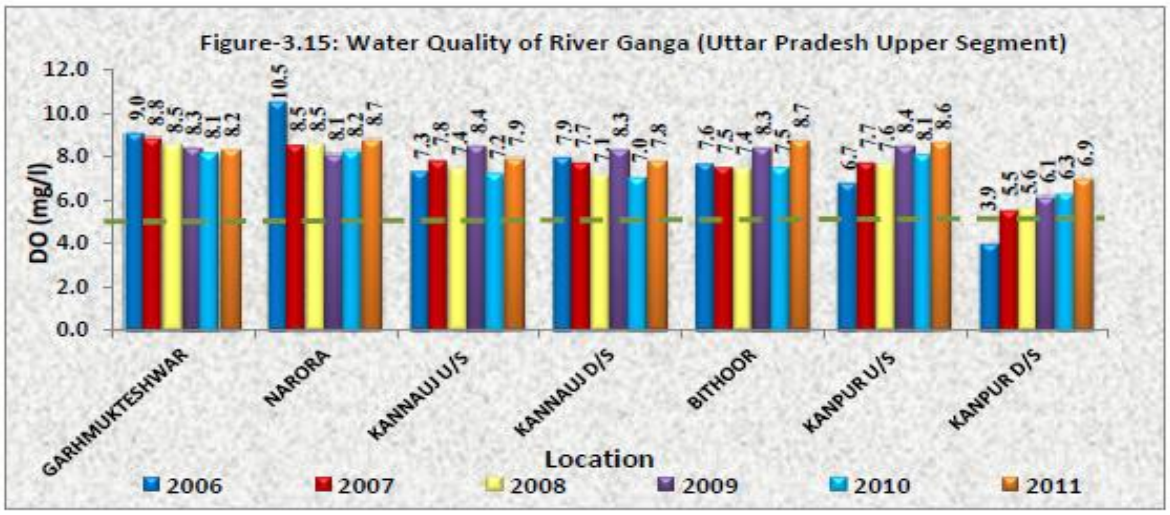


Figure-3.15: Water Quality of River Ganga (Uttar Pradesh Upper Segment)
DO (mg/l)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
9.0 8.8 8.5 8.3 8.1 8.2
10.5 8.5 8.5 8.1 8.2 8.7
7.3 7.8 7.4 8.4 7.2 7.9
7.9 7.7 7.1 8.3 7.0 7.8
7.6 7.5 7.4 8.3 7.5 8.7
6.7 7.7 7.6 8.4 8.1 8.6
3.9 5.5 5.6 6.1 6.3 6.9
GARHMUKTESHWAR
NARORA
KANNAUJ U/S
KANNAUJ D/S
BITHOOR
KANPUR U/S
KANPUR D/S
Location
2006
2007
2008
2009
2010
2011

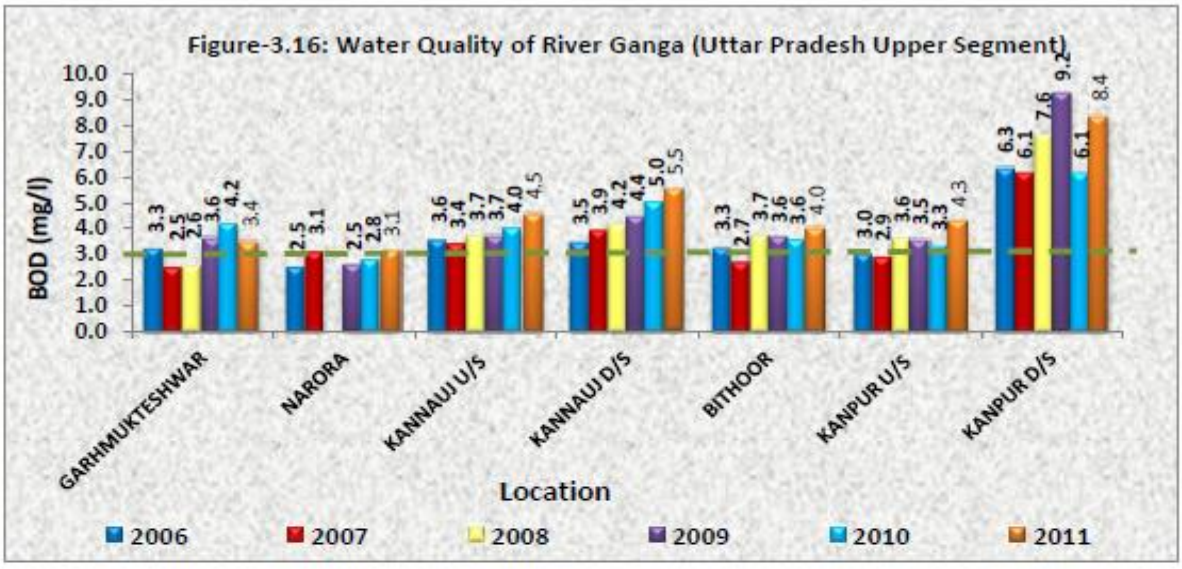


Figure-3.16: Water Quality of River Ganga (Uttar Pradesh Upper Segment)
BOD (mg/l)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
3.3 2.5 2.6 3.6 4.2 3.4
2.5 3.1
2.5 2.8 3.1
3.6 3.4 3.7 3.7 4.0 4.5
3.5 3.9 4.2 4.4 5.0 5.5
3.3 2.7 3.7 3.6 3.6 4.0
3.0 2.9 3.6 3.5 3.3 4.3
6.3 6.1 7.6 9.2 6.1 8.4
GARHMUKTESHWAR
NARORA
KANNAUJ U/S
KANNAUJ D/S
BITHOOR
KANPUR U/S
KANPUR D/S
Location
2006
2007
2008
2009
2010
2011

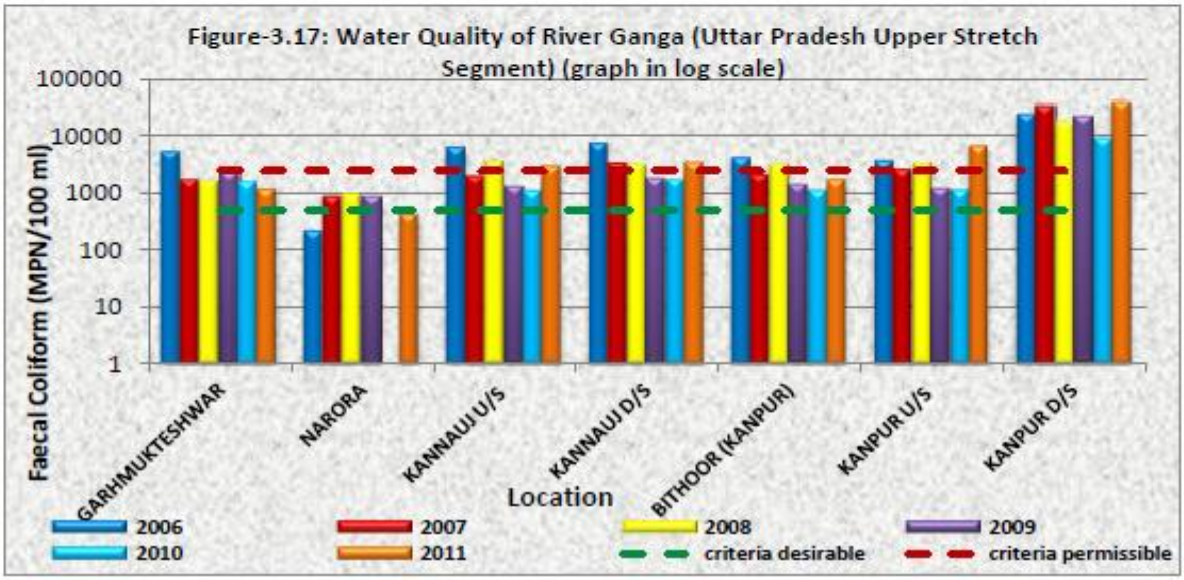


Figure-3.17: Water Quality of River Ganga (Uttar Pradesh Upper Stretch Segment) (graph in log scale)
Faecal Coliform (MPN/100 ml)
100000
10000
1000
100
10
1
GARHMUKTESHWAR
NARORA
KANNAUJ U/S
KANNAUJ D/S
BITHOOR (KANPUR)
KANPUR U/S
KANPUR D/S
Location
2006
2007
2008
2009
2010
2011
criteria desirable
criteria permissible

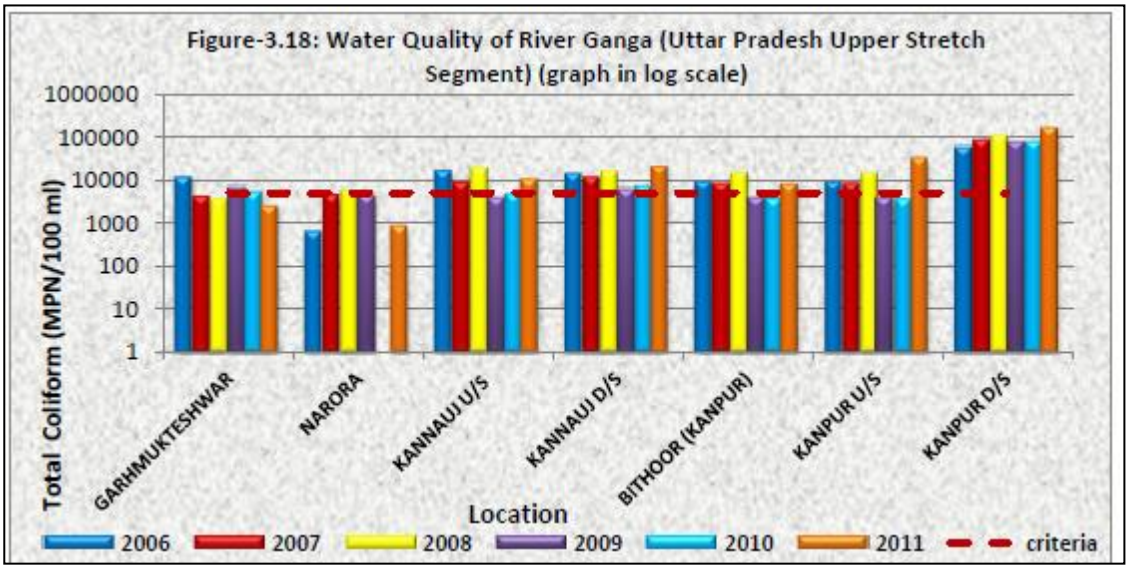


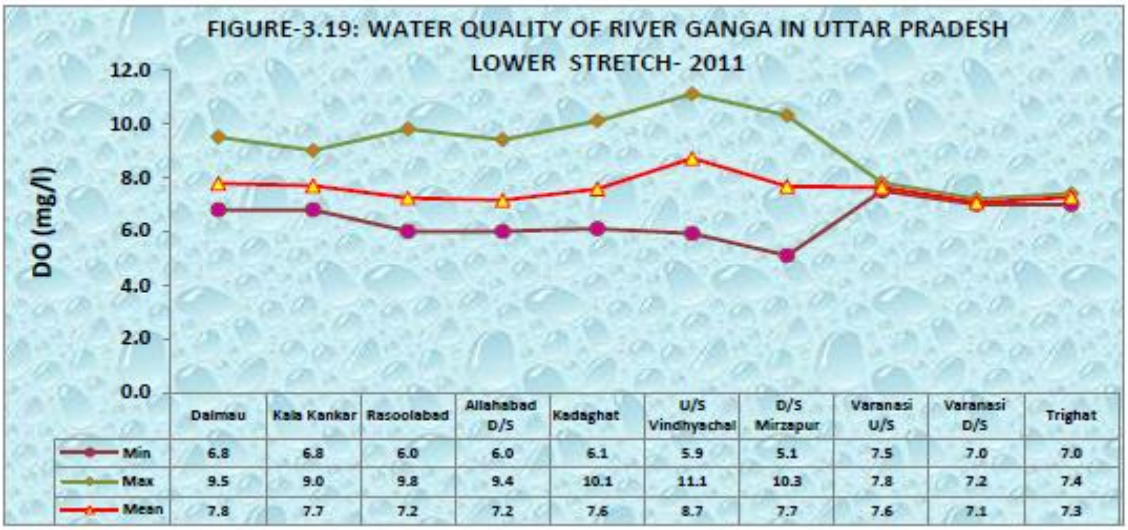
Fig 3.4 Water quality of river ganga Uttar Pradesh upper stretch(DO, Total coliform ,Faecal coliform)

3.2.5 Water Quality Assessment in Uttar Pradesh Lower Stretch (from Dalmau to Trighat)

In the lower stretch of Uttar Pradesh from Dalmau to Trighat the results are depicted in figure 3.19 to 3.23. From the figures it is observed that:

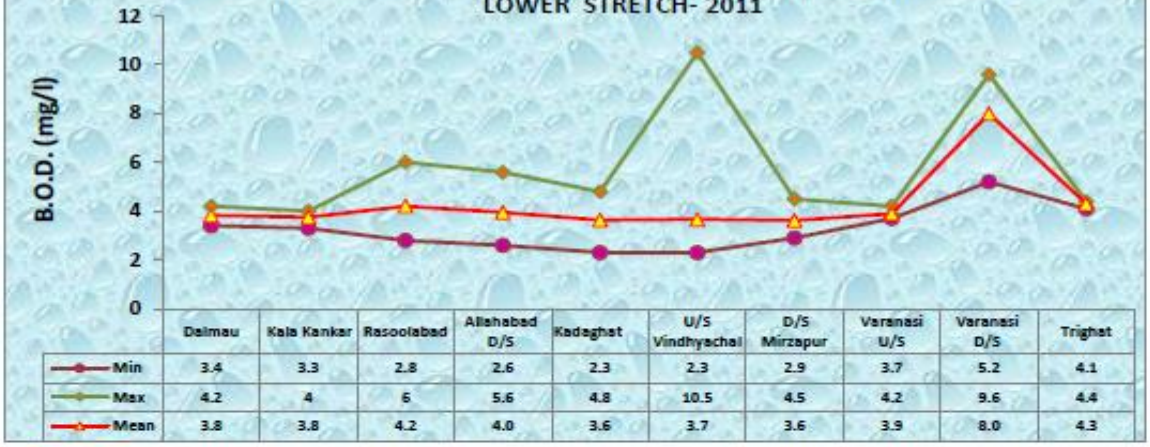
- DO & pH - meeting thewater quality criteria for bathing at all the monitoring locations.
- Conductivity meeting the primary water quality criteria based on designated best use.
- DO varies from 5.1-11.1 mg/l.
- BOD ranges from 2.3-10.5 mg/l. The maximum value of BOD has been measured at U/s Vindhyachal (Mirzapur). All the monitoring locations are exceeding the water quality criteria notified for bathing.
- Faecal Coliform values range from 40-46000 MPN/100ml and not meeting the water quality criteria for bathingat all monitoring locations except U/s Vindhyachal.
- While the Total Coliform value ranges 110- 70,000 not meeting the criteria for category 'C' of designated best use concept at all monitored locations.

