Ganga River Basin Management Plan-2015

Volume 3: Ganga River Basin and its Management- Salient Aspects

Centre for Ganga River Basin Management and Studies
Indian Institute of Technology Kanpur

VOLUME 3 OF 12

NATIONAL MISSION FOR CLEAN GANGA (NMCG)

NMCG is the implementation wing of National Ganga Council which was setup in October 2016 under the River Ganga Authority order 2016. Initially NMCG was registered as a society on 12th August 2011 under the Societies Registration Act 1860. It acted as implementation arm of National Ganga River Basin Authority (NGRBA) which was constituted under the provisions of the Environment (Protection) Act (EPA) 1986. NGRBA has since been dissolved with effect from the 7th October 2016, consequent to constitution of National Council for Rejuvenation, Protection and Management of River Ganga (referred to as National Ganga Council).

www.nmcg.in

CENTRE FOR GANGA RIVER BASIN MANAGEMENT AND STUDIES (cGanga)

cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this it is also responsible for introducing new technologies, innovations and solutions into India.

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ACKNOWLEDGEMENT

This document is a collective effort of a number of experts, institutions and organisations, in particular those who were instrumental in preparing the Ganga River Basin Management Plan which was submitted to the Government of India in 2015. Contributions to the photographs and images for this vision document by individuals are gratefully acknowledged.

SUGGESTED CITATION

GRBMP by cGanga and NMCG

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GANGA RIVER BASIN MANAGEMENT PLAN - 2015

Volume 3: Ganga River Basin and its Management- Salient Aspects

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Ganga river in
Himalayas mountains

River Ganga at a Glance:
Identification of Issues and Priority Actions for Restoration

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay	IIT Delhi	IIT Guwahati	IIT Kanpur	IIT Kharagpur	IIT Madras	IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRB EMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who are members of the concerned thematic groups and those who have taken lead in preparing this report are given on the reverse side.

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Contents

1. Introduction

River systems have been the birthplace of civilizations all over the world. They are woven into the social and economic fabric of society and penetrate deep into the psyche of the people living around them. Nowhere is this more evident than in India where the Ganga, Indus, Narmada and other rivers possess the cultural identity transmitted down the ages through sacred literature, the Puranas and the Vedas, as well as through popular myths and legends.

The river Ganga (commonly called as Bhagirathi in the stretch Gangotri to Devprayag and Hubli in the stretch Farakka to Ganga Sagar) occupies a unique position in the ethos of people of India. Emotional attachment to the river and the centers of pilgrimage on its banks runs deep and long in the Indian History.

The Ganga originates from the ice caves at Gaumukh (N 30°55´, E 79°7´) at an elevation of 4100 m. Alaknanda, its main tributary in the mountainous stretch, rises beyond Manna Pass, 8 km form Badrinath (N 30°44´, E 79°41´) at an altitude of 3123 m, and meets at Devprayag. The Ganga traverses a distance of ≈2510 km from its source to its mouth (Ganga Sagar), draining eleven states of India (Figure 1). In her course she is joined by many tributaries, important being Bhilangana, Alaknanda, Ramganga, Kali, Yamuna, Gomti, Ghagra, Gandak, Kosi and Sone (Figure 2 and 3).

The entire stretch of river Ganga (main stem) can be viewed into three segments:

A.	**Upper Ganga**	≈ 294 **km**	**Gaumukh to Haridwar**
B.	**Middle Ganga**	≈ 1082 **km**	**Haridwar to Varanasi**
C.	**Lower Ganga**	≈ 1134 **km**	**Varanasi to Ganga Sagar**

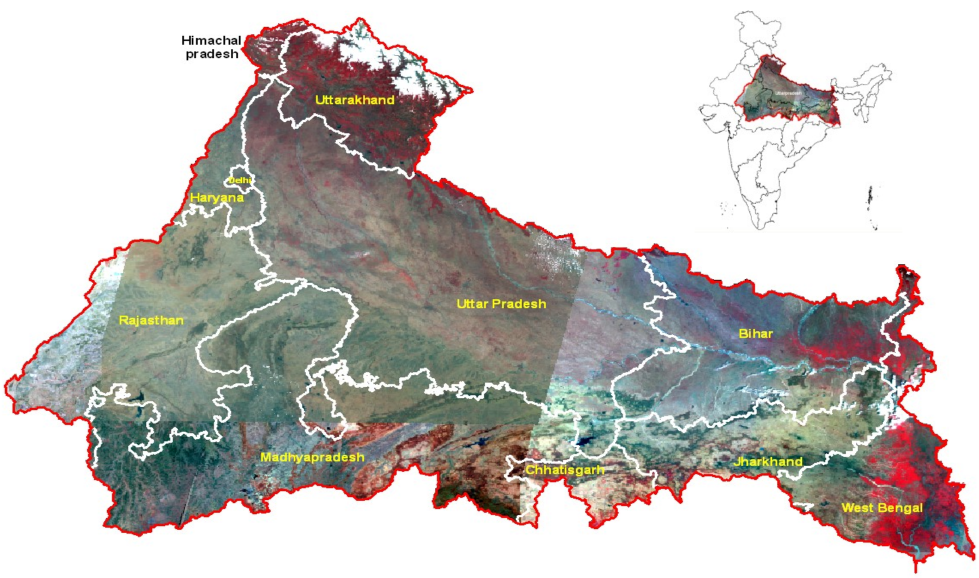


Figure 1: Drainage Area of the Ganga River Covering 11 States in India (AIWFS Data)

These three segments not only differ in their geomorphology, ecology and rheology but are different in terms of issues that need to be addressed:

A. The river in the upper segment flows on steep and narrow bed, mostly rocks and boulders, carries cold water, is subjected to much less anthropogenic pollution, has highly sensitive and fragile ecosystem and biodiversity, and most importantly considered to have potential for harnessing hydropower.

B. The river in the middle segment enters and flows in plains, meandering mostly on bed of fine sand, has wide river bed and flood plain, and most importantly modified through human interventions in terms of huge quantities of water diversion/abstraction and subjected to high degree of pollutant loads from domestic, industrial and agricultural activities.

C. The river in the third segment has experienced considerable changes in the sediment transport and deposition, causes wide spread flooding, undergoes frequent changes in her channel path, and most importantly is subjected to international disputes on flows and interventions made and/or are being carried out/planned.

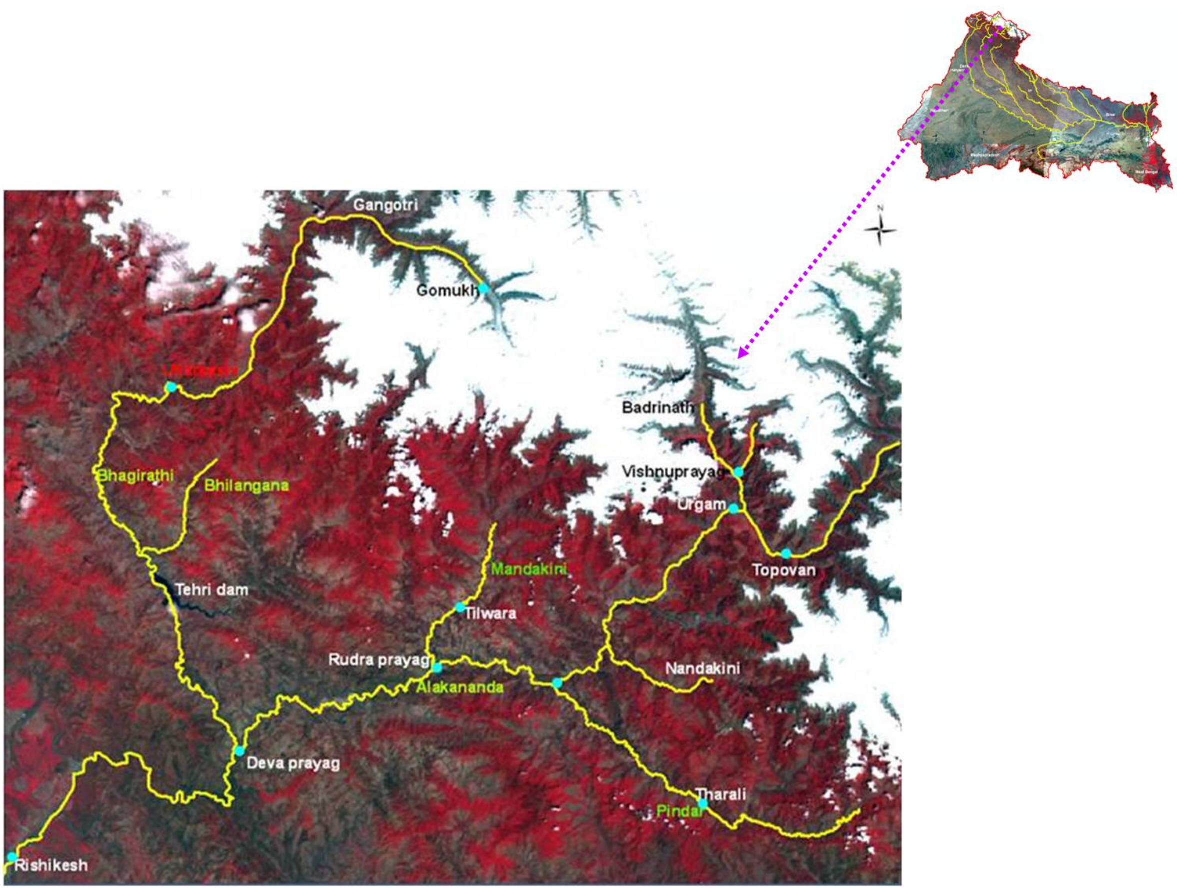


Figure 2: Major Tributaries of River Ganga (Bhagirathi) in the Upper Ganga Segment

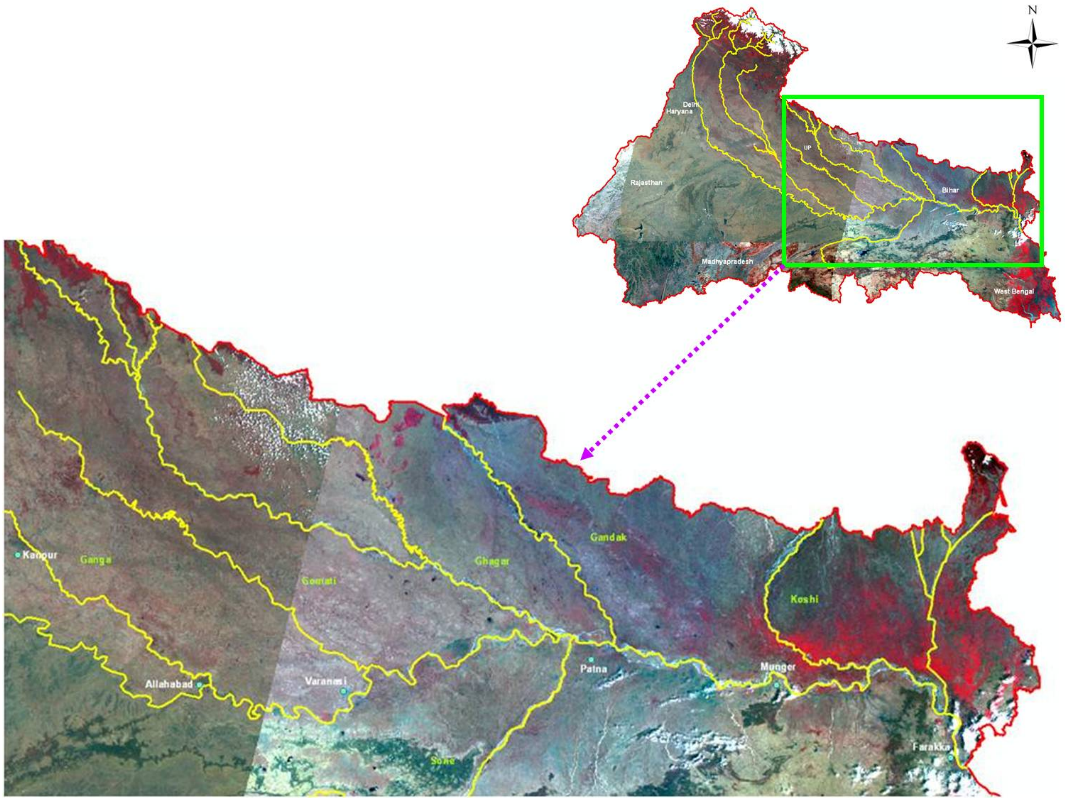
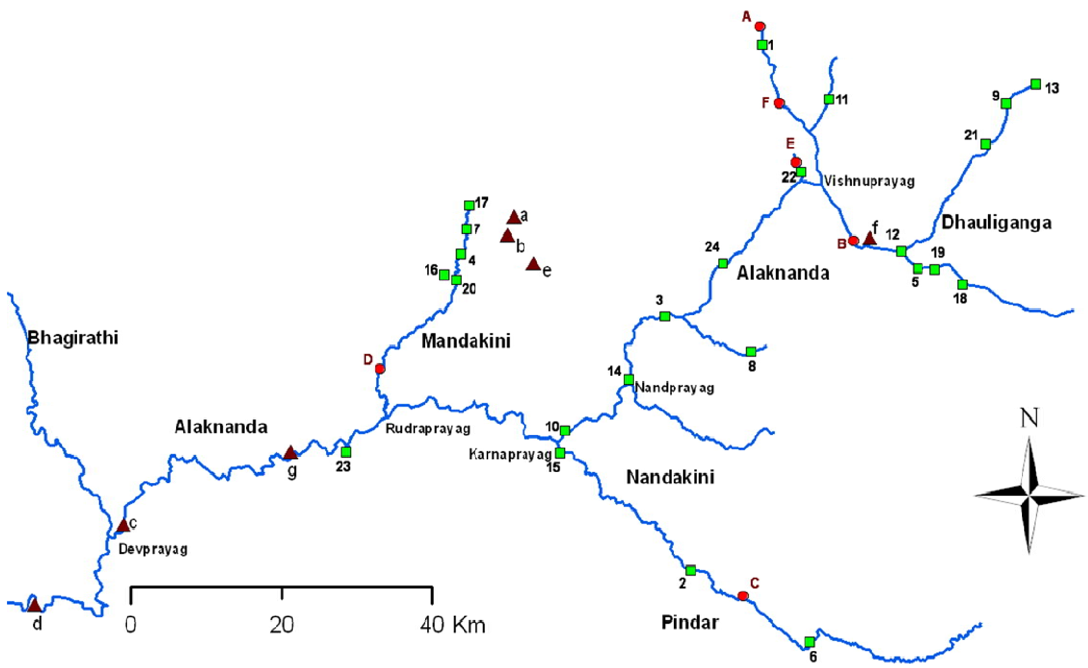


Figure 3: Major Tributaries of River Ganga (Bhagirathi) in the Middle and Lower Ganga Segments

2. Upper Ganga Segment: Gaumukh to Haridwar

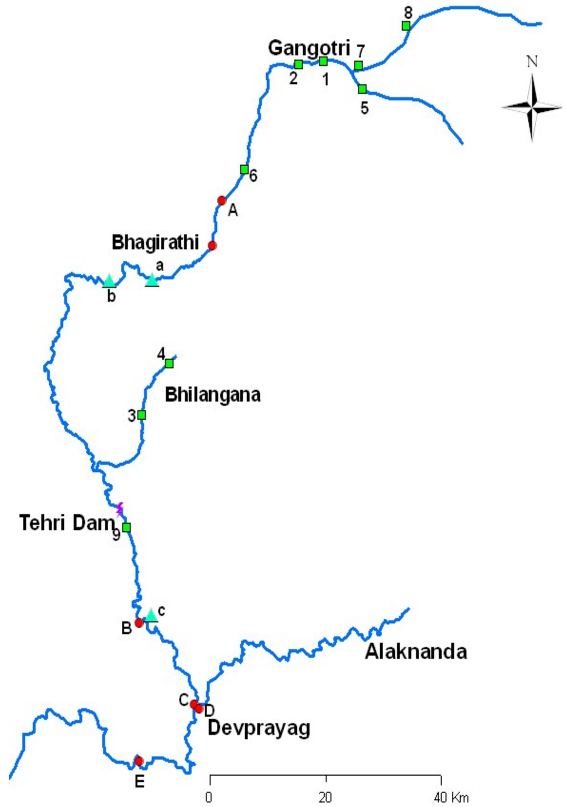
In the Upper Ganga Segment (UGS) from Gaumukh to Rishikesh, the river flows mostly on steep bed with an average approximate slope 1 in 70. The river has turbulent flow and high velocities in most part of this segment. The habitat is stony intermingled with pebbles and sand. With limited nutrients in the water body, the growth of phytoplankton and other aquatic plants is limited. The grazing food chain with fish (carps, occasionally cat fish) as top species predominates. Mahasheer and Trout have been sighted at many places. Specifically Trout has been reported at Harshil, Uttara Khand and in one of the tributaries of river Ganga (i.e. in river Assi, a few thousand meters upstream of its confluence with river Ganga at Uttarkashi). The phytoplankton is dominated by diatoms (*Bacillariophyceae*) in winters followed by green algae (*Desmids*, *Chlorophyceae*). The zooplankton is represented mostly by cilliates. A few rotifers also have been reported.

The most important modifications in the river system in this segment have occurred due to construction of Run of the River and Run of the River with Ponding (ROR + RORP) hydro-electric projects. Location of most of such projects (under operation, construction and proposed) is presented in Figure 4 and 5. Implementation of these projects have resulted in significant alteration in hourly, daily and seasonal flows over substantial river length. A substantial part of the river flow is forced through tunnels or the river stretch has been converted into deep impoundments. An estimated 82 km length of the river in this segment out of total UGS length (≈ 294 km) has been converted into impoundments or the major portion of the flow has been forced into the tunnels and only an estimated 80 km stretch from Gaumukh to some distance downstream of Jhala flows in natural and near pristine form. The area under the influence of hydroelectric projects is suspected to undergo decline in its forest cover and experience enhanced landslides. Potential release of greenhouse gases from impoundments, drying of local water resources, and damage to residential structures, moderation in local climate leading to breeding of mosquito and other insects causing health hazard, are also reported. The river ecosystem is under stress and the reverine environment tends to shift to lacustrine environment. Some salient features of different stretches (refer Figure 6) within the UGS are presented in Exhibit 1.



- ***Existing***: **A.** Badrinath (1.25MW); **B.** Tapovan (0.8MW); **C.** Tharali (0.2MW); **D.** Tilwara (0.2MW); **E.** Urgam (3MW); **F.** Vishnuprayag (400 MW)
- ***Under Construction***: **a.** Kaliganga-I (4MW); **b.** Kaliganga-II(6MW); **c.** Kotli Bhel IB (93.20MW); **d.** Madhmaheswar (10 MW); **e.** Topovan Vishnugad(520 MW); **f.** Shrinagar (330MW)
- ***Proposed***: **1.** Alaknanda (Badrinath) (300MW); **2.** Bagoli (72MW); **3.** Bowla Nandprayag (132MW); **4.** Chuni Semi (24MW); **5.** Deodi (60MW); **6.** Devsari Dam (255MW); **7.** Gaurikund (18.6MW); **8.** Gohana Tal (60MW); **9.** Jelam Tamak (60MW); **10.** Karnaprayag (160MW); **11.** Lakshmanganga (4.4MW); **12.** Lata Tapovan (310MW); **13.** Maleri Jelam (55MW); **14.** Nandprayag Langasu (141MW); **15.** Padli Dam (27MW); **16.** Phata-Byung (10.8MW); **17.** Rambara (24MW); **18.** Rishi Ganga-I (70MW); **19.** Rishi Ganga-II (35MW); **20.** Singoli-Bhatwari (99MW); **21.** Tamak Lata (280MW); **22.** Urgam- II(3.8MW); **23.** Utiyasu Dam (860MW); **24.** Vishnuprayag Pipalkoti (444MW)

Figure 4: Hydroelectric Projects in Alaknanda River Basin

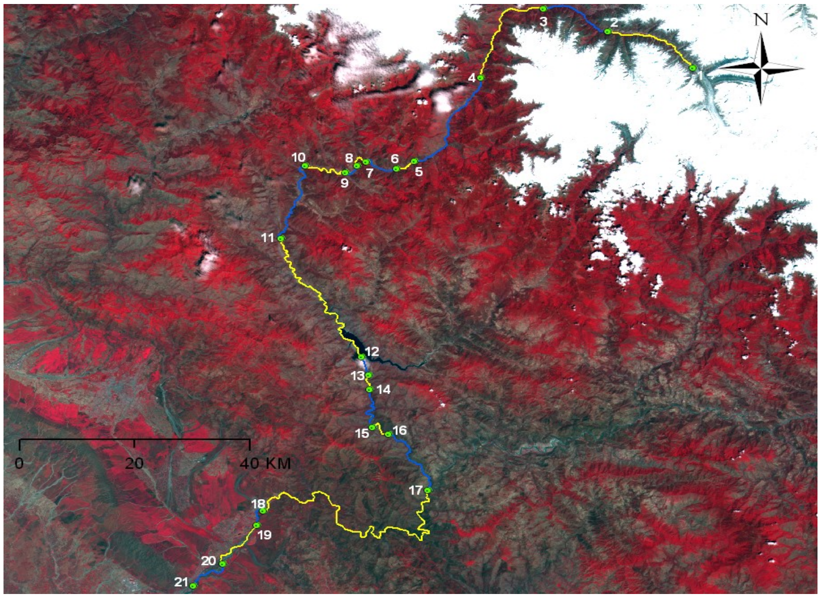


▲ ***Existing***: **a.** Maneri Bhali I (99 MW); **b.** Maneri Bhali II (304 MW); **c.** Tehri (1000 MW)

● ***Under Construction*** : **A.** Loharinag Pala, now abandoned (600 MW); **B.** Koteshwar (400 MW); **C.** Kotli Bhel IA (195MW); **D.** Kotli Bhel IB (320 MW); **E.** Kotli Bhel II (530MW); **F.** Pala Maneri I (480MW)

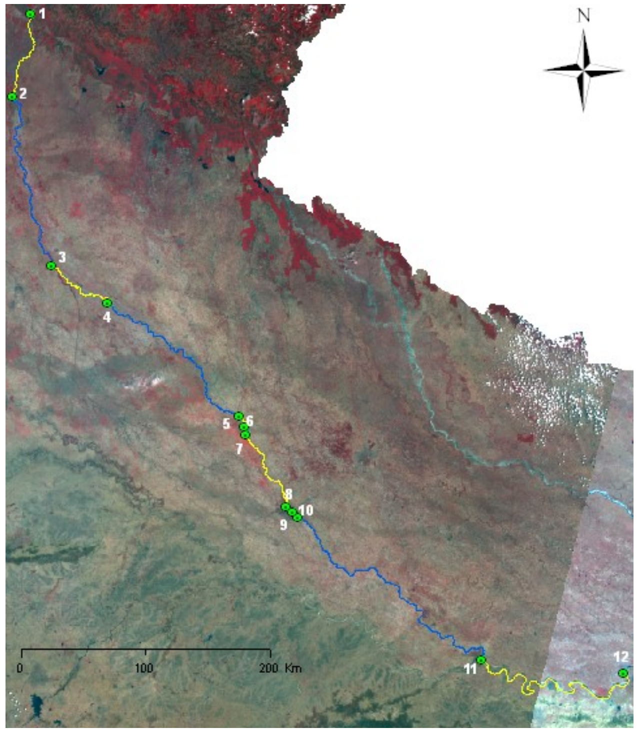
■ ***Proposed***: **1.** Bhaironghati I (380 MW); **2.** Bhaironghati II (65 MW); **3.** Bhilangana I (22.5 MW); **4.** Bhilangana II (11 MW); **5.** Gangotri (55 MW); **6.** Harsil (210 MW); **7.** Jadhganga (50 MW); **8.** Karmoli (140 MW); **9.** Tehri PSS (1000 MW)

Figure 5: Hydroelectric Projects on Ganga (Bhagirathi) and Bhilangana River



Station	Longitude, E	Latitude, N	Elevation, m
1. Gomukh	79.03	30.56	4238
2. Gangotri	78.54	31.00	3037
3. Mukhaba	78.47	31.02	2569
4. Jhala	78.40	30.55	2120
5. MB-1-U/S	78.33	30.45	1355
6. MB 1	78.31	30.44	1297
7. MB-1 Tail water	78.28	30.45	1278
8. MB 2-U/S	78.27	30.44	1126
9. MB 2	78.26	30.44	1122
10. MB-2 Tail water	78.21	30.44	1055
11. Tehri Dam U/S	78.19	30.36	845
12. Tehri Dam	78.28	30.23	830
13. Tehri Dam Tail water	78.29	30.21	653
14. Koteswar U/S	78.29	30.20	604
15. Koteswar Dam	78.29.	30.15	555
16. Koteswar Tail water	78.31	30.15	551
17. Devprayag	78.36	30.09	474
18. Rishikesh U/S	78.18	30.06	345
19. Rishikesh Barrage	78.17	30.04	334
20. Satyanarayana	78.14	30.00	316
21. Bheem Gauda Barrage	78.10	29.57	290

Figure 6: Upper Ganga Segments



Station	Longitude, E	Latitude, N	Elevation, m
1. Bheem Gauda Barrage	78.10	29.57	290
2. Bijnore Barrage	78.02	29.22	221
3. Narora Barrage	78.23	28.11	182
4. Kachla Ghat	78.51	27.56	165
5. Kusumkher	79.56	27.08	130
6. Kannauj U/S	79.59	27.04	128
7. Kannauj D/S	79.59	27.00	127
8. Kanpur Barrage	80.19	26.30	118
9. Shuklaganj	80.22	26.28	116
10. Jajmau	80.24	26.26	115
11. Allahabad	81.53	25.25	76
12. Varanasi	83.01	25.18	74

Figure 7: Middle Ganga Segments

2.1. Suggestions and Recommendations

- Gangotri Valley to be viewed as a place of pilgrim tourism and spiritual activities. All commercial activities in the vicinity of Gangotri (say within 500 m) to be transformed into eco friendly activities. Plan for environment protection and preservation of natural and pristine conditions (e.g. hotel culture to be changed to hut culture; severe restrictions on overnight stay of tourists, promotion of pilgrim tourism than commercial tourism, facilitating "Pad Yatra", encouraging use of locally available materials, provision for segregated collection of entire solid waste of all kinds, entirely eliminating disposal of any kind of waste from anthropogenic sources in the valley, complete recycle/reuse and conversion into acceptable products of wastes generated; sanitation and bathing facilities with no direct/indirect discharge into river valley, control of noise and artificial lighting, etc.).

- Harshil to be developed as nature friendly, zero waste terminal pilgrim tourist spot with facilities of ashrams, guest houses, parking, internet, etc.
- Environmental Flow (E Flow) to be estimated at various places, particularly for those stretches where river flow has been modified (IIT Consortia to work on this as part of the efforts to develop GRBMP). Flow measurement and display devices to be developed for all such stretches by the project implementer.
- All existing hydro electric projects may be redesigned and operated based on requirement of E flows.
- Community toilets and wash rooms with zero discharge of solid and liquid wastes to be developed at number of places as per approved plan for the entire UGS.
- River Bank and River Water Quality Management Plan to be prepared as described in the report prepared by IIT consortia developing GRBMP for Uttarkashi, Shrinagar, New Tehri Town, Rudra Prayag, Dev Prayag and Rishikesh on priority.
- Eutrophication potential of all impoundments to be assessed and measures taken to control release of nutrients from point and non-point sources.
- Detailed studies and documentation on changes due to implementation of hydroelectric projects in the region including, but not limited to the following: (i) drying of local water sources, (ii) enhancement of landslides, (iii) impact on hills surrounding the impoundments due to yearly fluctuations in water levels because of filling and emptying, (iv) damage/changes to residential buildings and hills, (v) potential changes in forest cover due to draining of waters in the tunnels, (vi) estimation of release of greenhouse gases from impoundments, (vii) differences in water temperature between a free flowing river and modified river, (viii) changes in the travel time/distance for local residents, (ix) employment generation, (x) loss of livelihood for local people, (xi) rehabilitation issues, (xii) effect of release of E flows on income from power generation, (xiii) aesthetic value, and (xiv) socio-cultural aspects (IIT Consortia to make such documentation as part of GRBMP efforts with help/assistance from concerned agencies if MOEF provides reports of all studies (including backup data) conducted through sponsored projects/consultancy assignments given to various agencies, institutions, universities, etc.).

3. Middle Ganga Segment: Haridwar to Varanasi

The river enters into the plains. The river bed consists of boulders, gravels and sand initially but subsequently consists of fine sand only. The river bed is essentially flat (slope ≈1 in 5000) and the river channel meanders, bifurcates into several channels in some parts and consists of dynamic system of pools and riffles. Substantial portion of the river flow is diverted to support agricultural activities through system of canals referred as Upper Ganga

Canal (from Bhimgaura Barrage commissioned in 1854 and renovated in 1984-85 just upstream of Haridwar), Madhya Ganga Canal (from Bijnore Barrage commissioned in 1977-78; essentially flood water or kharif canal system), and Lower Ganga Canal (from Narora Barrage commissioned in 1878). Substantial amount of flow, conveyed through a feeder canal originating from the barrage at Kalagarh on the river Ramganga, is introduced into the river Ganga just downstream of Garhmukteshwar to ensure sufficient quantities of water for Narora Atomic Power Plant. The confluence of Ramganga at Kusumkher, Kali at Kannauj and Yamuna at Allahabad augment the flow in the river. However, these rivers, particularly Ramganga and Kali also bring in a lot of domestic/industrial pollution load. In addition, several towns, industries and agricultural activities contribute to the point and non-point pollution load in this segment. Thus river flow and water quality are the key concerns in this segment in addition to general degradation of river system and encroachment of river bed, gravel/sand mining, riverbed farming, active netting of fish, open defecation, etc. In many places dumping of solid wastes including floral offering and other materials used for religious purposes, washing of clothes, wallowing of animals, throwing un-burnt/partially burnt dead bodies adversely affect aesthetics, water quality and aquatic life. Many important small, large and mega religious conglomerations are a part of socio-cultural dimensions of the riverine system at several places, the most important being at Haridwar, Allahabad and Varanasi.

In the initial parts of this segment, fish population predominates depending upon grazing and detritus food chain. The next portion has turtles, crocodiles, ghariyals and Gangetic dolphin alongwith active breeding sites. Pallaze, a practice to grow cucurbetaceous crop in the sand bed produced by meandering river is very common. At a number of places water is pumped out from the river or riverside wells to grow sugarcane and other crops. Riparian vegetation also is noteworthy. Some salient features of different stretches (refer Figure 7) within the UGS are presented in Exhibit 2.

3.1. Suggestions and Recommendations

- River Bank and River Water Quality Management Plan to be prepared as described in the report prepared by IIT consortia developing GRBMP for Haridwar, Garhmukteshwar, Kanpur, Allahabad and Varanasi on priority. IIT consortia to give priorities for the various work packages in the above plan. The priority work packages to be executed on fast track as per the guidelines.
- Industries directly or indirectly discharging their solid/liquid wastes into Ramganga, Kali and Ganga must be directed to follow best available practices for managing solid/liquid wastes and attain complete recycling of water and proper disposal of solid wastes/sludges as per norms enforced by the regulating agencies.
- Ganges Dolphin Conservation Zone Garhmukteshwar – Narora Barrage to be declared as “NO GO AREA” for which detailed studies have been done by WWF-India.

4. Lower Ganga Segment: Varanasi to Ganga Sagar

In this segment, the river Ganga receives water from three categories of rivers. In the first category are perennial rivers that originate in Himalayas and carry snow fed flows with significant discharge in the non-monsoon season. This includes Kosi, Gandak, Karnali (Ghaghra) and Mahakali (Sharda) river systems. In the second category are the rivers which originate in the midlands of Mahabharat range of mountains and are fed by precipitation as well as ground water, including springs. Mechi, Kankalm, Kamla, Bagmati, West Rapti and Babai rivers fall under this category. Although these rivers are also perennial, they are commonly characterized by wide seasonal fluctuations in discharge. The third category of river systems includes a large number of small rivers in the terrain which originate from the southern Shiwalik range of hills. These rivers are seasonal with little flows during the dry season but characterized by flash floods during the monsoon. This part of the basin, particularly the alluvial belt, is viewed as play ground for many rivers. There is spilling of river banks and drainage congestion because of peculiar deltaic formation of soil.

Major changes in nature of surface flow have been observed in this segment. This change is due to the massive silt coming along with the flow. Planning for this massive silt is as important as the surface water flow itself. The problem of development and water resources management is highly complex in this segment. Flood, drought and water logging occur frequently. Flood is a big menace and agriculture is badly affected, though the land is very fertile.

Several towns, industries and agricultural activities contribute to the point and non-point pollution load in this segment. In addition to general degradation of river system, encroachment of river bed, sand mining, riverbed farming, active netting of fish, open defecation, etc. are also of concern. In many places dumping of solid wastes including floral offering and other materials used for religious purposes, washing of clothes, wallowing of animals, throwing un-burnt/partially burnt dead bodies adversely affect aesthetics, water quality and aquatic life. Many important small, large and mega religious conglomerations are a part of socio-cultural dimensions of the riverine system at several places, the most important being at Ganga Sagar where the river merges into the sea. This segment offers unique biodiversity with many important wetland systems. In some portions Ganges Dolphins are of great significance from ecological point of view and the general health of the river system. The food chain is typically detritus with dominance of fishes.

4.1. Suggestions and Recommendations

- Hydrological and geomorphological studies for managing sediment transport and water resources. FGM, WRM and EQP group of IIT Consortia to work on this.
- River Bank and River Water Quality Management Plan to be prepared as described in the report prepared by IIT consortia developing GRBMP for priority towns to be identified

within the next three months (Action by the EQP group of IIT consortia). IIT consortia to also give priorities for the various work packages in the above plan. The priority work packages to be executed on fast track as per the guidelines.

- Industries directly or indirectly discharging their solid/liquid wastes into Ganga must be directed to follow best available practices for managing solid/liquid wastes and attain complete recycling of water and proper disposal of solid wastes/sludges as per norms enforced by the regulating agencies.

Exhibit 1: Salient Features in Various Parts of the Upper Ganga Segment

Sub-Stretch and Its Description
UGS_1: Gaumukh *to* **Gangotri (≈ 19 km)** Represents near natural and pristine conditions; Steep bed with rocks and boulders; No apparent human intervention and negligible pollution
UGS_2: Gangotri *to* **Mukhoba (≈ 14 km)** Represents near natural and pristine conditions; Known to reemerge as Janhavi river; narrowest channel; Steep bed with rocks and boulders; Deep Gorges; Slight distributed pollution due to wastes from eating-joints on the Gangotri-shrine; guest houses. Problem of sanitation is most important.
UGS_3: Mukhoba *to* **Jhala** (≈ **22 km)** Represent near pristine and natural conditions; Historical and religious importance due to joining of three rivers, known as Hari Prayag; Wide flood plain; Flat bed with pebbles and sand; Meandering and bifurcating into several channels with dynamic system of riffles and pools; Slight pollution due to domestic and commercial (hotels/guest houses) establishments
UGS_4: Jhala *to* **U/S MB-1** (≈ **24 km)** Represents near pristine and natural conditions; Steep and narrow river bed intermingled with boulders, pebbles and sand; Slight pollution due to domestic activities
UGS_5: MB-1 U/S *to* **MB-1 Barrage** (≈ **4 km)** Modified to impoundment; Reverine environment shifting to lacustrine environment; Slight pollution due to domestic activities; High eutrophication potential
UGS_6: MB-1 Barrage *to* **MB-1 Tail Waters** (≈ **7 km)** Flow substantially reduced; River bed may dry up for sometime; Discontinuity in flow regime; Aquatic life severely affected
UGS_7: MB-1 Tail Waters *to* **MB-2 U/S** (≈ **4 km)** Modified fluctuating flows depending upon power generation at MB-1 power plant; Additional flows due to Gadera's; River bed consisting of small stones and pebble; River in combination of riffles and pools.
UGS_8: MB-2 U/S *to* **MB-2 Barrage** (≈ **3 km)** Modified to impoundment; Reverine environment shifting to lacustrine environment; Slight pollution due to domestic activities; High eutrophication potential

Sub-Stretch and Its Description
UGS_9: MB-2 Barrage *to* **MB-2 Tail Waters** (≈ **10 km**)
Flow substantially reduced; River bed may dry up for sometime; Discontinuity in flow regime; Aquatic life severely affected
UGS_10: MB-2 Tail Waters *to* **Tehri U/S** (≈ **21 km**)
Modified fluctuating flows depending upon power generation at MB-2 power plant; River bed consisting of small stones and pebble; River in combination of riffles and pools. Slight pollution due to domestic activities
UGS_11: Tehri U/S *to* **Tehri Dam** (≈ **38 km**)
Modified to impoundment; Reverine environment shifting to lacustrine environment; Slight pollution due to domestic activities; High eutrophication potential; Potential for release of greenhouse gases due to decomposition of submerged biomass in the lake
UGS_12: Tehri Dam *to* **Tehri Tail Waters (≈ 4 km**)
Flow substantially reduced; River bed may dry up for sometime; Discontinuity in flow regime; Aquatic life severely affected
UGS_13: Tehri Tail Waters *to* **Koteshwar U/S** (≈ **3.5 km**)
Substantially modified fluctuating flows depending upon power generation at Tehri power plant; River bed consisting of small stones and pebble; River in combination of riffles and pools. Slight pollution due to domestic activities
UGS_14: Koteshwar U/S *to* **Koteshwar Dam** (≈ **11 km)**
Will be modified to impoundment; Reverine environment likely to shift to lacustrine environment; Slight pollution due to domestic activities; High eutrophication potential
UGS_15: **Koteshwar Dam *to* Koteshwar Tail Waters (≈ 5 km)**
Flow substantially reduced; River bed may dry up for sometime; Discontinuity in flow regime; Aquatic life severely affected
UGS_16: Koteshwar Tail Waters *to* **Dev Prayag (≈ 17 km**)
Modified fluctuating flows depending upon power generation at Koteshwar power plant; River bed consisting of small stones and pebble; River in combination of riffles and pools. Slight pollution due to domestic activities
UGS_17: Dev Prayag *to* **Rishikesh U/S** (≈ **64 km**)
Substantially modified fluctuating flows depending upon power generation at Tehri and Koteshwar power plants; Flow augmented due to confluence with Alaknanda; Hydroelectric projects under construction/proposed on Alaknanda and its tributaries may further influence hourly variation in flow; River bed consisting of small stones and pebble; River in combination of riffles and pools. Slight pollution due to domestic activities, bathing and other cultural religious activities; Initiation of detritus food chain with fish at the top of food chain; Riverine ecosystem under stress due to frequent fluctuations in flow and water quality (e.g. temperature and turbidity)

Sub-Stretch and Its Description
UGS_18: Rishikesh U/S *to* **Rishikesh Barrage** (**≈ 4 km**)
Substantially modified fluctuating flows depending upon power generation at Tehri and Koteshwar power plants; Flow augmented due to confluence with Alaknanda; Hydroelectric projects under construction/proposed on Alaknanda and its tributaries may further influence hourly variation in flow; River bed consisting of large and small pebble with some boulders and sand; River in combination of riffles and pools. Slight pollution due to domestic activities, bathing and other cultural/religious activities; Development of detritus food chain with fish at the top of food chain; Riverine ecosystem under stress due to frequent fluctuations in flow and water quality (e.g. temperature and turbidity)
UGS_19: Rishikesh Barrage *to* **Satyanarayana** (**≈ 11km**)
Flow pattern modified depending upon modified fluctuating flow received from upstream and power generation at Chilla power station; River bed consisting of small stones and pebble; Active fish breeding area; Fish netting and rampant stone mining; Riverine ecosystem under stress due to frequent fluctuations in flow and water quality (e.g. temperature and turbidity)
UGS_20: Satyanarayana *to* **Bhim Gauda Barrage** (**≈ 9 km**)
Flow pattern modified depending upon modified fluctuating flow received from upstream; Wide flood plain; Flat bed with pebbles and sand; Meandering and bifurcating into several channels with dynamic system of riffles and pools; Much of the water diverted to Har-ki-paudi through canal and much less water released in the main stream as Neel Dhara; Moderate pollution due to domestic and commercial (hotels/guest houses) establishments

Exhibit 2: Salient Features in Various Parts of the Middle Ganga Segment

Sub-Stretch and Its Description
MGS_1: Bheem Gauda Barrage *to* **Bijnor Barrage (≈ 82 km)**
Most of the water is diverted to Har-ki-Paudi; Excess flow from canals is returned at 6-8 km downstream; Wide flood plain, River meandering and bifurcating into several channels; River bed consisting of pebble and sand**;** Reported re-appearance of Mahasheer at Balawali; Occurrence of Otters, Crocodiles, Ghariyal, Turtle in some parts indicating good biodiversity; Active breeding grounds for fish in some parts; Moderate pollution due to domestic and agricultural activities.
MGS_2: Bijnor Barrage *to* **Narora Barrage (≈ 176 km) NO GO ZONE**
Low flow during non-monsoon period in the initial portion of the stretch up to Garhmukteshwar; Subsequently flow modified through discharge of Ramganga waters through feeder canal; Impoundment and abstraction of water through Lower Ganga Canal system at the tail end; Wide flood plain and sandy bed with some pebbles; Ganges Dolphin conservation site; Moderate pollution due to domestic and agricultural activities

Sub-Stretch and Its Description
MGS_3: Narora Barrage *to* **Kachla Ghat (≈ 70 km)** Extremely low flows during non-monsoon period; Only occasional releases of water during non-monsoon period; Wide flood plain; Meandering river with dynamic system of pools and riffles; Sandy bed**;** Breeding site for Turtles and Ghariyal; Agricultural activities in river bed, predominantly Cucurbetaceous crops known as "Pallaze"; Significant degradation of river water quality.
MGS_4: Kachla Ghat *to* **Kusumkher (≈ 182 km)** Extremely low flows during non-monsoon period; Only occasional releases of water during non-monsoon period; Wide flood plain; Meandering river with dynamic system of pools and riffles; Sandy bed**;** Agricultural activities in river bed, predominantly Cucurbetaceous crops known as "Pallaze"; Significant degradation of river water quality.
MGS_5: Kusumkher *to* **Kannauj U/S (≈ 12 km)** Additional flow and pollutant load from river Ramganga; Low flows during non-monsoon period; Only occasional increase in flows during non-monsoon period; Wide flood plain; Meandering river with dynamic system of pools and riffles; Sandy bed**;** Agricultural activities in river bed, predominantly Cucurbetaceous crops known as "Pallaze"; Use of excessive pesticides. Significant degradation of river water quality.
MGS_6: Kannauj U/S *to* **Kannauj D/S (≈ 9 km)** Additional highly polluted flow from river Kali; Low flows during non-monsoon period; Only occasional increase in flows during non-monsoon period; Wide flood plain; Meandering river with dynamic system of pools and riffles; Sandy bed**;** Agricultural activities in river bed, predominantly Cucurbetaceous crops known as "Pallaze"; Use of excessive pesticides. Significant degradation of river water quality.
MGS_7: Kannauj D/S *to* **Kanpur Barrage (≈ 78 km)** Low flows during non-monsoon period; Only occasional increase in flows during non-monsoon period; Wide flood plain; Meandering river with dynamic system of pools and riffles; Sandy bed**;** Impoundment in the part downstream of Bithoor near Barrage; Ganges Dolphins Spotted; Agricultural activities in river bed, predominantly Cucurbetaceous crops known as "Pallaze"; Use of excessive pesticides. Significant degradation of river water quality.
MGS_8: Kanpur Barrage *to* **Shuklaganj (≈ 7.5 km)** Low flows during non-monsoon period; Only occasional increase in flows during non-monsoon period; Wide flood plain; Meandering river with dynamic system of pools and riffles; Sandy bed**;** Agricultural activities in river bed, predominantly Cucurbetaceous crops known as "Pallaze"; Use of excessive pesticides. Extensive degradation of river water quality due to domestic and industrial wastes, dumping of solid wastes, animal wallowing, throwing of un-burnt dead bodies.

Sub-Stretch and Its Description
MGS_9: Shuklaganj *to* **Jajmau (≈ 5.5 km)**
Low flows during non-monsoon period; Only occasional increase in flows during non-monsoon period; Wide flood plain; Meandering river with dynamic system of pools and riffles; Sandy bed**;** Agricultural activities in river bed, predominantly Cucurbetaceous crops known as "Pallaze"; Use of excessive pesticides. Extensive degradation of river water quality due to domestic and industrial wastes, dumping of solid wastes, animal wallowing, throwing of un-burnt dead bodies; The most critical stretch.
MGS_10: Jajmau *to* **Allahabad (≈ 247 km)**
Low flows during non-monsoon period; Only occasional increase in flows during non-monsoon period; Wide flood plain; Meandering river with dynamic system of pools and riffles; Sandy bed**;** Agricultural activities in river bed, predominantly Cucurbetaceous crops known as "Pallaze"; Use of excessive pesticides. Discharge of domestic and some industrial wastes, dumping of solid wastes, animal wallowing, throwing of un-burnt dead bodies; Gradual but very slow recovery of the river system; Ganges Dolphin spotted; Several important major and mega religious/cultural conglomeration held on the riverside.
MGS_11: Allahabad *to* **Varanasi (≈ 212 km)**
Slight increase in flow due to joining of a major tributary Yamuna; Wide flood plain; Meandering river with dynamic system of pools and riffles; Sandy bed**;** Agricultural activities in river bed, predominantly Cucurbetaceous crops known as "Pallaze"; Use of excessive pesticides. Discharge of domestic and some industrial wastes, dumping of solid wastes, animal wallowing, throwing of un-burnt/half burnt dead bodies; Ganges Dolphin spotted.

Water Quality in the Ganga River and Efficacy of Sewage Treatment Processes in Coliform Removal:

A Case for Adopting Tertiary Treatment

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay	IIT Delhi	IIT Guwahati	IIT Kanpur	IIT Kharagpur	IIT Madras	IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. A list of persons who have contributed directly and names of those who have taken lead in preparing this report is given on the reverse side.

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Contents

1. Introduction

The Ganga River,the longest river system in India, drains a basin of extraordinary variation in altitude, climate, land use, cropping patternand socio-economic condition. The Ganga River basin, which is the largest river basin in India, houses about 40% population of the country. The river provides a wide range of commodities and services that are pivotal in supporting the livelihoods for a large number of people in the basin. Due to the prevailing semi-arid climate and highly erratic monsoonal rains in the basin,the river flow heavily fluctuates and hassubsequently been regulated by various human interventions like dams and barrages for domestic watersupply and irrigation.During the course of her journey from Gangotri to Ganga Sagar, municipal wastewaters from large urban centers, trade effluents from industries and pollutants from several other point and diffused sources are released into the river and thereby severely degrading her water quality.Over the last few decades, increased attention has been given by the Government of India (GoI) in the form of River Action Plan (RAP), namely Ganga Action Plan (GAP) to maintain the river water quality through abatement of pollution. Unfortunately, the implementation of GAP has more or less failed to get the desired result as the GAP monotonously focused on the reduction of point sources of organic pollution rather than microbial pollution and diffused or non-point sources of pollution. Moreover, the majority of secondary-level sewage treatment technologies adopted under GAP are highly incapable in removing microbial pollution. In regard to the microbial pollution in the river, attention has been paid to blindly importing and fixing the 'bathing class' standards from the developed countries in terms of coliforms only as a measure of fecal pollution. Currently, countries worldwide adopt 'zero discharge' or 'no return flow' concept to maintain river water quality by recycling and reusing the treated wastewater/effluent for non-potable, non-human contact uses. In these contexts, this report is primarily aimed at analyzing water quality trend of the entire course of the Ganga River for the last 25 years (since the implementation of GAP) in order to substantiate and propagate the adoption of tertiary-level treatment of wastewater in the Ganga River Basin.

Section 2 of the report presents water quality trends in terms of organic pollution (dissolved oxygen, biochemical oxygen demand) and microbial pollution (total and fecal coliform) over 70 locations in entire course of the Ganga River for the past 25 years and inferences from the water quality analysis. Section 3 of the report discusses comparative monsoon characteristics and river flows of the western rivers *vis-à-vis* Indian rivers, the Ganga River in particular. The microbial pollution removal potential of the secondary-level sewage treatment technologies has been critically reviewed and discussed in Section 4 of the report. The last section of the report(Section 5) analyzes and evaluates the performance of commonly adopted disinfection technologies in terms of microbial pollution removal and other key parameters including hazardous by-product formation, required footprint of the technology, treatment cost and life-cycle cost.

This report is primarily based on the collation of secondary data, available mainly in the form of reports, papers and articles on flow and water quality of the Ganga River, microbial pollution removal potential of secondary-level sewage treatment technologies, and the performance of commonly adopted treatment technologies for disinfection of secondary sewage effluent.

2. Water Quality Trends of the Ganga River

Conventionally surface water quality and pollution, both organic and microbial, are assessed through analysis of various parameters like dissolved oxygen (DO), biochemical oxygen demand (BOD_5), total and fecal coliform (TC and FC), and hence historical data of the past 25 years (1986-2010) on these parameters were collated. Water quality data ofthe selected parameters over 70 locations in entire course of the Ganga River has beengathered by various investigators/organizations at the behest of the National River Conservation Directorate (NRCD). These data for the past 25 years (1986-2010) have been collated from the NRCD and used for analysis to depict the water quality trends. Simple average of twelve months in a year is considered as annual average while the simple average of dry months (November through June) and wet months (July to October) in a year are taken as average for dry and wet seasons, respectively for a particular location. Trends in various water quality parameters are observed by grouping five year data and observing spatial variation in five-year averages during dry and wet seasons as well as over twelve months. The results are presented in Figures 1 to 4. Statistically, the confidence level (as percentage) of observations conforming to the designated best-use classification (Classes A, B and C considered only) of inland surface water, as specified by the CPCB, have also been computed and presented in Annexure I. Following observations and inferences on the trends in water quality parameters of the Ganga River can be made from the information presented in Figures 1 to 4 and the confidence level values presented in Annexure I:

- The averages of DO (Figure 1) and BOD_5 (Figure 2) during dry as well as wet seasons and annually over the years at all locations in the entire course of the Ganga River appear to have remained fairly constant. The DO values over the years, in general, are on the higher side and conform to the designated best-use classification. Organic content as measured by BOD_5, however, does not conform to the limit specified for the designated best-use classificationat some of the locations as revealed by the very low confidence level values (Annexure I). The DO values during wet season are lower as compared to dry season although the level of organic pollution (BOD_5) remains fairly constant during both the seasons at most of the locations. The level of organic pollution (BOD_5) is substantially high in the Fatehgarh-Tarighat stretch during dry as well as wet seasons over the years despite the fact that the DO level is on the higher side. Higher level of organic pollution in the Fatehgarh-Tarighat stretch is due to the fact that the stretch is subjected to severe anthropogenic pollution in the form of discharge of partially-treated or untreated sewage and industrial effluents.

- Coliform levels, both total and fecal (Figures 3-4) during dry as well as wet seasons are substantially higher and do not conform to the designated best-use classification at most places (Annexure I) barring few upstream locations. The coliform levels during wet season are significantly higher as compared to dry season at most of the locations. The coliform levels in the river are observed to be decreased during 1991-1995 as compared to 1986-1990. Since then, however, the coliform levels are on the rise and substantially increased from 1996 through 2010 at all locations in the entire course of the Ganga River.

- No significant change is observed in most of the water quality parameters except for total and fecal coliforms during dry as well as wet seasons and annually over the years at all locations in the entire course of the Ganga River. Hence, the river is subjected to severely increasing microbial pollution despite insignificantly higher organic pollution.

- Based on the aforementioned observations it may be stated that trends in water quality parameters and level of organic and microbial pollution do not support the postulate that interception, diversion and treatment schemes under GAP and other programmes lead to improvements in river water quality, particularly the most targeted parameters, namely DO, BOD_5 and coliform. On the contrary, the microbial pollution in the river is observed to be ever increasing since 1996. Implementation of intervention schemes and regulatory mechanisms under RAP has only changed the pattern of discharge of wastewaters generated through domestic and industrial activity rather than the improvement in river water quality, especially microbial pollution. Therefore, it makes sense to adopt tertiary level treatment of wastewater in India, the Ganga River basin in particular considering the level of microbial pollution in the Ganga River.

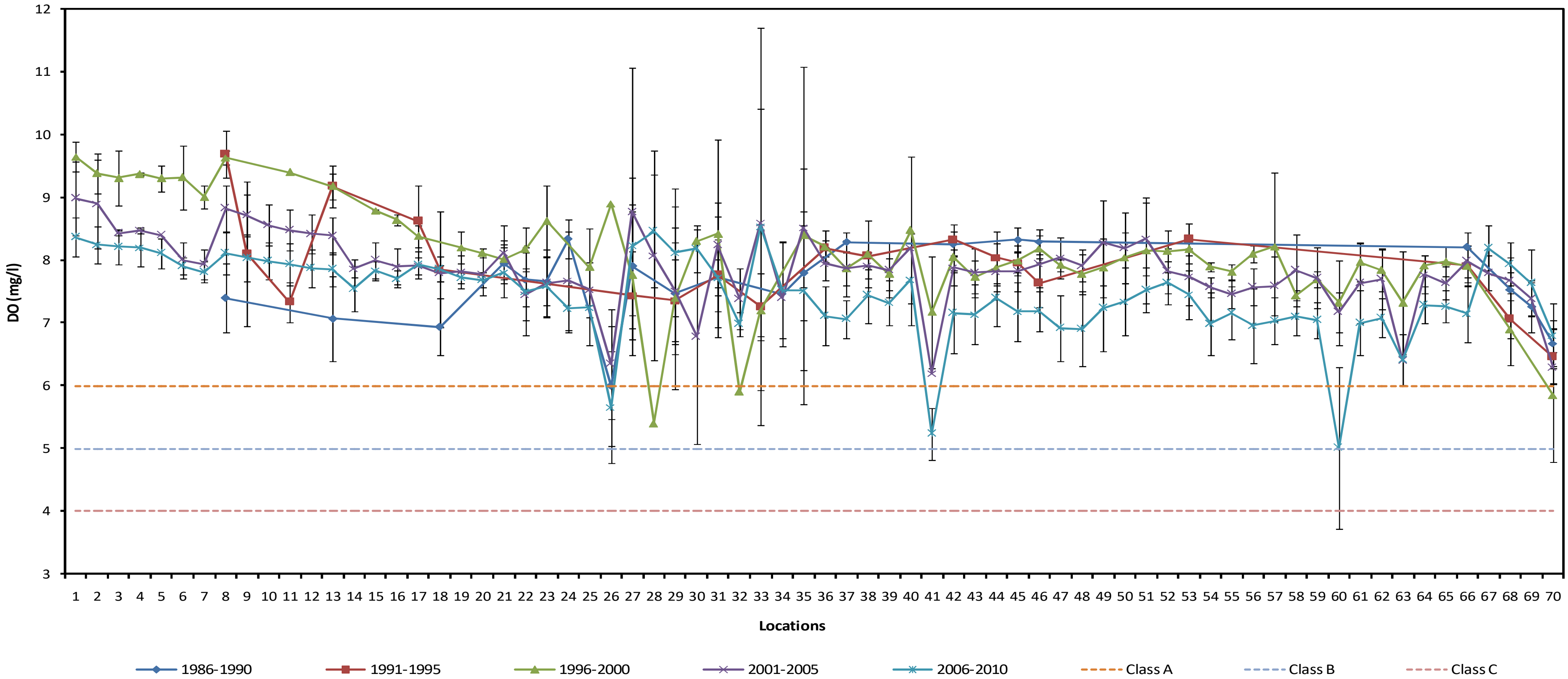

Figure 1(a): Variation in 5-year Average DO at Various Locations along the Ganga River during Dry Season

1	Uttarkashi u/s (Bhagirathi)	15	Bijnore u/s (Ganga)	29	D/s Deehaghat	43	Hajipur u/s (River Gandak)	57	Sultanganj d/s
2	Uttarkashi d/s (Bhagirathi)	16	Bijnore d/s (Ganga)	30	Vindhyachal, Pakka Ghat	44	Hajipur d/s (River Gandak)	58	Bhagalpur u/s
3	Devprayag u/s (Bhagirathi)	17	Garhmukteshwar u/s	31	Varanasi u/s	45	Patna u/s	59	Bhagalpur d/s
4	Devprayag u/s (Alaknanda)	18	Garhmukteshwar d/s	32	Dashashawmedh Ghat	46	Patna d/s	60	D/s Champanala
5	Devprayag d/s (Ganga)	19	Anoopshahr u/s (Ganga)	33	D/s at Kaithy	47	Fatuha u/s	61	Kahalgaon u/s
6	Ranipur u/s (Ganga)	20	Anoopshahr d/s (Ganga)	34	Near Malviya Bridge	48	Fatuha d/s	62	Kahalgaon d/s
7	Ranipur d/s (Ganga)	21	Fatehgarh u/s	35	Tarighat	49	Barh u/s	63	D/s NTPC Drain
8	Rishikesh u/s	22	Kannauj u/s (a/c with Ramganga & b/c with Kali)	36	Buxar u/s	50	Barh d/s	64	Sahebganj u/s
9	Rishikesh d/s	23	Kannauj d/s (a/c with Kali)	37	Buxar d/s	51	Mokama u/s	65	Sahebganj d/s
10	Haridwar u/s	24	Kanpur u/s (Bithoor)	38	Chapra u/s (Ghaghra)	52	Mokama d/s	66	Rajmahal d/s
11	Har-ki-Paudi	25	Kanpur d/s (Shuklaganj)	39	Chapra d/s (Chapra)	53	D/s Bata - McDowell	67	Berhampore (Middle)
12	Lalta Rao	26	Kanpur d/s (Jane Village)	40	Arrah u/s (River Gangi)	54	Munger u/s	68	Palta (Middle)
13	Dam Kothi	27	Allahbad u/s (Ujahni, Fatehpur)	41	Arrah d/s (River Gangi)	55	Munger d/s	69	Dakshineswar (Middle)
14	Mishrpur	28	Bathing Ghats at Sangam	42	Koliwar (River Sone)	56	Sultanganj u/s	70	Uluberia (Middle)

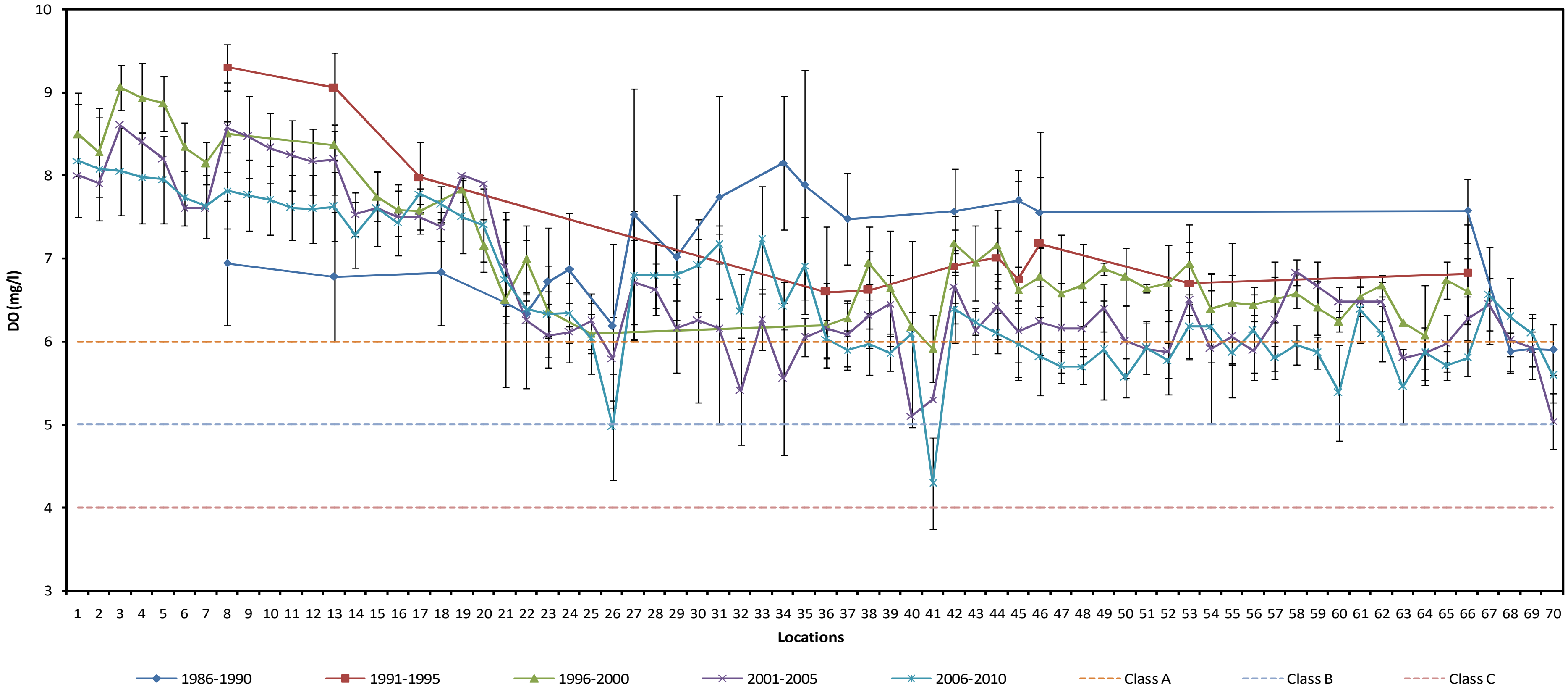

Figure 1(b): Variation in 5-year Average DO at Various Locations along the Ganga River during Wet Season

1	Uttarkashi u/s (Bhagirathi)	15	Bijnore u/s (Ganga)	29	D/s Deehaghat	43	Hajipur u/s (River Gandak)	57	Sultanganj d/s
2	Uttarkashi d/s (Bhagirathi)	16	Bijnore d/s (Ganga)	30	Vindhyachal, Pakka Ghat	44	Hajipur d/s (River Gandak)	58	Bhagalpur u/s
3	Devprayag u/s (Bhagirathi)	17	Garhmukteshwar u/s	31	Varanasi u/s	45	Patna u/s	59	Bhagalpur d/s
4	Devprayag u/s (Alaknanda)	18	Garhmukteshwar d/s	32	Dashashawmedh Ghat	46	Patna d/s	60	D/s Champanala
5	Devprayag d/s (Ganga)	19	Anoopshahr u/s (Ganga)	33	D/s at Kaithy	47	Fatuha u/s	61	Kahalgaon u/s
6	Ranipur u/s (Ganga)	20	Anoopshahr d/s (Ganga)	34	Near Malviya Bridge	48	Fatuha d/s	62	Kahalgaon d/s
7	Ranipur d/s (Ganga)	21	Fatehgarh u/s	35	Tarighat	49	Barh u/s	63	D/s NTPC Drain
8	Rishikesh u/s	22	Kannauj u/s (a/c with Ramganga & b/c with Kali)	36	Buxar u/s	50	Barh d/s	64	Sahebganj u/s
9	Rishikesh d/s	23	Kannauj d/s (a/c with Kali)	37	Buxar d/s	51	Mokama u/s	65	Sahebganj d/s
10	Haridwar u/s	24	Kanpur u/s (Bithoor)	38	Chapra u/s (Ghaghra)	52	Mokama d/s	66	Rajmahal d/s
11	Har-ki-Paudi	25	Kanpur d/s (Shuklaganj)	39	Chapra d/s (Chapra)	53	D/s Bata - McDowell	67	Berhampore (Middle)
12	Lalta Rao	26	Kanpur d/s (Jane Village)	40	Arrah u/s (River Gangi)	54	Munger u/s	68	Palta (Middle)
13	Dam Kothi	27	Allahbad u/s (Ujahni, Fatehpur)	41	Arrah d/s (River Gangi)	55	Munger d/s	69	Dakshineswar (Middle)
14	Mishrpur	28	Bathing Ghats at Sangam	42	Koliwar (River Sone)	56	Sultanganj u/s	70	Uluberia (Middle)

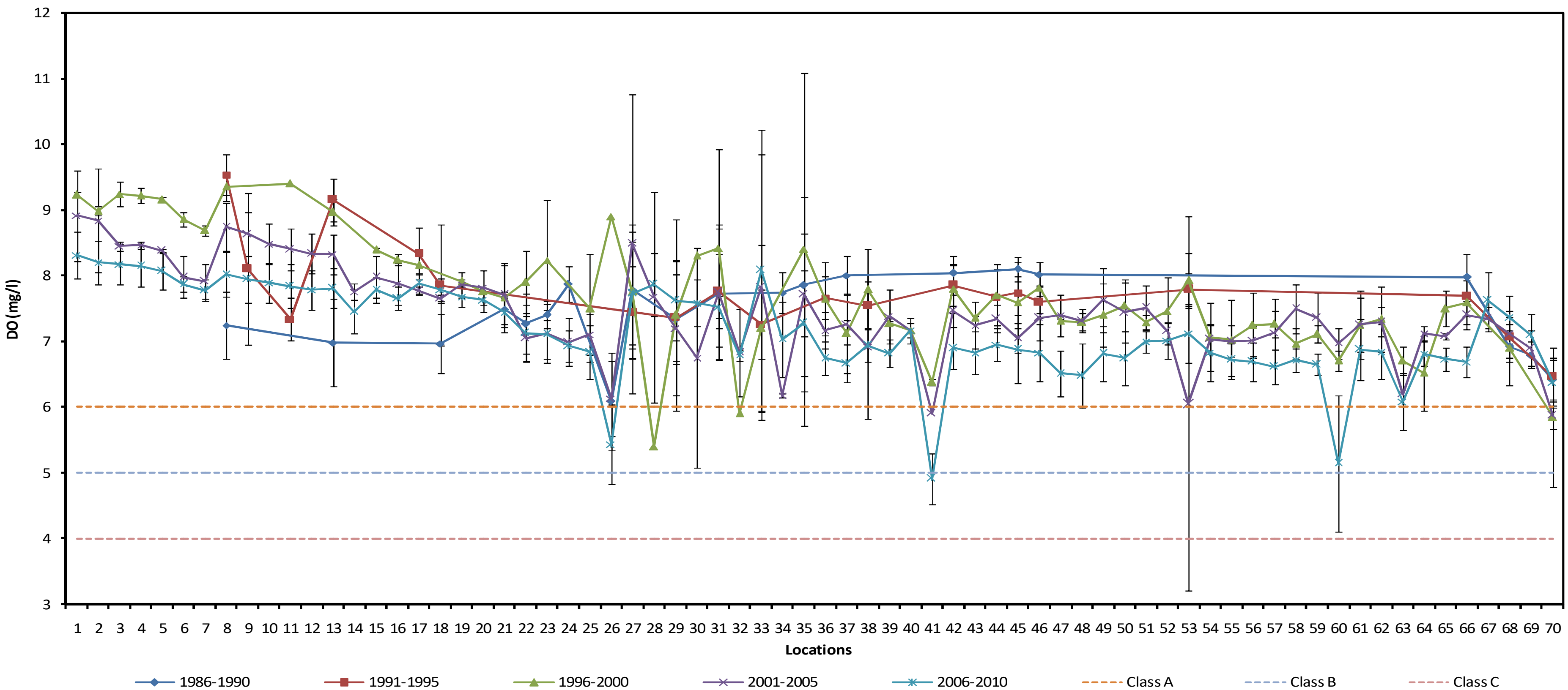

Figure 1(c): Variation in 5-year Average DO at Various Locations along the Ganga River

1	Uttarkashi u/s (Bhagirathi)	15	Bijnore u/s (Ganga)	29	D/s Deehaghat	43	Hajipur u/s (River Gandak)	57	Sultanganj d/s
2	Uttarkashi d/s (Bhagirathi)	16	Bijnore d/s (Ganga)	30	Vindhyachal, Pakka Ghat	44	Hajipur d/s (River Gandak)	58	Bhagalpur u/s
3	Devprayag u/s (Bhagirathi)	17	Garhmukteshwar u/s	31	Varanasi u/s	45	Patna u/s	59	Bhagalpur d/s
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7	Ranipur d/s (Ganga)	21	Fatehgarh u/s	35	Tarighat	49	Barh u/s	63	D/s NTPC Drain
8	Rishikesh u/s	22	Kannauj u/s (a/c with Ramganga & b/c with Kali)	36	Buxar u/s	50	Barh d/s	64	Sahebganj u/s
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10	Haridwar u/s	24	Kanpur u/s (Bithoor)	38	Chapra u/s (Ghaghra)	52	Mokama d/s	66	Rajmahal d/s
11	Har-ki-Paudi	25	Kanpur d/s (Shuklaganj)	39	Chapra d/s (Chapra)	53	D/s Bata - McDowell	67	Berhampore (Middle)
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13	Dam Kothi	27	Allahbad u/s (Ujahni, Fatehpur)	41	Arrah d/s (River Gangi)	55	Munger d/s	69	Dakshineswar (Middle)
14	Mishrpur	28	Bathing Ghats at Sangam	42	Koliwar (River Sone)	56	Sultanganj u/s	70	Uluberia (Middle)

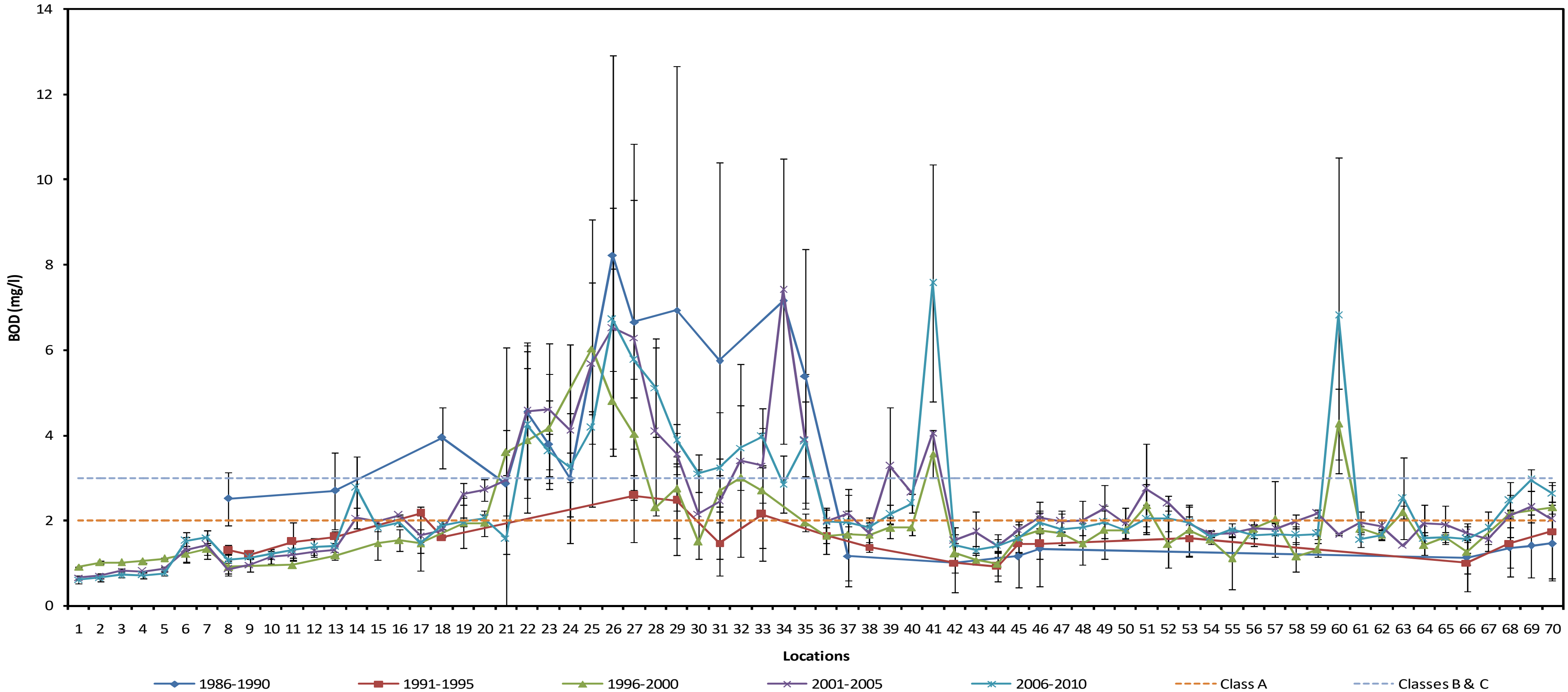

Figure 2(a): Variation in 5-year Average BOD_5 at Various Locations along the Ganga River during Dry Season

