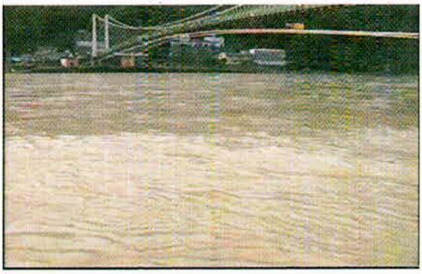
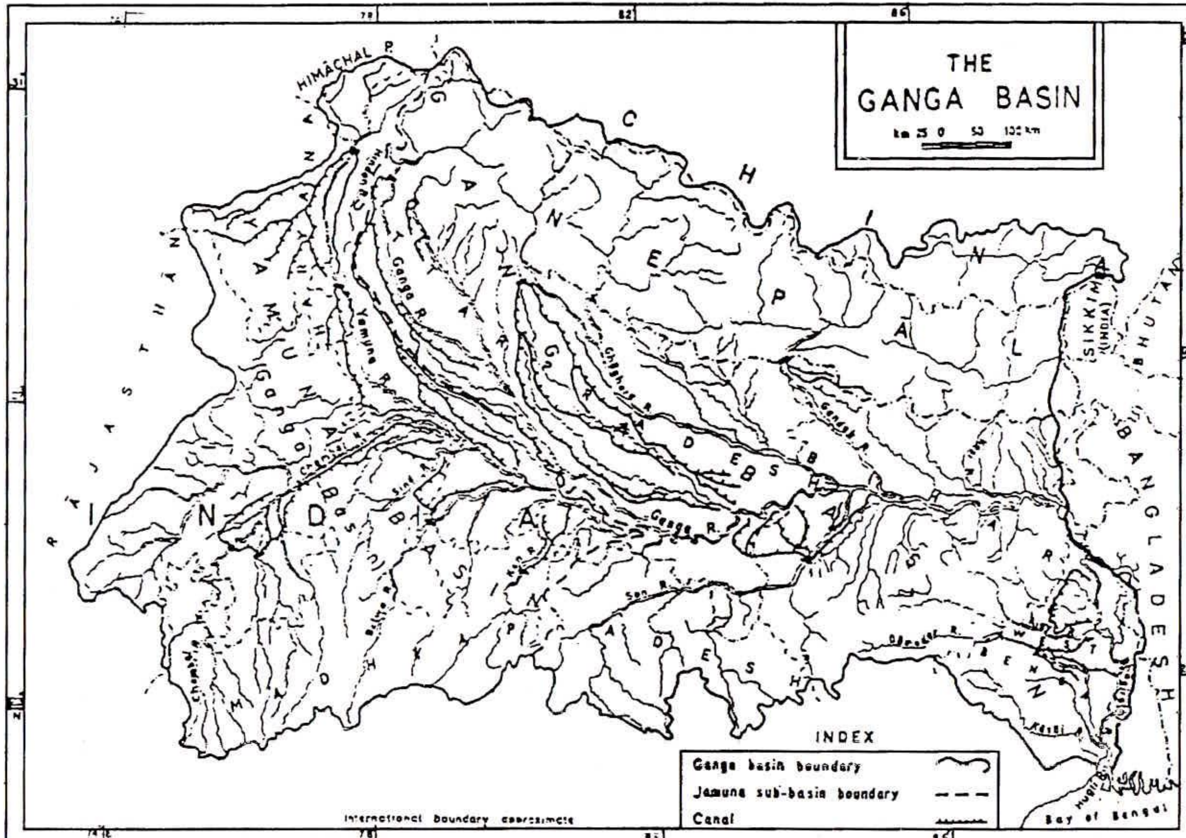
THE GANGA

NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
ROORKEE-247 667

August 2006


THE GANGA BASIN
km 25 0 50 100 km
HIMACHAL P.
CHINA
NEPAL
SIKKIM (INDIA)
BHUTAN
BANGLADESH
RAJASTHAN
HARYANA
UTTAR PRADESH
BIHAR
WEST BENGAL
MADHYA PRADESH
INDIA
YAMUNA BASIN
GANGA BASIN
Hindon R.
Ganga R.
Yamuna R.
Ghaghara R.
Gandak R.
Kosi R.
Chambal R.
Sind R.
Betwa R.
Ken R.
Son R.
Damodar R.
Kasai R.
Hugli R.
Bay of Bengal
INDEX
Ganga basin boundary
Jamuna sub-basin boundary
Canal
International boundary approximate

THE GANGA

NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
ROORKEE-247 667
August 2006

PREFACE

The Ganga River occupies a unique position in our country. A large number of tributaries of varying dimensions merge their identity with this mighty river, which is worshipped by millions of Indians. The Ganga River and its tributaries constitute one of the largest river systems in the world. Besides, being a source of supply of drinking water to the people inhabiting the cities, towns and villages, it is also being used for navigation, irrigation, bathing, washing, fishing and for industrial purposes.

However, during the last few decades, the water of this river, which has been considered as 'nectar' and carried to far off places for drinking and religious purposes, has become polluted. Despite the mineral ingredients and micro-flora and fauna present in it, the self-purification capacity of the Ganga River is limited. Depleted every day for irrigation and drinking water, assailed constantly by the discharge of industrial effluents and municipal wastes and increased pressure of settlements on its banks, are collectively threatening the water quality of the sacred river.

Keeping in view the above points, it was considered appropriate to bring out this Information Brochure for creating mass awareness about quality of water of the Ganga River, its effect on human health and responsibilities of public to safeguard water resources in general and the Ganga River in particular. The brochure also highlights attempts made by the Government of India to tackle the problem and also the need for further research.

The brochure has been prepared by Drs. C K Jain, Sc. 'E2' and M K Sharma, Sc. 'B' of Environmental Hydrology Division of the Institute. It is hoped that the information provided in the brochure will be useful to water resources engineers, professionals, scientists as well as the stakeholders.

K D Sharma
Director

1. River Basins of India

India with a total geographical area of 329 million hectare has been blessed with a large number of rivers, big and small. All the river basins are classified into major, medium and minor. River basins with catchment area of 20,000 km^2 and above are categorized under major river basins and are twelve in number. River basins with catchment area between 20,000 and 2,000 km^2 are classified as medium river basins and are forty six in number while rivers with catchment area below 2,000 km^2 are called minor rivers. Major and medium river basins contribute 90% of the total runoff while minor rivers account for about 8 of the total runoff (CWC, 1988). Recently, the National Commission for Integrated Water Resources Development estimated the basin-wise average annual flow in Indian river system as 1953 km^3 (NCIWRD, 1999). The catchment area of the basins as per NCIWRD (1999) are given in Table No. 1.

Harnessing the waters of the major rivers that flow from the Himalayas is an issue of great concern with reference to flood control, drought prevention, hydroelectric power generation, job creation, environmental quality as well as traditional lifestyles and cultural continuities. The Indus, the Ganga and the Brahmaputra, which receive substantial amounts of flow as snow and glacier melt runoff from the Himalayas, are considered to be the life-line of the Indian subcontinent. The majority of the rivers have their upper catchments in the snow covered areas and flow through steep mountain valleys. The perennial nature of these rivers and appropriate topographical settings provide excellent conditions for the development of hydropower resources. The role of these rivers and their tributaries in irrigation and water supply is also vital.