FIGURE-3.19: WATER QUALITY OF RIVER GANGA IN UTTAR PRADESH
LOWER STRETCH- 2011



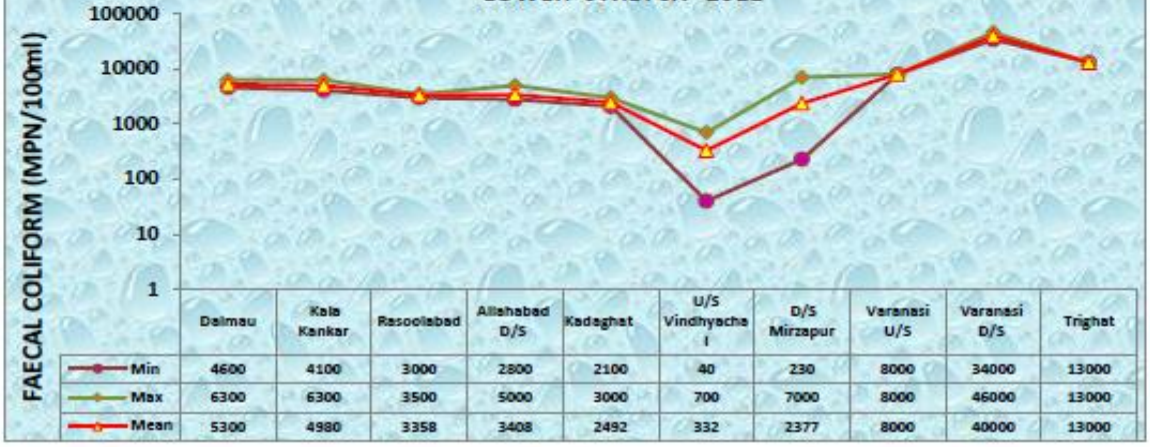
	Dalmau	Kala Kankar	Rasoolabad	Allahabad D/S	Kadaghat	U/S Vindhyachal	D/S Mirzapur	Varanasi U/S	Varanasi D/S	Trighat
Min	6.8	6.8	6.0	6.0	6.1	5.9	5.1	7.5	7.0	7.0
Max	9.5	9.0	9.8	9.4	10.1	11.1	10.3	7.8	7.2	7.4
Mean	7.8	7.7	7.2	7.2	7.6	8.7	7.7	7.6	7.1	7.3

FIGURE-3.20: WATER QUALITY OF RIVER GANGA IN UTTAR PRADESH
LOWER STRETCH- 2011

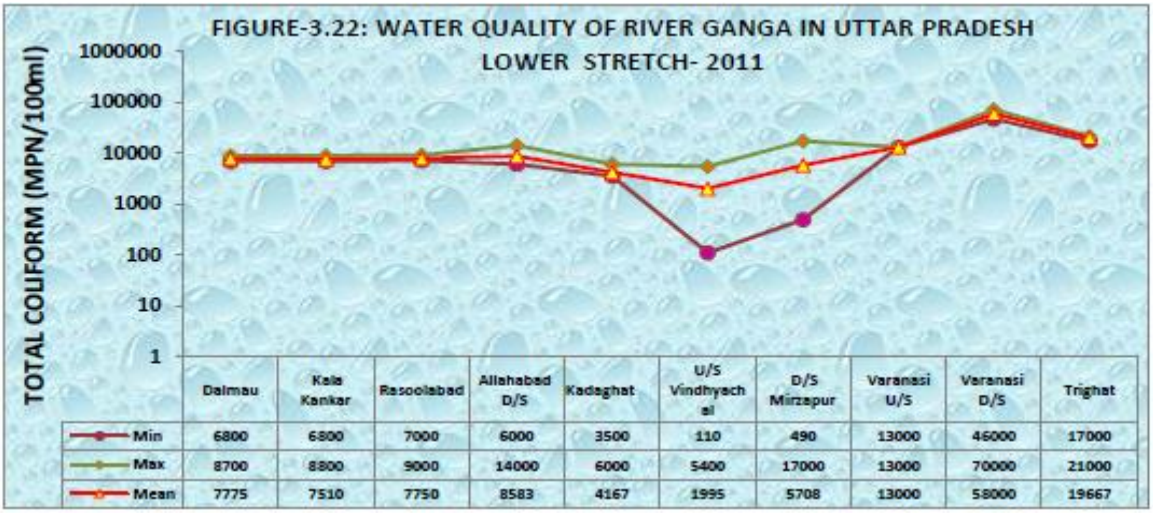


	Dalmau	Kala Kankar	Rasoolabad	Allahabad D/S	Kadaghat	U/S Vindhyachal	D/S Mirzapur	Varanasi U/S	Varanasi D/S	Trighat
Min	3.4	3.3	2.8	2.6	2.3	2.3	2.9	3.7	5.2	4.1
Max	4.2	4	6	5.6	4.8	10.5	4.5	4.2	9.6	4.4
Mean	3.8	3.8	4.2	4.0	3.6	3.7	3.6	3.9	8.0	4.3

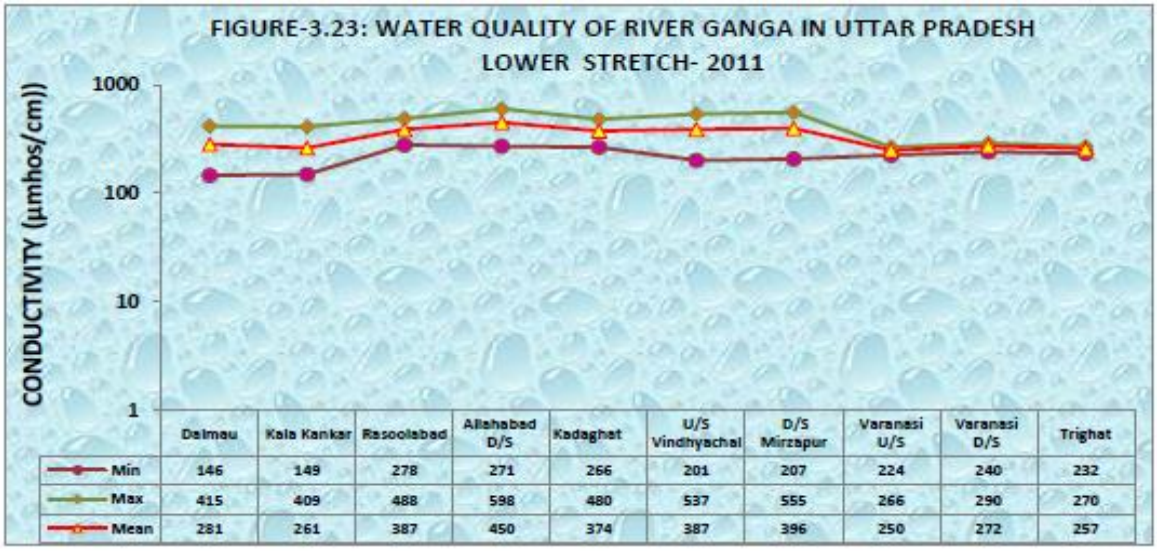
FIGURE-3.21: WATER QUALITY OF RIVER GANGA IN UTTAR PRADESH
LOWER STRETCH- 2011



	Dalmau	Kala Kankar	Rasoolabad	Allahabad D/S	Kadaghat	U/S Vindhyachal	D/S Mirzapur	Varanasi U/S	Varanasi D/S	Trighat
Min	4600	4100	3000	2800	2100	40	230	8000	34000	13000
Max	6300	6300	3500	5000	3000	700	7000	8000	46000	13000
Mean	5300	4980	3358	3408	2492	332	2377	8000	40000	13000



	Dalmau	Kala Kankar	Rasoolabad	Allahabad D/S	Kadaghat	U/S Vindhyachal	D/S Mirzapur	Varanasi U/S	Varanasi D/S	Trighat
Min	6800	6800	7000	6000	3500	110	490	13000	46000	17000
Max	8700	8800	9000	14000	6000	5400	17000	13000	70000	21000
Mean	7775	7510	7750	8583	4167	1995	5708	13000	58000	19667



	Dalmau	Kala Kankar	Rasoolabad	Allahabad D/S	Kadaghat	U/S Vindhyachal	D/S Mirzapur	Varanasi U/S	Varanasi D/S	Trighat
Min	146	149	278	271	266	201	207	224	240	232
Max	415	409	488	598	480	537	555	266	290	270
Mean	281	261	387	450	374	387	396	250	272	257

Fig 3.5 Water quality of river Ganga in Uttar Pradesh lower stretch(conductivity,DO,BOD)

3.2.6 Spatial and Temporal trend of water quality in Uttar Pradesh lower stretch

An overall summary of the trend in BOD, DO, FC and TC at various locations of lower stretch of Uttar Pradesh is presented in Figures 3.24-3.27. The results of this stretch clearly indicate that:

- Average values of DO comply with the standards for the period of 2006-2011 at most of the locations.
- BOD does not comply with the standards at most of the locations for the period of 2006-2011. An increasing trend of BOD is observed at all monitoring locations except Varanasi D/s, however every year (2006-2011) highest BOD is always observed at Varanasi D/s.

- Faecal Coliform and Total coliform both are observed higher than the criteria at most of the locations, while the highest value is always observed at Varasi D/s. No specific trend is observed in these two parameters.
- In overall analysis, the River Ganga in lowerstretch of Uttar Pradesh is polluted.

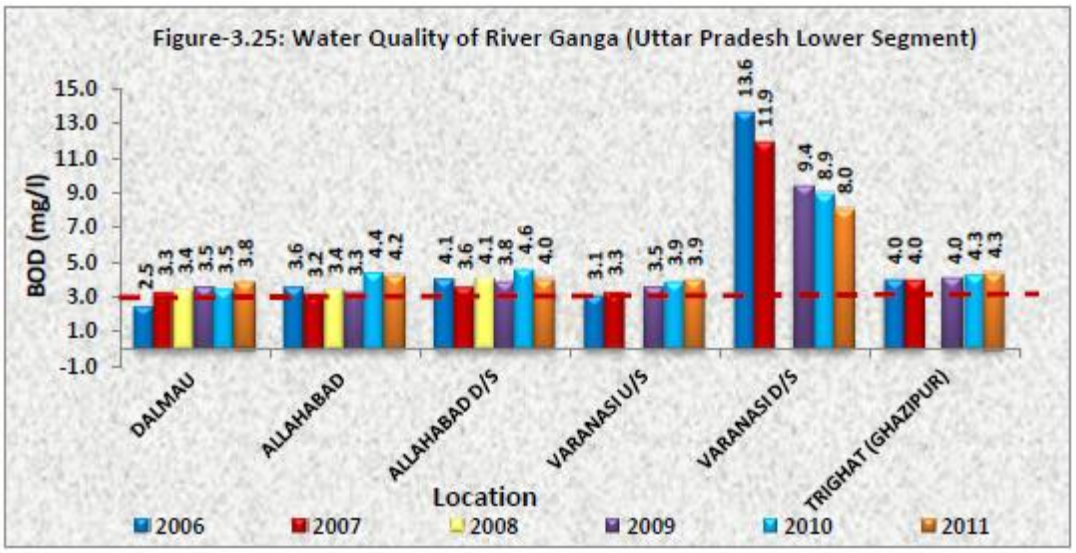


Figure-3.25: Water Quality of River Ganga (Uttar Pradesh Lower Segment)