1	Uttarkashi u/s (Bhagirathi)	15	Bijnore u/s (Ganga)	29	D/s Deehaghat	43	Hajipur u/s (River Gandak)	57	Sultanganj d/s
2	Uttarkashi d/s (Bhagirathi)	16	Bijnore d/s (Ganga)	30	Vindhyachal, Pakka Ghat	44	Hajipur d/s (River Gandak)	58	Bhagalpur u/s
3	Devprayag u/s (Bhagirathi)	17	Garhmukteshwar u/s	31	Varanasi u/s	45	Patna u/s	59	Bhagalpur d/s
4	Devprayag u/s (Alaknanda)	18	Garhmukteshwar d/s	32	Dashashawmedh Ghat	46	Patna d/s	60	D/s Champanala
5	Devprayag d/s (Ganga)	19	Anoopshahr u/s (Ganga)	33	D/s at Kaithy	47	Fatuha u/s	61	Kahalgaon u/s
6	Ranipur u/s (Ganga)	20	Anoopshahr d/s (Ganga)	34	Near Malviya Bridge	48	Fatuha d/s	62	Kahalgaon d/s
7	Ranipur d/s (Ganga)	21	Fatehgarh u/s	35	Tarighat	49	Barh u/s	63	D/s NTPC Drain
8	Rishikesh u/s	22	Kannauj u/s (a/c with Ramganga & b/c with Kali)	36	Buxar u/s	50	Barh d/s	64	Sahebganj u/s
9	Rishikesh d/s	23	Kannauj d/s (a/c with Kali)	37	Buxar d/s	51	Mokama u/s	65	Sahebganj d/s
10	Haridwar u/s	24	Kanpur u/s (Bithoor)	38	Chapra u/s (Ghaghra)	52	Mokama d/s	66	Rajmahal d/s
11	Har-ki-Paudi	25	Kanpur d/s (Shuklaganj)	39	Chapra d/s (Chapra)	53	D/s Bata - McDowell	67	Berhampore (Middle)
12	Lalta Rao	26	Kanpur d/s (Jane Village)	40	Arrah u/s (River Gangi)	54	Munger u/s	68	Palta (Middle)
13	Dam Kothi	27	Allahbad u/s (Ujahni, Fatehpur)	41	Arrah d/s (River Gangi)	55	Munger d/s	69	Dakshineswar (Middle)
14	Mishrpur	28	Bathing Ghats at Sangam	42	Koliwar (River Sone)	56	Sultanganj u/s	70	Uluberia (Middle)

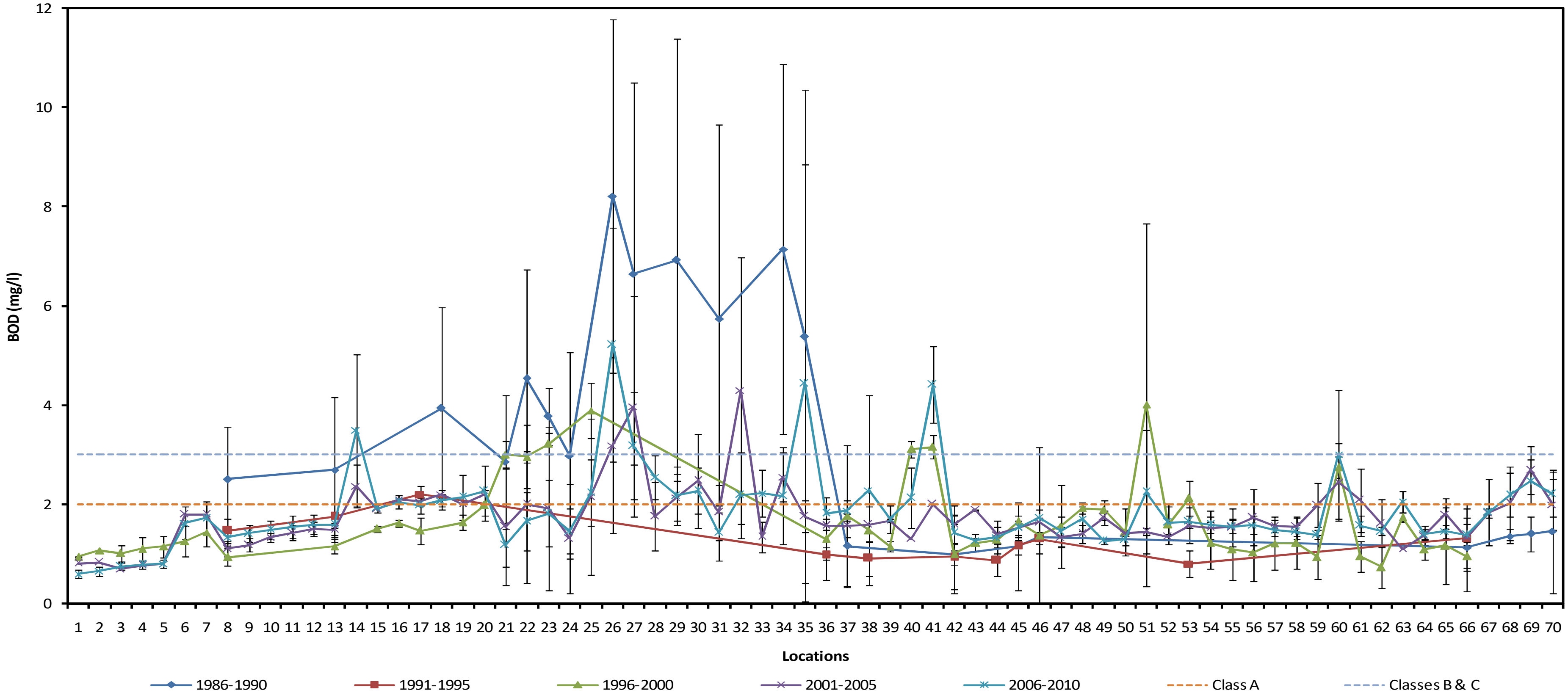

Figure 2(b): Variation in 5-year Average BOD_5 at Various Locations along the Ganga River during Wet Season

1	Uttarkashi u/s (Bhagirathi)	15	Bijnore u/s (Ganga)	29	D/s Deehaghat	43	Hajipur u/s (River Gandak)	57	Sultanganj d/s
2	Uttarkashi d/s (Bhagirathi)	16	Bijnore d/s (Ganga)	30	Vindhyachal, Pakka Ghat	44	Hajipur d/s (River Gandak)	58	Bhagalpur u/s
3	Devprayag u/s (Bhagirathi)	17	Garhmukteshwar u/s	31	Varanasi u/s	45	Patna u/s	59	Bhagalpur d/s
4	Devprayag u/s (Alaknanda)	18	Garhmukteshwar d/s	32	Dashashawmedh Ghat	46	Patna d/s	60	D/s Champanala
5	Devprayag d/s (Ganga)	19	Anoopshahr u/s (Ganga)	33	D/s at Kaithy	47	Fatuha u/s	61	Kahalgaon u/s
6	Ranipur u/s (Ganga)	20	Anoopshahr d/s (Ganga)	34	Near Malviya Bridge	48	Fatuha d/s	62	Kahalgaon d/s
7	Ranipur d/s (Ganga)	21	Fatehgarh u/s	35	Tarighat	49	Barh u/s	63	D/s NTPC Drain
8	Rishikesh u/s	22	Kannauj u/s (a/c with Ramganga & b/c with Kali)	36	Buxar u/s	50	Barh d/s	64	Sahebganj u/s
9	Rishikesh d/s	23	Kannauj d/s (a/c with Kali)	37	Buxar d/s	51	Mokama u/s	65	Sahebganj d/s
10	Haridwar u/s	24	Kanpur u/s (Bithoor)	38	Chapra u/s (Ghaghra)	52	Mokama d/s	66	Rajmahal d/s
11	Har-ki-Paudi	25	Kanpur d/s (Shuklaganj)	39	Chapra d/s (Chapra)	53	D/s Bata - McDowell	67	Berhampore (Middle)
12	Lalta Rao	26	Kanpur d/s (Jane Village)	40	Arrah u/s (River Gangi)	54	Munger u/s	68	Palta (Middle)
13	Dam Kothi	27	Allahbad u/s (Ujahni, Fatehpur)	41	Arrah d/s (River Gangi)	55	Munger d/s	69	Dakshineswar (Middle)
14	Mishrpur	28	Bathing Ghats at Sangam	42	Koliwar (River Sone)	56	Sultanganj u/s	70	Uluberia (Middle)

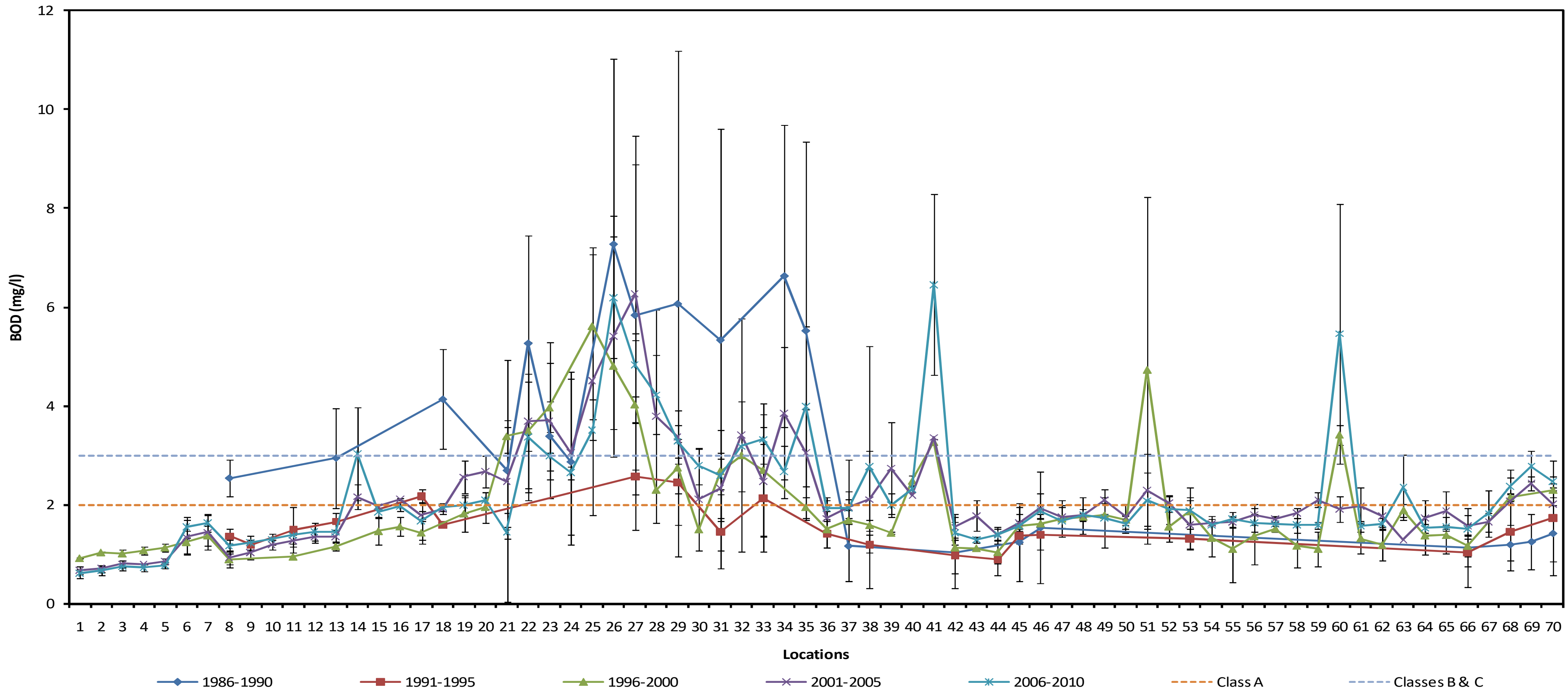

Figure 2(c): Variation in 5-year Average BOD_5 at Various Locations along the Ganga River

1	Uttarkashi u/s (Bhagirathi)	15	Bijnore u/s (Ganga)	29	D/s Deehaghat	43	Hajipur u/s (River Gandak)	57	Sultanganj d/s
2	Uttarkashi d/s (Bhagirathi)	16	Bijnore d/s (Ganga)	30	Vindhyachal, Pakka Ghat	44	Hajipur d/s (River Gandak)	58	Bhagalpur u/s
3	Devprayag u/s (Bhagirathi)	17	Garhmukteshwar u/s	31	Varanasi u/s	45	Patna u/s	59	Bhagalpur d/s
4	Devprayag u/s (Alaknanda)	18	Garhmukteshwar d/s	32	Dashashawmedh Ghat	46	Patna d/s	60	D/s Champanala
5	Devprayag d/s (Ganga)	19	Anoopshahr u/s (Ganga)	33	D/s at Kaithy	47	Fatuha u/s	61	Kahalgaon u/s
6	Ranipur u/s (Ganga)	20	Anoopshahr d/s (Ganga)	34	Near Malviya Bridge	48	Fatuha d/s	62	Kahalgaon d/s
7	Ranipur d/s (Ganga)	21	Fatehgarh u/s	35	Tarighat	49	Barh u/s	63	D/s NTPC Drain
8	Rishikesh u/s	22	Kannauj u/s (a/c with Ramganga & b/c with Kali)	36	Buxar u/s	50	Barh d/s	64	Sahebganj u/s
9	Rishikesh d/s	23	Kannauj d/s (a/c with Kali)	37	Buxar d/s	51	Mokama u/s	65	Sahebganj d/s
10	Haridwar u/s	24	Kanpur u/s (Bithoor)	38	Chapra u/s (Ghaghra)	52	Mokama d/s	66	Rajmahal d/s
11	Har-ki-Paudi	25	Kanpur d/s (Shuklaganj)	39	Chapra d/s (Chapra)	53	D/s Bata - McDowell	67	Berhampore (Middle)
12	Lalta Rao	26	Kanpur d/s (Jane Village)	40	Arrah u/s (River Gangi)	54	Munger u/s	68	Palta (Middle)
13	Dam Kothi	27	Allahbad u/s (Ujahni, Fatehpur)	41	Arrah d/s (River Gangi)	55	Munger d/s	69	Dakshineswar (Middle)
14	Mishrpur	28	Bathing Ghats at Sangam	42	Koliwar (River Sone)	56	Sultanganj u/s	70	Uluberia (Middle)

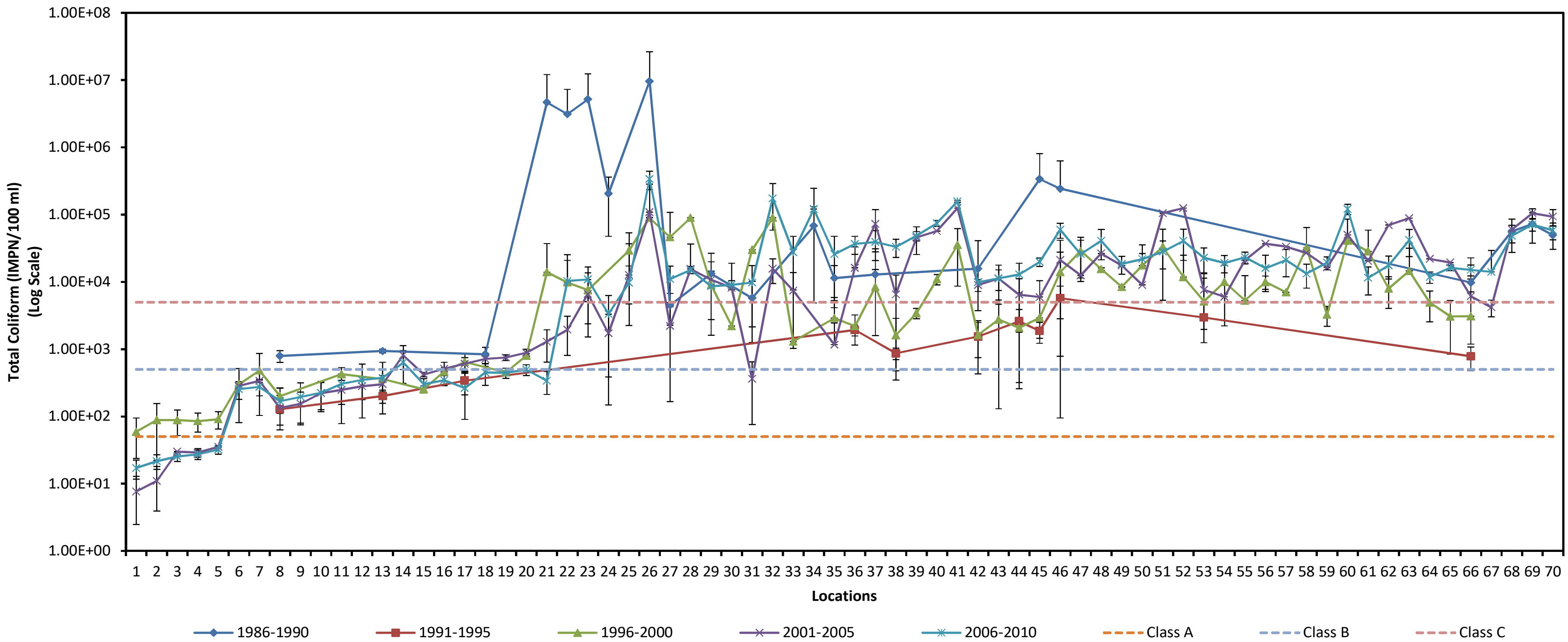

Figure 3(a): Variation in 5-year Average Total Coliform at Various Locations along the Ganga River during Dry Season

1	Uttarkashi u/s (Bhagirathi)	15	Bijnore u/s (Ganga)	29	D/s Deehaghat	43	Hajipur u/s (River Gandak)	57	Sultanganj d/s
2	Uttarkashi d/s (Bhagirathi)	16	Bijnore d/s (Ganga)	30	Vindhyachal, Pakka Ghat	44	Hajipur d/s (River Gandak)	58	Bhagalpur u/s
3	Devprayag u/s (Bhagirathi)	17	Garhmukteshwar u/s	31	Varanasi u/s	45	Patna u/s	59	Bhagalpur d/s
4	Devprayag u/s (Alaknanda)	18	Garhmukteshwar d/s	32	Dashashawmedh Ghat	46	Patna d/s	60	D/s Champanala
5	Devprayag d/s (Ganga)	19	Anoopshahr u/s (Ganga)	33	D/s at Kaithy	47	Fatuha u/s	61	Kahalgaon u/s
6	Ranipur u/s (Ganga)	20	Anoopshahr d/s (Ganga)	34	Near Malviya Bridge	48	Fatuha d/s	62	Kahalgaon d/s
7	Ranipur d/s (Ganga)	21	Fatehgarh u/s	35	Tarighat	49	Barh u/s	63	D/s NTPC Drain
8	Rishikesh u/s	22	Kannauj u/s (a/c with Ramganga & b/c with Kali)	36	Buxar u/s	50	Barh d/s	64	Sahebganj u/s
9	Rishikesh d/s	23	Kannauj d/s (a/c with Kali)	37	Buxar d/s	51	Mokama u/s	65	Sahebganj d/s
10	Haridwar u/s	24	Kanpur u/s (Bithoor)	38	Chapra u/s (Ghaghra)	52	Mokama d/s	66	Rajmahal d/s
11	Har-ki-Paudi	25	Kanpur d/s (Shuklaganj)	39	Chapra d/s (Chapra)	53	D/s Bata - McDowell	67	Berhampore (Middle)
12	Lalta Rao	26	Kanpur d/s (Jane Village)	40	Arrah u/s (River Gangi)	54	Munger u/s	68	Palta (Middle)
13	Dam Kothi	27	Allahbad u/s (Ujahni, Fatehpur)	41	Arrah d/s (River Gangi)	55	Munger d/s	69	Dakshineswar (Middle)
14	Mishrpur	28	Bathing Ghats at Sangam	42	Koliwar (River Sone)	56	Sultanganj u/s	70	Uluberia (Middle)

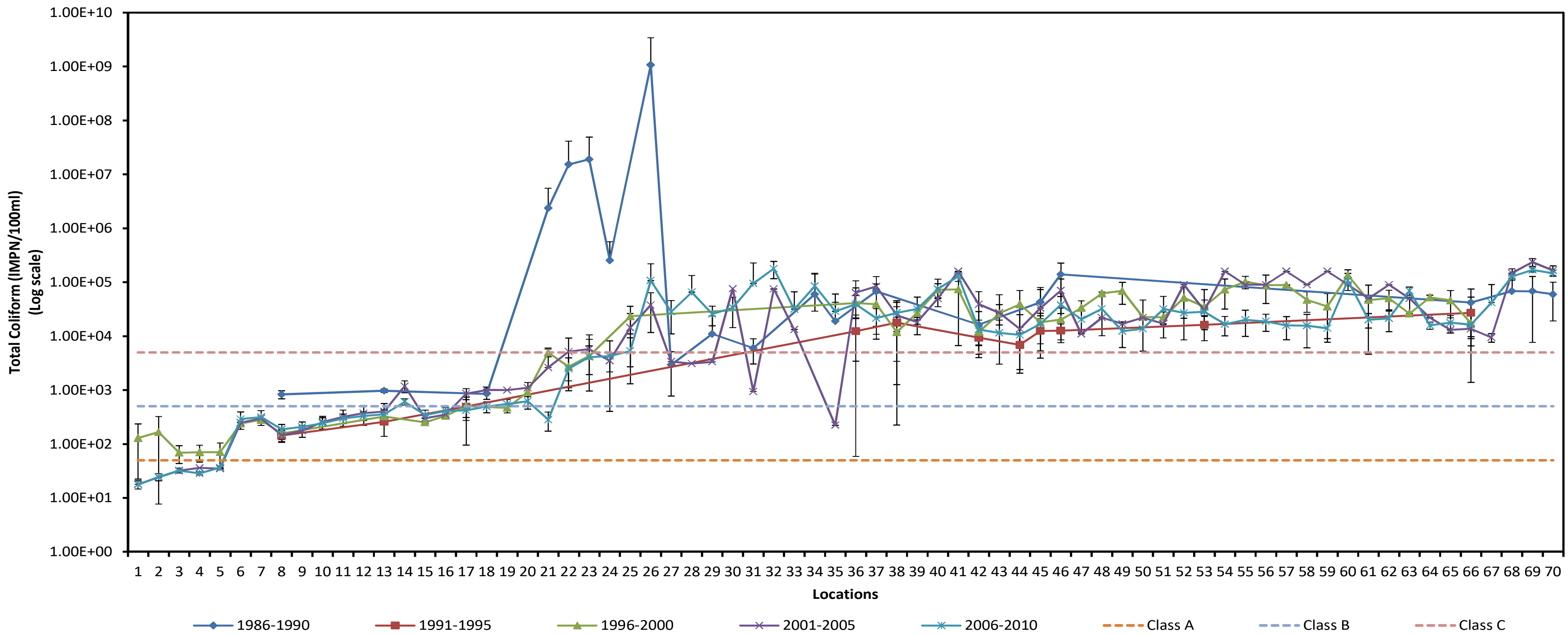

Figure 3(b): Variation in 5-year Average Total Coliform at Various Locations along the Ganga River during Wet Season

1	Uttarkashi u/s (Bhagirathi)	15	Bijnore u/s (Ganga)	29	D/s Deehaghat	43	Hajipur u/s (River Gandak)	57	Sultanganj d/s
2	Uttarkashi d/s (Bhagirathi)	16	Bijnore d/s (Ganga)	30	Vindhyachal, Pakka Ghat	44	Hajipur d/s (River Gandak)	58	Bhagalpur u/s
3	Devprayag u/s (Bhagirathi)	17	Garhmukteshwar u/s	31	Varanasi u/s	45	Patna u/s	59	Bhagalpur d/s
4	Devprayag u/s (Alaknanda)	18	Garhmukteshwar d/s	32	Dashashawmedh Ghat	46	Patna d/s	60	D/s Champanala
5	Devprayag d/s (Ganga)	19	Anoopshahr u/s (Ganga)	33	D/s at Kaithy	47	Fatuha u/s	61	Kahalgaon u/s
6	Ranipur u/s (Ganga)	20	Anoopshahr d/s (Ganga)	34	Near Malviya Bridge	48	Fatuha d/s	62	Kahalgaon d/s
7	Ranipur d/s (Ganga)	21	Fatehgarh u/s	35	Tarighat	49	Barh u/s	63	D/s NTPC Drain
8	Rishikesh u/s	22	Kannauj u/s (a/c with Ramganga & b/c with Kali)	36	Buxar u/s	50	Barh d/s	64	Sahebganj u/s
9	Rishikesh d/s	23	Kannauj d/s (a/c with Kali)	37	Buxar d/s	51	Mokama u/s	65	Sahebganj d/s
10	Haridwar u/s	24	Kanpur u/s (Bithoor)	38	Chapra u/s (Ghaghra)	52	Mokama d/s	66	Rajmahal d/s
11	Har-ki-Paudi	25	Kanpur d/s (Shuklaganj)	39	Chapra d/s (Chapra)	53	D/s Bata - McDowell	67	Berhampore (Middle)
12	Lalta Rao	26	Kanpur d/s (Jane Village)	40	Arrah u/s (River Gangi)	54	Munger u/s	68	Palta (Middle)
13	Dam Kothi	27	Allahbad u/s (Ujahni, Fatehpur)	41	Arrah d/s (River Gangi)	55	Munger d/s	69	Dakshineswar (Middle)
14	Mishrpur	28	Bathing Ghats at Sangam	42	Koliwar (River Sone)	56	Sultanganj u/s	70	Uluberia (Middle)

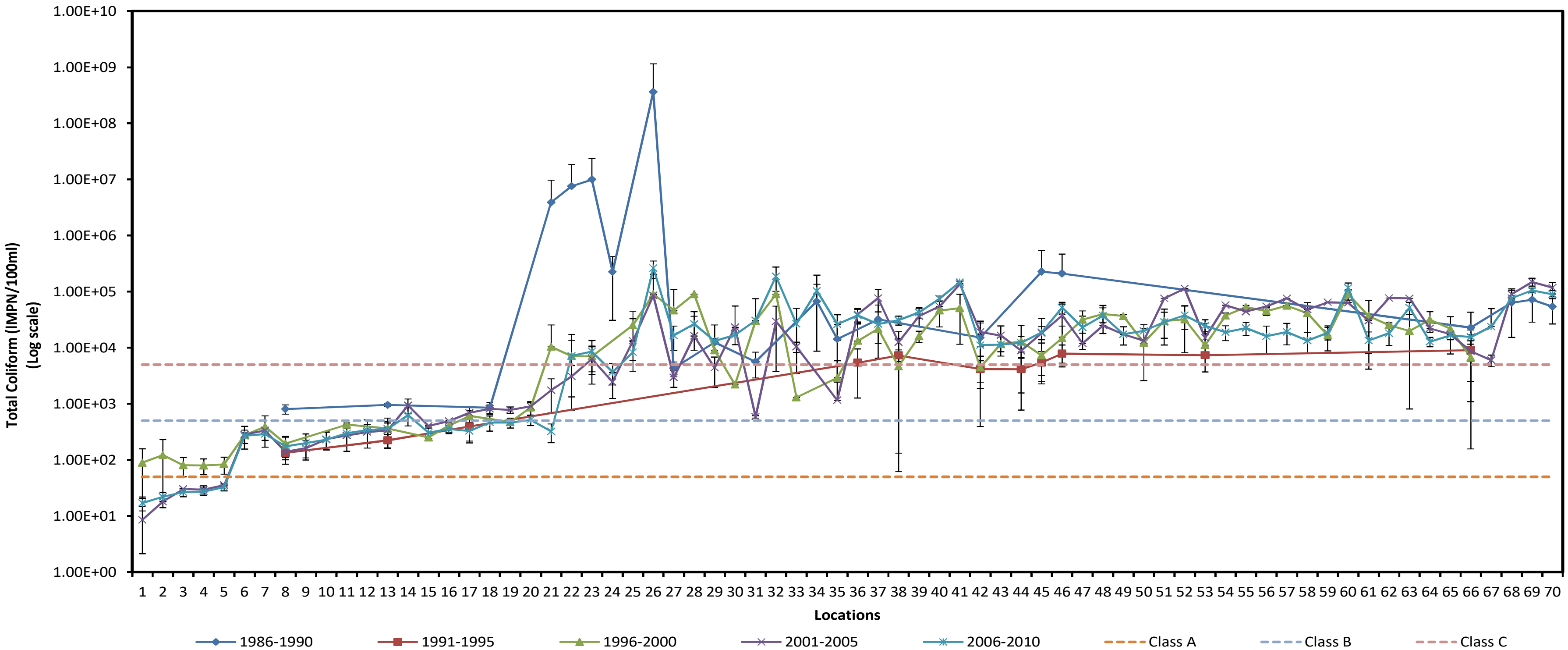

Figure 3(c): Variation in 5-year Average Total Coliform at Various Locations along the Ganga River

1	Uttarkashi u/s (Bhagirathi)	15	Bijnore u/s (Ganga)	29	D/s Deehaghat	43	Hajipur u/s (River Gandak)	57	Sultanganj d/s
2	Uttarkashi d/s (Bhagirathi)	16	Bijnore d/s (Ganga)	30	Vindhyachal, Pakka Ghat	44	Hajipur d/s (River Gandak)	58	Bhagalpur u/s
3	Devprayag u/s (Bhagirathi)	17	Garhmukteshwar u/s	31	Varanasi u/s	45	Patna u/s	59	Bhagalpur d/s
4	Devprayag u/s (Alaknanda)	18	Garhmukteshwar d/s	32	Dashashawmedh Ghat	46	Patna d/s	60	D/s Champanala
5	Devprayag d/s (Ganga)	19	Anoopshahr u/s (Ganga)	33	D/s at Kaithy	47	Fatuha u/s	61	Kahalgaon u/s
6	Ranipur u/s (Ganga)	20	Anoopshahr d/s (Ganga)	34	Near Malviya Bridge	48	Fatuha d/s	62	Kahalgaon d/s
7	Ranipur d/s (Ganga)	21	Fatehgarh u/s	35	Tarighat	49	Barh u/s	63	D/s NTPC Drain
8	Rishikesh u/s	22	Kannauj u/s (a/c with Ramganga & b/c with Kali)	36	Buxar u/s	50	Barh d/s	64	Sahebganj u/s
9	Rishikesh d/s	23	Kannauj d/s (a/c with Kali)	37	Buxar d/s	51	Mokama u/s	65	Sahebganj d/s
10	Haridwar u/s	24	Kanpur u/s (Bithoor)	38	Chapra u/s (Ghaghra)	52	Mokama d/s	66	Rajmahal d/s
11	Har-ki-Paudi	25	Kanpur d/s (Shuklaganj)	39	Chapra d/s (Chapra)	53	D/s Bata - McDowell	67	Berhampore (Middle)
12	Lalta Rao	26	Kanpur d/s (Jane Village)	40	Arrah u/s (River Gangi)	54	Munger u/s	68	Palta (Middle)
13	Dam Kothi	27	Allahbad u/s (Ujahni, Fatehpur)	41	Arrah d/s (River Gangi)	55	Munger d/s	69	Dakshineswar (Middle)
14	Mishrpur	28	Bathing Ghats at Sangam	42	Koliwar (River Sone)	56	Sultanganj u/s	70	Uluberia (Middle)

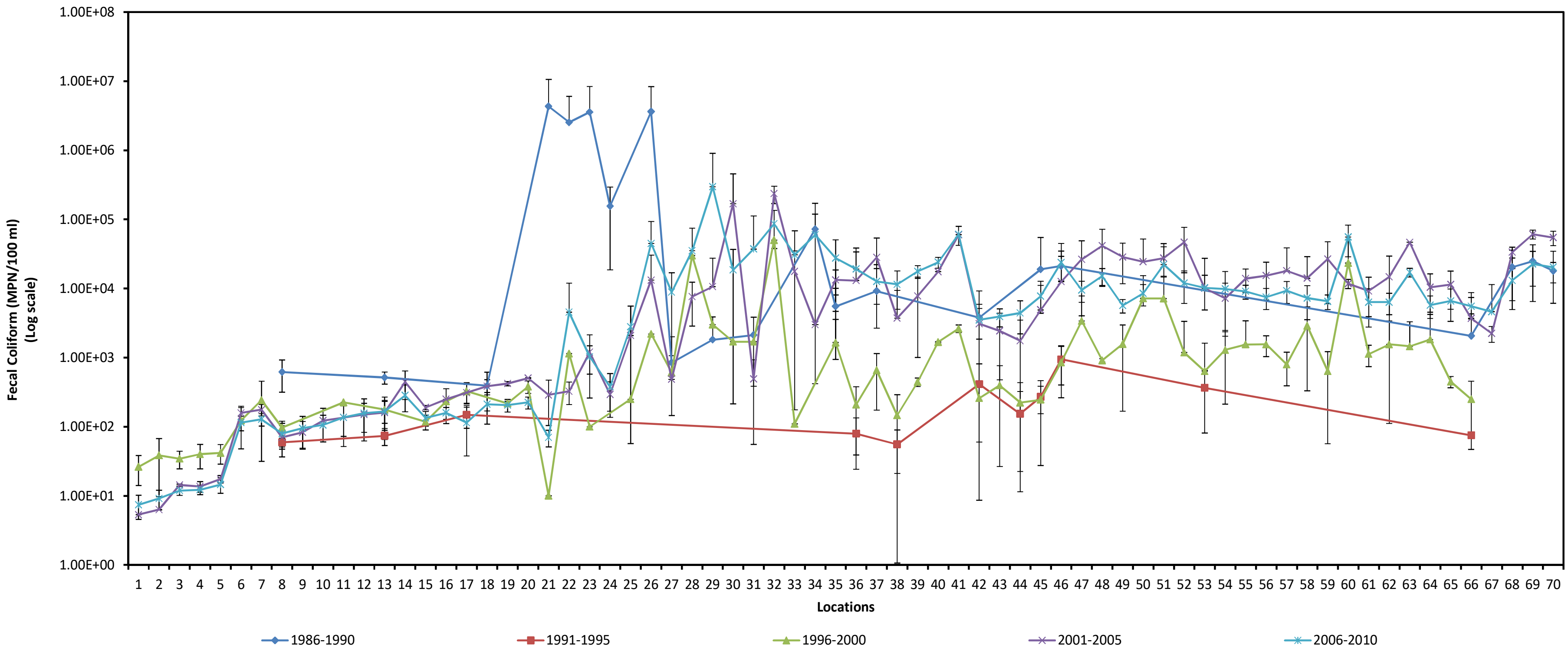

Figure 4(a): Variation in 5-year Average Fecal Coliform at Various Locations along the Ganga River during Dry Season

1	Uttarkashi u/s (Bhagirathi)	15	Bijnore u/s (Ganga)	29	D/s Deehaghat	43	Hajipur u/s (River Gandak)	57	Sultanganj d/s
2	Uttarkashi d/s (Bhagirathi)	16	Bijnore d/s (Ganga)	30	Vindhyachal, Pakka Ghat	44	Hajipur d/s (River Gandak)	58	Bhagalpur u/s
3	Devprayag u/s (Bhagirathi)	17	Garhmukteshwar u/s	31	Varanasi u/s	45	Patna u/s	59	Bhagalpur d/s
4	Devprayag u/s (Alaknanda)	18	Garhmukteshwar d/s	32	Dashashawmedh Ghat	46	Patna d/s	60	D/s Champanala
5	Devprayag d/s (Ganga)	19	Anoopshahr u/s (Ganga)	33	D/s at Kaithy	47	Fatuha u/s	61	Kahalgaon u/s
6	Ranipur u/s (Ganga)	20	Anoopshahr d/s (Ganga)	34	Near Malviya Bridge	48	Fatuha d/s	62	Kahalgaon d/s
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8	Rishikesh u/s	22	Kannauj u/s (a/c with Ramganga & b/c with Kali)	36	Buxar u/s	50	Barh d/s	64	Sahebganj u/s
9	Rishikesh d/s	23	Kannauj d/s (a/c with Kali)	37	Buxar d/s	51	Mokama u/s	65	Sahebganj d/s
10	Haridwar u/s	24	Kanpur u/s (Bithoor)	38	Chapra u/s (Ghaghra)	52	Mokama d/s	66	Rajmahal d/s
11	Har-ki-Paudi	25	Kanpur d/s (Shuklaganj)	39	Chapra d/s (Chapra)	53	D/s Bata - McDowell	67	Berhampore (Middle)
12	Lalta Rao	26	Kanpur d/s (Jane Village)	40	Arrah u/s (River Gangi)	54	Munger u/s	68	Palta (Middle)
13	Dam Kothi	27	Allahbad u/s (Ujahni, Fatehpur)	41	Arrah d/s (River Gangi)	55	Munger d/s	69	Dakshineswar (Middle)
14	Mishrpur	28	Bathing Ghats at Sangam	42	Koliwar (River Sone)	56	Sultanganj u/s	70	Uluberia (Middle)

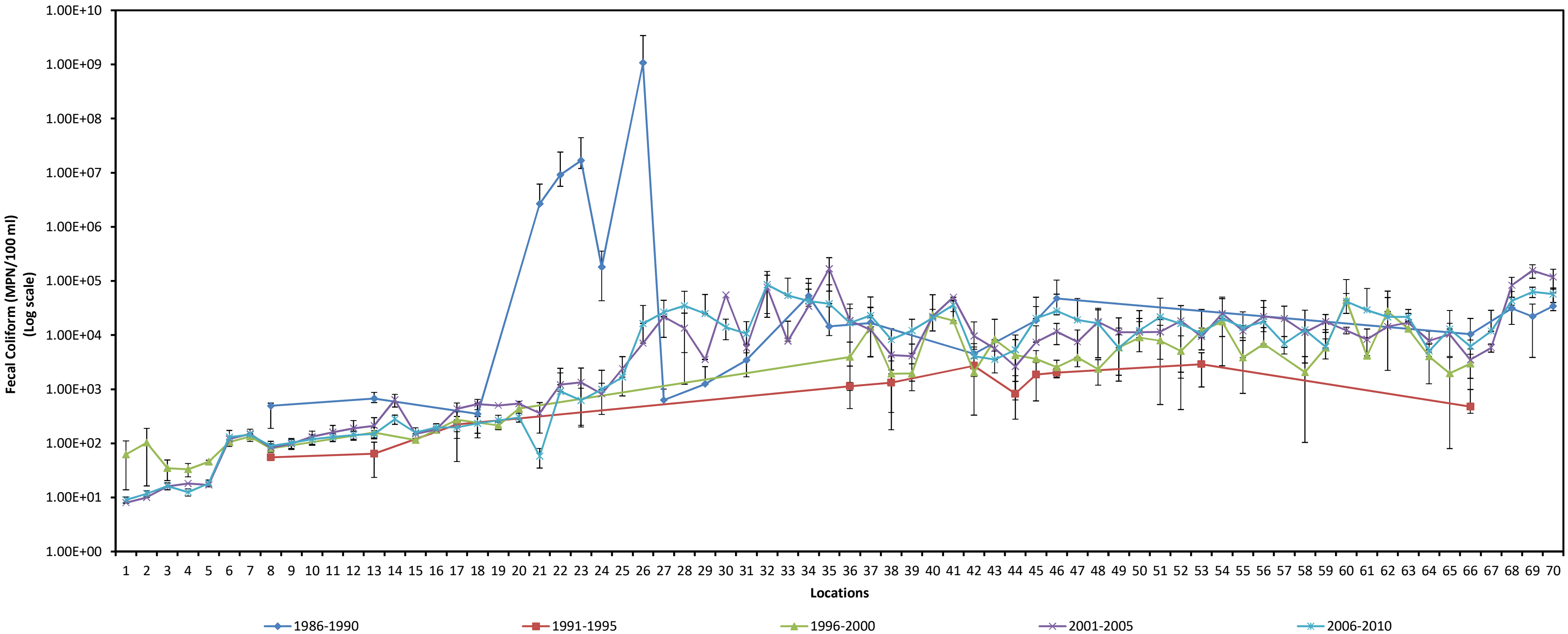

Figure 4(b): Variation in 5-year Average Fecal Coliform at Various Locations along the Ganga River during Wet Season

1	Uttarkashi u/s (Bhagirathi)	15	Bijnore u/s (Ganga)	29	D/s Deehaghat	43	Hajipur u/s (River Gandak)	57	Sultanganj d/s
2	Uttarkashi d/s (Bhagirathi)	16	Bijnore d/s (Ganga)	30	Vindhyachal, Pakka Ghat	44	Hajipur d/s (River Gandak)	58	Bhagalpur u/s
3	Devprayag u/s (Bhagirathi)	17	Garhmukteshwar u/s	31	Varanasi u/s	45	Patna u/s	59	Bhagalpur d/s
4	Devprayag u/s (Alaknanda)	18	Garhmukteshwar d/s	32	Dashashawmedh Ghat	46	Patna d/s	60	D/s Champanala
5	Devprayag d/s (Ganga)	19	Anoopshahr u/s (Ganga)	33	D/s at Kaithy	47	Fatuha u/s	61	Kahalgaon u/s
6	Ranipur u/s (Ganga)	20	Anoopshahr d/s (Ganga)	34	Near Malviya Bridge	48	Fatuha d/s	62	Kahalgaon d/s
7	Ranipur d/s (Ganga)	21	Fatehgarh u/s	35	Tarighat	49	Barh u/s	63	D/s NTPC Drain
8	Rishikesh u/s	22	Kannauj u/s (a/c with Ramganga & b/c with Kali)	36	Buxar u/s	50	Barh d/s	64	Sahebganj u/s
9	Rishikesh d/s	23	Kannauj d/s (a/c with Kali)	37	Buxar d/s	51	Mokama u/s	65	Sahebganj d/s
10	Haridwar u/s	24	Kanpur u/s (Bithoor)	38	Chapra u/s (Ghaghra)	52	Mokama d/s	66	Rajmahal d/s
11	Har-ki-Paudi	25	Kanpur d/s (Shuklaganj)	39	Chapra d/s (Chapra)	53	D/s Bata - McDowell	67	Berhampore (Middle)
12	Lalta Rao	26	Kanpur d/s (Jane Village)	40	Arrah u/s (River Gangi)	54	Munger u/s	68	Palta (Middle)
13	Dam Kothi	27	Allahbad u/s (Ujahni, Fatehpur)	41	Arrah d/s (River Gangi)	55	Munger d/s	69	Dakshineswar (Middle)
14	Mishrpur	28	Bathing Ghats at Sangam	42	Koliwar (River Sone)	56	Sultanganj u/s	70	Uluberia (Middle)

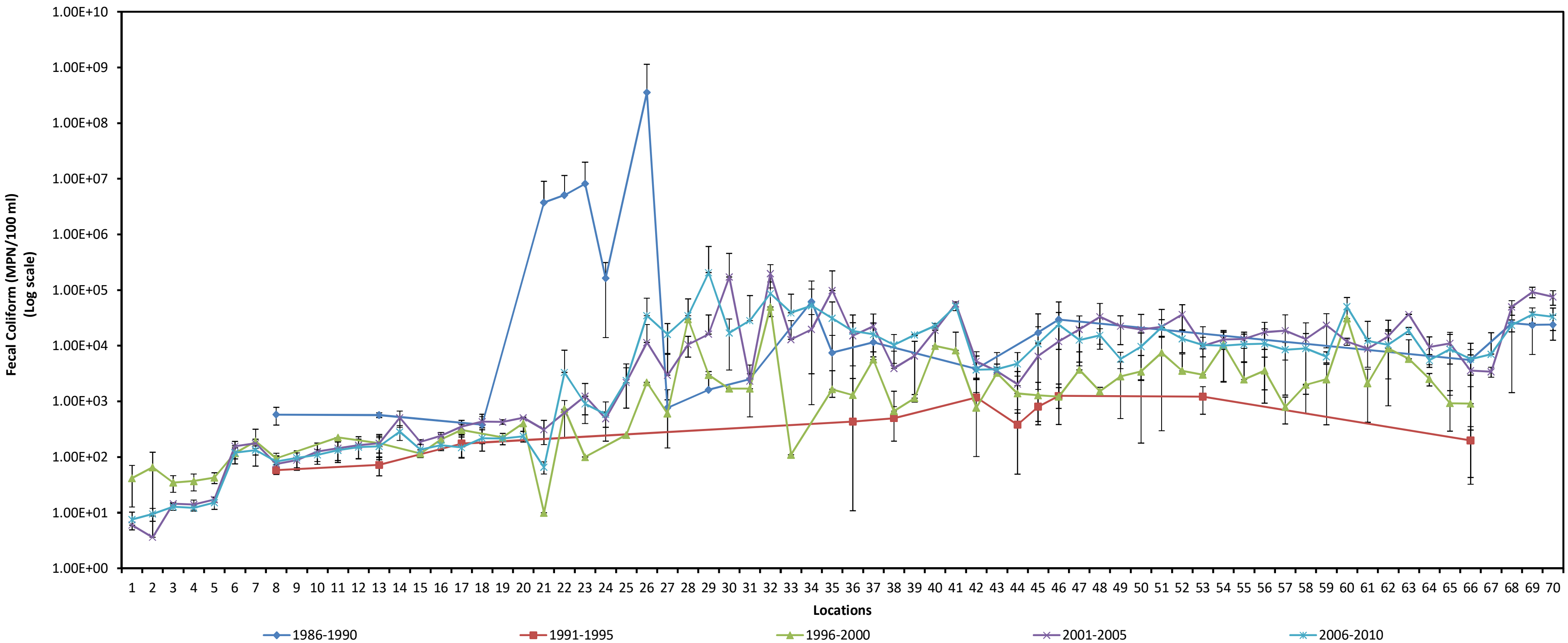

Figure 4(c): Variation in 5-year average Fecal Coliform at Various Locations along the Ganga River

1	Uttarkashi u/s (Bhagirathi)	15	Bijnore u/s (Ganga)	29	D/s Deehaghat	43	Hajipur u/s (River Gandak)	57	Sultanganj d/s
2	Uttarkashi d/s (Bhagirathi)	16	Bijnore d/s (Ganga)	30	Vindhyachal, Pakka Ghat	44	Hajipur d/s (River Gandak)	58	Bhagalpur u/s
3	Devprayag u/s (Bhagirathi)	17	Garhmukteshwar u/s	31	Varanasi u/s	45	Patna u/s	59	Bhagalpur d/s
4	Devprayag u/s (Alaknanda)	18	Garhmukteshwar d/s	32	Dashashawmedh Ghat	46	Patna d/s	60	D/s Champanala
5	Devprayag d/s (Ganga)	19	Anoopshahr u/s (Ganga)	33	D/s at Kaithy	47	Fatuha u/s	61	Kahalgaon u/s
6	Ranipur u/s (Ganga)	20	Anoopshahr d/s (Ganga)	34	Near Malviya Bridge	48	Fatuha d/s	62	Kahalgaon d/s
7	Ranipur d/s (Ganga)	21	Fatehgarh u/s	35	Tarighat	49	Barh u/s	63	D/s NTPC Drain
8	Rishikesh u/s	22	Kannauj u/s (a/c with Ramganga & b/c with Kali)	36	Buxar u/s	50	Barh d/s	64	Sahebganj u/s
9	Rishikesh d/s	23	Kannauj d/s (a/c with Kali)	37	Buxar d/s	51	Mokama u/s	65	Sahebganj d/s
10	Haridwar u/s	24	Kanpur u/s (Bithoor)	38	Chapra u/s (Ghaghra)	52	Mokama d/s	66	Rajmahal d/s
11	Har-ki-Paudi	25	Kanpur d/s (Shuklaganj)	39	Chapra d/s (Chapra)	53	D/s Bata - McDowell	67	Berhampore (Middle)
12	Lalta Rao	26	Kanpur d/s (Jane Village)	40	Arrah u/s (River Gangi)	54	Munger u/s	68	Palta (Middle)
13	Dam Kothi	27	Allahbad u/s (Ujahni, Fatehpur)	41	Arrah d/s (River Gangi)	55	Munger d/s	69	Dakshineswar (Middle)
14	Mishrpur	28	Bathing Ghats at Sangam	42	Koliwar (River Sone)	56	Sultanganj u/s	70	Uluberia (Middle)

3. Monsoon and River Flow Characteristics – Western Rivers *vis-à-vis* Indian Rivers

In order to further substantiate the argument for adapting tertiary-level of wastewater treatment, a comparative assessment of monsoon and river flow characteristics of western rivers *vis-à-vis*Indian rivers would be useful. It is important to note that the rivers in western countries are either snow-fed and/or rain-fed, whereas the Indian rivers are mainly rain-fed. Further insights on Indian sub-tropical climatic conditions suggest that much of the rainfall occurs during monsoon season (June to September) and a dramatic increase in river flow is observed. River flow declines sharply during post-monsoon season (October to November). With occasional bursts of winter rainfall due to retreat of the south-west monsoon, the river flow continues to decline during both winter (December to February) and summer (March to May) seasons.Figure5 presents the monthly rainfall and river flow plots for some of the western as well as Indian rivers in a typical year. It is evident from Figure5 that the western rivers are snow-fed and/or rain fed for at least 120 days in a year whereas, flows in Indian rivers last merely for 30-60 days during monsoon only.

The western countries generally treat wastewater up to tertiary level despite having adequate river flows for dilution of the discharged effluent. The Indian paradigmadopts treatment of wastewater up to secondary level only and promotes disposal of secondarily-treated wastewater effluent into rivers despite having lean season of river flows of about 10 months in a year. This results in further degradation of the water quality of the river, especially in terms of fecal contamination. Therefore, the case for adopting tertiary level treatment of wastewaterin India, the Ganga River basin in particular, finds further substantiation due to the prevailing climatic and monsoon characteristics and lean river flows during most of the time in a year.

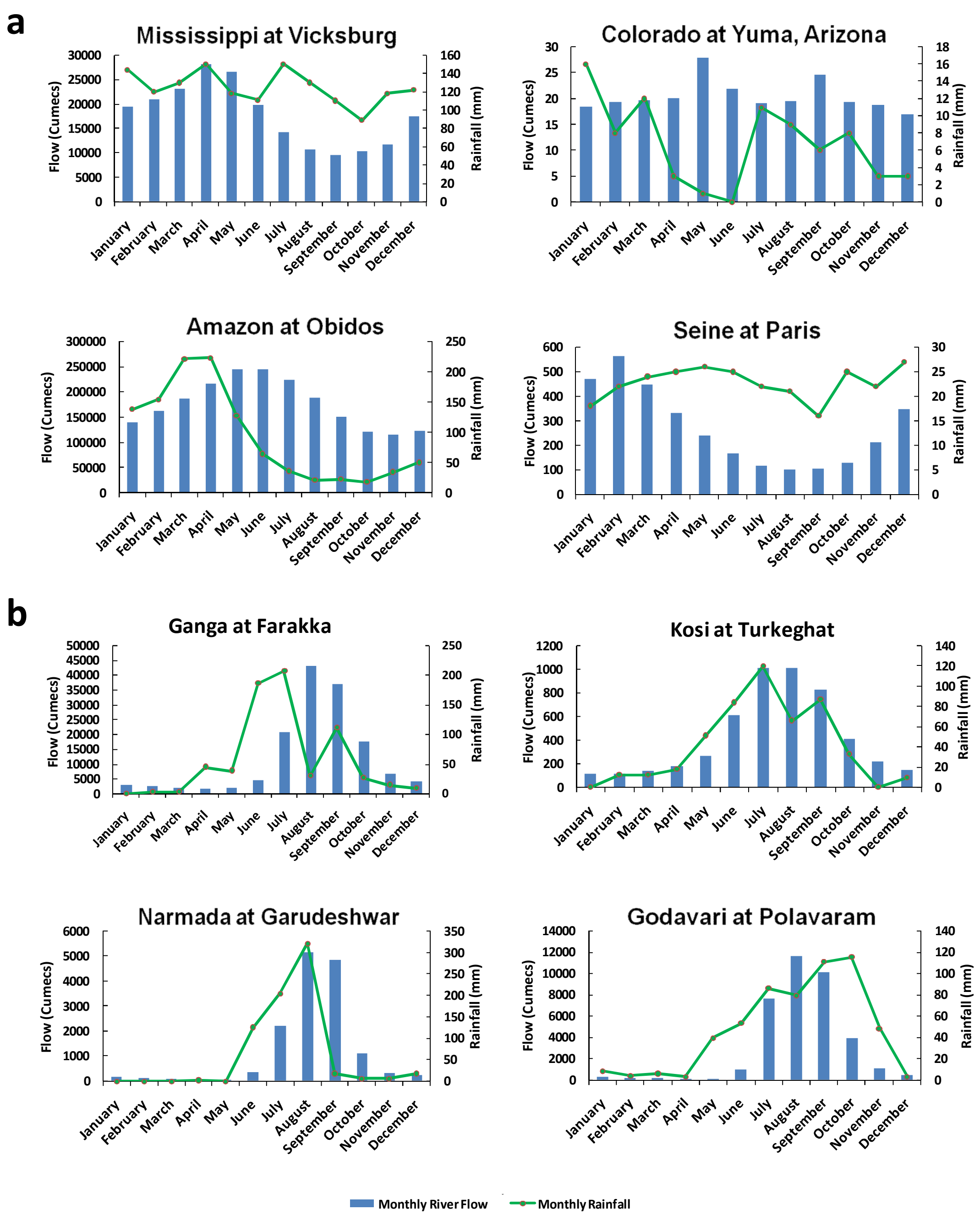

Figure 5: **Monthly Rainfall and River Flow in a Typical Year for (a) Western Rivers, and (b) Indian Rivers**

4. Microbial Pollution Removal Potential of Secondary-level Sewage Treatment Technologies

The water quality analysis, presented in the preceding section, suggests high levels of coliform across all the stretches of the Ganga River despite the implementation of the GAP. It has been widely argued and perceived that the increasing microbial pollution in the river is due to the inappropriate choice of secondary-level sewage treatment techniques, which are largely incapable of removing total and fecal coliforms. In order to substantiate the claim, the microbial removal potential of secondary-level sewage treatment techniques, such as activated sludge process (ASP) and its variants, trickling filter (TF), upflow anaerobic sludge blanket (UASB) reactor, waste stabilization pond (WSP) and its variants, sequencing batch reactor (SBR) and membrane bioreactor (MBR) has been reviewed based on a set of background documents viz. detailed project reports, pollution control board status reportsand research publications during the period of 1990-2011.The review mainly focuses on the pathogens removal performance of the full-scale installations treating sewage in the Ganga River basin as well as world-wide except the advanced treatment techniques like SBR and MBR. The microbial pollution removal potential of various secondary-level sewage treatment techniques is presented in Annexure II in detail and summarized in Table 1.

Table 1: Summary of Comparative Evaluation forPathogen Removal of Various Sewage Treatment Technologies

Parameter/Technology		ASP & Its Variants	TF	UASB	WSP	SBR	MBR
Total Coliform	Effluent Quality*	10^3-10^7	10^3-10^5	10^5-10^8	10^2-10^6	10^4-10^6	<2-10^2
	Log Removal	1.0-6.0	0.3-3.0	0.3-2.5	1.0-3.0	1.0-2.0	4.0-6.0
Fecal Coliform	Effluent Quality*	10^3-10^6	10^3-10^6	10^5-10^7	10^2-10^5	10^4-10^5	<2-10
	Log Removal	1.0-4.0	0.3-3.0	0.3-2.0	1.0-3.0	1.0-2.0	4.0-6.0
E. coli	Effluent Quality*	10^3-10^4	-	10^5-10^6	-	10^2-10^4	<2-10^2
	Log Removal	1.0-3.0	-	0.5-1.0	-	0.2-2.0	5.0-7.0
Fecal Streptococcus	Effluent Quality*	10^3-10^5	10^3-10^5	-	10^2-10^4	10^3-10^5	<2
	Log Removal	1.0-3.0	0-2.0	-	1.0-2.5	1.0-2.0	>5.0
Helminths Egg	Effluent Quality*	0-5	-	1-5	0-7	-	0-1
	% Removal	75-100	-	60-99	50-100	-	99-100

*Effluent quality is expressed in MPN/100 ml except Helminths egg (No./L)

It is evident from the review that the potential of pathogen removal inall conventional aerobic processes is more or less of the sameorder,and are largely incapable of pathogen removal. The pathogen removal in anaerobic processes (e.g. UASB) isgenerally 1-2 log lower than that of conventional aerobic processes. The advanced treatment techniques like MBR has shown to be highly efficient in removing pathogens. In general, the pathogen removal in the secondary level sewage treatment technologiesmainly depends on level of suspended solids, organic contents including humic substancesin effluent as a function of solids retention time (SRT) of the system. It has been demonstrated that secondarily-treated sewage effluent contains particle-associated microorganisms in general, particle-associated coliforms (PACs) in particular in form of solids carry over as a function of operating SRT of the biological system (Oliver and Cosgrove, 1975; Severin, 1980; Ho and Bohm, 1981; Qualls *et al*., 1983; Qualls and Johnson, 1985; Scheible, 1987; Cairns, 1993; Emerick and Darby, 1993; Darby *et al*., 1995; Emerick *et al*., 1999; 2000). The level of PACs in secondarily-treated sewage effluent decreaseswith longer SRTs and vice versa.

The wastewater interception, diversion and treatment schemes under the GAP essentially focused on the reduction in organic pollution, eliminate visible pollution and maintaining aesthetics rather than reduction in microbial pollution in the river. With the implementation of RAP, it was widely perceivedthat reduction in organic pollution load will have substantial positive impact on DO levels in theriver. Accordingly, the secondary wastewater treatment techniques adopted under RAP primarily targeted BOD reduction, whereas the reduction in total and fecal coliforms has been purely incidental. Such technologies adopted under the GAP were capable of treating sewage to conform the 'Class B' bathing standards of the designated best-use classification of inland surface waterfor DO and BOD only. Moreover, some of the technologies (e.g. UASB) favored under RAP has been proved to be largely ineffective in removal of total and fecal coliform and the effluent is highly unsuitable for further disinfection. Unlike other technologies, the UASB effluent carries high concentration ofhumic substances and therefore is highly unsuitable for subsequent disinfection. Additionally, consumption of chemicals used for disinfection of UASB effluent will be high as major portions of chemicalswould be used for satisfying BOD and instantaneous oxygen demand (IOD). Therefore, the secondary wastewater treatment techniques adopted under RAP are vastly ineffective in removing microbial pollution and the situation warrants adapting tertiary level of treatment of wastewater.

5. Techno-economic Assessment of Treatment Options for Disinfection of Secondary Sewage Effluent

The entire stretch of the Ganga River is subjected to increasing microbial pollution, in terms of total and fecal coliforms as demonstrated by the water quality analysis presented in the preceding section. Disinfection is a crucial unitin wastewater treatment chain to kill pathogenic organisms. Choosing a suitable disinfectant for a wastewater treatment system is dependent on the following criteria: (i) ability to penetrate and destroy infectious agents under normal operating conditions, (ii) effective in pathogens removal under all operating conditions irrespective of degree of pre-treatment employed, (iii) safe and easy in handling, storage, and shipping, (iv) absence of toxic residuals and mutagenic or carcinogenic compounds after disinfection, and (v) affordable capital and operation and maintenance costs. Therefore, the disinfection techniqueneeds to be selected based on the degree of pre-treatment employed and resulting effluent quality from the pre-treatment steps. Under GAP, several disinfection technologies such as chlorination and its variants, solar-based technique, ultraviolet (UV) radiation and ozonation have been employed to sanitize the secondarily-treatedsewage effluent. However, all these methods proved ineffective and resulted in degradation of water quality in terms of microbial pollution as these methods suffer from severe limitations in disinfecting the secondarily-treatedsewage effluent. In this context, a techno-economic appraisal of various disinfection options employed under GAP apart from peracetic acid (PAA) has been performed for the secondarily-treated sewage effluent. It is important to note that PAA is a promising new alternative disinfectant.Comprehensive analysis of technicalities like dosage, contact time, pathogens removal potential, effluent quality, process complexity, process reliability, environmental issues apart from economic considerations including capital cost, energy cost, operation and maintenance costs, reinvestment cost, treatment cost, life-cycle cost and land requirement of various disinfection options based on data obtained from various pilot-scale initiatives in the Ganga River basin and elsewhere in the world has been done. The comparative techno-economic evaluation has been summarized in Table 2 for various disinfection options. In order to provide additional factors for furtherevaluation, key parameters of the disinfection techniques have beenrelatively compared as shown in the Exhibit 1. The matrix attributes are ranked as Very Good, Good, Average or Poor recognizing that differences between processes are relative, and often, the result of commonly accepted observations.

The disinfection methods can generally be applied to the treated sewage effluent which meets certain quality requirements in terms of suspended solids, organic contents, etc. Various secondary level sewage treatment technologies produce effluent water containing varying level of suspended solids, organic contents including humic substances. Most of the disinfection techniques prove to be ineffective in sanitizing secondarily-treated sewage effluent due to the presence and interference of particle-associated microorganisms in general, particle-associated coliforms (PACs) in particular with the disinfection process (Oliver and Cosgrove, 1975; Severin, 1980; Ho and Bohm, 1981; Qualls *et al*., 1983; Qualls and Johnson, 1985; Scheible, 1987; Cairns, 1993; Emerick and Darby, 1993; Darby *et al*., 1995; Emerick *et al*., 1999; 2000). It has been demonstrated that the presence of PACs in effluent of secondary level sewage treatment processes is a function of prevailing solids retention time (SRT) adopted in the secondary sewage treatment processes with longer SRTs result in decrease of PACs in effluent and vice versa. Chlorination and its variants are most widely used disinfectant for secondarily-treated sewage effluent and efficient under wide range of operating conditions.It is evident from the analysis that chlorination has the least life-cycle cost and it offers a fairly high degreeof bactericidal efficiency. The technology is well established and robust and the chemicalagent is cheaply and easily available. However, chlorination mode of disinfection requires higher dosage if secondary effluent is partially-/non-nitrified and contains suspended and colloid solids, organic contents including humic substances and compounds with unsaturated bond by exerting additional and immediate chlorine demand (Sung, 1974; Metcalf and Eddy, 2003).Additionally, chlorination may require high dosages if used for anaerobic effluentsand effluents with high ammonical and organic nitrogen.Moreover, the chlorine dose for disinfection cannot be increased beyond a certain limit. If the chlorine dose applied is more than prescribed norm it is harmful to aquatic flora and fauna and requires dechlorination of effluent, an additional treatment step.The USEPA recommends for dechlorination to levels of total chlorineless than 0.05 mg/L in effluent discharged to receiving water bodies.Undesirable toxic effects of chlorination on receiving water biota have been vastly documented (Johnson and Jensen, 1986; TFWD, 1986; USEPA, 1986; Rein *et al*., 1992; Hijnen *et al*., 2006; WEF, 2010).Free and combined chlorine elicita toxic response on aquatic flora and fauna including fish,daphnids, oysters and copepods at extremely low concentrations (Johnson and Jensen, 1986; USEPA, 1986; Hijnen *et al*., 2006; WEF, 2010).Residual chlorine concentrations as low as 0.02 mg/L have reportedly induced toxic effects in aquatic flora and fauna (TFWD, 1986). Dechlorination may be effective in eliminating residual chlorine, but effluent toxicity on aquatic biota will remain due to the presence of less-active and more persistent combined residual chlorine in the dechlorinated effluent (Rein *et al*., 1992). The most acute problem related to chlorination of secondarily-treated sewage effluent is the formation of carcinogenic disinfection byproducts (DBPs). Various natural organic matters (NOMs) such as humic acid, fulvic acid, carbohydrate, proteins, etc. and other anthropogenic organic constituentspresent in the secondary effluent act as precursors and react with chlorine in the disinfection step to form DBPs, viz. trihalomethane (THM), N-nitrosodimethylamine (NDMA) and haloacetic acids (HAAs), which are considered as carcinogen (Singer, 1999).Both free and combinedresidual chlorine can produce DBPs that are carcinogenic to humans and harmful to aquatic biota of receiving streams (WEF, 2010). The DBP formation is more acute problem for chlorination of anaerobic effluents like UASB effluent which contains much higher fraction of humic substances which act as precursors. Under most of the circumstances, dechlorination has been shown to be ineffective in eliminating DBPs in chlorinated effluent (WEF, 2010).

Similarly, solar radiation and UV technology are ineffective in disinfecting the secondarily-treated sewage effluent. Disinfection of effluent using solar irradiation is highly dependent of prevailing climatic conditions and therefore microorganism inactivation efficiency fluctuates. Methylene blue, a chemical is generally needed to add to the effluent to increase the light absorption capacity for effective disinfection. An alternative source light energy is required for night operation of the solar disinfection. Many organic and inorganic constituents, viz. suspended and colloidal solids, dissolved organic carbon, humic substances, iron, nitrate and particle-associated microorganisms present in the secondary effluent can absorb and/or scatter solar or UV energy, thus reducing the transmittance of the water. This results in a reduced transmittance (50 to 60% reduction) of solar and UV irradiation and consequently lowers the disinfection efficiency. It has been shown that UV disinfection of effluent from pond treatment system becomes ineffective as a result of low transmittance (often as low as 40 to 50%) during algal blooms and solids washout events (WEF, 2010). The presence of turbidity and SS in secondary effluent and size distribution of SS generally affect the solar and UV irradiation that microorganisms receive as SS can absorb and scatter visible and UV light. Presence of SS and particulates in secondary effluent interferes with the solar and UV disinfection processes to a greater degree as compared to the chemical-assisted disinfection systems. Particulates present in the secondary effluent can shield microorganisms from damaging effects of solar and UV irradiation and thereby reducing the disinfection efficiency as some organisms can become embedded within, or absorbed upon the particles themselves (Darby *et al*., 1993). It has been also demonstrated that organisms can sometimes repair and reverse the destructive effects of UV when applied at low doses (WEF, 2010). The warm temperatures produced by UV lamps promote the precipitation of dissolved organic and inorganic constituents, mainly iron and other metals apart from oil, grease, suspended and colloidal solids present in the effluent and subsequently form an amorphous film on the surface of the quartz sleeves causing the lamp fouling when the lamps are placed directly within the wastewater stream (Mann and Cramer, 1992; Blatchley *et al*., 1996). Secondary effluent with high hardness also causes lamp fouling and thereby reducing the disinfection efficiency of UV technology. Thus, it has been widely suggested that secondary effluent requires an additional treatment step to reduce suspended and colloidal solids and turbidity before applying UV irradiation for disinfection (Andreakis *et al*., 1999; Gómez *et al*., 2007).

Disinfection of secondary effluent employing ozonation proves to be inefficient mainly due to the presence of humic substances. With the increase in humic acid in the effluent, a decrease in reaction rate and subsequently decrease in disinfection efficiency of ozone has been shown (Xiong andGraham, 1992).Ozone also increases the biodegradability of non-biodegradable matter in secondarily-treated wastewater,which can result in regrowth problems (Servais *et al*., 1994).Ozone produces lowmolecular weight, polar and hydrophilic by-productssuch as carboxylic acids,aldehydes, ketones and keto acids, which are readilybiodegradable resulting in the regrowth potential in thereceiving waters (Kitis, 2004). Additionally, ozone mode of disinfection involves comparatively much higher energy requirement and energy cost.

Major limitations associatedwith peracetic acid (PAA) disinfection of secondarily-treated sewage effluent are the potential microbialregrowth and increase in effluent organic loaddue to the presence of residual acetic acid in the disinfected effluent (Lefevre*et al*., 1992; Sanchez-Ruiz et al., 1995; Lazarova *et al*., 1998). It has been shown that the disinfection efficiency of PAA decreases with increasing suspended solids (SS) andbiochemical oxygen demand (BOD) (Meyer, 1976; Sanchez-Ruiz *et al*., 1995; Colgan and Gehr, 2001; Stampi *et al*., 2001) of wastewater to be disinfected.PAA becomes ineffective as disinfectant while secondarily-treated effluent SS are more than 50 mg/L (Lefevre *et al*., 1992; Lazarova *et al*., 1998). Although PAA is considered to decompose to harmlessproducts and to form little to no by-products that are toxic ormutagenic, the possibility that it could form DBPs cannot becompletely ignored (Crathorne *et al*., 1991; Kitis, 2004).It has been shown that, under certain conditions like high PAAdosages, sufficient contact times, and adequate concentration of organic and mineralconstituents in the secondary effluent, formation of halogenated DBPlike aldehydesis a problem(Crathorne *et al*., 1991).Another disadvantage of the use of PAA as disinfectant is its highcost, which is partly as result of limited production capacity worldwide (Kitis, 2004).

It is imperative from the comprehensive techno-economic appraisal that all these disinfection techniques suffer from several limitations and are more or less ineffective in disinfecting the secondarily-treated sewage effluent.The present Indian paradigm of wastewater treatment employing primary and secondary treatment techniques is vastly inadequate and ineffective and hence any attempt to adopt disinfection of secondarily-treated sewage effluent is bound to be unsatisfactory.Therefore, the comprehensive techno-economic appraisal and the limitations of various techniques for disinfection of secondary sewage effluent provide more substance to the argument for adapting tertiary level of wastewater treatment in India, the Ganga River basin in particular.