2. The Ganga Basin

A system of rivers normally flowing into a common terminus constitute a single drainage basin as per the definition given in the convention on the non-navigational uses of International Water Courses adopted by United Nations. Therefore Ganga-Brahmaputra and Barak/ Meghana constitute a single basin as they have common outfall. The Ganga basin under the convention may be called the Ganga sub-basin.

The Ganga basin is the largest amongst the major river basins of India occupying about one-fourth of the total land area of the country.

Table 1 : River basins of India

S. No.	River Basin	Catchment Area, km²	States covered in the basin
1.	Indus	321289	J&K, Punjab, H.P., Rajasthan and Chandigarh
2.	Ganga-Brahmaputra -Meghna Basin		
	2a Ganga Sub-basin	862769	U.P.,H.P., Haryana, Rajasthan, M.P.,Bihar,W.B.&Delhi
	2b Brahmaputra sub-basin	197316	Arunachal, Assam, Meghalaya, Nagaland, Sikkim & W.B
	2c Meghna (Barak) sub-basin	41157	Assam, Meghalaya, Nagaland, Manipur, Mizoram and Tripura
3.	Subarnarekha	29196	Bihar, West Bengal and Orissa
4.	Brahmani-Baitarani	51822	M.P., Bihar and Orissa
5.	Mahanadi	141589	M. P., Maharashtra, Bihar and Orissa
6.	Godavari	312812	Maharashtra, A. P., M. P., Orissa and Pondicherry
7.	Krishna	258948	Maharashtra, A. P. and Karnataka
8.	Pennar	55213	A. P. and Karnataka
9.	Cauvery	87900	T. N., Karnataka, Kerala & Pondicherry
10.	Tapi	65145	M. P., Maharashtra and Gujarat
11.	Narmada	98796	M. P., Maharashtra and Gujarat
12.	Mahi	34842	Rajasthan, Gujarat and M. P.
13.	Sabarmati	21674	Rajasthan and Gujarat
14	West-flowing rivers of Kachchh and Saurashtra including Luni	334390	Rajasthan, Gujarat and Daman & Diu
15	West-flowing rivers south of Tapi	113057	Karnataka, Kerala, Goa, Tamil Nadu, Maharashtra, Gujarat, Daman & Diu and Nagar Haveli
16	East-flowing rivers between Mahanadi and Godavari	49570	A. P. and Orissa
17.	East-flowing rivers between Godavari and Krishna	12289	Andhra Pradesh
18.	East-flowing rivers between Krishna and Pennar	24649	Andhra Pradesh
19.	East-flowing rivers between Pennar and Cauvery	64751	A. P., Karnataka and Tamilnadu
20.	East-flowing rivers south of Cauvery	35026	Tamilnadu and Pondicherry UT
21.	Area of North Ladakh not draining into Indus	28478	Jammu & Kashmir
22.	Rivers draining into Bangladesh	10031	Mizoram and Tripura
23.	Rivers draining into Myanmar	26271	Manipur, Mizoram and Nagaland
24.	Drainage areas of Andaman, Nicobar and Lakshadweep Islands	8280	Andaman, Nicobar and Lakshadweep
	Total	3287260	

Source : NCIWRD (1999)

The Ganga basin encompasses an area of more than a million square kilometers (10,60,000 km^2) spread over four countries: India, Nepal, Bangladesh and China. The catchment area of the river Ganga in India is 8,61,404 km^2, covering 26.2% of the total geographical area of the country and 79.32% of its own basin. Some tributaries like the Ghaghara, the Gandak and the Kosi drain areas in Nepal amounting to 1,90,000 km^2 while the Mahananda has 9,000 km^2 catchment area in Bangladesh. Thus the total drainage basin of the Ganga is 10,60,000 km^2 (Rao, 1979; CBPCWP, 1984).

The watershed of river Ganga spread over ten states of India, namely Uttaranchal, Uttar Pradesh, Bihar, Jharkhand, West Bengal, Himachal Pradesh, Rajasthan, Haryana, Madhya Pradesh and Delhi.

The Ganga and its tributaries are regarded as sacred rivers and are used for bathing by the people apart from being the source of water supply. Nearly 40% of the population of the country lives in the Ganga basin.

3. The Ganga

The Ganga is the largest and the most important river of India, associated in mythology and present social life with the land and people of India as well as neighboring countries like Bangladesh. The river basin is bounded by the snow peaks of the Himalaya in the north and the Peninsular uplands and the Vindhya range on the south. The total length of the river from its source in Himalayas to its outfall in the Bay of Bengal is 2525 km. The rich soils of the basin provide the home of more than one third of Indian population.

The main river, rising in the northern most part of Uttaranchal, flows through Uttaranchal, Uttar Pradesh, Bihar, Jharkhand and West Bengal and finally falls into the Bay of Bengal. The river has a large number of tributaries. Some of these are of Himalayan origin and have considerable large flow. The important tributaries within India are the Ramganga, the Yamuna, the Gomti, the Son, the Ghaghara, the Gandak, the Kosi and Mahanadi etc. The Yamuna although a tributary of the Ganga is virtually a large river by itself and its major tributaries are the Chambal, the Sind, the Betwa and the Ken. The main plateau tributaries of the Ganga are the Tons, the Son, the Damodar and the Kasai-Haldi.

The Ganga served as the cradle of the India civilization. The river houses the town like Rishikesh, Haridwar, Garhmukteswar, Kannauj, Allahabad, Mirzapur, Varanasi, Patna and Nabadwip, which are important pilgrim centres with a very large number of people taking dip in the river. In fact, all along the course of the Ganga, from its source at Gaumukh to its mouth at Sagar Island the river is considered holy and millions of people take bath in it every day to purge away the sins. For the purpose of bathing, the second highest (Class B) level of quality of water is essential. It, therefore, becomes imperative that strict monitoring of the quality of water along different reaches of the river is maintained and adequate measures are taken to keep the Ganga free from pollution particularly at the bathing ghats, places of pilgrimage and at abstraction points on its course.

The Ganga is widely used for domestic and industrial purposes in towns and villages located on its course for which it is also equally necessary to continuously watch the level of possible pollution of the water in different seasons, so that adequate measures can be taken to keep the concentration of various water quality constituents within permissible limits.

The other wide use of the Ganga water is in the field of irrigation. A large quantity of water is taken out by the Upper Ganga Canal network off the headworks located at Haridwar for irrigating a major portion of the Ganga-Yamuna doab in Uttaranchal and Uttar Pradesh. As it flows further downstream 240 km from Haridwar, a few minor tributaries join adding to the volume of water till Narora is reached, the flow in the river rises further. Here another large irrigation network (Lower Ganga Canal) takes off at a barrage leaving again a much reduced flow downstream.

3.1 Origin and Course of the Ganga

The Ganga rises in the Garhwal Himalaya under the name of Bhagirathi. The ice-cave of Gaumukh at the snout of the Gangotri glacier, some 7010 m above sea level in Uttarkashi district of Uttaranchal, is recognized as the traditional source of the Ganga. It descends down at the valley to Devprayag, where the Alaknanda, another hill stream rising from the Bhagirath Kharak and the Satopanth twin glaciers joins it. After the confluence with Alaknanda, the combined stream is called the Ganga. After traversing nearly 250 km, it descends onto the plains at Rishikesh and turns southwestwards for another 30 km, to finally debouch onto the vast Indo-Gangetic plain at Haridwar, where it swells into a mighty stream. At Haridwar lot of people take a dip in the sacred Har-ki-Pouri.