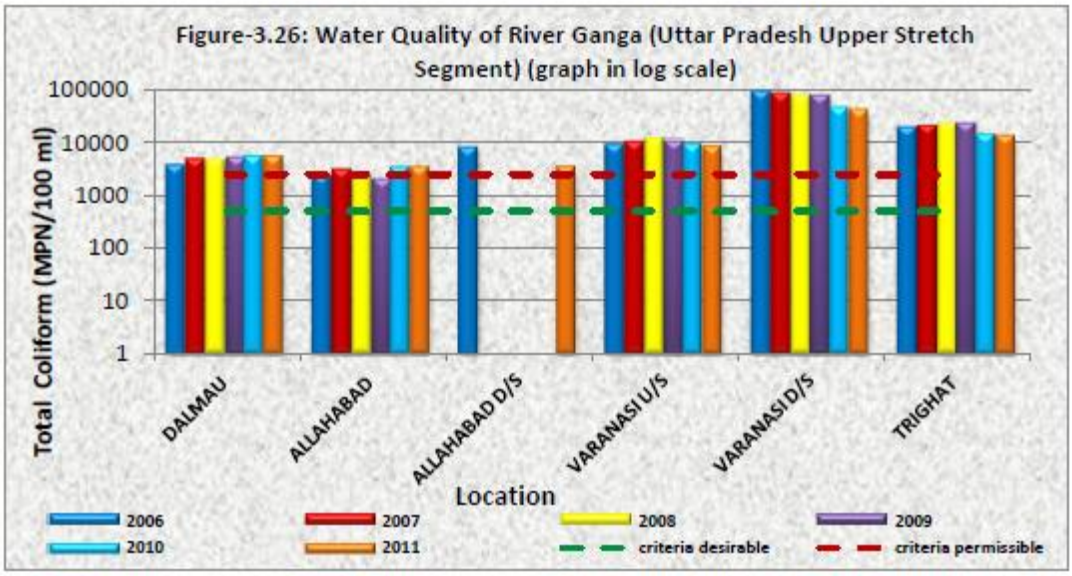
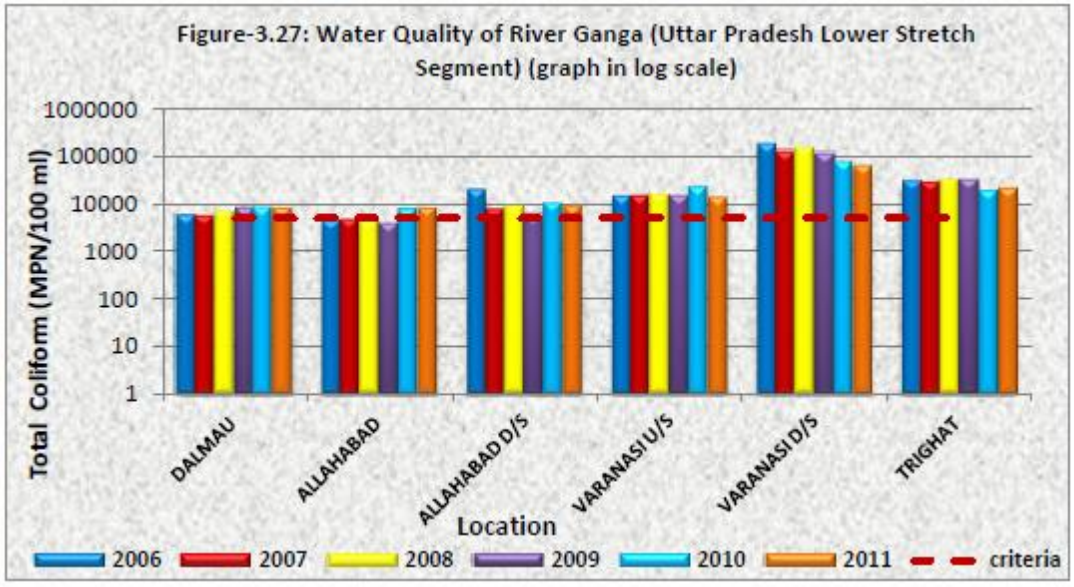


Figure-3.26: Water Quality of River Ganga (Uttar Pradesh Upper Stretch Segment) (graph in log scale)

00000

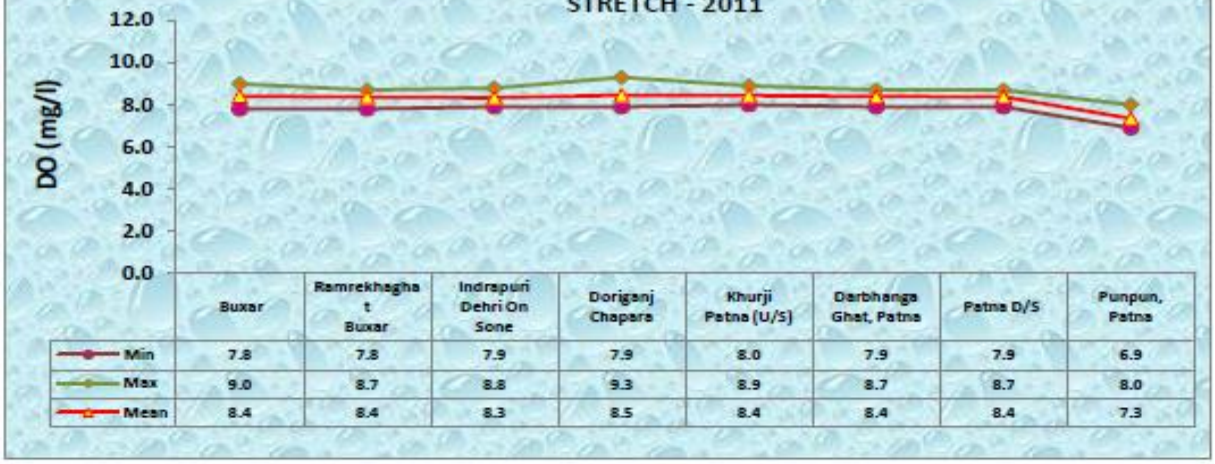


3.2.7 Water Quality Assessment in Bihar (from Buxar to Khalgaon)

The water quality of river Ganga in the stretch of Bihar with respect to BOD, DO, Conductivity, Faecal Coliform and Total Coliform is depicted in Figure 3.28 to 3.37 in two stretches, upper stretch (from Buxar to Phunphun) & lower stretch (from Fathua to Khalgaon). In the overall stretch of Bihar from Buxar to Khalgaon, it is observed that

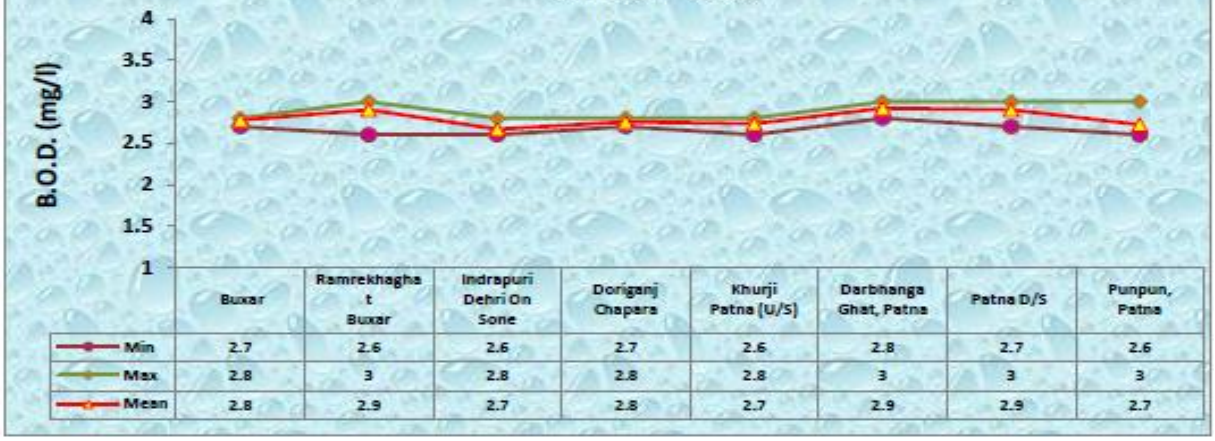
- DO & pH is meeting the water quality criteria for bathing at all the monitoring locations.
- Conductivity meeting the primary water quality criteria based on designated best use.
- DO varies from 6.2-9.3 mg/l.
- BOD ranges from 2.6-3.0 mg/l and meeting the water quality criteria notified for bathing at all monitoring locations and all occasions.
- Faecal coliform values range from 700-9000 MPN/100ml. Faecal coliform is observed higher than the criteria at most of the locations monitored.
- Total Coliform values range from 1400- 90,000 not meeting the based on designated best use for category 'C' at most of the monitored locations.
- The stretch in Bihar is almost clean with respect to organic pollution. High faecal contamination is observed.

FIGURE-3.28: WATER QUALITY OF RIVER GANGA IN BIHAR UPPER STRETCH - 2011



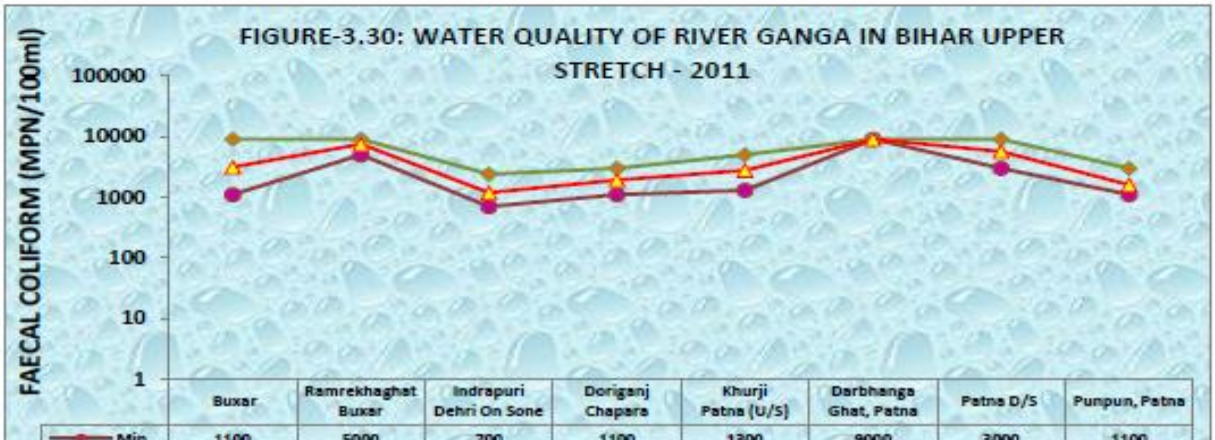
	Buxar	Ramrekhaghat Buxar	Indrapuri Dehri On Sone	Doriganj Chapara	Khurji Patna (U/S)	Darbhanga Ghat, Patna	Patna D/S	Punpun, Patna
Min	7.8	7.8	7.9	7.9	8.0	7.9	7.9	6.9
Max	9.0	8.7	8.8	9.3	8.9	8.7	8.7	8.0
Mean	8.4	8.4	8.3	8.5	8.4	8.4	8.4	7.3

FIGURE-3.29: WATER QUALITY OF RIVER GANGA IN BIHAR UPPER STRETCH - 2011

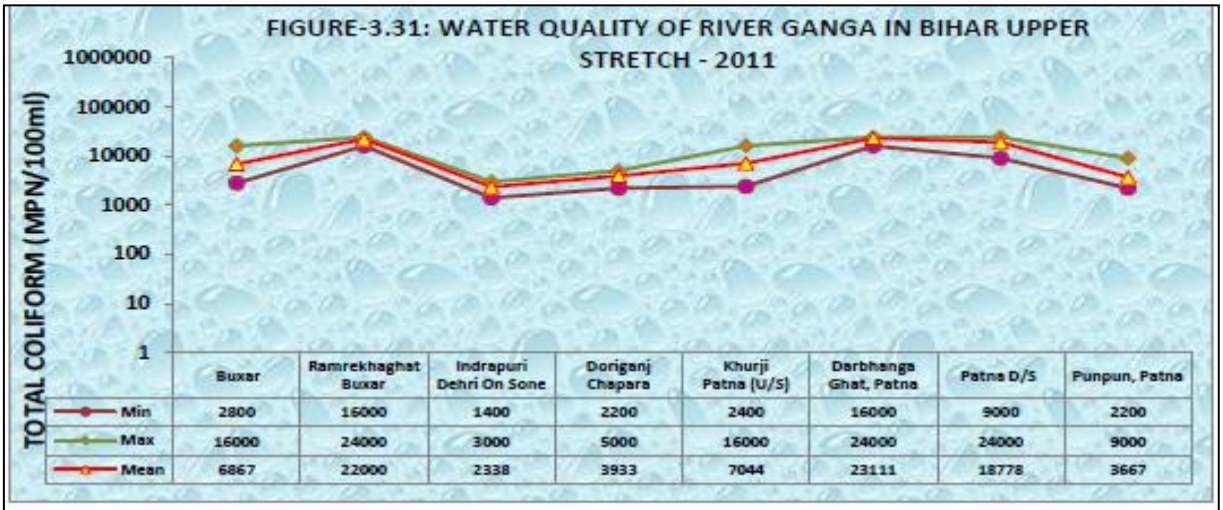


	Buxar	Ramrekhaghat Buxar	Indrapuri Dehri On Sone	Doriganj Chapara	Khurji Patna (U/S)	Darbhanga Ghat, Patna	Patna D/S	Punpun, Patna
Min	2.7	2.6	2.6	2.7	2.6	2.8	2.7	2.6
Max	2.8	3	2.8	2.8	2.8	3	3	3
Mean	2.8	2.9	2.7	2.8	2.7	2.9	2.9	2.7