Table 2: Comparative Evaluation of Various Technologies for Disinfection of Secondary Sewage Effluent

S No.	Assessment Parameter/Technology	Chlorination & Its Variants	Solar	UV	Ozone	PAA
1	**Contact Time**					
	Nominal Range (min.)	1-150	20-60	0.1-0.7	0.25-60	15-120
	Average Range (min.)	30-60	30-40	0.2-0.5	10-20	50-70
2	**Disinfection Dose**					
	Nominal Range	6-20 mg/L	2400-7200 mW-s/cm^2	2-200 mW-s/cm^2	3-20 mg/L	0.6-100 mg/L
	Average Range	10-15 mg/L	3600-4800 mW-s/cm^2	30-50 mW-s/cm^2	5-10 mg/L	5-20 mg/L
3	**Inactivation Efficiency**					
	Effluent Fecal Coliform, *MPN/100 ml*	<1000	<1000	<200	<50	<1000
	Fecal Coliform, *log unit*	upto 4<5	upto 2<3	upto 4<5	upto 4<5	upto 4<5
4	**Average Capital Cost,** *RsLacs/MLD*	**16.4**	**71.8**	**30.8**	**41.0**	**10.0**
	Civil Works, *% of capital costs*	60	60	40	35	30
	E&M Works, *% of capital costs*	40	40	60	65	70
	Average Area Requirement, *m^2 /MLD*	25	160	15	10	30
5	**Energy Costs**					
	Total Power Requirement,*kWh/ MLD (avg)*	**18.8**	**33.6**	**63.9**	**246.2**	**15.5**
	Daily Power Cost, *(@Rs 4.0/KWhr), Rs/MLD/hr*	3.10	5.60	10.70	41.00	2.60
	Yearly Power Cost , *RsLacs PA/MLD*	0.27	0.49	0.93	3.59	0.23
6	**Annual Operation & Maintenance Costs,** *Rs Lacs/MLD*	**3.7**	**9.0**	**8.3**	**7.4**	**22.2**
	Avg. Land Cost Assumed, *Rs Lacs/m^2*	0.01	0.01	0.01	0.01	0.01
	Unit Land Cost, *Rs Lacs/MLD*	0.25	1.60	0.15	0.10	0.30
	Unit Capital Cost including Land Cost, *Rs Lacs/MLD*	16.65	73.40	30.95	41.10	10.30
	Rate of compound interest, *r (adopted), % per year*	10	10	10	10	10
7	**Treatment Cost^,** *Rs/KL*	**1.61**	**5.05**	**3.38**	**3.50**	**6.44**
8	**Unit Life Cycle Costs for 15 Years,***Rs Lacs/MLD*	**44.8**	**141.9**	**94.1**	**97.4**	**179.2**

^ excluding land cost

Exhibit 1: Assessment of Technology Options for Disinfection of Secondary Sewage Effluent

Criteria/Technology	Chlorination & Its Variants	Solar	UV	Ozone	PAA
Degree of Pre-treatment Required	Low	Very High	High	High	Medium
Relative Complexity of Technology	Low	Low	Medium	Very High	Low
Performance in Terms of Inactivation Efficiency					
Bactericidal	High	High	Very High	Very High	High
Virucidal	Medium	Low	Very High	Very High	Low
Cysticidal	Low	Low	Low	High	Low
Potential of Persistent Residual (Potential of No Regrowth)	High	Low	High	High	Low
Potential of Meeting the RAPs Coliform Standards	High	Medium	Very High	Very High	High
Performance Reliability	Very High	Medium	High	Very High	Low
Environmental Impacts					
Potential of Hazardous By-products Formation	Very High	Low	Low	Medium	Low
Potential of Posing Fish Toxicity	High	Low	Low	Low	Medium
Potential of Creating Corrosion	High	Low	Low	Very High	Medium
Safety Concerns					
Potential of Low Level of On-site Safety Risks	Low	Very High	Very High	Medium	High
Potential of Low Level of Safety Risks during Transportation	Low	Very High	Very High	High	Medium
Potential of Low Level of Safety Risks to STP Staff/Operator	Low	Very High	High	Medium	Medium
Potential of No Adverse Impacts on Surrounding Community	Low	Very High	Very High	High	High
Potential of Low Energy Requirement	Very High	High	Medium	Low	Very High
Potential of Low Land Requirement	Medium	Low	High	Very High	Medium
Potential of Low Capital Cost	Very High	Low	High	Medium	Very High
Potential of Low Recurring Cost	Medium	Very High	High	Medium	Low
Potential of Low Reinvestment Cost	High	Low	Low	High	High
Potential of Low Level of Skill in O&M	Very High	High	High	Medium	High
Track Record	Very High	Medium	High	Very High	Low
Typical Capacity Range, MLD	All Flows	Smaller	Smaller - Medium	Medium - Larger	All Flows

Low	Medium	High	Very High

6. Concluding Remarks and Recommendations

Based on the comprehensive analysis of general flow pattern and water quality of the Ganga River, microbial pollution removal potential of secondary-level sewage treatment technologies and the performance of commonly adopted treatment technologies for disinfection of secondary sewage effluent, following inferences and general recommendations can be made:

- The water quality analysis of some routinely monitored parameters (DO, BOD_5, total and fecal coliforms) in the Ganga River suggests that the river is subjected to increasing microbial pollution despite the implementation of intervention schemes and regulatory mechanisms under the GAP. The situation gets further aggravated by the low river flows during most of the periods in a yeardue to the prevailing climatic and monsoon characteristics and results in further degradation of the water quality of the river in terms of microbial pollution (fecal contamination).
- The primary goals of the wastewater treatment schemes under the GAP seem to be the reduction in organic pollution, eliminatevisible pollution and maintaining aesthetics rather than reduction in microbial pollution in the river. The secondary wastewater treatment techniques adopted under RAP primarily target BOD reduction, whereas the reduction in total and fecal coliforms has been purely incidental. Some of the technologies (e.g. UASB) favored under RAPhas been proved to beineffective in removal of total and fecal coliforms and the effluent is highly unsuitable for further disinfection. Hence, the present Indian paradigm of wastewater treatment employing primary and secondary treatment techniques is vastly ineffective and hence any attempt to adopt disinfection of secondarily-treated sewage effluent is bound to be unsatisfactory.
- The comprehensive analysis presented in the report, therefore, clearly suggest and point out towards adapting the tertiary level of wastewater treatment in India, the Ganga River basin in particular.Zero discharge municipality/city concept (i.e. completely prohibit the disposal of treated or untreated wastewater into surface water bodies) needs to be implemented in the Ganga Basin by recycling and reusing tertiary-treated effluentfor 'non-potable, non-human contact' uses within the municipality/city.
- The combination of two or more disinfection processes in the treatment chain should be adopted as multiple disinfection processes in series can provide an additional margin of safety through complementary inactivation of various types of pathogens. Ozonation followed by UV treatment and/or chlorination can be adopted to enhance the robustness of the treatment chain with the multiple barrier approach to disinfection.

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Annexure I

Table A1.1: Conformation of Ganga River Water Quality with the Designated Best-use Classification of Inland Surface Water (CPCB) during Dry Season for the Period 1986 – 2010

S. No.	Location	Confidence Level (%) of Observations Conforming the Designated Best-use Classification of Inland Surface Water (CPCB)								
		Dissolved Oxygen (DO)			Biochemical Oxygen Demand (BOD_5)			Total Coliform (TC)		
		A (≥6 mg/L)	B (≥5 mg/L)	C (≥4 mg/L)	A (≤2 mg/L)	B (≤3 mg/L)	C (≤3 mg/L)	A (≤5.00E+01 MPN/100ml)	B (≤5.00E+02 MPN/100ml)	C (≤5.00E+03 MPN/100ml)
1	Uttarkashi u/s (Bhagirathi)	100	100	100	100	100	100	99.9	100	100
2	Uttarkashi d/s (Bhagirathi)	100	100	100	100	100	100	69.2	100	100
3	Devprayag u/s (Bhagirathi)	100	100	100	100	100	100	50.0	100	100
4	Devprayag u/s (Alaknanda)	100	100	100	100	100	100	50.0	100	100
5	Devprayag d/s (Ganga)	100	100	100	100	100	100	21.2	100	100
6	Ranipur u/s (Ganga)	100	100	100	100	100	100	0.03	100	100
7	Ranipur d/s (Ganga)	100	100	100	100	100	100	0.03	100	100
8	Rishikesh u/s	100	100	100	100	100	100	0.03	100	100
9	Rishikesh d/s	100	100	100	100	100	100	0.03	100	100
10	Haridwar u/s	100	100	100	100	100	100	0.03	100	100
11	Har-ki-Paudi	100	100	100	100	100	100	0.03	100	100
12	Lalta Rao	100	100	100	100	100	100	0.03	100	100
13	Dam Kothi	100	100	100	100	100	100	0.03	88.5	100
14	Mishrpur	100	100	100	0.1	100	100	0.03	0.03	100
15	Bijnore u/s (Ganga)	100	100	100	100	100	100	0.03	100	100
16	Bijnore d/s (Ganga)	100	100	100	99.5	100	100	0.03	94.5	100
17	Garhmukteshwar u/s	100	100	100	4.5	100	100	0.03	0.1	100
18	Garhmukteshwar d/s	100	100	100	100	100	100	0.03	1.4	100
19	Anoopshahr u/s (Ganga)	100	100	100	38.2	100	100	0.03	46.0	100
20	Anoopshahr d/s (Ganga)	100	100	100	8.1	100	100	0.03	0.2	100
21	Fatehgarh u/s	100	100	100	0.03	91.9	91.9	5.5	5.5	5.5
22	Kannauj u/s (a/c with Ramganga & b/c with Kali)	100	100	100	0.03	0.03	0.03	0.5	0.5	0.5
23	Kannauj d/s (a/c with Kali)	100	100	100	0.03	0.03	0.03	0.5	0.5	0.5
24	Kanpur u/s (Bithoor)	100	100	100	0.03	1.8	1.8	2.9	2.9	3.6
25	Kanpur d/s (Shuklaganj)	100	100	100	0.03	0.03	0.03	0.03	0.03	0.03
26	Kanpur d/s (Jane Village)	54.0	100	100	0.03	0.03	0.03	5.5	5.5	5.5
27	Allahbad u/s (Ujahni, Fatehpur)	100	100	100	0.03	0.03	0.03	0.03	0.03	11.5
28	Bathing Ghats at Sangam	100	100	100	0.03	0.1	0.1	0.3	0.3	3.6
29	D/s Deehaghat	100	100	100	0.03	0.1	0.1	0.1	0.1	5.5
30	Vindhyachal, Pakka Ghat	100	100	100	0.03	65.5	65.5	0.03	0.05	6.7
31	Varanasi u/s	100	100	100	0.03	3.6	3.6	0.03	0.03	9.7
32	Dashashawmedh Ghat	100	100	100	0.03	0.8	0.8	0.03	0.03	0.03
33	D/s at Kaithy	99.9	100	100	0.03	1.1	1.1	0.03	0.03	0.05
34	Near Malviya Bridge	100	100	100	0.03	0.03	0.03	0.05	0.05	0.1

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S. No.	Location	Confidence Level (%) of Observations Conforming the Designated Best-use Classification of Inland Surface Water (CPCB)								
		Dissolved Oxygen (DO)			Biochemical Oxygen Demand (BOD_5)			Total Coliform (TC)		
		A (≥6 mg/L)	B (≥5 mg/L)	C (≥4 mg/L)	A (≤2 mg/L)	B (≤3 mg/L)	C (≤3 mg/L)	A (≤5.00E+01 MPN/100ml)	B (≤5.00E+02 MPN/100ml)	C (≤5.00E+03 MPN/100ml)
35	Tarighat	100	100	100	0.03	0.03	0.03	0.03	0.03	0.3
36	Buxar u/s	100	100	100	97.7	100	100	0.03	0.03	0.03
37	Buxar d/s	100	100	100	99.9	100	100	0.03	0.03	0.03
38	Chapra u/s (Ghaghra)	100	100	100	100	100	100	0.03	0.03	2.3
39	Chapra d/s (Chapra)	100	100	100	9.7	100	100	0.03	0.03	0.03
40	Arrah u/s (River Gangi)	100	100	100	2.9	100	100	0.03	0.03	0.03
41	Arrah d/s (River Gangi)	21.2	98.2	100	0.03	0.03	0.03	0.03	0.03	0.03
42	Koliwar (River Sone)	100	100	100	100	100	100	0.03	0.03	4.5
43	Hajipur u/s (River Gandak)	100	100	100	100	100	100	0.03	0.03	0.03
44	Hajipur d/s (River Gandak)	100	100	100	100	100	100	0.03	0.03	13.6
45	Patna u/s	100	100	100	100	100	100	2.3	2.3	2.9
46	Patna d/s	100	100	100	99.9	100	100	4.5	5.5	5.5
47	Fatuha u/s	100	100	100	93.3	100	100	0.03	0.03	0.03
48	Fatuha d/s	100	100	100	93.3	100	100	0.03	0.03	0.03
49	Barh u/s	100	100	100	46.0	100	100	0.03	0.03	0.03
50	Barh d/s	100	100	100	98.2	100	100	0.03	0.03	0.1
51	Mokama u/s	100	100	100	2.9	100	100	0.03	0.03	0.03
52	Mokama d/s	100	100	100	69.2	100	100	0.03	0.03	0.03
53	D/s Bata - McDowell	100	100	100	99.9	100	100	0.03	0.03	0.03
54	Munger u/s	100	100	100	100	100	100	0.03	0.03	0.03
55	Munger d/s	100	100	100	100	100	100	0.03	0.03	0.03
56	Sultanganj u/s	100	100	100	100	100	100	0.03	0.03	0.03
57	Sultanganj d/s	100	100	100	100	100	100	0.03	0.03	0.03
58	Bhagalpur u/s	100	100	100	100	100	100	0.03	0.03	0.03
59	Bhagalpur d/s	100	100	100	99.9	100	100	0.03	0.03	0.03
60	D/s Champanala	18.4	98.6	100	0.03	0.03	0.03	0.03	0.03	0.03
61	Kahalgaon u/s	100	100	100	100	100	100	0.05	0.1	0.6
62	Kahalgaon d/s	100	100	100	100	100	100	0.03	0.03	0.03
63	D/s NTPC Drain	100	100	100	99.4	100	100	0.8	0.8	3.6
64	Sahebganj u/s	100	100	100	100	100	100	0.03	0.03	0.03
65	Sahebganj d/s	100	100	100	100	100	100	0.03	0.03	0.03
66	Rajmahal d/s	100	100	100	100	100	100	0.03	0.03	4.5
67	Berhampore (Middle)	100	100	100	100	100	100	0.03	0.03	15.9
68	Palta (Middle)	100	100	100	65.5	100	100	0.03	0.03	0.03
69	Dakshineswar (Middle)	100	100	100	1.1	100	100	0.03	0.03	0.03
70	Uluberia (Middle)	100	100	100	42.1	100	100	0.03	0.03	0.03

Table A1.2: Conformation of Ganga River Water Quality with the Designated Best-use Classification of Inland Surface Water (CPCB) during Wet Season for the Period 1986 – 2010

S. No.	Location	Confidence Level (%) of Observations Conforming the Designated Best-use Classification of Inland Surface Water (CPCB)								
		Dissolved Oxygen (DO)			Biochemical Oxygen Demand (BOD_5)			Total Coliform (TC)		
		A (≥6 mg/L)	B (≥5 mg/L)	C (≥4 mg/L)	A (≤2 mg/L)	B (≤3 mg/L)	C (≤3 mg/L)	A (≤5.00E+01 MPN/100ml)	B (≤5.00E+02 MPN/100ml)	C (≤5.00E+03 MPN/100ml)
1	Uttarkashi u/s (Bhagirathi)	100	100	100	100	100	100	9.7	100	100
2	Uttarkashi d/s (Bhagirathi)	100	100	100	100	100	100	5.5	100	100
3	Devprayag u/s (Bhagirathi)	100	100	100	100	100	100	34.5	100	100
4	Devprayag u/s (Alaknanda)	100	100	100	100	100	100	30.9	100	100
5	Devprayag d/s (Ganga)	100	100	100	100	100	100	21.2	100	100
6	Ranipur u/s (Ganga)	100	100	100	100	100	100	0.03	100	100
7	Ranipur d/s (Ganga)	100	100	100	100	100	100	0.03	100	100
8	Rishikesh u/s	100	100	100	78.8	100	100	0.03	100	100
9	Rishikesh d/s	100	100	100	100	100	100	0.03	100	100
10	Haridwar u/s	100	100	100	100	100	100	0.03	100	100
11	Har-ki-Paudi	100	100	100	100	100	100	0.03	100	100
12	Lalta Rao	100	100	100	100	100	100	0.03	100	100
13	Dam Kothi	100	100	100	69.2	100	100	0.03	65.5	100
14	Mishrpur	100	100	100	0.03	57.9	57.9	0.03	0.03	100
15	Bijnore u/s (Ganga)	100	100	100	100	100	100	0.03	100	100
16	Bijnore d/s (Ganga)	100	100	100	98.9	100	100	0.03	100	100
17	Garhmukteshwar u/s	100	100	100	0.3	100	100	0.03	0.03	100
18	Garhmukteshwar d/s	100	100	100	0.03	100	100	0.03	0.03	100
19	Anoopshahr u/s (Ganga)	100	100	100	90.3	100	100	0.03	18.4	100
20	Anoopshahr d/s (Ganga)	100	100	100	15.9	100	100	0.03	0.1	100
21	Fatehgarh u/s	100	100	100	78.8	100	100	4.5	4.5	5.5
22	Kannauj u/s (a/c with Ramganga & b/c with Kali)	100	100	100	0.3	84.1	84.1	9.7	9.7	9.7
23	Kannauj d/s (a/c with Kali)	100	100	100	2.9	99.7	99.7	5.5	5.5	5.5
24	Kanpur u/s (Bithoor)	100	100	100	86.4	100	100	4.5	4.5	5.5
25	Kanpur d/s (Shuklaganj)	91.9	100	100	0.3	97.1	97.1	0.03	0.03	0.3
26	Kanpur d/s (Jane Village)	97.7	100	100	0.03	0.03	0.03	15.9	15.9	15.9
27	Allahbad u/s (Ujahni, Fatehpur)	100	100	100	0.03	5.5	5.5	0.03	0.05	2.3
28	Bathing Ghats at Sangam	100	100	100	9.7	98.9	98.9	2.9	2.9	5.5
29	D/s Deehaghat	100	100	100	0.8	38.2	38.2	0.03	0.03	0.1
30	Vindhyachal, Pakka Ghat	99.8	100	100	9.7	98.2	98.2	2.3	2.3	3.6
31	Varanasi u/s	100	100	100	8.1	72.6	72.6	8.1	8.1	11.5
32	Dashashawmedh Ghat	72.6	100	100	4.5	38.2	38.2	0.1	0.1	0.1
33	D/s at Kaithy	100	100	100	46.0	100	100	0.1	0.1	0.3
34	Near Malviya Bridge	100	100	100	0.2	13.6	13.6	0.03	0.03	0.05
35	Tarighat	100	100	100	0.5	8.1	8.1	0.8	0.8	2.9

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S No.	Location	Confidence Level (%) of Observations Conforming the Designated Best-use Classification of Inland Surface Water (CPCB)								
		Dissolved Oxygen (DO)			Biochemical Oxygen Demand (BOD_5)			Total Coliform (TC)		
		A (≥6 mg/L)	B (≥5 mg/L)	C (≥4 mg/L)	A (≤2 mg/L)	B (≤3 mg/L)	C (≤3 mg/L)	A (≤5.00E+01 MPN/100ml)	B (≤5.00E+02 MPN/100ml)	C (≤5.00E+03 MPN/100ml)
36	Buxar u/s	90.3	100	100	100	100	100	0.03	0.03	0.03
37	Buxar d/s	100	100	100	99.9	100	100	0.03	0.03	0.03
38	Chapra u/s (Ghaghra)	100	100	100	100	100	100	0.03	0.03	0.03
39	Chapra d/s (Chapra)	84.1	100	100	100	100	100	0.03	0.03	0.03
40	Arrah u/s (River Gangi)	61.8	100	100	1.8	99.2	99.2	0.03	0.03	0.03
41	Arrah d/s (River Gangi)	0.03	42.1	100	0.03	2.9	2.9	0.03	0.03	0.03
42	Koliwar (River Sone)	100	100	100	100	100	100	0.03	0.03	0.03
43	Hajipur u/s (River Gandak)	99.7	100	100	100	100	100	0.05	0.1	0.6
44	Hajipur d/s (River Gandak)	100	100	100	100	100	100	0.03	0.03	0.2
45	Patna u/s	100	100	100	100	100	100	0.03	0.03	0.03
46	Patna d/s	93.3	99.2	100	99.9	100	100	0.03	0.03	0.03
47	Fatuha u/s	61.8	100	100	100	100	100	0.03	0.03	0.03
48	Fatuha d/s	65.5	100	100	99.5	100	100	0.03	0.03	0.03
49	Barh u/s	97.7	100	100	100	100	100	0.2	0.3	0.8
50	Barh d/s	34.5	100	100	100	100	100	0.03	0.03	1.4
51	Mokama u/s	86.4	100	100	57.9	100	100	0.03	0.03	0.03
52	Mokama d/s	93.3	100	100	100	100	100	0.03	0.03	0.03
53	D/s Bata - McDowell	100	100	100	100	100	100	0.03	0.03	0.03
54	Munger u/s	98.6	100	100	100	100	100	0.03	0.03	0.1
55	Munger d/s	81.6	100	100	100	100	100	0.03	0.03	0.03
56	Sultanganj u/s	91.9	100	100	100	100	100	0.03	0.03	0.03
57	Sultanganj d/s	75.8	100	100	100	100	100	0.05	0.1	0.2
58	Bhagalpur u/s	99.4	100	100	100	100	100	0.03	0.03	0.1
59	Bhagalpur d/s	93.3	100	100	100	100	100	0.2	0.2	0.8
60	D/s Champanala	21.2	99.5	100	0.8	57.9	57.9	0.03	0.03	0.03
61	Kahalgaon u/s	100	100	100	100	100	100	0.03	0.03	0.03
62	Kahalgaon d/s	99.9	100	100	100	100	100	0.03	0.03	0.1
63	D/s NTPC Drain	100	100	100	100	100	100	0.6	0.6	1.1
64	Sahebganj u/s	24.5	100	100	100	100	100	0.1	0.1	0.5
65	Sahebganj d/s	50.0	100	100	100	100	100	0.2	0.2	0.8
66	Rajmahal d/s	100	100	100	100	100	100	0.03	0.03	0.03
67	Berhampore (Middle)	100	100	100	99.5	100	100	0.03	0.03	0.03
68	Palta (Middle)	65.5	100	100	98.6	100	100	0.03	0.03	0.03
69	Dakshineswar (Middle)	34.5	100	100	50.0	100	100	0.03	0.03	0.03
70	Uluberia (Middle)	72.6	91.9	98.6	97.7	100	100	0.03	0.03	0.03

Table A1.3: Overall Conformation of Ganga River Water Quality with the Designated Best-use Classification of Inland Surface Water (CPCB) for the Period 1986 – 2010

S. No.	Location	Confidence Level (%) of Observations Conforming the Designated Best-use Classification of Inland Surface Water (CPCB)								
		Dissolved Oxygen (DO)			Biochemical Oxygen Demand (BOD_5)			Total Coliform (TC)		
		A (≥6 mg/L)	B (≥5 mg/L)	C (≥4 mg/L)	A (≤2 mg/L)	B (≤3 mg/L)	C (≤3 mg/L)	A (≤5.00E+01 MPN/100ml)	B (≤5.00E+02 MPN/100ml)	C (≤5.00E+03 MPN/100ml)
1	Uttarkashi u/s (Bhagirathi)	100	100	100	100	100	100	54.0	100	100
2	Uttarkashi d/s (Bhagirathi)	100	100	100	100	100	100	13.6	100	100
3	Devprayag u/s (Bhagirathi)	100	100	100	100	100	100	38.2	100	100
4	Devprayag u/s (Alaknanda)	100	100	100	100	100	100	38.2	100	100
5	Devprayag d/s (Ganga)	100	100	100	100	100	100	13.6	100	100
6	Ranipur u/s (Ganga)	100	100	100	100	100	100	0.03	100	100
7	Ranipur d/s (Ganga)	100	100	100	100	100	100	0.03	100	100
8	Rishikesh u/s	100	100	100	100	100	100	0.03	100	100
9	Rishikesh d/s	100	100	100	100	100	100	0.03	100	100
10	Haridwar u/s	100	100	100	100	100	100	0.03	100	100
11	Har-ki-Paudi	100	100	100	100	100	100	0.03	100	100
12	Lalta Rao	100	100	100	100	100	100	0.03	100	100
13	Dam Kothi	100	100	100	100	100	100	0.03	88.5	100
14	Mishrpur	100	100	100	0.03	100	100	0.03	0.03	100
15	Bijnore u/s (Ganga)	100	100	100	100	100	100	0.03	100	100
16	Bijnore d/s (Ganga)	100	100	100	100	100	100	0.03	99.7	100
17	Garhmukteshwar u/s	100	100	100	0.1	100	100	0.03	0.03	100
18	Garhmukteshwar d/s	100	100	100	99.2	100	100	0.03	0.03	100
19	Anoopshahr u/s (Ganga)	100	100	100	57.9	100	100	0.03	30.9	100
20	Anoopshahr d/s (Ganga)	100	100	100	4.5	100	100	0.03	0.03	100
21	Fatehgarh u/s	100	100	100	0.3	100	100	2.3	2.3	2.3
22	Kannauj u/s (a/c with Ramganga & b/c with Kali)	100	100	100	0.03	0.03	0.03	3.6	3.6	3.6
23	Kannauj d/s (a/c with Kali)	100	100	100	0.03	0.03	0.03	1.1	1.1	1.1
24	Kanpur u/s (Bithoor)	100	100	100	0.03	72.6	72.6	0.6	0.6	1.1
25	Kanpur d/s (Shuklaganj)	100	100	100	0.03	0.03	0.03	0.03	0.03	0.03
26	Kanpur d/s (Jane Village)	24.2	100	100	0.03	0.03	0.03	15.9	15.9	15.9
27	Allahbad u/s (Ujahni, Fatehpur)	100	100	100	0.03	0.03	0.03	0.03	0.03	1.1
28	Bathing Ghats at Sangam	100	100	100	0.03	0.8	0.8	0.1	0.2	1.1
29	D/s Deehaghat	100	100	100	0.03	0.1	0.1	0.03	0.03	0.5
30	Vindhyachal, Pakka Ghat	100	100	100	0.03	94.5	94.5	0.3	0.5	2.3
31	Varanasi u/s	100	100	100	0.03	9.7	9.7	2.3	2.9	9.7
32	Dashashawmedh Ghat	100	100	100	0.03	2.3	2.3	0.03	0.03	0.03
33	D/s at Kaithy	100	100	100	0.03	34.5	34.5	0.03	0.03	0.03
34	Near Malviya Bridge	100	100	100	0.03	0.03	0.03	0.03	0.03	0.03
35	Tarighat	100	100	100	0.03	0.05	0.05	0.03	0.03	0.1

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S. No.	Location	Confidence Level (%) of Observations Conforming the Designated Best-use Classification of Inland Surface Water (CPCB)								
		Dissolved Oxygen (DO)			Biochemical Oxygen Demand (BOD_5)			Total Coliform (TC)		
		A (≥6 mg/L)	B (≥5 mg/L)	C (≥4 mg/L)	A (≤2 mg/L)	B (≤3 mg/L)	C (≤3 mg/L)	A (≤5.00E+01 MPN/100ml)	B (≤5.00E+02 MPN/100ml)	C (≤5.00E+03 MPN/100ml)
36	Buxar u/s	100	100	100	100	100	100	0.03	0.03	0.03
37	Buxar d/s	100	100	100	100	100	100	0.03	0.03	0.03
38	Chapra u/s (Ghaghra)	100	100	100	100	100	100	0.03	0.03	0.03
39	Chapra d/s (Chapra)	100	100	100	65.5	100	100	0.03	0.03	0.03
40	Arrah u/s (River Gangi)	100	100	100	0.3	100	100	0.03	0.03	0.03
41	Arrah d/s (River Gangi)	1.1	96.4	100	0.03	0.03	0.03	0.03	0.03	0.03
42	Koliwar (River Sone)	100	100	100	100	100	100	0.03	0.03	0.03
43	Hajipur u/s (River Gandak)	100	100	100	100	100	100	0.03	0.03	0.03
44	Hajipur d/s (River Gandak)	100	100	100	100	100	100	0.03	0.03	0.2
45	Patna u/s	100	100	100	100	100	100	1.1	1.1	1.4
46	Patna d/s	100	100	100	100	100	100	1.1	1.1	1.4
47	Fatuha u/s	100	100	100	100	100	100	0.03	0.03	0.03
48	Fatuha d/s	100	100	100	99.7	100	100	0.03	0.03	0.03
49	Barh u/s	100	100	100	86.4	100	100	0.03	0.03	0.03
50	Barh d/s	100	100	100	100	100	100	0.03	0.03	0.03
51	Mokama u/s	100	100	100	46.0	100	100	0.03	0.03	0.03
52	Mokama d/s	100	100	100	99.7	100	100	0.03	0.03	0.03
53	D/s Bata - McDowell	100	100	100	100	100	100	0.03	0.03	0.03
54	Munger u/s	100	100	100	100	100	100	0.03	0.03	0.03
55	Munger d/s	100	100	100	100	100	100	0.03	0.03	0.03
56	Sultanganj u/s	100	100	100	100	100	100	0.03	0.03	0.03
57	Sultanganj d/s	100	100	100	100	100	100	0.03	0.03	0.03
58	Bhagalpur u/s	100	100	100	100	100	100	0.03	0.03	0.03
59	Bhagalpur d/s	100	100	100	100	100	100	0.03	0.03	0.03
60	D/s Champanala	11.5	99.9	100	0.03	0.1	0.1	0.03	0.03	0.03
61	Kahalgaon u/s	100	100	100	100	100	100	0.03	0.03	0.03
62	Kahalgaon d/s	100	100	100	100	100	100	0.03	0.03	0.03
63	D/s NTPC Drain	100	100	100	100	100	100	0.05	0.1	0.3
64	Sahebganj u/s	100	100	100	100	100	100	0.03	0.03	0.5
65	Sahebganj d/s	100	100	100	100	100	100	0.03	0.03	0.03
66	Rajmahal d/s	100	100	100	100	100	100	0.03	0.03	0.03
67	Berhampore (Middle)	100	100	100	100	100	100	0.03	0.03	0.03
68	Palta (Middle)	100	100	100	91.9	100	100	0.03	0.03	0.03
69	Dakshineswar (Middle)	100	100	100	2.9	100	100	0.03	0.03	0.03
70	Uluberia (Middle)	93.3	100	100	72.6	100	100	0.03	0.03	0.03

Annexure II

Table A2.1: Pathogen Removal Potential of Sewage Treatment Plants (STPs) based on Activated Sludge Process and Its Variants

Location	Treatment Variation	TC (MPN/100 ml)			FC (MPN/100 ml)			*E. coli* (MPN/100 ml)			FS (MPN/100 ml)			Helminths Egg (No./L)			Reference	Remarks, if any
		I	E	Log R	I	E	Log R	I	E	Log R	I	E	Log R	I	E	%R		
Tubli, Bahrain, Arabian Gulf*	EA	8.0E+06-1.3E+08		>2.0	2.1E+06-1.0E+07		>2.0										Qureshi *et al.* (1990)	*TC and FC in CFU/100 ml
St Petersburg, Florida*	ASP	8.2E+07±2.3E+07	1.5E+06±1.6E+06	1.8	2.2E+07±0.6E+07	1.9E+05±0.2E+05	2.1									75.0	Rose *et al.* (1996)	*TC and FC in CFU/100 ml
Helwan, Egypt	ASP	9.1E+07-4.0E+10	7.3E+01-1.1E+04	4.0	3.6E+07-2.0E+10	3.6E+01-1.1E+04	4.0				3.5E+07-4.5E+10	2.4E+03-1.1E+04	4.0				El-Gohary *et al.* (1998)	
Al-Khobar, Saudi Arabia	ASP			1.7-2.0			1.7-2.0										Saleem *et al.* (2000)	
Nangal Punjab, India	ASP	1.6E+08	8.0E+04	3.3	1.6E+08	4.0E+04	3.6			1.05-2.00							CPCB (2005)	
Beur, Patna, India	ASP	5.0E+07	1.7E+05	2.5	1.1E+07	8.0E+05	1.1										CPCB (2005)	
Saidpur, Patna, India	ASP	1.6E+08	1.1E+06	2.2	1.4E+07	5.0E+05	1.5										CPCB (2005)	
Raipur Khurd, Chandigarh, India	ASP	5.0E+08	1.1E+06	2.7	3.0E+08	5.0E+05	2.8										CPCB (2005)	
Narela, Delhi, India	ASP	1.7E+07	1.1E+05	2.2	1.7E+07	4.0E+03	3.6										CPCB (2005)	
Snowdon, Shimla, India	EA	9.0E+08	1.4E+06	2.8	1.7E+08	9.0E+05	2.3										CPCB (2005)	
Dhalli, Shimla	EA	9.0E+07	1.4E+06	2.8	5.0E+07	1.4E+06	1.6										CPCB (2005)	
Summer Hill Shimla, India	EA	3.5E+07	2.0E+05	2.2	2.0E+07	2.0E+05	2.0										CPCB (2005)	
Maliana, Shimla, India	EA	5.0E+08	8.0E+05	2.8	3.0E+08	5.0E+05	2.8										CPCB (2005)	
North Disposal, Shimla, India	EA	5.0E+08	2.2E+06	2.4	1.7E+08	1.4E+06	2.1										CPCB (2005)	
Swisttal, Germany*	ASP	6.3E+07±1.0E+08	2.0E+04±1.6E+04	3.4±1.0				9.0E+06±5.4E+06	6.0E+03±7.2E+03	3.2±1.0	2.1E+06±1.1E+06	2.0E+03±3.2E+03	3.1±0.9				Kistemann *et al.* (2008)	**E. coli* and FS in CFU/100 ml
Heinersreuth, Germany*	ASP	3.6E+07±4.3E+07	3.0E+04±2.4E+04	3.1±1.2				1.3E+07±3.9E+06	4.0E+03±3.2E+03	3.5±0.4	3.3E+06±1.6E+06	4.0E+03±4.0E+03	2.9±0.3				Kistemann *et al.* (2008)	**E. coli* and FS in CFU/100 ml
Kirchheim, Germany*	ASP	2.5E+07±1.7E+07	5.7E+05±5.1E+05	1.6±0.5				7.0E+06±2.8E+06	8.5E+04±1.1E+05	1.9±0.8	1.3E+06±7.8E+05	2.0E+05±4.2E+05	0.8±1.0				Kistemann *et al.* (2008)	**E. coli* and FS in CFU/100 ml
Rheinbach, Germany*	ASP	1.2E+07±1.1E+07	4.0E+04±3.2E+04	2.5±0.8				3.0E+06±3.3E+06	1.6E+04±4.8E+03	2.3±0.7	1.8E+06±2.0E+06	4.0E+03±2.0E+03	2.7±0.5				Kistemann *et al.* (2008)	**E. coli* and FS in CFU/100 ml
Mahres, Sfax, Tunisia*	ASP	1.2E+04-6.1E+05	6.0E+03-1.7E+05	0.6	6.0E+03-2.0E+05	4.0E+03-3.0E+04	0.9				2.0E+03-5.0E+05	1.7E+03-1.3E+05	0.7	19.0±3.0	5.0±1.0	74.1	Ellouze *et al.* (2009)	*TC and FC in CFU/100 ml
Ksour-Essaf, Sfax, Tunisia*	ASP	1.1E+04-6.3E+04	4.0E+03-5.5E+03	0.8	4.0E+03-2.8E+04	1.0E+03-1.0E+03	0.9				1.0E+03-3.5E+04	2.0E+03-5.0E+03	0.8	11.0±3.2	4.5±1.2	59.0	Ellouze *et al.* (2009)	*TC and FC in CFU/100 ml
Matsulu, South Africa *	ASP	1.4E+06	8.0E+01	4.2	7.2E+03	6.0E+02	1.1										Samie *et al.* (2009)	*TC and FC in CFU/100 ml
Sabie, South Africa*	ASP	2.4E+05	5.4E+02	2.7	1.6E+04	1.8E+02	2.0										Samie *et al.* (2009)	*TC and FC in CFU/100 ml
Machadodorp, South Africa*	ASP	3.2E+06	6.5E+04	1.7	9.7E+04	7.2E+03	1.1										Samie *et al.* (2009)	*TC and FC in CFU/100 ml

TC: Total coliform; FC: Fecal coliform; FS: Fecal streptococcus; I: Influent; E: Effluent; Log R: Log removal; %R: Percent removal

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Location	Treatment Variation	TC (MPN/100 ml)			FC (MPN/100 ml)			*E. coli* (MPN/100 ml)			FS (MPN/100 ml)			Helminths Egg (No./L)			Reference	Remarks, if any
		I	E	Log R	I	E	Log R	I	E	Log R	I	E	Log R	I	E	%R		
Belfast, South Africa*	ASP	7.2E+05	1.2E+02	3.8	2.0E+05	5.0E+01	3.6										Samie *et al.* (2009)	*TC and FC in CFU/100 ml
Dullstroom, South Africa*	ASP	5.4E+06	6.0E+00	6.0	5.8E+04	7.0E+00	3.9										Samie *et al.* (2009)	*TC and FC in CFU/100 ml
Middleburg, South Africa*	ASP	2.3E+06	4.3E+01	4.7	1.3E+03	1.5E+01	1.9										Samie *et al.* (2009)	*TC and FC in CFU/100 ml
Haridwar, Uttarakhand, India	ASP	3.2E+07±6.9E+07	1.9E+05±6.9E+07	2.2	9.9E+06±2.4E+07	5.9E+04±2.8E+06	2.2				6.1E+05±1.4E+07	6.5E+03±2.0E+05	2.0	43.4±17.8	1.7±1.1	96.1	Tyagi *et al.* (2010)	
Vasant Kunj, Delhi, India	EA	2.7E+07±4.9E+07	1.8E+04±5.1E+04	3.0	1.1E+07±2.2E+07	8.7E+03±1.8E+04	3.0				7.8E+05±1.4E+06	1.6E+03±4.9E+03	2.7	42.3±11.4	1.2±2.1	97.2	Tyagi *et al.* (2010)	
Ribeirão Preto, Sao Paulo, Brazil	ASP													1.2E+03-5.8E+04	0-7.0E+03	27.0-100	Tonani *et al.* (2011)	
Kondli, Delhi, India	ASP				7.4E+07	1.6E+04	3.7				4.2E+06	7.8E+03	2.7				Jamwal and Mittal (2010)	
Yamuna Vihar, Delhi, India	ASP				1.0E+07	1.2E+05	1.9				9.1E+05	5.1E+04	1.3				Jamwal and Mittal (2010)	
Rithala I, Delhi, India	ASP				3.5E+06	2.3E+05	1.2				7.8E+06	2.5E+05	1.5				Jamwal and Mittal (2010)	
Coronation Pillar, Delhi, India	ASP				1.0E+06	6.9E+04	1.2				1.5E+04	4.0E+02	1.6				Jamwal and Mittal (2010)	
Okhla, Delhi, India	ASP				8.1E+06	1.9E+05	1.6				2.8E+06	3.1E+04	2.0				Jamwal and Mittal (2010)	
Nilothi, Delhi, India	ASP				1.4E+07	1.6E+04	3.0				2.0E+06	1.7E+04	2.1				Jamwal and Mittal (2010)	
Keshopur, Delhi, India	ASP				1.9E+07	1.5E+05	2.1				7.8E+06	8.7E+05	0.9				Jamwal and Mittal (2010)	
Papankallan, Delhi, India	ASP				4.0E+06	2.6E+05	1.2				4.4E+06	1.7E+05	1.4				Jamwal and Mittal (2010)	
Vasant Kunj I, Delhi, India	EA				2.0E+07	4.0E+04	2.7				3.0E+07	1.3E+04	3.4				Jamwal and Mittal (2010)	
Mehrauli, Delhi, India	EA				1.3E+07	1.0E+03	4.1				1.8E+06	8.3E+02	3.3				Jamwal and Mittal (2010)	
Nazafgarh, Delhi, India	EA				3.2E+06	7.6E+03	2.6				2.0E+05	2.6E+03	1.9				Jamwal and Mittal (2010)	
Rithala II, Delhi, India	High-rate Aeration				3.5E+06	4.4E+05	0.9				7.8E+06	3.4E+05	1.4				Jamwal and Mittal (2010)	
Allahabad, India	ASP	1.2E+08±2.4E+08	5.3E+06±8.0E+06	1.3	6.2E+07±1.5E+08	3.4E+06±8.7E+06	1.3										NRCD (2010)	
Bhagwanpur, Varanasi, India	ASP	1.1E+08±1.2E+08	4.8E+06±7.8E+06	1.4	5.3E+07±1.1E+08	3.6E+06±7.5E+06	1.2										NRCD (2010)	
DLW, Varanasi, India	ASP	1.6E+08±1.2E+08	5.7E+06±9.8E+06	1.4	8.4E+07±6.4E+07	4.3E+06±7.5E+06	1.3										NRCD (2010)	
Dinapur, Varanasi, India	ASP	1.8E+08±3.1E+08	2.4E+07±3.3E+07	0.9	7.1E+07±1.1E+08	8.9E+06±1.2E+07	0.9										NRCD (2010)	
Jajmau, Kanpur, India	ASP	6.2E+07±6.3E+07	1.2E+06±6.3E+05	1.7	5.2E+06±4.8E+06	3.2E+05±2.4E+05	1.2										NRCD (2010)	

TC: Total coliform; FC: Fecal coliform; FS: Fecal streptococcus; I: Influent; E: Effluent; Log R: Log removal; %R: Percent removal

Table A2.2: Pathogen Removal Potential of Sewage Treatment Plants (STPs) based on Trickling Filter

Location	Treatment Variation	TC (MPN/100 ml)			FC (MPN/100 ml)			*E. coli* (MPN/100 ml)			FS (MPN/100 ml)			Helminths Egg (No./L)			Reference	Remarks, if any
		I	E	Log R	I	E	Log R	I	E	Log R	I	E	Log R	I	E	%R		
Kortowo, Poland	TF	9.0E+04-2.5E+06	4.5E+04-2.5E+05	0.3-1.4	1.4E+04-1.4E+06	2.5E+03-1.4E+05	0.26-1.00				4.0E+04-2.5E+05	2.5E+03-1.4E+05	0-2.0				Filipkowska and Krzemieniewski (1998)	
Gent, Belgium*	TF	7.9E+04±6.3E+01	1.6E+02±3.2E+01	2.7	7.9E+03±4.0E+01	1.3E+02±1.6E+01	1.8				7.9E+03±4.0E+01	1.0E+02±7.9E+00	1.9				Kuai *et al.* (1999)	*TC, FC and FS in CFU/100 ml
T. T. Nagar, Bhopal, India	TF	1.7E+03	2.0E+02	0.9	2.0E+01	<2.0E+00	-										CPCB (2005)	
Howrah, West Bengal, India	TF					1.1E+06											CPCB (2005)	
Chandannagore, West Bengal, India	TF					9.0E+05											CPCB (2005)	
Kalyani, West Bengal, India	TF					2.2E+04											CPCB (2005)	
Baranagar, West Bengal, India	TF					5.0E+06											CPCB (2005)	
Serampore, West Bengal, India	TF					3.0E+06											CPCB (2005)	
Witbank, South Africa*	TF	2.5E+06	2.8E+04	2.0	2.2E+04	3.6E+05	-										Samie *et al.* (2009)	*TC and FC in CFU/100 ml, Increase in effluent FC number
Lydenburg, South Africa*	TF	1.6E+06	1.6E+03	3.0	1.2E+05	4.8E+02	2.4										Samie *et al.* (2009)	*TC and FC in CFU/100 ml
Kuching City, Malaysia*	TF				1.4E+06	6.3E+01	4.4										Ling *et al.* (2009)	*FC in CFU/100 ml
Coronation Pillar, Delhi, India	TF				1.0E+06	3.3E+04	1.5				1.5E+04	4.5E+02	1.5				Jamwal and Mittal (2010)	
Nakuru, Kenya	TF+MP				5.4E+07-1.6E+08	2.0E+02-2.3E+04	3.7										Ngari *et al.* (2011)	

TC: Total coliform; FC: Fecal coliform; FS: Fecal streptococcus; I: Influent; E: Effluent; Log R: Log removal; %R: Percent removal

Table A2.3: Pathogen Removal Potential of Sewage Treatment Plants (STPs) based on Upflow Anaerobic Sludge Blanket Reactor

Location	Treatment Variation	TC (MPN/100 ml)			FC (MPN/100 ml)			*E. coli* (MPN/100 ml)			FS (MPN/100 ml)			Helminths Egg (No./L)			Reference	Remarks, if any
		I	E	Log R	I	E	Log R	I	E	Log R	I	E	Log R	I	E	%R		
Amazonas, Brazil	UASB+SP (Pilot Plant)						4.0									100	Dixo *et al.* (1995)	
Negev Desert, Israel	UASB+SP (Pilot Plant)				6.3E+05±1.3E+06	3.3E+02±5.0E+03	2.4-3.3										Van der Steen *et al.* (1999)	
Salta, Argentina	UASB+SP (Pilot Plant)						6.0										Seghezzo (2004)	
Vitoria ES, Brazil	UASB							1.0E+07	2.0E+06	0.7				19.5	5.0	74.3	Keller *et al.* (2004)	
Yamunanagar I,Haryana, India	UASB+FPU	3.0E+06	1.7E+05	1.3	2.3E+06	1.1E+05	1.3										CPCB (2005)	
Yamunanagar II,Haryana, India	UASB+FPU	1.7E+06	8.0E+05	0.3	8.0E+05	4.0E+05	0.3										CPCB (2005)	
Karnal, Haryana, India	UASB+FPU	1.3E+07	4.0E+05	1.5	8.0E+06	2.0E+05	1.6										CPCB (2005)	
Sonipat, Haryana, India	UASB+FPU	3.0E+08	5.0E+05	2.8	4.0E+07	3.0E+05	2.1										CPCB (2005)	
Ghaziabad, India*	UASB	1.3E+06	2.4E+06	-	1.7E+06	2.0E+05	0.9										CPCB (2005)	*Increase in effluent TC number
Sector 54, Noida, India	UASB+FPU	2.3E+07	3.0E+05	1.9	8.0E+06	8.0E+04	2.0										CPCB (2005)	
Sector 50, Noida, India	UASB+FPU	3.0E+07	4.0E+05	1.9	1.7E+07	4.0E+05	1.6										CPCB (2005)	
Agra, Uttar Pradesh, India	UASB+FPU	9.0E+07	5.0E+06	1.3	3.0E+07	5.0E+06	0.8										CPCB (2005)	
Rishikesh, Uttarakhand, India	UASB+FPU	5.0E+08	9.0E+07	0.7	2.4E+08	3.0E+07	0.9										CPCB (2005)	
Trans Hindon Area, Ghaziabad, India	UASB+FPU	-	2.4E+06	-	-	1.3E+05	-										CPCB (2005)	
James Town(Mudor), Accra	UASB				6.8E+05-1.0E+06	1.4E+05-2.9E+05	0.54-0.7										Awuah and Abrokwa (2008)	
Saharanpur, Uttar Pradesh, India	UASB+FPU	1.2E+07±1.5E+07	8.9E+04±9.6E+04	2.2	3.1E+06±5.5E+06	1.1E+04±1.3E+04	2.4				4.3E+05±3.2E+07	2.3E+03±3.2E+04	2.3	46.4±12.4	0.1±0.1	99.8	Tyagi *et al.* (2010)	
Jajmau I, Kanpur, India	UASB	1.3E+09±1.8E+09	3.3E+07±3.4E+07	1.6	9.3E+07±1.0E+08	3.9E+06±4.4E+06	1.4										NRCD (2010)	
Jajmau II, Kanpur, India	UASB	4.3E+09±2.2E+09	8.0E+08±2.0E+09	0.7	9.0E+08±9.4E+08	6.3E+07±9.2E+07	1.2										NRCD (2010)	
Mirjapur, India	UASB	8.2E+07±1.2E+08	3.7E+06±4.0E+06	1.3	2.4E+07±4.7E+07	1.9E+06±2.6E+06	1.1										NRCD (2010)	
Vadodara, Gujarat, India	UASB	8.0E+12	5.0E+07	5.2	3.0E+12	1.9E+07	5.2										Mungray and Patel (2011)	
Vadodara, Gujarat, India	UASB+ASP	8.0E+12	5.2E+05	7.0	3.0E+12	3.7E+05	7.0										Mungray and Patel (2011)	
Surat, Gujarat, India	UASB	2.7E+12	1.9E+07	5.2	1.0E+10	6.8E+06	3.2										Mungray and Patel (2011)	
Surat, Gujarat, India	UASB+ASP	2.7E+12	6.7E+05	6.7	1.0E+10	2.2E+05	4.7										Mungray and Patel (2011)	

TC: Total coliform; FC: Fecal coliform; FS: Fecal streptococcus; I: Influent; E: Effluent; Log R: Log removal; %R: Percent removal

Table A2.4: Pathogen Removal Potential of Sewage Treatment Plants (STPs) based on Waste Stabilization Pond and Its Variants

Location	Treatment Variation	TC (MPN/100 ml)			FC (MPN/100 ml)			*E. coli* (MPN/100 ml)			FS (MPN/100 ml)			Helminths Egg (No./L)			Reference	Remarks, if any
		I	E	Log R	I	E	Log R	I	E	Log R	I	E	Log R	I	E	%R		
Ixtapan de la Sal, Mexico	WSP	1.1E+03±1.1E+03	9.0E+00±9.0E+00	2.0	1.4E+02±1.5E+02	4.0E+00±2.0E+00	1.5				1.1E+03±1.1E+03	2.0E+00±1.0E+00	2.7				Alcocer *et al.* (1993)	
Rabat, Morocco	WSP	2.4E+08	2.0E+07	1.1	2.1E+07	4.6E+03	3.7				2.2E+07	2.3E+04	3.0			99.3	El-Hamouri *et al.* (1994)	
Melbourne, Australia	WSP							1.2E+07	8.0E+01	5.2							Hodgson and Paspaliasis(1996)	
Burwarton Estate, Shropshire, UK	WSP				1.1E+07	1.2E+02	5.0										Mara *et al.* (1998)	
Murviel les Montpellier, France*	WSP				3.6E+06	2.7E+04	2.1										Brissaud *et al.* (2000)	*FC in CFU/100 ml
Akuse, Ghana	WSP	8.0E+05-1.1E+07	0-2.7E+04	4.0	2.0E+04-1.0E+07	0-9.0E+01	4.0										Hodgson(2000)	
Catacamas, Honduras	WSP				1.8E+07	4.2E+05	1.6										Oakley *et al.* (2000)	
Tela, Honduras	WSP				1.2E+06	7.6E+03	2.2										Oakley *et al.* (2000)	
Masaya, Nicaraguya	WSP				1.5E+08	3.2E+06	1.7										Oakley *et al.* (2000)	
Granada, Nicaraguya	WSP				6.1E+07	4.6E+05	2.1										Oakley *et al.* (2000)	
Benslimane, Morocco	WSP	5.2E+08	8.0E+01	6.7	3.0E+06	3.0E+01	5.0				1.8E+06	5.0E+01	4.6	23	0	100	Kouraa *et al.* (2002)	
Pahari, Patna, India	AL	2.4E+08	9.0E+05	2.4	9.0E+07	5.0E+05	2.3										CPCB (2005)	
Karnal, India	OP	1.3E+07	1.1E+06	1.1	8.0E+06	8.0E+05	1.0										CPCB (2005)	
Sultanpur Lodhi, Punjab, India	OP	5.0E+07	4.0E+06	1.1	2.4E+07	9.0E+05	1.4										CPCB (2005)	
Phillore, Punjab, India	OP	9.0E+07	1.5E+07	0.8	9.0E+07	8.0E+06	1.1										CPCB (2005)	
Akosombo, Ghana	WSP	2.3E+05-3.8E+07	2.9E+02-1.8E+05	2.2	1.9E+04-1.7E+07	4.0E+01-9.0E+02	4.0										Hodgson (2007)	
Albireh, Israel	WSP				2.1E+07	2.6E+04	2.4				2.1E+06	6.5E+04	1.2				Al-Sa`ed *et al.*(2007)	
Sfax, Tunisia*	AL	1.4E+04-5.0E+07	2.0E+03-9.0E+05	1.7	4.3E+03-2.5E+07	1.0E+03-8.0E+05	1.4				1.7E+03-3.5E+06	1.3E+03-4.5E+05	1.2	15.5±1.6	7.4±1.0	52.2	Ellouze *et al.* (2009)	*TC and FC in CFU/100 ml
Malelane, South Africa*	WSP	2.5E+06	5.4E+05	0.7	1.8E+05	1.8E+04	1.0										Samie *et al.* (2009)	*TC and FC in CFU/100 ml
Rishikesh, Uttarakhand, India	WSP	2.3E+07±1.5E+08	1.1E+05±7.2E+05	2.3	5.3E+06±3.8E+07	2.5E+04±3.5E+05	2.3				4.7E+05±2.2E+06	1.7E+03±9.6E+03	2.4	50.0±18.4	0.2±0.30	99.6	Tyagi *et al.* (2010)	
Timarpur, Delhi, India	OP				3.5E+05	1.2E+02	3.5				8.5E+05	7.2E+01	4.1				Jamwal and Mittal (2010)	
Farrukhabad, India	OP	3.9E+07±6.1E+07	1.0E+05±3.2E+05	2.6	2.5E+06±3.4E+06	6.8E+03±1.8E+04	2.6										NRCD (2010)	
Nakuru, Kenya	WSP				5.4E+07-1.6E+08	4.0E+01-9.0E+02	4.0										Ngari *et al.* (2011)	

TC: Total coliform; FC: Fecal coliform; FS: Fecal streptococcus; I: Influent; E: Effluent; Log R: Log removal; %R: Percent removal

Table A2.5: Pathogen Removal Potential of Sewage Treatment Plants (STPs) based on Sequencing Batch Reactor

Location	Treatment Variation	TC (MPN/100 ml)			FC (MPN/100 ml)			*E. coli* (MPN/100 ml)			FS (MPN/100 ml)			Helminths Egg (No./L)			Reference	Remarks, if any
		I	E	Log R	I	E	Log R	I	E	Log R	I	E	Log R	I	E	%R		
Jurong Town, Singapore	SBR (Pilot)	3.0E+07-16.0E+07	0.2E+06-3.0E+06	1.7-2.2	8.0E+06-1.6E+08	4.0E+04 - 3.0E+06	1.7-2.3										Ng *et al.* (1993)	
Santiago de Compostela, Spain*	SBR (Bench Scale)				3.7E+04-1.0E+05	4.0E+03-1.0E+05	0.1	3.7E+04-1.0E+05	3.0E+02-4.3E+04	0.2							Arrojo *et al.* (2005)	*FC and *E. coli* in CFU/100 ml
Santiago de Compostela, Spain*	SBR (Bench Scale)				1.2E+06-1.8E+06	4.0E+03-1.0E+04	2.3	1.0E+06-1.4E+06	2.0E+03-4.1E+03	2.6							Arrojo *et al.* (2005)	*FC and *E. coli* in CFU/100 ml
Beer-Sheva, Israel*	SBR (Pilot)	2.5E+07	8.0E+05	1.5	5.4E+06	2.4E+05	1.4										Brenner *et al.*(2000)	*TC and FC in CFU/100 ml
Delhi Gate, Delhi, India	BIOFOR				1.0E+07	4.7E+05	1.4				1.6E+07	5.4E+05	1.5				Jamwal and Mittal (2010)	
Sen Nursing Home, Delhi, India	BIOFOR				1.0E+07	5.2E+05	1.3				9.8E+06	9.3E+05	1.0				Jamwal and Mittal (2010)	

TC: Total coliform; FC: Fecal coliform; FS: Fecal streptococcus; I: Influent; E: Effluent; Log R: Log removal; %R: Percent removal

Table A2.5: Pathogen Removal Potential of Sewage Treatment Plants (STPs) based on Membrane Bioreactor

Location	Treatment Variation	TC (MPN/100 ml)			FC (MPN/100 ml)			*E. coli* (MPN/100 ml)			FS (MPN/100 ml)			Helminths Egg (No./L)			Reference	Remarks, if any
		I	E	Log R	I	E	Log R	I	E	Log R	I	E	Log R	I	E	%R		
Indio, California, USA*	MBR (Pilot)	5.6E+07	2.0E+01	6.4													Côté *et al.* (1997)	*TC in CFU/100 ml
Maisons-Laffitte, France*	MBR (Pilot)	5.9E+07	4.3E+01	6.1													Côté *et al.* (1997)	*TC in CFU/100 ml
Tsukuba, Ibaraki, Japan	MBR (Pilot)				4.8E+07±6.9E+07	6.0E+00±3.8E+00	6.0										Ueda and Hata (1999)	
Owlwood, Leeds, UK*	MBR (Bench-scale)				8.8E+06-1.2E+07	<3.0E+00	6.9				5.2E+05-7.7E+05	<2.0E+00	>5.8				Ueda and Horan (2000)	*FC and FS in CFU/100 ml
Hammarby Sjostad, Stockholm, Sweden	MBR (Pilot)							-	-	5.0±0.9							Ottoson *et al.* (2006)	
Technion, Haifa, Israel*	MBR (Pilot)				3.4E+05±4.2E+05	2.7E+01±5.6E+01	4.1										Friedler *et al.* (2006)	*FC in CFU/100 ml
Guelph, Ontario, Canada*	MBR (Pilot)	2.5E+07	2.5E+02	5.0	9.6E+06	<2.0E+00	-										Zhang and Farahbakhsh (2007)	*TC and FC in CFU/100 ml
Sfax, Tunisia*	MBR (Pilot)	3.7E+04±9.0E+03	<2.0E+00	-	2.1E+04±5.0E+03	<2.0E+00	-				3.5E+04±8.0E+03	<2.0E+00	-	15±4	0	100	Saddoud *et al.* (2007)	*TC, FC and FS in CFU/100 ml
Daejeon, Korea*	MBR (Pilot)	-	1.1E+01	-	-	5.0E+00	-	-	2.0E+00	-							Chae *et al.* (2007)	*TC, FC and *E. coli* in CFU/100 ml
METU, Inönu Bulvari, Ankara, Turkey	MBR (Pilot)	-	1.4E+02-3.50E+02	5.0-6.0	-	<2.0E+00-1.8E+01	7.0										Komesli *et al.* (2007)	
Rabat, Morocco	MBR (Bench-scale)				1.4E+05±1.1E+05	6.8E+01±1.2E+02	2.0										Merz *et al.* (2007)	
Bradford, London, UK*	MBR (Pilot)	2.5E+05±6.3E+00	4.0E+00±1.0E+01	4.7				6.3E+03±1.2E+01	6.3E+02±6.3E+00	1.0							Winward *et al.* (2008)	*TC and *E. coli* in CFU/100 ml
Castle Hill, Sydney, Australia*	MBR (Bench-scale)	2.7E+04	4.3E+03±2.4E+03	0.8													Guo *et al.* (2008)	*TC in CFU/100 ml
Sfax, Tunisia*	MBR (Pilot)	2.1E+04-5.0E+07	<2.0E+00	-	9.0E+03-3.0E+07	<2.0E+00	-				3.5E+03-3.0E+06	<2.0E+00	-				Ellouze *et al.* (2009)	*TC and FC in CFU/100 ml
Verona, Italy	MBR (Pilot)	1.0E+06-9.2E+07	7.0E+01-2.0E+02	4.7-5.1				Present	Absent	NC							Bolzonella *et al.* (2010)	
Bologna, Italy*	MBR	7.9E+06-2.0E+08	2.6E+01-3.1E+03	4.8-5.5	2.1E+06-1.7E+08	1.0E+00-1.3E+01	6.0-6.3	1.4E+06-7.9E+07	1.0E+00 - 4.0E+00	6.2-7.0							Zanetti *et al.* (2010)	*TC and FC in CFU/100 ml
Seoul, Korea*	MBR (Bench-scale)				1.2E+03	7.0E+02	0.2	4.0E+03	1.3E+03	0.5							Jong *et al.* (2010)	*FC and *E. coli* in CFU/100 ml
San Diego, California, USA*	MPR (Pilot)	1.0E+05-2.0E+08	<1.0E+01	5.8-6.9	4.0E+05-4.3E+07	<1.0E+01	5.5-6.0										Hirani *et al.* (2010)	*TC and FC in CFU/100 ml
Sydney, Australia	MBR							-	-	5.4-6.7							Pettigrew *et al.* (2010)	
Castell d'Aro, Catalonia, Spain	MBR (Pilot)							1.0E+06	<2.0E+00	5.1							Marti *et al.* (2011)	**E. coli* in CFU/100 ml
Garching, Germany	MBR (Pilot)				4.3E+06	4.9E+01	5.0										Martinez-Sosa *et al.* (2011)	
UNAM, Mexico	MBR (Pilot)				3.6E+06-4.7E+06	<2.0E+00	-							10±2	<1	99	Herrera-Robledo *et al.* (2011)	
Riyadh, Saudi Arabia*	MBR (Pilot)				1.5E+07	2.0E+03	3.9										Zahid and El-Shafai (2011)	*FC in CFU/100 ml

TC: Total coliform; FC: Fecal coliform; FS: Fecal streptococcus; I: Influent; E: Effluent; Log R: Log removal; %R: Percent removal

Emerging Contaminants in Ganga River Basin

with Special Emphasis on Pesticides

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay	IIT Delhi	IIT Guwahati	IIT Kanpur	IIT Kharagpur	IIT Madras	IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin: Environment Management Plan (GRB EMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Environment Management Plan (GRBEMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin: Environment Management Plan (GRB EMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRB EMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who have contributed directly and those who have taken lead in preparing this report is given on the reverse side.

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Contents

1. Introduction

India is a predominantly agrarian economy that is also rapidly industrializing. Chemicals production in India has been unprecedented in the last few decades. Today, the chemicals manufacturing industry accounts for 3% of the country's GDP (Department of chemicals and petrochemicals, 2011). While India's chemical production is still far below that of developed and most developing nations, the consequences are becoming visible already. A news report in the prestigious scientific journal, *Nature,* highlighted the gravity of the situation where concentrations of some common medicines (drugs) like ciprofloxacin and cetirizine were found at concentrations of 31 and 1.4 mg/L (Nature, 2009). Pharmaceutical companies in the area that were discharging large amounts of wastewater were responsible for the situation. Given the lack of regulations for dealing with the discharge of such chemicals, no action can be taken in these cases. There are many more examples of such unchecked releases of unregulated but harmful chemicals, also called emerging contaminants (EC).

The list of ECs includes pharmaceuticals, personal care products, antibiotics, prescription and non-prescription drugs, steroids and hormones, pesticides, plasticizers, surfactants, and fire retardants (Bhandari *et al.*, 2009). Major sources of these chemicals include residential, agricultural and industrial activities. This report provides a summary of EC regulations in different countries, a brief introduction to the major EC categories, and the current state-of-knowledge in India regarding emerging contaminants in Ganga river basin.

1.1 Regulations for Emerging Contaminants and Research in other Countries

Many developed nations already have maximum contaminant levels (MCLs) and health advisory levels (HALs) for a variety of these ECs. Guidelines and health advisory levels for pesticides are summarized in **Table 1** while those for heavy metals are summarized in **Table 2.** At present in India, there are no regulations or guidelines for individual pesticides in drinking water. IS10500 recommends a level of 1 micro-g/L for total pesticides while standards are recommended for various heavy metals and are included in **Table 2.**

An extensive survey was conducted in the US for a large number of chemicals that are routinely found in streams and are potentially toxic to animals or humans (Kolpin *et al.*, 2002). Water samples from 139 streams across the US were analyzed for 95 contaminants. 82 of the analyzed contaminants were detected and natural contaminants like steroids were detected most frequently. Non-prescription drugs and pesticides were the other frequently detected categories of contaminants. Concentrations of surfactants were the highest amongst all contaminant categories followed by steroids and plasticizers.

Table 1: Guidelines or advisory levels for pesticides in different countries

Pesticide	ADWG 2004 *Australia*		CDWQG 2008 *Canada*	NZWQG 2005 *New Zealand*	JWQG 2004 *Japan*	US 2011 ***United States***
	Guideline value	Health value	MAC	MAV	Target value	MCL
	mg/L	mg/L	mg/L	mg/L	mg/L	μg/L
1,2-dichloropropane				0.05		
1,3-dichloropropene				0.02		
2,4-D	0.0001	0.03		0.04		
Acephate		0.01		0.02		
Aldicarb	0.001	0.001	0.0007	0.01		
Aldrin (and dieldrin)	0.00001	0.0003		0.00004		
Ametryn	0.005	0.05				
Amitrole	0.001	0.01				
Asulam		0.05				
Atrazine	0.0001	0.04	0.005	0.002		
Azinphos-methyl	0.002	0.003	0.02	0.004		
Benomyl		0.1				
Bentazone		0.03		0.4		
Bioresmethrin		0.1				
Bromacil	0.01	0.3		0.4		
Bromophos-ethyl		0.01				
Bromoxynil		0.03	0.005			
Carbaryl	0.005	0.03	0.09			700
Carbendazim		0.1				
Carbofuran	0.005	0.01	0.09	0.008		
Carbophenothion		0.0005				
Carboxin	0.002	0.3				
Chlordane	0.00001	0.001		0.0002		2
Chlorfenvinphos		0.005				
Chlorothalonil	0.0001	0.03				
Chlorotoluron				0.04		
Chloroxuron		0.01				
Chlorpyrifos		0.01	0.09	0.04		20
Chlorsulfuron		0.1				
Clopyralid	1	1				
DDT	0.00006	0.02		0.001		
Diazinon	0.001	0.003	0.02	0.01		0.6
Dicamba		0.1	0.12			
Dichlobenil		0.01				
Dichlorprop				0.1		
Dichlorvos	0.001	0.001				
Diclofop-methyl		0.005				
Dicofol		0.003				
Dieldrin (see aldrin)	0.00001	0.0003				0.2

Pesticide	ADWG 2004 *Australia*		CDWQG 2008 *Canada*	NZWQG 2005 *New Zealand*	JWQG 2004 *Japan*	US 2011 ***United States***
	Guideline value	**Health value**	**MAC**	**MAV**	**Target value**	**MCL**
	mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**μg/L**
Difenzoquat		0.1				
Dimethoate		0.05		0.008		
Diphenamid	0.002	0.3				
Diquat	0.0005	0.005	0.07	0.01		
Disulfoton	0.001	0.003				
Endrin				0.001		
Hexachlorobenzene				0.0001		
Isoproturon				0.01		
Malathion				1		
Oryzalin		0.3		0.4		
Oxadiazon				0.2		
Oxamyl	0.005	0.1				
Paraquat	0.001	0.03	0.01			
Parathion		0.01				
Parathion methyl	0.0003	0.1				2
Pebulate	0.0005	0.03				
Pendimethalin		0.3		0.02		
Pentachlorophenol	0.00001	0.01		0.009		
Permethrin	0.001	0.1		0.02		
Phenylphenol				1.4		
Picloram		0.3	0.19	0.2		
Piperonyl butoxide		0.1				
Pirimicarb		0.005				
Pirimiphos-ethyl		0.0005				
Pirimiphos-methyl		0.05		0.1		
Primisulfuron methyl				0.9		
Procymidone				0.7		
Profenofos		0.0003				
Promecarb		0.03				
Propachlor	0.001	0.05				
Propanil	0.0001	0.5		0.02		
Propargite		0.05				
Propazine	0.0005	0.05		0.07		
Propiconazole	0.0001	0.1				
Pyridate				0.1		
Pyriproxifen				0.4		
Terbuthylazine				0.008		
1,2-dibromo-3-chloropropane				0.001		
2,4,5-T	0.00005	0.1		0.01		
2,4-DB				0.1		

Pesticide	ADWG 2004 *Australia*		CDWQG 2008 *Canada*	NZWQG 2005 *New Zealand*	JWQG 2004 *Japan*	US 2011 ***United States***
	Guideline value	**Health value**	**MAC**	**MAV**	**Target value**	**MCL**
	mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**μg/L**
Cyanazine				0.0007		
Diuron		0.03	0.15	0.02		
DPA(2,2-DPA)		0.5				
EDB	0.001	0.001				
Endosulfan	0.00005	0.03				
Endothal	0.01	0.1				
EPTC	0.001	0.03				
Ethion		0.003				
Ethoprophos	0.001	0.001				
Etridiazole	0.0001	0.1				
Fenamiphos		0.0003				
Fenarimol	0.001	0.03				
Fenchlorphos		0.03				
Fenitrothion		0.01				
Fenoprop		0.01		0.01		
Fensulfothion	0.01	0.01				
Fenvalerate		0.05				
Flamprop-methyl		0.003				
Fluometuron		0.05				
Formothion		0.05				
Fosamine		0.03				
Glyphosate	0.01	1				
Heptachlor including its epoxide	0.00005	0.0003		0.00004		
Hexaflurate		0.03				
Hexazinone	0.002	0.3		0.4		
Lindane	0.00005	0.02		0.002		0.2
Maldison		0.05				
MCPA				0.002		
MCPB				0.03		
Mecoprop				0.01		
Metalaxyl				0.1		
Methidathion		0.03				
Methiocarb	0.005	0.005				
Methomyl	0.005	0.03				
Methoxychlor	0.0002	0.3	0.9	0.02		
Methyl parathion				0.01		
Metolachlor	0.002	0.3		0.01		
Metribuzin	0.001	0.05		0.07		
Metsulfuron-methyl		0.03				
Mevinphos	0.005	0.005				

Pesticide	ADWG 2004 *Australia*		CDWQG 2008 *Canada*	NZWQG 2005 *New Zealand*	JWQG 2004 *Japan*	US 2011 ***United States***
	Guideline value	**Health value**	**MAC**	**MAV**	**Target value**	**MCL**
	mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**μg/L**
Molinate	0.0005	0.005		0.007		
Monocrotophos		0.001				
Napthalene				20		
Napropamide	0.001	1				
Nitralin		0.5				
Norflurazon	0.002	0.05				
Propyzamide	0.002	0.3				
Pyrazophos		0.03				
Quintozene		0.03				
Silvex(see						
Simazine	0.0005	0.02	0.01	0.002		
Sulprofos		0.01				
Temephos	0.3	0.3				
Terbacil	0.01	0.03				
Terbufos	0.0005	0.0005	0.001			
Terbutryn	0.001	0.3				
Tetrachlorvinphos	0.002	0.1				
Thiabendazole				0.4		
Thiobencarb		0.03				
Thiometon		0.003				
Thiophanate		0.005				
Thiram		0.003				
Triadimefon	0.1	0.002				
Trichlorfon		0.005				
Triclopyr		0.01		0.1		
Trifluralin	0.0001	0.05	0.045	0.03		
Vernolate	0.0005	0.03				

Table 2: Guidelines or advisory levels for heavy metals in different countries

Heavy metals	ADWG 2004 *Australia*		CDWQG 2008 *Canada*	NZWQG 2005 *New Zealand*	JWQG 2004 *Japan*	CWQG 2006 *China*	SAWQG *South Africa*	IS10500
	Guideline value	**Health value**	**MAC**	**MAV**	**Target value**	**Limiting value**	**TWQR**	**Permissible (desirable)**
	mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Aluminum			0.1/0.2		0.2	0.2	0 - 0.15	0.2 (0.03)
Arsenic	0.007		0.01	0.01	0.01	0.01	0-10	0.05
Cadmium	0.002		0.005	0.004	0.01	0.005	0 - 0.005	0.01
Chromium (VI)	0.05		0.05	0.05	0.05	0.05	0 - 0.050	0.05
Copper	2	1		2	1	1	0 - 1	1.5 (0.05)

Heavy metals	ADWG 2004 *Australia*		CDWQG 2008 *Canada*	NZWQG 2005 *New Zealand*	JWQG 2004 *Japan*	CWQG 2006 *China*	SAWQG *South Africa*	IS10500
	Guideline value	**Health value**	**MAC**	**MAV**	**Target value**	**Limiting value**	**TWQR**	**Permissible (desirable)**
	mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Iron		0.3			0.3	0.3	0 - 0.1	1.0 (0.3)
Lead	0.01		0.01	0.01	0.01	0.01	0 - 10	0.05
Manganese	0.5	0.1		0.4	0.05	0.1	0 - 0.05	0.3 (0.1)
Mercury	0.001		0.001	0.002	0.005	0.001	0 - 1	0.001
Molybdenum	0.05			0.07	0.07			
Nickel	0.02			0.02				
Silver	0.1			0.1				
Zinc		3			1	1	0 - 3	15 (5)

1.2 Overview of Emerging Contaminants

Pharmaceuticals (Adams, 2009): Pharmaceuticals include prescription and non-prescription drugs and are discharged into the environment by human use, industrial wastewaters, and animal husbandry activities. Many of these chemicals are endocrine disruptors. Endocrine disruption effects of hormonal pharmaceuticals, due to their high potency at extremely low concentrations, are of particular concern for humans and animals. Antibiotics are also especially important because of their potential to form and promote antibiotic resistance for human pathogens, and their potential to significantly impact natural microbial consortia (Kümmerrer, 2001). Other classes of pharmaceuticals, such as analgesics and psycho-pharmacologicals, may also be important due to their strength and common use.