The Upper Ganga Canal takes off from a weir at Hardwar, 240 km below which is the Narora Barrage from where the lower Ganga Canal takes off. After another 530 km to Allahabad, past the famous ghats of Mirzapur, the Yamuna joins the Ganga. At the confluence, the slow moving clearer water of the Yamuna gets churned up into the muddy whirlpools of the Ganga. It sweeps for another 245 km to Varanasi. In the upper region, the Ganga receives the Ramganga, Gomti and Tons from the north and the Chambal from the south.

After confluence with Yamuna, the Ganga enters Bihar in the middle region about 155 km from Varanasi. In this region, a large number of tributaries such as the Ghaghara, Gandak, Burhi Gandak, Son, Bagmati and Kosi join the river Ganga. In the lower Ganga basin only the Mahananda joins. Later 100 km downstream from Rajmahal, the river ceases to be known as the Ganga. It bifurcates into Bhagirathi, the lower portion of which is known as the Hooghly and the Padma, which form the boundary between India and Bangladesh. That is why, in West Bengal the Bhagirathi is treated as the main Ganga for all purposes. The Padma, carrying the major share of water of the Ganga, eventually flows southeastwards into Bangladesh, while the Bhagirathi (Ganga) winds southwards down the deltaic plains of West Bengal.

After traversing 220 km further down in Bangladesh, the Brahmaputra joins it at Goalundo and after meeting the Meghna 100 km downstream, the Ganga joins the Bay of Bengal under the name of Hugli. Towards the end, the river breaks into a number of estuaries and passes through the dense forests of Sunderbans.

3.2 Major Tributaries

The description of major tributaries joining the river Ganga is given below (Rao 1979):

The Ramganga: The Ramganga river rises at an altitude of 3,110 m in the Garhwal district and emerges from the hills into the plains at Kalagarh, the boundary of the district. After traversing through some more distance, it joins the Ganga at Kannauj. Its total length is 596 km. The basin covers an area of 32,493 km^2. A number of tributaries join the river from the left. The important ones are the Khoh, the Gangan, the Aril, the Kosi and the Deoha (Gorra).

The Gomti: The Gomti rises about 3 km east of Pilibhit town in Uttar Pradesh at 200 m elevation. It drains the area between the Ramganga and the Ghaghara systems. Its tributaries are the Gachai, the Sai, the Jomkai and the Barna, the Chuha and the Sarayu. Lucknow town is located on the bank of the Gomti. The length of the river is 940 km and it drains a total area of 30,437 km^2. The Sai is its most important tributary and has a drainage area of a little over a third of the Gomti.

The Ghaghara: The Ghaghara is called Manchu and Karnali in Nepal and has its source near Lake Mansarover. Its total catchment area is 1,27,950 km^2 of which 45% is in India. Its important tributary is the Sarda or Chauka which forms the boundary between India and Nepal. The other tributary in India is the Sarju, famous for the location of Ayodhya on its banks. Other tributaries are the Rapti and the Chhoti Gandak. The Ghaghara joins the Ganga a few km downstream of Chapra town in Bihar. The length of the Ghaghara is 1080 km and it carries more water than the Ganga before its confluence.

The Gandak: The Gandak is also known as the Kali in Nepal and rises at 7,620 m in Tibet near the Nepal border overlooking the Dhaulagiri peak. Its drainage area is 46,300 km^2 of which 7,620 km^2 is in India. In Nepal there are a number of tributaries like the Mayangadi, the Bari, and the Trisuli. The Gandak debouches into the plains at Tribeni in Bihar. The Gandak flows for another 300 km before it joins the Ganga near Hajipur.

The Burhi Gandak: The Burhi Gandak known as the Sikrahana in its upper reaches, rises in Champaran district of Bihar at an elevation of 300 m. It has a drainage area of 10,150 km^2 and a length of 320 km. It joins the Ganga opposite Munger town.

The Bagmati: The Bagmati rises in the Shivapuri Hills of Nepal at an elevation of 1,500 m, cuts across the Mahabharata range of hills and enters India in Muzaffarpur district. It has a drainage area of 13,400 km^2 of which 6,320 km^2 lie in India. On the banks of this river is the famous temple of Pasupatinath in Nepal. The waters of Bagmati have a high fertility value as they carry nutritious silt. It joins the Kosi in the lower reaches.

The Kamla: The Kamla rises in Nepal at an elevation of 1,200 m. It has a number of tributaries in Nepal. It enters India near Jaynagar in Darbhanga district and joins the Kosi. As it has occupied the course of the river Balan it is also called in the last reaches as the Kamla Balan.

The Kosi: The Kosi is formed by the confluence of three rivers, the Sun Kosi, the Arun Kosi and the Tamur Kosi in Nepal. The total drainage area is 74,500 km^2 of which 11,000 km^2 lie within India. Of the total water the Sun Kosi contributes 44%, the Arun Kosi 37% and the Tamur Kosi 19%. The Tamur Kosi has the steepest slopes. Mount Everest and Mount Kanchanjunga lie in the catchment of the Arun Kosi.

After the confluence, the river flows through a narrow gorge for 10 km and enters the plains at Chatra. After traversing a further 25 km, it enters India near Hanumannagar. It forms the boundary between India and Nepal for a distance of 20 km. After running for 320 km below Chatra, the Kosi joins the Ganga near Kursela. The Mahananda rises in the hills of Darjeeling district at 2,100 m with a number of tributaries, viz. Balsan, Mechi, Ratna and Kankai. The Kankai is an erratic stream and as it rises in Nepal Hills, it carried a lot of silt. The total drainage area of Mahananda is 20,600 km^2 of which 11,530 km^2 lie in India. The river forms a boundary between India and Bangladesh in the last reaches before it enters Bangladesh to join the Ganga at Godagiri.

The Yamuna: The Yamuna is the most important tributary of the Ganga joining it on the right bank at Allahabad. It receives in its turn on the right a large tributary, the Chambal, and four other important tributaries, the Hindon, the Sarda, the Betwa and the Ken. It rises from Yamunotri Glacier in Tehri Garhwal district of Uttaranchal at an elevation of 6,330 m. Many small streams, the Rishiganga, the Uma and the Hanuman Ganga and several others join it in the mountains. The Tons, the longest tributary, rises at an elevation of 3,900 m and joins Yamuna below Kalsi.

The Yamuna emerges from the hills near Tajewala where the water is taken off by the western and eastern Yamuna canals. It flows further 280 km down to Okhla in Delhi territory from where the Agra Canal takes off. The Hindon, 256 km long rises in the district of Saharanpur and joins the Yamuna on its left bank 40 km below Okhla. From Delhi at 130 km is located the holy place of Mathura and further down 50 km the city of Agra with the world famous Taj Mahal as its principal tourist attraction. It flows in the south easterly direction till it reaches Allahabad. Small tributaries like, the Karan, the Sagar and the Rind join it on its left bank and the Chambal, the Sind, the Betwa and the Ken flowing from the Vindhyas join it on its right bank. The total length of the Yamuna from its origin to Allahabad is 1,376 km, the drainage area is 3,66,223 km^2 of which 1,39,468 km^2 is the drainage area of the Chambal alone.

The Chambal: The Chambal rises in Vindhya ranges and flows for 965 km before it joins the Yamuna. It flows through the flat fertile Malwa Plateau and then enters a gorge at Chaurasingarh. The gorge is 96 km long and stretches upto Kotah city. The river runs for another 34 km flowing through the plains. The total drop between the source and outfall is 766 m. As the river flows much below the banks and due to poor rainfall, severe erosion has occurred over centuries and numerous deep ravines have been formed in Chambal Valley.