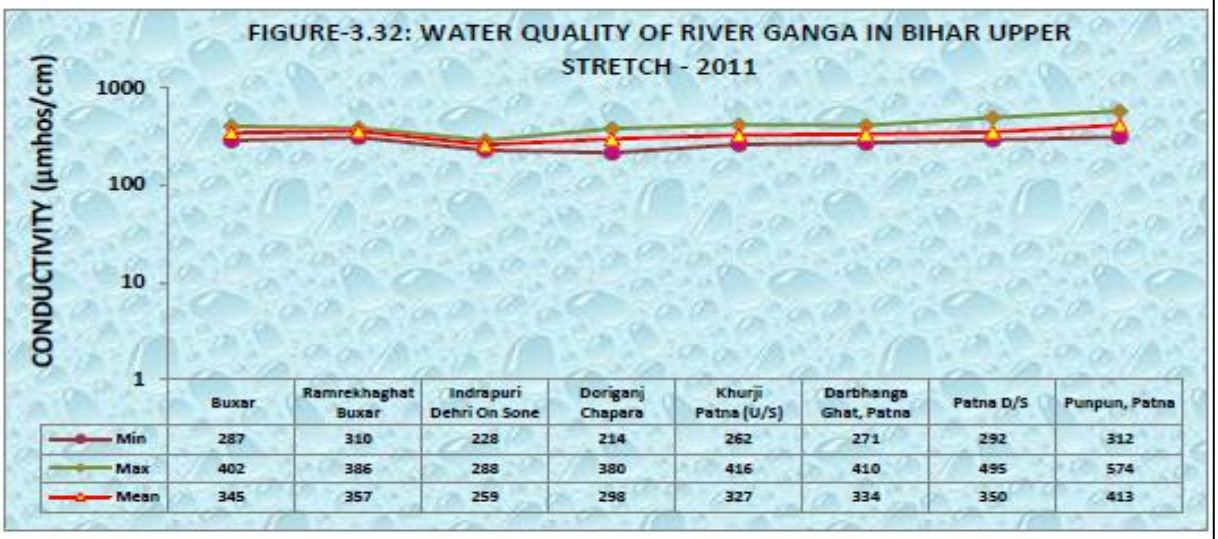
FIGURE-3.30: WATER QUALITY OF RIVER GANGA IN BIHAR UPPER STRETCH - 2011



	Buxar	Ramrekhaghat Buxar	Indrapuri Dehri On Sone	Doriganj Chapara	Khurji Patna (U/S)	Darbhanga Ghat, Patna	Patna D/S	Punpun, Patna
Min	1100	5000	700	1100	1300	9000	3000	1100
Max	9000	9000	2400	3000	5000	9000	9000	3000
Mean	3122	7500	1188	1922	2767	9000	5667	1589

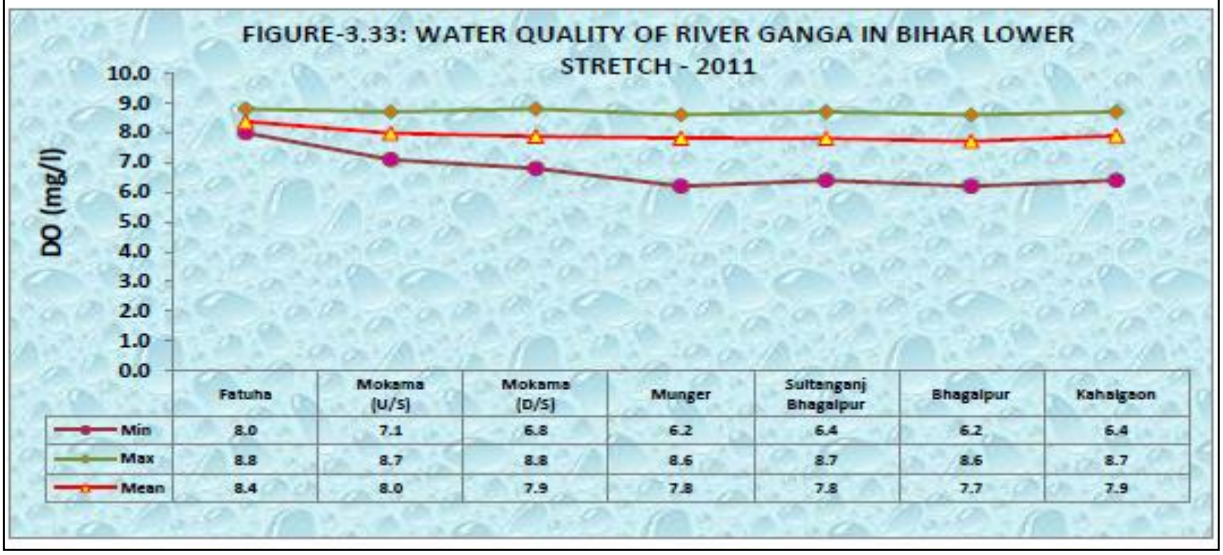


	Buxar	Ramrekhaghat Buxar	Indrapuri Dehri On Sone	Doriganj Chapara	Khurji Patna (U/S)	Darbhanga Ghat, Patna	Patna D/S	Punpun, Patna
Min	2800	16000	1400	2200	2400	16000	9000	2200
Max	16000	24000	3000	5000	16000	24000	24000	9000
Mean	6867	22000	2338	3933	7044	23111	18778	3667



	Buxar	Ramrekhaghat Buxar	Indrapuri Dehri On Sone	Doriganj Chapara	Khurji Patna (U/S)	Darbhanga Ghat, Patna	Patna D/S	Punpun, Patna
Min	287	310	228	214	262	271	292	312
Max	402	386	288	380	416	410	495	574
Mean	345	357	259	298	327	334	350	413

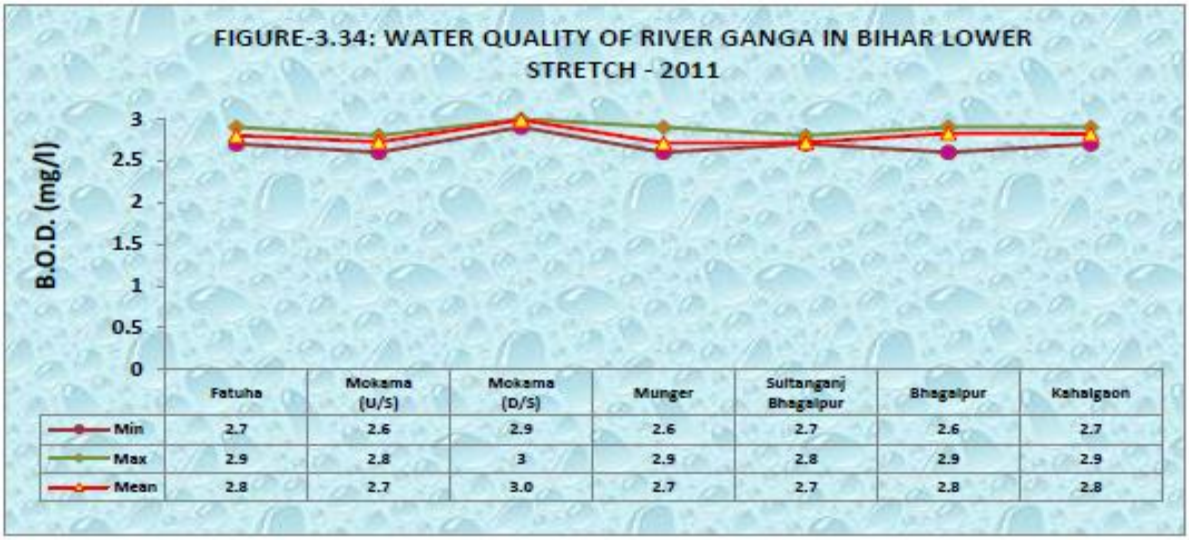
Water Quality of River Ganga in Bihar (Lower Stretch)



	Fatuha	Mokama (U/S)	Mokama (D/S)	Munger	Sultanganj Bhagalpur	Bhagalpur	Kahalgaon
Min	8.0	7.1	6.8	6.2	6.4	6.2	6.4
Max	8.8	8.7	8.8	8.6	8.7	8.6	8.7
Mean	8.4	8.0	7.9	7.8	7.8	7.7	7.9

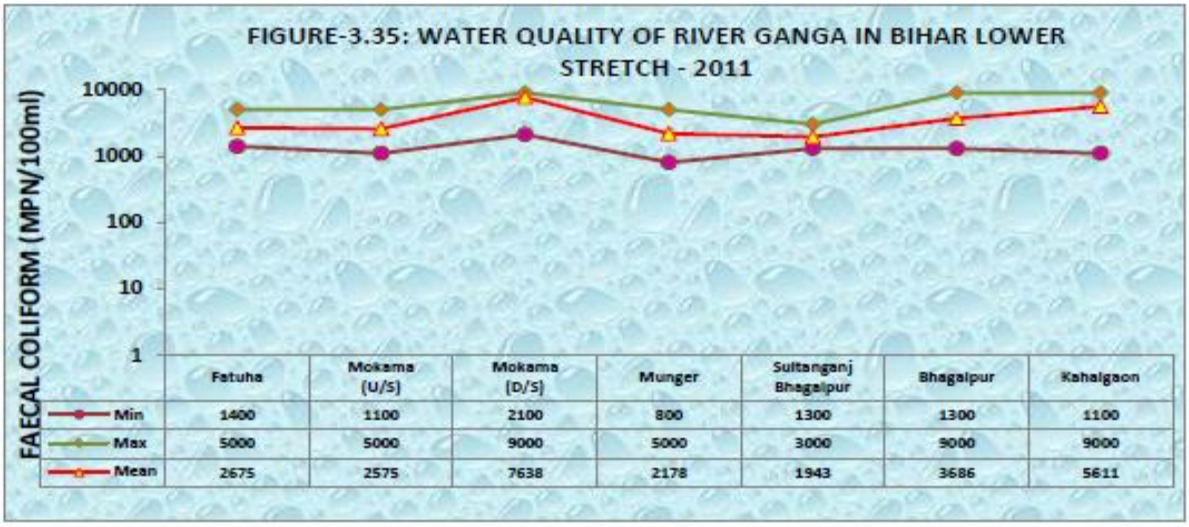
Fig 3.6 Water quality of river ganga in Bihar upper stretch(DO,BOD,Total coliform,Fecal coliform

FIGURE-3.34: WATER QUALITY OF RIVER GANGA IN BIHAR LOWER STRETCH - 2011



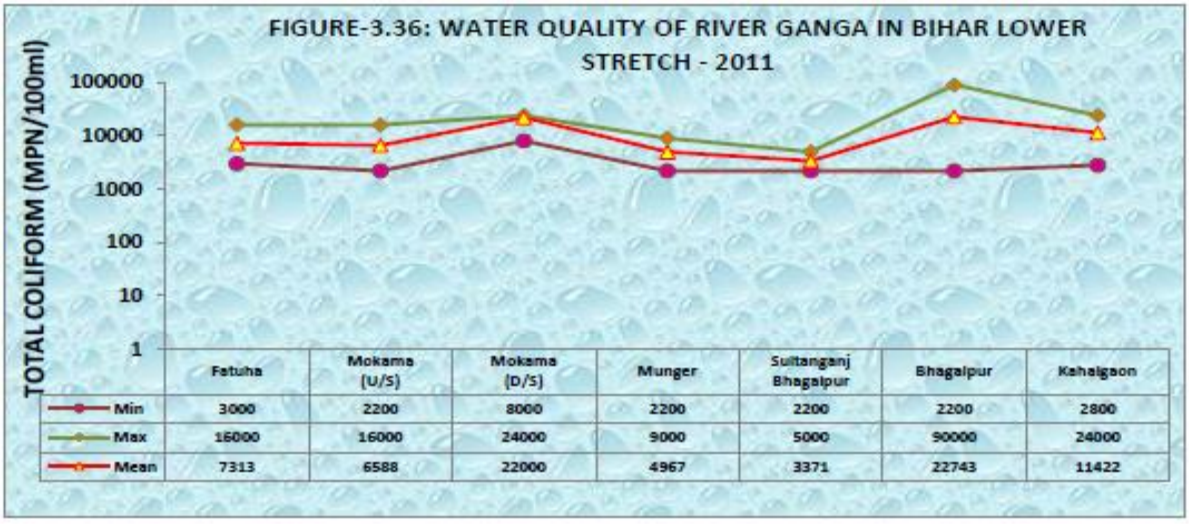
	Fatuha	Mokama (U/S)	Mokama (D/S)	Munger	Sultanganj Bhagalpur	Bhagalpur	Kahalgaon
Min	2.7	2.6	2.9	2.6	2.7	2.6	2.7
Max	2.9	2.8	3	2.9	2.8	2.9	2.9
Mean	2.8	2.7	3.0	2.7	2.7	2.8	2.8