Personal Care Products (Champagne, 2009): Personal care products (PCPs) include those compounds which are marketed for direct use primarily on the human body (mainly dermal contact). Prescription drugs, over-the-counter pharmaceutical products with documented physiological effects (Daughton and Ternes, 1999), nutraceuticals and food supplements are excluded from this category. PCPs are generally not intended for injection or ingestion. There are thousands of chemicals that are constituents of PCPs. These are diverse and are used as active ingredients or preservatives in cosmetics, skin care, dental care, hair care products, soaps, cleansers, insect repellents, sunscreen agents, fragrances, and flame retardants. Many of these PCPs are used in large quantities, and often at dosages and frequencies higher than recommended.

The active ingredients in a number of PCPs are considered bioactive chemicals. This implies that they have the potential to affect the flora and fauna of soil and aquatic receiving environments. In some cases, bioactive ingredients are first subject to metabolism by the consumer and the excreted metabolites and parent components are then subject to further transformation in the receiving environment. Personal care products differ from pharmaceuticals in that large quantities can be directly introduced into receiving environments (air, surface and ground water, sewage, sludge and bio-solids, landfills, soils) through regular use, such as showering, bathing, spraying, excretion or disposal of expired or used products. Because of this uncontrolled release, they can bypass possible treatment systems. As a result, PCPs are referred to as pseudo-persistent contaminants (Barceló and Petrovic, 2007).

The environmental fate and effects of many of the broad class of chemical constituents found in PCPs are poorly understood. PCPs can be considerably persistent and can bio-accumulate in non-target aquatic organisms (Ternes *et al.*, 2004). Some PCPs have been found to exhibit negative hormonal and toxic effects on a number of aquatic organisms at concentrations as low as µg/kg (Daughton and Ternes, 1999). To date, few studies have considered the interactive effects of combined low concentrations of various classes of PCPs, and whether their chemical constituents, metabolites and transformation products have any significance with respect to ecological function. Of particular concern is the fact that subtle immediate effects could occur and go undetected in the flora and fauna of receiving environments, but long-term cumulative effects could result in irreversible changes by the time they are recognized (Daughton and Ternes, 1999). Data are also limited regarding the effects of unexpected exposure on human health.

Steroids and Hormones (Limpiyakorn *et al.*, 2009): Hormones are the body's chemical messengers that affect and control most of the organisms' major activities including growth, development, metabolism, sexual and reproductive functions, psychological and physiological well-being. Based on their chemical structure, hormones can be divided into 3 broad classes: peptide hormones, amine hormones and steroid hormones. Peptide hormones consist of polypeptide hormones and oligo-peptide hormones. Peptide hormones are from the anterior pituitary gland, placenta, stomach, duodenum, pancreas and liver. Oligo-peptide hormones are from the posterior pituitary gland and the hypothalamus. Peptide hormones consist of chains of amino acids and examples would include insulin and growth hormones. Amine hormones are derived from the amino acids, tyrosine and tryptophan. Examples of major amine hormones are dopamine, nor-epinephrine, and epinephrine. Steroid hormones are synthesized by chemical modification of cholesterol and derived from the adrenal cortex, gonads and placenta. Steroid hormones can be subcategorized into corticosteroids and sex steroids.

Of concern in the environment are peptide hormones and steroid hormones. In the mid-1990s, several researchers reported the presence of steroidal estrogen hormones in surface waters, municipal wastewaters and wastes from concentrated animal feeding operations (Ternes *et al.*, 1999a; 1999b; Matsui *et al.*, 2000; Koplin *et al.*, 2002; Hanselman *et al.*, 2003). Estrogens have endocrine disrupting properties and are known to disrupt the endocrine system of humans, aquatic and animal species at ng/L (Tyler *et al.*, 2005; Purdom *et al.*, 1994). Human and animal steroidal hormones have extremely high estrogenic potency in comparison to synthetic chemicals such as organo-chlorine aromatic compounds. For example, the estrogenic potency of endogenous steroidal estrogens was reported to be

10,000-100,000 times higher than exogenous endocrine disrupting compounds (Hanselman *et al.*, 2003). Studies by several researchers have found that aquatic species such as turtles, trout, and minnows were sexually inhibited or reserved by the presence of natural estrogens at concentrations as low as few tens of ng/L (Jobling *et al.*, 1998; Irwin *et al.*, 2001; Lange *et al.*, 2001). At a concentration of 5 ng/L of estradiol, production of female specific proteins was found to be induced in male Japanese medaka (Tabata *et al.*, 2001).

In recent years, use of estrogenic compounds in hormone therapy of humans and in livestock farming has increased. Since estrogenic compounds are naturally produced, it is expected that the presence of these compounds in wastewaters and in the environment will continue to increase. The fate and behaviour of these compounds in the environment are not well understood. Consequently, the risks of these chemicals to humans, aquatic organisms and animals are also not well understood. Many estrogenic compounds are not routinely analyzed or the analysis methods are too tedious or are not available in media such as bio-solids and sediments. Currently available analytical methods allow for the quantification of steroids like cholesterol, coprostanol, stigmastanol, and hormones like methyltestosterone, testosterone, estradiol (17β-E2 and 17α-E2), estriol (E3), and estrone (E1)). These compounds are frequently detected in municipal wastewaters and livestock farming and streams (Koplin *et al.*, 2002).

Phthalate Plasticizers and Degradation Products (Barnabé *et al.*, 2009): Plastic products have always been of major concern in terms of toxicity and persistence in the environment. They contain a myriad of additives including plasticizers, which can make up to 40% of plastic formulations. Plasticizers are low molecular weight organic compounds that are essential for effective processing and tailoring of plastic formulations. The production of flexible plastics with multiple applications ranging from automotive industry to medical and commodity products is due to plasticizers. They are manufactured in hundred millions of tons annually and represent an overwhelmingly large fraction of the plastic industry.

It has been established that plasticizers are toxic to a certain extent and some can exhibit endocrine-disrupting properties. In fact, these compounds may also leach out from the plastics as they are not chemically bound to the plastic polymers. Hence, leaching is a major process for contamination of the environment by the ubiquitous plasticizers. Meanwhile, it has been estimated that the average ingestion rate of plasticizers could be about 8 mg per person per day. The abundance, potential endocrine-disrupting effects and the growing interest in their fate, transport and treatment makes them emerging contaminants of major concern. It is also corroborated by the fact that their biodegradation in the environment can release breakdown products which can be potentially more toxic than the parent compounds. Hence, there is a need to understand the fate and behavior of plasticizers and their degradation products in natural and engineered environments, including industrial and municipal effluents, sewage sludge, and landfill leachates.

Surfactants (Yan *et al.*, 2009): Surfactants (surface active agents or wetting agents) are organic chemicals that reduce surface tension in water and other liquids. Surfactants represent major, multipurpose groups of organic compounds. Nearly $3x10^{10}$ kg of surfactants are produced per year all over the world (Berna *et al.*, 1998). The most familiar use of surfactants is in soaps, dishwashing liquids, laundry detergents and shampoos. Other important uses are in industrial applications such as lubricants, emulsion polymerization, textile processing, mining flocculates, petroleum recovery, and a variety of other products and processes. Surfactants are also used as dispersants after oil spills (Scott and Jones, 2000; Petrovic *et al.*, 2002).

There are hundreds of compounds that can be used as surfactants. These are usually classified by their ionic behavior in solutions: anionic, cationic, non-ionic or amphoteric (zwitter-ionic). The two major groups of surfactants are the anionics and non-ionics with a global production of around 2.5 and 0.5 million tons per year, respectively (Lara-Martin *et al.*, 2006). Their main components are linear alkylbenzene sulfonates (LAS) for the anionics and alkylphenol polyethoxylates (APEOs) for the non-ionics.

Brominated Fire Retardants (Banerji *et al.*, 2009): Fire retardants are substances that can delay or prevent combustion. The most common fire retardant is water. However, many chemicals can be used as fire retardants and these eventually enter the environment and are potentially toxic. BFRs are endocrine-disrupting chemicals that are potentially toxic and bio-accumulative. There are more than 175 different types of compounds that are used as fire retardants. These compounds can be placed in four categories – halogenated organics, phosphorus-based, nitrogen based and other inorganic compounds. The halogenated compounds (chlorinated and brominated) are the most common fire retardants as they are less expensive and are quite effective. In this group, brominated compounds are more common than the chlorinated types. The phosphorus and nitrogen-based fire retardants are monoammonium phosphate, diammonium phosphate, ammonium polyphosphate and ammonium sulfate. These compounds individually or in combination are mixed with other chemicals such as corrosion inhibitors, alcohol, gum thickeners and surfactants in a fire retardant formulation. In the other inorganic compounds category, compounds like aluminium hydroxide, antimony oxides and chlorides may be included.

Brominated fire retardants (BFRs) are the most common fire retardants and have serious environmental effects. There are more than 75 different brominated fire retardants (Birnbaum and Staskal, 2004). BFRs contribute to about 38% of the global bromine demand. The electronic industry is the major consumer of BFRs. The four main applications of BFRs in computers are: printed circuit boards, connectors, plastic covers and cables. BFRs are also used in many other products such as TV plastic covers, carpets, paints, upholstery and domestic kitchen appliances. Their effectiveness for fire prevention and hindrance to the spread of fire makes them very useful fire retardants. Since they are not bound to the polymers, they can enter the environment by leaching.

Pesticides (Zhang *et al.*, 2009): The word "pesticide" is a generic term, which covers any substance or mixture of substances used for preventing, destroying, repelling or mitigating pests, or intended for use as plant regulators, defoliants or desiccants (USEPA, 2007a). Pests are considered to be any unwanted living organism that can cause damage to crops, humans or other animals. Examples of pests include insects, mice, unwanted plants (weeds), fungi, bacteria and viruses. Pesticides are not just natural or synthetic chemicals, but can include microorganisms or their components such as endotoxins from *Bacillus thuringiensis*, or macroorganisms such as predatory wasps specifically bred to control caterpillars and aphids (Tyagi *et al.*, 2002; Hamilton and Crossly, 2004). Currently, the most common types of pesticides being used are herbicides, insecticides, fungicides and bactericides. Other pesticides being applied include nematicides for controlling parasitic microscopic worms living in soil, avicide for birds, molluscicide for snails and slugs, piscicide for fish, algicides, rodenticides, and miticides (AGCare, 2007).

1.3 Emerging Contaminants in Ganga River Basin

Of the categories noted above, monitoring and assessment of water quality in India has been limited to heavy metals, pesticides, and antibiotics in the last few decades. Separate chapters have been written on each of these contaminant categories and the extent to which these contaminants are present in various environmental media due to contamination of the waters of Ganga river basin.

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2. Pesticides in Ganga River Basin

Pesticides have contributed greatly to the increase in crop yields in agriculture by controlling pests and diseases and also by controlling insect-borne diseases like malaria, dengue, encephalitis, filariasis, etc. (Abhilash and Singh, 2009). Pesticides are indispensable in modern agriculture, but their use or misuse may lead to contamination of both, ground water and surface water. These pesticides enter into rivers like those of the Ganga watershed through various pathways. Some of these pathways are described as follows .

(a) When fertilizers, insecticides, and fungicides are applied to cropland, some residue remains in the soil after plant uptake and is transported to streams and rivers by surface runoff,
(b) Pollutants also may enter water bodies by wind or by their own passive movement,
(c) Spray drifts during application of pesticides may carry pesticides to surface waters,
(d) Volatilization and precipitation,
(e) Leaching into ground waters, and
(f) Drain flow and through flow (Carter, 2000)

Pesticides can be very dangerous and harmful to human beings and animals due to their potential cytotoxicity and/or genotoxicity. Pesticides are often persistent, broad-spectrum toxins that can accumulate in the food web posing a threat to both, the ecosystem and human health. Many of these compounds are 'endocrine disruptors' which are defined as chemicals that can interfere with the hormonal systems of organisms including humans. Some developing countries including India continue to use these compounds because of their low cost and versatility in industry and agriculture and their long-term efficiency against pests. Consequently, environmental problems associated with these toxic contaminants are of great concern. It is reported that approximately three million people are poisoned and 200,000 die each year around the world from pesticide poisoning, and a majority of them belong to developing countries. It is also believed that in developing countries, the incidence of pesticide poisoning may be greater than reported due to under-reporting, lack of data and misdiagnosis (Sarkar et al., 2008a).

2.1 Pesticide Manufacturing and Use in India

Use of pesticides in India began in 1948 while manufacturing of DDT and benzene hexachloride (BHC or Lindane) began in the year 1952 (Gupta, 2004). In 1958, India was producing over 5000 metric tonnes of pesticides. Currently, there are approximately 145 pesticides registered for use, and production has increased to approximately 85,000 metric tonnes. The first report of poisoning due to pesticides in India came from Kerala in 1958 where over 100 people died after consuming wheat flour contaminated with parathion. Despite the fact that the consumption of pesticides in India is still very low, about 0.5 kg/ha of pesticides against 6.60 and 12.0 kg/ha in Korea and Japan, respectively, there has been widespread contamination of food commodities with pesticide residues. In India, 51% of food commodities are contaminated with pesticide residues and out of these, 20% have pesticides residues above the maximum residue levels on a worldwide basis.

Lists of pesticides registered in India along with those banned are available on the website of the Central Insecticides Board (2011). No information could be found on the production and utilization of individual pesticides in the Indian market. This information is essential for tracking the use of certain pesticides and determining the risks associated with their use.

2.2 Classification of Pesticides

Basically pesticides are divided into three to four main classes (Mohapatra et al., 1995):

(a) Organochlorine pesticides (OCPs): These pesticides tend to be persistent in the environment and have a tendency to bioaccumulate. Organochlorines are responsible for many acute and chronic illnesses. Examples of organochlorine pesticides include DDT and its degradation products, DDD and DDE, which are known to be equally or more toxic than the parent compound. Endosulfan and Lindane (γ-hexachlorocyclohexane – also called HCH) are other commonly used OCPs in India (Abhilash and Singh, 2009).

(b) Organophosphorous pesticides (OPPs): Organophosphates work by interfering with the nervous system of insects, mammals, birds, and fish. Examples of organophosphate pesticides that are commonly used in India include Malathion (Flit), Parathion (Baygon), Quinalphos and Chlorpyrifos (Abhilash and Singh, 2009).

(c) *Carbamates:* Carbamates are esters of carbamic acid. These insecticides can cause enzyme inhibition. Examples of carbamates include Aldicarb (Chopra et al. 2011), Carbofuran and Carbaryl (Abhilash and Singh, 2009).

(d) *Synthetic Pyrethroids*: These are esters of chrysanthemic acid and its derivatives. To mimic the insecticidal activity of the natural compound 'pyrethrum' another class of pesticides, pyrethroid pesticides, has been developed. These are non-persistent compounds, which are sodium channel modulators, and are much less acutely toxic than organophosphates and carbamates. Compounds in this group are often applied against household and garden pests. Examples include cypermethrin and imiprothrin (Hit), prallethrin (All-Out), deltamethrin and allethrin (Mortein). The consumption of technical grade pesticides in India is presented in Table 3.

Table 3: Consumption of Technical Grade Pesticides in India (Mohapatra et al., 1995).

Pesticide	Consumption thousand tons
Organochlorine pesticides	29.8
Organophosphorous pesticides	13.6
Carbamates	1
Synthetic Pyrethroids	1

2.3 Pesticide Contamination in Ganga River Basin

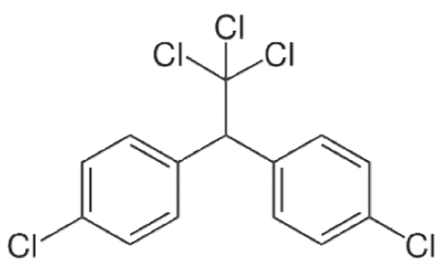
Research groups from different organizations in India have been actively monitoring pesticide levels in various environmental media including water, sediment, biota, agricultural products and humans for the last three decades. A summary of pesticide concentrations in different environmental media within the Ganga River basin is provided here.

2.3.1 Pesticides Detected and their Fate and Transport in the Environment

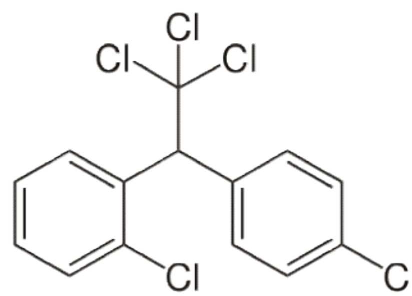
DichloroDiphenylTrichloroethane (DDT - $C_{14}H_9Cl_5$)

Dichloro**D**iphenyl**T**richloroethane (DDT - $C_{14}H_9Cl_5$) is one of the most well-known synthetic pesticides. It is a chemical with a long, unique, and controversial history. First synthesized in 1874, DDT's insecticidal properties were not discovered until 1939, and it was used with great success in the second half of World War II to control malaria and typhus among civilians and troops. After the war, DDT was made available for use as an agricultural insecticide (Wikipedia, 2011). DDT is currently banned world-wide under the Stockholm Convention and India is the only country that continues to manufacture and consume this pesticide (Wikipedia, 2011).

DDT is an organochlorine compound, similar in structure to the insecticide methoxychlor and the acaricide dicofol. It is a highly hydrophobic, colorless, crystalline solid with a weak, chemical odor. It is nearly insoluble in water but has good solubility in most organic solvents, fats, and oils. DDT does not occur naturally, but is produced by the reaction of chloral (CCl_3CHO) with chlorobenzene (C_6H_5Cl) in the presence of sulfuric acid, which acts as a catalyst.



p,p'-dichlorodiphenyltrichloroethane.



o,p'-dichlorodiphenyltrichloroethane

Structure of DDT

Commercial DDT is a mixture of several closely related compounds. The major component (77%) is the *p*,*p*-isomer while the *o*,*p*-isomer is also present in significant amounts (15%). Dichlorodiphenyldichloroethylene (DDE) and dichlorodiphenyldichloroethane (DDD) make up the balance. DDE and DDD are also the major metabolites and breakdown products in the environment. The term "**total DDT**" refers to the sum of all DDT-related compounds (*p,p'*-DDT, *o,p'*-DDT, DDE, and DDD) in a sample (http://en.wikipedia.org/wiki/DDT).

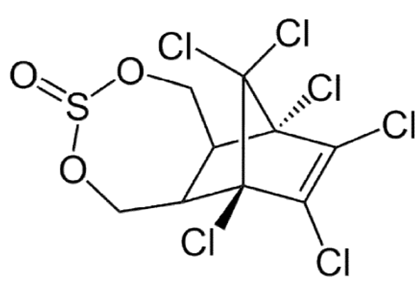
Fate and transport: When DDT enters the aquatic environment, it is quickly absorbed by organisms and by soil or it evaporates, leaving little DDT dissolved in the water itself. Its breakdown products and metabolites, DDE and DDD, are also highly persistent and have similar chemical and physical properties. DDT and its breakdown products are transported from warmer regions of the world to the Arctic by the phenomenon of global distillation, where they then accumulate in the region's food web. Because of its lipophilic properties, DDT has a high bioaccumulation potential, especially in predatory birds where these compounds are stored mainly in body fat. DDT and DDE are very resistant to metabolism; in humans, their half-lives are 6 to 10 years, respectively. DDT is toxic to a wide range of animals in addition to insects, including marine animals such as crayfish, daphnids, sea shrimp and many species of fish. Most famously, it is a reproductive toxin for certain bird species, and it is a major reason for the decline of the bald eagle, brown pelican, peregrine falcon, and osprey. Birds of prey, waterfowl, and song birds are more susceptible to eggshell thinning than chicken and related species, and DDE appears to be more potent than DDT (Wikipedia, 2011 http://en.wikipedia.org/wiki/DDT)

Endosulfan ($C_9H_6Cl_6O_3S$)

Endosulfan ($C_9H_6Cl_6O_3S$) is an organochlorine insecticide and became a highly controversial agrichemical due to its acute toxicity, potential for bioaccumulation, and role as an endocrine disruptor. Because of its threats to human health and the environment, a global ban on the manufacture and use of endosulfan was negotiated under the Stockholm Convention in April 2011. More than 80 countries had already banned it or announced phase-outs by the time the Stockholm Convention ban was agreed upon. However, it is still used extensively in India, China, and a few other countries.

Endosulfan has been used in agriculture around the world to control insect pests including whiteflys, aphids, leafhoppers, Colorado potato beetles and cabbage worms. Because of its unique mode of action, it is useful in resistance management; however, because it is non-specific, it can negatively impact populations of beneficial insects (http://en.wikipedia.org/wiki/Endosulfan).

Endosulfan is one of the most toxic pesticides in the market today, responsible for many fatal pesticide poisoning incidents around the world. Endosulfan can act as an endocrine disruptor, causing reproductive and developmental damage in both animals and humans.

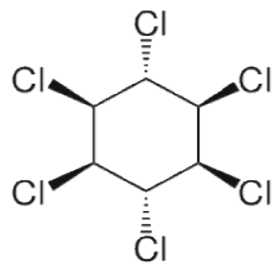


Structure of Endosulfan

Endosulfan breaks down into endosulfan sulfate and endosulfan diol, both of which have structures similar to the parent compound and are also of toxicological concern. The estimated half-lives for the combined toxic residues ranges from roughly 9 months to 6 years. Endosulfan is a very persistent chemical which may stay in the environment for lengthy periods of time, particularly in acid media. Endosulfan has relatively high potential to bioaccumulate in fish. It is also toxic to amphibians (Wikipedia, 2011; http://en.wikipedia.org/wiki/ Endosulfan).

Lindane or Hexachlorocyclohexane (HCH)

HCH – hexachlorocyclohexane, also called benzene hexachloride (BHC), is a six chlorine substituted cyclohexane, a polyhalogenated compound. It comes in many forms, some of which are pesticides. α-HCH, β-HCH, γ-HCH (lindane or gammaxene), δ-HCH, t-HCH. γ-HCH is considered as a pesticide and popularly known as lindane (Wikipedia, 2011; http://en.wikipedia.org/wiki/Hexachlorocyclohexane).



Structure of Lindane or Hexachlorocyclohexane (HCH)

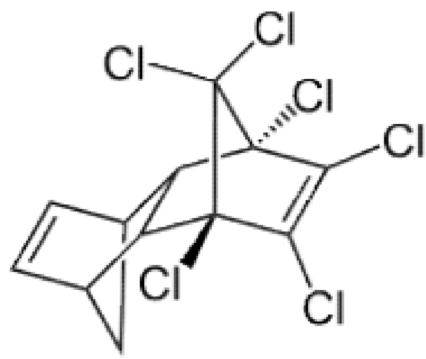
Lindane (γ-HCH) is an organochlorine chemical variant of hexachlorocyclohexane that has been used both as an agricultural insecticide and as pharmaceutical treatment for lice and scabies. The World Health Organization classifies Lindane as "Moderately Hazardous," and its international trade is restricted. In 2009, the production and agricultural use of Lindane was banned under the Stockholm Convention on persistent organic pollutants. A specific exemption to that ban allows it to be used as a second-line pharmaceutical treatment for lice and scabies (Wikipedia, 2011; http://en.wikipedia.org/wiki/Lindane).

It has an oral LD_{50} of 88 mg/kg in rats and a dermal LD_{50} of 1000 mg/kg. Most of the adverse human health effects reported for lindane have been related to agricultural uses and chronic, occupational exposure of seed treatment workers. Exposure to large amounts of lindane can harm the nervous system, producing a range of symptoms from headache and dizziness to seizures, convulsions and more rarely death. Prenatal exposure to β-HCH has been associated with altered thyroid hormone levels and could affect brain development (Wikipedia, 2011; http://en.wikipedia.org/wiki/Lindane).

When Lindane is used in agriculture, an estimated 12-30% of it volatilizes into the atmosphere, where it is subject to long-range transport and can be deposited by rainfall. Lindane in soil can leach to surface and even ground water and can bioaccumulate in the food chain. However, biotransformation and elimination are relatively rapid when exposure is discontinued. Most exposure of the general population to Lindane has resulted from agricultural uses and the intake of foods, such as produce, meats and milk, produced from treated agricultural commodities (Wikipedia, 2011; http://en.wikipedia.org/wiki/Lindane).

Aldrin ($C_{12}H_8Cl_6$)

Aldrin ($C_{12}H_8Cl_6$) is an organochlorine insecticide that was widely used until the 1970s, when it was banned in most countries. It is a colourless solid. Before the ban, it was heavily used as a pesticide to treat seed and soil. Aldrin and related "cyclodiene" pesticides became notorious as persistent organic pollutants.



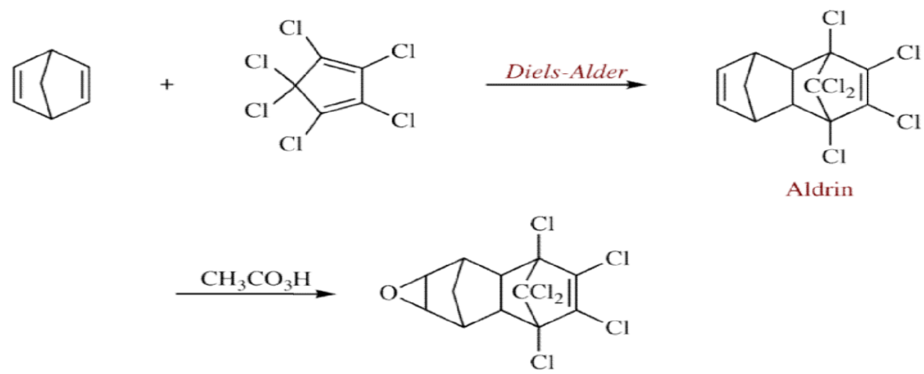
Structure of Aldrin

Aldrin has a rat LD_{50} of 39 to 60 mg/kg. Like related polychlorinated pesticides, aldrin is highly lipophilic and its solubility in water is only 0.027 mg/L, which exacerbates its persistence in the environment. It was banned by the Stockholm Convention on Persistent Organic Pollutants in 2009 (Wikipedia, 2011; http://en.wikipedia.org/wiki/Aldrin).

Dieldrin ($C_{12}H_8Cl_6O$)

Dieldrin ($C_{12}H_8Cl_6O$) is a chlorinated hydrocarbon and is closely related to aldrin, which reacts further to form dieldrin. Aldrin is not toxic to insects; it is oxidized in the insect to form dieldrin which is the active compound. However, it is an extremely persistent organic pollutant; it does not easily break down. Furthermore it tends to biomagnify as it is passed along the food chain. Long-term exposure has proven toxic to a very wide range of animals including humans, far greater than to the original insect targets. For this reason it is now banned in most of the world (Wikipedia, 2011; http://en.wikipedia.org/wiki/Dieldrin).

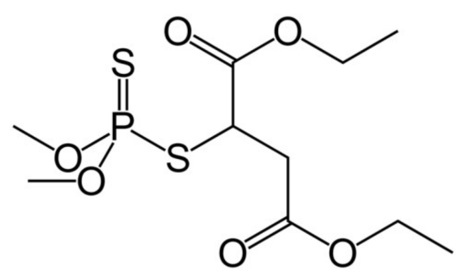
It can be formed from the synthesis of hexachloro-1,3-cyclopentadiene with norbornadiene in a Diels-Alder reaction, followed by epoxidation of the norbornene ring.



Structure of Dieldrin

Malathion

Malathion is an organophosphate compound which binds irreversibly to cholinesterase. Malathion is an insecticide of relatively low human toxicity. However, recent studies have shown that children with higher levels of malathion in their urine seem to be at an increased risk of attention deficit hyperactivity disorder. (http://en.wikipedia.org/wiki/Malathion).



Structure of Malathion

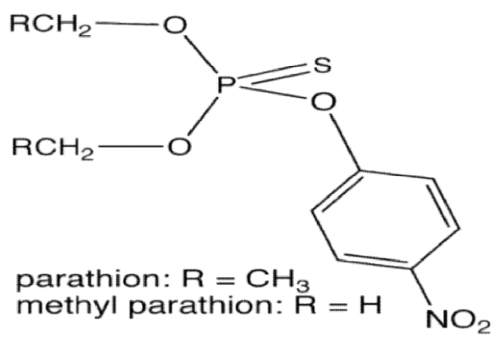
Malathion is a pesticide that is widely used in agriculture, residential landscaping, public recreation areas, and in public health pest control programs such as mosquito eradication. Malathion in low doses (0.5% preparations) is used as treatment for *Head lice, Body lice, Scabies.* Absorption or ingestion of malathion into the human body readily results in its metabolism to malaoxon, which is substantially more toxic. (http://en.wikipedia.org/wiki/Malathion)

Malathion should be used in well-ventilated rooms; lack of proper ventilation can seriously poison the occupants living or working in this environment. A possible concern is that malathion being used in an outdoor environment could enter a house or other building.

Parathion

Parathion, also called parathion-ethyl or diethyl parathion, is an organophosphate compound. It is a potent insecticide and acaricide. It is highly toxic to non-target organisms, including humans. Its use is banned or restricted in many countries, and there are proposals to ban it from all use. Parathion is generally applied by spraying. The usual concentrations of ready-to-use solutions are 0.05 to 0.1% (http://en.wikipedia.org/wiki/Parathion).

Parathion acts on the enzyme acetylcholinesterase, but indirectly. After being ingested by insects (and unintentionally, by humans), parathion is oxidized by oxidases to give paraoxon, replacing the double bonded sulfur with oxygen. (http://en.wikipedia.org/wiki/Parathion).



Structure of Parathion

Parathion is a cholinesterase inhibitor. It generally disrupts the nervous system by inhibiting the acetylcholinesterase. It is absorbed via skin, mucous membranes, and orally. Absorbed parathion is rapidly metabolized to paraoxon. Parathion has been used as a chemical weapon, and is very toxic to bees, fish, birds, and other forms of wildlife. Parathion can be replaced by many safer and less toxic alternatives (http://en.wikipedia.org/wiki/Parathion).

2.3.2 Pesticide Concentrations in Different Environmental Media

In Water: The most commonly monitored pesticides in the rivers of the Ganga river basin were hexachlorocyclohexane (HCH or Lindane), DDT and its products (DDD and DDE), and endosulfan. The earliest publication was in 1986 when DDT concentrations were measured in water samples from R. Yamuna. Total DDT concentrations were 0.24 micro-g/L (Pillai, 1986). Subsequent studies found average concentrations of total HCH and total DDT to be 245 and 247 parts per trillion (pptr or ng/L), respectively and endosulfan concentration was 38.3 ng/L (Agnihotri et al., 1994). A summary of pesticide concentrations reported in various publications is provided in Table 4 to Table 6.

Insecticide residues were found in Ganga river water near Farrukabad, India and the average concentration of *Aldrin* was more than that of *Dieldrin*. *Aldrin* residues often exceeded the World Health Organization (WHO) guideline value for drinking water, and the concentration of heptachlor occasionally exceeded the specified limits as well (Agnihotri et al., 1994).

Water samples were collected from 34 locations in Varanasi along R. Ganga and analyzed for DDT, HCH and endosulfan residues. Of the studies reported here, pesticide concentrations in this study were the highest with 12.9, 13.1 and 10.65 micro-g/L of total DDT, HCH and endosulfan, respectively. All these pesticides are capable of accumulating in the food chain of the river (Nayak et al., 1995). The authors suggest that pesticide levels were higher on the city-side of the river as compared to the cultivated side (opposite bank).

Residues of organochlorine pesticides (OCPs) namely, isomers of HCH and endosulfan, DDT and its metabolites, aldrin, and dieldrin were analysed in river Yamuna water along its stretch passing through Haryana and Delhi and the canals originating from it. The concentration of HCH and DDT at different sites along the river ranged between 12.76 – 593.49 ng/L (with a mean of 310.25 ng/L) and 66.17–722.94 ng/L (with a mean of 387.9 ng/L), respectively. In canals, the values were found between 12.38 – 571.98 ng/L and 109.12 – 1572.22 ng/L for HCH and DDT, respectively (Kaushik et al., 2008).

In a similar study, pesticides were analysed in water samples from the river Ghaggar in Haryana. Analysis showed that aldrin and dieldrin were below detection limits. Both, hexachlorocyclohexane (HCH) and dichloro-diphenyltrichloroethane (DDT) were traceable in all the water samples. High concentration of β-HCH among Total HCH indicates old pollution source whereas predominance of p,p-DDT among total DDT reflects its recent use in the catchment area of the river (Kaushik et al., 2010).

Pesticide residues were detected in River Ganga water between Kachla and Kannauj, U.P, India. Some pesticides like DDT, α-BHC, DDD, Aldrin, Dieldrin, were present in the concentration ranges of 3.33 - 5.33 ppb (or micro-g/L), 1.73 - 3.01 ppb, 0.88 - 2.41 ppb, 0.49 - 4.11 ppb. Organophosphorous pesticides like dimethoate and methyl parathion were also detected at concentration levels of 0.41-0.56 ppb and 0.16-0.50 ppb (Rehana et al., 1995).

Organochlorine pesticides were reported in the waters of Gomti river. Total OCPs residues ranged between 2.16 and 567.49 ng/L. It is suggested that the source of DDT contamination is from aged and weathered agricultural soils with signature of recently used DDT in the river catchments. (Malik et al., 2009).

Sewage water in Kolkata was evaluated for pesticides and heavy metals along with other water quality parameters in a detailed three-season study (Purkait et al., 2009). Total DDT, total HCH and total organophosphates were detected in all three seasons and the five locations that were sampled. Average (spatial) total pesticide concentrations ranged between 37 to 38.4 ng/L over the three seasons.

In Sediments of River and Marine Environments: The levels of 16 priority polycyclic aromatic hydrocarbons (PAHs) were identified during pre-monsoon, monsoon and post-monsoon seasons in sediments collected from the banks of River Yamuna, Delhi. The sum of 16 PAH compounds ranged from 4.50 to 23.53 µg/g with a mean concentration of 10.15 ± 4.32 µg/g (dry weight) (Agarwal et al., 2006).

Soil and surface water of the northern Indo-Gangetic alluvial plains region were found to be severely contaminated with several persistent organic pesticides. In samples collected in the Unnao district in the area between the rivers Ganga and Sai, β and δ- isomers of HCH were detected most frequently, whereas, methoxychlor was the least detected pesticide. The total OCPs level ranged from 0.36–104.50 ng/g and 2.63–3.72 µg/L in soil and surface water samples, respectively (Singh et al., 2007).

Organochlorine pesticide residues (OCs) such as hexachlorocyclohexane isomers (HCHs), dichlorodiphenyltrichloroethane and its six metabolites (DDTs), and hexachlorobenzene (HCB) have been found in sediment cores of Sunderban Wetlands in the Northeastern Part of Bay of Bengal, India. The pooled mean values of the mass fraction of ΣHCHs, ΣHCB, and ΣDDTs in the sediments were 0.05 – 12, 0.05 – 1.4, and 0.05 – 11.5 ng/g dry weight, respectively (Sarkar et al., 2008b).

Samples were collected and analyzed to determine the distribution of persistent organochlorine pesticide residues in bed sediments of Gomti river. Organochlorine pesticides were reported in sediments of Gomti river and ranged between 0.92 and 813.59 ng/g. The bed sediments of Gomti river were contaminated with Lindane, Endrin, Heptachlor epoxides and DDT (Malik et al., 2009).

In Biotic Environment: Organochlorine pesticides were reported in fish samples collected from Gomti river with concentrations ranging between 2.58 – 22.56 ng/g. Neither spatial nor temporal trends could be observed in the distribution of the OCPs. Aldrin was the predominant OCP, whereas, HCB and methoxychlor could not be detected. α-HCH and β-HCH among the isomers of HCH and p,p-DDE among the metabolites of DDT were the most frequently detected OCPs (Malik et al., 2007).

In Humans: Humans are exposed to various environmental chemicals such as Organo-Chlorine pesticide residues, etc. It is reported that organochlorine residues are present in blood of North Indian People. Analysis of maternal and cord blood samples of a normal person revealed the presence of organochlorine pesticide residue, mostly HCH followed by Endosulfan, DDE and DDT (Pathak et al., 2008).

In summary, it is evident that significant and detectable concentrations of commonly used pesticides like DDT and HCH which are considered persistent contaminants were found in most studies. While their concentrations in river water samples were below the permissible Indian standards for drinking water, they pose a risk to human health due to their potential for bioaccumulation. The high concentrations noted in fish tissue in various studies highlight food rather than water as a major route of exposure to these contaminants. A comprehensive health risk assessment can be done for pesticides that would account for all routes of exposure and the risks associated with exposure.

Table 4: Pesticide concentrations in water samples collected from Ganga River basin

S No.	River	Σ DDT	Σ HCH	Σ Endosulfan	Aldrin	Diedrin	2, 4-D	Heptachlor	ΣOCPs	Malathion	Dimethoate	Methyl Parathion	ΣOC+OP	Season	References
1	Yamuna	240	-	-	-	-	-	-		-	-	-			Pillai. M.K.K, 1986
2	Ganga	-	-	ND	-	-	-	-	<100	-	-	-			Sengupta et al, 1989
3	Ganga	247.2	244.6	38.3	25.6	12.7	-	36.7		-	-	-			Agnihotri et al, 1994
4	Ganga	12940	13144	10650	-	-	-	-		-	-	-			Nayak et al, 1995
5	Ganga	3074	1930	250	-	1753	ND	-		-	486.6	383.3			Rehana et al, 1995
6	Ganga	1460	-	ND	-	410	30	-		-	200	410			Rehana et al, 1996
7	Ganga	ND	(γ) 259	ND	ND	-	-	-		2658	-	ND			Shankararamak rishnan et al, 2005
8	Between Ganga and Sai	8	60	7	-	ND	-	4	90	-	-	-			Singh et al, 2007
9	Yamuna	506.74	191.34	-	-	-	-	-		-	-	-			Kaushik et al, 2008
10	Gomti								113.02 ±	-	-	-			Malik et al, 2009
11	Ganga	16.536	7.518	-	-	-	-	-		-	-	-	38.038	Summer	Purkait et al, 2009
12	Ganga	15.982	7.736	-	-	-	-	-		-	-	-	37.12	Winter	Purkait et al, 2009
13	Ganga	16.584	6.868	-	-	-	-	-		-	-	-	38.412	Monsoon	Purkait et al, 2009
14	Kuano	0.45-2	0.145-1	-	-	-	-	-		-	-	-			Singh et al, 2009
15	Ghaggar		119.74 ± 76.54	587.3 ± 201.18	-	-	-	-		-	-	-			Kaushik et al, 2010

Cells with dashes indicate pesticide was not monitored.
ND = Not detected

Table 5: Pesticide Concentrations in Sediments of Ganga River Basin

River	∑DDT ng/l	∑HCH ng/l	Endosulfan ng/l	Heptachlor ng/l	∑PAHs ng/l	HCB ng/l	References
Yamuna	240	-	-	-	-	-	Pillai. M.K.K: 1986
Ganga	0.875	6.96	-	-	-	-	Hans et al, 1999
Yamuna	-	-	-	-	10150	-	Agarwal et al, 2006
Between Ganga & Sai rivers	13.81	1.65	0.23	0.25	-	0.060	Singh et al, 2007
River Hooghly	0.05-11.5	0.05-12	-	-	-	0.015-1.4	Sarkar et al, 2009
Sunderbans	1.71	2.87	-	-	575.8	0.247	Binelli et al, 2008

Table 6: Pesticide concentrations in fish tissue samples from Ganga river basin

River	Tissue	∑DDT ng/l	∑HCH ng/l	Endosulfan ng/l	Dimethoate ng/l	Malathion ng/l	∑OCPs ng/l	Season	References
Gomti	Fish Tissue						9.66 ±5.6		Malik et al, 2007
Ganga	Cat Fish	7582.68	3061.12	-	-	-	-		Singh et al, 2008
	Carp Fish	3338.9	1360.243	-	-	-	-		
Gomti	Cat Fish	5891.633	3536.726	-	-	-	-		Singh et al, 2008
	Carp Fish	2018.19	2428.28	-	-	-	-		
Ganga	Fish Tissue	78.4	985.2	286.4	390	10.4		Season 1	Akthar et al, 2009
		276.4	1174.4	353.6	349.6	1000		Season 2	
		905.8	1166.4	746.4	823.2	784.8		Season 3	

2.4 Conclusions

- Pesticide contamination poses significant risks to the environment and non-target organisms range from beneficial soil microorganisms to insects, plants, fish, birds and humans.
- A limited number of studies have been conducted in the last three decades in Ganga river basin where pesticide concentrations have been monitored in various environmental media. In general, total DDT and total HCH concentrations have been reported in detectable and significant concentrations by most researchers.
- Pesticide levels in water samples from the Ganga River basin ranged from non-detectable to a maximum total pesticide concentration of 13.1 micro-g/L in the city of Varanasi. Only four of the fifteen studies reviewed here showed total pesticide concentrations higher than the permissible levels of 1 micro-g/L.
- Pesticide levels in sediments ranged from 0.05 ng/g to 240 ng/g.
- Significant and high pesticide levels have been reported in fish tissue with maximum total DDT concentration of 7.5 micro-g/g in cat fish and maximum total HCH concentration of 3.5 micro-g/g in cat fish. These results indicate that pesticides like DDT and HCH bioaccumulate to significant levels in fish tissue. Health risks associated with these levels of pesticides in food need to be examined in greater detail.
- In order to control water pollution by these substances, domestic and industrial wastes (both solid and liquid) should not be allowed to be discharged/dumped into water bodies without proper pretreatment.
- Further, constant monitoring and analysis for the most commonly used pesticides in all environmental media by appropriate agencies is essential for a comprehensive risk assessment.

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Cultural-Religious Aspects of Ganga Basin

GRBMP: Ganga River Basin Management Plan

by

Indian Institutes of Technology

| IIT Bombay | IIT Delhi | IIT Guwahati | IIT Kanpur | IIT Kharagpur | IIT Madras | IIT Roorkee |

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who have contributed directly and those who have taken lead in preparing this report is given on the reverse side.

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We express our sincere appreciation to our research scholars, namely, Ms. Kumkum Bharati, Ms Anita Sengar, Ms Ritika Mahajan, Mr Devendra Kumar, Mr Rupesh Kumar who helped us in different ways to complete this report.

Mr Deep Pathak, MBA student of 2010-2012 batch, Mr Sidharth Gupta, B Tech student of 2008-2012 batch also contributed in data collection, analysis and report generation.

Contents

1. Introduction

River Ganga, the holiest of all rivers, carries profound significance for the entire Indian society and the diaspora – for a vast majority this emerges from religious and spiritual faith and mythology while for others this could be related to socio-cultural and economic opportunities that it offers. This diverse relationship of the river with the people and the culture of India needs no formal introduction as this is deeply rooted in the psyche of every Indian since childhood through folklores, scriptural references and a host of customs and traditions which in turn mobilise round the year a large number of pilgrims to its banks along its entire stretch all the way from its origin in the Himalayas to its mouth on the Bay of Bengal. Driven by faith, tens of millions of pilgrims take holy dip in the Ganga every year and some or the other part of their lives is associated through the rituals they perform. An inventory of types of congregations, rituals and routine activities of the population staying along this sacred river suggests strong interrelationship and emotional dependence of the people. With almost 37% of Indian population living in its basin, and the rest being directly or indirectly associated with it, River Ganga is evidently an inseparable facet of the Indian society. Ganga water, known as '*Gangajal'* is considered sacred and typically found in a majority of Hindu households across the length and breadth of the country eminently qualifies for inclusion under the Geographical Indication registry.

Box1: Significance of Gangajal in a Hindu Household

Gangajal - the sacred water of River Ganga is stocked in almost all Hindu households and its use is considered auspicious – purifying all individuals and places wherever it is sprinkled and driving away evil spirits. With this belief Gangajal is used in all types of yajna/homam to bring prosperity such as Gangapujan, Laghurudra, Maharudra, Atirudra, Durgapuja, Laxchandi Yagna, Navchandi Yagna, Gayatri Yagna, Bhoomi Pujan, Shilanyas,, Murti Pratishtha, Vastu Shanti, Grah Shanti, Naxtra Shanti, Kalsarp Shanti, Shradh Karma, Narayanbali, 'abhishek' of Shivlingam,Vivah Samskara (marriage ceremony), etc. The holy water virtually represents the life-line for the Hindu society that is used all the way till the end of life – drops of water into the mouth of a dying person are believed to secure instant salvation.

Interestingly, Gangajal, with hitherto undefined chemical/biological properties is known to have indefinite shelf life and which add to its aura of sacredness. Gangajal is considered to possess more medicinal elements than water of any other rivers and because of its supernatural effects it is used in ayurvedic and naturopathic applications for curing a range of ailments. This mystical property is attributed to the vast reservoir of minerals and herbs available in the catchments of upper Himalayan reaches of the river.

Given this potent combination of spiritual significance and medicinal properties, almost all pilgrims to its holy ghats of Rishikesh and Haridwar collect Gangajal as an inalienable ritual and carry it to their homes. It is not surprising that many small establishments and micro-enterprises take it upon themselves to market the holy water in sealed metallic vessels or plastic containers.

Evidently the spiritual and religious significance of River Ganga is greater than any other river on the planet. Recognising its profound significance for the entire Indian society, the Government of India, albeit after almost 50 year of independence, declared it as the

National River on November 4, 2008. Accordingly, under the Constitution of India this special status calls for taking special measures for the protection of River Ganga on the part of the central, state and local governments as well as the civil society at large.

2. Objectives

The main objective of this report is to develop a clear understanding of the relationship between River Ganga and the Indian society in general and the people living along its banks in particular; assess significance of the river in their lives, attempt correlation of possible impacts of diverse rituals from water quality point of view and ultimately contribute in framing the overall strategy for restoration of the river to its old glory. In this context, the key aspects that have been investigated as part of the study are as follows:

(a) Historical account of cultural-religious practices in the Ganga basin.
(b) Changes that have taken place in socio-cultural milieu of Ganga over a period of time.
(c) Role of various stakeholders comprising, among others, government agencies, academia and intelligentsia, civil society, religious institutions, etc.
(d) Various problems and issues with regard to, among others, impact on the river water quality.
(e) Perceived solutions.

3. Research and Methodology

At the outset of the study it was noted that structured data especially explaining the impact and association of socio-cultural practices on the river ecology or water quality was not available[1]. In order to develop the data and improve understanding of the relationship between diverse socio-cultural practices and the River Ganga detailed interviews were conducted with key persons who have been instrumental or associated with Ganga related socio-cultural practices and environment issues in its basin. In addition, about 10 focused group discussions (FGDs) involving different interest groups (civil society, local administrators, academicians, priest community, residents along the banks, etc.) were conducted. Some of the FGDs were aimed to corroborate findings of the interviews with individual respondents while the rest were aimed at identifying issues and understand perspectives of stakeholders and possible solutions with respect to River Ganga and its basin in general.

A detailed historic account of various cultural and religious practices was developed through literature survey – primarily Hindu scriptures, and primary data collected as part of

[1]Most of the efforts of getting suitable data with regards to the influx of people and the related aspects were not structurally fruitful.

engagement with the community/stakeholders. Further, to understand various issues related to cultural and religious aspects of River Ganga, members of the team visited few important pilgrimage centres on the river, among others, Gangotri which is located in a very fragile ecological setting; and participated in important festivals at Haridwar as well as in the Mahakumbh at Allahabad which coincidentally occurred during the term of this study in March 2013.

4. Pilgrimage Places

The Ganga Basin as a whole is of immense religious and cultural importance to followers of, among others, Hindu and Sikh religions. There are several sites venerated by Hindus which are located along the main stream of the River Ganga as well as away from the river. In the upper reach of the Ganga basin some of these sites are Gaumukh, Gangotri, Uttarkashi, and Tehri in the Bhagirathi basin; and Badrinath, Vishnuprayag, Nandaprayag, Karnaprayag, Rudraprayag, Ukhimath and Srinagar in the Alaknanda basin. Given the difficult Himalayan topography, harsh winters and hazard of monsoons, these locations are accessed only during summers when millions of pilgrims visit seeking salvation. Further down when the river emerges out of the hills and descends to the plains the important centres of pilgrimage are Rishikesh and Haridwar which are typically visited round the year on various occasions by millions as well.

Besides being centres of pilgrimage, these locations/towns help in driving the economy of the hill State of Uttarakhand and generate livelihood for a very large number of people. Evidently this is one of the major areas of revenue generation for the relatively new state of Uttarakhand and hence impetus on promotion of tourism notwithstanding the ecological, geographical and infrastructural limitations. Some of the important locations are briefly described in the paragraphs that follow.

Important locations in the Hills

This section lists out a set of important pilgrimage centres in the upper reaches of the Ganga basin and briefly describes religious significance of each location.

Gomukh

On the spiritual platform, according to the Hindu scriptures[2] while Ganga is believed to originate from the toe of Lord Krishna and thereafter from the jata (hair locks) of Lord Shiva on the material platform physically it emerges from a glacier called 'Gangotri'. The origin of the river is known as Gomukh (literally meaning 'mouth of cow') which is situated at a height of around 3,500 m above mean sea level. According to the legend, in historic times, the origin appeared like mouth of a cow – again a sacred animal in Hindu religion. Given this

[2] Among others, the four *Vedas, 18 Puranas, Upnishads, Smriti, Samhita, Bhagwatam, Mahabharat, Bhagvad Gita, etc.*

background, for time immemorial Gomukh has been considered an important place of pilgrimage in Hindu religion and the journey to this place, which is among the most difficult tracks, is considered a form of penance.

Char Dham

The Bhagirathi basin has two of the venerated sites of Hinduism, namely Gaumukh and Gangotri. Similarly, the Alaknanda basin has two of the most venerated shrines namely Badrinath and Kedarnath. Badrinath, Kedarnath, Gangotri along with Yamunotri in the Yamuna basin (the origin of another sacred river - River Yamuna) constitute the 'Char Dham' – four important seats of spiritual power.

Gangotri

Gangotri is situated 19 km from Gomukh at a height of 3100 m above mean sea level. It is considered the origin of the River Ganga. The river is called Bhagirathi at the source and acquires the name 'Ganga' from Devprayag onwards where it meets another river called Alaknanda.For a large number of pilgrims and tourists alike, the town of Gangotri serves as the starting point for the popular trekking routes viz.,Gangotri-Gomukh-Tapovan and Gangotri-Kedartal.

Badrinath

On pan India basis, Badrinath is one of the four most important pilgrimage centres associated with *Lord Vishnu* – the sustainer. It is the seat of the deity, more popularly known as 'Vishal Badri'and which represents final destination for any seeker of salvation. Evidently every Hindu and particularly every Vaishnavite desires to visit at least once in his/her lifetime. The temple housing the deity is surrounded by Nara and Narayana mountains (dual form of Lord Vishnu) on either side, and river Alakananda (literally meaning 'the most beautiful') flows in the front, its sound symbolising pious rhyme Har-Har.

Other Pilgrimage locations on way to Badrinath

On way to the town of Badrinath, there are number of locations which are associated with some legend and carry religious significance, though at a smaller level. These locations are viz., Pipalkote, Pandukeshwar and Hanuman Chatti.

- **Pipalkote** is known for its proximity to *Garud Ganga* where, as per legend, *Garuda* (the mount of Lord Vishnu) performed penance to atone killings of snakes during his lifetime. There are 2 small temples dedicated to Lord Vishnu along with *Mahalakshmi* and a separate temple for *Garudazhwar*. It is believed that the pebbles collected from this river ward off snakes and other evil spirits and facilitate pregnant women with safe delivery. As per another legend it is believed that *Nagadosham* (curse of snake) gets wiped off if one consumes sacred waters of the river from this location.

- **<u>Pandukeshwar</u>** is believed to be the birth place of the *Pandavas* and accordingly it derives its name. During winters when the town of Badrinath becomes inaccessible this places becomes the abode of *Lord Badrinarayanan*.

- **<u>Hanuman Chatti</u>** on the otherhand is a small settlement where a temple dedicated to Lord Hanuman exists which represents a stopover on the pilgrimage circuit.

Kedarnath

Kedarnath is the seat of one of the holiest Hindu temples dedicated to Lord Shiva. According to a legend the *Pandavas* came to this place in penance in search of Lord Shiva seeking blessings and to be absolved of the sins of having killed their kith and kin in the battle of the Mahabharata.

The town of Kedarnath is located at an altitude of about 3,584m above mean sea level near the origin of river Mandakini and involves one of the most difficult and precarious treks over 14 km. Being one of the main stops on the *Char Dham yatra*, notwithstanding the challenges of the long trek, a large number of pilgrims visit the temple every summer.

Yamunotri

Yamunotri is the source of the Yamuna River and the seat of Goddess Yamuna in Hinduism. It is situated at an altitude of 3,293 metres above mean sea level in the Garhwal Himalayas. Again this being one of the main stops on the *Char Dham yatra*, a large number of pilgrims come here during summers.

Panch- Prayag

'Prayag' in *Sanskrit* means 'confluence' of rivers. In the hilly region of the Ganga basin there are five main confluences which eventually lead to the formation of the main river and which is then know as Ganga in the plains. The locations associated with these confluences derive religious significance in one or the other form and represent important stopover on the pilgrimage circuit. Each of the five *'*prayag*'* is listed with a brief narrative as follows:

- **Vishnuprayag** starting from the head reaches represents the first confluence when River Alaknanda, which originates in the eastern slopes of glacier fields of Chaukhamba is joined by the River Saraswathi at Village Mana near the international border with China. The combined stream known as Alaknanda then flows in front of the Badrinath temple.
- **Nandaprayag** is the second prayag in the cascade sequence of the confluences where Nandakini River joins the main Alaknanda River. According to one legend, a noble King

Nanda performed *yagnya* (fire-sacrifice) and sought blessings of God and hence, the confluence is named after him.

- **Karnaprayag** is the location where River Alaknanda is joined by the Pindar River. The epic Mahabharata legend narrates that Karna – the legendry son of Sun performed penance here and earned the protective gear of *Kavacha* (armour) and *Kundala* (ear rings) from his father which bestowed him invincibility**.**

- **Rudraprayag** is the point of confluence of River Alaknanda with River Mandakini. The confluence derives its name after Lord Shiva. According to a popular legend, Lord Shiva performed here *Tandava* - a vigorous dance that is the source of the cycle of creation, preservation and dissolution; *rudra* representing its violent form connoting destruction. According to another legend Lord Shiva is also said to have played his favourite musical instrument *Rudra Veena* here whereby enticing Lord Vishnu and converting him to water**.**

- **Devprayag** is the last of the five prayags where River Alaknanda joins River Bhagirathi - the main stream which is then known as River Ganga. From religious and cultural point of views, this confluence carries same significance as that of the famous *Triveni Sangam* at Allahabad-confluence of River Ganga with River Yamuna and the my thological River Saraswati.

Important Pilgrimage Centres in the Plains

In the plains River Ganga carries undiminished religious significance, is easily accessible and hence attracts large number of pilgrims round the year. There are particular locations on this stretch which have evolved over the generations and where the crowds swell to very large numbers on specials occasions. Some of these locations starting from the upper reaches are described in the paragraphs that follow.

Rishikesh

Rishikesh is one of the names of Lord Krishna/ Lord Vishnu that means 'Lord of the senses'. The place gets its name after Lord Vishnu who appeared to *Raibhya Rishi* (as a result of his penance) as Lord Rishikesha. In the sacred text of *Bhagwad Gita*, Arujna addresses Lord Krisha as 'Rishikesha' for mastery over the senses. According to one legend Lord Rama performed penance here for killing Ravana - the demon king of Lanka. Two of the landmark bridges across the river here derive their names from Lord Rama and his younger brother viz., Ram Jhula and Lakshman Jhula respectively.

Being in the foot hills of the Himalayas, the place has its own charms and significance. It represents 'the gateway to the Himalayas' as all journeys to the pilgrimage centres described in the preceding section commence from here. There are number of temples and spiritual centres (*math* and *ashram*) along both the banks of the river where devotees can enhance spiritual quotient and aspire towards salvation. Year round religious activities attract large number of Hindu pilgrims of all denominations to this holy town which also holds the distinction of being perhaps the only urban centre in the country where slaughtering of animals or sale and consumption of meat/ meat products is prohibited by law. The Ganga *Arati* – prayer offerings to the sacred river, which is performed at dusk at the Triveni Ghat is very popular and attracts large number of devotees, pilgrims and tourists alike.

Haridwar

Haridwar,which is about 250 km from Gomukh and about 20 odd km from Rishikesh is regarded as one of the seven holiest places in the world by the followers of Hindu religion. The word 'Haridwar' literally translates into 'doors to the kingdom of God'.

According to the Hindu scriptures, subsequent to the *'samudra manthan'* – the fight between the demigods and the demons, Haridwar along with Allahabad, Ujjain and Nasik happened to be one of four locations where *Amrit* - the elixir of immortality was spilled accidentally. In recognition of this celestial 'accident' all the four cities carry high significance on the pan Indian pilgrimage circuit. Accordingly, among others, this is celebrated under special planetary configuration in the form of very large congregation of humanity at each of these four places once every 12 years and which is known as 'Maha Kumbh' or 'Kumbha Mela'. During the Kumbha Mela millions of pilgrims, devotees, *sanyasis* and tourists congregate at Haridwar to perform ceremonial bathing on the banks of the River Ganga with the belief to wash away their sins/ *karmic* debt and attain *Moksha*/ salvation[3].

There are references to *'Gangadwar'* (Haridwar) and *Kankhal* (a well-known habitation next to Haridwar) in the sacred Hindu text *Mahabharata* (*Vana Parva: Tirtha-yatra Parva: Section XC*) which describe the attribute due to which the place is considered sacred.

On the bank of the river at Haridwar is a place which is believed to bear footprints of Lord Vishnu. It is said that as a mark of everlasting reverence to the Lord, River Ganga touches this spot perennially. It is believed that the *Brhama Kund* – the pool of water at the *Har-ki-pairi* is the spot where the drops of *amrit,* as referred above fell. It is further believed that the sacred *ghat* (constructed river front) *Har-ki-pairi* was constructed by King Vikramaditya (1st century BC). Devout Hindus aspire to take holy dip in the river at this place with the belief to wash away sins/ *karmic* debt accruing from misdeeds in this and previous lives and attain *Moksha*/ salvation.

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[3] Hinduism believes in eternal nature of the soul and its reincarnation in a cycle of birth and death according to ones *karma.*

To the right of *Har-ki-pairi* is the *Kushavarta-ghat,* for which it is believed that *pindadana* performed (oblations for the departed ancestors) at this spot ensures eternal peace to soul. Based on this belief Bhishma - the legendry son of Ganga is said to have performed the ritual for his father Santanu at this very spot and accordingly it is also known as *Santanu-tirtha*. Likewise it is believed that immersion of *asthi* (ashes) performed at these locations in particular ensures peaceful passage for the departed soul and stay in the heaves as long as the ashes remain under the water of the Ganga.

For the followers of Sikh religion Haridawar carries special significance as the founder Guru Nanak visited here on the day of *Baisakhi* in 1504 and took holy dip in Ganga at *'Kushwan Ghat'*. Subsequently the third Sikh Guru, Sri Amar Das also visited Haridwar twenty two times during his lifetime.

Evidently, among other locations on the bank of the Ganga, Haridwar has profound significance particularly for the Hindus which translates into a strong belief and a set of customs and rituals that are woven around it.

Allahabad

Allahabad is another ancient and important holy place along the Ganga way down in the plains which finds several references in the Vedic scriptures. Its original name Prayag – meaning 'place of offerings', is derived from its being located at the confluence of three holy rivers, viz., Ganga, Yamuna and the mythological Sarasvati. The point of confluence is known as Sangam which accords a special religious significance and hence taking a holy dip is considered auspicious among the Hindus. As mentioned earlier, it is also one of the four sacred locations where Mahakumbh is held once every 12 years, and besides Haridwar it also hosts an Ardh-Kumbh once every six years.

Varanasi

Varanasi is perhaps the most venerated, mystical and popular of all the cities located on the banks of river Ganga. It is considered as the cultural capital of India and attracts thousands of Hindu pilgrims and visitors from all parts of the world. Varanasi has been a traditional centre of learning of *Sanskrit,* religion, philosophy and astrology. According to scriptures it is believed to be the eternal seat of Lord Shiva and therefore every Hindu aspiring for salvation longs to spend his/her last days here and be cremated on the bank of Ganga. Varanasi is famous for its *ghats* – the stone lined stepped banks of the river and buildings with classical architecture, one of which represents *Mahashmshana* or the 'great cremation ground' where the legendry King Harishchandra is said to have worked as a menial labour. Given this belief, it is not surprising to find a constant influx of dead bodies from the hinterland and round the clock cremation being performed on this *ghat.*

Gaya

In the mid-reach of Ganga, the town of Gaya in Bihar is another place of religious and spiritual significance where thousands of devout Hindus congregate to its revered *ghats.* According to scriptures, it is believed that oblations for ones ancestors when offered at this place facilitate overcoming their sins and their transmigration to higher planets.

Ganga Sagar

Ganga Sagar on the east coast of India in the state of West Bengal is the mouth of the River Ganga where its journey ultimately comes to an end as it merges into the Bay of Bengal. Given its geographical significance, Ganga Sagar is the final destination in the chain of holy places which are located on the bank of the river. On the occasion of *Makar Sankranti* i.e., 14th January when the Sun moves from the southern hemisphere to the northern hemisphere, Ganga Sagar hosts a large fair when couple of lakhs of pilgrims from across the country congregate.

5. Important Rituals on the River Banks of the Ganga

Hindu religion, among others, is recognised by a very wide range of rituals associated with every occasion – be it prayers to particular Gods or demigods, festivals, special events in family or congregations to celebrate specific community level functions, etc. Water, considered as one of the five constituting elements of the human body (*panch-mahabhut*[4]), plays a central role, and what could be more auspicious than the proximity to the holy *Gangajal*.

The rituals along the course of Ganga are varied, distinct and draw tens of millions of people every year. The historical origin of these rituals dates back thousands of years and the faith and belief are rooted deep into *vedic* scriptures which in turn accord special status to the River Ganga – as a mother and thereby as a sacred entity. These rituals and festivals have evolved over time and have impacted Ganga and her devotees in numerous ways and have also been impacted in their turn. In this context, this section attempts to capture in brief the beliefs and the significance of some of the main *samskaras,* rituals and festivals typically performed / celebrated along the bank of River Ganga.

[4]Earth, water, fire, air and ether.

Mundan Samskara

Mundan or Chudakaran Samskara[5] is the eighth of the sixteen *samskaras* that a Hindu is supposed to undergo in his/her lifetime. It is the first hair cut for a child and involves tonsuring before the first or after the third birth anniversary and is based on the belief that hair from the birth represent link to undesirable traits of the previous life which need to be severed. It is a typical ritualistic ceremony performed on holy places such as Rishikesh, Hardiwarr, etc. Besides tonsuring for the young ones, typically grown ups also resort to shaving of their heads on various occasions while visiting holy places. The hair thus removed is symbolically offered to the river – in this case River Ganga.

Antim Samskara/ Antyeshti

Antim Samskaraor cremation is the last of the sixteen *samskaras* that (the soul of) a Hindu is supposed to undergo/embrace upon death. It is a ritualistic process where in the mortal remains of an individual are consigned to the flames. Significance of cremation is far beyond the mere disposal of a dead body in hygienic method – the main objective is to severe the link between the gross body and the astral/ subtle body and thereby facilitate onward journey/ transmigration of the departed soul to heavenly planets. This is based on the belief – as stated in Bhagvad Gita, that the soul is indestructible which continues its journey in a cycle of birth and death according to accumulated *karma,* and therefore cremation (as compared to burial or disintegration in the open) is considered to be the most effective form for this disengagement. Typically river banks are preferred places for cremation and accordingly Kankhal in Haridwar and Manikarnika Ghat in Varanasi are two such well known locations (with several legends woven around them) in the country. Cremation is followed by immersion/disposal of the ashes and the remains, if any into the river.

Immersion of Ashes

According to Hindu scriptures Ganga descended on the Earth in response to the penance performed by *Bhagirath* (hence the name *Bhagirathi* for the river in its early stage) who persevered to secure salvation for 60,000 of his ancestors. Therefore since aeons Hindu society has come to believe that a soul would get *moksha* /salvation (freedom from the cycle of birth and death) if the ashes are immersed into Ganga and it will continue to reside in heavenly planets as long as the ashes remain submerged under its holy waters. This custom is known as *'asthi visarjan'* and Hindu families from across the length and breadth of India as well as among the diaspora aspire to perform it ideally in Haridwar or any other location along its banks.

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[5] The *Samskāra* are a series of sacraments, sacrifices and rituals that serve as rites of passage and mark the various stages of the human life and to signify entry to a particular *varnashram*. Basically all these rituals are of the nature of purification and they are believed to remove sins (*pāpa*) and/or bestow good qualities (*gunas*). These *samskaras* or rituals along with special occasions/ festivals are conducted year round on the banks of the Ganga.

Jal Samadhi

For a *sadhu* or a *sanyasi* (a renunciate) it is believed that his/her soul is already liberated (*mukta atma*) and hence unlike a householder (*sansarik/ baddha atma*) upon death the body need not be cremated, instead it can be released into a water body or even buried. The custom of releasing the dead body into a river is known as *Jal Samadhi* where the intention is to serve some purpose even after death whereby lesser species could feed on the body.

Tarpan

The word *'tarpan'* is formed from the root word *'trup'* which means satisfying others. *Tarpan* represents symbolic offerings of water and flowers to the God, the Sun, sages, and ancestors seeking their satisfaction and in return blessings for the individual. Typically this is performed on the banks of holy rivers and other water bodies at pilgrimage centres.

Snan

A dip in the Ganga anywhere along its course, but especially at the holy places listed earlier is believed to offer riddance from sins (*karmic* debt) of this and the previous lives. This belief alone attracts a large number of pilgrims and tourists alike to the banks of the Ganga round the year. Significance of a holy dip is believed to be far more on special occasions e.g., *Makar Sankranti,* solar eclipse*, Mahakumbh, etc.* and accordingly footfalls during such occasions is many fold as compared to normal days.

Aarti

Aart*i* is a routine ritual which is performed daily or several times in a day and which represents paying obeisance to the deity. It can be an elaborate ritualistic process accompanied by offerings of sacred fire, water, flowers, incense and of course blowing of conch, bells, cymbals and drum beats, etc. At many places along Ganga e.g., Rishikesh, Haridwar and Varanasi an elaborate *Aarti* is performed every evening which has also emerged as a major draw for the pilgrims, tourists and *sadhus* and sages alike. Besides the head priests, individuals also perform the same ritual and release the little lamp and floral offerings into the river.

Shraadh

According to Hindu scriptures it is believed that depending on its *karma* a soul after departure from its human form could wander into different realms and could suffer. Based on this belief, the religious/ social custom of *shraadh* has evolved for expressing one's respectful obeisance to ancestors, satiate their desires, if any and alleviate sufferings of the soul(s). This is performed during special days in a year and could involve a range of rituals at home as well as on the bank of the river or other water bodies.

Other special rituals that are performed round the year on the *ghats* of Ganga especially in Haridwar comprise prayers to save oneself from *Pitra Dosha, Kalsarp Yoga, Shani Dosha, Manglik Dosha, Balarisht/Alpayu Yoga, Mrityu Yoga,* etc.

6. Issues and Concerns

The engagements of investigation team with a very wide range of respondents, stakeholders and the discussions in focused groups brought out a number of interesting socio-cultural aspects related to River Ganga and the Indian society in general. This section attempts to capture key issues and messages and narrows down on some of the possible elements of the evolving overall strategy to address the problem of the National River.

Association of People with River Ganga

Association of Ganga with socio-cultural aspect is well established and there cannot be any debate on this subject. Even communities that do not perform any rituals at its banks consider River Ganga as sacred. Every festival, every ritual, every aspect of a Hindu's life is associated with Ganga who, it is believed, as the all encompassing mother descended to the earth for purifying and nourishing the lives of the people . The sanctity of the socio-cultural activities is as old as the river itself.

However, during the discussions with various stakeholders, particularly the pilgrims, intriguingly it was found that in some sections of the society the well established sanctity of the river as the giver and the mother may be diminishing. This could be attributed to ignorance about the scriptural injunctions and general drifting of the society away from the age old customs, traditions and beliefs.

In this context, the need for soul searching i.e., to analyze whether River Ganga should be considered as a religious and/or spiritual entity or merely as another geographical and hydrological feature of the Indian subcontinent or even as a commodity is well recognised. This earnestness emerges from the fact that the perception which will develop will then eventually define the approach to address the complex issues affecting the ecosystem of River Ganga.

Changing Perspective of Pilgrims

A sea change appears to have come in the perception of the pilgrims as regards importance to performance of particular rituals vis-a-vis the wellbeing of the river. It is noted that pilgrims and visitors alike are very particular and highly sensitive about the recognised auspicious days/dates and the time for congregation on the banks of the river to take the customary holy dip, but are not at all concerned or virtually insensitive about the possible adverse impacts of their activities on the health of the river – either from aesthetics or water quality point of views. This incongruity in perception could be attributed to general lack of respect for the spiritual entity or the belief that the river has capacity to absorb almost everything thrown into it - be it immersion of ashes, disposal of hair, offerings of flowers, or clothes, photos, *kanwars*, etc. as discussed in previous section. On the material dimension this uncaring behaviour could be attributed to the perceived vast difference in the flow of the river and insignificant scale of an individual's transgression or purely lack of awareness and concern.