The Sind: The Sind rises in Vidisha district of Madhya Pradesh at an elevation of 543 m. It is 415 km long and drains an area of 25,085 km^2. It joins the Yamuna downstream of the confluence of the Chambal with the Yamuna. The Parvati, Kunwari and Pahuj are some of its tributaries.

The Betwa: The Betwa rises at an elevation of 470 m in district Bhopal in Madhya Pradesh. It joins the Yamuna near Hamirpur after flowing 590 km. The total catchment area of the basin is 45,580 km^2. The Dhasan is one of its important tributaries.

The Ken: The Ken rises in the Kaimur hills of Satna district of Madhya Pradesh. It is 360 km long upto its point of confluence with the Yamuna near Chilla. It drains an area of 28,224 km^2.

The Tons: The Tons has a drainage area of 16,860 km^2. It rises in a tank at Tamakund in the Kaimur range of hills at an elevation of 610 m and flows through the fertile lands of the Rewa and Satna districts. The river receives the Belan in Uttar Pradesh and joins the Ganga about 311 km downstream of the confluence of the Ganga and Yamuna. The total length of the river is 264 km.

The Son: The Son Basin extends over an area of 71,259 km^2 and rises at Sonabhadra, in Madhya Pradesh, at an elevation of 600 m. After passing in cascades over the hill reaches, it receives the Rihand tributary across which the Rihand dam was constructed in 1963 as well as the Kanhar and the Ghagar tributaries. It passes through the Palamau district of Bihar where it receives the tributary, north Koel. It joins the Ganga about 16 km upstream of Dinapur in Patna district. The total length of the river is 784 km. The important tributaries of the Son are the Mahanadi, the Banas, the Gopat, the Rihand, the Kankar and the North Koel. Below the Son on the right side of the Ganga, there are a large number of tributaries. Of these the Punpun and the Kiul are the large ones.

The Punpun: The Punpun rises in the Chota Nagpur Plateau and joins the Ganga about 25 km east of Patna. Its tributaries are the Butane, the Madar and the Morhar. Its length is 200 km and the drainage area is 8,530 km^2. It often causes flood damage on the eastern side of Patna city.

The Kiul: The Kiul with a length of 111 km and a drainage area of 16,580 km^2 also rises in the Chota Nagpur Plateau and joins the Ganga near Swaggarha. Its tributaries are the Harhar, the Barnar, the Azan and the Ulan.

The Dwarka: There are few important tributaries which join the Bhagirathi-Hooghly, the original course of the Ganga. The first of them, the Dwarka, rises in the Birbhum hills and joins the Bhagirathi in Murshidabad district. One of its important tributaries is the Mayurakshi. The river has a length of 134 km and drainage area of 8,850 km^2.

The Ajoy: The Ajoy rises in the Santhal Pargana Hills and joins the Bhagirathi near Katwa. Its length is 276 km and it drains 6,050 km^2.

The Damodar: The Damodar is 541 km long and has a catchment area of 25,820 km^2. It rises in the south-east area of the Palamau district and receives the important tributary the Barakar. After flowing through Bankura and Burdwan districts, it joins the Hooghly near Fulta point. The Damodar passes through an important industrial and mining area of the country.

The Rupnarayan: The Rupnarayan rises in the Tilabi Hills of Bihar and after passing 254 km, joins the Hooghly near Nurpur, downstream of the confluence of the Damodar for its entire course, it has a catchment area of 8,530 km^2.

The Haldi: The Haldi has an important tributary the Kasai. It has area of 10,210 km^2. It joins the Hooghly below its confluence with the Rupnarayan.

4. Pollution Status of River Ganga

Urban settlements and growing industrial development, combined with rapid increasing demand for water, are causing more and more water quality problems. Much of water quality problems in India are due to indiscriminate discharge of municipal wastes. These wastes being biodegradable produce a series of directional but predictable changes in water bodies. Industrial effluents are responsible for pollution to a lesser extent but the effects produced by them may be more serious as nature is often unable to assimilate them. Agriculture is also responsible for degrading the river water quality by generating runoff from agricultural farms containing chemical fertilizers, pesticides and animal husbandry units.

The water of the river Ganga has traditionally been regarded as an inexhaustible gift of nature. In recent decades rapid development of agriculture and industry have, however, put severe strains on the river and, to an extent, have resulted in degradation of its quality. Problems of water pollution have not only surfaced but also begun to assume serious dimensions in certain stretches of the long course of the river Ganga (Jain, 1999).

According to scientific theory, the level of pollution in a river depends upon the concentration of pollutants and the discharge of the river. Both concentration and discharge are affected by hydrologic, geomorphologic, topographic and cultural factors. The rivers of the Ganga basin drain the southern slopes of the Great Himalaya and carry one of the largest sediment loads on earth. Deglaciation at the headwaters of tributaries that form the Ganga, human-instigated forms of erosion such as tree felling, farming and construction of settlements, all contribute to the river's discharge and concentrations of pollution.

Taking hydraulic characteristics into consideration, the entire 2525 km course of the Ganga can be divided into the following five major sections:

Table 2 : Stream Characteristics along Different Sections of the Ganga

S. N.	Stretch	Section	Length (km)	Average Slope
1.	Source to Rishikesh	Mountainous	250	1 in 67
2.	Rishikesh to Allahabad	Upper plain	770	1 in 4,100
3.	Allahabad to Farakka	Middle plain	1,005	1 in 13,800
4.	Farakka to Nabadwip	Deltaic non-tidal plain	230	1 in 23,000
5.	Nabadwip to outfall	Deltaic tidal plain	240	1 in 24,000

Source : CBPCWP, 1984

The mountainous section stretches from the source to Rishikesh, with an average bed slope of one in 67. The subsequent upper plain section extends from Rishikesh downstream to Allahabad before the confluence with the Yamuna with a bed slope of one in 4,100. The third middle plain section stretches from Allahabad to Farakka having a slope of one in 13,800. Next to this lies the upper deltaic non-tidal plain section with a slope of one in 23,000 and the last is the lower deltaic tidal plain section with a slope of one in 24,000.

Studies on water quality of river Ganga in various stretches have been conducted by several workers. In the plains the main sources of pollution are urban liquid waste, large scale wallowing of cattle and throwing of dead bodies into the river. In addition, flower offerings, remains of dead bodies are responsible for the degradation of the river. The cultural and religious factors in polluting Ganga and its main tributary Yamuna is also noteworthy. This is increased especially during Kumbh and other auspicious occasions when millions of people believing in Ganga's perpetual sacredness bath in Ganga. The staggering increase in the coliform count during such mass bathing is to be seen to be believed. This phenomenon, defiling of the sacred river by the very people who worship her is ironic (Jain, 2000).

Pollution specific studies conducting physico-chemical analysis and bacteriological analysis on river Ganga have been reported by a number of workers (Pande and Pande, 1980; Chandra and Krishna, 1984; Handa and Bhatia, 1993; Chattopadhya et al., 1984; Saxena et al., 1966; Sehgal and Siddiqui, 1969; Ray and David, 1966; David and Ray, 1960; Upadhyay et al., 1982; Singh et al., 1988, 1989a,b). The quality of water is quite unsatisfactory.