FIGURE-3.35: WATER QUALITY OF RIVER GANGA IN BIHAR LOWER STRETCH - 2011

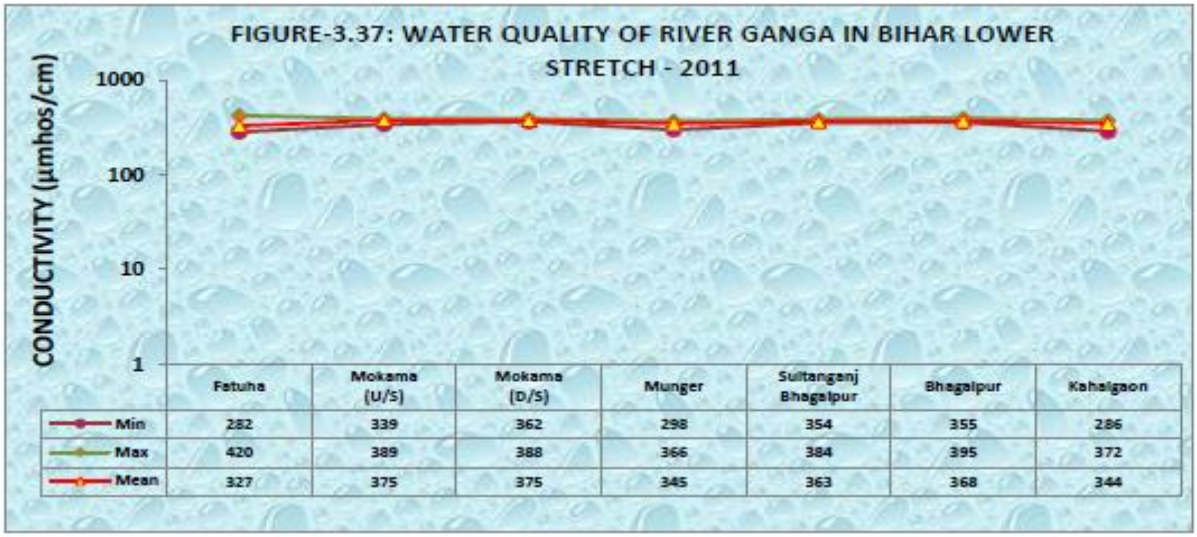


	Fatuha	Mokama (U/S)	Mokama (D/S)	Munger	Sultanganj Bhagalpur	Bhagalpur	Kahalgaon
Min	1400	1100	2100	800	1300	1300	1100
Max	5000	5000	9000	5000	3000	9000	9000
Mean	2675	2575	7638	2178	1943	3686	5611

FIGURE-3.36: WATER QUALITY OF RIVER GANGA IN BIHAR LOWER STRETCH - 2011



	Fatuha	Mokama (U/S)	Mokama (D/S)	Munger	Sultanganj Bhagalpur	Bhagalpur	Kahalgaon
Min	3000	2200	8000	2200	2200	2200	2800
Max	16000	16000	24000	9000	5000	90000	24000
Mean	7313	6588	22000	4967	3371	22743	11422



	Fatuha	Mokama (U/S)	Mokama (D/S)	Munger	Sultanganj Bhagalpur	Bhagalpur	Kahalgaon
Min	282	339	362	298	354	355	286
Max	420	389	388	366	384	395	372
Mean	327	375	375	345	363	368	344

Fig 3.7 Water quality of river ganga in bihar lower stretch(conductivity,total coliform,DO,BOD)

3.2.8 Spatial and Temporal trend of water quality in Bihar stretch :

The trend of BOD, DO, FC and TC at various locations of Bihar is presented in Figures 3.38 to 3.41.

- It is observed that average value of DO complies with the standards for the period of 2006-2011 at all locations.
- BOD also complies with the standards at all locations for the period of 2006-2011. An increasing trend in BOD is observed at all monitoring locations.
- A decreasing trend in faecal coliform is observed at all monitoring locations in Bihar. Average value of FC is observed higher at downstream of urban centres in comparison of other locations.
- Similarly a decreasing trend is observed with respect to Total coliform.
- In overall analysis, the River Ganga is comparatively clean in the stretch of Bihar with respect to organic pollution. Faecal contamination is observed high and beyond the criteria at most of the locations.

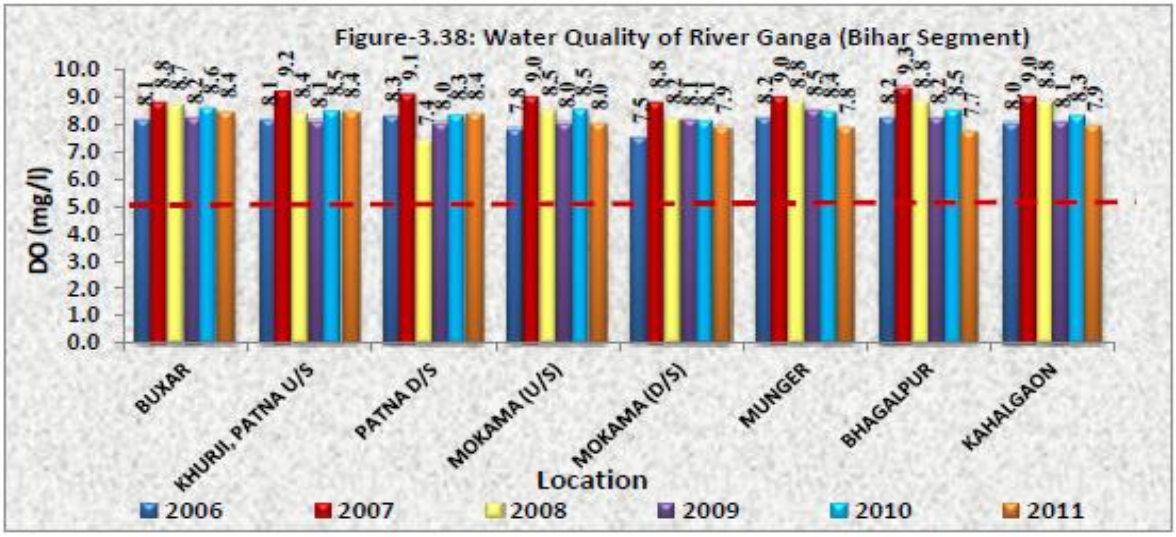


Figure-3.38: Water Quality of River Ganga (Bihar Segment)
DO (mg/l)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
BUXAR
KHURJI, PATNA U/S
PATNA D/S
MOKAMA (U/S)
MOKAMA (D/S)
MUNGER
BHAGALPUR
KAHALGAON
Location
2006
2007
2008
2009
2010
2011

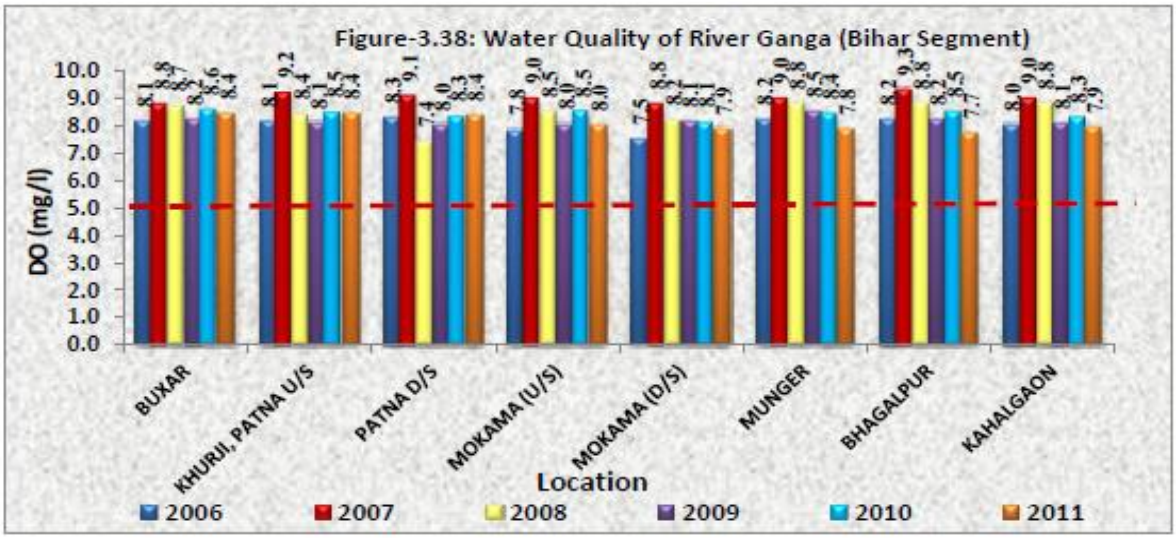
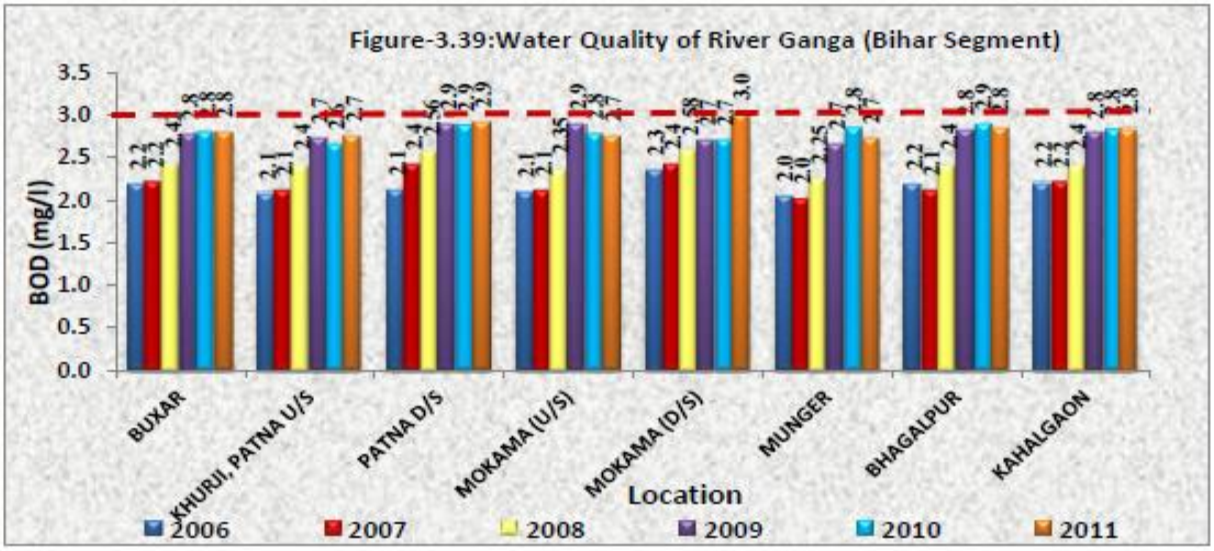
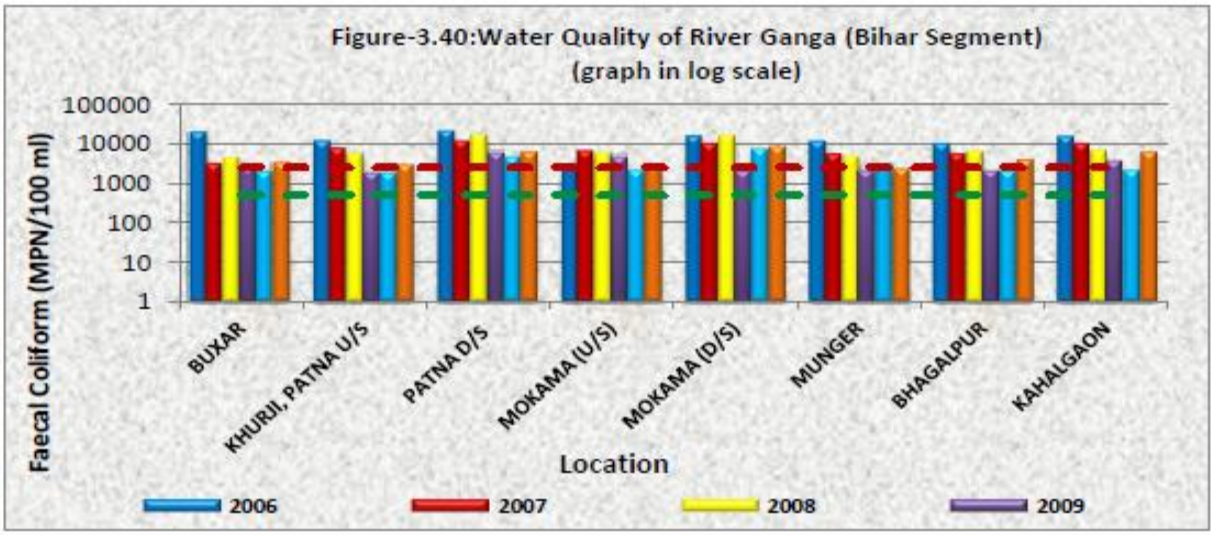


Figure-3.38: Water Quality of River Ganga (Bihar Segment)
DO (mg/l)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
BUXAR
KHURJI, PATNA U/S
PATNA D/S
MOKAMA (U/S)
MOKAMA (D/S)
MUNGER
BHAGALPUR
KAHALGAON
Location
2006
2007
2008
2009
2010
2011