Although people performing such acts can see that their 'offerings' do not blend with the river water and instead constitute a form of pollution (physical/aesthetic, if not chemical or biological) but because their thoughts a fixed on the ongoing rituals, perhaps they do not perceive their act as transgression. Secondly, this could also be attributed to typical 'mob behaviour', as there are people of all backgrounds with significant disparity in level of education, awareness, concern and commitment towards natural heritage and environment. Evidently the underlying belief that the river descended on the earth to wash away sins of its people and absorb everything is overwhelming and resistance to think otherwise is very high. In this context, it is interesting to note the findings of a survey wherein almost 60% of respondents representing *ashrams* and other religious institutions do not perceive performance of rituals as polluting activity and do not approve any modifications in established practices. On the other hand, among the tourists apparently over two third perceive rituals on river banks as polluting activities and over three fourth may be willing to adopt modifications/ alternative practices, if introduced through appropriate mechanisms/ channels.

Nature of rituals and increasing popularity

Rituals have more or less remained the same but over the years their popularity and participation of devotees has increased due to, among others, increasing population, enhanced accessibility through improved affordability and means of transportation and larger financial allocation from governments, civil society and religious institutions. It is not that religious orientation of people has increased but also it has become a trend and the positive expectations of people have been increasing. Secondly, for a large part of the Indian society tourism/vacation has always been construed as a visit to a centre of pilgrimage. For example it is estimated that footfalls during *Kanwar Yatra*, *Kartik Poornima*, *Kumbh Mela* and *Amavasya Snan* have gone up by over 15 times during last two decades; and during 2006 to 2010 pilgrim influx has increased three times. A decade ago *Kanwar Yatra* (performed during the *Shravan mas* – July/August every year) to Haridwar would get about 2-3 lakh pilgrims every year but now it has crossed a million mark. Allahabad *Kumbh* in 2013 reported the biggest congregation of humans on the earth perhaps since the beginning of inception of human life on the planet i.e. more than 30 million people on the day of *Shahi Snan* - one of the main holy baths and the total number of visitors during the entire Mela (stretching almost over 2 months) was reported to be around 70 million. Haridwar *Kumbh* in 2011, reported around 50-55 million visitors, while some other agencies reported around 70 million visitors. A major credit goes to the large organizations and ashrams who have increased the popularity of the religious places manifold, so much so that Haridwar and Rishikesh alone have received an estimated 250 million people during last decade. Some of the major *ashrams* attracting large number of visitors are Patanjali Yogpeeth, Premnagar Ashram, Shantikunj, Jairam Ashram, at Haridwar and Geeta Ashram, Shivanand Ashram and Parmarth Niketan at Rishikesh.

Intriguingly, the local administration agencies count only those persons as tourists/pilgrims who stay overnight but do not take into account the day visitors. The latter category typically coming from nearby areas can be very large which adds to the pressure on the infrastructure and administrative system. Thus the above numbers could be an underestimate and may not enable realistic assessment of the problem[6].

Challenge of the Carrying Capacity

The exponential rise in the number of pilgrims has not been accompanied with commensurate increase in infrastructure, especially for access to the river front, basic services and the capacity of the host urban local bodies. Evidently this leads to a massive congregation in small areas around locations of religious/ historical significance which invariably poses significant risks to human life (due to stampede and other similar problems) and is a huge challenge for local administration and security agencies. It is not surprising that the latter two agencies have expressed concerns on this parameters. Interestingly rest of the stakeholders comprising, among others, priests, local traders, petty merchants, hotel and restaurant operators, etc. are happy with increasing business and rising incomes. Apparently there is a consensus on the need to regulate footfalls through strong administrative and legal measures, as simplistic measures through awareness, deterrence, etc. will not dissuade rising multitude of pilgrims who are driven purely by faith.

Unregulated growth of hotels, Ashrams and Dharmshalas

Evidently this large growth in the number of pilgrims has led to unregulated growth of hotels, *ashrams* and *dharamshalas* which offer places for overnight stay to the weary tourists/ pilgrims/ visitors. There are issues related to town planning, land use, safety, access, supporting infrastructure, etc. which have not received the required level of attention, particularly in the fragile setting of the hilly region beyond Rishikesh.

[6]No detailed and structured data is available with the local administration authorities in relation to any event.

Sanitation and Public Health

Needless to mention that the challenges of sanitation and solid waste management remain unaddressed due to, among others, limited resources, infrastructure and capacity on the part of the concerned urban local bodies/ *panchayats*. Under such a situation it would not be surprising if the general level of environmental sanitation and public health are severely compromised as the holy river doubles up as the ultimate receptacle of sewage and municipal solid waste. This deficit in infrastructure represents **breach of faith** as millions of pilgrims on the downstream at Rishikesh and Haridwar collect supposedly holy *Gangajal* which is seemingly laden with sewage and solid waste.

Other issues

Increased construction activity in the region has led to high demand for building materials and this has led to unregulated and illegal mining of sand and boulders on the banks of the river. This has in turn made adverse impact on the river morphology and its interaction with the flora, fauna and the habitation along the banks.

Another issue that emerged during the discussions pertains to the inadvertent damage inflicted to the *Bhoj Patra* trees (*Betula utilis*/ Himalayan birch) by the pilgrims going to Gangotri and Goumukh.

7. Options for Workable Solutions

Given the disparate perceptions among diverse stakeholders and complexity of issues - particularly related to the behaviour of millions of pilgrims thronging its banks, it is rather challenging to identify and evolve a set of agreeable and workable solutions in the realms of culture and sociology in the short- to medium-terms. Nonetheless, the investigators have attempted to explore a set of options that could be considered in the larger frame of the strategy that is to be proposed for improving water quality of the River Ganga and attaining the objectives of *aviral* and *nirmal dhara.* These are broadly classified in social, institutional and technical/infrastructural categories and summarised in the paragraphs that follow.

Social measures

A host of issues that emerge out the analysis pertain to socio-cultural aspects/ practices and hence the solutions as perceived or proposed by the stakeholders are presented first hereunder.

Awareness Generation

There is a strong felt need to undertake a sustained and widespread campaign through all media and channels to sensitise the society at large on the spiritual and religious significance and the natural heritage of the River Ganga. The campaign should attempt to revive the spirit of the Mother or Goddess Ganga and hence the feeling of reverence towards the sacred river.

Pilgrims visiting the river banks and other shrines in the hills also need to be sensitised through appropriate means as regards the code of conduct (spiritual and otherwise) while in a fragile or sensitive environmental setting. This also applies to non-pilgrims who are visiting as tourists, trekkers, for river rafting or other entertainment activities.

Gangajal Mahima

Profound significance of *Gangajal* is well recognised and the same should be leveraged to convey range of messages for preserving the sanctity of the river. Likewise this very belief should be used to motivate devotees to perform some of the rituals at homes with the *Gangajal* rather than undertaking arduous journey all the way to the banks of the river. However, the latter is easier said than done.

Community Participation

There is a need to identify and organise diverse stakeholders, take into account their interests and accordingly ensure their participation in addressing the issues. Secondly, there is a need to mobilise participation of the communities (comprising all age groups and affiliations) living along or in the vicinity of River Ganga. To this effect a well defined, coordinated and sustained programme under an appropriate institutional mechanism needs to be implemented whereby effective results in terms of change in perception and behaviour can be derived.

It is also advised to explore assistance at the local level from opinion leaders, religious leaders, voluntary organisations, etc. Further, the practice of *Kar Sewa* as followed by the Sikh community needs to be promoted at local level with the help of NGOs and CBOs.

Community Organisation

In order to enhance community participation on a sustained basis, there is a need to organise the community (evidently at mass level) along certain common threads e.g., school clubs, youth clubs, units of National Social Service in undergraduate colleges, village committees, trader communities, priest community, *ashrams, Ganga Sevak Sabha*, etc. In order to create such wide range of 'community based organisations' centred on the theme of Ganga, evidently there is a need to build capacity (in the form of, among others, trained, experienced and dedicated socials workers) at the local and state government levels.

Innovation in Social Practices

Some social organisations such as Shanti Kunj in the Narmada basin have demonstrated positive results in modifying behaviour of communities and pilgrims through innovative approaches which represent alternatives to the traditional rituals. Such initiatives need to be documented, disseminated/ replicated and popularised in the Ganga basin and other river basins in the country as well.

Institutional Measures

A set of institutional measures that emerge from the discussions with stakeholders are summarised hereunder. These pertain to local bodies as well as state and central agencies as regards introducing new approaches, regulations and systems.

Capacity Building of Local Bodies

Given the large influx of pilgrims and tourists alike, evidently the urban local bodies of Rishkesh and Haridwar and those of the smaller towns and villages in the hills are not prepared to respond to the challenges. There is a need to build capacity of the local bodies on diverse aspects for, among others, planning, monitoring, supervision, community engagement, mobilisation, facilitation, awareness creation; creation of requisite infrastructure and extending services, etc.

Realistic Assessment of Tourist Inflows

In order to assess realistic pressure on the infrastructure, the local agencies need to also to account for the day visitors and accordingly change the method of enumeration. In addition to considering those staying overnight at a particular station, they also need to take into account total entries and exits from a town.

Entry Regulations

Recognising the threat to public safety and security due to unusually high density of floating population on certain important occasions on selected *ghats* of River Ganga, there is strong need to adopt unconventional institutional measures (administration and security) to regulate entry of pilgrims. These measures must take into account, among others, the carrying capacity of the town/ location and the administrative capacity of the local bodies. To dissuade people on specials occasions, entry fee/ taxes, higher vehicle parking charges, etc. need to be explored.

Regulation on Construction Activity

There is a strong need to control construction activity on or near the banks of the river. Similarly there is need to ensure appropriate environmental safeguards at the time of planning and implementation of such works so that sewage and solid waste are not disposed of into the river.

It is also imperative to carry out monitoring of diverse sources of water pollution from urban, commercial and industrial activities and take appropriate and timely preventive measures. To this effect inspectors from state and local agencies need to be deployed for taking timely action.

Regulation on Sand Mining

Increased construction activity has created a local industry of mining of sand and boulders from the bed and banks of the river which is having adverse impacts on the local ecosystem. There is a need to appraise the issues objectively and scientifically and adopt appropriate safeguards as well as offer alternate sources of building materials. Local agencies/ micro-entrepreneurs involved in sand mining should be properly rehabilitated by offering alternate livelihood opportunities.

Regulation of Other Activities

It is observed that a number of camping sites on the bank of the river have developed which cater to a different group i.e., adventure tourists. Likewise it is noted that a large number of vehicles which drive into the towns of Haridwar and Rishikesh are often washed on the river banks. Although small, these activities lead to localised pollution of the river and need to be suitably controlled.

Infrastructure and Services

Deficit in terms of infrastructure and services is one of the major bottlenecks affecting local environment, sanitation and the river water quality. Some of the proposed solutions are listed hereunder.

Diffusing Pressure on the Ghats

Given the challenge of large number of visitors on selected *ghats* it is recommended to develop more *ghats* and facilities to perform diverse rituals. Alternative to *'Har-ki-pairi'* and other historical *ghats* will help in diffusing the pressure on the infrastructure and prevent chances of any mishaps. All agencies need to coordinate to plan, develop and then motivate pilgrims to use them.

Public Conveniences

There is an urgent need to construct high quality public conveniences at suitable/convenient locations to cater to the rising number of visitors of all background. It is also of paramount importance to ensure high level of maintenance and services so that the facilities are put to intended use over the designed life period. Lack of public conveniences is resulting in indiscriminate and open defecation which affects sanctity of the locations as well as public health.

Sewerage and Solid Waste Management

There are two aspects to this problem of sewage and solid waste disposal – one on the *ghats* and other across the town/city. As regards the activities on the *ghats,* it is recommended to lay, where feasible, appropriate sewer lines to collect sewage and wastewaters from hotels, restaurants, other small establishments and divert them to the citywide system. Likewise for the solid waste, it is imperative to install adequate number of collection bins on the *ghats* and engage service providers (through the local bodies or CBOs) for regular timely removal of the waste. Evidently, pilgrims alsoneed to be informed of the available facilities and services and to be motivated to use them.

Although it does not necessarily fall within the mandate of this study, but strengthening of the city/town wide infrastructure/ system for sewage and solid waste collection, treatment and disposal is imperative. Needless to say that the capacity of the concerned local bodies also should be augmented if commensurate benefits need to be derived on a sustained basis. In this respect it is appropriate to recommend promotion of the practice of home composting in front/back yard of houses, wherever feasible, so that load on the municipal system and the receiving environment is minimised.

Afforestation and Watershed Management

Mining and deforestation in the catchment area of the river are known to be causing significant impacts on the local environment as well as on the river. In order to prevent or mitigate such impacts there is strong demand for, among others, initiating afforestation and watershed management activities which will in turn generate jobs for the unskilled and improve local economy.

Regulation of Flows Downstream of Hydel Projects

In the upper reaches of the river system its continuity is known to have been broken due to construction of a number of hydel projects. A section of the respondents have expressed concerns on this issue and have proposed release of water in dry weather to ensure certain minimum flow whereby people living in those stretches can continue to relate with the river and perform their traditional customs and rituals

8. Conclusions

Ganga is a source of emotional, physical, spiritual and economic prosperity. *Aviral* and *nirmal* Ganga can only help in achieving all these aspirations of the people who come to its banks or who live in its basin or along its banks. It is important to understand the spiritual aura of global significance of this river and the aspirations of its people. Given this cultural heritage and the recently assigned status of 'National River', it is imperative that the national policy and planning must accord highest priority for restoring the holy river to its old glory. While the people may have resigned to the current state of poor quality of water of the river in the plains and discontinuity in the upper reaches, there is a strong desire for improvement.

Further, given the relative magnitude of pollution loads from point sources viz., urban sewage and industrial effluent discharges vis-à-vis the floral and other offerings during rituals, the latter is not perceived to be significant. Given the tens of millions of renewing actors spread over a large area with vastly disparate educational background and environmental construct, physically it may be extremely challenging, if not impossible to correct the behavior of pilgrims. When the belief dimension is added to these considerations, there is strong resistance to change.

Notwithstanding the challenges, there is a need to allocate adequate resources for anchoring sustained campaign for sensitizing people across the country about the unique natural, cultural and spiritual heritage and bringing a sense of pride for having the one and only 'National River' for the billion plus people.

Trends in Agriculture and Agricultural Practices in Ganga Basin

An Overview

GRBMP: Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay | IIT Delhi | IIT Guwahati | IIT Kanpur | IIT Kharagpur | IIT Madras | IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. A list of persons who have contributed directly and names of those who have taken lead in preparing this report is given on the reverse side.

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Contents

1. Introduction

The Ganga River, being a perennial source of water, facilitates both surface and groundwater irrigation in the basin area. However, high population growth, rising per capita income and increase in standard of living of people, have encouraged the farmers to diversify agriculture towards high water intensive crops such as sugarcane, paddy and wheat which put more stress on the water resources. For the effective and sustainable management of the basin, among others, an understanding of growth and composition of population, sectoral composition of workforce, change in land and water use patterns, settlement patterns, livelihood patterns and their possible impact on the river water resources is imperative. Ganga River Basin (GRB) managementneeds to be viewed as a part of the broader environment and in relation to socio-economic demands and potentials, acknowledging the political and cultural context, as water is not only an economic resource but is also a socio-cultural and environmental resource. The Ganga Basin constitutes 26 percent of the country's land mass and supports about 43% of population (448.3 million as per 2001 census). Agriculture is the major livelihood activity of majority of rural population in the basin area. It is, therefore, necessary to study the dynamics of agriculture with a view to understand the nature and extent of dependency on it and suggest alternative livelihood options to augment income of rural workforce and reduce the stress on river water resources. Keeping these aspects in view, this report attempts topresent the status of agriculture in the basin and its implications for the river basin management. For this purposethe entire basin has beendivided into several parts. The three most significant parts from the point of view of agriculture and irrigation are Upper Ganga Basin (mostly in Uttarakhand), Middle Ganga Basin (mostly in Uttar Pradesh) and Lower Ganga Basin (mostly in Bihar and West Bengal).

It may be pertinent to mention here that this report is designed to prepare a comprehensive overview of the status and prospects of agriculture in the basin area in order to study its implications for water-use, and point/non-point[1] sources of pollution that flows/seeps into river, posing a danger to all forms of life that is dependent on the river water. The information provided is expected to be useful in suggesting(i) ways and means to optimize the use of river water per se, and (ii) modifications in agricultural practices.

2. Scope

This series of reports is envisaged to document the following aspects and issues of agriculture in the Ganga River Basin:

- Agriculture land-use and cropping patterns, size of land holdings
- Crop-diversification
- Sources of irrigation, area irrigated and status of ground water in the basin area

[1] It has been observed that in many a places, river beds have been encroached to grow cucurbetaceous crops known as "Pallaze" where a fair amount of chemical fertilizers and pesticides are used. These chemicals eventually get washed into the river water and thus becoming diffused or non-point source of pollution.

- Use of fertilizers, pesticides, and other inputs
- Agricultural production, productivity, costs and returns in agriculture
- Agricultural practices having an implication for water-use.
- Implications for River Basin

3. General Relevant Information

The Ganga River Basin – which also extends into parts of Nepal, China and Bangladesh – accounts for 26 per cent of India's landmass, 30 per cent of its water resources and more than 40 per cent of its population. The Ganga river basin is one of the most densely populated and fertile river basins in the world. It supports about 300 million people over an area of approximately 80000 sq. km of which some 100 million are directly dependent on the river and its tributaries. Thus Ganga basin supports one of the world's highest densities of population. If one accounts for the entire reach, including all small tributaries of river Ganga, the basin area comprises the part of 11 states including 236 districts within the national administrative boundary.

The states (in order of maximum districts involved) included in the Basin area are Uttar Pradesh (70), Bihar (37), Madhya Pradesh (33),Rajasthan (20), Jharkhand (17), West Bengal (16), Haryana (14), Uttarakhand (13), Delhi (9), Chhattisgarh (4),andHimachal Pradesh (3). However, the Ganga with its main tributaries flows mainly across the Uttarakhand, Uttar Pradesh, Bihar, and West Bengal. The Ganga River Basin has 1949 cities and towns, with an estimated population of 125 million. Average population density in the Ganga River Basin is 520 persons per square km as compared to 312 for India (2001 census). Considering the trend, pattern, influence, ascendancy, problems, and prospects etc. of the Ganga River Basin area, this report focuses only on three parts mostly covering four states of India, i.e. Uttarakhand, Uttar Pradesh, Bihar, and West Bengal (Figure1). A brief account of the four states is given in following sections for ready reference.

Figure 1: Geographical Delineation of the Portion of Ganga River Basin Considered Significant from Agriculture and Irrigation

3.1. Uttarakhand

Uttarakhand Statewas carved out of parent State of Uttar Pradesh on 9th November 2000, and became 27th State of the Republic of India. In January 2007, the name of the State was changed to Uttarakhand from its earlier name Uttaranchal. The Statehas a total geographical area of 53,483 square kilometer (sq. kms) of which 93 percent is mountainous. About 34,650 sq. kms area is under forest cover. The recorded forest area constitutes 64.79 percent of the total reported area, though the actual cover based on remote sensing and satellite imagery information is only 44 percent[2]. As per the 2001 census, population density is 159 persons per square kilo metres. More importantly, with over fifteen important rivers and over a dozen glaciers in the State, Uttarakhand is a valuable fresh water reserve. The average annual rainfall of the state, as recorded is 1,547 mm. For the administrative purposes, the State has been divided into two sub-divisions, i.e., Kumaon and Garhwal divisions. Kumaon division includes six districts, namely, Almora, Bageshwar, Champawat, Nainital, Pithoragarh, and Udham Singh Nagar; while *Garhwal division* consists of seven districts, viz., Dehradun, Haridwar, Pauri, Rudraprayag, Tehri and Uttarkashi. The State has 78 tehsils, 95 development blocks, 671 NyayaPanchayats, 7,227 Gram Panchayats and 15,761inhabited villages.[3]

According to Census 2001, the State accounts for 8.48 million population with 4.32 million males and 4.16 million females. Out of total 8.48 million population of the State, SC and ST constitute 1.51 million and 0.25 million respectively. The decadal growth rate of the population of the State has declined from 24.23% during 1981-91 to 19.20% during 1991-2001. It has sex ratio of 962 and has a literacy rate of 71.6 percent with 83.3 percent literacy among males and 59.6 percent among females. Literacy rates among SC and ST are relatively lower at 63.4 percent and 63.2 percent respectively.

The workforce constitutes 36.57 percent of total population, of which 27 percent are main workers and 9.57 percent marginal workers. Out of the total workforce, 1.56 million are cultivators (including main and marginal cultivators), 0.25 million are agricultural labourers, 0.06 million people work in household industries and 1.23 million people are engaged in other activities.

The major source of livelihood of the population in the state is agriculture. Almost 70 percent of the population is engaged in agriculture. Out of the total reported area, only 14 percent is under cultivation and over 55 percent of the cultivated land in the state is rain-fed

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[2]Uttarakhand State: Perspective and Strategic Plan 2008-2027, Watershed Management Directorate, Dehradun, Uttarakhand.

[3]UTTARAHKAND: at a Glance 2008-09, http://gov.ua.nic.in/uaglance

with cropping intensity at 161 percent. Agriculture covers 7.81 lakh hectares of land, out of which 4.43 lakh hectares appear to be under Hill regions which is around 56.8 percent of the total agricultural land while the plain region constitutes 3.37 lakh hectares (43.2%). Irrigated areas in the Hills are around 10 percent whereas it is around 85 to 90 percent in the plain areas. The average size of land holding is around 0.68 hectare in the hills and 1.77 hectare in the plains. Of the total 9.26 lakh farmers in the state, small and marginal farmers constitute around 88 percent. The subsistence nature of agriculture in the hill districts provides nothing but a low and unstable annual income to the people, causing a sizeable out-migration of male members from the family, leaving behind a large number of female-headed households. As per the BPL survey 2008, about 36.5 percent of the population of the state lives below poverty line.

3.2. Uttar Pradesh

Uttar Pradesh is one of the most populated States of India. As per the 2001 Census, there were about 22.3 million households in the State of which about 18 million were rural households and 4.3 million urban households. The State comprises 16 percent of the country's population and 7.3% of the area. In 2001, Uttarakhand was created as a new State comprising 13 districts of the hilly region of the State. The creation of Uttarakhand has led to significant loss to the State in terms of loss in forest area, geographical area and tourism revenue as most of the holy places of pilgrims are located within the hilly region. The State, though gifted with fertile soil and rivers, is one of the poorest States of India (Govt of UP, 2002).

The state is organized into 17 divisions, 70 districts, 300 Tehsils and 813 development blocks. It has 52,028 Gram Panchayats, covering 97,134 inhabited villages and 689 towns (Kumar, 2005). It is divided into four economic regions, namely, Western Region (WR), Central Region (CR), Bundelkhand Region (BKR) and Eastern Region (ER). In terms of socio-economic development, there exists a vide disparity across regions. For example, population and area of WR and ER are almost same but there is a marked difference in their levels of socio-economic development. The ER and BKR are more backward as compared to WR and CR. The ER is largest among all the regions. It commands over nearly 36 percent of the State's geographical area and a little over 40 percent of the total population. Next to it is WR which comprise one-third of the State's area and about 37 percent of population. These two regions together constitute 68.7 percent of the total area and over three-fourth of the total population of the State. Other two regions - CR and BKR are relatively smaller both in terms of area and population. Density of population varies significantly across regions. It is highest in the ER (776 per sq. km), followed by WR (765 per sq. km.). It is lowest in BKR (280 per sq. km.). Decadal growth of population (1999-2001) is also observed highest in the ER and lowest in the BKR. Urbanisation in the State is lesser than the national average. As against 27.78 percent population living in urban areas in India, only 20.78 percent of the state resides in the urban areas. The percentage of urbanisation also varies significantly across the regions. It is as high as 28.3 percent in WR and as low as 11.6 percent in ER. The highest population density and lowest urban population in the ER imply that there is very high dependence of population on rural area, especially on the farm sector. This makes the ER relatively poorer than the WR and CR regions.

Figure 2 shows region-wise percentage distribution of rural and urban population in the State. The percentage of rural population marginally declined from 80.3% in 1991 to 79.2% in 2001. This reveals that there is 1.1 percentage point decadal increase in the share of urban population. If the region-wise distribution of population is looked at, it is noticed that urbanization is highest (28.25 percent) in WR, followed by CR (25.11 percent) and BKR (22.46 percent). The ER does not evince any increase in the share of urban population.

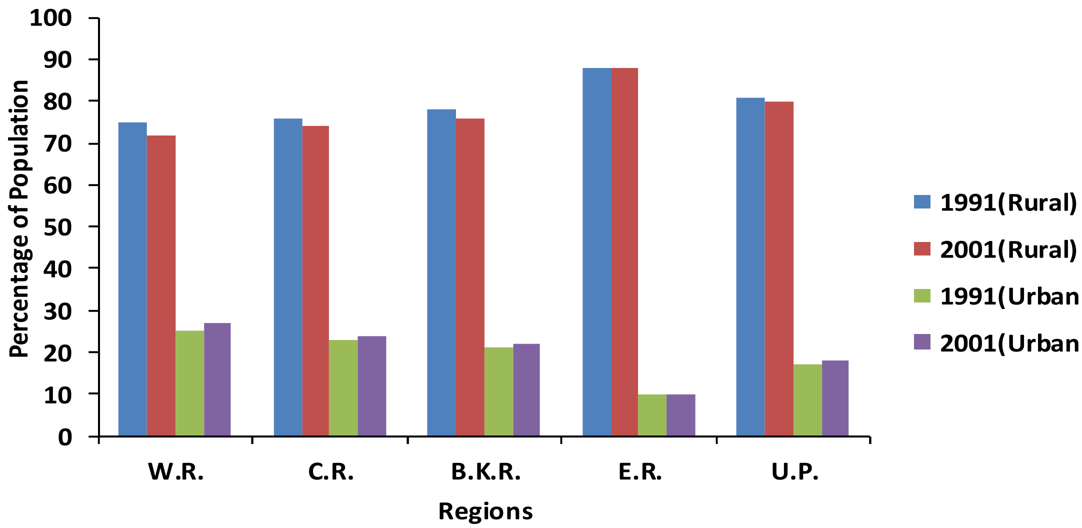

Figure 2: Region-wise Percentage Distribution of Rural and Urban Population of Uttar Pradesh

The State is well known for its success in the green revolution and is the highest producer of food grains and sugarcane in the country; however average yields of most crops are lower as compared to neighboring states Punjab and Haryana. The State shares 16.3 percent of total cropped area and 20.7 percent of total production of food grains of India (GOI, Ministry of Agri, 2007). The State economy is still dependent on the agriculture for its livelihood with industry and services constituted 5.6 percent and 28.5 percent of total workforce, respectively, in 2001 (Figure 3). Agriculture constituted 65.89% of total workforce of the State whereas the corresponding percentage for all-India was only 58.4, indicating that the economy of the State is largely rural and agricultural based. As per the Agricultural Census 2000-01, average size of holdings in Uttar Pradesh was only 0.83 hectare while the All-India average was 1.32 hectare. About 77 percent of the total operational holdings were below 1.0 hectare and 91 percent were below two hectare (GOI, Ministry of Agriculture, 2007). Forest cover of the State declined drastically from 5.2 million hectares to 1.69 millions hectares due to creation of Uttarakhand. The State has about 75 percent of net sown area under irrigation, with relatively higher percentage share of groundwater irrigation through tube wells (Govt. of Uttar Pradesh, HDR 2003).

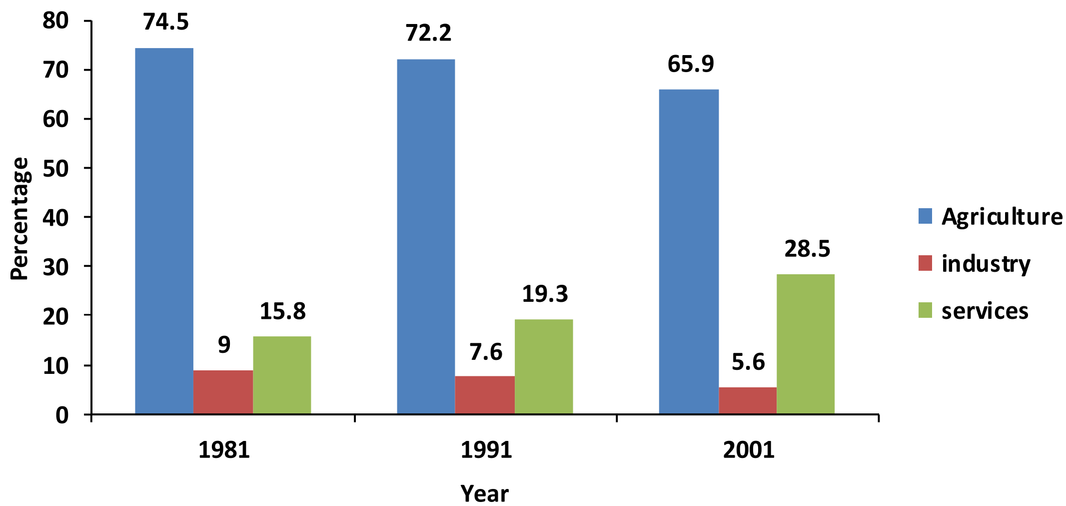

Figure 3: Trends in Structure of Employment in Uttar Pradesh

In terms of other socio-economic indicators too, the State is far behind from many other States. Although literacy rate has increased from 42 percent in 1991 to 57 percent in 2001, it is much below the all-India average of 65 percent. Female literacy, at 43 percent, is also below the all-India average of 54 percent. Maternal mortality is high at 7.07 deaths per 1000 live births compared to 4.08 in India. The infant mortality rate (IMR) is 85 per 1000 live births, which is among the highest in India. IMR is considered the most important measure of how well the government distributes available resources for health, education, status of women and public spending. In rural areas, it is nearly twice as high as in the urban areas. Children in the rural areas have 80 percent higher risk of dying before their fifth birthday than urban children. About 71 percent of UP's population (85 percent in rural and 19 percent in urban) do not have access to sanitary toilets (Government of Uttar Pradesh, 2005). Uttar Pradesh continues to languish at a low level of human development and is in the lowest cluster of States, along with Bihar, Madhya Pradesh, Rajasthan and Orissa. As per the National Human Development Report 2001, HDI of the State was 0.388 as against the all-India 0.472. It ranked 13 among the 15 major Indian States, just above Bihar and Assam (Government of India, HDR 2001).

3.3. Bihar

Bihar has been an agrarian economy and 90 percent of its population lives in rural areas (Economic Survey, 2010-11). The state is located in the fertile Gangetic Plains. Bihar is the ninth largest state of India in terms of its area and the second largest in terms of population. It is bounded by Nepal on the north, Orissa on the south, west Bengal on west and Uttar Pradesh on the east. Bihar lies mid-way between the humid West Bengal in the east and the sub humid Uttar Pradesh in the west. The Bihar plain is divided into two unequal halves by the river Ganga which flows through the middle from west to east. The total area covered by the state of Bihar is 94,163 sq. km. Bihar is mainly a vast stretch of very fertile flat land. It has several rivers namely Ganga, Son, Bagmati, Kosi, BudhiGandak, and Falgu. Central parts of Bihar have some small hills, for example the Rajgir hills. The Himalayan Mountains are to the north of Bihar, in Nepal. Chota Nagpur plateau lies towards the south of Bihar**.**

In 1936, Bihar was separated from Orissa. Later in November 2000, Bihar was bifurcated and a new state Jharkhand was made by transferring 13 districts to the new state. The remaining 29 districts have been reorganized into 38 districts. Hence, currently Bihar is divided into 38 districts and 9 divisions for administrative purposes. After the bifurcation of Bihar in 2000, the industrial and mineral-rich zone has gone to Jharkhand and Bihar was left with fertile land water resources. Bihar is richly endowed with water resources, both at the ground water resource and the surface water resource. Bihar has substantial water from rainfall as well as the rivers which flow within the territory of the State. The river Ganga flows right across it from west to east. North Bihar is extremely fertile, the land being watered by the rivers Sarayu, Gandak and Ganga. Twelve districts of Bihar fall on bank of river Ganga. The other rivers are the Sone, Poonpoon, Falgu, Karmanasa, Durgawati, Kosi, Ghaghara etc.

The economy of Bihar is mainly based on agricultural and trading activities. The soil of Bihar is extremely fertile which makes it ideal for agriculture. Agriculture is the vital source of wealth in Bihar. 76% of its population is engaged in agricultural pursuits. Paddy, wheat, maize and pulses are the principal food crops of Bihar. Main cash crops are sugarcane, potato, tobacco, oilseeds, onion, chillies and jute. Bihar is the third largest producer of vegetables and fourth largest producer of fruits in the country. It is the largest producer of litchi, makhana, guava, lady's finger and honey in the country. However, with improved methods and better management, State's contribution in food grain, fruit,vegetables, spices and flowers can be increased manifold. The major agro based industries of Bihar are of rice, sugar, edible oil.

Though endowed with good soil, adequate rainfall and good ground water availability, Bihar has not yet realized its full agricultural potential. Its agricultural productivity is one of the lowest in the country, leading to rural poverty, low nutrition and migration of labour. Based on soil characterization, rainfall, temperature and terrain, three main agro-climatic zones in Bihar have been identified. These are: Zone-I, North Alluvial Plain, Zone-II, north East Alluvial Plain,and Zone-III comprising of Zone-IIIA South East Alluvial Plain and Zone-IIIB South West Alluvial Plain, each with its own unique prospects.

3.4. West Bengal

West Bengal, one of the major states in the eastern part of the country, has predominantly an agrarian economy. It is endowed with rich natural resources and climatic conditions favorable for agriculture. These include large areas of good alluvial soil, abundant surface water and groundwater resources, and good rainfall. The climate of the region (other than in the hill regions) is tropical, hot and humid. Annual rainfall is between 1,300 mm and 1,750 mm. Despite these favourable conditions, the State has witnessed wide fluctuations in the growth of agricultural production (Rawal and Swaminathan, 1998). In line with the changing trend across the country, West Bengal has experienced a structural shift in output front as the share of agriculture in the State's GDP is recorded to have come down from about 33 percent in 1999-2000 to about 25 percent in 2007-08.

The river Ganga is considered the life line of West Bengal. It is a perennial source of water to the plains of West Bengal for irrigation as well as human and industry consumptions. The river is navigable and it acts as a major transport system in the State with heavy traffic flow. The entire State of West Bengal, except four districts namely Darjeeling, Cooch Behar, Jalpaiguri and Purulia fall under the lower Gangetic Plains region. The Ganges and its numerous distributaries have resulted in highly fertile soils in this region. Accordingly, agriculture has become the key to the economy of the State. A large section of the population derives their livelihood from agriculture. This region also covers many major tributaries of the Ganga.

The agro-climatic zone in West Bengal can be divided into four sub-zones, viz., Barind Plains, Central Alluvial Plains, Alluvial Coastal Saline Plains, and Rarh Plains. The zone of Barind plains that covers two districts namely West Dinajpur and Malda has a relatively high rainfall. It has high NSA but the irrigation facilities are not developed. The zone, central alluvial plains, on the other hand, is the largest sub-zone in the lower Gangetic plains covering around 3.5 million hectares i.e. about 40 percent of the total land. It covers the districts of Murshidabad, Nadia, Burdwan, Hooghly, Howrah and Medinipur. About 68 percent of the land of this zone is cultivated and over 60 percent of the cultivated land is irrigated resulting in a reasonably high cropping intensity. The alluvial coastal saline plains cover the districts of North and South 24-Parganas along with the metropolitan city of Calcutta. Only about 26 percent of the NSA of this is irrigated. The rarh plains that include Birbhum and Bankura districts are mostly rural and poorly developed. About two-thirds of the land in this zone is cultivated with 23 percent falling under forest cover. Poor irrigation facilities in this zone have resulted in a very low cropping intensity.

The seven districts of West Bengal which is part of the Ganga River Basin are 24 Pargana South, 24 Pargana North, Hoogli, Howrah, Kolkota, Maldah, and Medinipur. In all, out of around 42,630,182 people that reside in the Ganga River Basin of this state, about 9,293,861 people live in major towns like Maheshtala, RajpurSonarpur, Serampore, Hugli-Chinsurah, Chandannagar, Haora, Kolkota, Bhatpara, South Dum Dum and so on. Bengal has 160 towns and cities, out of which 27 are class I and 27 are class II cities.

4. Data Sources

District-wise data for different states have been taken from 'Statistical Abstracts' published by these four states for different years. These abstracts were procured from the respective State Planning Commissions and divisional headquarters. The State-wise and district-wise data (for 125 districts) in the Ganga River basin Catchment Area were taken from the following Study: *Bhalla G. S. and Gurmail Singh, 2010, 'Growth of Indian Agriculture: A District Level Study' Final Report on Planning Commission Project, CSRD, JNU, New Delhi.*Most of the data were available in the form of published documents.

5. Data Limitations

In general, in any kind of study based on temporal and spatial growth trends and patterns, there always remain some sorts of limitations due to variations in the units of measurement, definition of certain variables, period of data collection, etc. Such variations may pose problems with regard to comparability of the data. In addition, the data suffers from a few other limitations specific to the agricultural indicators. One of such a major problem pertains to the mixed crops where along with a cereal crop, other crops such as rapeseed/mustard, sesamum and castorseed are also grown. In such case, it becomes difficult to estimate the area in which they are grown. Another major limitation arises out of the fact that most of the states in India do not maintain data for a long period. However, in case of the state of UP, data on almost all major aspects of economic sectors and other Census based information are available for a long time span.

6. Agriculture in Basin Area

Thissection provides an overview of the state of agriculture in the Ganga River Basin area ataggregate level following the levels and growth of selected agricultural indicators over a period of four decades. The main discussion revolves around the level and growth of crop output, crop yield, gross and net sown area, cropping intensity, gross and net irrigated area, fertilizer consumption, use of important power-based agricultural equipments, and the human resources involved in the agriculture in the basin area.At gross level, mainly two types of statistics have been used: one, the district-level average value of selected agricultural indicators in the Ganga River Basin area during the period 1962-65, 1970-73, 1980-83, 1990-93, and 2003-06; and the other, level and growth of selected indicators at state level.

It is important to mention here that although districts in Ganga River Basin area here actually mean the districts which are part of the aforementioned four states, nevertheless, a few adjustments have been made to account for reshuffling of administrative boundaries at district and to some extent, at the state levels. Consequently,there were71 composite districtunits constituted by combining 130 districts (in the four states of the basin area) during 1990-93 and 2003-06 in order to make them comparable with the initial district units of the "sixties", the "seventies" and the "eighties". Appendix I gives details about the formation of the 71 district units. However, the figures for the states are at aggregate level, and the figures represented by Uttar Pradesh and Bihar include Uttarakhand and Jharkhand respectively. The main source of the agricultural statistics presented in a different perspective in the present report originates from the Planning Commission report on the Growth of Indian Agriculture, submitted by Bhalla and Singh (2010).

6.1. Level and Growth of Selected Agricultural Indicators

6.1.1. Crop Output

The new Borlaug seed-fertilizer technology introduced in the mid-sixties made a major impact on raising yield and output levels of some crops and of aggregate crop output in

India (Bhalla and Singh, 2010). The average value of crop output in the districts of Ganga River Basin area reflects an almost four-fold growth from Rs. 1.97 billion during 1962-65 to Rs. 5.24 billion during 2003-06 at 1990-93 prices (Figure 4).

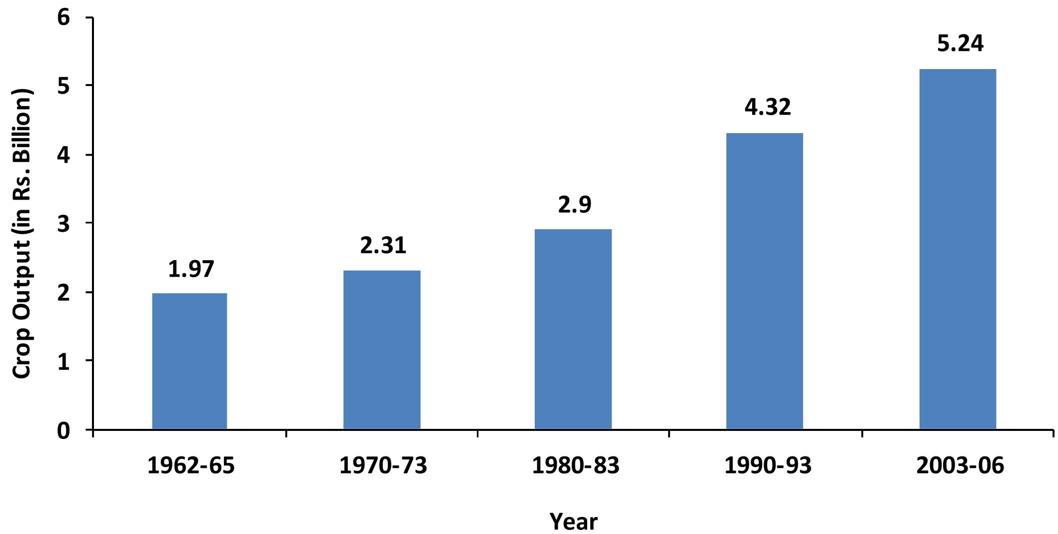

Figure 4: Average value of Crop Output (in Rs Billion) per district in GRB, 1962-65 to 2003-06

Average value of the crop output during 1970-73 is statistically not significantly different than that in 1962-65. This suggests that there was hardly any difference in the level of output value during the initial period of Green revolution (1962-65 to 1970-73) across the districts in the basin area. It is worth mentioning here that the estimation of value level of crop output is based on 35 crops at 1990-93 constant prices (Bhalla and Singh, 2010).

Figure 5 illustrates the level of crop output value across the states in the Ganga River Basin area. In absolute terms, although Uttar Pradesh recorded the maximum output value, yet the production growth indicates that West Bengal has had edge over Uttar Pradesh and Bihar. The period 1980-83 to 1990-93 marks a turning point in India's agricultural development for the reason that during this period, green revolution spread to larger areas and more crops due to ‘wider technology dissemination’. At all-India level, the growth rate of crop output accelerated from 2.24 per cent per annum during 1962-65 to 1980-83 to 3.37 per cent per annum during 1980-83 to 1990-93. An interesting feature of the eighties was that agricultural growth permeated to all regions in India. However, comparing the statistics in Ganga river Basin, it can be observed that during the period 1980-83 to 1990-93, the growth in output value of West Bengal was more than doubled and rose almost by 63% for UP, while there was no significant improvement in the production in Bihar. Major contribution in the agricultural output came from faster rise in the rice yield which went from 1.5 per cent during 1967-68 and 1980-81 to 3.3 per cent during 1981-82 to 1991-92. The major jump was seen for the West Bengal during this period arising out of tenancy reforms undertaken in the state after 1977-78 and provision of adequate public supply of credit and other inputs to small farmers (Ramchandran*et al.,*2003).

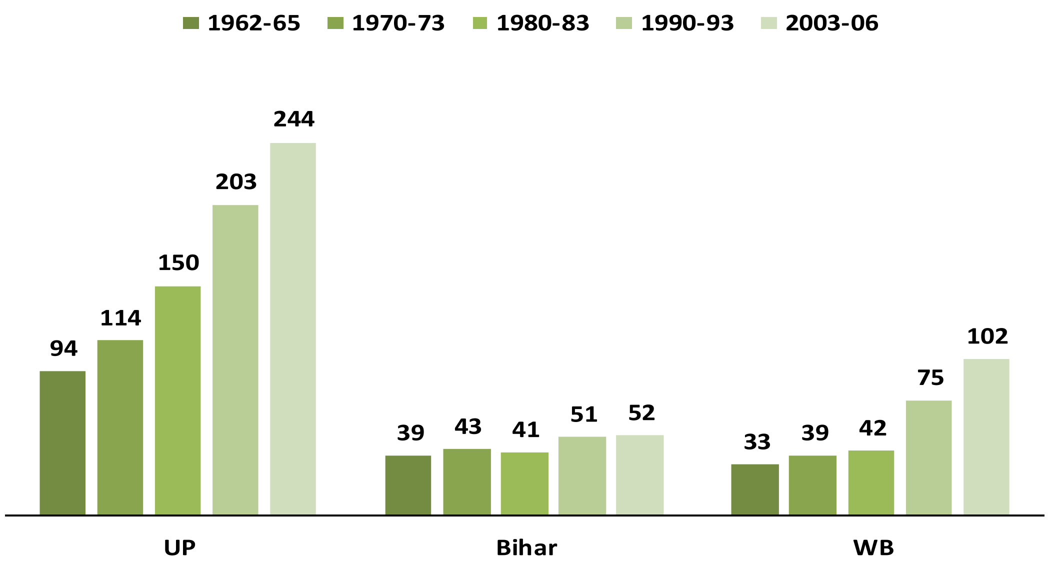

Figure 5: Value of Crop Output (in Rs. Billion) across States in GRB, 1962-65 to 2003-06

The agricultural revolution that swept West Bengal during this period is further corroborated by the data presented in Figure 6.

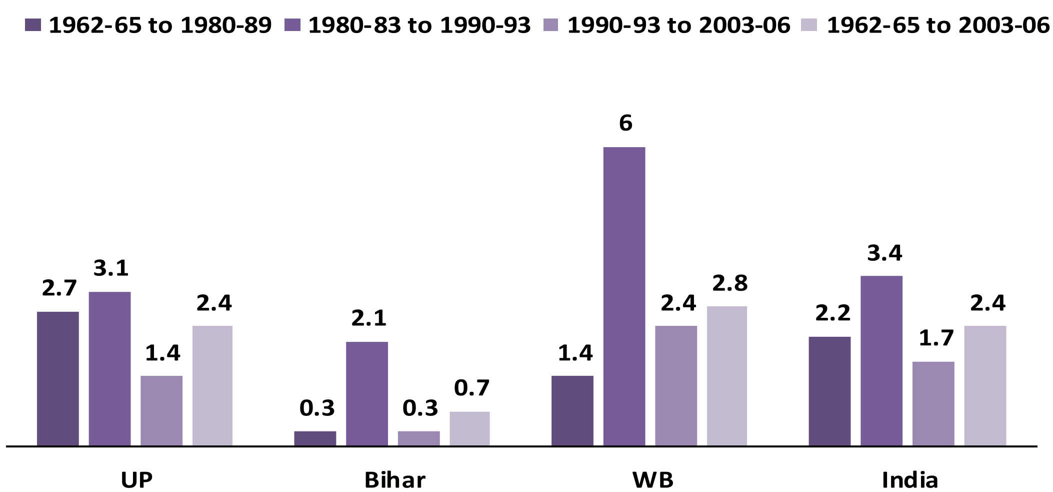

Figure 6: Annual Compound Growth Rate (%) of Crop Value across States in GRB

6.1.2. Crop Yield

Figure 7highlights an increase in the crop yield (in monetary terms)across the districts of the Ganga River Basin area, which grew from a level of Rs. 4,300 per hectare of gross cropped area during the period 1962-65 to Rs.9,900 per hectare during 2003-06 at 1990-93 prices.

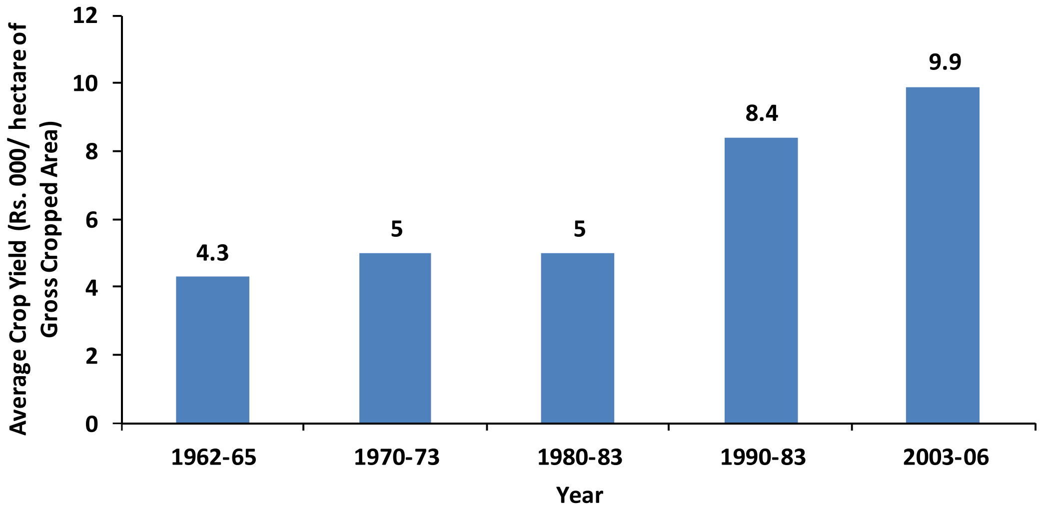

Figure 7: **Average Crop Yield (Rs. 000/ hectare of Gross Cropped Area) per district in GRB, 1962-65 to 2003-06**

In terms of crop yield during the period 1962-65 to 2003-06, the growth rate has been recorded almost similar for Uttar Pradesh and West Bengal i.e. slightly more than 2%, besides the higher rate (4.8%) of growth shown by West Bengal as compared to Uttar Pradesh (3.7%) during 1980-83 to 1990-93 (Figure 8). Bihar has shown the very modest rate of 1% annual compound growth rate of crop yield during the overall period (1962-65 to 2003-06).

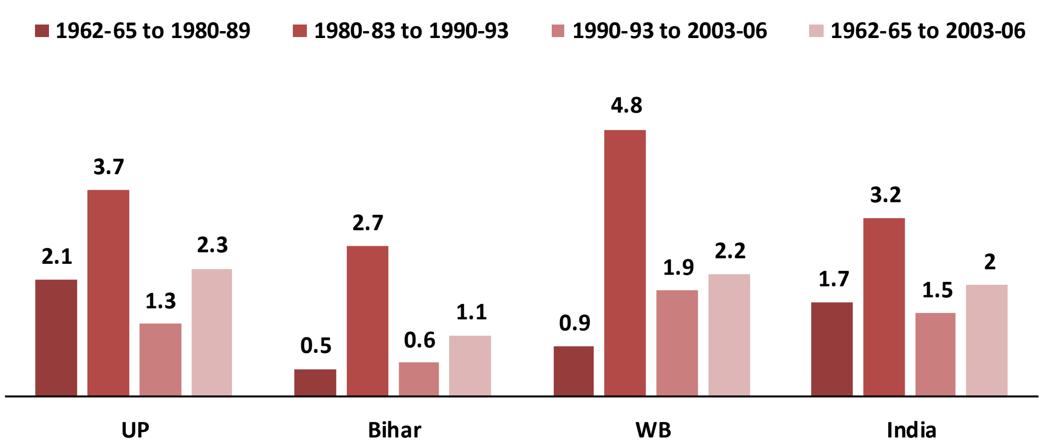

Figure 8: **Annual Compound Growth Rate (%) of Crop Yield across States in GRB**

6.1.3. Net Sown Area

Due to competing demands on area available for cultivation from increase in rural habitations, forestation, urbanization and industrialization, the net sown area throughout the country has registered a rapid deceleration in its growth over time. Figure 9, which illustrates the average net sown area in the Ganga River basin, clearly indicates that there were no substantial differences in the average level during 1962-65 to 2003-06.

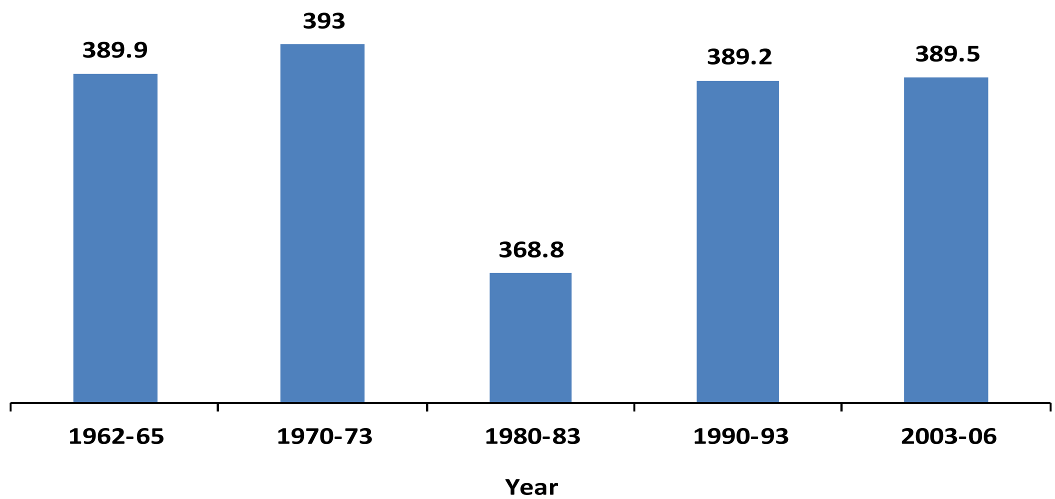

Figure 9: **Average Net Sown Area (Thousand hectares) per district in GRB, 1962-65 to 2003-06**

At state level, the average net sown area as illustrated in Figure 10 indicates that the states in the Ganga river basin area have either registered a decline or a constant pattern during 1962-65 to 2003-06. Bihar and West Bengal have registered a slight decline during the period, while Uttar Pradesh has had a very negligible annual compound growth rate of around 0.02 percent during the period 1962-65 to 2003-06.

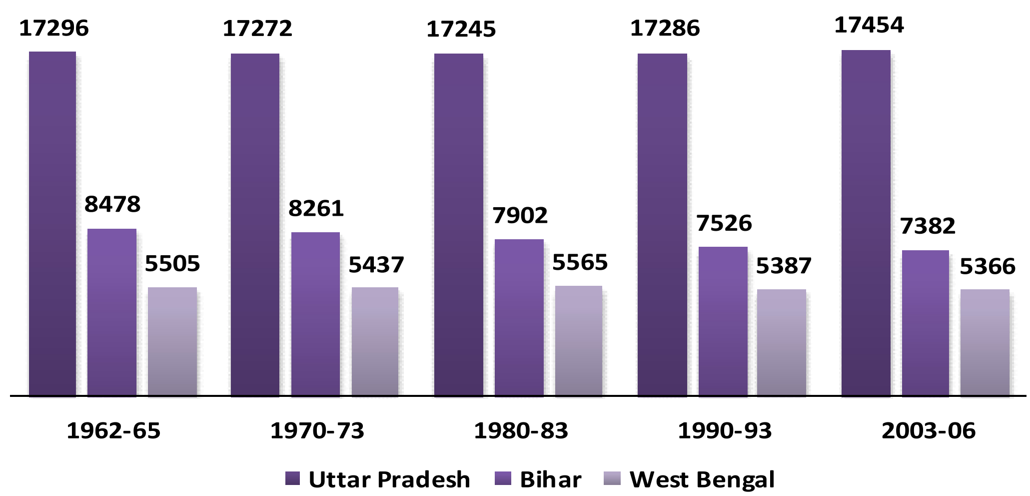

Figure 10: **Average Net Sown Area (thousandhectares) across states in GRB, 1962-65 to 2003-06**

The growth rates in net area sown across the states in the Ganga River Basinduring the period 1962-65 to 2003-06 (with decadal growth rate as well) are well illustrated in Figure 11.

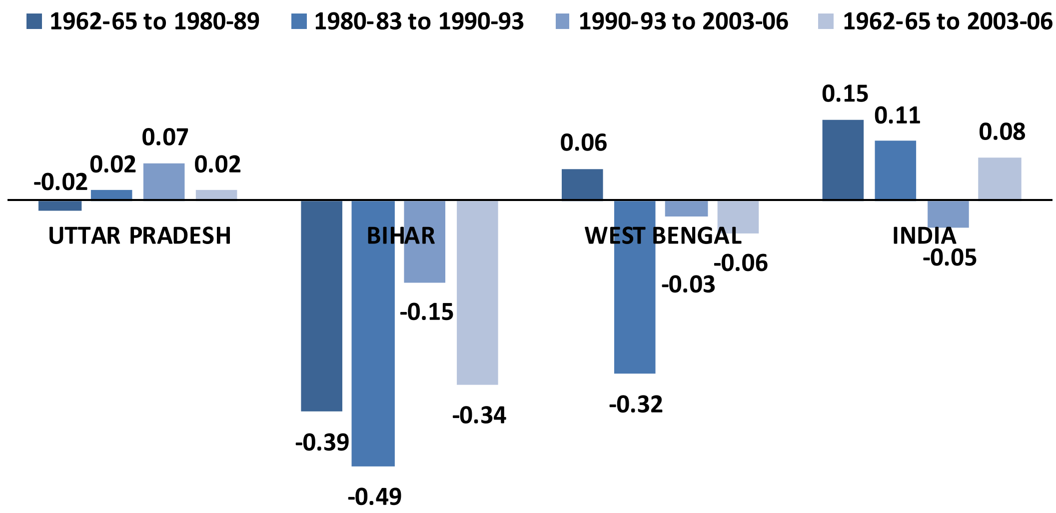

Figure 11: Annual Compound Growth Rate (%) of Net Sown Area across States in GRB

6.1.4. Gross Cropped Area

Notwithstanding the fact that yield growth has become the dominant contributor to growth of output after the advent of green revolution, growth of gross cropped area continues to be an important source of growth of output. The average gross cropped area in the Ganga River Basin area grew from 501.7 thousand hectare during 1962-65 to 598.9 thousand hectare during 2003-06(Figure 12). Though, there has been a growth of more than 19 percent in the average gross cropped area in the districts of the Ganga River Basin, there was minimumgrowth (less than 4%)registered in the average gross cropped area across the districts in the initial period of the green revolution (during 1962-65 and 1970-73).

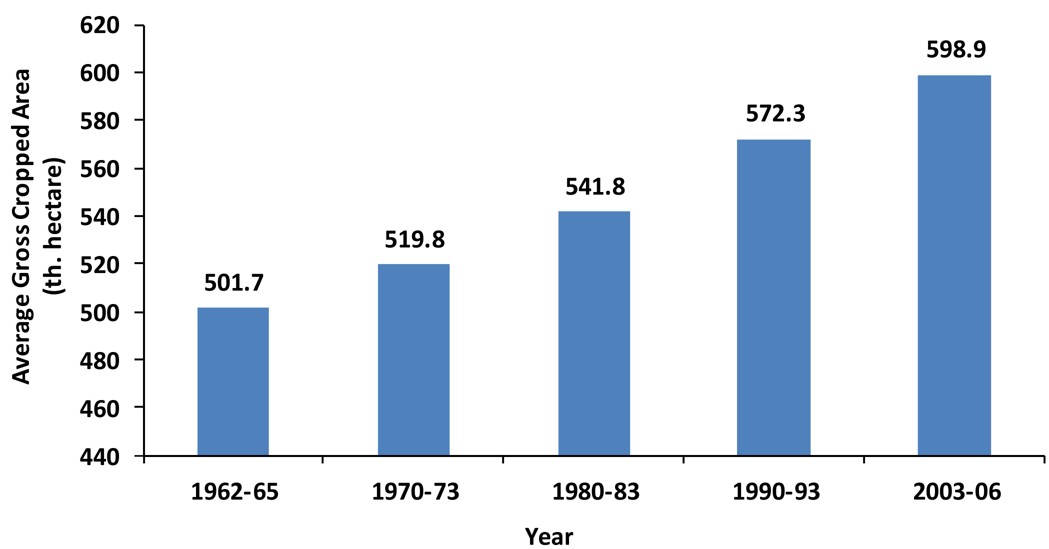

Figure 12: Average Gross Cropped Area (thousand hectares) per district in GRB, 1962-65 to 2003-06

At the state level, the growth in the gross cropped area was almost 6 times higher in West Bengal as compared to Uttar Pradesh during 1962-65 to 2003-06, while Bihar had a continuous decline in the gross cropped area throughout the period (Figure13).

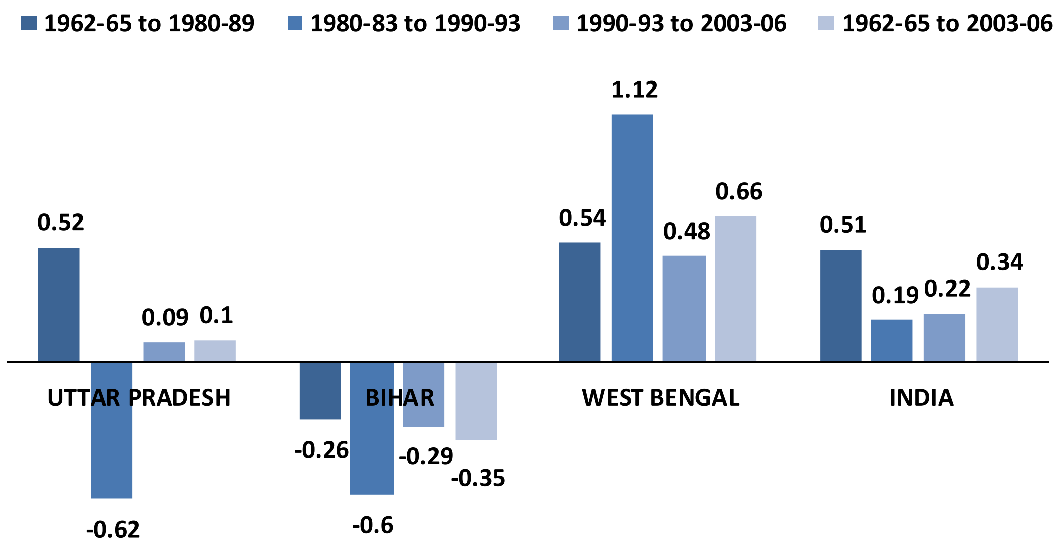

Figure 13: Annual Compound Growth Rate (%) of Gross Cropped Area across States in GRB

Area under crops can grow either through increase in net area sown or through increase in intensity of cultivation. Since a limit has reached with regard to the possibility of increasing net sown area on a substantial scale, hence, the only method of increasing gross cropped area was through increased intensity of cultivation brought about through irrigation and through the introduction of short duration crops.

6.1.5. Cropping Intensity

As discussed above, despite registering a decline of around 0.06% in net sown area during the period 1962-65 to 2003-06, West Bengal managed to record a six-times growth in the gross cropped area as compared to Uttar Pradesh during the same period which can be attributed to the tenancy reforms and adequate provisions for farm related credits.It had registered a substantial growth in the cropping intensity i.e. the number of crops grown from the same land in a year, during 1990-93 (160%) and 2003-06 (176%) as can be seen from Figure 14. The cropping intensity in West Bengal grew from a level of 118% during 1962-65 to 176% during 2003-06 compared to the respective figures of Uttar Pradesh as 128% and 150%. However, the lower cropping intensity in Uttar Pradesh is observed due to some measurement problem, as the cultivation of sugarcane, a major crop, in Uttar Pradesh is an annual crop and should be considered equivalent to two crops (Kharif + Rabi) when it comes to measuring cropping intensity.

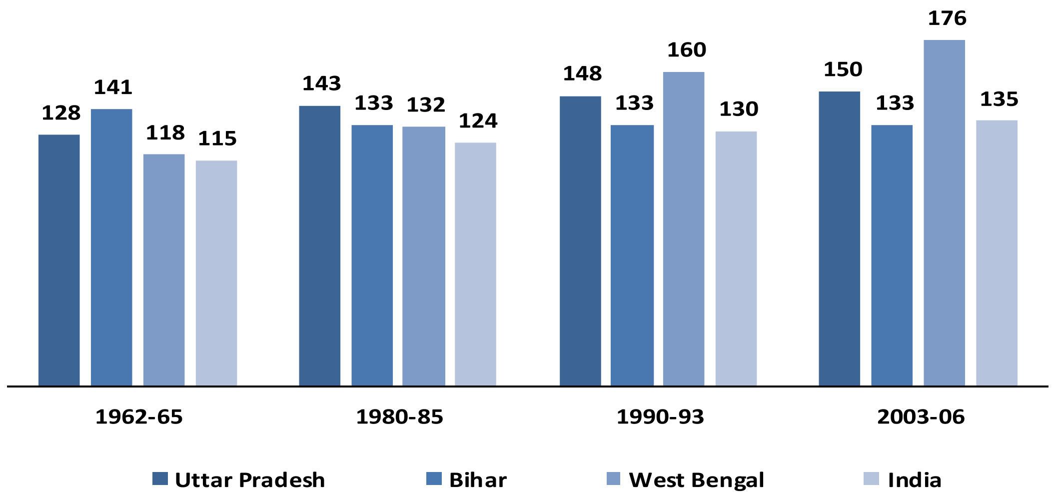

Figure 14: Cropping Intensity (%) across States in GRB, 1962-65 to 2003-06

6.1.6 Trends in Net and Gross Irrigated Area

The improvement in irrigation facilities over the period has had a very important role to play in the spectacular increase in the growth of output in agriculture in the Ganga River Basin area. Construction of canals along Ganga and other small rivers, increasing use of mechanized equipments to exploit the ground water as well as to divert stored surface water in ponds or wells at desired place in the agricultural fields, and other small sources of irrigation like temporary drainage etc. have facilitated a tremendous growth in the proportion of irrigated area in the basin, similar to other areas in the country. Figure 15 indicates the growth of average net irrigated area in theGanga River Basin area. The average net irrigated area in the basin has grown from the level of 89.6 thousand hectare during 1962-65 to 243.6 thousand hectare during 2003-06.

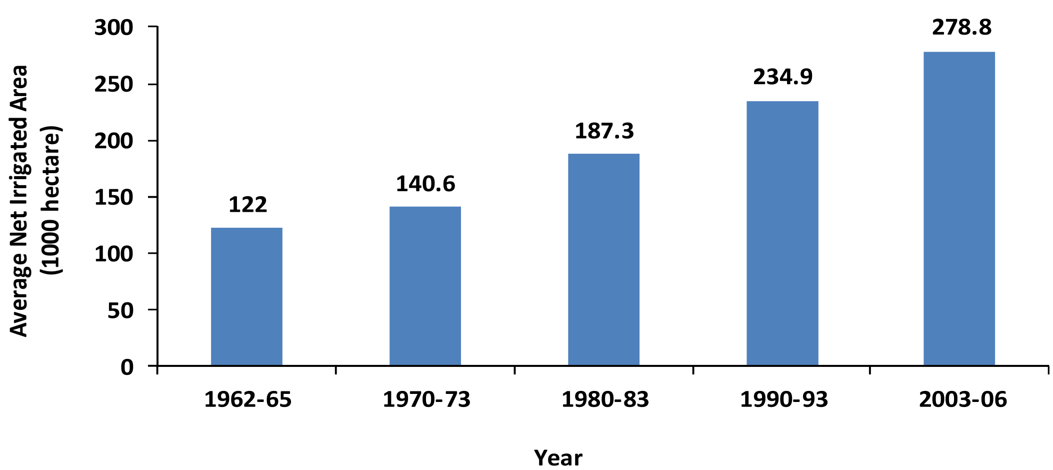

Figure 15: Average Net Irrigated Area (thousandhectare) per district in GRB, 1962-65 to 2003-06

Figure 16 shows the average gross irrigated area in the basin area, which indicates that during the period 1962-65 to 2003-06, there has been anincreaseof more than 200 percent in the average gross irrigated area in the basin.

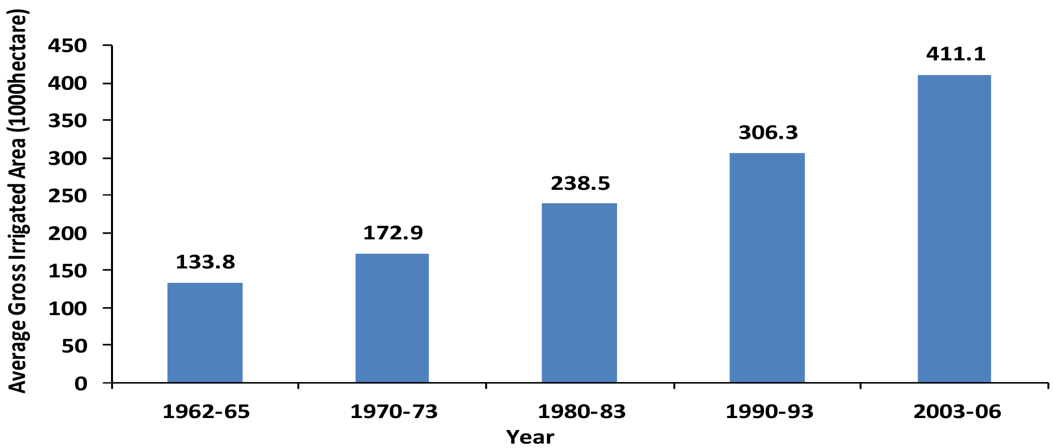

Figure 16: Average Gross Irrigated Area (1000 hectare) per district in GRB, 1962-65 to 2003-06

The average gross irrigated area per district which was recorded at a level of 133.8 thousand hectares during 1962-65 grew to a level of 411.1 thousand hectaresduring the period 2003-06.At the state level, Uttar Pradesh has registered a tremendous increase of around 159 percent in the gross irrigated area during the period 1962-65 to 2003-06 (Figure 17). Uttar Pradesh, which also includes Uttarakhand, recorded a level of only 27 percent irrigated area during early 60's and then managed to get 70 percent of the total cropped area irrigated during 2003-06. On the other hand, having maintained one fourth of the total cropped area irrigated during the period 1962-65 to 1980-83, West Bengal registered a growth of more than 115 percent in GIA during the period 1980-83 to 1990-93, which recorded a little decline during the period 1990-93 to 2003-06. Needless to say, Bihar also registered a tremendous growth (more than 150 percent) in the proportion of irrigated area from the level during 1962-65 (18%) to 2003-06 (48%).

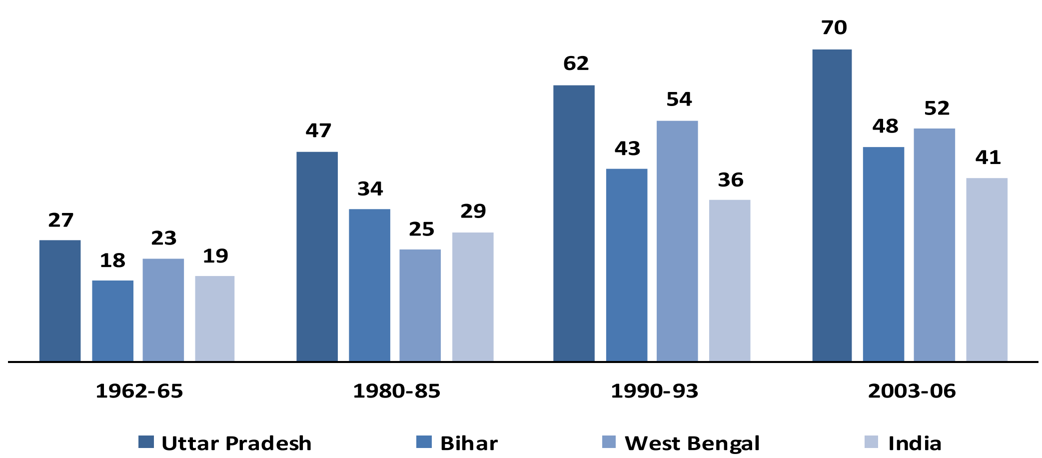

Figure 17: Trends in GIA across States in GRB, 1962-65 to 2003-06

The information provided in Table 1 suggests that UP and Uttarakhand together accounts for the largest net irrigated area from all sources and that it has the highest net irrigated to net sown area.