Agarwal et al. (1976) studied the physico-chemical and bacteriological characteristics of the river Ganga at Varanasi. Bacteriological studies conducted near the ghats of Varanasi indicated the BOD ranges between 2.1-7.8 mg/L and fecal coliform counts between 500-23000 per 100 mL. This state of affairs caused concern in the people who understood the risks of the rising level of river pollution. Mathur et al. (1987) conducted a study on river Ganga at Varanasi with special emphasis on heavy metal pollution. Mishra et al. (1992) have reported that about 85% of the total pollution of the river at Varanasi is due to the disposal of sewage into the river. The major amount of the wastewater flows through the main sewer outfall downstream of the city whereas most of the remaining flow enters through other major outlets. From the point of view of industrial pollution, the situation has not been very bad at Varanasi because toxic pollutants are stated to be either absent or present only in insignificant quantities in the water of the bathing areas. Ecological studies of the Ganges river at Varanasi were studied by Rai (1978) and Sikandar et al. (1989).

The quality of river Ganga at Patna, the most populated city of Bihar state, has been reported by Rao et al. (1990) with special reference to domestic waste and major industries of the area. The over all values of DO and BOD indicate that the river water in Bihar could be used as drinking water source without conventional treatment but with disinfection and also suitable for bathing, swimming and recreation. They further reported that the amount of dissolved oxygen throughout the river in Bihar was above 70% saturation and well within the requirements of propagation of fish. Further detailed studies on Physico-chemical characteristics of river Ganga from Mirzapur to Ballia have been studied by Shukla et al. (1989). Their study reveals that the Ganga water quality was quite good at the point where it enters the city and gets highly polluted at midstream as a result of assimilation from a number of sewage and industrial drains. The downstream water at Varanasi was observed highly polluted in comparison to all other sites, this is due to discharge of sewage mixed with industrial effluents through Rajghat nala, however the water quality at Ballia was recorded fairly clean. Ecology of river Ganges from Patna to Farakka was studied by Bilgrami and Datta (1985).

Sinha et al. (1993) conducted some studies in Rai-Bareli district and reported that deterioration in water quality of the river Ganga in Rae-Bareli district is due to age-old practice of mass bathing, washing of clothes, cremation and dumping of garbage into the river. Other studies on river Ganga include pollution status of the river water in West Bengal (Sinha and Banerjee, 1987; Sengupta et al., 1988).

A comprehensive survey of the Ganga basin conducted by Central Pollution Control Board, Delhi revealed that the river, despite its extra ordinary resilience, is heavily polluted at several places. Such a situation calls for immediate action, specially, because of the fact that 80% of the diseases are water brone. Comparison of water quality on river Ganga between 1986 and 2003 revealed that the dissolved oxygen levels were in the range of 5.9 to 6.6 mg/L in Allahabad to Varanasi stretch and in 2003, the range improved to 7.2 to 10.0 mg/L. The BOD in river Ganga was ranging from 5.5 mg/L to 15.5 mg/L in the critical stretch of Kannauj to Varanasi in 1986. As against this the value of BOD in 2003 in the stretch of Kannauj to Varanasi is 1.20-6.1 mg/L (Trivedi, 2006).

The literature available on the studies of heavy metals speciation in water-sediment system of river. Ganga is relatively scanty. The research initiative in this direction started only a decade back (Jha et al., 1990). Subramanyam et al. (1987) studied distribution of heavy metals in sediments of Ganga and Brahmaputra rivers while Ajmal et al. (1987) analysed heavy metals in water and sediments of the Ganga river. Modak et al. (1992) determined the concentrations of mobile and bound trace metals associated with sediment components of the lower reaches of river Ganga.

Saikia (1987) and Saikia et al. (1988) studied the incidence and transport of heavy metals (Mn, Fe, Co, Ni, Cu, Zn, Cd and Pb) in water and sediments of upper regions of river Ganga and reported that suspended load is the prominent mode of transport of these metals. The study also showed that adsorption of Cu, Zn and Pb on the bed sediments is quite significant. Jain (2001) studied adsorption characteristics of bed sediments of river Ganga in their natural state of occurrence to demonstrate the role of bed sediments in controlling metal pollution.

Pollution from industrial and urban sources has, no doubt, serious deleterious effects on the water quality of the river Ganga, but at the same time the runoff from rural areas and agricultural fields is likely to be toxic enough to pollute the prevailing water bodies and drainage system. The heavy silt load brought down by the runoff also affects the water quality and cause other environmental hazards in the basin.

In the Ganga basin, during the monsoon season, heavy surface runoff and vigorous stream flows, often charged with residues of fertilizers, pesticides and other chemicals used in agriculture, may have a strong impact on the stream water quality through surface wash-off of pollutants emanating from rural communities, cattle rearing farms and agricultural holdings. During the non-monsoon period, leaching and seepage from the underlying strata and topsoils reach the natural drainage system, carrying with them residues of organic and inorganic pollution generated from fertilizers and pesticides. In addition, the pollution generated out of agricultural land use, open defecation and large scale outdoor bathing in rivers by thousands upon thousands of people in India, especially during the festive days, introduce heavy bacteriological pollution in the drainage system.

The Central Pollution Control Board (CPCB) estimates that the main sources of pollution along the stretch of the river are bathing, urban liquid waste, industrial liquid waste, large scale bathing of cattle, surface run-off from solid waste landfills and dumpsites, runoff from industrial solid waste landfills or dumpsites.

The CPCB reports that three fourths of the pollution of the river comes from the discharge of untreated municipal sewage, of which 88% is dumped by Class-I cities (cities with population above 1,00,000). Industrial wastewater is discharged by a number of industries situated in the riparian zone. In 1995, the Central Board has listed 191 grossly polluting industries in the state of Uttar Pradesh, 6 in the state of Bihar and 67 in the state of West Bengal. These industries were discharging toxic substances into effluent flows with BOD concentrations of more than 100 mg/L and each unit was generating over one million liters of wastewater per day. The industries represented in this river basin are sugar and paper mills, cloth, woolen, cotton, and rayon mills, tanneries, ordinance factories, battery industries, thermal power houses, chemical plants, metal and steel factories, distilleries and fertilizer corporations. Heavy metals such as cadmium, zinc, nickel, lead, chromium and copper are concentrated in the river water and the sediments.

As a first step towards cleaning of polluted rivers, the Govt. of India in 1985 launched the Ganga Action Plan (GAP). This plan was taken up in 25 class I towns. Pollution abatement measures under this plan include interception, diversion and treatment of municipal sewage, and construction of toilet complexes, electric crematorium and bathing ghats. After GAP, the same abatement measures were adopted to the Yamuna and the Gomti in 1993 as Yamuna Action Plan and Gomti Action Plan respectively.

5. The Ganga Action Plan Phase-I (GAP-I)

5.1 The pollution level of the river Ganga, both from point as well as non-point sources, has been recognized by the Ministry of Environment & Forests, Govt. of India. It has been seen that about

75% of pollution load comes from municipal source and rest 25% comes from industrial source. Therefore, in order to improve its deteriorating water quality, a programme called the 'Ganga Action Plan' (GAP-I) was launched in 1986. The GAP concentrated on tackling municipal waste water. To begin with, programmes in 25 class-I towns (population exceeding 1 lakh) in the States of Uttar Pradesh (including, present Uttaranchal), Bihar and West Bengal were taken up. The major thrust of this programme was to intercept, divert and treat municipal waste generated from these towns before being discharged into the Ganga. Various components of works included under the plan are:

i. Interception and Diversion (I&D) of sewage generated in the town
ii. Setting up of Sewage Treatment Plant (STP) to treat the sewerage
iii. Construction of Electric Crematoria (EC)
iv. Constructing improved Wood Crematoria (WBC)
v. Construction of Low Cost Community toilets (LCS) near the river banks or drains joining river
vi. Improvement of Bathing Ghats (RFD)
vii. Aforestation (AFF) of river banks

5.2 Out of 1340 mld of waste water generation in the year (1990 estimates), a capacity to treat 865 mld has been created. The GAP-I was completed in March 2003 at an estimated cost of Rs. 452 crore including cost of operation and maintenance.