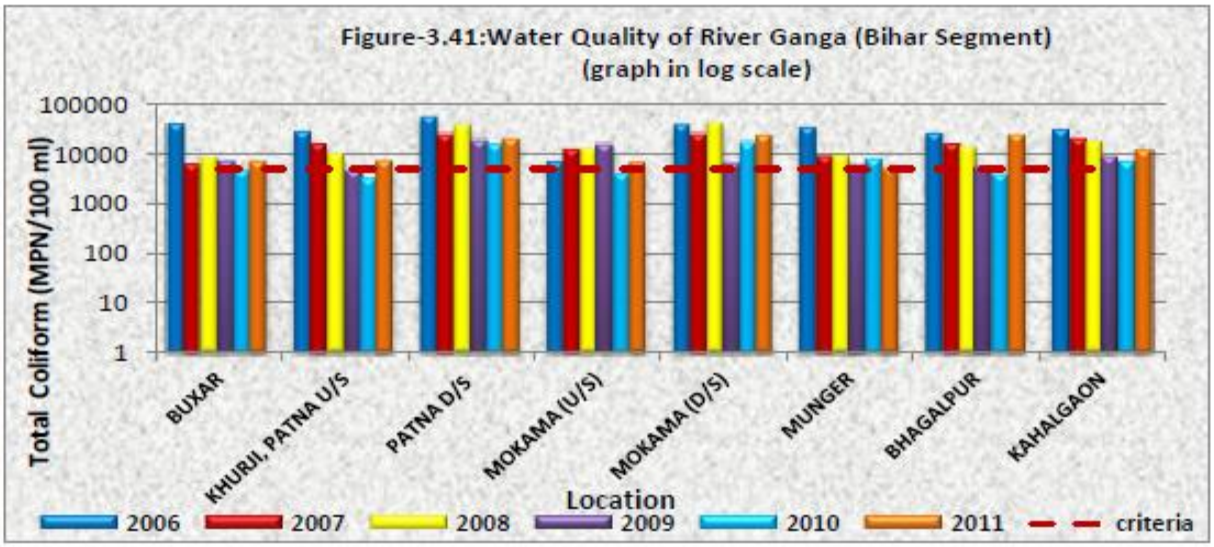


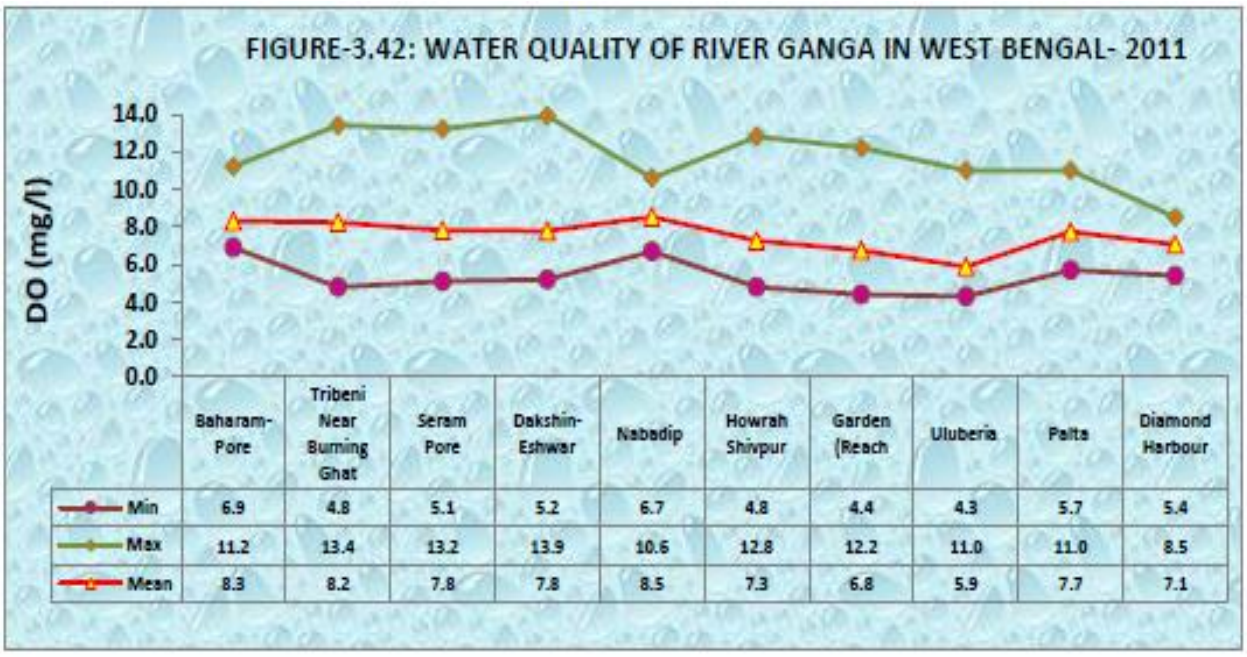
Fig 3.8 Water quality of river ganga(Bihar segment)

3.2.9 Water Quality Assessment in West Bengal

The water quality of river Ganga (named Hoogly in this stretch) with respect to DO, BOD, Faecal Coliform, Total Coliform and conductivity in the stretch of West Benagal from Baharampur to Diamond Harbour for the year 2011 is depicted in figure-3.42 to 3.46. From the figures it is observed that

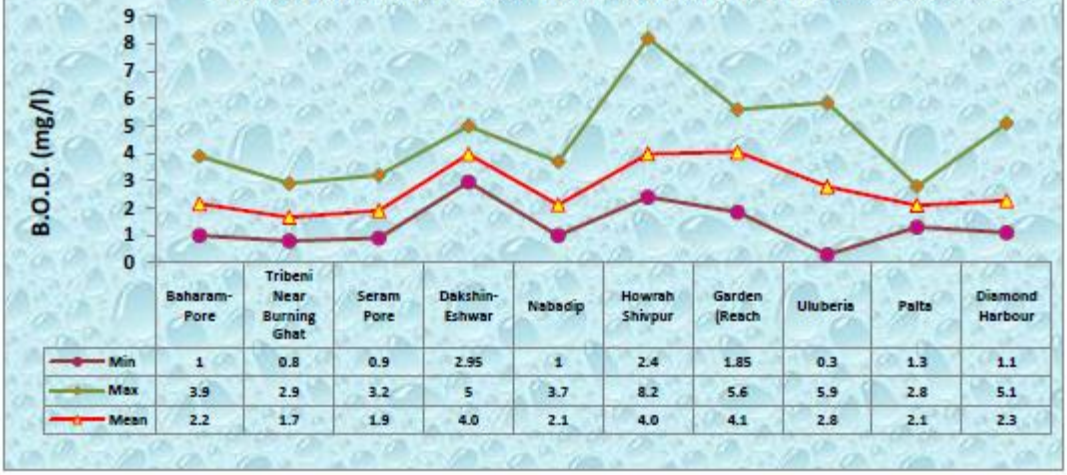
- pH - meeting the water quality criteria. for bathing at all the monitoring locations.
- Conductivity meeting the primary water quality criteria based on designated best use at all locations except Diamond harbour due to sea water intrusion. Highest Conductivity here observed is 10240 µmhos/cm.
- DO varies from 4.3-13.4 mg/l and not meeting the water quality criteria notified for bathing at Tribeni, Howrah-Shibpur, Garden Reach and Uluberia.
- BOD ranges from 0.3-8.2 mg/l and not meeting the water quality criteria notified for bathing at most of the monitoring locations except Tribeni and Palta.
- Faecal coliform value ranges from 700-11,00,000 MPN/100ml. Faecal coliform is observed higher than the criteria at all monitoring locations.
- □ Total Coliform value ranges 900- 25,00,000 not meeting the based on designated best use for category 'C' at all monitored locations.

FIGURE-3.42: WATER QUALITY OF RIVER GANGA IN WEST BENGAL- 2011



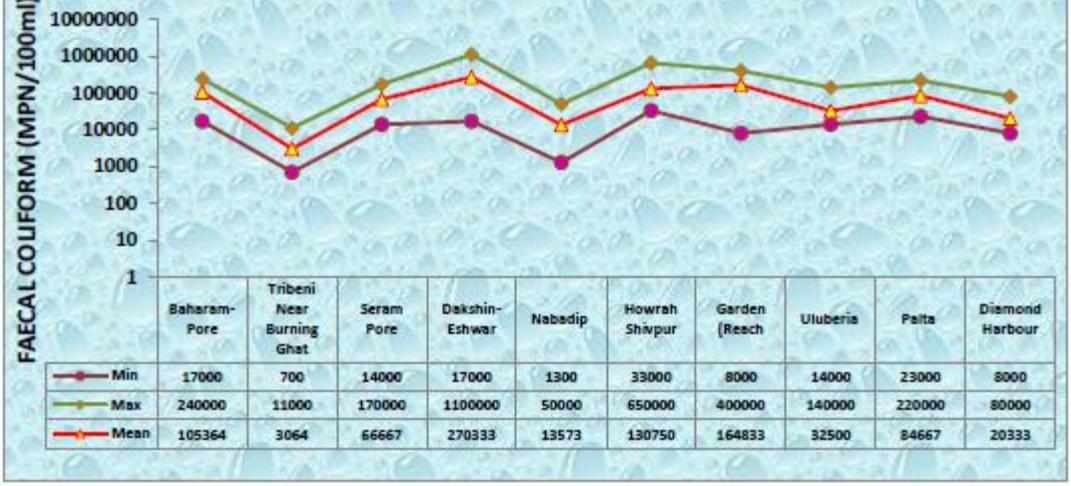
	Baharam-Pore	Tribeni Near Burning Ghat	Seram Pore	Dakshin-Eshwar	Nabadip	Howrah Shivpur	Garden (Reach	Uluberia	Palta	Diamond Harbour
Min	6.9	4.8	5.1	5.2	6.7	4.8	4.4	4.3	5.7	5.4
Max	11.2	13.4	13.2	13.9	10.6	12.8	12.2	11.0	11.0	8.5
Mean	8.3	8.2	7.8	7.8	8.5	7.3	6.8	5.9	7.7	7.1

FIGURE-3.43: WATER QUALITY OF RIVER GANGA IN WEST BENGAL- 2011



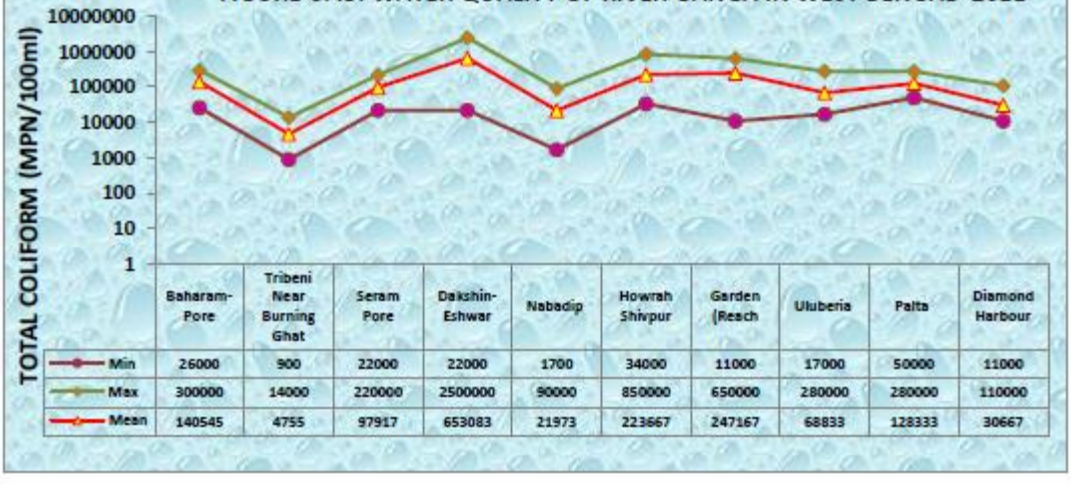
	Baharam-Pore	Tribeni Near Burning Ghat	Seram Pore	Dakshin-Eshwar	Nabadip	Howrah Shivpur	Garden (Reach	Uluberia	Palta	Diamond Harbour
Min	1	0.8	0.9	2.95	1	2.4	1.85	0.3	1.3	1.1
Max	3.9	2.9	3.2	5	3.7	8.2	5.6	5.9	2.8	5.1
Mean	2.2	1.7	1.9	4.0	2.1	4.0	4.1	2.8	2.1	2.3

FIGURE-3.44: WATER QUALITY OF RIVER GANGA IN WEST BENGAL- 2011



	Baharam-Pore	Tribeni Near Burning Ghat	Seram Pore	Dakshin-Eshwar	Nabadip	Howrah Shivpur	Garden (Reach	Uluberia	Palta	Diamond Harbour
Min	17000	700	14000	17000	1300	33000	8000	14000	23000	8000
Max	240000	11000	170000	1100000	50000	650000	400000	140000	220000	80000
Mean	105364	3064	66667	270333	13573	130750	164833	32500	84667	20333

FIGURE-3.45: WATER QUALITY OF RIVER GANGA IN WEST BENGAL- 2011



	Baharam-Pore	Tribeni Near Burning Ghat	Seram Pore	Dakshin-Eshwar	Nabadip	Howrah Shivpur	Garden (Reach	Uluberia	Palta	Diamond Harbour
Min	26000	900	22000	22000	1700	34000	11000	17000	50000	11000
Max	300000	14000	220000	2500000	90000	850000	650000	280000	280000	110000
Mean	140545	4755	97917	653083	21973	223667	247167	68833	128333	30667

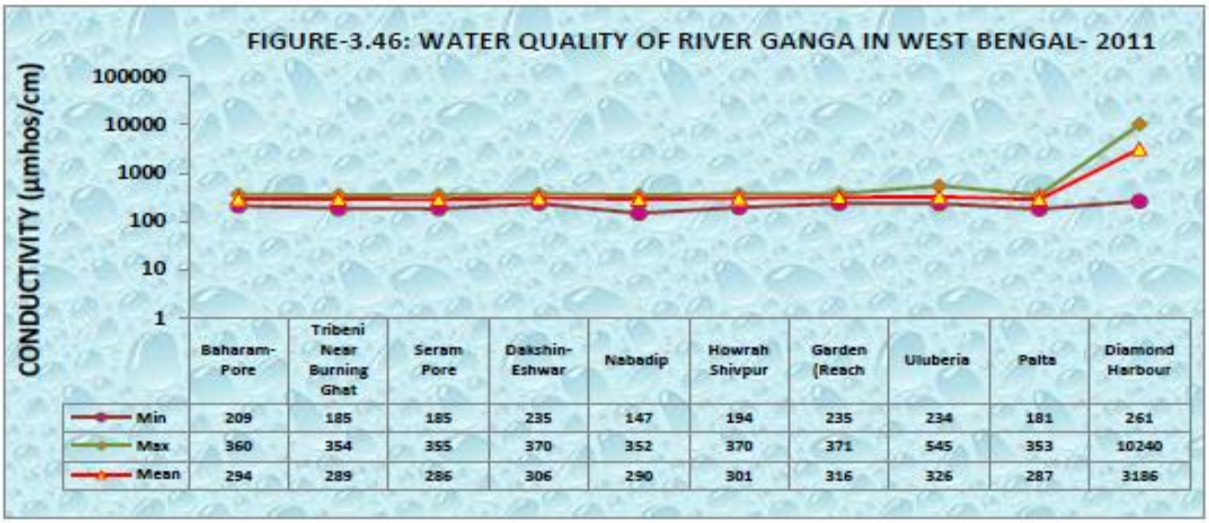


Fig 3.9 Water quality of river Ganga in West Bengal(Total coliform,DO,BOD)

3.2.10 Spatial and Temporal trend of water quality in West Bengal stretch:

The trend of BOD, DO, FC and TC at various locations of West Bengal is presented in Figures 3.47 to 3.50.