Table 1: State-wise Irrigation Intensity in the Ganga River Basin (1999-2008)*

State	Net Irrigated Area from All Sources, km^2	Gross Area Irrigated from All Sources, km^2	Net Area Sown, km^2	Net Irrigated to Net Sown Area (Percent)
Bihar and Jharkhand	36460	48820	70920	51%
Uttar Pradesh and Uttarakhand	134260	196960	171820	78%
West Bengal	31360	36610	52960	59%
India	630990	764430	1408610	44%

**Source: Ministry of Agriculture, 2008, Quoted on page 32Environmental and Social Management Framework (ESMF) Volume I - Environmental and Social Analysis, January 2011, Prepared by The Energy and Resources Institute, Delhi for National Ganga River Basin Authority (NGRBA),Ministry of Environment and Forests, Government of India.*

Different sources of water have been used to provided irrigation facilities to the farmland. Although there is a good network of canals especially in Uttar Pradesh, nevertheless canal water meets only 24% of the irrigation requirement of the agriculture in this state. The highest contribution of canals to the irrigation can be seen in case of Bihar and Jharkhand where canals water caters to 39% of the total irrigation requirement. Wells, however, provide the nearly twice that amount, especially in Uttar Pradesh and Uttarakhand (73%), West Bengal (59%), and Bihar and Jharkhand (49%). The detailed information in this regard is provided in Table 2.

Table 2: State/Source-wise net area irrigated (2000-2001) in the Ganga River Basin*

State	Canals,km^2	Tank,km^2	Wells,km^2	Other Sources,km^2	Total Area, All Sources,km^2
Bihar	11360	1550	20930	2410	36250
Uttar Pradesh	30910	820	93840	2590	128160
West Bengal	2610	1730	13970	5230	23540
India	159890	25240	332770	28920	546820

**Source: Water Data- Complete Book, Central Water Commission, GoI, 2005; Quoted on page 33 Environmental and Social Management Framework (ESMF) Volume I - Environmental and Social Analysis, January 2011, Prepared by The Energy and Resources Institute, Delhi for National Ganga River Basin Authority (NGRBA), Ministry of Environment and Forests, Government of India.*

Although ground water is, by and large, used for irrigation purposes, it also provides water for the domestic and industrial uses, as highlighted in Table 3. In fact, throughout the alluvial area of the GangaRiver Basin, the major urban water supply schemes are dependent upon groundwater resources. Similarly, a large number of industries also withdraw significant amounts of groundwater, especially from the easily accessible aquifers in the alluvial zone. The highest availability of the ground water is also found to be in Uttar Pradesh (Table 3).

Table 3: State-wise Groundwater Usage Pattern in the Ganga River Basin States*

State	Annual Groundwater Draft (BCM per year)			Net Annual Groundwater Availability (BCM/Year)
	Irrigation	Domestic and Industrial Uses	Total	
Bihar	9.39	1.37	10.77	27.42
Uttar Pradesh	45.36	3.42	48.78	70.18
Uttarakhand	1.34	0.05	1.39	2.1
West Bengal	10.84	0.81	11.65	27.46
India	212.37	18.05	230.41	398.7

**Source: Central Groundwater Board, 2008 and Central Water Commission, 2008)*

6.1.7 Fertilizer Consumption

Since the very inception of green revolution, the seed-fertilizer technology was the main catalyst to boost up the growth of Indian agriculture. Figure 18 very clearly points out the increasing trend in fertilizer consumption. From the period during 1962-65, when the average level of fertilizer consumption was recorded at just 1.7 thousand tones per district in the GangaRiver Basin area, the average level of fertilizer consumption grew up tremendously to a level of 102.6 thousand tones during 2003-06.This issue needs to be looked at very seriously for the reason that increasing use of chemical fertilizer has become the non-point source of ground and river water pollution. It also puts a big question mark on the sustainability of agricultural growth.

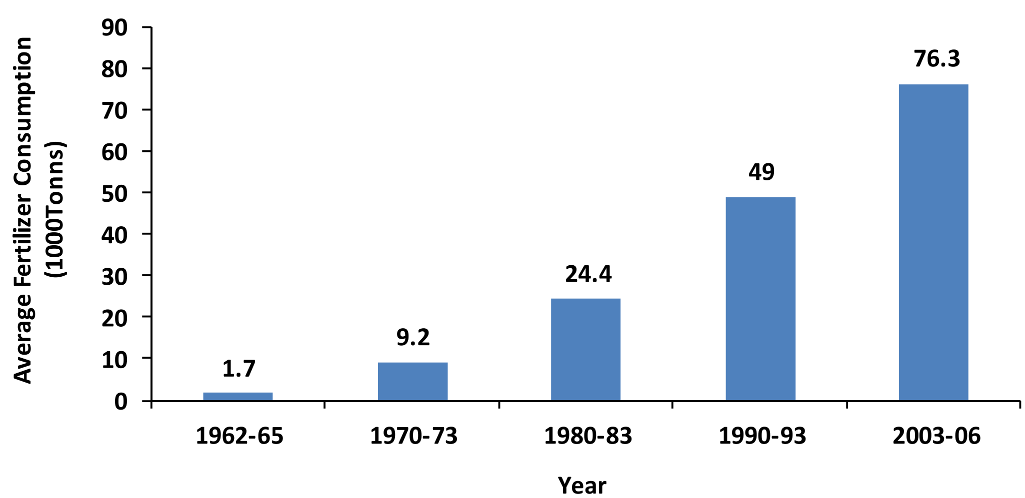

Figure 18: Average Fertilizer Consumption (thousand tonnes) per district in GRB, 1962-65 to 2003-06

If one observes the trend in fertilizer consumption across states in the basin area, West Bengal seems to have registered a tremendous growth in the use of chemical fertilizers from the level of only 5 kg/hectare during 1962-65 to a level of 226 kg/hectare during 2003-06. Uttar Pradesh also followed, more or less, the same level of growth throughout the period with a level of only 4 kg/hectare during 1962-65 to 205 kg/hectare during 2003-06 (Figure 19). Comparatively, Bihar has registered a modest growth in the fertilizer consumption.

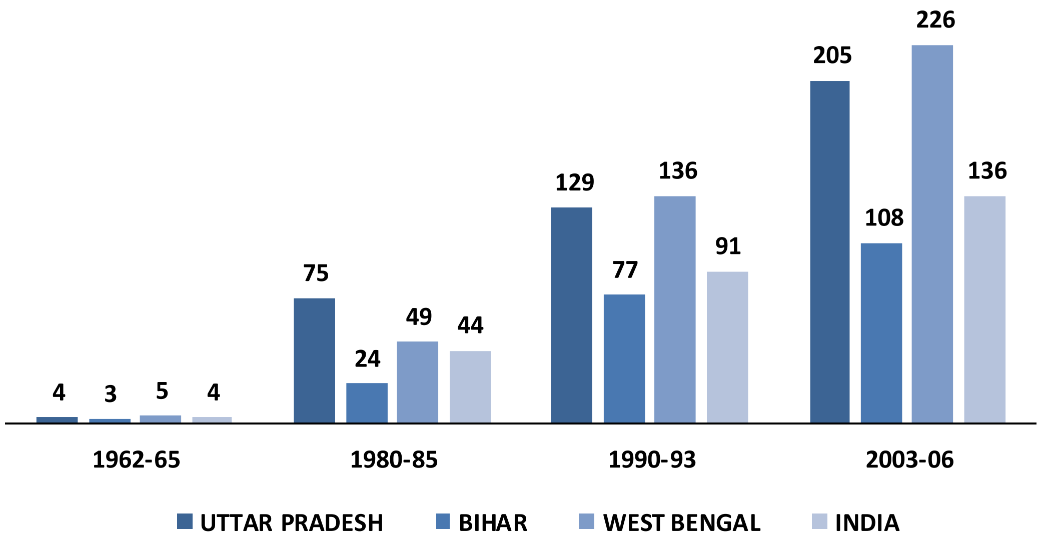

Figure 19: Fertilizer Consumption (kg/hectare) across States in GRB, 1962-65 to 2003-06

It may be mentioned here that the Ganga basin states comprising Bihar, Haryana, Himachal, Jharkhand, Madhya Pradesh, Rajasthan, UP, Uttarakhand, and West Bengal, consume nearly 10 million tones of chemical fertilizers per year, which constitutes 45 percent of the total chemical fertilizer consumption in the country. Of this, Uttar Pradesh alone consumes 38% of the fertilizer used. Such an intensive use of fertilizer may lead to disposal of high levels of nitrogen and phosphorus as part of the agricultural runoff into surface water bodies. As per available estimates, 0 to 15 per cent of the nutrients added to the soils through fertilizers eventually find their way to the surface water systems. Runoff from arable lands may contain nitrogen up to 70 mg/l and phosphorus ranging from 0.05 to 1.1 mg/l, with potential to raise the nutrient level to a considerable degree in stream waters. Similarly, pesticide consumption in the Ganga basin states is about 21,000 tones per year (47.6% of the total pesticide consumption in the country). Pesticides, being highly toxic and chemically more stable than the fertilizer residues, do have much bigger a potential for polluting the surface and ground water and consequently causing harm to the human health and aquatic fauna [*Environmental and Social Management Framework (ESMF) Volume I - Environmental and Social Analysis, January 2011, Prepared by The Energy and Resources Institute, Delhi for National Ganga River Basin Authority (NGRBA), Ministry of Environment and Forests, Government of India. p.127]*.

6.1.8 Mechanization and Power Resources

Agriculture in the basin area has been successfully powered by the increasing use of time-saving, labour-saving and efficient equipments replacing the cumbersome wood and iron age of traditional Indian agriculture. The very successful replacement of traditional plough by the tractors provided a very efficient manner to dig out and shuffle the soil to keep the content of the soil rich and refreshing. So was the relief provided by the increasing use of diesel-based/electric pump-sets to take out the ground water, especially when the rain water falls deficient.

In this regard, it would be interesting to have a look at the growth of these power-based equipments in the Ganga River Basin area. Figures 20 and 21 demonstrate the growth pattern in the average use of tractors and pump-sets per district in the basin area. As could be discerned, the use of tractors grew tremendously from the level of only 1 tractor per thousand hectare of NSA (on an average) per district during 1962-65 to an average level of 33 tractors per thousand hectare of NSA per district in the basin. The significant increase in the use of tractors was registered since the period 1980-83.

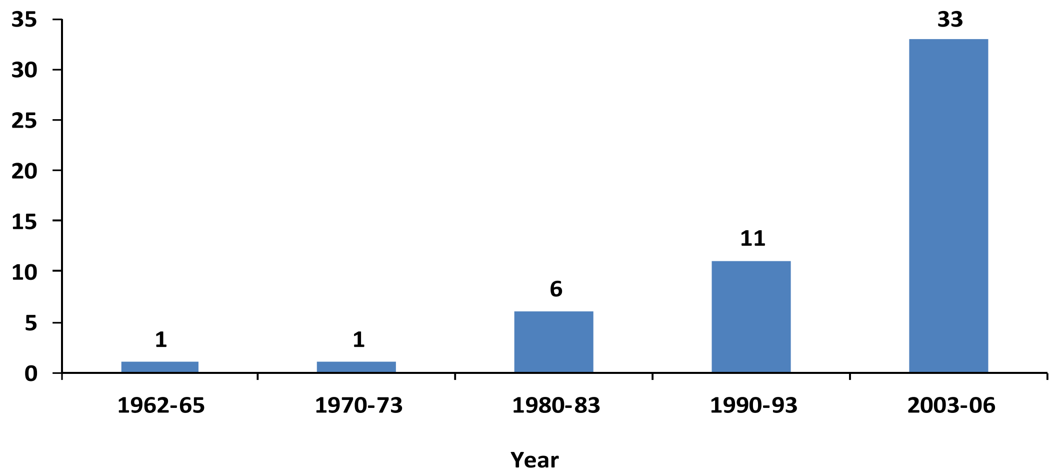

Figure 20: **Average use of tractors (per thousand hectare of net sown area) per district in GRB, 1962-65**

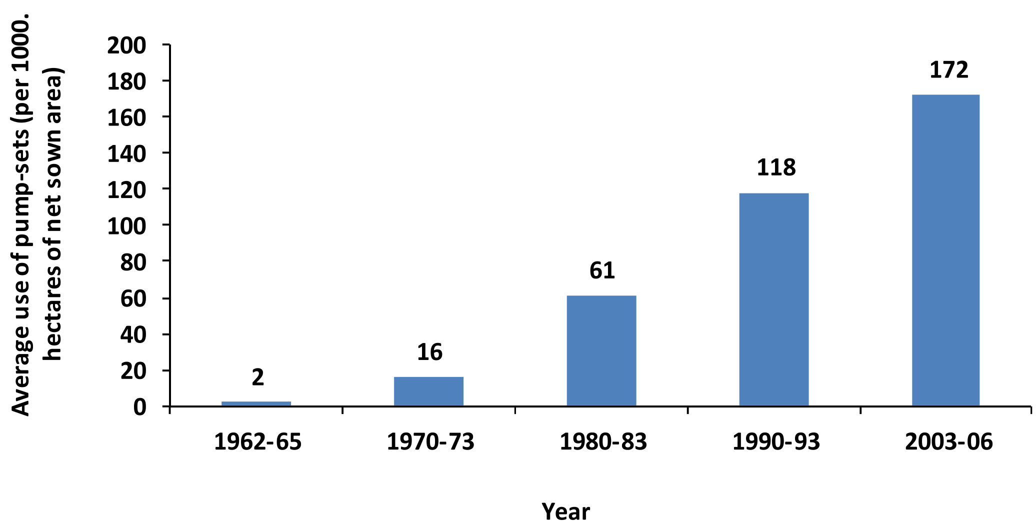

Figure 21: **Average use of pump-sets (per thousand hectares of net sown area) per district in GRB, 1962-65 to 2003-06**

Similarly, since the period 1980-83, the average use of pump-sets per thousand hectare of NSA grew from a level of 61 pump-sets per thousand hectares to an average level of 172 pump-sets per thousand hectare of NSA during 2003-06; a substantial increase of more than 200 percent. The increasing use of pump sets signifies the increasing utilization of the ground water which might sometime exceed the replenishment rate.

6.1.9 Agriculture as a Main Source of Livelihood

The one of the most peculiar characteristics of the Ganga River Basin is the dependence of larger number of its population on agriculture for their livelihood. Figure 22 illustrates clearly that even after increasing use of efficient and power-based agricultural equipments, the use of agricultural workers per 10 hectares of NSA continued to increase substantially since the period 1980-83.

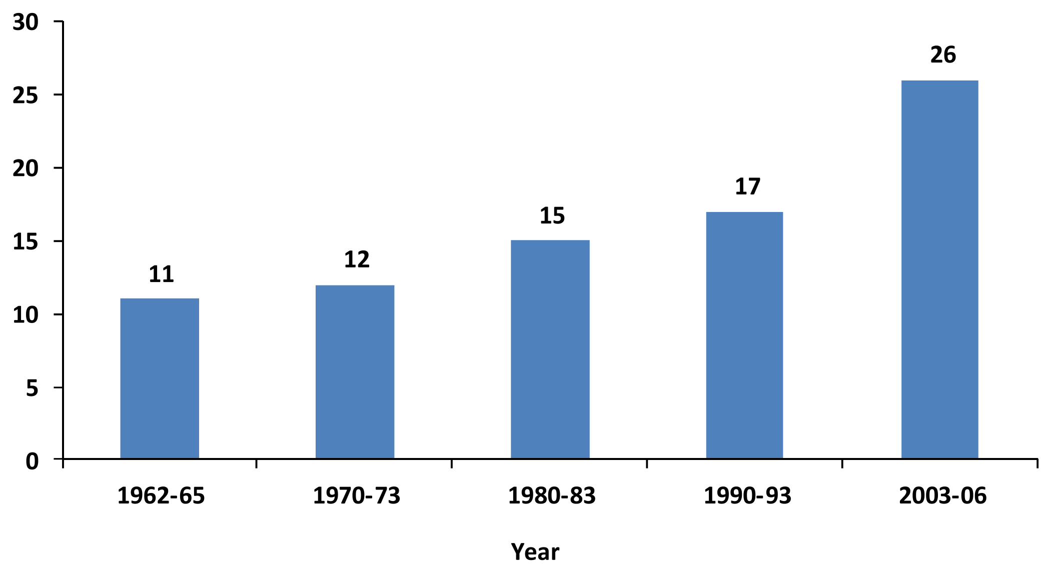

Figure 22: Average Male Agricultural Workers (per 10 hectare of NSA) per district in GRB, 1962-65 to 2003-06

The average male agricultural workers who were employed per 10 hectares of NSA in Ganga River Basin was recorded as 11 during the period 1962-65, grew up to a level of around 26 male agricultural workers per 10 hectares of NSA during the period 2003-06.

7. Summary Remarks

Following summary remarks can be made based on the review of selected agricultural input and output indicators in the Ganga River Basin.

- Crop output, in the basin area, has increased tremendously during last four decades albeit at varying rates across the states.
- The area under agriculture, as illustrated by the declining or the constant rate of growth in the net and gross cropped area, has declined over time as an impact of growing industrialization and urbanization.

- The uses of other inputs like fertilizer and modern agricultural equipments have increased massively over the period.
- Due to improvement in the irrigation facilities, the dependence on the monsoon has declined, which resulted into intensive cultivation (more than one crop a year) as well as crop diversification in the basin area. The green revolution brought a significant change in the agricultural practices in mid sixties, the result of which reflects in the growth pattern during 1980-83 to 1990-93.
- Uttar Pradesh, especially the Western Uttar Pradesh, cashed a major benefit from the green revolution, while the eastern part including Bihar and West Bengal evidenced a relatively slow agricultural growth.
- The decomposition of growth brings to the fore that almost half of growth in output is contributed by modern inputs, namely fertilizer, tractors and tube-wells, about 12-14 per cent by increased use of traditional inputs, namely land and labour, 5-8 per cent by growth of rural infrastructure, and remaining about one-third by the total factor productivity growth in Indian agriculture (Bosworth and Collins, 2008).

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State of Health in the Ganga River Basin

GRBMP: Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay | IIT Delhi | IIT Guwahati | IIT Kanpur | IIT Kharagpur | IIT Madras | IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. A list of persons who have contributed directly and names of those who have taken lead in preparing this report is given on the reverse side.

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1. Introduction

This report presents the status of health along with morbidity and public and private healthcare expenditure in the Ganga River Basin. Historically, Ganga River is considered as one of the most sacred rivers of India. However, with the passage of time, this sacred river has been polluted by its own people due to various factors (Wickramasekera A., 2013). With a growing population and urbanization in the Ganga basin, per capita availability of water, drinking water and safe drinking water has declined significantly. The links between population growth and environmental degradation are under congestions because the ever-increasing numbers of people depend on a fixed natural resource base (Dwivedi and Pathak, 2007). Discharge of untreated sewage and industrial effluent are major causes of degradation of river water quality. The total wastewater generation from 222 towns in Ganga basin is estimated to be 8250 million litres per day (MLD), out of which 2538 MLD is directly discharged into the Ganga River, 4491 MLD is disposed into its tributaries and 1220 MLD is disposed of on land or low lying areas. Furthermore, Uttar Pradesh contributed more than 55% of the total urban and industrial pollution load to the basin. (CPCB, “Status of Sewage Treatment Plants in Ganga Basin”)

The untreated or improperly treated wastewaters discharged into water bodies, from where the downstream city’s water requirements are met, constitute a big public health hazard in terms of their potential for spreading water borne diseases. It may also be mentioned that the existing public healthcare infrastructure is not adequate to meet the ever increasing healthcare requirement in the basin. Most of the health expenditure is supported by private spending, primarily Out of Pocket (OOP), with public funds constituting an insufficient amount. Around 39.5 million people fell below the poverty line in India due to out-of-pocket health payments in 2004–2005. Policies to reduce poverty in India need to include measures to reduce catastrophic out-of pocket payments on health (Bonu et al, 2007).

Inadequate and inefficient public healthcare infrastructure and rising health hazards owing to inadequate access to safe drinking water and sanitation put enormous monetary burden of medical and health expenditure on households, with the spread of some alarming vector diseases in this region. Huge amount of public and private expenditure on water-borne diseases could be saved if quality of water is improved by controlling pollution and reducing degradation of river and ground water and. It is in this context that this study is carried out to examine the water, sanitation and health related issues in the Ganga basin.

1.1 Rationale of the Study

Water, sanitation and health are very closely related. Inadequate access to safe drinking water & sanitation facilities and poor hygiene practices lead to ill-health of the people of the Ganga basin. With rising urbanization and industrialization and population pressure in the basin, the demand for water has been constantly increasing in all the sectors, including domesticuse, which causes not only depletion of both surface and groundwater resources but also contaminate these resources and thereby adversely affecting human health. Untreated industrial wastes, domestic sewage, open defecation and increasing use of chemicals for agriculture pollute water resources. Therefore, maintaining *aviral* and *nirmal* Ganga is not only desirable for the sustainability of environment and ecosystem but also for the health of people living in the basin. The health of the river is directly associated with the health of the people and the economy as well. Keeping this aspect in view, the present study attempts to examine health status of people of the basin. Although this study presents an overview of existing public healthcare infrastructure and makes detailed discussion on healthcare expenditure, however, the focus is on water-related health issues and diseases. An attempt has also been made to assess the private cost of treated drinking water, including bottled water.

1.2 Scope of the Study

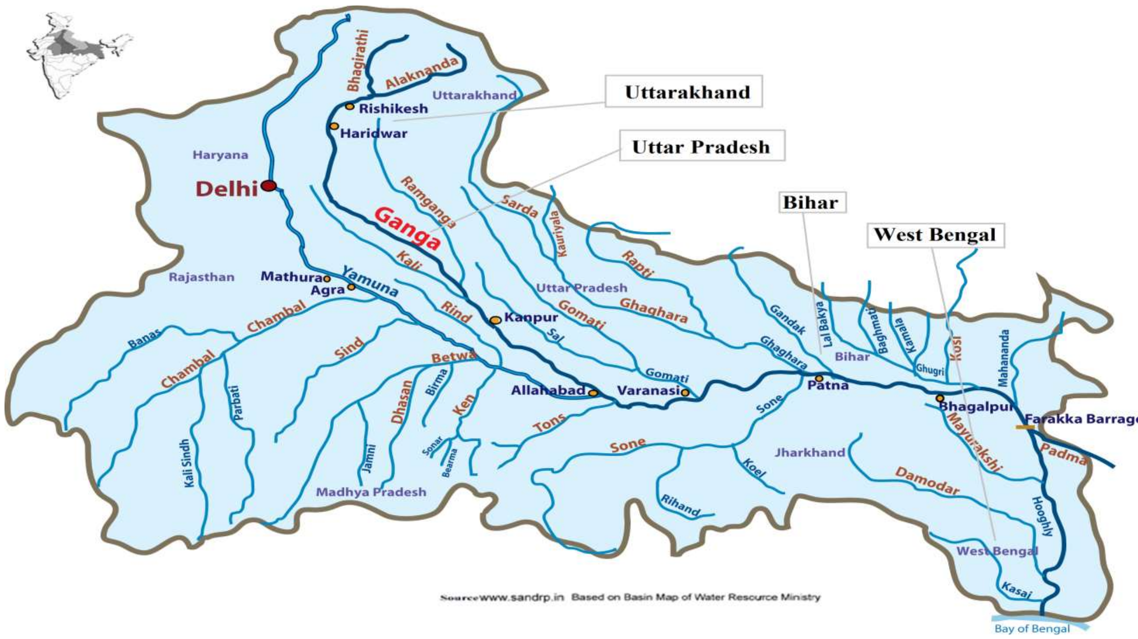
The foremost objective of the study is to analyse health status along with medical & health expenditure incurred by the households across the basin. With the premise of significantly enhanced water pollution in the basin, it has been inferred that medical and health expenditure of the residents has increased, especially in relation to water related diseases. This report has been divided into two major sections, one for aggregate analyses (section 4 to 6) and another for district-wise analyses (Section 7 and 8). Both the sections are further subdivided into three analytical parts. Sections 4 and 7 deal with service and education health infrastructure at aggregate and district level respectively. Sections 5 and 8 discuss issues related to drinking water, sanitation and health, particularly for Ganga basin states at aggregate and district level, respectively. Section 8 presents health expenditure - mainly public and private expenditure at aggregate level. This section also analyses medical treatment expenditure and loss of household income for non-hospitalised and hospitalised treatment in the Ganga basin states. The report ends with Sections 9 which presents conclusions, policy implication and recommendations.

2. Data Sources and Methodology

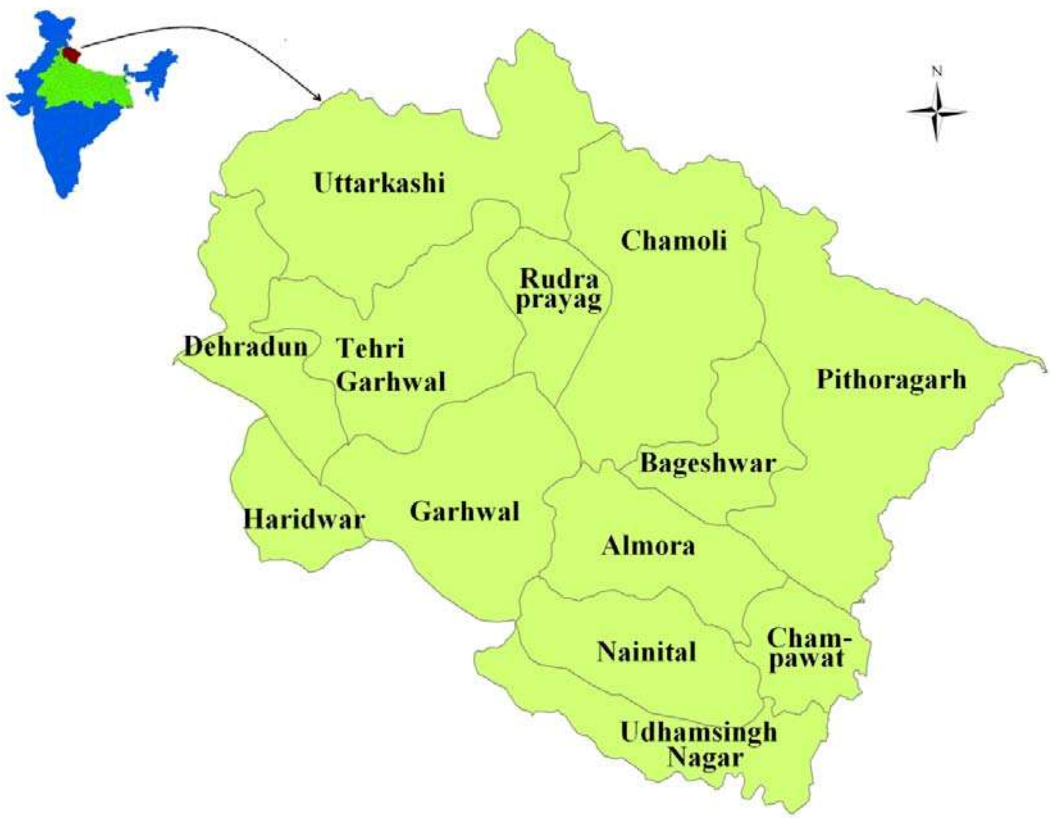
The study is based on the secondary data drawn from various published sources, such as National Health Profile (NHP), National Health Account (NHA) of India, Rural Health Status (RHS) Bulletin, National Rural Health Mission and Census of India (2001, 2011). The data collected through the unit level records of the 60th Round of the NSSO (Report of the 60th Round on Morbidity, Healthcare and Condition of the Aged, 2004) has been used to estimate household expenditures on health. This survey covered 73,868 households and 3,83,338 persons spread across all the states and union territories of India, Out of which 19,078 households (25.83% of the total surveyed households) and 1,07,635 persons (28.08% of the total surveyed persons) were surveyed in the Ganga Basin that covers Uttar Pradesh, Uttarakhand, Bihar and West Bengal. Information on utilization of healthcare services by households for hospitalized treatments by type or nature of ailment and a number of related characteristics have been collected through this survey. Also, number of households using bottled water, and treatment at point of use has also been collected to find out expenditure incurred by households on such practices. Data on medical expenditure and loss of household income due to hospitalisation have also been collected from this particular round of NSS. Census of India has also been an important source of data for distribution of population identified by major sources of drinking water, sanitation, drainage, etc. For some indicators of water borne diseases, data from National Health Profile (NHP) and unit level records of 60th NSS round (2004) have been taken. Public and private expenditure on health has been taken from National Health Accounts (NHA) of India.

The present report considers Uttarakhand, Uttar Pradesh, Bihar and West Bengal states as part of Ganga Basin and the remaining states and UTs are considered as 'non-basin states' or 'others'. The comparison among the basin states, non-basin states and overall India scenario has been made on various important aspects. As discuss earlier, the report is divided into two parts. First part discuses aggregate estimates of Ganga basin states and second part deals comprehensively with the disaggregated estimates of Ganga Basin states. However, for three large states in the basin (in terms of population) i.e., Uttar Pradesh, Bihar and West Bengal, the disaggregated discussion is carried out in terms of groups or regions. On the basis of proximity to River Gang in the case of Bihar and West Bengal the districts are classified into two categories, i.e., viz., bank districts and non-bank districts; and in the case of Uttar Pradesh the classification is into five regions viz., Northern Upper Ganga Plains-NUGP (10 districts), Southern Upper Ganga Plains-SUGP (18 districts), Central Region-CR (9 districts), Southern Region-SR (7 districts of Bundelkhand region), and the Eastern Region-ER (26 districts).

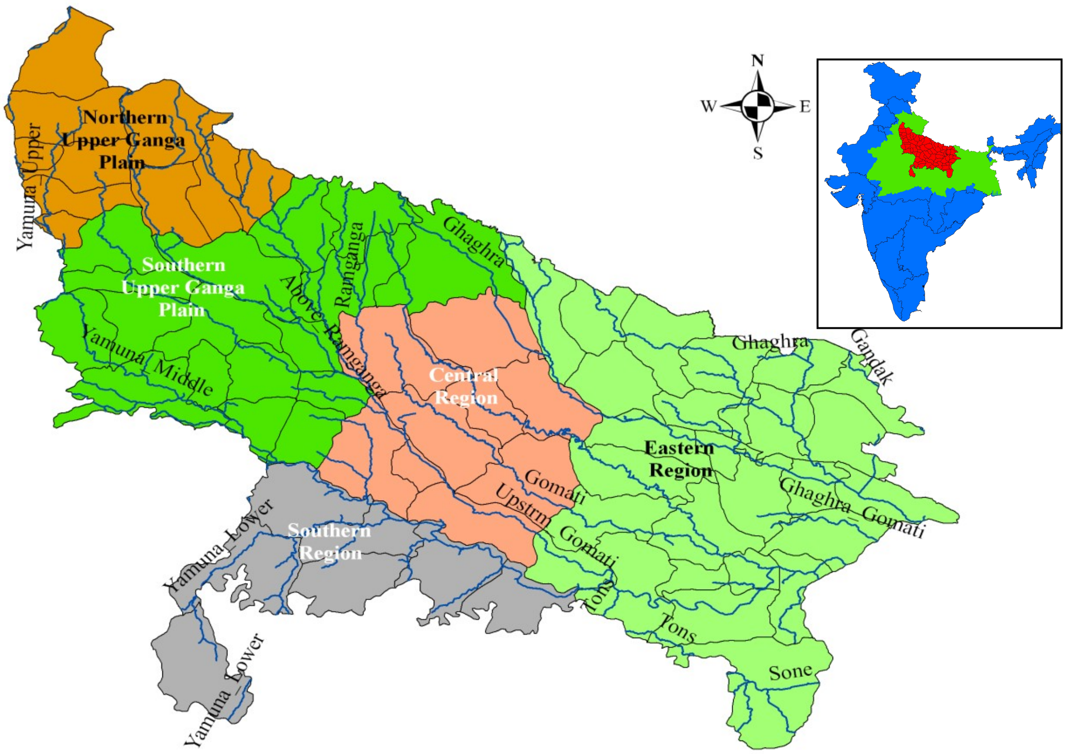
Map-1 depicts the location of the Ganga Basin, along with its adjoining states. Map-2 illustrates the location of districts in Uttarakhand. Map-3 shows map of Uttar Pradesh along with all five regions. Map 4 and 5 depict position of bank and non- bank districts in Bihar and West Bengal, respectively.



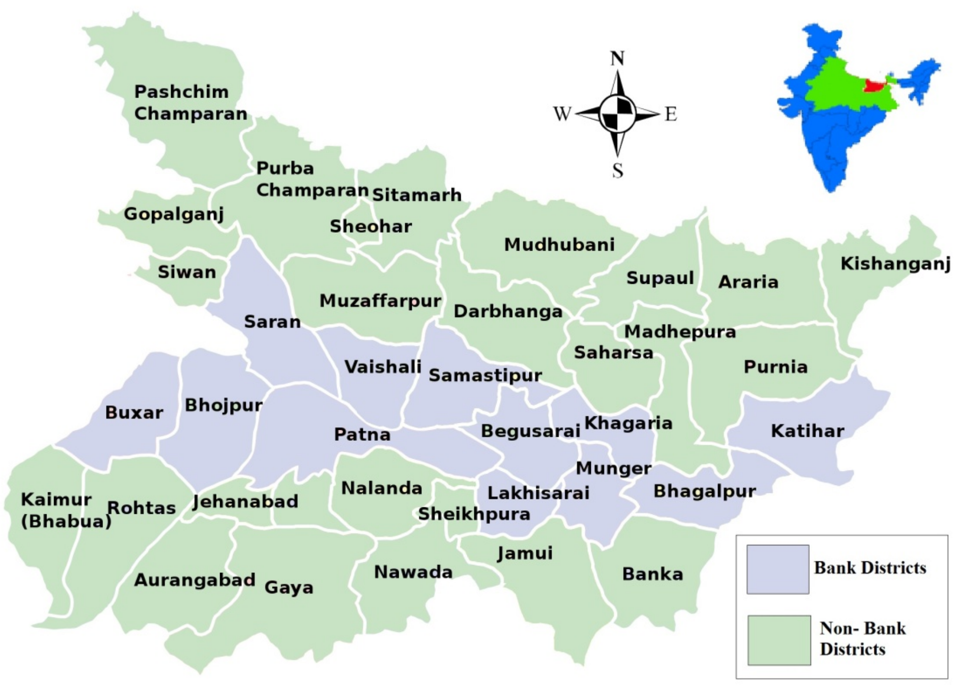
Map 1: Location of the Ganga Basin



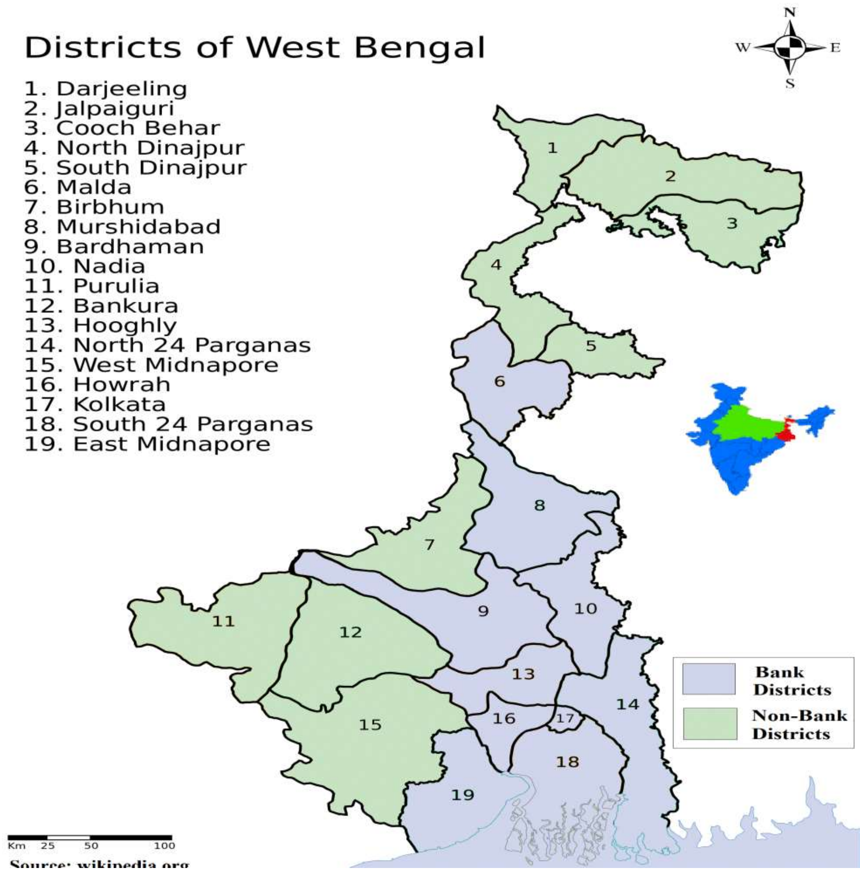
Map 2: District map of Uttarakhand



Map 3: Region-wise Ganga basin map of Uttar Pradesh



Map 4: Bank and non-bank districts in the Bihar part of the Ganga Basin



Map 5: Bank and non-bank districts in the West Bengal part of the Ganga Basin

3. An Overview of the Health Status

Increasing population pressure, rapid industrialization and agricultural activities in the Ganga Basin adversely affect the quality of drinking water and as a result health of the people. Direct discharge of untreated industrial effluents and domestic sewage, indiscriminate open disposal of municipal solid waste from urban areas along the river banks (on account of, among others, lack of sanitary landfill sites), disposal of animal carcasses, open defecation and finally non-point discharges of pesticides and chemical fertilizers represent main causes of degradation of surface and ground water resources. Ganga River has slowly become a safe haven for viruses and bacteria causing host of deadly diseases like dysentery, cholera, hepatitis A, typhoid fever, etc. Diarrhea, as per global health figures, is said to be the second largest contributor for infant mortality rates (IMR) in the world and India as well. The factors like unsafe drinking water, poor sanitation and hygiene conditions are undoubtedly the most to blame. These issues will be examined in the ensuing sections. Here, we briefly discuss some vital statistics, such as birth rate, death rate, IMR, CMR and expectation of life at birth to assess the general health profile of people in the Ganga basin (refer Table 1).

Table 1: Overview of Health Profile in Ganga Basin States and India

States	Birth Rate *			Death Rate*			Infant Mortality Rate*			Child mortality Rate (0-4)**			Expectation of Life at Birth **		
	T	R	U	T	R	U	T	R	U	T	R	U	T	R	U
Bihar	28.1	28.8	22	6.8	7	5.6	48	49	38	14.7	15.1	9.9	61.6	60.7	67.5
UK	19.3	20.2	16.2	6.3	6.7	5.1	38	41	25	(-)	(-)	(-)	(-)	(-)	(-)
U P	28.3	29.2	24.2	8.1	8.5	6.3	61	64	44	20.1	21	15.4	60	59.2	64
WB	16.8	18.6	11.9	6	6	6.3	31	32	25	7.9	8.6	5.5	64.9	63.5	69.9
India	22.1	23.7	18	7.2	7.7	5.8	47	51	31	14.1	15.7	8.7	63.5	62.1	68.8

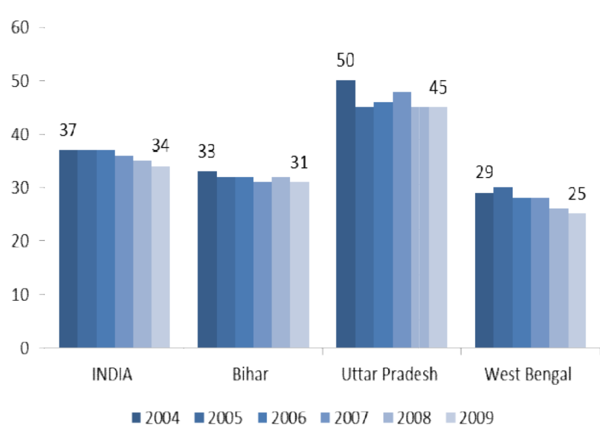
*Sources: * SRS Bulletin (December 2011), Census of India.*
*** Family Welfare statistics in India, 2011 Statistics Division Ministry of Health and Family Welfare, Government of India*
*Note: * Birth Rate , Death Rate and Infant Mortality Rate (2010) .*
***Child Mortality Rate (2009) ** Expectation of Life at Birth (2002-2006)(Latest available)*

The data shown in Table 1 clearly reveals that overall the birth rate (BR) was observed highest in Uttar Pradesh (28.3), closely followed by Bihar (28.1) and lowest in West Bengal (16.8). BRs in Uttarakhand and West Bengal were lower than the national average, while in the most populated stretch of Uttar Pradesh and Bihar states, these rates were higher than the national average. Further, BRs were observed much higher in rural than urban areas in all the states. Death rate (DR) was also observed highest in Uttar Pradesh (8.1) and lowest in West Bengal (6.0). Except for Uttar Pradesh, DRs were lower in the basin states than the national average. The table also indicates that DR was higher in rural than urban areas in all the basin states. Infant mortality rate (IMR) - an important indicator of health status, was found highest in Uttar Pradesh (61), followed by Bihar (48). It was lowest in West Bengal (31). This shows that IMR in Uttar Pradesh was almost double of West Bengal. Rural-urban difference in the IMR is substantial in all the states and this is attributed to poor access to healthcare infrastructure in rural areas in the entire basin.

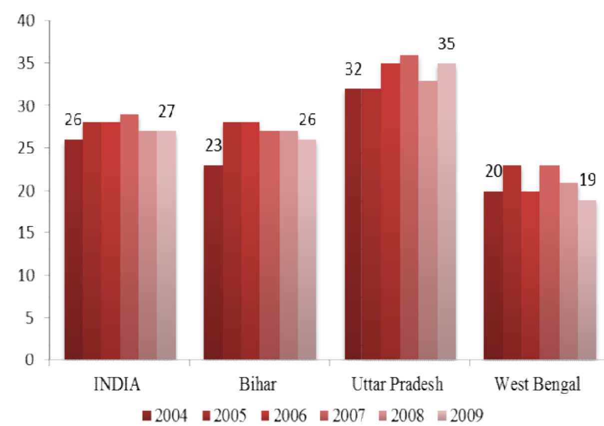
The child mortality rate (CMR), which is taken as a good proxy for incidence of water borne diseases, shows poor performance of health care services in Bihar and Uttar Pradesh; On the other hand West Bengal appears to have performed better that the national average. Overall status of primary health indicators shows that the states in the basin do not have adequate healthcare infrastructure and water purification and sanitation facilities. Overall CMR in Uttar Pradesh (20.1) was more than two and half times that of West Bengal (7.9). In urban areas, IMR in Uttar Pradesh was 15.4, whereas in West Bengal, it was only 5.5. As far as life expectancy at birth is concerned, it was observed highest in West Bengal (64.9) and lowest in Uttar Pradesh (60). Further, it was found much higher in urban than rural areas in all the states.

Based on the above it can be concluded that overall health profile is better in West Bengal and Uttarakhand and poor in Uttar Pradesh and Bihar. As shown in the next section, better performance in Uttarakhand and West Bengal can be attributed to, among others, better public healthcare infrastructure.

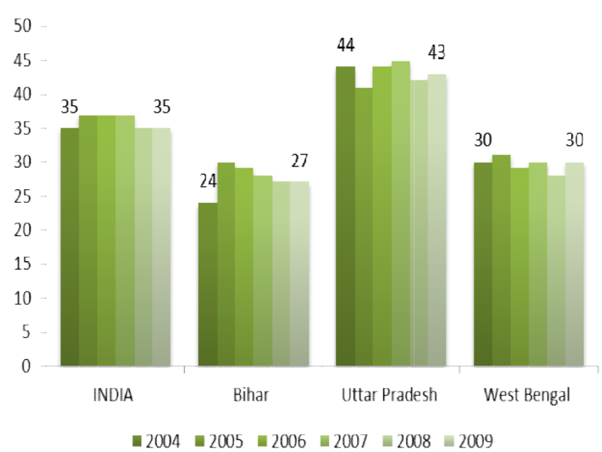
Figure 1 shows neo-natal mortality rate, early neo-natal mortality rate, peri-natal mortality rate and still birth rate in UP, Bihar and West Bengal(data for Uttarakhand is not available). These indicators reflect on several aspects related to health infrastructure and environmental condition and pollution. It is evident that all the indicators are highest in Uttar Pradesh and lowest in West Bengal (except still birth rate which was lowest in Bihar). This shows that that general health status in West Bengal is better than Uttar Pradesh and Bihar, which could be attributed to, among others, improved access, nutrition, etc. but not necessarily to water and sanitation as the latter faces similar challenges in the entire belt.



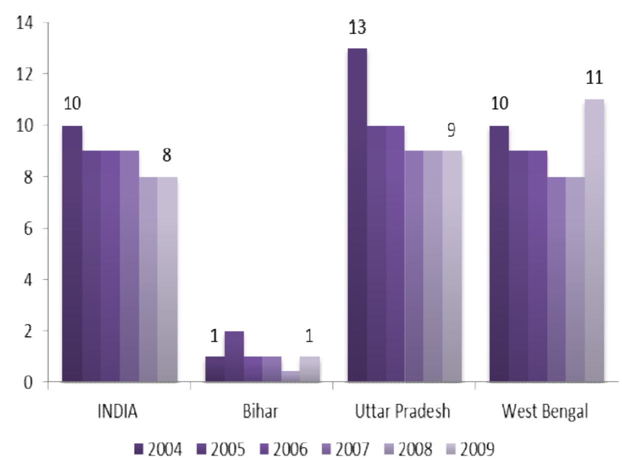
Neo Natal Mortality Rate



Early Neo Natal Mortality Rate



Peri-Natal Mortality Rate



Still Birth Rate

Source: Family welfare statistics of India (2011), Statistics Division, Ministry of Health and Family Welfare, GOI

Figure 1: State-wise Neo-natal, Early Neo-natal, Peri-natal and Still Birth Rates (2004 to 2009)

PART I: STATE-WISE ANALYSIS

4. Health Care Infrastructure

Since number of factors such as adequate food/nutrition, housing, basic sanitation, lifestyles, protection against environmental hazards and communicable diseases impact health, definition of health is extended beyond the narrow limits of medical care. Thus "health care" implies more than "medical care". It includes a multitude of "services provided to individuals or communities by agents of the health services or professions, for the purpose of promoting, maintaining, monitoring or restoring health" (Park, 2011). Health infrastructure is an important indicator to understand the healthcare delivery provisions and mechanisms in a country/region. It is divided into two categories, viz., service infrastructure and educational infrastructure. Service infrastructure in health includes sub-centers, primary health centres (PHCs), community health centres (CHCs), government district hospitals, availability of hospital beds at various levels, etc., while educational infrastructure provides comprises medical colleges, nursing and paramedical colleges, etc.

4.1. Service Infrastructure

Healthcare services are designed to meet health needs of communities through the use of available knowledge and resources. The purpose of these services is to improve health status of the population through reduction of morbidity and mortality, improve life expectancy at birth, low population growth rate, improvement in nutritional status, and basic sanitation.

4.1.1 Sub-centres

Sub-centre is the peripheral outpost of the existing health delivery system in rural areas. It acts as the first point of contact between the primary healthcare system and a community. Each sub-centre is required to be manned by at least one Auxiliary Nurse Midwife (ANM)/Female Health Worker and one Male Health Worker. One sub-centre is established to serve 5000 persons in plain areas and 3000 persons in hilly areas. These centres are responsible for establishing regular communication and dissemination so as to bring about behavioral change and provide services in relation to maternal and child health, family welfare, nutrition, immunization, diarrhea control and control of communicable diseases. They are provided with basic medicines for minor ailments needed for taking care of essential health needs of population (GOI, National Health Profile, 2012).

Table 2 shows that number of sub-centres functioning in the Ganga Basin has increased by almost 40% from 30,052 during the 6th Plan to 42,331 during the 11th Plan. However, during the same period its share in the overall number of sub-centres across India has declined from 35.62% to 28.58%, implying higher growth in the non-basin states. Within the Ganga Basin, in line with relative population/ area Uttar Pradesh accounts for a major proportion of sub-centres i.e. more than 48%, whereas Uttarakhand being thinly populated and smaller state accounts for only around 4%. Table 2 also shows that the number of sub-centres functioning in Uttar Pradesh and Uttarakhand has remained same during the 10th and the 11th Plans, while the number in the Ganga Basin as well as in India has increased over the same period . Bihar accounted for 22.69% of total sub-centres of the basin in the 11th Plan. The number of sub-centres in Bihar has gone up from 8299 in the 6th plan to 14799 in the 9th Plan. (The fall in numbers in Bihar between Ninth and Tenth Plans is due to bifurcation of the State) . In West Bengal, the number has increased constantly up to the 10th Plan and there was no addition during the entire 11th Plan period.

Table 2: Plan-wise Number and Percentage of Health sub-centers in UP, UK, Bihar, WB, Ganga Basin and all India

Location	Sixth Plan [1981-85]	Seventh Plan [1985-90]	Eighth Plan [1992-97]	Ninth Plan 1997-2002]	Tenth Plan [2002-2007]	Eleventh Plan [2007-2012]
Uttarakhand	(--)	(--)	(--)	(--)	1,765	1,848
UK % from Ganga Basin	(--)	(--)	(--)	(--)	*4.25%*	*4.37%*
UK % from India	(--)	(--)	(--)	(--)	*1.21%*	*1.25%*
Uttar Pradesh	15,653	20,153	20,153	20,153	20,521	20,521
UP % from Ganga Basin	*52.09%*	*47.06%*	*47.06%*	*46.78%*	*49.39%*	*48.48%*
UP % from India	*18.55%*	*15.48%*	*14.79%*	*14.68%*	*14.13%*	*13.85%*
Bihar*	8299	14799	14799	14799	8,909	9,606
BR % from Ganga Basin	*27.62%*	*34.56%*	*34.56%*	*34.35%*	*21.44%*	*22.69%*
BR % from India	*9.84%*	*11.37%*	*10.86%*	*10.78%*	*6.13%*	*6.49%*
West Bengal	6,100	7,873	7,873	8,126	10,356	10,356
WB % from Ganga Basin	*20.30%*	*18.38%*	*18.38%*	*18.86%*	*24.92%*	*24.46%*
WB % from India	*7.23%*	*6.05%*	*5.78%*	*5.92%*	*7.13%*	*6.99%*
Ganga Basin	30,052	42,825	42,825	43,078	41,551	42,331
Basin % from India	*35.62%*	*32.90%*	*31.43%*	*31.37%*	*28.60%*	*28.58%*
All India Total	84,376	1,30,165	1,36,258	1,37,311	1,45,272	1,48,124

**There is a reduction in the number of Centres functioning at the end of 10th Plan as compared to those functioning at the end of Ninth Plan due to the division of State.*

Source: RHS 2012

Over the years although an extensive infrastructure for medical and health services in the public and rivate sectors has been created, however, there is significant gap in supply and demand for the infrastructure for health services. Inadequacy of health infrastructure in terms of number of sub-centres in the Ganga Basin is presented in Table 3.

Table 3: Requirement, availability and deficit in sub-centres in the three main state of Ganga Basin

State/ UT	Requirement			Availability			Deficit		
	2008	**2010**	**2012**	**2008**	**2010**	**2012**	**2008**	**2010**	**2012**
Uttarakhand	1294	1294	2341	1765	1765	1848	*	*	493
Uttar Pradesh	26344	26344	31037	20521	20521	20521	5823	5823	10516
Bihar	14959	14959	18533	8858	9696	9696	6101	5263	8837
West Bengal	12101	12101	13186	10356	10356	10356	1745	1745	2830
Ganga Basin	54698	54698	65097	41500	42338	42421	13669	12831	22676
India	158792	158792	189094	146036	147069	148366	20486	19590	43776

Note : *Surplus

Source: RHS Bulletin 2008,2010,2012

Table 3 shows that the existing sub-centres in the Ganga Basin as well as in India are inadequate to meet the requirement. For instance, in 2012 in Uttar Pradesh alone, there was a shortfall of 35% and which accounts for around 48% deficit when looked at the entire Ganga basin level.. It is significant to note that the Ganga Basin constituted about 62% of India's total shortfall of sub-centres.

It is also noted that the deficit is highest in Bihar at 48% followed by UP at 34%. Both Uttarakhand and West Bengal fare better with deficit of only 21% in 2012. Interestingly Uttarakhand reported surplus in 2008 and 2010. The high deficit in Bihar represents a rather serious situation .

4.1.2 Primary Health Centre (PHC)

PHC is the first point of contact between village community and a medical officer. It functions as health service institution with little community involvement. The PHCs are envisaged to provide an integrated curative and preventive health care to the rural population with emphasis on preventive and promotional aspects of healthcare. One PHC is supposed to cover population of 20,000 in hilly/ tribal/ difficult areas and 30,000 in plain areas. As per minimum requirement, a PHC is to be manned by a medical officer supported by 14 paramedical and other staff. Under NRHM, there is a provision for two additional staff nurses at PHCs on contract basis. It acts as a referral unit for 6 sub-centres and has 4 to 6 beds for admitting indoor patients. PHCs provide curative, preventive, promotional and family welfare services (GOI, National Health Profile, 2012).

Table 4 shows that the number of PHCs in the Ganga Basin has increased substantially from 3137 in the 6th Plan to 7279 in 9th Plan and thereafter the number declined to 6703 in the 11th Plan. The share of the Ganga Basin in the total PHCs of the country shows a continuous decline over the period. It has gone down from 34.42% in 6th Plan to 28.06% in the 11th Plan. This implies that the number of PHCs has grown faster in non-basin states of India. Uttar Pradesh has the highest share (55%) in the total PHCs working in the basin, followed by Bihar (27.72%) and West Bengal (13.52%). However, these percentages do not imply that Uttar Pradesh has better healthcare infrastructure in terms of number of PHCs than the other states because Uttar Pradesh is the largest state in terms of population and area.

Table 4: Plan-wise Number and Percentage of PHCs in UP, UK, Bihar, WB, Ganga Basin and all India

Location	Sixth Plan [1981-85]	Seventh Plan [1985-90]	Eighth Plan [1992-97]	Ninth Plan [1997-2002]	Tenth Plan [2002-2007]	Eleventh Plan [2007-2012]
Uttarakhand	(-)	(-)	(-)	(-)	232	257
UK % from Ganga Basin	*(-)*	*(-)*	*(-)*	*(-)*	*3.59%*	*3.82%*
UK % from India	*(-)*	*(-)*	*(-)*	*(-)*	*1.04%*	*1.08%*
Uttar Pradesh*	1,169	3,000	3,761	3,808	3,660	3,692
UP % from Ganga Basin	*37.26%*	*47.99%*	*52.00%*	*52.31%*	*56.64%*	*54.93%*
UP % from India	*12.83%*	*16.07%*	*16.98%*	*16.65%*	*16.36%*	*15.46%*
Bihar*	796	2001	2209	2209	1648	1863
BR % from Ganga Basin	*25.37%*	*32.01%*	*30.54%*	*30.35%*	*25.50%*	*27.72%*
BR % from India	*8.73%*	*10.72%*	*9.97%*	*9.66%*	*7.37%*	*7.80%*
West Bengal	1,172	1,250	1,262	1,262	922	909
WB % from Ganga Basin	*37.36%*	*20.00%*	*17.45%*	*17.34%*	*14.27%*	*13.52%*
WB % from India	*12.86%*	*6.69%*	*5.70%*	*5.52%*	*4.12%*	*3.81%*
Ganga Basin	3,137	6,251	7,232	7,279	6,462	6,721
Basin % from India	*34.42%*	*33.48%*	*32.65%*	*31.82%*	*28.89%*	*28.14%*
India	9,115	18,671	22,149	22,875	22,370	23,887

*** :** ***There is a reduction in the number of Centres functioning at the end of 10th Plan as compared to those functioning at the end of Ninth Plan due to the division of State***

Source: RHS 2012

It may be noted that these PHCs came under criticism as they were not able to provide adequate health coverage partly due to ill-equipped staff and partly because of large population - exceeding one lakh in their catchments. Table 5 presents data on PHC which shows significant deficit across all states in the basin and across the country as well., Uttarakhand being an exception. In 2012 the deficit in the entire basin is 38% while that across the entire country is 26%. Among the three main states under considerations, West Bengal has highest deficit at 58%, followed by Bihar at 40% and UP at 29% respectively. Evidently the situation as regards availability of of healthcare infrastructure in terms of number of PHCs is quite alarming in the basin in general and West Bengal in particular.

Table 5: Required, Position and Shortfall in Health Infrastructure in PHCs

State /UT	Requirement			Availability			Deficit		
	2008	2010	2012	2008	2010	2012	2008	2010	2012
Uttarakhand	214	214	351	239	239	257	*	*	94
Uttar Pradesh	4390	4390	5172	3690	3692	3692	700	698	1480
Bihar	2489	2489	3083	1641	1863	1863	848	626	1220
West Bengal	1993	1993	2166	924	909	909	1069	1084	1257
Ganga Basin	9086	9086	10772	6494	6703	6721	2617	2408	4051
India	26022	26022	30565	23458	23673	24049	4477	4252	7954
Note:* Surplus									
Source: RHS Bulletin 2008,2010,2012									

4.1.3 Community Health Centre (CHC)

CHCs are established and maintained by the State Government under the MNP/BMS programme. As per central norms four medical specialists i.e. a surgeon, a physician, a gynecologist and a pediatrician supported by paramedical and other staff are required in each CHC. It serves as a referral centre for 4 PHCs and also provides facilities for obstetric (relating to childbirth) care and specialist consultations. One CHC covers population of 80,000 in hilly/tribal/difficult areas and 1,20,000 in plain areas (GOI, National Health Profile, 2012). The specialists at the CHC may refer a patient directly to the state level hospital or nearest appropriate medical college hospital, as may be necessary, without the patient having to go first to the sub-divisional or district hospital (Park, 2011).

Table 6 shows that the number of CHCs in the Ganga Basin has increased from 149 in the 6th Plan to 988 in the 11th Plan (a more than six-fold rise). In Uttar Pradesh, the number has gone up significantly from 74 in the 6th Plan to 515 in the 11th Plan. As the Table depicts, Uttar Pradesh accounted for the highest share in the total CHCs of the Basin (52%), followed by West Bengal (7.24%) and Bihar (7.06%). Except for Bihar, in all other states, the number of CHCs has increased during the period under consideration. In the case of Bihar, the number of CHCs increased up to the 8th Plan, remained constant during the 9th Plan and then declined. While the decline in Bihar is attributed to bifurcation of the state. However, lack of growth in Bihar during the long period of the 8th,to 11th Plans can be attributed to poor governance. Interestingly during the same period when the state of UP was bifurcated, the two states of Uttarakhand and the rest of the UP have recorded considerable increase. A perusal of Table 6 reveals that the health infrastructure in terms of PHC is quite dismal in Bihar.

Table 6: Plan-wise Number and Percentage of CHCs in UP, UK, Bihar, WB, Ganga Basin and all India

Location	Sixth Plan [1981-85]	Seventh Plan [1985-90]	Eighth Plan [1992-97]	Ninth Plan [1997-2002]	Tenth Plan [2002-2007]	Eleventh Plan [2007-2012]
Uttarakhand	(-)	(-)	(-)	(-)	49	59
UK % from Ganga Basin	*(-)*	*(-)*	*(-)*	*(-)*	5.76%	5.95%
UK % from India	*(-)*	*(-)*	*(-)*	*(-)*	1.21%	1.23%
Uttar Pradesh*	74	177	262	310	386	515
UP % from Ganga Basin	49.66%	43.07%	52.51%	55.66%	45.36%	51.92%
UP % from India	9.72%	9.27%	9.95%	10.15%	9.54%	10.71%
Bihar*	52	147	148	148	70	70
BR % from Ganga Basin	*34.90%*	*35.77%*	*29.66%*	*26.57%*	*8.23%*	*7.06%*
BR % from India	*6.83%*	*7.70%*	*5.62%*	*4.85%*	*1.73%*	*1.46%*
West Bengal	23	87	89	99	346	348
WB % from Ganga Basin	15.44%	21.17%	17.84%	17.77%	40.66%	35.08%
WB % from India	3.02%	4.55%	3.38%	3.24%	8.55%	7.24%
Ganga Basin	149	411	499	557	851	992
Basin % from India	19.58%	21.52%	18.95%	18.24%	21.04%	20.63%
India	761	1,910	2,633	3,054	4,045	4,809

* : *There is a reduction in the number of Centres functioning at the end of 10th Plan as compared to those functioning at the end of Ninth Plan due to the division of State*

Source: RHS 2012

Table 7 presents status of CHC availability across all the states in the Ganga basin. While it may be a consolation that the new state of Uttarakhand reported surplus in 2008 and 2010, but otherwise across the country and the entire Ganga basin the situation is rather alarming. Particularly in all the states while the requirements have gone up, however the availability has remained static over the period of 2008 to 2012, indicating complete lack of investment in this segment.

In 2012 while pan India deficit is 40%, it is 63% in the entire Ganga basin. Among the four states, in 2012 the deficit is highest in Bihar at 91% followed by UP at 60%, while West Bengal and Uttarakhand report deficit of around 35%.

Table 7: Required, Position and Shortfall in Health Infrastructure in CHCs

State /UT	Requirement			Availability			Deficit		
	2008	2010	2012	2008	2010	2012	2008	2010	2012
Uttarakhand	53	53	87	55	55	59	*	*	28
Uttar Pradesh	1097	1097	1293	515	515	515	582	582	778
Bihar	622	622	770	70	70	70	552	552	700
West Bengal	498	498	541	349	348	348	149	150	193
Ganga Basin	2270	2270	2691	989	988	992	1283	1284	1699
India	6491	6491	7631	4276	4535	4833	2337	2115	3044
Note:* Surplus									

Source: RHS Bulletin 2008,2010,2012

4.1.4 Government Hospitals

No country in the world is committed to universal health care at affordable cost without the active participation of the government. So, for making people healthy, public sector plays a dominant role in provision of health services. Health services are provided by the government through the government hospitals established in rural as well as urban areas. Table 8 shows that in 2011 out of the total government hospitals functioning in the country, only around 20% are working in the Ganga Basin and evidently this is not in proportion to the total population residing in the basin.

The inadequacy of government hospitals is clear from Figure 2 and 3 which shows the average population served per government hospital and average population served per bed in a government hospital in the Ganga basin states. In 2011 while Uttarakhand presents a respectable ratio of one hospital for every 13,685 persons, the situation in UP (1 for 2,29,118), Bihar (1 for 4,51,325) and West Bengal (1 for 1,39,676) is rather alarming. On the whole the numbers represent a significant deficit in health infrastructure and need for major investments from government.

Table 8 : Number of Govt. Hospitals & Beds in Rural & Urban Areas (Including CHCs) In India

Location	Rural Hospitals						Urban Hospitals						Total Hospitals					
	No.			Beds			No.			Beds			No.			Beds		
	2008	2010	2011	2008	2010	2011	2008	2010	2011	2008	2010	2011	2008	2010	2011	2008	2010	2011
Uttar Pradesh	397	515	515	11910	15450	15450	528	346	346	20550	40934	40934	925	861	861	32460	56384	56384
% of Basin	34.17	43.1	32.07	57.19	71.54	44.5	62.78	52.82	41.49	29.66	41.98	34.3	24.87	46.54	35.29	28.83	47.34	36.6
Uttarakhand	666	666	666	3746	3746	3746	29	29	29	4219	4219	4219	695	695	695	7965	7965	7965
% of Basin	57.31	55.73	41.47	17.99	17.35	10.79	3.45	4.43	3.48	6.09	4.33	3.54	18.68	37.57	28.48	7.07	6.69	5.17
Bihar	NA	NA	61	NA	NA	1830	NA	NA	169	NA	NA	16686	1717	1717	230	22494	22494	18516
% of Basin	NA	NA	3.8	NA	NA	5.27	NA	NA	20.26	NA	NA	13.98	46.16	92.81	9.43	19.98	18.89	12.02
West Bengal	99	14	364	5171	2399	13693	284	280	290	44510	52360	57498	383	294	654	49681	54759	71191
% of Basin	8.52	1.17	22.67	24.83	11.11	39.44	33.77	42.75	34.77	64.25	53.7	48.18	10.3	15.89	26.8	44.12	45.97	46.21
Ganga Basin	1162	1195	1606	20827	21595	34719	841	655	834	69279	97513	119337	3720	1850	2440	112600	119108	154056
% of India	18.45	17.59	21.86	14.63	14.43	21.58	30.32	17.48	20.12	21.37	24.43	19.29	32.95	14.5	20.35	22.77	20.65	19.63
India	6298	6795	7347	142396	149690	160862	2774	3748	4146	324206	399195	618664	11289	12760	11993	494510	576793	784940

Notes: Figures are for varying periods and thus are provisional and subject to change

Source: Directorate General of Health Services

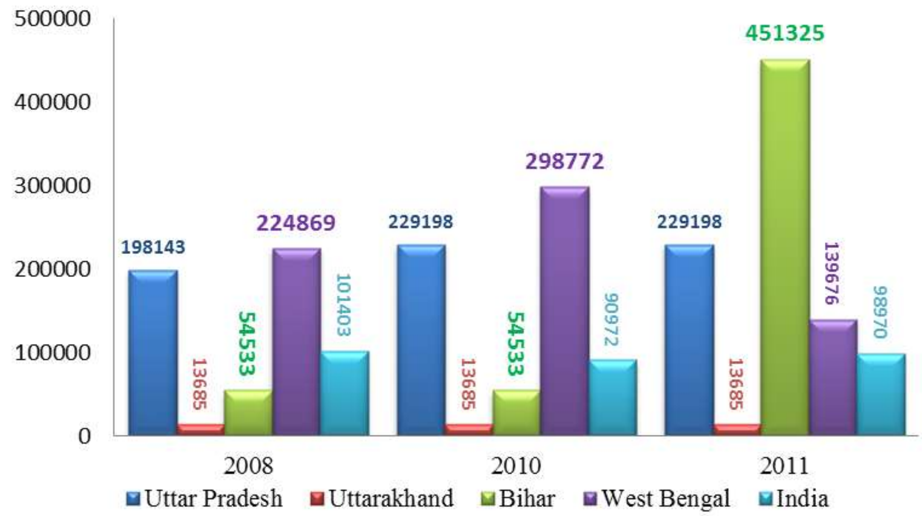


Figure 2: Average Population Served Per Govt. Hospital

Figure 3 shows state-wise average population served per hospital bed. It is observed that Uttarakhand and West Bengal have relatively better service levels in terms of number persons per bed compared to Uttar Pradesh and Bihar as well as even the national average. It is also observed that over 2008-2011 service levels in UP and West Bengal have, in Uttarakhand it has remained rather constant while in the case of Bihar it has woesened.

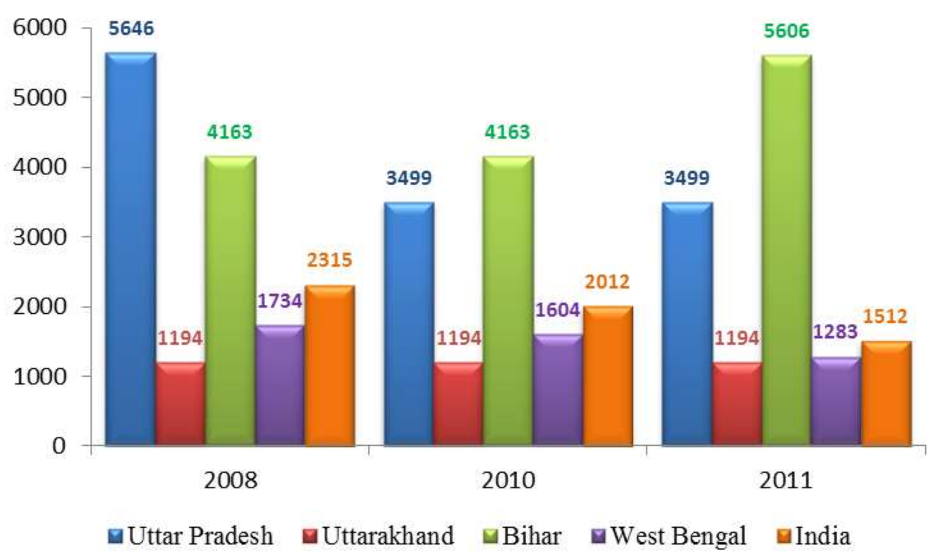


Figure 3: Average Population Served per Govt. Hospital Bed

4.2 Education Infrastructure

Educational infrastructure includes the educational institutes and courses provided in the states for betterment of health services through better knowledge.

4.2.1 Medical Colleges

Medical College are generally having hospitals attached to them. These colleges consist of number of medical specialists for different departments. But the availability of medical colleges is not appropriate in relation to the population. The highly uneven distribution of medical colleges has resulted in skewed production and unequal availability of doctors even across the country. There is, for instance, only one medical college for a population of 11.5 million in Bihar and 9.5 million in Uttar Pradesh, compared to Kerala and Karnataka who have one medical college for a population of 1.5 million (GOI, Planning Commission of India, 2011).

Availability of medical colleges in the basin is presented in Table 9. As evident from this set of data Uttar Pradesh has the highest number of medical colleges among the basin states followed by West Bengal Bihar and Uttarakhand. Out of total 32205 beds in the hospitals attached to the medical colleges of the basin, more than 50% were only in Uttar Pradesh. Student admission capacity in these medical colleges was also observed highest in Uttar Pradesh (3049), followed by West Bengal (1750).