5.3 With the implementation of GAP-I, improvement in water quality has been observed. The Water quality of the Ganga is being monitored at 27 locations from Rishikesh to Uluberia by institutions such as Pollution Control Research Institute of Bharat Heavy Electrical Limited (PCRI, BHEL), Ranipur, Hardwar; Central Pollution Control Board (CPCB), Delhi; Indian Institute of Technology (IIT), Kanpur; Patna University, Patna and Bidhan Chandra Krishi Vishwavidyalaya, Kalyani, West Bengal. However at present, there is no continuous water quality monitoring station operated by CPCB. The summer average values of two important parameters viz. Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) for some of the important monitoring stations are given in Table No. 3.

Table 3 : Summer Average Values of DO and BOD for Some of the Important Monitoring Stations under Ganga Action Plan

Station	Distance (in km)	Dissolved Oxygen (mg/L)			Biochemical Oxygen Demand (mg/L)		
		1986	2002	2003	1986	2002	2003
Rishikesh	0	8.1	8.30	8.1	1.7	1.10	0.5
Hardwar/D/S	30	8.1	7.90	8.1	1.8	1.60	0.8
Garhmukteshwar	175	7.8	-	7.8	2.2	-	1.2
Kannauj U/S	430	7.2	7.65	7.2	5.5	1.17	1.2
Kannauj D/S	433	NA	6.50	NA	NA	4.23	3.3
Kanpur U/S	530	7.2	6.27	7.2	7.2	3.80	3.7
Kanpur D/S	548	6.7	6.75	6.7	8.6	4.90	6.1
Allahabad U/S	733	6.4	13.00	6.4	11.4	-	4.8
Allahabad D/S	743	6.6	8.20	6.6	15.5	3.80	3.2
Varanasi U/S	908	5.6	10.80	5.6	10.1	3.00	2.5
Varanasi D/S	916	5.9	7.50	5.9	10.6	2.50	5.4
Patna U/S	1188	8.4	7.08	8.4	2.0	1.88	2.0
Patna D/S	1198	8.1	7.10	8.1	2.2	1.95	2.8
Rajmahal	1508	7.8	7.93	7.8	1.8	1.48	2.2
Palta	2050	NA	7.25	NA	NA	2.66	2.2
Uluberia	2500	NA	5.43	NA	NA	1.94	1.9

1. Mean value for the months of March to June when the temperatures are high and flows are low. NA – Data not available, U/S – Upstream, D/S – Downstream.

2. Bathing Standard Quality: DO>5 mg/L, BOD≤ 3 mg/L

6. Programme under GAP-II

6.1 The success of GAP has been established through a Cost Benefit Analysis Study. The report brought out multifarious benefits besides improvement of water quality. The programme has been subsequently extended to its 2nd phase covering 59 towns on the main stem of Ganga, besides 21 towns on river Yamuna and 15 towns on river Gomti and Damodar. Yamuna, Gomti and Damodar being very potential polluter as tributaries, have also been included under the purview of pollution abatement. Thus, another 2210 mld of domestic pollution load is targeted to be tackled. The plan is under implementation. A list of GAP main stem towns is given in Table No. 4.

Table 4 : Details of Ganga Action Plan Towns and Sanctioned Costs

S.No.	State/Town	STP Capacity to be created (mld)	Sanctioned Cost (Rs. in lakhs)
STATE: BIHAR			
1	Arrah	14.00	255.20
2	Barahya	0.00	41.26
3	Barh	0.00	68.69
4	Bhagalpur	3.20	516.77
5	Buxar	2.00	76.14
6	Chapra	0.00	167.62
7	Fatwah	0.00	66.56
8	Hazipur	6.50	292.63
9	Kahelgaon	2.00	206.92
10	Mokamah	5.00	176.68
11	Munger	0.00	116.38
12	Patna	18.50	1163.57
13	Sultanganj	0.00	93.81
	Sub Total (Bihar)	51.20	3242.23
STATE: JHARKHAND			
14	Sahebganj	1.20	47.50
	Sub Total (Jharkhand)	1.20	47.50
STATE: UTTAR PRADESH			
15	Allahabad	92.00	3272.36
16	Anupshaher	3.00	549.07
17	Bijnor	11.00	718.20
18	Chunar	3.00	468.30
19	Farrukkhabad	0.00	51.02
20	Garhmukteshwar	0.00	153.90
21	Ghazipur	14.00	771.78
22	Kanpur	200.00	8573.88
23	Mirzapur	3.00	369.60
24	Mugal Sarai	13.50	409.02
25	Saidpur	1.00	61.62
26	Varanasi	60.00	4505.97
	Sub Total (UP)	400.50	19904.72
STATE: UTTARANCHAL			
27	Badrinath	0.61	67.54

28	Deo Prayag	0.20	381.19
29	Gopeshwar	1.77	97.42
30	Haridwar & Rishikesh	7.00	648.00
31	Joshimath	0.00	43.82
32	Karna Prayag	0.65	29.23
33	Ranipur	9.00	746.09
34	Rudra Prayag	0.70	209.38
35	Srinagar	5.00	707.85
36	Uttar Kashi	2.40	918.08
	Sub Total (Uttaranchal)	27.33	3848.60
STATE: WEST BENGAL			
37	Badreshwar & Champdani	24.00	3378.84
38	Baidyabati	9.00	1291.11
39	Bansberia	16.00	2680.59
40	Barrackpore	11.00	2395.18
41	Budge-Budge	6.00	985.37
42	Chakdah	8.57	235.06
43	Circular Canal	16.00	901.82
44	Dhulian	3.79	371.05
45	Diamond Harbour	1.41	342.53
46	Garulia	10.00	1035.82
47	Goyespur, Halilshar & Kanchanpara	25.00	2591.60
48	Jangipur	3.13	335.09
49	Jijganj Azimganj	2.80	556.54
50	Katwa	3.74	357.61
51	Kharda (Extended)	7.68	986.17
52	Konnagar	8.00	1486.50
53	Maheshtala	3.50	1275.72
54	Murshidabad	0.93	488.65
55	Naihati	12.00	2322.05
56	North Barrackpore	7.30	1922.23
57	Rishra	11.00	1191.24
58	Tolly's Nallah	66.00	3545.36
59	Uttarpara Kotrung	13.00	1069.93
60	CETP, Calcutta	30.00	6500.00
	Sub Total (W.B)	299.85	38246.06
	Grand Total (Ganga)	780.08	65289.11

6.2 Tackling industrial waste water has also been given priority under the plan. For this, grossly polluting industries along river Ganga have been identified. Apart from Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCB), National River Conservation Directorate (NRCD) also monitors levels of pollution of these industries. As a result, untreated discharge of trade effluent has been substantially reduced.