- It is observed that average value of DO complies with the standards for the period of 2006-2011 at all locations.
- An increasing trend of BOD is observed at Serampore, Dakshineshwar, Howrah-Shivpur, Uluberia and Diamond Harbour. Average value of of BOD is observed high thanth criteria at Dakshineshwar, Howrah-Shivpur, Garden Reach, Uluberia, Palta and Diamond Harbour.
- Faecal Coliform and total coliform is not meeting the desired criteria at all monitoring locations. A fluctuating trend is observed in FC and TC.
- In overall analysis, the River Ganga is polluted with respect to organic and coliform pollution the stretch of West Bengal at most of the monitoring locations.

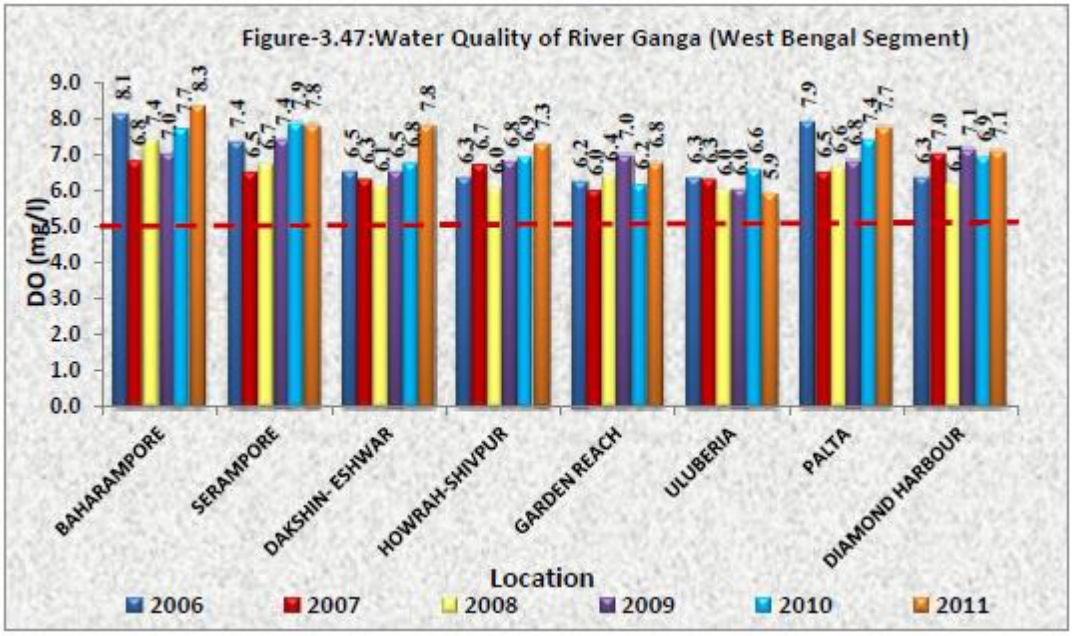
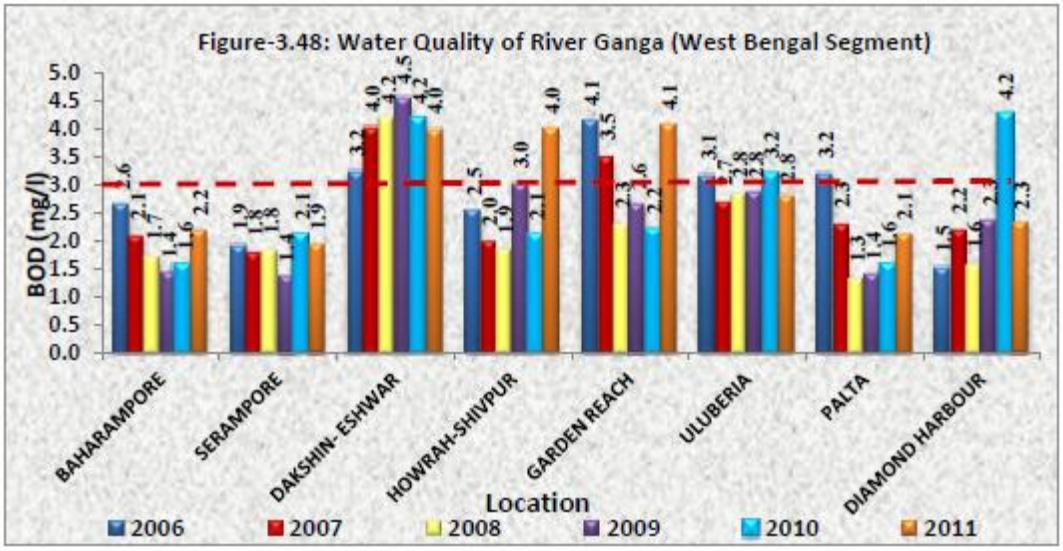
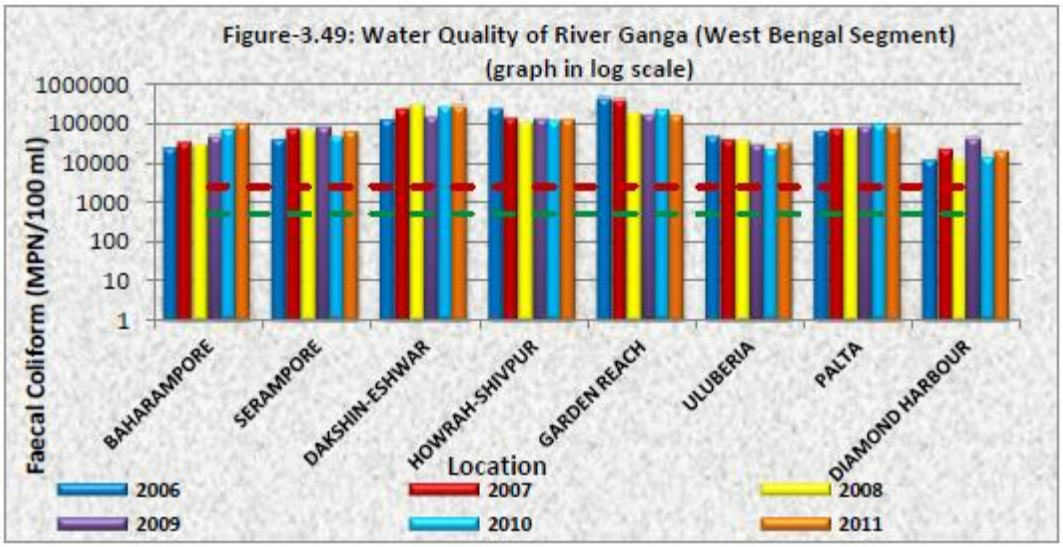


Figure-3.47:Water Quality of River Ganga (West Bengal Segment)
DO (mg/l)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
8.1 6.8 7.4 7.0 7.7 8.3
7.4 6.5 6.7 7.4 7.9 7.8
6.5 6.3 6.1 6.5 6.8 7.8
6.3 6.7 6.0 6.8 6.9 7.3
6.2 6.0 6.4 7.0 6.2 6.8
6.3 6.3 6.0 6.0 6.6 5.9
7.9 6.5 6.6 6.8 7.4 7.7
6.3 7.0 6.1 7.1 6.9 7.1
BAHARAMPORE
SERAMPORE
DAKSHIN- ESHWAR
HOWRAH-SHIVPUR
GARDEN REACH
ULUBERIA
PALTA
DIAMOND HARBOUR
Location
2006
2007
2008
2009
2010
2011





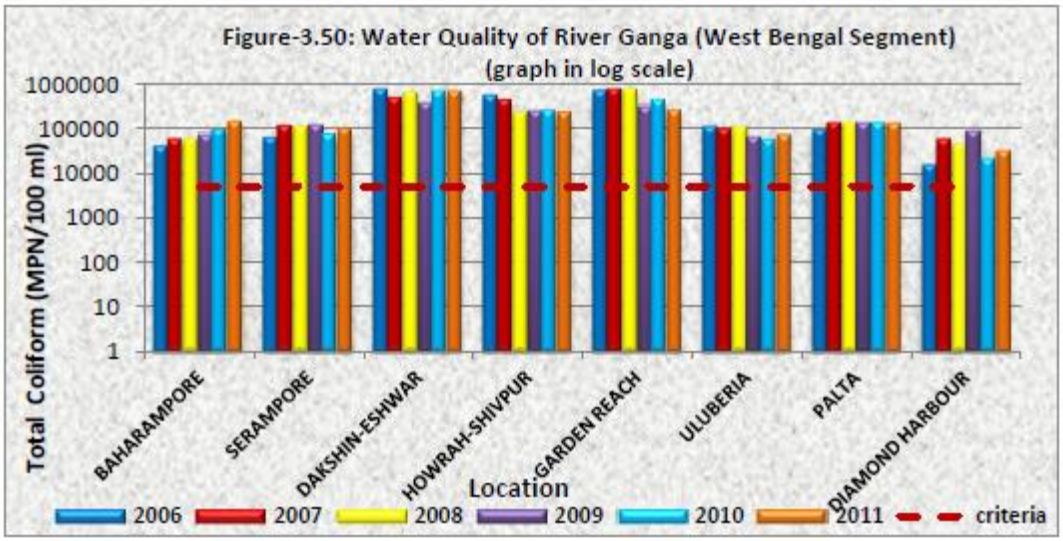


Fig 3.10 Water quality of river Ganga(West Bengal segment)

3.2.11 Polluted Stretches in river Ganga

CPCB identified three polluted stretch in river Ganga D/s of Haridwar, from Kannauj to Varanasi D/s and D/s Dakshineshwar.

Chapter - 4

4. Objective, Scopes and Methodology of the Study :

4.1 Green Area of the Research:

The water quality of River Ganga is to be ascertained in terms of appropriate indices in order to ascertain the level of water pollution, which is supposed to be absent in larger context.

4.2 Objective of the Study:

The objective of the present study can be summarized as- *"To provide an in-depth analysis of the Status of Grossly Polluting Industries Discharging Effluent in River Ganga and its Impact on Water Quality".*

4.3 Scopes of the Study:

- *To study the status of Grossly Polluting Industries Discharging Effluent in River Ganga*
- *To study the impact of wastewater discharge on Water Quality of Ganga*
- *To represent the water quality in terms of Water Pollution Index (WPI)*

4.4 Methodology:

The present investigation has been carried out entirely based on the secondary data provided by CPCB, India.

Chapter - 5

5. Results and Discussions :

5.1 Water Pollution Index (WPI):

Several indices have been developed to define water quality for human consumption, but each one has some drawbacks that limit their wide applicability. So there is a need for a new approach to classify water quality that can be accepted universally. Pollution load or water quality status of any river or water body can be presented by applying newly formulated water pollution index (WPI) method. This new technique is flexible and easy to calculate compared to the existing methods. According to this new approach water quality is principally based on observed concentration (*Ci*) and standard permissible concentration (*Si*); and can be adjusted to the number of total applied variables (*n*) as user wants. WPI suggested four categories of water quality: $WPI < 0.5$ signifies an excellent quality, $0.5 > WPI < 0.75$ indicates good quality, $0.75 > WPI < 1$ is moderately polluted water, whereas if $WPI > 1$, indicates highly polluted water. In this study area, WPI ranged from 0.38 to 1.94 with a mean value of 0.831, indicating samples in PRM and 2%, 34%, 38%, 26% samples in POM were found as excellent, good, moderately polluted and highly polluted water respectively. Empirical bayesiankriging (EBK) interpolation based GIS spatial map clearly reflected the change in seasonal variation of WPI. Normality test of the data sets were checked through Kolmogorov–Smirnov test and significant difference ($p < 0.003$) was observed. The new WPI was validated through Bland-Altman analysis using limits of agreement (LoA) and bias value (δ). WPI fitted very well indicating its better applicability and output in diverse water pollution studies than the existing water quality indices.