Table 9: Medical Colleges in Ganga Basin and India (2011)

State	Government	Private	No. of Beds in Attached Hospital	Admission Capacity
Uttar Pradesh	11	14	17812	3049
Uttarakhand	2	2	2350	400
West Bengal	12	2	5883	1750
Bihar	7	3	6160	760
Ganga Basin	32	21	32205	5959
Non- Basin States	118	162	134977	34066
India	150	183	167182	40025

Source: National Health Profile, 2011

5. Water, Sanitation and Health

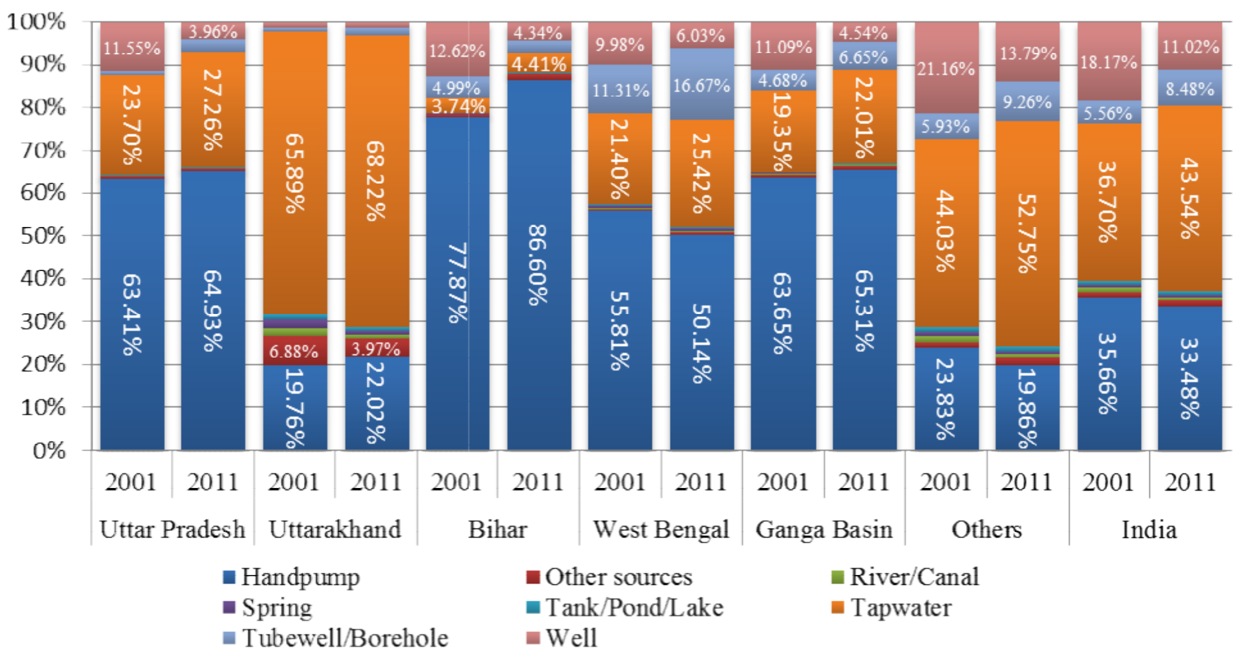
Supply of safe drinking water and provision of sanitation are the most important contributing factors for improving health of people. Faeces deposited near homes, contaminated drinking water (sometimes caused by poorly designed or maintained sewage systems), fish from polluted rivers and coastal waters, and agricultural produce, fertilized with human waste are all health hazards. Lack of water supply and poor sanitation are the primary reasons for wide prevalence of diarroheal diseases in developing countries (Park, 2011). As per a report from World Health Organization (WHO), 80 % of the diseases are due to unhygienic conditions and unsafe drinking water. It is estimated that every year about 1.5 million children under five years of age die in India due to water borne diseases. (IIMC Report on behalf of Rajiv

Gandhi National Drinking Water Mission, 1998). The WHO/UNICEF Joint Monitoring Programme considers an ''improved'' water supply as ''one that is likely to supply safe water'' not injurious to health, such as a household piped water connection, a borehole, a protected dug well, a protected spring, or rainwater collection

5.1 Drinking Water Use and its Sources

Water is the basic right of every citizen and to get clean and safe drinking water is even more so. The quality and quantity of water used for drinking are very important determinants of health condition. The source from where drinking water is collected by the household roughly indicates its quality (GOI, NSS Report, 2005). The most prevalent source of drinking water in India is 'tap water'.

Figure 4 shows percentage distribution of households by sources of drinking water in India and in the Basin States. While at all-India level, tap water with 44% households was the main source of drinking water ; in the Ganga Basin, hand pump was the main source as about 65% households depend on it. This clearly shows that hierarchy of uses of difference sources of drinking water varies across basin and non-basin states. The proportions of households reporting use of drinking water from three dominating sources –'Tap water' , ' Hand pumps' and 'wells' in India were 44%, 34%, and 11%, respectively and in other states, these were 53%, 20% and 14%, respectively in 2011. The same three sources were also the most important in Ganga Basin till 2001, but this sequential order of 'wells' was replaced with 'Hand pumps' for the Ganga Basin in 2011.



Source: Census of India, 2001 & 2011.

Figure 4: Distribution of Households by Main sources of Drinking water

A significant point to note is that out of four states of Ganga basin, three states, namely, Uttar Pradesh, Uttarakhand and Bihar, witnessed increase in proportion of households using 'Hand pumps' and ' Tap water' as sources of drinking in 2011 over 2001. As a result. estimates for Ganga basin also show such trends. But for other than Ganga basin states and all-India, it is the proportion of 'Tube wells/Borehole' and 'Tape water 'that has shown improvement in 2011 over 2001. One more point embraced from the above Figure is that the proportion of 'Tap water' has increased for all the states. This implies that access to safe drinking water had increased during the last decade.

5.1.1. Access to Safe Drinking Water

Safe water has been defined as the water which is free from pathogenic agents, harmful chemical substances; pleasant to the taste, i.e., free from colour and odour. It is said to be polluted when it does not fulfil these criteria.

Water pollution is a growing hazard in many developing countries owing to human activity. Without ample and safe water drinking, we cannot provide healthcare to the community. The biological contamination of large number of drinking water sources is a serious problem primarily due to wide prevalence of the practice of open defecation, discharge of untreated sewage and insanitary conditions around drinking water sources, especially in rural areas. Table 9(a) shows that there has been improvement in access to safe drinking water in both rural and urban areas in the basin states and well as all India. The number of households having access to safe drinking water has increased significantly in all the states since 1981, as is apparent from the data shown in Table 9 (a). For instance, in Bihar, the number has gone up from 37.6% in 1981 to 94% in 2011. Similar increase is also observed in other basin states. However, increasing access of households to tap/hand pump/tube well water does not mean that the households have clean and safe drinking water. There may be possibility of contamination of drinking water due to pollution of ground or surface water resources.

Table 9(a): Households (in %) Access to Safe Drinking Water (Tap/Hand pump/Tube well)

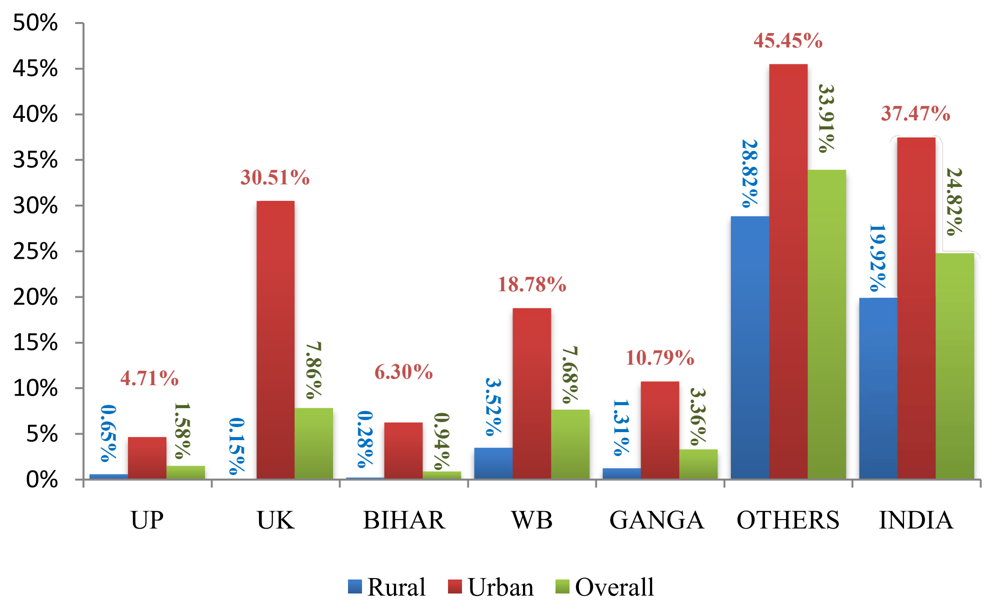
Location	1981			1991			2001			2011		
	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban
Bihar	37.6	33.8	65.4	58.8	56.5	73.4	86.6	86.1	91.2	94	93.9	94.7
Uttar Pradesh	33.8	25.3	73.2	62.2	56.6	85.8	87.8	85.5	97.2	95.1	94.3	97.9
Uttarakhand	a	A	a	a	a	a	86.7	83	97.8	92.2	89.5	98.7
West Bengal	69.7	65.8	79.8	82	80.3	86.2	88.5	87	92.3	92.2	91.4	93.9
All India	38.2	26.5	75.1	62.3	55.5	81.4	77.9	73.2	90	85.5	82.7	91.4

Source : Economic Survey, 2012-13; Office of the Registrar General, Ministry of Home Affairs

a - Created in 2001. Uttarakhand and Jharkhand for 1981 and 1991 are included under Uttar Pradesh and Bihar respectively.

5.1.2. Purified Water and its Sources

Figure 5 illustrates proportion of households that used treated water by various means for drinking in the Ganga basin. More than 35% households in urban and not less than 20% in rural areas were reported to treat water before its use in India in 2004. Figure 5 demonstrates that rural as well as urban areas of non-basin states hold higher proportion of such households than the Ganga basin states. For instance, as against 3.36% of households using treated water in the Ganga Basin, the corresponding percentage in non-basin states was much higher at 33.91%. Within the Ganga Basin, the highest percentage of households using treated water was found in Uttarakhand (7.86%), closely followed by West Bengal (7.68%). It was observed lowest in Bihar. There is huge rural-urban disparity in access to treated drinking water. At the Basin level, just 1.31% of rural households treated water by any mean before drinking, compared to 10.79% of households in urban areas. The difference was highest in Uttarakhand, followed by West Bengal. On the whole it is noted that the condition was rather dismal in Uttar Pradesh and Bihar, more so among urban households where infrastructure is generally expected to be beter.



Source: NSS 60th round Unit level data, 'Morbidity, Health Care and the Condition of the Aged, Jan.-June, 2004

Figure 5: Distribution of households having water treated before drinking, 2004

The choice of method for purification of water before drinking depends on quality of raw water, cost of treatment and the desired output quality. Table 10 provides proportion of households treating water at point of use by various methods in the Ganga basin states and across the country. On the whole it is noted that this healthy practice is not as widely prevalent in the basin states as is the case across the country. For instance in the urban and rural areas of the basin states there are only 108 and 13 households per 1000 households which resort to some form of treatment as compared to the national average of 375 and 199 respectively.

Among the rural households practicing treatment at the point of use, the most commun options comprise ceramic/sand filer, followed by boiling and cloth filter. On the other hand, among the practicing urban households it is intriguing to note that over two third have reported bioling as the preferred option which happens to be one of the safest from microbiological point of views but also involves highest operating costs. Higher preference to boiling can be attributed to higher concern of faecal contamination. In rural areas ceramic/ sand filter has been promoted by a number of agencies to combat problems of microbiological contamination as well as iron and manganese. It is interesting to note that a proportion of households even in rural areas have also installed relatively expensive RO and UV based compact commerical treatment units which again point towards higher level of awareness towards water quality and health impacts.

Table 10: Proportion of Households Adoptiong Water Treatment at Point of Use, 2004

Region	Sectors	Ultra-violet/ resin/ reverse osmosis	Filter	Boiling	Cloth screen	Any disinfectant	Others	No. HH/ 1000 Treating water at point of use
UP	Rural	13.66%	40.59%	11.44%	8.75%	0.69%	24.87%	7
	Urban	12.96%	11.72%	57.68%	8.87%	5.74%	3.02%	47
UK	Rural	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1
	Urban	6.03%	40.83%	50.47%	0.00%	0.00%	2.67%	305
BIHAR	Rural	1.62%	41.06%	6.48%	37.69%	0.00%	13.16%	3
	Urban	0.00%	4.07%	95.41%	0.00%	0.00%	0.52%	63
WB	Rural	1.36%	29.75%	25.33%	21.46%	11.51%	10.59%	35
	Urban	16.20%	6.92%	72.22%	1.88%	1.10%	1.68%	188
GANGA	**Rural**	**4.58%**	**32.79%**	**21.02%**	**19.22%**	**8.34%**	**14.06%**	**13**
	Urban	**13.51%**	**11.03%**	**68.41%**	**3.11%**	**1.94%**	**2.00%**	**108**
OTHERS	**Rural**	**0.70%**	**24.67%**	**8.65%**	**63.54%**	**0.94%**	**1.49%**	**288**
	Urban	**4.74%**	**26.39%**	**24.63%**	**42.10%**	**0.93%**	**1.21%**	**455**
INDIA	Rural	0.78%	24.84%	8.92%	62.60%	1.09%	1.76%	199
	Urban	5.32%	25.37%	27.53%	39.51%	0.99%	1.27%	375

Source: NSS 60th round Unit level data, 'Morbidity, Health Care and the Condition of the Aged, Jan.-June, 2004

5.1.3 Bottled Water

The concept of safe drinking water has gained much importance in present scenario due to higher awareness for health. Apparently packaged water in bottles is considered as the safest source in the present scenario. These days, people are willing to use this expensive source to have a healthy life. The public perception is that bottled water is of high quality. This belief is encouraged by publicly reported problems with tap water and by aggressive advertising by the bottled water industry. Highly subjective preferences for taste and flavor in water help to drive the market for bottled water. Water has different flavors and tastes depending on its origin, type and duration of storage, treatment, and method of delivery. Other than water quality, the most common reason offered to explain the growing use of bottled water is dissatisfaction with the taste of locally available tap water (Geick, 2004).

Figure 6 shows distribution of households using bottled drinking water in rural and urban areas of the basin states. In the Ganga basin, there were only 0.3% households using bottled drinking water as compared to 1.6% all across India and 5.2% across the non-basin states. Among the urban households in the Ganga basin and non-basin states the usage is 0.7% and 12.9% respectively. Likewise among the rural households the usage in Ganga basin states is insignificant at 0.1% compared to non-basin states at 3.1%. As per NSS Report 2004, it is noteworthy that in Bihar bottled drinking water was not reported to in used. Low or no usage of bottled water is indicative of generally lower level of affordability among the large section of the basin population.

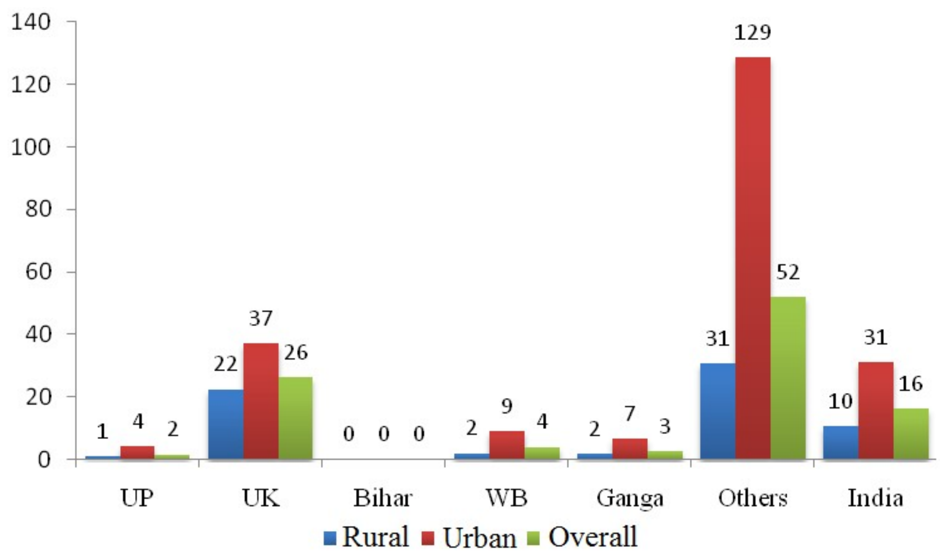


Figure 6: Distribution of households (per 1000) using 'bottled' drinkingwater, 2004

5.1.4 Expenditure on Purified Drinking Water

Table 11 shows the distribution of surveyed households by type of treatment. Apart from traditional methods of water purification, some households in rural and urban areas also used RO and filters to treat drinking water. At the all-India level, 5.32% of urban households and 0.78% of rural households used RO to purify the drinking water, whereas the corresponding percentages in the Ganga Basin were 13.51 and 4.58, respectively. This reveals that the percentage of households using RO was much higher in the Ganga Basin than the other states of India.

Table 11: Estimated Number of households surveyed by major source of drinking water and average household size

Regions	Sector	Types of water treatment								
		Ultra-violet/ resin/reverse osmosis	Filter	Boiling	Cloth screen	Any disinfectant	Others	Total	Avg. HH size	Total Households
UP	Rural	19501	57939	16335	12494	982	35501	142752	5.88	21834655
	Urban	39210	35465	174477	26823	17367	9150	302492	5.23	6416082
UK	Rural	1876	0	0	0	0	0	1876	5.00	1266408
	Urban	7932	53744	66435	0	0	3521	131632	3.94	431404
BIHAR	Rural	495	12582	1986	11549	0	4034	30646	5.59	11019526
	Urban	0	3518	82421	0	0	450	86389	5.32	1370711
WB	Rural	5838	127829	108861	92208	49479	45511	429726	4.78	12208382
	Urban	139288	59530	621006	16166	9459	14486	859935	4.03	4577936
GANGA	Rural	27710	198350	127182	116251	50461	85046	605000	5.45	46328971
	Urban	186430	152257	944339	42989	26826	27607	1380448	5.48	12796133
OTHERS	Rural	195669	6888109	2416089	17739956	261570	417011	27918404	4.61	96877649
	Urban	922230	5130511	4787751	8183589	179830	235978	19439889	4.61	42767919
INDIA	Rural	223379	7086459	2543271	17856207	312031	502057	28523404	4.99	143206620
	Urban	1108660	5282768	5732090	8226578	206656	263585	20820337	4.39	55564052

Source: NSS 60th round Unit level data, 'Morbidity, Health Care and the Condition of the Aged, Jan.-June, 2004

It is evident that a large number of households in the Ganga basin use various methods to treat drinking water at the point of use. All these measures entail certain costs on the user and among them RO represent the highest. It is estimated that installation of household level RO units alone would have involved a collective invesmtnet of approximately Rs. 1,52,100 million by households in the entire Ganga basin. Likewise, a ball park estimate of total expenditure on bottled water in Ganga basin works out to be Rs.1,422.66 million (Rs.749.18 million in urban areas and 673.48 million in rural areas).

From the above, it can be concluded that people spend a considerable amount on drinking water to safeguard their families against water borne diseases. If expenditure summed up, the collective household expenditure on ROs and bottled water from in the Ganga Basin is about Rs.1,53,523 million. In this context, given the deteriorating quality of surface and ground water, it is noteworthy that the poor households suffer the most for their inability to bear the extra costs at the point of use.

5.2 Sanitation and Drainage

5.2.1 Access to Toilets

Collection and treatment of sewage and drainage is an issue that is closely associated with safety of water supplies. When sanitation is lacking, faecal contamination of water sources/ supplies can cause diarrhea, cholera, jaundice/ hepatitis, typhoid, and other water borne diseases.

The WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation defines ‘‘improved’’ sanitation as household latrine connection to a public sewer or septic system, a pour flush latrine, a simple pit latrine, or a ventilated improved pit latrine. These conditions necessarily mean that proportion of water closet (or, septic/ pour) /flushs latrine or at least pit latrine must increase along with a corresponding decline in proportion of households that have no latrine facility. For measurement of improvement in access to toilet facility this definition can work out. But in relation to water pollution and safety of drinking water, the types of latrine facility which does not contaminate groundwater or piped supplies is of importance.

Census 2011 of India surveyed households on four broad categories of latrine systems/processes that are installed or used by them. Table 13 provides proportion of household by availability of toilet connectivity enumerated during 2011 and comparative distribution of households by main categories of latrine in the Ganga basin, non-basin states and India in 2001 and 2011 respectively. It is noted that in 2011 nearly half of India’s 1.2 billion people did not have acces to a toilet at home. Only 46.9% of the households possessed toilets, while 49.8% defecated in open. They squatted on roadsides, in agriculture fields or along railway tracks and defecated in the open. The remaining 3.2% used public toilets. Out of 46.9% of the households who possessed toilets, 36% had water closet and 9% had pit toilet.

In contrast to the all India scenario the data in the Ganga basin is more alarming where in 2011 more than 60% of the households did not have access to toilet facility within premises. Among the states, Bihar is characterised by highest deficit at 75% followed by UP at 65% and West Bengal at 41%. Needless to say that the situation is rather alarming and requires very intense inputs towards behaviour change among both urban and rural sections of the population if public health has to be adequately safeguarded.

Table 13: Percentage of Household by Availability of Toilet Connectivity , 2011

State	Latrine facility Available within premises	Flush/pour flush latrine connected to			Pit latrine		Other latrine			Latrine Not available within premises		
		Piped sewer system	Septic tank	Other system	With slab/ ventilated improved pit	Without slab/ open pit	Night soil disposed into open drain	Night soil removed by human	Night soil serviced by animal	Total	Public latrine	Open
Uttar Pradesh	35.65	8.10	19.91	1.77	3.44	0.74	0.46	0.99	0.24	64.35	1.32	63.04
Uttarakhand	65.77	11.79	40.00	1.42	11.29	0.58	0.34	0.24	0.13	34.23	1.14	33.08
Bihar	23.06	1.81	15.97	2.31	1.72	0.78	0.21	0.07	0.18	76.94	1.13	75.81
West Bengal	58.85	5.55	20.72	5.62	22.32	3.24	0.39	0.65	0.36	41.15	2.52	38.63
Ganga Basin	39.53	5.89	19.66	2.94	8.34	1.42	0.37	0.64	0.26	60.47	1.59	58.87
Others	50.07	14.54	23.28	1.99	7.32	1.98	0.60	0.19	0.18	49.93	3.95	45.98
India	46.92	11.95	22.20	2.28	7.63	1.81	0.53	0.32	0.20	53.08	3.24	49.84

Source: Census of India, 2011.

Figure 7 shows change in access to toilet in the Ganga basin over the last decade. It is noted that during this period the proportion of households having 'no latrines within premises' declined by only 7% in the basin states as compared to a fall of 10% across the country. Among the Ganga basin states, highest decline is observed in Uttarakhand (20%), followed by West Bengal, Bihar and Uttar Pradesh. This is attributed to intensive efforts at the national and state levels under the Total Sanitation Campaign and other urban sector programmes, however it is evident that there is still a long way to go before one can consider satisfactory level of sanitation in and around the urban and rural habitations in the basisn states.

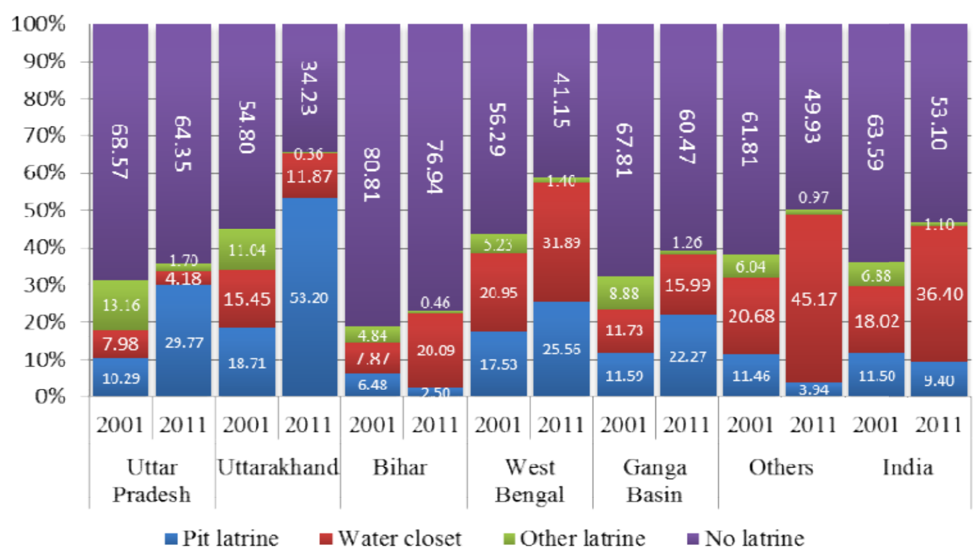


Figure 7: Change in access to toilet during 2001-2011 in the Ganga basin

5.2.2 Access to Sewerage and Drainage Facilities

Drainage has a significant impact on the hygiene practices and public health. There is a close linkage between the type of drainage system used by the households and intensity of water related diseases, particularly diarrhoea. Some studies confirm that improvement in sewerage systems can typically reduce diarrhoeal incidence by about 30% or perhaps as much as 60% when baseline sanitation conditions are very poor. But in many contexts, sewerage might be less cost effective and less sustainable than onsite sanitation alternatives (Norman et. al,). Another study also shows that urban sanitation can have an impact on diarrheal disease, even without measures to promote hygiene behavior (Moraes et. al, 2003). Effective drainage of storm/ rain water from habitation areas is also critical for prevention of water based and water related diseases. In this regard, presence of efficient drainage and sewerage system should be considered as important factor in ensuring better public health in communities.

For analyzing India's scenario regarding sewage and sanitation condition, Census 2011 provides that at the country level, around 49% households did not have any drainage facilities; while 34% of households have only open drainage system and the rest have closed drainage. Figure 8 provides change and distribution of households by type of drainage system over the ten year period from 2001 and 2011. It is found that that more than 48% of the households have 'no drainage' in the Ganga basin as well as in non-basin states. Among the basin states, highest deficit is found in West Bengal (68%) followed by Bihar (58%).

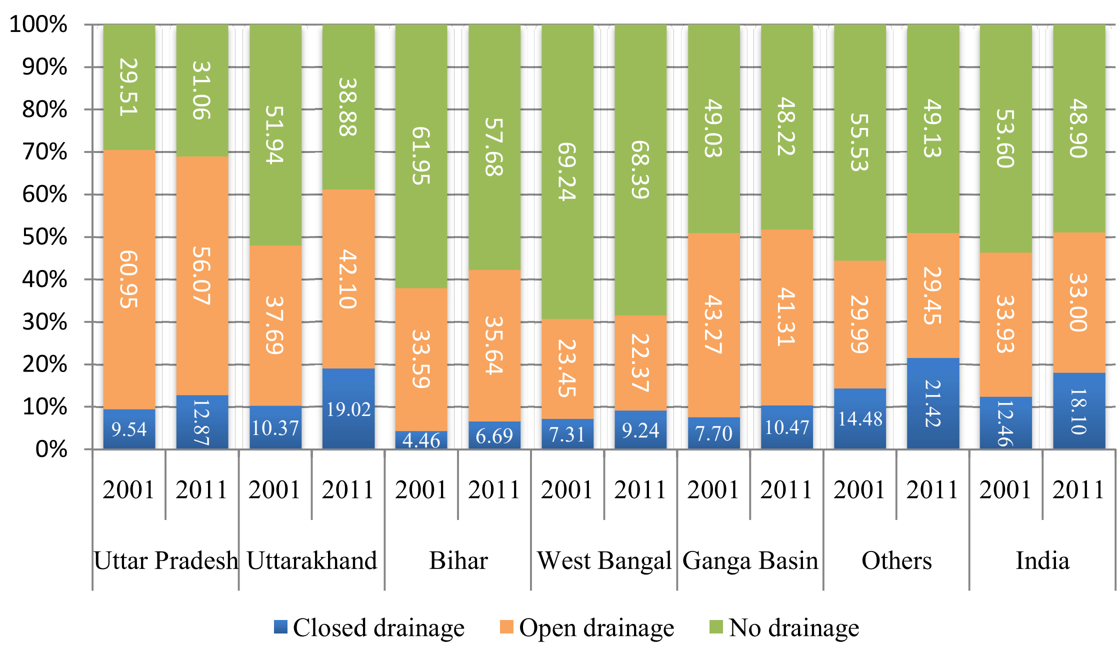


Figure 8: Distribution of Households by Sources of Drainage in the Ganga Basin

5. 3 Morbidity

5.3.1 General Morbidity by Proportion of Ailing Persons (PAP)

Ailment or illness or injury, mean any deviation from the state of physical and mental well-being. The prevalence of morbidity for any particular place can be evaluated as proportion of ailing persons (PAP) (however this could be due to a variety of factors not restircted communicable water borne diseases only). The 60th NSS round measures it as the number of persons reporting ailment during a 15-day period per 1000 persons for each region and for some broad age-groups. By using unit level records of this round, PAP for the basin states has been estimated and presented in Figure 9. As per this the countrywide PAP is 99 while that in the Ganga basin is 117, indicating relatively higher level of ailment. Among the four states, West Bengal was found to have highest PAP at 157 while Uttarakhand with generally salubrious climatic conditions was found to have the lowest at 65. In general PAP in urban areas was found to be slightly higher than in rural areas across all geographical units. It is interesting to note that Bihar PAP data is almost similar to that of Uttarakhand indicating generally lower level of morbidity among the popualtion.

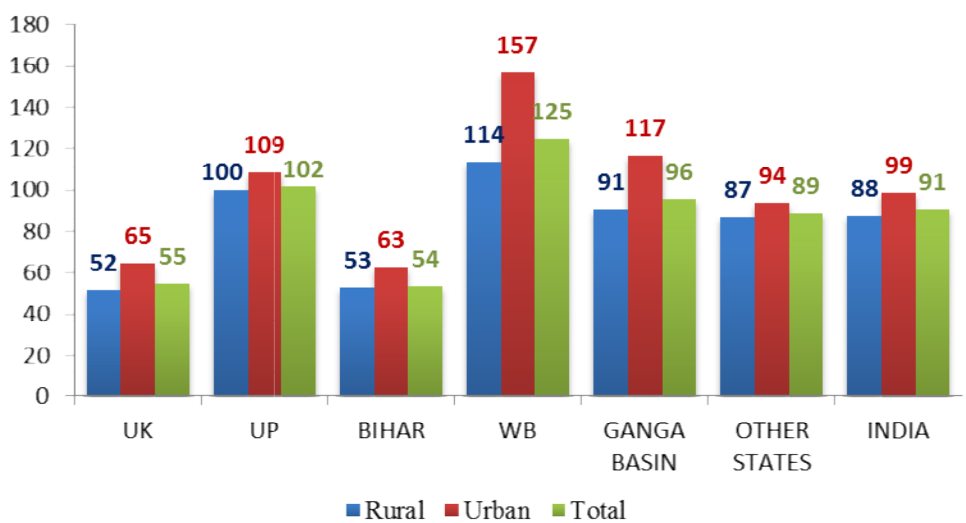
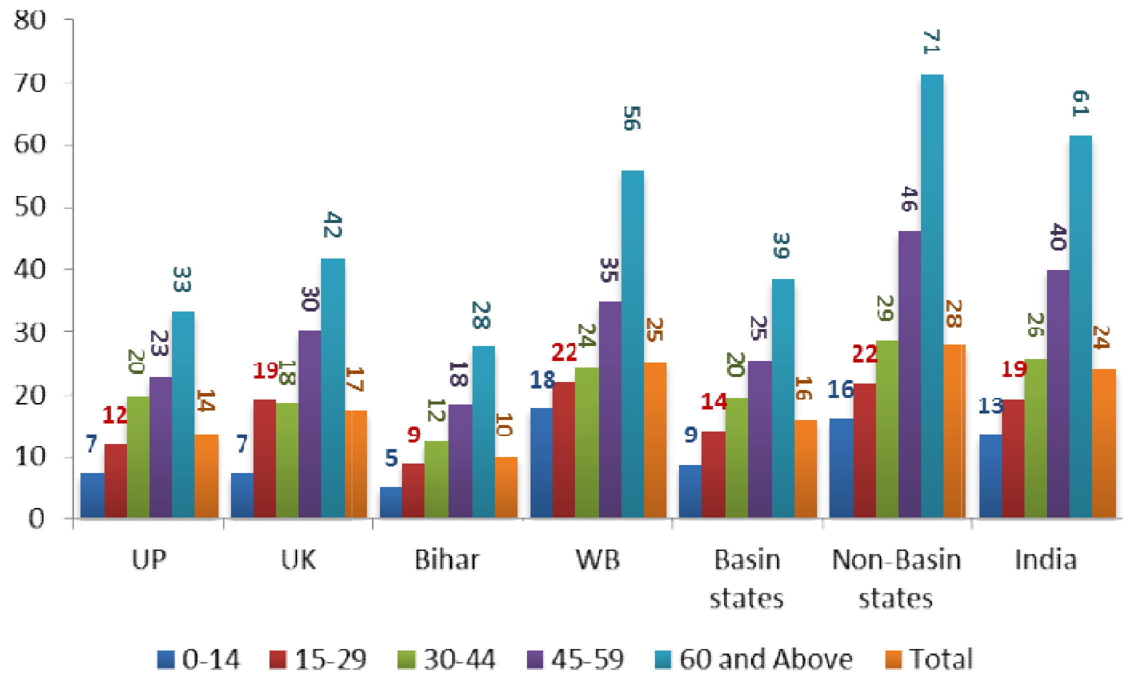


Figure 9: Proportion of ailing persons (per 1000) during a 15 days period, 2004

5.3.2 General Morbidity by Number of Persons Hospitalised

As per the 60th NSS round, an individual was considered hospitalised if he/she had availed of medical services as an indoor patient in any hospital. For this survey, hospitals covered public hospitals, community health centres and primary health centres (if provided with beds), ESI hospitals, private hospitals, nursing homes, etc. Figure 10 presents number of persons hospitalised per 1000 population across rural and urban areas and age group in the Ganga basin states. As expected, the number of persons hospitalised per 1000 was highest in the age group 60 year and above, followed by age group 45-59 year. On an average, the number of persons hospitalised for every 1000 population was recorded lowest in Bihar and highest in West Bengal. However, it is difficult to draw any conclusion from the above analysis regarding the status of health. Less cases of hospitalisation can be attributed to, among others, low access, unaffordabilityed, etc. and not necessarily better public health.



Source: NSS 60th round Unit level data, 'Morbidity, Health Care and the Condition of the Aged, Jan.-June, 2004'

Figure 10: Number of persons (per 1000) hospitalised, 2004

5.3.3 Water Borne and Water Related Diseases

The link between water and communicable diseases is well established and in general as shown in Box 1 it can be classified into four broad categories, viz., 'water borne', 'water washed', 'water based', and 'water related'. Water borne diseases are caused primarily due to ingestion of faecally contaminated water which is the main concern of this report. Water washed diseases are attributed to personal hygiene habits and the quality and quantity of water available to individuals for external cleaning. On the other hand the latter two diseases are mainly related to drainage of water/ wastewater.

Box 1: Water-Related Diseases

Waterborne diseases: caused by the ingestion of water contaminated by human or animal faeces or urine containing pathogenic bacteria or viruses; include cholera, typhoid, amoebic and bacillary dysentery and other diarrheal diseases.

Water-washed diseases: caused by poor personal hygiene and skin or eye contact with contaminated water; include scabies, trachoma and flea, lice and tick-borne diseases.

Water-based diseases: caused by parasites found in intermediate organisms living in contaminated water; include dracunculiasis, schistosomiasis, and other helminths.

Water-related diseases: caused by insect vectors, especially mosquitoes, that breed in water; include dengue, filariasis, malaria, onchocerciasis, trypanosomiasis and yellow fever.

SOURCE: Gleick, Peter H. - Dirty Water: Estimated Deaths from Water-Related Diseases 2000-2020 - Research Report, August 15, 2002 - Pacific Institute for Studies in Development, Environment, and Security

Appendix Table A 2 (refer, appendix Table A 2) presents number of persons hospitalised (per 1000 population) due to various ailments. Among others, the main diseases of concern in the context of this study in the Ganga basin are diarrhoea, gastroentritries, hepatitis, and 'fever of unknown origin'. Overall hospitalisation cases due to 'diarrhoea/dysentery' in the rural and urban areas in the entire Ganga basin states are 12% and 9% respectively. In rural areas, due to poor health services and diagnosis, reporting of 'fever of unknown origin' is very common however it can be corelated to one or the other form of waste borne disease or viral infection. Estimates shown in the Table A2 bring out relatively higher incidence of diarrhoeal diseases in the Ganga basin states as compared to the non-basin states. Among the four basin states Bihar and West Bengal and urban areas of Uttar Pradesh experience relatively higher morbidity due this disease.

The influence of water related diseases can also be examined through number of cases of deaths, provided by National Health Profile of India. As per the data presented in the Appendix Table A3 it is found that :

***Cholera**:* More than 25% cases of cholera were found in the basin states during 2011. Further, within the basin, 95-99% cases were found only in West Bengal.

Acute diarrhoel diseases: during the 6 year period from 2005 to 2011 the number of cases in the basin states rose by 74% from 1.5 million to 2.6 million. During the same time internal, across the basin the reported cases of death are 622 and 499 respectively.

Enteric Fever (Typhoid)*:* Most of the cases and deaths are found in the Ganga Basin states. While data on Bihar is not available but among the rest of basin states, maximum cases are reported from West Bengal, followed by Uttar Pradesh and Uttarakhand.

Viral Hepatitis (All Causes): Out of the total cases of viral hepatitis, 24% cases were reported in the Ganga basin during 2009, which is the highest since 2001. Ganga Basin accounted for about 27% of total deaths due to viral hepatitis in India (UNDP, 2006). Table A3 describes the incidence and fatal consequence due to the water borne and wector borne (water based or water related) diseases.

Japanese Encephalitis: It is caused by mosquito-borne Japanese encephalitis virus. The percentage share of the Ganga Basin in the total cases of Japanese encephalitis occurred in India has increased significantly from 57 in 2001 to 93 in 2005. But after that the number of people suffering from this disease declined to 61% during 2011. More cases were reported in Uttar Pradesh and West Bengal from 2001-2011 but during the same period no such cases were found in Uttarakhand. Although, number of cases has declined, however it is still one of the major disease burden affecting 5027 cases and 834 deaths in Ganga Basin during the year 2011.

Malaria: It is a mosquito- borne infectious disease of humans and other animals caused by parasitic protozoan. Commonly, the disease is transmitted via a bite from an infected female Anopheles mosquito. The proportion of people suffering from malaria was more than 9% of the total cases in country during 2011 which was a decline from 18% during 2003. The highest cases were reported in West Bengal (52%), followed by Uttar Pradesh (44%), Bihar (1.8%) and Uttarakhand (0.09%) during 2011 and out of the total number of deaths (16) in Ganga Basin during 2011, 14 people died in West Bengal and 2 in Uttarakhand due to Malaria, but no deaths were found in Uttar Pradesh and Bihar due to it.

Dengue: Dengue fever also known as **breakbone fever**, is an infectious tropical disease caused by the dengue virus. The number of cases of Dengue detected in Ganga Basin during 2001 to 2011 was up to 5% of the total cases. However, in 2005 in West Bengal, dengue cases increased to 54% and which also resulted in 34 deaths.

Box-3

How deadly are water borne diseases in Gorakhpur?

The Times of India: Water-borne encephalitis the new scourge in UP.

When Mahendra Kumar had a little money saved, over 10 years ago, he installed a hand pump outside his small house in Badhariya village. The first he heard of the hand pump being too shallow was when his nine-year-old daughter Saloni died of encephalitis this year and the grieving father was told it was because of the water she had drunk from the handpump. With water-borne acute encephalitis syndrome (AES) now making up close to 95% of the encephalitis cases across eastern Uttar Pradesh, there is a renewed focus on the water the area's children are drinking. "The big problem in this area is that since it is low-lying and surrounded by rivers, the water table is very high, which makes contamination easier," as per Gorakhpur's district magistrate Ravi Kumar.

6. Healthcare Expenditure and Financing

6.1 Public and Private Expenditure on Health

Current challenges in healthcare systems are related to reducing the financial burden of health care on poor households and enhance their access to quality healthcare services. The challenge is immense, as nearly 68% (Census of India, 2011) of the country's population lives in rural areas and 29.8% lives below poverty level (GOI, Planning Commission, 2012). India lacks strong healthcare infrastructure and also has several inherent weaknesses in its healthcare system. The healthcare delivery segment is dominated by the private sector which comprises about 75% share in the total healthcare market of India. India spends a little over 4% of GDP on health. Public expenditure on core health (both plan & non-plan and taking Centre and States together) was about 1.04% of GDP in 2011-12. If drinking water, sanitation, ICDS and mid-day meal are included, total public spending on health comes to 1.94% of GDP in 2011-12(GOI, 2012). Out-of-pocket expenditure on healthcare alone comprises about two-third of total expenditure on health. Contamination of drinking water due to point and non-point sources of pollution, including open defecation increases intensity of water bone diseases and consequently financial burden of diseases on households.

Table 14 shows that at the all-India level, total health expenditure from both the sources (Public and Private) has increased from Rs. 1,032,495 million in 2001-02 to Rs. 1,307,268 million during 2004-05. However, share of public sector in the total expenditure has marginally declined from 20.76 % in 2001-02 to 20.13 % in 2004-05. Further Table 14 shows that out of total expenditure on health in India, approximately 30% was spent in the Ganga basin states during 2001-02, which reduced to 25% in 2004-05. This reduction is because of fall in the private expenditure that contributes the major share. The share of Ganga basin in India's total public expenditure on health, however, has increased from 17.71% in 2001-02 to 18.27% in 2004-05, while that of private sector has declined from 34.15% to 27.22% during the same years. This implies that the private expenditure on healthcare has increased faster in non-basin states of India than that in the basin states.

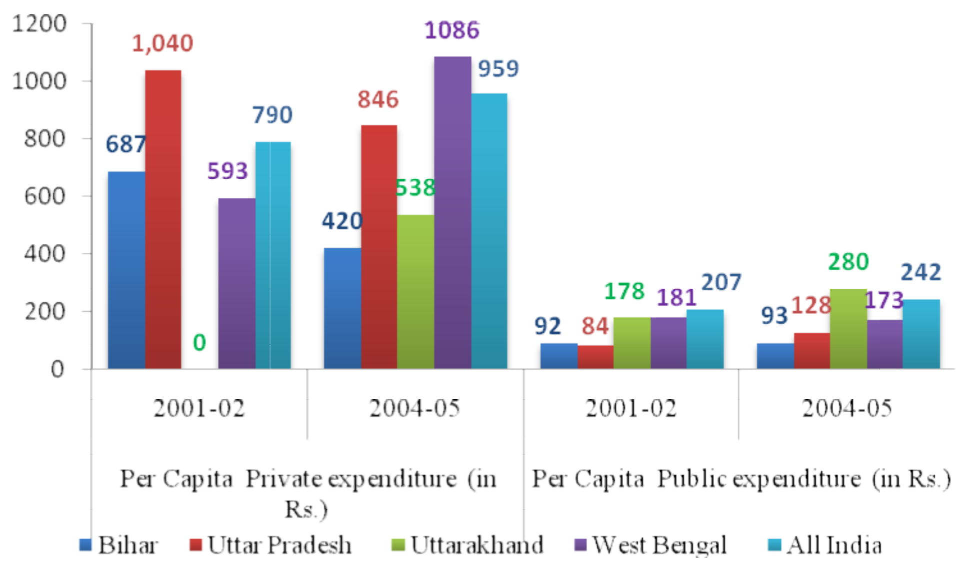
States within the Ganga basin also show similar trends. For example, proportion of Bihar in the overall health expenditure of the basin fell from 20.53% in 2001-02 to 13.70% in 2004-05 and that of Uttar Pradesh fell from 59.27% to 52.31% during the same years, while share of Uttarakhand and West Bengal in the total health expenditure of the basin has increased substantially. Although, share of private sector in the total expenditure in all states has declined in 2004-05, it still accounts for a major share in the overall expenditure on health, except in West Bengal. In Bihar, share of the private expenditure fell from 88.17% in 2001-02 to 81.85% in 2004-05, while in Uttarakhand, it went down from 92.51% to 86.88% during the same period. Contrary to this, it has increased from 76.59% to 86.28% in West Bengal during the same period.

Table 14: Public and Private Expenditure on Health in Ganga Basin and India (2001-02 and 2004-05)

States	Health expenditure in (Rs. 000s)					
	2001-02			2004-05		
	Private	Public	Total	Private	Public	Total
Uttar Pradesh	174,025,330	14,088,564	188,113,894	151,006,063	22,805,122	173,811,185
% from basin	62.28%	37.10%	59.27%	53.13%	47.44%	52.31%
% from India	21.27%	6.57%	18.22%	14.46%	8.67%	13.30%
Uttarakhand	0	1,523,325	1,523,325	4,852,994	2,520,531	7,373,525
% from basin	0.00%	4.01%	0.48%	1.71%	5.24%	2.22%
% from India	0.00%	0.71%	0.15%	0.46%	0.96%	0.56%
Bihar	57,455,419	7,708,790	65,164,209	37,256,449	8,264,168	45,520,617
% from basin	20.56%	20.30%	20.53%	13.11%	17.19%	13.70%
% from India	7.02%	3.60%	6.31%	3.57%	3.14%	3.48%
West Bengal	47,924,620	14,649,483	62,574,103	91,102,485	14,485,984	105,588,469

% from basin	17.15%	38.58%	19.72%	32.05%	30.13%	31.78%
% from India	5.86%	6.83%	6.06%	8.73%	5.51%	8.08%
Ganga Basin	279,405,369	37,970,162	317,375,531	284,217,991	48,075,805	332,293,796
% from India	34.15%	17.71%	30.74%	27.22%	18.27%	25.42%
Others	538,698,663	176,420,856	715,119,519	759,917,941	215,056,328	974,974,269
% from India	65.85%	82.29%	69.26%	72.78%	81.73%	74.58%
All India	**818,104,032**	**214,391,018**	**1,032,495,050**	**1,044,135,932**	**263,132,133**	**1,307,268,065**
Source: National Health Accounts						
Note: State-wise data do not include family planning services, health expenditure by local governments, firms and NGOs. NA-Not Available						
# All India public expenditure including expenditure by the MOHFW, Central Ministries and local bodies, while private expenditure includes health expenditure by NGOs, firms and households						

Figure 11 shows that over time per capita public and private health expenditure in India has increased. At the all India level public expenditure is found to be about 25% of the private expenditure, the latter being in the range of Rs. 790 to Rs. 959. Among the basin states while Bihar and UP have reported fall in private expenditure, there is sharp rise in the case of West Bengal. On the other hand on public expenditure side there was a general rise except in the case of West Bengal which recorded a marginal drop of 4%.



Source: National Health Accounts, M/o. Health & Family Welfare, GOI

Figure 11: Per Capita Public and Private Expenditure (in Rs.) on Health

Table 15 shows year-wise budgetary allocation on health sector in Ganga Basin states and India. It is noted that the budgetary allocation on the health sector in the basin has increased by 300% from Rs.4,908 crores during the 10th Plan to Rs.20,098 crores during the 11th Plan. Intriguingly, during the same period there was decrease of 20% in the case of Bihar (from Rs.1079 crores to Rs. 873 crores), while in all other states it increased substantially ranging 275% to 450%.

Table 15: Budgetary Allocation under Health Sector during 10th and 11th Plan Period (Rs. in Lakhs)

State	Bihar	Uttar Pradesh	Uttarakhand	West Bengal	Ganga Basin	All India
10th Plan (2002-2007)	**107920**	**240543**	**38767**	**103618**	**490848**	**2176734**
2002-03	10731	25950	5769	14138	56588	297061
2003-04	12343	19746	6315	18585	56989	3560112
2004-05	14390	38353	9979	15392	78113	400876
2005-06	16318	19746	6303	18590	60957	389402
2006-07	13700	188763	18600	44290	265353	767639
11th Plan (2007-12)	**87254**	**1319405**	**214882**	**388301**	**2009842**	**6103802**
2007-08	25706	149360	26519	31840	233425	832364
2008-09	11283.	184739	16546	43056	255625	1038282
2009-10	14009	168324	15202	56608	254143	1254179
2010-11	19500	152913	30310	68435	271158.	1578558.
2011-12	54450	204964	42376	87385	389174	2075451
Source: National Health Profile of India Reports (2005-2011)						

Table 16 shows year-wise share of the basin states in the total budgetary allocation on health in India. The table reveals that the percentage share of the basin states in the total budgetary allocation for the health sector during the last decade ranges from 15.65% to 34.57%. The percentage varies significantly across years and does not evince any trend. Within the basin, highest budgetary allocation towards health sector was made in Uttar Pradesh, followed by West Bengal. It is observed from the table that during the 11th Plan, the proportion of budgetary allocation towards the health sector for Bihar and Uttarakhand is somewhat similar, although these two states are highly distinctive in respect of socio-economic and demographic indicators. For example, 53.5% of the population in Bihar was below poverty line in 2009-10, whereas the corresponding percentage in Uttarakhand was only 18 (Planning Commission, 2012). Further, more than 75% of the Bihar households did not have toilet facility at homes in 2011; while the corresponding percentage in Uttarakhand was only 34. Also, 58% of household in Bihar had ‘no drainage’ in 2011, while in the case of Uttarakhand it was only 39%.

Table 16: Proportion from All India Budgetary Allocation Under Health Sector (10th and 11th Plan)

Years	Bihar	Uttar Pradesh	Uttarakhand	West Bengal	Ganga Basin
2002-03	3.61%	8.74%	1.94%	4.76%	19.05%
2003-04	3.47%	5.55%	1.77%	5.22%	16.01%
2004-05	3.59%	9.57%	2.49%	3.84%	19.49%
2005-06	4.19%	5.07%	1.62%	4.77%	15.65%
2006-07	1.78%	24.59%	2.42%	5.77%	34.57%
2007-08	3.09%	17.94%	3.19%	3.83%	28.04%
2008-09	1.09%	17.79%	1.59%	4.15%	24.62%
2009-10	1.12%	13.42%	1.21%	4.51%	20.26%
2010-11	1.24%	9.69%	1.92%	4.34%	17.18%
2011-12	2.62%	9.88%	2.04%	4.21%	18.75%

Source: National Health Profile of India Reports (2005-2011)

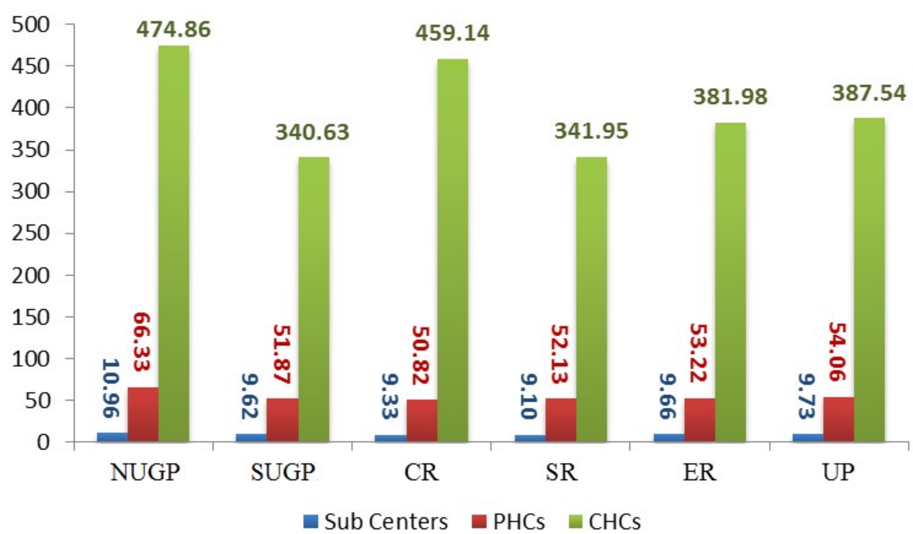
PART II: DISAGGREGATED ANALYSIS

In this section, we have made disaggregated (district-wise/region-wise) analysis of data related to healthcare infrastructure, water, sanitation and other health related aspects. Since Uttar Pradesh is very large in terms of area and population, it has been divided into five regions for analysis purpose. All districts of West Bengal and Bihar, however, were bifurcated into River Bank and Non- River Bank districts.

7. Health Care Infrastructure

7.1 Service Infrastructure

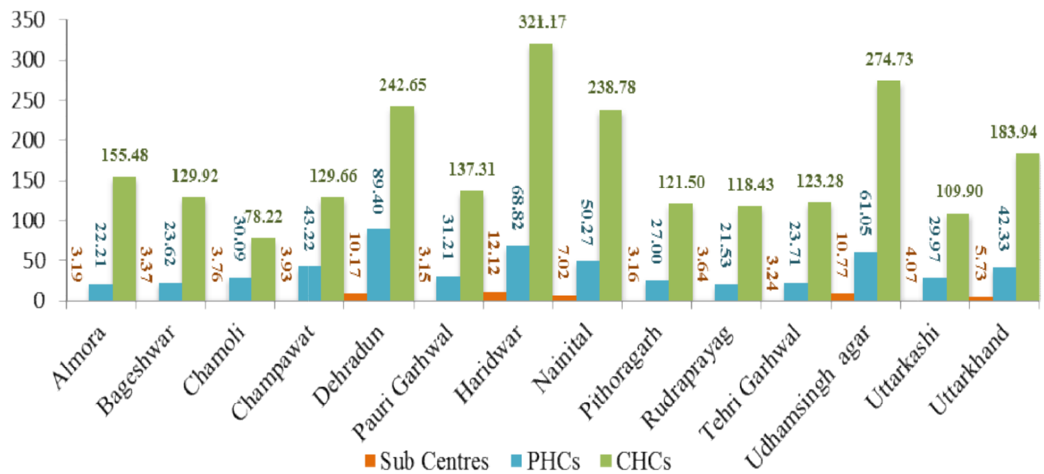
Figure 12 shows region-wise number of persons served per sub-centre, PHC, and CHC in Uttar Pradesh. According to the norms prescribed in the RHS bulletin (2012), a sub-centre is expected to serve 5000 persons in plain areas and 3000 persons in hilly areas but in Uttar Pradesh, one sub centre was serving more than 9000 persons in all the regions. The number of persons served per sub-centre was observed highest in NUGP, followed by ER (eastern region) and SUGP. Similarly, an average PHC in all the regions of the state was found to be over-loaded than the norm (One per 30 thousand). NUGP with 66.33 thousand per PHC was the highest) and CR with 50.82 thousand per PHC was the lowest. In the case of CHC also, the number of persons served was much higher than the norm (1.20 lakh) and the overload was in the range of 3.8 to 4.75 lakh. Across various regions. Evidently public healthcare infrastructure in all the regions of the state is overloaded and quite inadequate to meet requirement.



Source: RHS Bulletin (2011) & Census of India (2011)

Figure 12: Region-wise Population ('000) served per Sub-centre, PHC, CHC in Uttar Pradesh, 2011

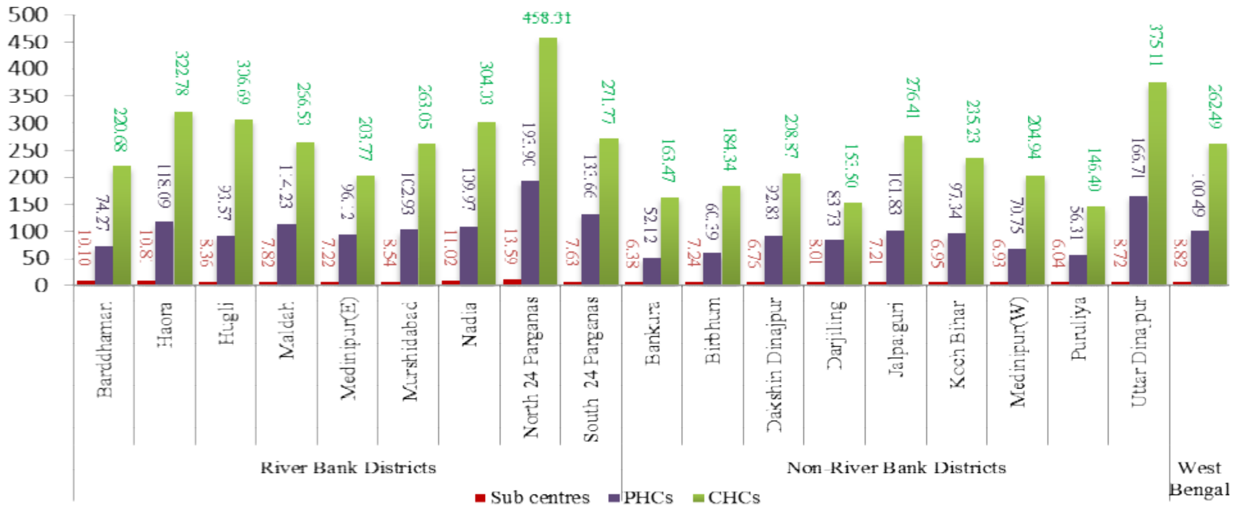
Figure 13 shows district-wise number of persons served per sub-centre/PHC/CHC in Uttarakhand in 2011. The Figure depicts that an average sub-centre in the districts of plain/semi-plain areas of the state (Dehradun, US Nagar, Haridwar and Nainital) served more number of people than that in the districts of hill areas of the state. It is evident that an average sub-centre in the plain areas served 7-12 thousand persons, while in the hilly areas, it served only 3 to 4 thousand persons in 2011 which can be attributed to lower population density in the hills. The same trend has been observed in the case PHCand CHC. For example, as against 89.40 thousand /PHC in Dehradun versus only 21.53 thousand/PHC in Rudraprayag; and 321 thousand/CHC in Haridwar versus (78 thousand/CHC in Chamoli.



Source: RHS Bulletin (2011) & Census of India (2011)

Figure 13: District-wise Population ('000) Served per Sub-centre, PHC, CHC in Uttarakhand, 2011

In the case of West Bengal, in general it is found that there are more number of persons per sub-centre, PHC and CHC in the river bank districts compared to the non-river bank districts. Figure 14 presents districtwise distribution for each type of facility. In West Bengal also, the public healthcare infrastructure was quite insufficient to meet the requirement as number of persons served per sub-centre/PHC/CHC were higher than the set norms.



Source: RHS Bulletin (2011) & Census of India (2011)

Figure 14: District-wise Population ('000) Served per Sub-centre, PHC, CHC in West Bengal, 2011

Figure 15 portrays the scenario in Bihar during 2011. Here the load on CHCs was more alarming for 'bank districts' than 'non-bank districts'. For instance, there are 16.7 lakh persons served per CHC in 2011 as against the central norm of 1.2 lakh. As regards sub-sentre and the PHCs there was no discernible difference between the 'bank districts' and non-bank districts', though there also overloading was recoded. For instance one sub-centre was serving an average of 10.7 thousand persons and one PHC was serving between 54-59 thousand persons.

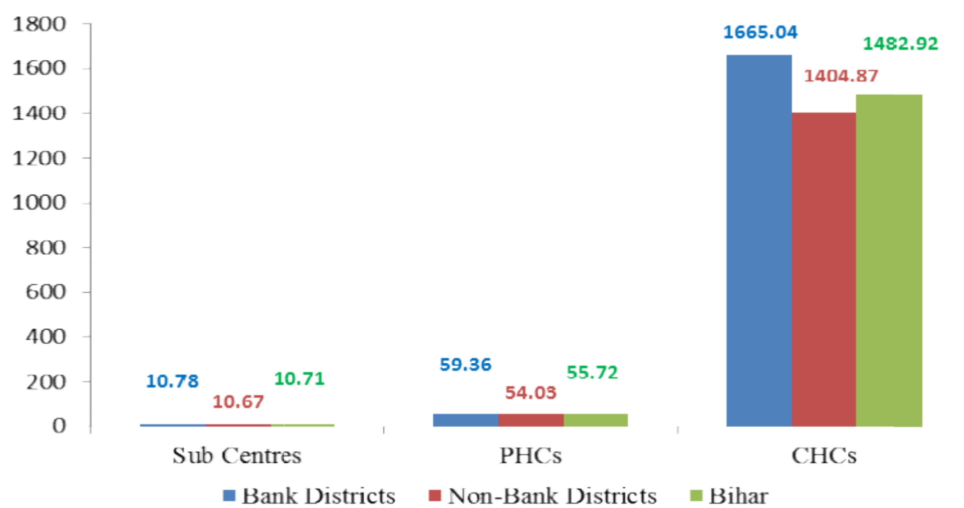


Figure 15: District-wise Population ('000) served per Sub-centre PHC, CHC in Bihar, 2011

7. 2 Health Educational and Hospital Infrastructure

In addition to the government hospitals at various levels, there are hospitals attached to medical colleges which also offer out- and in-patient serivces and play a crucial role in providing tertiary medical services. Appendix Table A5.1 to A5.4 present number of governmnet and private colleges in various districts in the four states of Ganga basin along with the agregate number of bed for in-patient admissions.

It is noted that in the case of UP tertiary healthcare facility is fairly widely distributed among varioud districts. Total hospitals are 15 and total bed capacity is close to 18,000 and is highest among all the four states. In this respect in relation to the total state population Bihar and West Bengal with total bed capacity of close to 6000 rank far behind and which may not be adequate to meet the requirements of the population.

Uttarakhand with 4 medical colleges And total bed capacity of 2350 appears to be reasonably equipped.

As far as number of medical colleges in West Bengal is concerned, Table 20 shows that out of total 14 medical colleges (12 government and 2 private), 50% were established only in the capital city of Kolkata, with about one-third of total number of hospital beds of the state. Several cities and towns of the state did not have any medical college.

8. Water, Sanitation and Health

This section examines district-wise/region-wise households' access to drinking water and sanitation and burden of diseases in the Ganga Basin states.

8.1 Drinking Water

Figure 15 shows distribution of households by main sources of drinking water in Uttarakhand. Uttarakhand is blessed with rich sources of water. Rivers like Ganga and Yamuna originate and flow through Uttarakhand. As per the Census 2001 the state is ranked 6th in availability of safe drinking water. In Uttarakhand, tap water is the main source of drinking water in all the districts (except Haridwar and U S Nagar). Further, percentage share of tap water has increased in 2011 over 2001. Except Haridwar and US Nagar districts, in all other districts, share of tap water ranges from 65 to 88 percent. Districts located in the hill region have relatively higher proportion of households using tap water than their counterparts in plains. In plain districts, particularly, Haridwar and US Nagar, hand pump was the main source of drinking water (54.05% in Haridwar and 58.46% in US Nagar in 2011). Households in the state also had tank/pond /lake, river/canal, spring etc. as sources of drinking water; however, their share in

the total was quite low, except for other source in a few districts of hill areas. A comparison of households distributed by sources of drinking water in Census 2001 to that of Census 2011 shows that there has been improvement in househols' access to safe drinking water.
Figure 16 shows that about 56% of households in Uttar Pradesh used hand pump as a source of drinking water. The proportion of households using hand pump as a source was observed highest in SR (71.64%), followed by ER (66.82%), SUGP (66.08) and CR (64.96%). Next to hand pump is tap water which constituted 27.26% of total households of the State, with highest proportion in NUGP (36.71%) and lowest in SR (17.36%).

Figure 17 for West Bengal reveals that it was mostly the hand pumps in all the districts and tap water especially in Kolkata, which constituted main sources of drinking water. Now hand pumps very often face crisis when water is highly contaminated with chemicals substances. Particularly in West Bengal, greater tendency to cultivate Boro variety of rice leads to usage of more fertilizer and more insecticide along with greater water usage. The used chemicals seep down into the surface water as well as ground water. Again more water consumption leadS to rapid use of shallow pumps in summer leading to fall in ground water level and chances of contamination with poisonous substances like Arsenic. Currently in West Bengal most of the areas under river bank districts e.g., Nadia, North 24 Parganas, Murshidabad & Maldah and some parts of Hooghly and South 24 Parganas are highly affected with Arsenic in ground water. Given the high usage of hand pumps in West Bengal e.g., 77% in Murshidabad and 67% Nadia - he two major arsenic hit districts, it would be a appropriate to investigate propensity of people to adopt purification and filtration process for drinking water purpose.

As in the case of UP and West Bengal, Figure 18 shows that in Bihar also hand pump is the major source of drinking water. In 2011 it was found that almost 89% of total households are using hand pump for drinking water followed by 4% using tap water and and equal percentage using well water. The situation becomes come complex due to shallow groundwater and therefore use of shallow hand pumps and the extremely low level of sanitation coverage across the state. As a result, people in rural as well as in urban areas of Bihar are more prone to water borne diseases.

The water collected by a household for drinking is sometimes not consumed directly but only after some cleaning/treatment. Prior cleaning/treatment of water before drinking is good indicator of health awareness and the pattern in Uttarakhand is presented in Figure 19. As per this, it is noted that in 2011 over 79% households use tap water after treatment. Dehradun being the most urbanised in the state the community here is most conscious about health and this is reflected in highest percentage of households (over 91%) using treated tap water for drinking purpose.

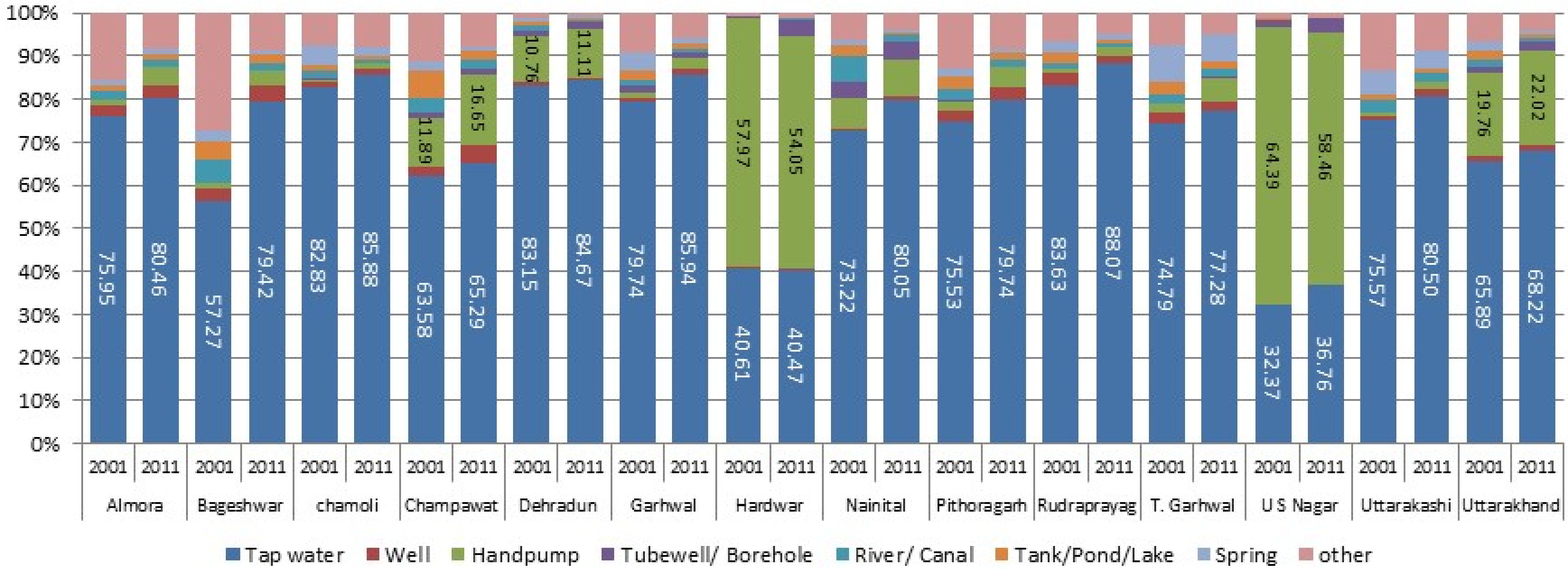


Figure 15: Distribution of Households by Main sources of Drinking water, Uttarakhand (2011)

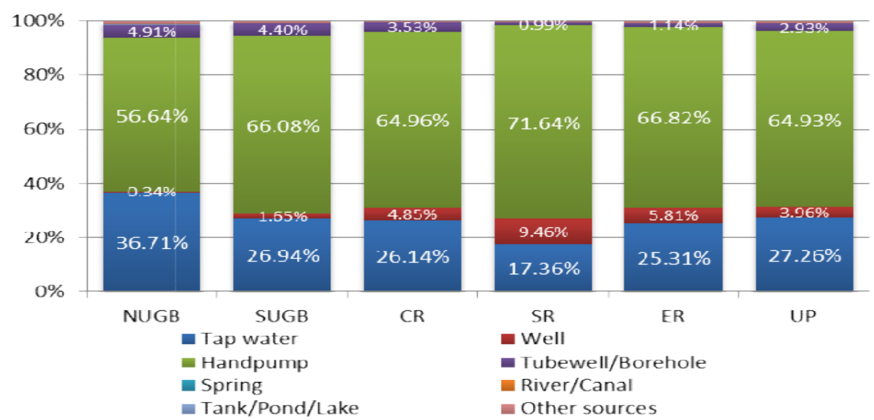


Figure 16: Distribution of Households by Main sources of Drinking water, Uttar Pradesh (2011)

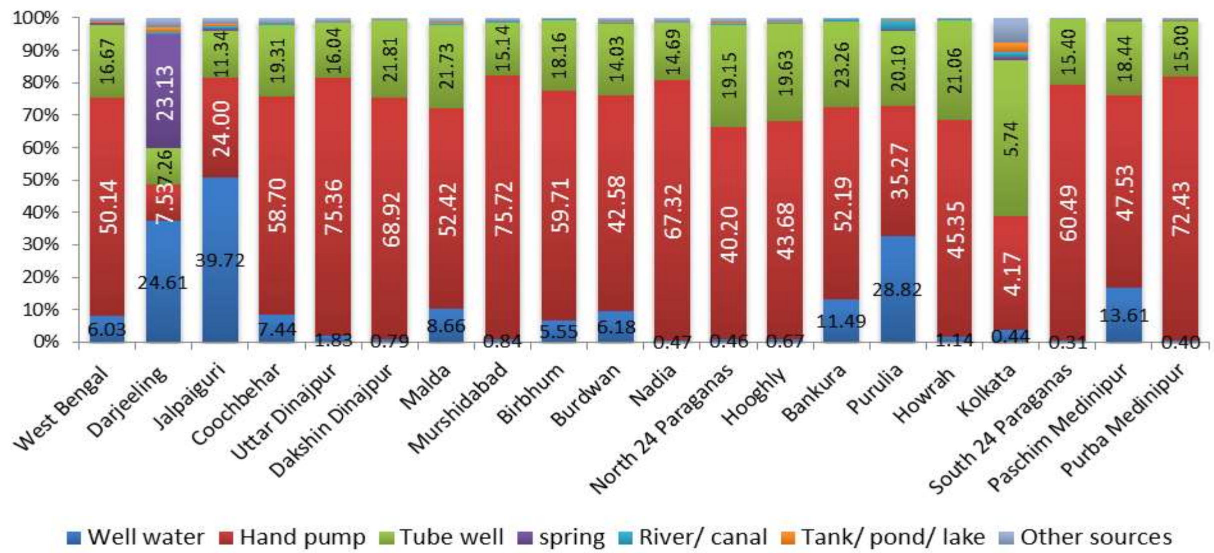


Figure 17: Distribution of Households by sources of Drinking water in West Bengal, 2011

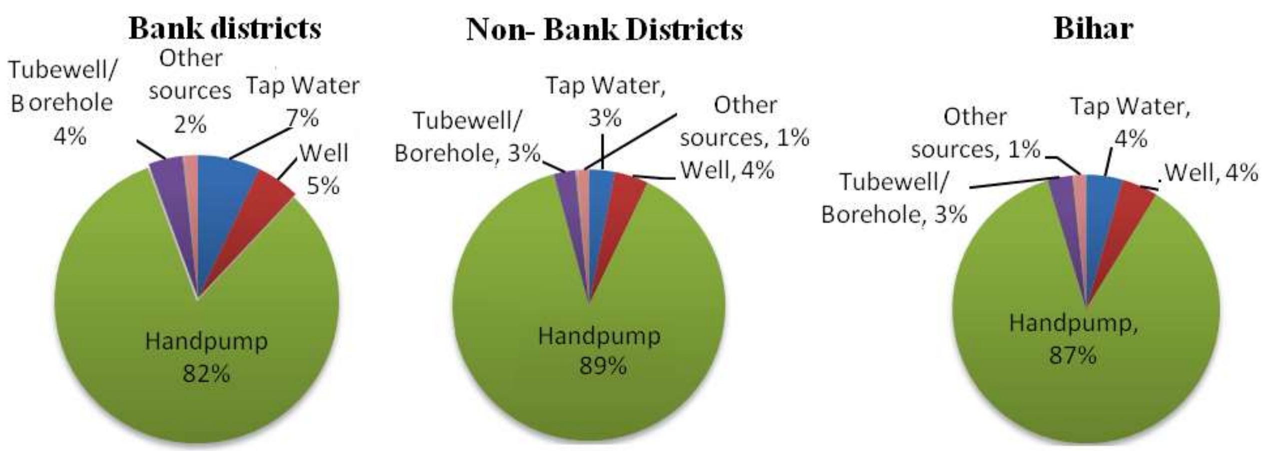


Figure 18: Distribution of Households by sources of Drinking water in Bihar, 2011

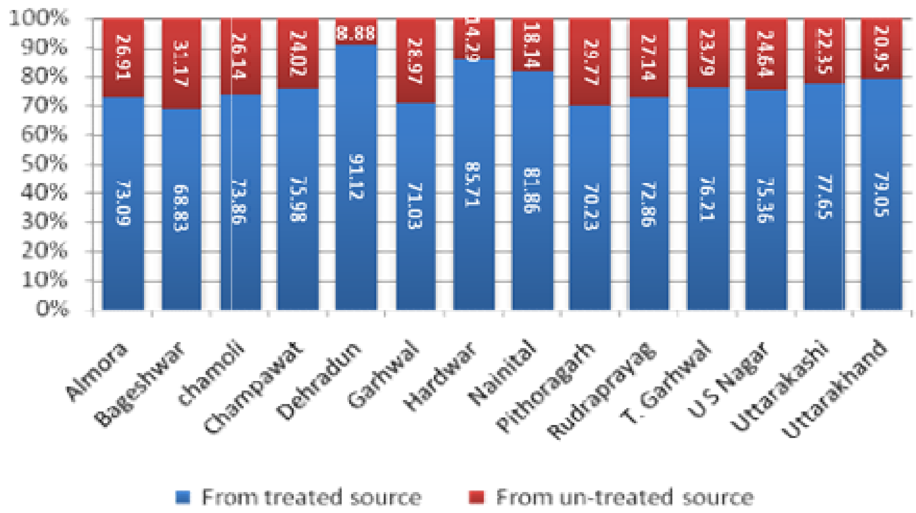
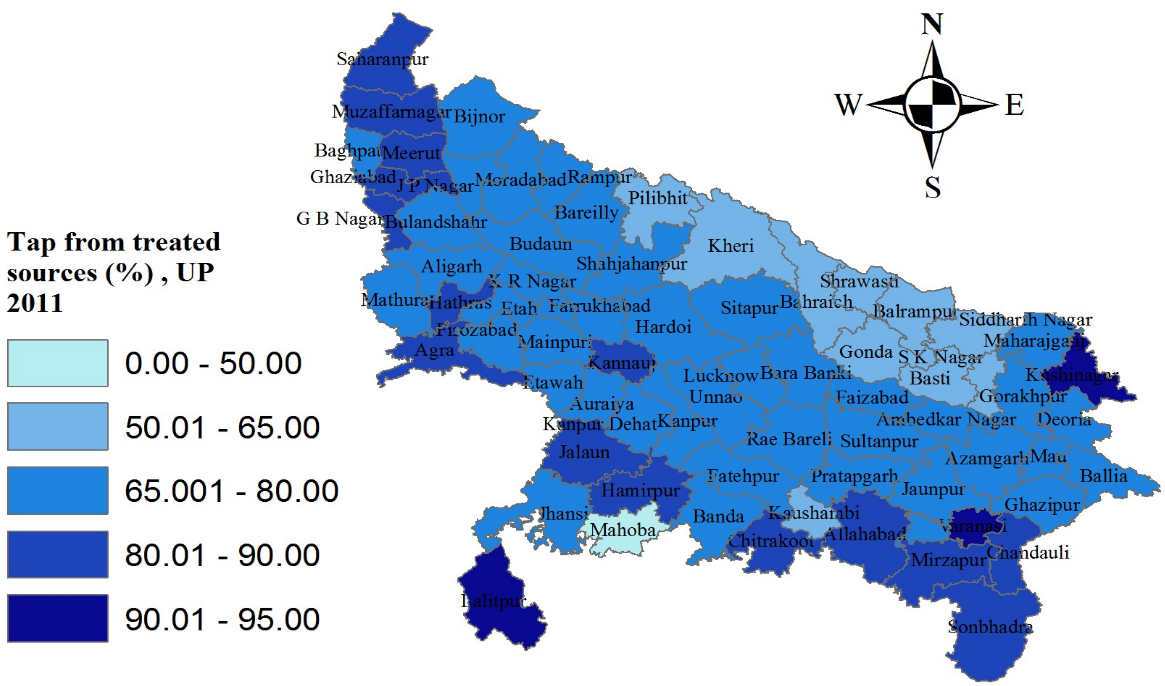


Figure 19: Distribution of Households by sources of Tap Water in Uttarakhand, 2011

Map 6 shows that more than 50% households in Uttar Pradesh were using tap water from treated sources. However, percentage of such households varies significantly across districts. In most of the districts, 65-80% of households were reported to use tap water. Only in 10 districts, percentage of such households was less than 50. Lalitpur, Varanasi and Kushinagar districts had the highest proportion of households (90-95%) using tap water from treated sources.