6.3 While the major thrust of the programme is to treat the sewage generated in the towns situated along the bank, the socio-economic conditions prevailing in the area has not been lost sight. The scheme provides for Electric Crematoria and Efficient Wood Crematoria in these towns to prevent pollution from throwing of unburnt/partly burnt bodies. These projects cut down fuel consumption heavily. Low cost toilets for weaker sections of the society, afforestation of river banks and improving bathing ghats also formed part of this programme. Components other than I&D and STP have been effective in controlling non-point sources of pollution.

6.4 It may also be mentioned that provision for reducing bacterial load was not planned under GAP-I. This has now been made mandatory under GAP-II. Therefore, after implementation of GAP-II, the quality of water is likely to improve.

6.5 Another aspect is very crucial in maintaining good water quality, is minimum flow in lean season. Even after treatment of domestic sewage, the effluent quality is not akin to pure water. It still contains pollutants but within prescribed limit. The ultimate pristine water quality is to be achieved as a result of dilution and self purification. This means that the river must have self assimilative capacity. This is sometimes not available near Kanpur where pollution is therefore, severe. It is worthwhile to mention that due to rapid urbanization and developmental activities along the Ganga, pollution loads on this river are increasing day by day. The situation would have been much worse by now without these efforts. With the completion of GAP-II, the position is expected to improve further.

7. Recommendations and Research Needs

For formulating the present and future water pollution control programmes and policies in the Ganga basin, in-depth knowledge of development of agriculture, use of fertilizers, pesticides, location and growth of industries, spread of human settlements, prevalent human use of rivers and social habits, development of sewer systems in urban communities, water supplies in urban and rural areas, etc. is essential.

Traditionally, river water quality monitoring has focused upon surface water concentrations to safeguard drinking water supplies and to characterise the contaminative state of the aquatic environment. However, the monitoring of surface water is hampered by the inherent variability in flow conditions. Changes in water discharge and variations in suspended solid loading have a considerable effect upon pollutant loading, particularly in areas where effluent emissions are irregular. Bottom sediments, on the other hand, provide a more stable base for contaminative studies and can identify pollution sources that could escape detection by water analysis alone. Therefore, an assessment of both the sedimentary and aqueous phase should be undertaken to adequately characterise the aquatic environment.

Adsorption is one another important phenomenon in water quality control, which may determine the fate and transport of pollutants in the aquatic environment. It is highly relevant to serious concerns about contaminant transport in rivers. The determination of the concentration levels of heavy metals in natural waters, as well as the elucidation of the chemical form in which they appear, is a prime target in environmental research today, because of the close relation between toxicity and speciation. Various studies describing effect of operating variables, kinetics and thermodynamics of adsorption processes on synthetic adsorbents have been documented in the literature. However, no attempt has been made to study kinetics and adsorption process on riverbed sediments in their natural state of occurrence. There is a need to study the adsorption characteristics of river sediments to assess the tolerance of the system for the added pollution load and to ascertain the risk of contamination.

The untreated municipal and industrial wastes should not be allowed to be discharged into the river. In the rural as well as urban areas, open defecation along the rivers should be discouraged by all means.

During recent years, non-point sources of water pollution have long been recognized as greater importance. However, due to various other difficulties, same thing is not being sufficiently attended to. This is due in part to the continuing efforts to reduce pollution from point sources over the past two decades as well as recognition that non-point sources, such as storm water, may contain harmful contaminants. In most cases the sources and concentrations of non-point source pollutants are the result of land use interactions with the transport system. In rural areas, nutrients and pesticides are released in surface and ground water and may degrade the quality of drinking water and cause various health problems to humans. Nutrients and pesticides are transported from cropland either by being absorbed onto eroded soil particles or dissolved in runoff water. This has increased the need to identify and quantify major sources of nutrients and pesticides deposited within the river system. A proper watershed management approach needs to be adopted to tackle the problem of non-point source pollution.

Awareness should be developed among the farmers and the river management authorities about the potential hazard of pollution due to excessive use of fertilizers and pesticides in agricultural fields. High inorganic nutrients levels in the river water accelerate the eutrophication process and contamination of the river with pesticides renders it toxic which affect the aquatic life. Therefore, a more judicious use of fertilizers and pesticides should be emphasized.

Facilities for micro-analysis of organic contaminants (pesticides, phenols, hydrocarbons, etc.) in the water resources should be made available at water analysis laboratories.

Research efforts are also needed to understand the various ongoing phenomena within the river system with the objective of pollution remedy and abatement. A challenging area in contaminant research is to determine the significance of contaminant residues in sediments to aquatic organisms. Mounting evidence shows environmental degradation in areas where water quality criteria are not exceeded, yet, organisms in or near sediments are adversely affected. A better understanding of the chronic effects, bioaccumulation and bioavailability of chemicals in sediments is needed to identify environmental risk in locations with moderate contamination and to evaluate chemicals that do not elicit acute responses. There is a need to develop chronic sediment toxicity testing methods. These methods can be used to evaluate the toxicity of contaminated sediments across the country.

For a more systematic and comprehensive study, continuous water quality monitoring stations should be installed at critical locations. Presence of toxic substances, heavy metals arising out of industrial effluents and pesticides from agricultural fields should be determined in the river water. A systems analysis and systems optimization study should also be taken up to derive more comprehensive and meaningful recommendations in terms of available self purification capacity of the different stretches, the desirable intensities and distribution of the inputs of organic loads, etc. This in turn, will help the town planers in reviewing the distribution and sizes of the existing towns and in locating new towns and growth centres on river banks in the Ganga basin. Intensive research on bacterial property of the Ganga water should also be undertaken.

8. References

1. Agarwal, D. K., Gaur, S. D., Tiwari, T. C., Narayanswami, N. and Marwah, S. M. (1976), Physico-chemical characteristics of Ganges water at Varanasi, Indian J. Environ. Hlth., 18, 201-206.
2. Ajmal, M., Khan, M. A. and Nomani, Z. A. (1987), Monitoring of heavy metals in the water and sediments of the Ganga river, India, Water Sci. Tech., 19, 107-117.
3. Bilgrami, K. S. and Dutta, M. (1985), Ecology of River Ganges, Impact of Human Activities and Conservation of Aquatic Biota (Patna to Farakka), Allied Press, Bhagalpur, India.
4. CBPCWP (1982), Basin Sub Basin Inventory of Water Pollution, The Ganga Basin, Part I, The Yamuna Sub-basin, Central Board for the Prevention and Control of Water Pollution, New Delhi.
5. CBPCWP (1984), Basin Sub Basin Inventory of Water Pollution: The Ganga Basin, Part II, Central Board for the Prevention and Control of Water Pollution, New Delhi.
6. Chandra, S. and Krishna, G. (1984), Effect of tannery waste disposal on the quality of the river Ganga at Kanpur, Poll. Res., 2, 63-64.
7. Chattopadhya, S. N., Routh, T., Sharma, V. P., Arora, H. C. and Gupta. R. K. (1984), A short term study on the pollutional status of river Ganga in Kanpur region, Indian .J. Environ. Hlth., 26, 244-257.
8. CWC (1988), Water Resources of India, CWC Publication No. 30/ 88, Central Water Commission, New Delhi.
9. David, A. and Ray, P. (1960), Some measurements of toxicity of tannery and textile wastes and their components to fish bioassay, Ind. J. Fish., 7, 423-442.
10. Handa, B. K. and Bhatia, S. S. (1993), Quality of Ganga river and its tributaries for irrigation use in U .P., Seminar on Ganga in the Service of Nation, Sep. 12-13, UOR, Roorkee.