Table-5.1: Categorization of Water Quality based on WQI values

WPI value	Category
<0.5	Excellent water
0.5 to 0.75	Good water
0.75 to 1	Moderately polluted water
>1	Highly polluted water

The complicated scientific information can be converted into a single number through WQI. It is a dimensionless number that can be arrived by studying many parameters that affects water quality into a single number making it easy for a common man to understand the quality of water. WQI is calculated on the basis of several physico – chemical parameters which is then multiplied by a weighing factor and the final aggregate is obtained using arithmetic mean. WQI tool is used successfully by many authors as a means to state the quality of water for water

bodies. The calculation of the WQI is well explained and the same formula was applied to calculate the WQI in the present study. However, in the present study the water quality index of the Ganga water at Rishikesh, where it is supposed to be least polluted. This study can be a bench mark for further studies on water quality of Ganga at different places in the downstream.

5.2 Calculation of WQI:

5.2.1 Calculation of Quality rating (Qi):

Quality rating for each parameter was calculated by using the following equation:

$$\mathbf{Qi} = \frac{(V_{actual} - V_{ideal})}{(V_{standard} - V_{ideal})} * 100$$

Where,

Qi = Quality rating of i^{th} parameter for a total of n water quality parameters.

V_{actual} = Actual value of the water quality parameter obtained from laboratory analysis

V_{ideal} = ideal value of that quality parameter can be obtained from the standard tables.

V_{ideal} for pH = 7.0 and for other parameters it is equating to zero and for DO V_{ideal} = 14.6 mg / L

$V_{standard}$ = Recommended WHO standard of the water quality parameter.

5.2.2 Calculation of Unit weight (Wi) :

Unit weight was calculated by a value inversely proportional to the recommended standard (Si) for the corresponding parameter using the following expression

$$\mathbf{Wi} = \frac{K}{Si}$$

Where,

Wi = Unit weight for nth parameter,

Si = Standard permissible value for nth parameter

K = proportionality constant, For the sake of simplicity, K is assumed as 1,

The overall WQI was calculated by aggregating the quality rating with unit weight linearly using the following equation.

$$WQI = \frac{\sum WiQi}{\sum Wi}$$

Where,

Qi = quality rating,

Wi = Unit weight

5.2.3 Water Quality of River Ganga at Rishikesh :

A. Temperature

Temperature is an important parameter as it is responsible to increase the solubility of many minerals, salts and gases. It was found to be 20°C for both the samples. (Table 5.1).

B. pH

pH is defined as the negative logarithm of hydrogen ion concentration. The pH for potable water should be between 7 to 8. There are many factors that affect the pH of the water such as presence of dissolved gases, salts, bases, acids. In the present study the pH was found to be 7.88 for S_1 and 8.0 for S_2, which according to ISI and WHO standards is high. (Table 5.1, Fig 5.1).

C. Alkalinity

Alkalinity is the capacity of water to neutralize the acids. The presence of bicarbonates, carbonates and hydroxides causes alkalinity in the water. These salts in water are due to the dissolution of minerals from rocks, soils, plant and microbial activities and discharge of industrial wastes. The alkalinity that was reported in the present study was also found to be on the higher end 125 mg/L in S_1 and 130 mg/L in S_2 respectively (Table 5.1, Fig 5.1).

D. Electrical Conductivity

Electrical conductivity is capacity of water to conduct electrical current. It is due to the presence of dissolved salts and minerals. The conductivity was found to be 90 µs/cm for both S_1 and S_2 samples.

E. Total hardness

Hardness is an important property of water that prevents lathering of water with the soap solution and if exceeds the tolerance limit may lead to serious illness. It causes serious damage to the products of industries and machinery if untreated water is used. The main causes of hardness in water are the presence of bicarbonates, chlorides and sulphates of calcium and magnesium. Total hardness was reported as 133 mg/L and 138 mg/L for samples S_1 and S_2 respectively, which according to WHO standards is high but average according to ISI standards. (Table 5.1, Fig 5.1).

F. Calcium and Magnesium ions

The presence of calcium and magnesium ions leads to hardness in the water. They are responsible for the formation of scales and sludge. The presence of Calcium ions was found to be 93 mg/L and 95 mg/L for S_1 and S_2 respectively, which is a very high concentration for drinking water. Magnesium ions according to ISI standards should

not be exceed 30 mg/L but in the present study it was found to be 40 mg/L and 43 mg/L for sample S_1 and S_2 respectively. These values suggest a very high concentration of Magnesium ions. (Table 5.1, Fig 5.1).

G. Total Dissolved Solids

Total Dissolved Solids is an aggregate of all the dissolved solids present in the water. The amount of Total Dissolved Solids was reported as 80 mg/L for both S1and S2samples which is not a matter of concern as it is in the safe limits. (Table 5.1, Fig 5.1).

Table-5.2 : Water quality parameters and there WHO & ISI standards:

Parameters	Methods	WHO standards	ISI standard	Samples of Ganga river water	
				S_1	S_2
Temperature	Thermometric	--	--	20°C	20°C
pH	pH meter	7.0 -8.0	6.5- 8.5	7.9	8
Electrical conductivity (µmho/cm)	Conductometry	1400	---	90	90
Total Dissolved Solids (mg/L)	Filtration method	1000	300	80	38
Total Hardness (mg/L as $CaCO_3$)	EDTA Titration	100	300	133	180
Calcium (mg/L as $CaCO_3$)	EDTA Titration	75	75	93	95
Magnesium (mg/L as $CaCO_3$)	EDTA Titration	150	30	40	43
Alkalinity (mg/L as $CaCO_3$)	Titration Method	20	200	125	130

Table- 5.3 : Calculation of WQI for S_1 Sample:

Parameter	Standard value	Observed value	Unit weight (Wi)	Quality rating (Qi)	Weighted value (WiQi)
pH	7.8	8.5	0.117	58.5	6.901
Electrical conductivity (µmho/cm)	90	300	0.003	30	0.099
Total Dissolved Solids (mg/L)	80	500	0.002	16	0.032
Total Hardness (mg/L as $CaCO_3$)	133	300	0.0033	44	0.1471
Calcium (mg/L as $CaCO_3$)	93	75	0.013	124	1.652
Magnesium (mg/L as $CaCO_3$)	40	30	0.033	133	4.444
Alkalinity (mg/L as $CaCO_3$)	125	120	0.008	104	0.861
			Wi = 0.18130		WiQi= 14.146
Water Quality Index (WQI) = $\sum$ WiQi / $\sum$ Wi = **78.0263**					

Table -5.4: Calculation of WQI for S_2 Sample

Parameter	Observed value	Standard value	Unit weight (Wi)	Quality rating (Qi)	Weighted value (WiQi)
pH	8.0	8.5	0.117	60.6	7.137
Electrical conductivity (µmho/cm)	90	300	0.0030	30.0	0.099
Total Dissolved Solids (mg/L)	80	500	0.002	16.0	0.032
Total Hardness (mg/L as $CaCO_3$)	138	300	0.003	46.0	0.153
Calcium (mg/L as $CaCO_3$)	95	75	0.013	126.6	1.688
Magnesium (mg/L as $CaCO_3$)	43	30	0.033	143.3	4.777
Alkalinity (mg/L as $CaCO_3$)	130	120	0.008	108.0	0.902
			Wi = 0.181306		WiQi= 14.791068
Water Quality Index (WQI) = ∑ WiQi / ∑ Wi = 81.58068					

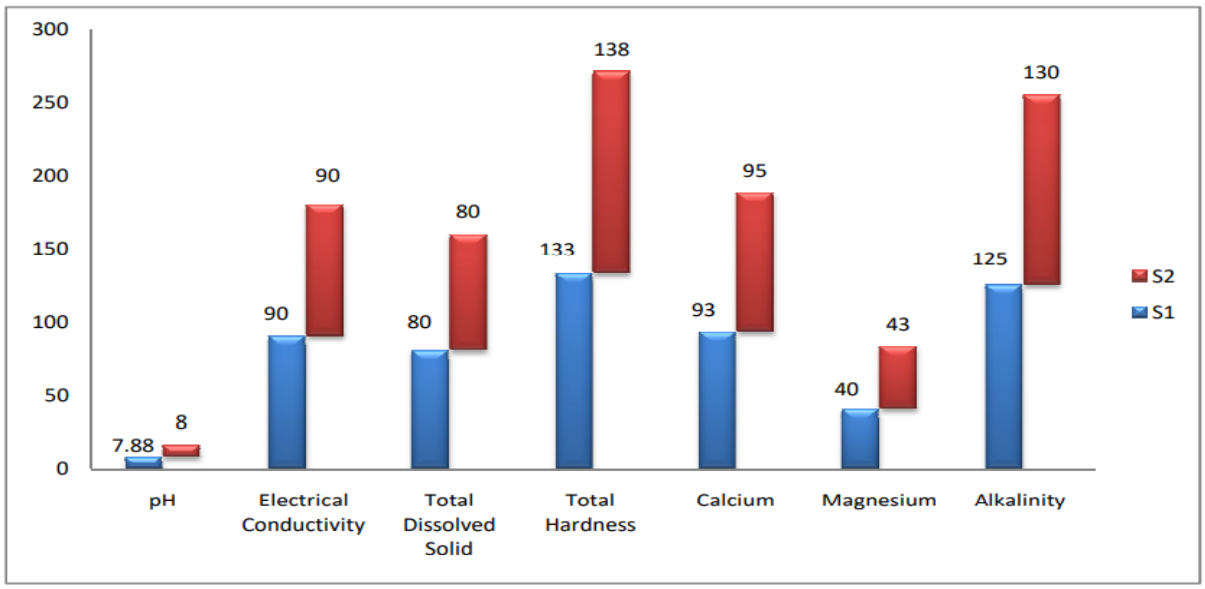


Fig 5.1 : Graphical representation of physico – chemical parameters of Ganga river water.

Chapter - 6

6. Conclusions :

- There are 764 grossly polluting industries discharging wastewater to main stem of River Ganga (either directly or through drains) and its two important tributaries Kali-east and Ramganga in Uttarakhand, Uttar Pradesh, Bihar and West Bengal.
- Out of 764 industries, 687 are located in Uttar Pradesh.
- The water consumed by grossly polluting industries is 1123 MLD.
- Total wastewater generated by grossly polluting industries is 501 MLD. This is 45% (approx) of total water consumed.
- In terms of number of industrial units, tannery sector is dominating where as in terms of wastewater generation, pulp & paper sectors dominate followed by chemical and sugar sector.
- It is observed that GPI in Bihar generate minimum wastewater (19%) in terms of water consumed whereas GPI in West Bengal generate maximum wastewater 75.5% in terms of water consumed this followed by Uttarakhand (56.7%) and Uttar Pradesh (39%%).
- In the riverine system Ramganga carries maximum industrial wastewater followed by main stream of river Ganga and Kali-East respectively.
- Based on long term assessment of mean value of water quality data, it is observed that the stretch of river Ganga from its origin to Rishikesh and in the segment of Bihar is found to be largely within the prescribed limits with respect to BOD.
- While the stretch of Rishikesh Downstream to Garhmukteshwar and Kannauj Upstream to Trighat and few locations at West Bengal (Dakshineshwar, Uluberia & Diamond Harbour) exceeds the criteria in terms of BOD.
- Dissolved Oxygen and pH are meeting the criteria at almost all the monitoring locations while Faecal Coliform is not meeting the criteria at most of the monitoring locations from Kanpur Downstream onwards upto Diamond Harbour.
- The quality of water is very poor at Rishikesh where it is considered least polluted. The WQI is found to be 78.0 and 81.5 in the samples S_1 and S_2 respectively. Therefore, the water cannot be recommended for drinking and other domestic purposes without subjecting it to purification. The study suggests that it is a pitiable situation that water at almost its source is not fit for human consumption and as it flows through other major cities it is most likely that water becomes highly polluted rising to the toxic levels. Water quality assessments at other locations can be subject of further investigations.

❖ Proposed Action plan:

A detailed plan of activities with milestones to be achieved will be formulated for approval of the Authority. This would include timelines and budgetary resources. Essential preliminary activities in this regard have been initiated. These are –

- Preparation of a River Basin Management Plan for the Ganga Basin
- Preparation of a Status paper on Ganga
- Discussion on modalities of setting up of Special Purpose Vehicles (SPVS) at appropriate locations as a means of mobilizing private sector resources and achieving efficiencies
- Mapping of the Ganga Basin
- Preparation of a Compendium of sewage treatment technologies
- Preparation of memorandum of agreement to be signed between the Central Government, state government and ULBs linking flow of funds to achievement of agreed milestones.

Chapter- 7

Future Scope of Study:

The present study may be extended in future to investigate on the following aspects:

- **Modification** of Grossly polluting industries so that the industries become discharge less effluent in to the river
- **Identification** of major polluting industries and minor polluting industries
- **Modification** purification technology to purify river water
- **Identification** the causes of failure of river cleaning programme and corrective measures
- There are a huge scope of work to relaunge Ganga river cleaning programme by which we can get major success and minor failure.

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