11. Jain, C. K. (1999), Adsorption of zinc on bed sediments of River Ganga, Technical Report No. CS(AR)9/98-99, National Institute of Hydrology, Roorkee.
12. Jain, C.K. (2000), Pollution status of river Ganga, Indian J. Environ. Prot., 20(6), 471-480.
13. Jain, C. K. (2001), Adsorption of zinc onto bed sediments of the river Ganga: Adsorption models and kinetics, Hydrological Sciences Journal, 46(3), 419-434.
14. Jha, P. K., Subramanian, V., Sitasawad, R. and Van Grickon, R. (1990), Heavy metals in the sediments of the Yamuna river (A tributary or the Ganges), India, The Sci. of the Total Environ., 95, 7-27.
15. Mathur, A., Sharma, Y. C., Rupainwar, D. C., Murthy, R. C. and Chandra, S. (1987), A study of river Ganga at Varanasi with special emphasis on heavy metal pollution, Poll. Res., 6, 37-44.
16. Mishra, V. B., Mishra, S. K. and Upadhyay, S. N. (1992), Theme Paper Presented at Seminar on Pollution Control in River Cities of India - A Case Study of Ganga at Varanasi, Jan. 14-17, Sankat Mochan Foundation, Varanasi.
17. Modak, D. P., Singh, K. P., Chandra, H. and Ray, P. K. (1992), Mobile and bound forms of trace metals in sediments of the lower Ganges, Wat. Res., 26(11), 1541-1548.
18. NCIWRD (1999), Integrated Water Resource Development: A Plan for Action, Report of the National Commission for Integrated Water Resources Development, Vol. I, Government of India, Ministry of Water Resources, New Delhi.
19. Pande, P. K. and Pande, G. N. (1980), Physico-chemical characteristics of river Ganga at Kanpur, J. Inst. Engrs., 61, 28-30.
20. Rai, L. C. (1978), Ecological studies of algal communities of the Ganges river at Varanasi, Indian J. Ecol., 5, 1-6.
21. Rao, K. L. (1979), India's Water Wealth - Its Assessment, Uses and Projections, Orient Longman Ltd., New Delhi.
22. Rao, S. N., Chaubey, R. and Srinivasan, V. K. (1990), Ganga water quality in Bihar, Indian J. Environ. Hlth., 32, 393-400.
23. Ray, P. and David, A. (1966), Effects of industrial wastes and sewage upon the chemical and biological composition and fisheries of the river Ganga at Kanpur, Env. Health, 8, 307-339.
24. Saikia, D. K. (1987), Studies on the sorptive properties of bed sediments of river Ganges and transport of some heavy metal ions,

Ph.D. Thesis, Department of Chemistry, University of Roorkee, Roorkee.

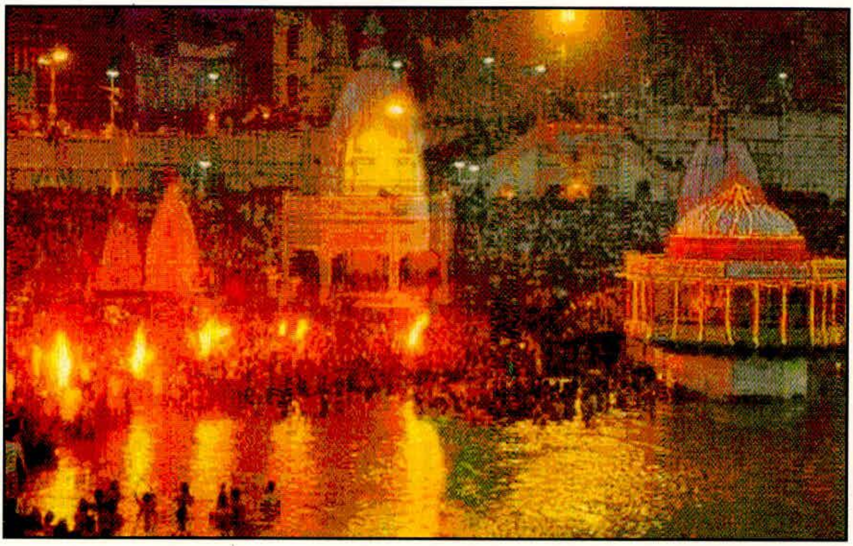
25. Saikia, D. K., Mathur, R. P. and Srivastava, S. K. (1988), Heavy metals in water and sediments of upper Ganga, India, Indian J. Environ. Hlth., 31(1), 11-17.
26. Saxena, K. L., Chakrabarty, R. N., Khan, A. Q., Chattopadhya, S. N. and Chandra, H. (1966), Pollution studies of the river Ganges near Kanpur, Env. Health, 8, 270-285.
27. Sehgal, J. R. and Siddiqi, R. H. (1969), Characterization of wastewater from Kanpur city, Env. Health, 11, 95-107.
28. Sengupta, B., Laskar, S., Das, A. K. and Das, J. (1988), Inorganic pollutants of Ganga water in the region of Berhampore to Katwa, West Bengal, Indian J. Environ. Hlth., 30, 202-208.
29. Shukla, S. C, Tripathi, B. D., Kant, R., Deepa Kumari, V. and Panday, V. S. (1989), Physico-chemical and biological characteristics of river Ganga from Mirzapur to Ballia, Indian J. Environ. Hlth., 31, 218-227.
30. Sikkandar, M., Tripathi, B. D. and Shukla, S. C. (1989), Possible ecological effects of the dead body cremation on the bank of river Ganga at Varanasi, Tropical Ecology, 30, 90-95.
31. Singh, J. P., Yadava, P. K. and Singh, L. (1988), Pollution status on Sangam and its adjoining rivers before Kumbh Mela at Allahabad, Indian J. Environ. Prot., 8(11), 839-842.
32. Singh, J. P., Yadava, P. K. and Singh, L. (1989a), Mass bathing effect on water quality of Sangam during Maha Kumbh Mela at Allahabad, Indian J. Environ. Prot., 9(3), 189-193.
33. Singh, J. P., Yadava, P. K. and Singh, L. (1989b), The assessment of water quality of Sangam and its adjoining rivers Ganga and Yamuna after Mahakumbh Mela at Allahabad, Indian J. Environ. Prot., 9 (5), 372-375.
34. Sinha, A. K., Srivastava, S. and Srivastava, K. N. (1993), Quality of river Ganga water in Rae-Bareli district, Proceedings of the Seminar on Ganga in the Service of Nation, Sep. 12-13, University of Roorkee, Roorkee.
35. Sinha, S. N. and Banerjee, R. D. (1987), Pollution status of the Ganga water near Palta, West Bengal, Environ. & Ecol., 5, 137-143.
36. Subramanian, Y., Griken, R. V. and Vant D. L. (1987), Heavy metal distribution in the sediments of Ganges and Brahmaputra rivers, Env.

Geol. Wat. Sci., 9(2), 93-103.
37. Trivedi, R. C. (2006), Water quality issues and status in India, Training Workshop on Water Quality and its Management organized by NIH and CSMRS at New Delhi, May 22-26, 2006, pp. 115-137.
38. Upadhyay, R., Dubey, A. P. and Pande, G. N. (1982), Monitoring or pollution at Sangam during Ardha Kumbha, Poll. Res., 1-2.

River Ganga

The Story of the Ganga from the source to the sea, from old times to new is the story of India's civilization and culture.

Pt. Jawahar Lal Nehru



printed by :
anubhav printers, rke ph. : 9719004321