Source: Census of India (Uttar Pradesh), 2011.

Map 6: Distribution of Households by sources of Tap Water (treated) in Uttar Pradesh, 2011

Figure 20 shows percentage distribution of households using treated and untreated tap water across districts of West Bengal. About 50% households in districts like Coochbehar, Darjeeling and Bankura received tap water from untreated sources. However the river bank districts have relatively higher proportion of households using treated tap water, except for Maldah, Murshidabad, Nadia and Purba Medinipur where 26.95%, 28.40%, 29.45% and 25.69% of households used untreated tap water respectively. The situation in Nadia is very critical given the intensity of ground water contamination.

Figure 21 shows percentage distribution of households using tap water from treated and untreated sources in Bihar. It is found that bank districts had slightly higher percentage of households using tap water from treated sources than non-bank districts.

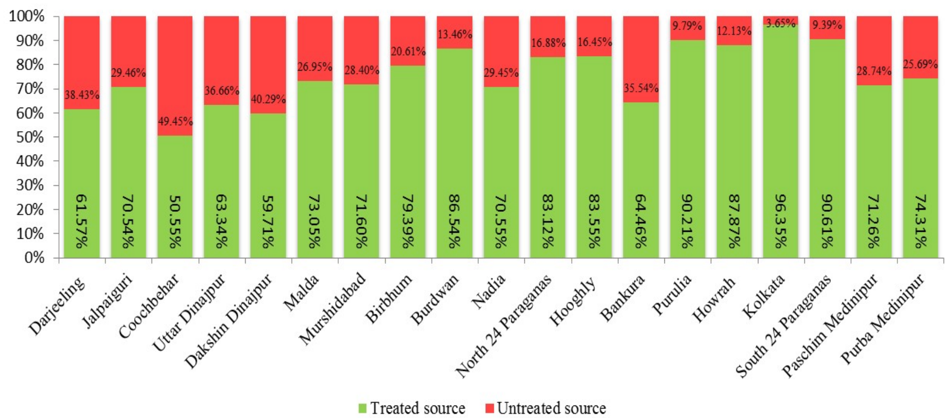


Figure 20: Distribution of Households by sources of Tap Water (treated) in West Bengal, 2011

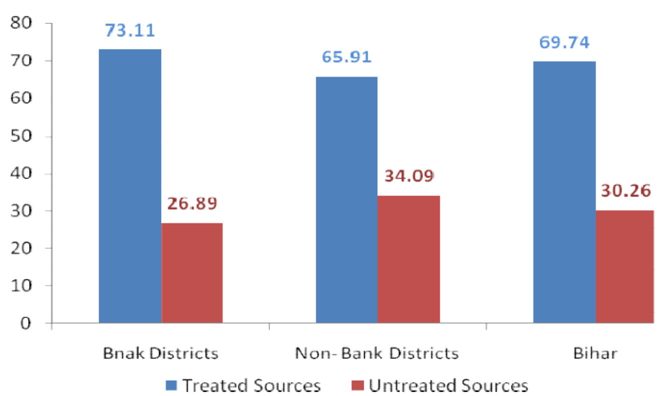


Figure 21: Distribution of Percentage of Households using Tap water from treated and Untreated Source in Bihar, 2011

8.1.1. Purified Water and Sources

Table 22 shows that Uttar Pradesh, the most populated states of the country, has just 7 households per 1000 in rural and 47 households per 1000 in urban areas that have used some kind of treatment process for drinking water. Region-wise analysis shows that number of households per 1000 treating water before drinking in urban areas was highest in ER (82), closely followed by CR (81) and SUGP (74), while in rural areas, the number was highest in SR (26), followed by SUGP (18) and ER (14). The percentage share of households using R-Os – an expensive option for water purification was much higher in urban than rural areas in all the regions, except ER where proportion in rural households was higher Similarly, rural households of NUGP and SUGP were found to using 'other than listed processes', whereas in rural SR, cloth screen and in rural CR and ER, filtration were commonly used to clean drinking water.

Table 22 : Proportion of households treating water before drinking and per 1000 distribution of such households by type of water treatment, Uttar Pradesh (2004)

Region	Sectors	Ultra-violet/ resin/reverse osmosis	Filter	Boiling	Cloth screen	Any disinfectant	Others	No. per 1000 Treating water Before drinking
NUGP	Rural	0.00%	9.56%	8.13%	0.00%	0.00%	82.31%	6
	Urban	20.96%	4.68%	65.06%	0.00%	8.58%	0.72%	58
SUGP	Rural	0.00%	41.43%	0.00%	0.00%	0.00%	58.57%	18
	Urban	23.39%	13.47%	42.80%	11.26%	4.87%	4.21%	74
CR	Rural	7.55%	72.74%	19.71%	0.00%	0.00%	0.00%	13
	Urban	0.48%	23.58%	64.22%	0.32%	6.19%	5.20%	81
SR	Rural	0.00%	0.00%	2.12%	58.09%	4.57%	35.23%	26
	Urban	0.00%	0.00%	13.79%	81.58%	0.00%	4.63%	66
ER	Rural	27.46%	45.28%	15.92%	0.00%	0.00%	11.33%	14
	Urban	15.47%	3.76%	80.78%	0.00%	0.00%	0.00%	82
UP	Rural	13.66%	40.59%	11.44%	8.75%	0.69%	24.87%	7
	Urban	12.96%	11.72%	57.68%	8.87%	5.74%	3.03%	47

Source: NSS 60th round Unit level data, 'Morbidity, Health Care and the Condition of the Aged, Jan.-June, 2004

The NSS 60th round (2004) does not provide sufficient district-wise estimates for comparing rural and urban areas of Uttarakhand in this respect. For urban areas, six districts and for rural areas only one district, i.e., Haridwar was evaluated to analyse the proportion of households treating water before drinking during 2004 as shown in Appendix Table A6. One district cannot possibly explain the real situation of overall rural Uttarakhand, therefore only urban Uttarakhand is considered for the analysis. Overall, about 30% of urban households used any method of purification of drinking water. Most of these households used boiling and filtration as the main methods of treatment of drinking water, except in urban Dehradun where more than 30% of such households used 'Ultra-violet/resin/reverse osmosis' types of techniques for water purification. At the state level, only about 6% of households who treated drinking water, used RO. However, the percentage of such households varies significantly across districts. The proportion of urban households using RO was reported to be highest in Dehradun, followed by Haridwar.

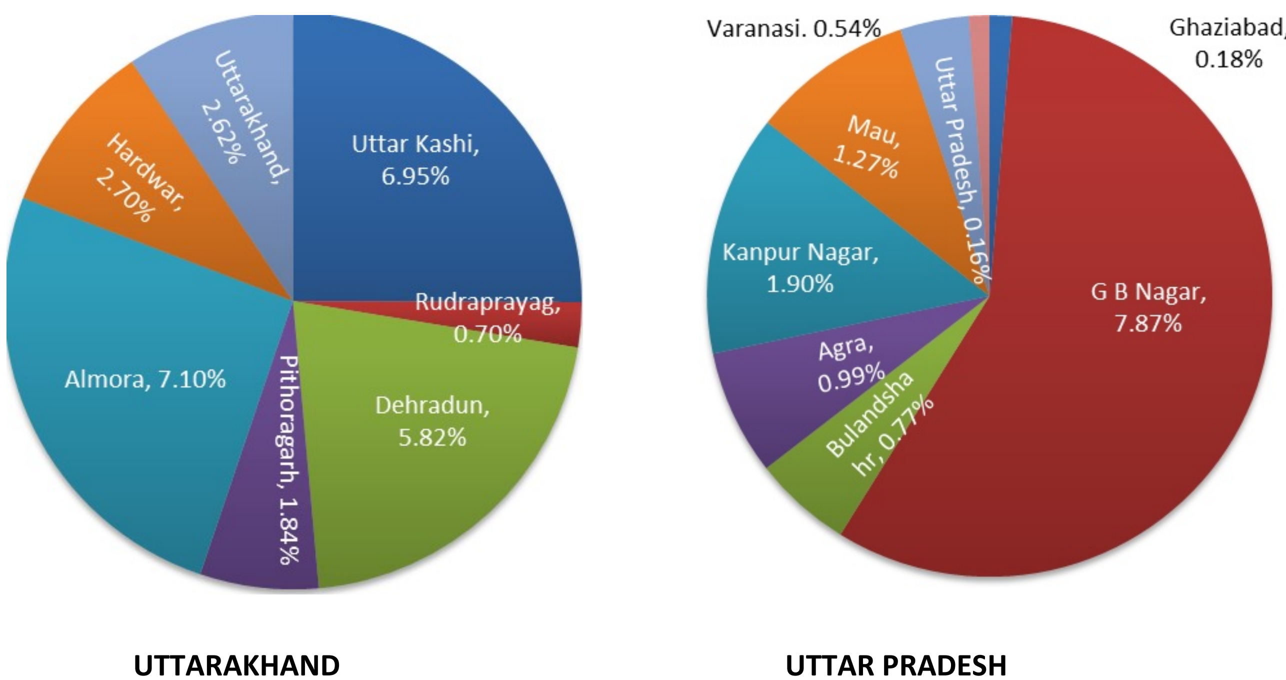
As far as households in Bihar are concerned, Appendix Table A7 shows that a majority of them dod not treat water at the point of use. At the state level only 6.3% of urban households and 0.30% of rural households use any purifying method. The highest number of such households in urban areas were found in Munger district (182 per 1000), followed by Muzzafarpur district (182 per 1000) and Saran district (161 per 1000). Except one rural household in Vaishali district, in all other districts not even a single household was found to use R-O treatment at point of use. This exceptinally low prevalence of treatment at point of use can be attributed to, among others, low awareness, lack of concern and possibly low level of affordability.

In West Bengal 188 urban households and 35 rural households per 1000 used water treatment at point of use. In urban areas, number of households treating water at point of use (per 1000) was found highest in Medinipur district (366), followed by Bankura District (324) and Murshidabad (304). In rural areas, it was observed to be highest in Bankura (125), followed by Howrah (94) and Jalpaiguri (61). On an average, in urban areas, domestic ceramic filter was the most common method used for water purification. Among those using treated water, the highest percentage in urban areas was of filter (72.22%), followed by RO (16.20%), whereas in rural areas, the highest percentage was of boiling (29.75%), followed by filter (25.33%) and cloth screen (21.46%). A perusal of Table A8 reveals that percentage distribution of households using different methods of water treatment varies significantly across districts and rural-urban location. In the case of RO, the percentage was higher in urban than in rural areas which is evident considering higher affordability among the former. The highest percentage of households using RO in urban areas was observed in Kolkata (33.29%), followed by Howrah (17.36%), Hugli (17.02%) and North 24 Parganas (14.53%). However, in more than 50% districts of the state, urban households did not use RO. In rural areas, except for a few districts, in a majority of of other districts, RO was not used by the households.

8.1.2 Bottled Water

Failure to provide municipal supply often affects the poorest populations either by leaving them to pay inflated prices for water provided by private vendors or compelling them to use unsafe water. As per the 60th NSS Round (2004-05), in Uttarakhand (refer Figure 22-a), some households in 6 out of 13 districts were using bottled water for drinking. The proportion of such households was highest in Almora district (7.10%), followed by Uttarkashi (6.95%), Dehradun (5.82%), Haridwar (2.70%), and Pithoragarh (1.84%).

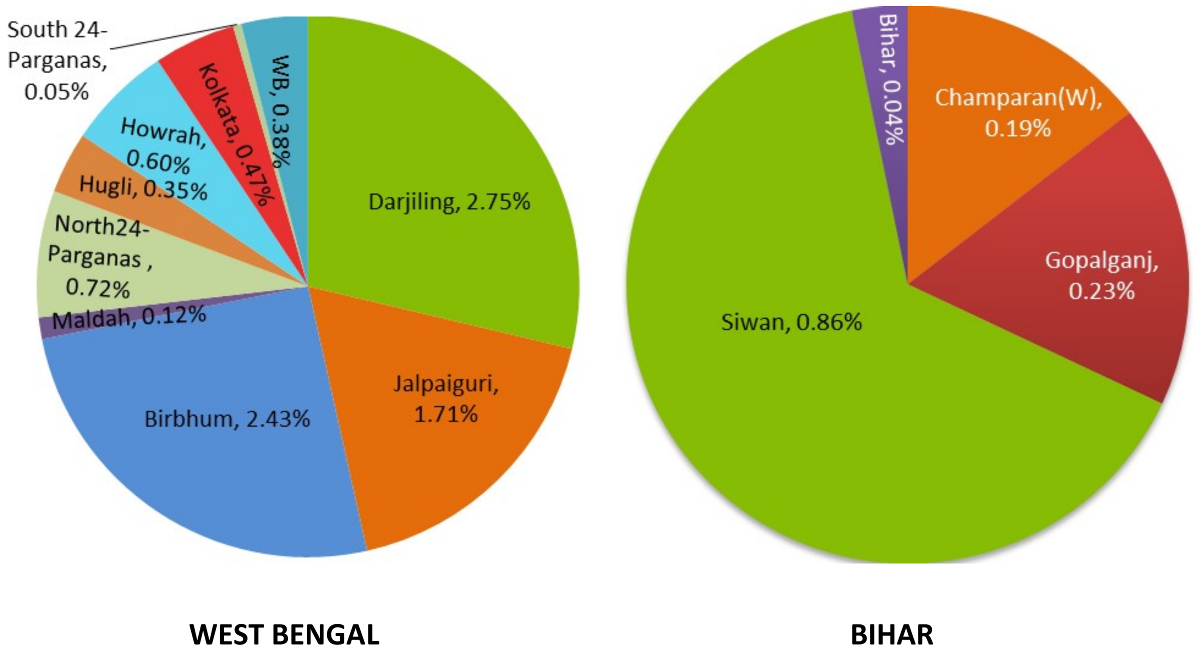
In Uttar Pradesh, bottled water was not reported to be used in all the districts. As per the 60th NSS Round (2004-05), only in 7 districts of the state (refer, Figure 22-b) households have reported use of bottled water. These districts and the percentage of households using bottled water are Gautam Budha Nagar/Noida (7.87%), Kanpur Nagar (1.90%), Mau (1.27%), Agra (0.99%), Bulandshahr (0.77%), Varanasi (0.54%) and Ghaziabad (0.18%). Evidently poor quality of water supply/sources, increasing awareness and concern for health, rising income of households, among others can be attributed to be some of the main reasons for use of 'Water Bottles'. Relatively higher usage of bottled water in Noida is not surprising, given that it is an extension of Delhi and is characterised by relatively high income community and at the same time rather poor quality of water supply.



Source: NSS unit level data 60th round 'MORBIDITY AND HEALTH CARE', 2004

Figure 22 (a, b) : Proportion of Households having 'Water Bottles' as Sources of Drinking water within Uttarakhand and Uttar Pradesh, 2004

In West Bengal (Refer, Figure 23-a), bottled water is used for drinking in 9 out of total 18 districts. Among all the households using bottled water, highest share was in Darjiling (2.75%), followed by Birbhum (2.43%) and Jalpaiguri(1.71%). On the other hand in the case of Bihar there are only three districts (Refer, Figure 23-b) where it is used. Among these districts, Siwan (0.86%) occupies highest proportion followed by Gopalganj (0.23%) and West Champaran (0.19%). It is interesting to note that in Bihar usage of bottled water was reported only in rural areas and it is rather intriguing that none of the urban households (not even in state capital) reported use of bottled water for drinking water . This is rather anamolous and can be attributed to error in sampling or data collection and analysis.



Source: NSS unit level data 60th round 'MORBIDITY AND HEALTH CARE', 2004

Figure 23 (a, b) : Proportion of Households having 'Water Bottles' as Source of Drinking water within West Bengal and Bihar, 2004

8.2 Access to Toilets

Figure 24 shows that in all the regions of Uttar Pradesh, percentage of households without toilet facilities has declined in 2011 over 2001, however considering the extent of the problem the decline can be termed as marginal. For instance in most of the regions the decline was only 1% to 3% except for NUGP where it was 10% and SR where it was a distant 5.3%. Notwithstanding the declines, it is clear that UP has a long long way to go since households without access to toilet is over 60%. Among various regions, ER with deficit of 78% ranks highest follwed by SR at 69%, CR at 65% and SUGP at 63%. WR (NUGP + SUGP) offers encouraging situation where the deficit in 2011is reported to be about 32%.

Figure 25 illustrates distribution of households categorised by main source of toilets across districts of Uttarakhand. The Figure reveals that in all the districts of Uttarakhand, there has been an increase in sanitation coverage, or to put in other words, decline in proportion of households not having any access to toilet facilities within the premises in 2011 over 2001. Dehradun ranked first in terms of access to toilet facilities within the premise in 2011. It is followed by Nainital, U S Nagar and Haridwar. The decline in the proportion of households without toilets is significant in almost all the districts in 2011 over 2001, with highest decline recorded in Bageshwar (30%), followed by Rudraprayag (26.60%). However, there are still several areas where coverage is low e.g., Uttarkashi with 56.27% households and Champawat with 53.63% households without access to toilets.

Figure 26 presents sanitation deficit in West Bengal as per which it emerges that apart from Kolkata, all other districts suffer from lack of proper household latrine facilities. The only other better performing districts are North 24 Parganas and Purba Medinipur. A apart from these districts, all other districts have acute shortage of latrine facilities. Bankura with deficit of 80% and Purulia with 90% represent the lowest ranking districts in West Bengal.

Distribution of households by main sources of latrine in Bihar in 2011 is shown in Appendix Table A9. Among 'bank districts', proportion of households having 'no latrine' varies from 47% in Patna to 83% in Katihar; whereas among the 'non-bank districts', this proportion varies from 69% in Nalanda to 91% in Araria. While no correlation can be drawn based on location of districts, it is evident that all across the state the satus of sanitation coverage is rather dismal and there are serious issues with environmental sanitation and public health.

Figure 24: Distribution of Households by Main Sources of Latrine, Uttar Pradesh

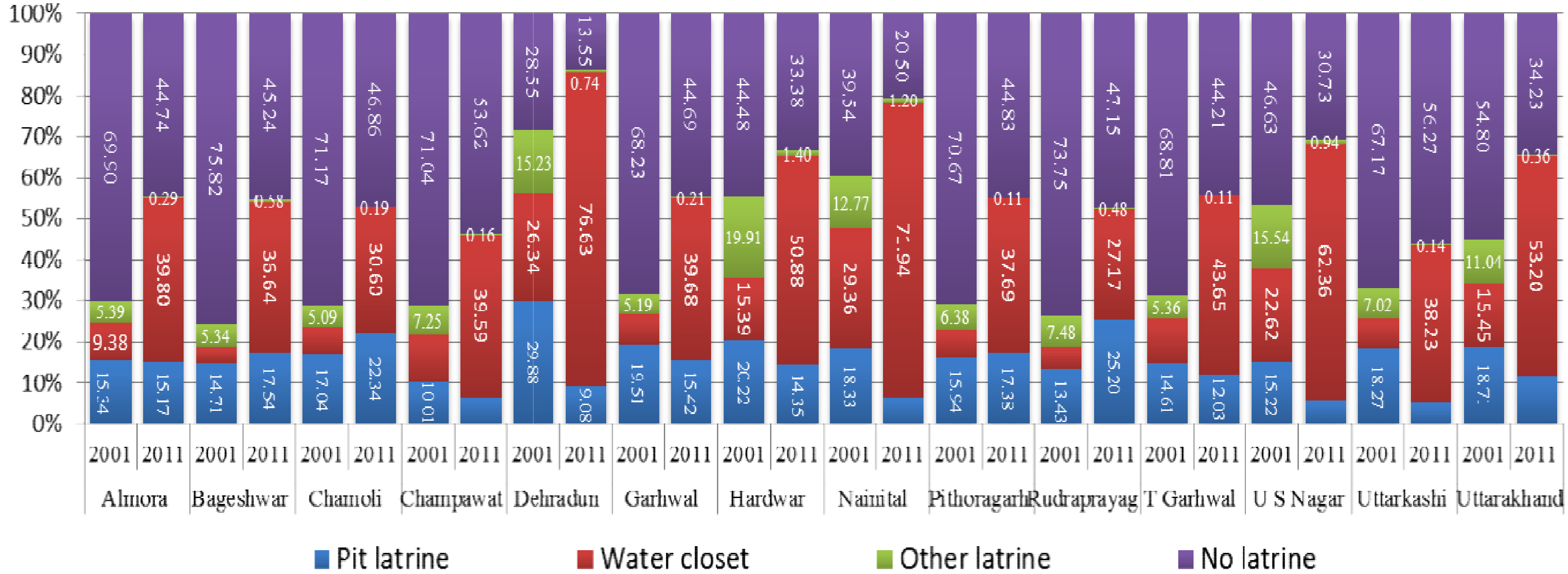


Figure 25: Distribution of Households by Main sources of Latrine, Uttarakhand

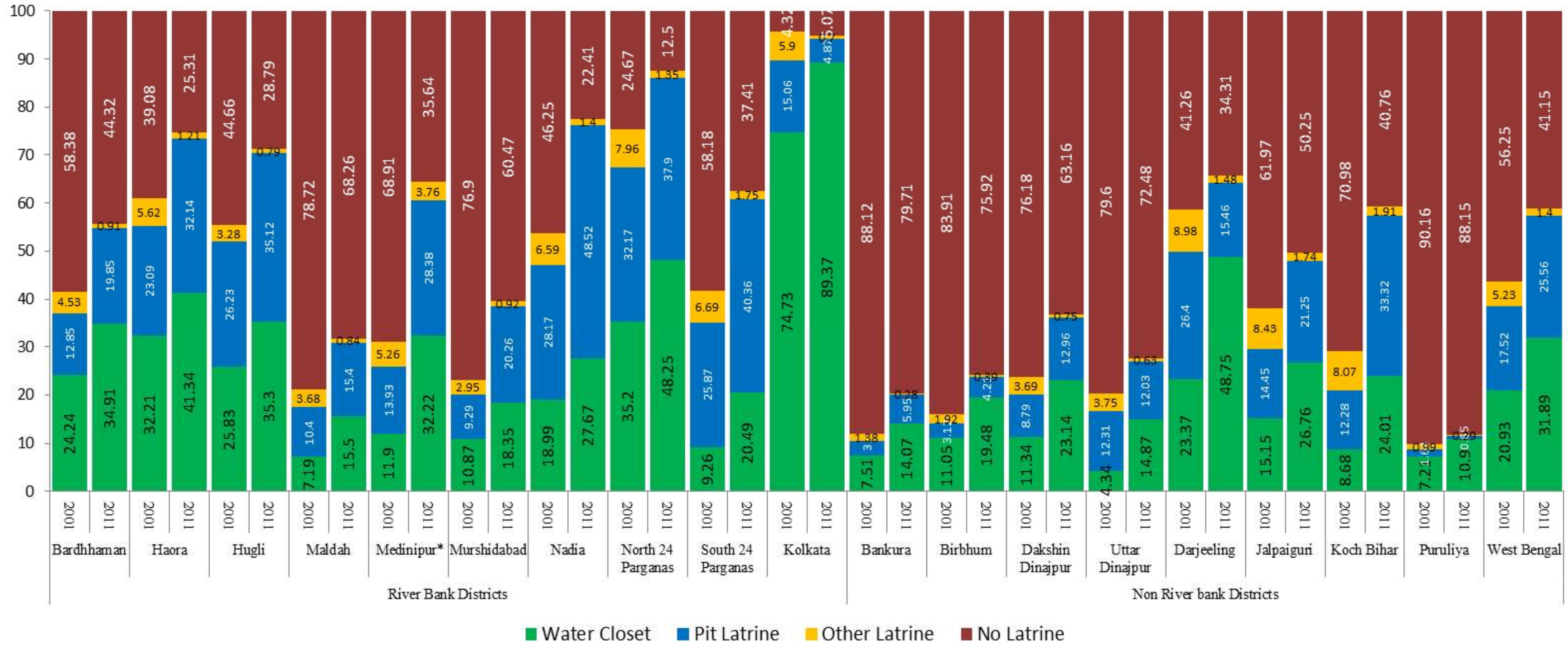


Figure 26: Distribution of Households by Main Sources of Latrine, West Bengal

8.3 Sewerage and Drainage Facilities

As shwon in Figure 27, in 9 out of 13 districts in Uttarakhand, more than 50% of the households did not possess any drainage system in 2011. These districts are Pithoragarh, Pauri Garhwal, Uttarkashi, Rudraprayag, Tehri Garhwal, Chamoli, Champawat, Almora and Bageshwar. This represents severe limitation of municipal infrastructure and also indicates challenges on account of, among others, topography and poor resource allocation.

Figure 28 shows regional distribution of households by types of drainage facilities in Uttar Pradesh. On this count the situation appears to be worse in lower part of Uttar Pradesh i.e., ER and SR where according to the Census 2011 more than 50% and 35% households respectively did not possess any dainage system.

Figure 29 depicts drainage scenario in West Bengal which brings out a rather dismal picture almost across the entire state except for Kolkata. It is noted that even in highly industrialised districts of North 24 Parganas, Howrah and Hooghly households without proper drainage/sewerage were 50%, 60% and 58% respectively which shows reliance on either on-site sanitation or open defecation and indiscriminate disposal of sullage .

In Bihar, the proportion of 'no drainage' households varies from 20% in Rohtas to 86% in Kisanganj during 2011 (Figure 30). Drainage situation in Bihar can be critical because of generally impervious soil leading to longer periods of stagnation of water and consequent offering of breeding sites for disease vectors such as mosquitoes.

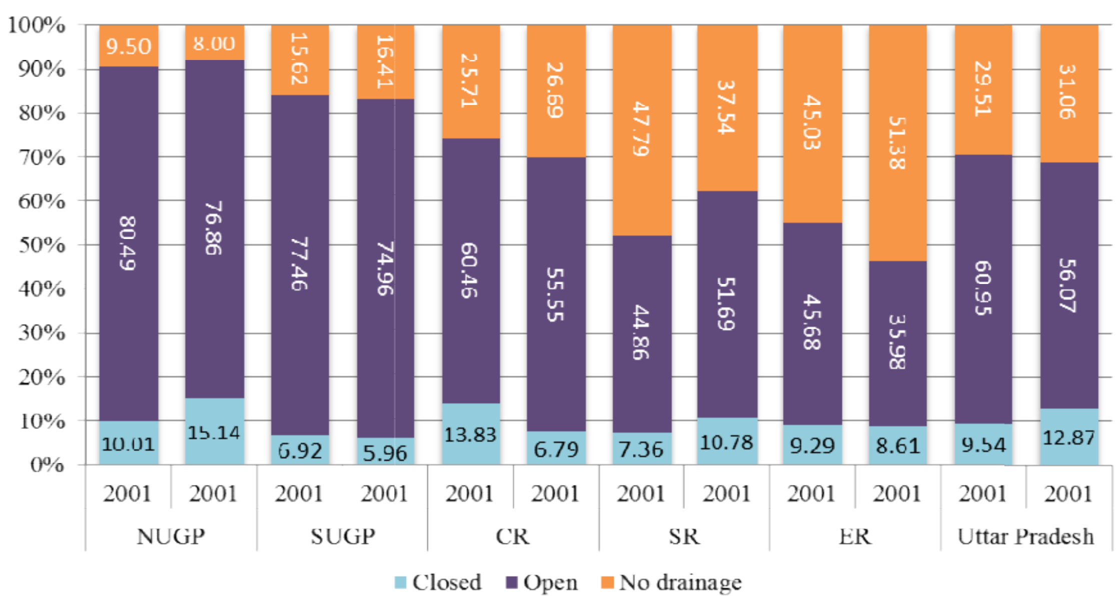


Figure 28: Region-wise Distribution of Households by Types of Drainage in Uttar Pradesh

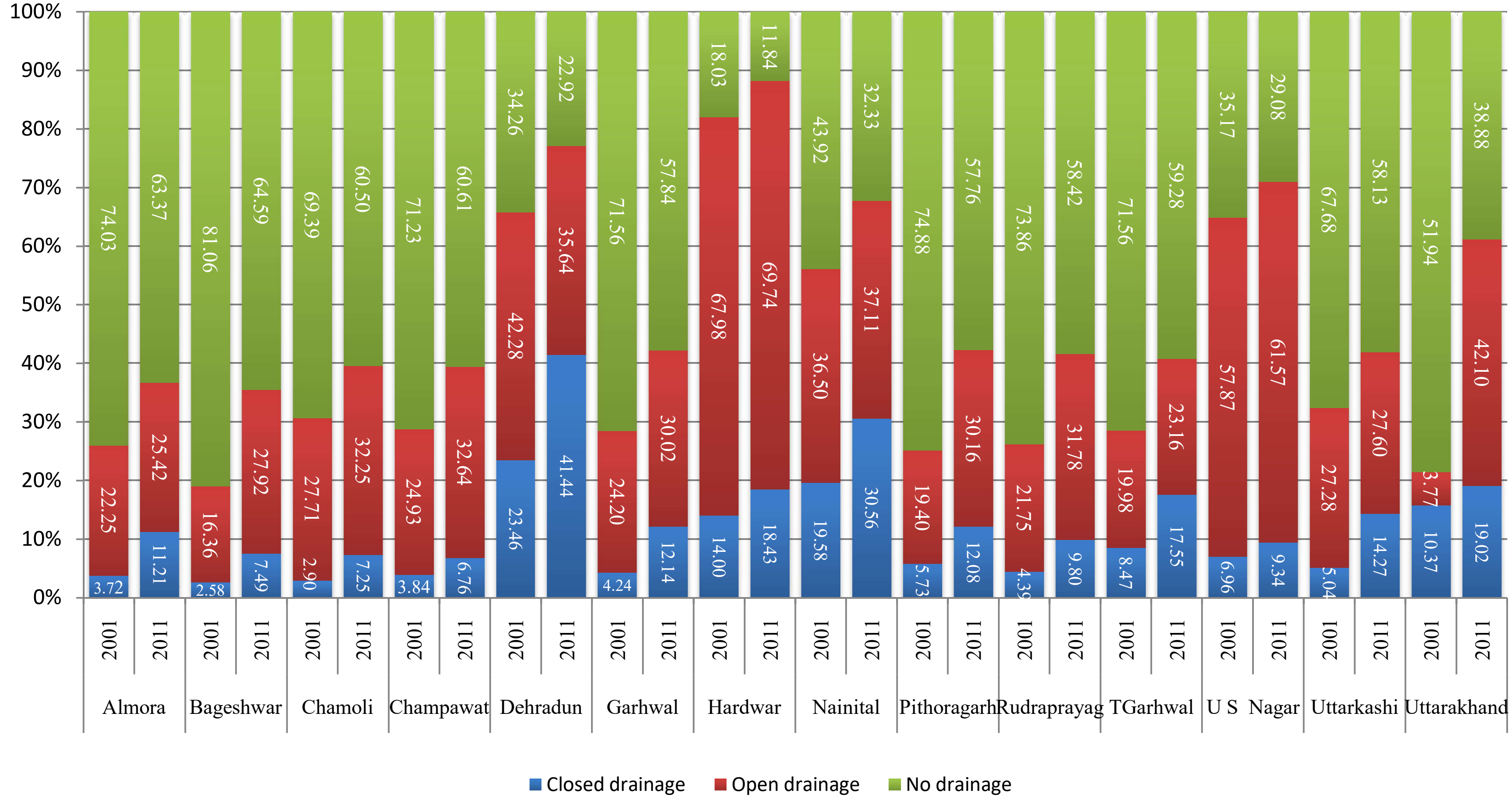


Figure 27: Distribution of Households by Main Types of Drainage in Uttarakhand

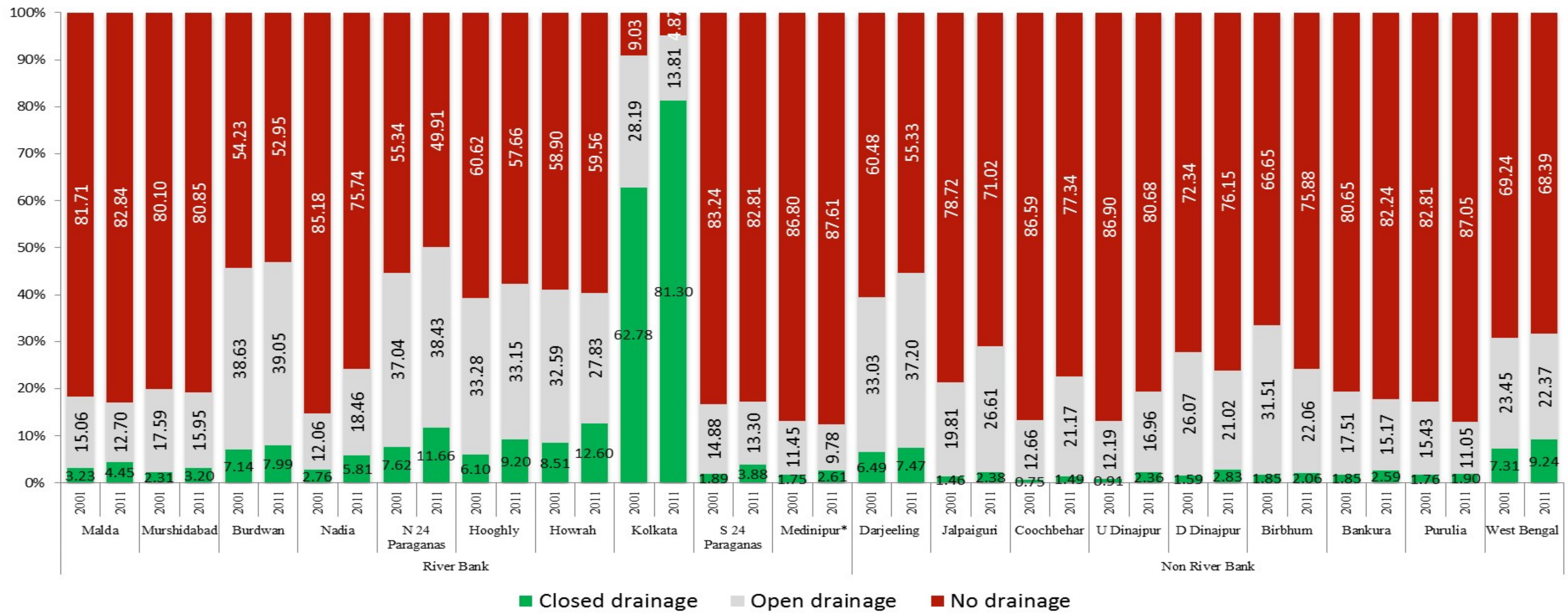


Figure 29: Distribution of Households by Main Types of Drainage in West Bengal

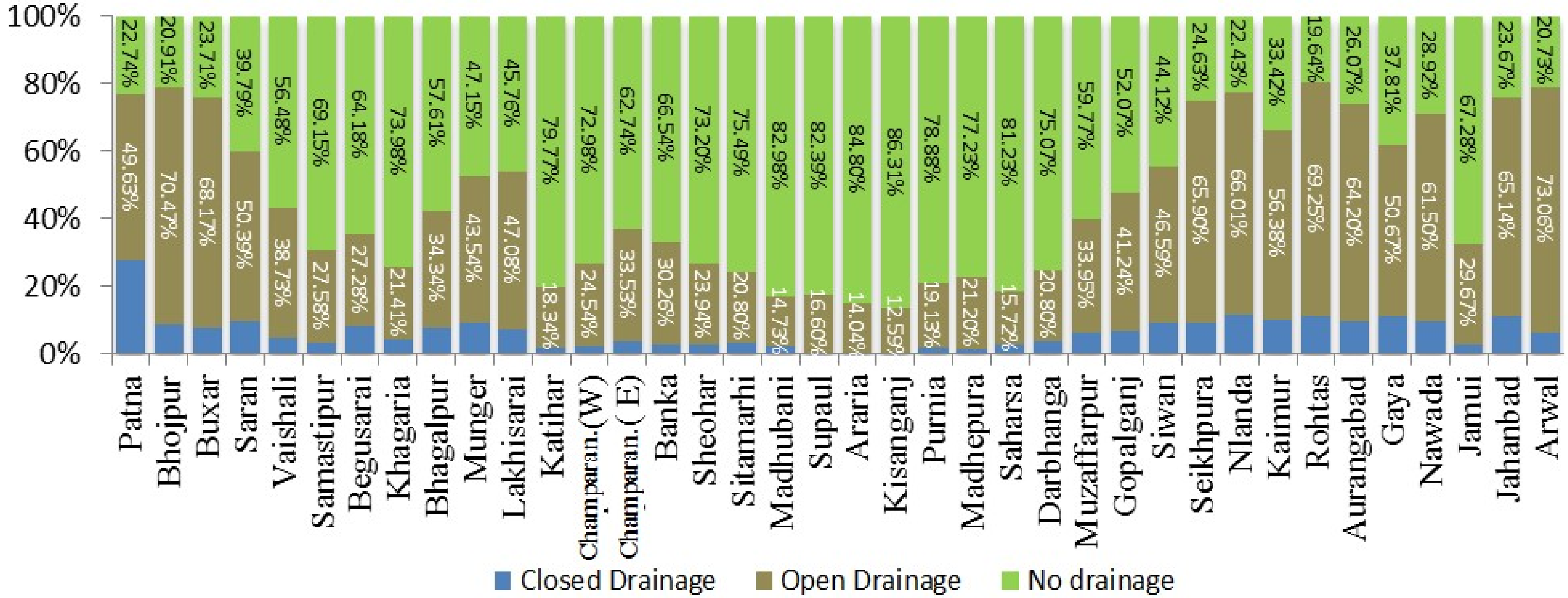
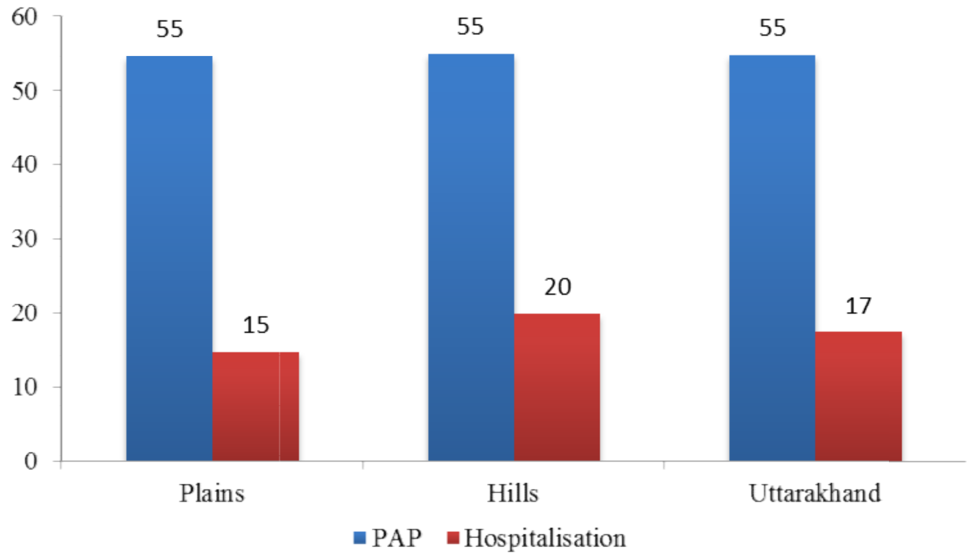


Figure 30: Distribution of Households by Main Types of Drainage in Bihar (2011)

8.4 Morbidity

8.4.1 General Morbidity by Proportion of Ailing Persons (PAP) and Number (per 1000) of Persons Hospitalised

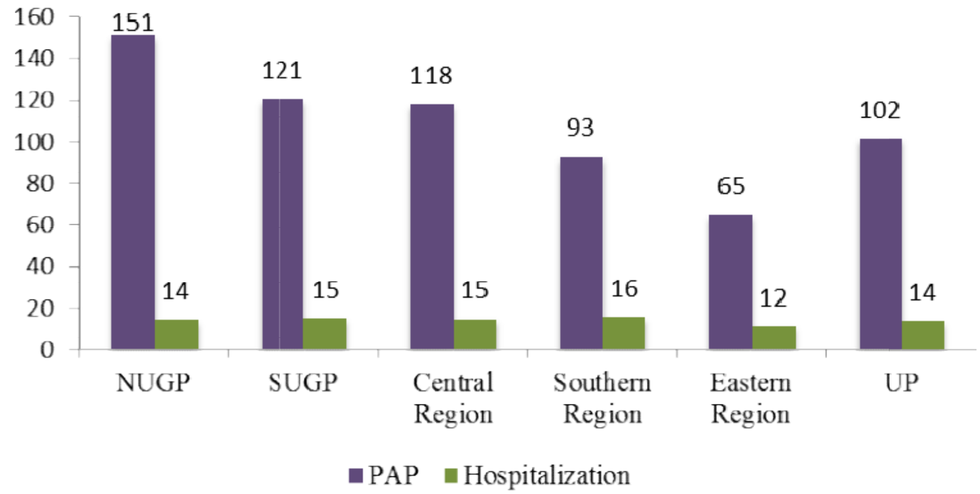
Figure 31 presents estimates on prevalence of morbidity in terms of Proportion of Ailing Persons (PAP) and Number of Persons Hospitalised (per 1000) in Uttarakhand. The PAPs estimate for overall Uttarakhand (including plains and hills) stands at 55 per 1000 persons. However, the number of persons hospitalized (per 1000) is found to be more in hills (22 per 1000) than in plains (15 per 1000) during 2004. Relatively poorer health in hill districts could be attributed to generally poor sanitation coverage and drainage infrastructure.



Source: NSS 60th round Unit level data, 'Morbidity, Health Care and the Condition of the Aged, Jan.-June, 2004'

Figure 31: Number (per 1000) of persons reporting ailment (PAP) during a period of 15 days and Number (per 1000) of persons hospitalised during 365 days in Uttarakhand, 2004

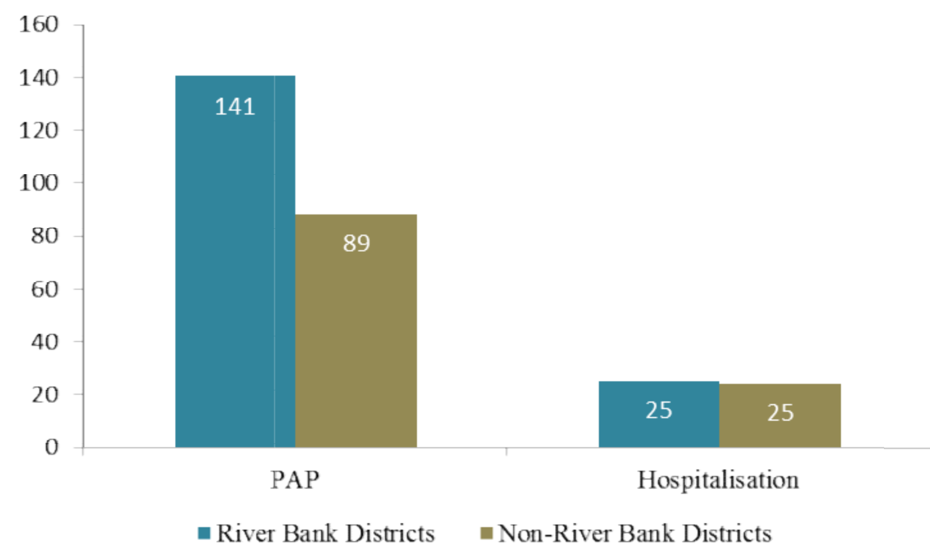
Figure 32 presents PAP and hospitalisation pattern across regions in UP in 2004. NUGP with PAP of 151 per 1000 was found to be highest while eastern region reported lowest at 65 per 1000. In NUGP 85% of the households had either open drainage or no drainage facility, 42% households were devoid of latrine facility and 56% households were using hand-pumps as a source of drinking water during 2011. Poor infrastructure and sanitation coverage coupled with the pressure of industrialisation and urbanisation in Western Uttar Pradesh (NUGP + SUGP) could be attributed to higher incidence of ailments.



Source: NSS 60th round Unit level data, 'Morbidity, Health Care and the Condition of the Aged, Jan.-June, 2004'

Figure 32: Number (per 1000) of persons reporting ailment (PAP) during a period of 15 days and Number (per 1000) of persons hospitalised during 365 days in Uttar Pradesh, 2004

Figure 33 presents PAP and hospitalisation pattern in West Bengal where there is a striking difference in ailments between 'river bank' and 'non-river bank' districts – the latter reporitng lower incidence than the former. It is noteworthy that in comparison to Uttarakhand PAP rates in UP and West Bengal are found to be significantly high, while the latter two are quite comparable.

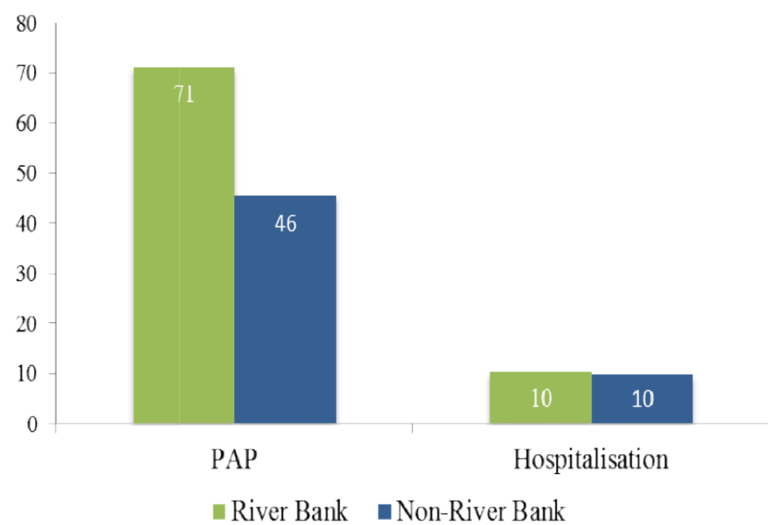


Source: NSS 60th round Unit level data, 'Morbidity, Health Care and the Condition of the Aged, Jan.-June, 2004'

Figure 33: Number (per 1000) of persons reporting ailment (PAP) during a period of 15 days and Number (per 1000) of persons hospitalised during 365 days in West Bengal, 2004

As shown in Figure 34 in Bihar also PAP was found lower in 'non-river bank' districts compared to 'river bank' districts. Interestingly PAP rate in non-river bank districts of Bihar is found to be even better than what is reported all across Uttarakhand.

With rather limited information on causative factors it is difficult to draw conclusions, but one trait that appears to be emerging is that with lower level of urbanisation, industrialisation and lower pressure of population lesser number of people have been reporting ailments. Besides water and sanitation, possibly the less stressful lifystyle and fresher air could also be contributing to lower level of ailments in Uttarakhand and parts of Bihar.



Source: NSS 60th round Unit level data, 'Morbidity, Health Care and the Condition of the Aged, Jan.-June, 2004'

Figure 34: Number (per 1000) of persons reporting ailment (PAP) during a period of 15 days and Number (per 1000) of persons hospitalised during 365 days in Bihar, 2004

9. Conclusions and Policy Implications

India spends a little over 4% of GDP on health. Public expenditure on health (both plan & non-plan and taking Centre and States together) consisted of 1.04% of GDP in 2011-12 (GOI, 2012). Private sector constitutes about 75% of total healthcare expenditure in India. Out-of-pocket expenditure alone comprised about two-third of total expenditure on health. Contamination of drinking water due to point and non-point sources of pollution, including open defecation increase incidence of water borne diseases. Diarrhoeal diseases are the second leading cause of death among children under five years of age. Economically marginalized people suffer more due to contaminated water and poor sanitation and hygiene conditions as they cannot afford to buy costly water purifiers and other sanitary and hygiene related facilities. Therefore, preventive measures can be more cost effective than the curative measures as these measures would ensure better health of the people and also prevent loss of productivity and missed educational opportunity that may occur due to morbidity among the workers and school going children. Human Development Report 2006 recognizes that 'water and sanitation are the most powerful preventive medicines available to governments to reduce the rate of infectious diseases'. About 1.5 million children under five years, which die every year in India due to water-borne diseases, could be saved if quality of water, sanitation and hygiene are improved. It is in this context that this study has been carried out to examine three inter-related issues—water, sanitation and health—in the Ganga basin and attempts to link the access to safe drinking water and sanitation facilities, including type of toilets and drainage facility with the intensity of water-related and water-borne diseases. Key Findings of the study are summarized in the following points:

9.1 Summary of Findings and Conclusions

1. Overall health profile was found better in West Bengal and Uttarakhand than Uttar Pradesh and Bihar, which may be attributed to better public healthcare infrastructure in these states.

2. Public healthcare infrastructure in the Ganga Basin states was inadequate to meet the requirement. On an average, the actual number of sub-centres, PHCs and CHCs in position met only 65%, 63%, and 37% of the requirement, respectively in 2012. Among the basin states, Bihar shows alarming situation in terms of deficit in healthcare infrastructure.

3. In India, about 44% of households use tap water as source of drinking water, while corresponding percentage in the Ganga Basin is only 22%. In the Ganga Basin, hand pump is the main source of drinking water for 65% of the households.

4. There has been some improvement in access to safe drinking water in both rural and urban areas in the basin states. However, increasing access of households to tap/hand pump/tube well water does not mean that the households have clean and safe drinking water. There may be possibility of contamination of drinking water due to pollution of ground or surface water resources. This is the reason that some households spend lots of money to treat at point of use.

5. Percentage of households treating water at point of use was higher in non-basin states (34%) than the basin states (3.5%). Within the Ganga Basin, the highest percentage of such households was found in Uttarakhand and West Bengal (~8%). Rural-urban difference was also observed in this regard. As against 11% of urban households resorting to treatment at point of use in the basin, there were only 1.3% such households in rural areas. The difference was observed highest in Uttarakhand, followed by West Bengal. As far as purification of water before drinking is concerned, the condition of households was quite dismal in Uttar Pradesh and Bihar.

6. Out of total urban households who reported use of any method of water purification in the Ganga Basin, about 14% used RO, while the corresponding percentage in non-basin states was only 5. In rural areas, proportion of such households was quite less (4.58% in the Ganga Basin and 0.70% in the non-basin states).

7. In Ganga basin, only 3 households per 1000 used water bottles as compared to 52 households per 1000 in non-basin states and 16 households per 1000 in India. In urban areas only 7 households per 1000 consumed bottled water in the Ganga Basin, while the corresponding numbers in non-basin states and India were 129 and 31 respectively. This suggests that proportion of households using bottled water for drinking water was higher in non-basin than the basin states. Within Ganga Basin, Uttarakhand has the highest proportion of households using bottled water in both rural (22 households per 1000) and urban (37 households per 1000) areas.

8. In Uttar Pradesh, bottled water was used only in 7 districts, viz., G B Nagar (35.62% of hhs), Kanpur Nagar (25.44% of hhs), Agra (13.39% of hhs), Bulandshahr (9.99% of hhs), Mau (6.98% of hhs), Varanasi (5.86% of hhs) and Ghaziabad (2.73% of hhs). Poor quality of water supply, high level of hardness in groundwater, rising income of households, increasing concern on health, among others are main reasons for rising reliance on bottled water.

9. About 13 million households in urban areas and 2.12 million households in rural area used RO to purify drinking water in the Ganga basin. The agrigate cost of using ROs by these households works out to be about Rs. 1,52,100 million (37% of total cost of ROs in India).

10. Total expenditure on bottled water used by households in the Ganga Basin is estimated to be Rs.1,423 million which constitues 5.75% of total expenditure on bottled water in India.

11. Notwithstanding increase in access to sanitation duirng 2001-2011, it is shocking to note that more than 60% of the households in the Ganga Basin did not have toilet facility within premises. Bihar, UP and West Bengal have reported widespread open defecation in the range of 41-75%.

12. On an average, proportion of ailing persons (PAP) was higher in urban than rural areas. The urban-rural difference in the PAP was higher in the Ganga Basin (2.6% point), than the national average (1.1% point). Further, PAP in both rural and urban areas was observed higher in the Ganga Basin than the non-basin states. Within the basin states, the intensity of morbidity measured in terms of PAP was highest in West Bengal, followed by Uttar Pradesh in rural and urban areas both. It was least in rural Bihar and Uttarakhand which is attributed to, among others, less stressful lifestyle, fresh air and water, etc.

13. Number of persons hospitalised per 1000 population varies significantly across rural and urban areas and age groups and it is difficult to draw any conclusions. For instance while Uttarakhand reports low PAP, but it also had highest number of persons hospitalised per 1000 in rural areas. On the otherhand while rural areas of Bihar reported lowest PAP, it also has lowest hospitalisation rates.

14. Both rural and urban areas have been significantly affected by diarrhoea/ dysentery and ‘fever of unknown origin’. Rural and urban households in Bihar and West Bengal and urban households in Uttar Pradesh were significantly affected by Diarrhoea/ dysentery. The study further finds that water borne diseases have led to higher rates of hospitalisation in the basin states than the non-basin states.

15. The share of Ganga basin in India’s total public expenditure on health has increased from 17.71% in 2001-02 to 18.27% in 2004-05, while that of private sector has declined from 34.15% to 27.22% during the same years. However, private sector still accounts for a major share in the overall expenditure on health.

16. The budgetary allocation on health sector in the basin has gone up from Rs.4,908.5 crores during the 10^{th} Plan to Rs.20,098.4 crores during the 11^{th} Plan. While in all other states the allocation during the same time period has increased substantially, surprisingly in the case of Bihar it went down from Rs.1079 crores to Rs.873 crores. This could be attributed to, among others, challenges in governance, political instability and lack of initiatives for implementation.

17. Total expenditure per treated ailment varied widely across the basin states. In rural areas, it varied from Rs.225 in West Bengal to Rs. 551 in Uttarakhand, and in the urban areas, from Rs.266 in Uttarakhand to Rs. 372 in Bihar. Interestingly, contrary to what is observed for most of the states as well as for the country as a whole, Uttar Pradesh and Uttarakhand reported higher expenditure per treated ailment in rural areas than in urban areas.

18. Loss of income due to illness put additional burden on households. The loss of income per ailment was observed highest in Bihar (Rs. 585), followed by Uttar Pradesh (Rs. 152) in rural areas. In urban areas also, the loss was estimated to be highest in Bihar (Rs. 150), followed by Uttar Pradesh (Rs. 117). Prevention of morbidly would not only reduce the burden of medical expenditure but also help to reduce the loss of productivity in the economy. It is also significant to note that loss of household income per ailment in rural areas of Bihar was even higher than the actual expenditure on treatment.

9.2 Recommendations

This study argues that health status of people of the Ganga basin can be improved and burden of diseases be reduced if access to safe drinking water and proper sanitary & drainage facilities are provided. Providing tap/hand pump water to the households may not always be considered as safe water if the very source of the water is polluted and contaminated due to point and non-point of sources of pollution. It is, therefore, necessary that no industrial effluents, domestic sewage, and pesticides & chemical fertilizers should go into the ground and surface water sources. For that, water, sanitation, health and environment related issues are required to be addressed in an integrated manner. This study suggests the following actionable points for the GRBEMP:

1. For properly functioning water supply and sanitation services, capacity of local self-government institutions be improved. Under 73rd and 74th constitutional amendments, water, sewage and sanitation are the subjects of these institutions. Apart from equipping them with trained staff and sufficient funds, elected members of these institutions be sensitized and made aware of the tangible and intangible benefits of proper operation construction, management and maintenance of safe drinking water and sanitation services. A clean hygienic environment can be ensured only when people make demand for clean water and integrated sanitation & sewage system. Therefore, with the involvement of civil society organizations, local demand for improved water and sanitation services should be created so that delivering institutions be pressurized to improve quality of services.

2. In rural areas, Gram Panchayats should be entrusted the task of formulation and implementation of village master plan for water supply, sewage and drainage with the technical assistance from line departments. Open air defecation should be discouraged to prevent water-borne diseases.

3. Public toilets may not be effective in providing sanitation services due to maintenance problems. Likewise indiscriminate construction of individual household latrines is not leading to desired outscome because quality of construction is very poor.There is a strong need to create capacity at the lowest level for proper implementation, supervision and monitoirng.

4. There is also an overarching need to promote sustainable on-site sanitation, especially in rural and semi-urban areas across the entire Ganga basin, whereby potential pollution arising from excreta/ sewage discharges can be minimised and a reasonable level of 'resource' recovery could be achieved. There is an urgent need to explore 'out of the box' solutions.

5. Monitoring quality of drinking water by the government machinery would not be feasible and economically viable in rural areas. There is need to train at least five young persons in each village in the areas of water, sanitation and health so that they may periodically monitor quality of drinking water, educate households about the benefits of safe drinking water and improved sanitation, and establish the link with the healthcare service providers. These trained youths should also be involved in maintaining the socio-economic, demographic and health related database at village level. Maintenance of such database is necessary to design, formulate and implement effective grassroots level sustainable community development works. These trained youths may be paid appropriate stipend/ remuneration by the respective Gram Panchayats.

6. As discussed in our report on "urbanization and industrialization", most of the cities/ towns in the basin do not have proper effluent and sewage treatment and disposal system. It is not only essential to build sewerage network, but also a cost-effective wastewater treatment and recycling system to prevent negative health consequences of urbanization and industrialization. It is envisioned that all cities of the basin would have sewage system properly integrated with toilets and sewage treatment plants.

7. There is a need to change households' behavioural and cultural practices related to water and sanitation. Disposal of solid and liquid wastes and open defecation should be restricted through effective regulation.

Notes

1. http://www.frost.com/prod/servlet/press-release.pag?docid=248728723
2. http://www.wssinfo.org/definitions-methods/watsan-categories/

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Appendix Tables

Table A1: Detailed description of water related diseases and its associated terms

Category	Description of category	Type of water exposure	Subcategories	Example(s)
Water-borne micro-biological disease	Diseases related to consumption of pathogens consumed in water; most due to human or animal faecal contamination of water	Drinking water	(i) Treated or untreated (raw) water (ii) Public (municipal) supplies or private supplies	Cholera, Typhoid fever, viral gastroenteritis e.g. due to Norovirus
Waterborne chemical disease	Disease related to ingestion of toxic substances in water	Drinking water	(i) Treated or untreated (raw) water (ii) Public (municipal) supplies or private supplies	Arsenicosis
Water hygiene diseases	Diseases whose incidence, prevalence or severity can be reduced by using safe (clean) water to improve personal and domestic hygiene	Any water used for washing/ personal hygiene	(i) Disease related to variations in water quality (ii) Disease related to water Shortage	Scabies, shigellosis; trachoma
Water contact diseases	Caused by skin contact with pathogen- infested water or with chemical-contaminated water	Recreational water	(i) fresh water sources (ii) marine waters	Schistosomiasis (bilharzia); cyanobacteria
Water vector habitat diseases	Diseases where vector lives all or part of its life in or adjacent to a water habitat	Untreated freshwater sources	(i) rivers, streams (ii) small collections of stagnant water e.g. water butts	Malaria (mosquitoes); filiariasis (mosquitoes); onchocerciasis (aquatic flies); schistosomiasis (snails); trypanosomiasis (tsetse flies)
Excreta disposal diseases	Diseases related to unsanitary disposal of human waste (faeces and urine)	Drinking water and untreated water sources	(i) diseases related to human/animal waste in drinking water (ii) diseases related to direct/ indirect contact with faeces/ urine	Ascariasis; faecal-oral infections e.g. shigellosis; schistosomiais; trachoma
Water aerosol diseases	Diseases related to respiratory transmission, where a water aerosol	Drinking or raw water sources	(i) water used in industrial/ residential buildings (ii) raw water sources	Legionellosis (legionnaires' disease; humidifier

Source: WATER AND HEALTH – Vol. I - Classification of Water-Related Disease - R Stanwell-Smith

Table A2: Distribution of Persons Hospitalised (Per 1000 Population) By Type Of Ailment

AILMENTS	U.P		U.K.		BIHAR		W.B.		GANGA		OTHERS		INDIA	
	R	U	R	U	R	U	R	U	R	U	R	U	R	U
Gastro-intestinal														
Diarrhoea/ dysentery	70	94	53	31	147	112	163	90	116	92	65	56	76	62
Gastritis/gastric or peptic ulcer	62	48	180	93	63	32	54	46	62	48	45	38	48	39
Worm infestation	9	7	0	13	3	2	3	3	6	5	3	4	4	4
Amoebiosis	5	8	8	0	3	5	1	3	3	5	3	3	3	4
Hepatitis/Jaundice	17	20	0	58	14	19	11	24	14	23	15	21	15	22
Cardiovascular Diseases														
Heart disease	33	52	37	136	33	59	56	82	42	68	43	83	43	80
Hypertension	12	20	10	0	6	34	6	18	9	19	21	35	18	32
Respiratory including ear/nose/throat ailments	27	25	45	14	11	15	37	30	28	27	37	30	35	30
Tuberculosis	35	25	27	0	50	25	24	19	33	22	30	17	30	17
Bronchial asthma	27	24	7	0	20	4	15	37	21	28	38	31	34	30
Disorders of joints and bones	14	37	106	34	29	39	5	13	16	26	27	26	25	26
Diseases of kidney/urinary system	37	38	59	84	36	31	39	53	38	46	37	50	37	49
Prostatic disorders	5	4	0	0	12	28	14	12	10	9	2	3	4	4
Gynecological disorders	66	45	30	17	72	87	38	43	56	46	51	52	52	50
Neurological disorders	23	23	4	0	50	35	22	17	27	20	33	35	32	32
Psychiatric disorders	15	11	2	0	10	2	5	10	10	10	10	5	10	6
Eye ailments														
Conjunctivitis	3	3	0	0	5	7	0	0	2	2	2	2	2	2
Glaucoma	19	46	0	0	6	4	3	10	10	27	3	3	5	7
Cataract	34	34	29	6	37	38	19	40	29	36	29	21	29	24
Diseases of skin	5	2	3	0	5	2	5	1	5	1	6	7	6	6
Goitre	0	0	0	0	0	0	0	0	0	0	1	2	1	1
Diabetes mellitus	14	12	0	59	6	17	2	13	8	14	20	26	18	24
Under-nutrition	1	1	0	0	2	5	2	0	1	1	1	2	1	2
Anaemia	7	2	0	0	4	15	12	6	8	4	9	12	9	11

AILMENTS	U.P		U.K.		BIHAR		W.B.		GANGA		OTHERS		INDIA	
	R	U	R	U	R	U	R	U	R	U	R	U	R	U
Sexually transmitted diseases	3	0	0	0	3	2	0	0	2	0	2	1	2	1
Febrile illnesses														
Malaria	6	11	0	0	12	2	23	10	13	10	37	42	32	36
Eruptive	0	2	0	0	1	0	0	0	0	1	4	1	3	1
Mumps	1	0	0	0	0	0	0	0	1	0	1	0	1	0
Diphtheria	1	2	0	0	1	0	0	0	0	1	2	5	1	4
Whooping cough	2	1	0	0	1	0	1	2	1	1	8	7	7	6
Fever of unknown origin	54	67	45	7	37	18	24	26	40	45	90	73	79	68
Tetanus	13	3	0	0	8	0	6	1	9	2	1	2	3	2
Filariasis/Elephantiasis	3	3	0	0	2	4	1	0	2	2	1	1	1	1
Disabilities														
Locomotor	19	6	19	0	20	6	6	11	14	8	13	9	13	9
Visual including blindness (excluding cataract)	5	1	0	0	4	0	1	0	3	0	4	4	4	3
Speech	0	0	0	0	0	0	6	0	2	0	0	0	1	0
Hearing	1	1	13	0	1	0	0	2	1	1	2	1	2	1
Diseases of Mouth/Teeth/Gum	2	1	0	0	3	3	3	0	3	0	2	2	2	2
Accidents/Injuries/Burns /Fractures/Poisoning	118	103	172	136	76	135	137	78	119	94	96	87	101	88
Cancer and other tumours	33	28	7	19	15	25	26	37	27	32	29	32	28	32
Others														
Other diagnosed ailments	174	176	132	263	166	158	185	253	176	212	161	155	164	166
Other undiagnosed ailments	25	14	12	29	28	29	44	10	32	13	16	15	19	15
TOTAL	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Source: Unit level records of NSS 60th round Unit level data, 'Morbidity, Health Care and the Condition of the Aged, Jan.-June, 2004'

Table A3: Number of Cases and Deaths due to water borne and vector -borne diseases

Diseases	Year	Uttarakhand		Uttar Pradesh		Bihar		West Bengal		Ganga Basin		India	
		Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths
Cholera	2001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2005	0	0	2	0	0	0	236	0	238	0	3155	6
	2011	0	0	9	0	0	0	652	0	661	0	2341	10
Acute Diarrhoeal Disease	2001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2005	48480	4	108147	73	NR	NR	1347500	545	1504127	622	9046892	1647
	2011	79643	26	554770	185	130276	0	1854651	288	2619340	499	10231049	1269
Enteric Fever (Typhoid)	2001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2005	4515	0	9691	22	NR	NR	54680	55	68886	77	567638	389
	2011	13760	1	117537	80	NR	NR	127180	34	273264	115	1062446	346
Viral Hepatitis (All Causes)	2001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2005	884	1	307	5	NR	NR	4837	114	6028	120	152087	651
	2011	3143	19	7749	28	202	0	5480	105	16574	152	94402	520
Japanese Encephalitis	2001	0	0	1005	199	48	11	119	21	1172	231	2061	479
	2005	0	0	6061	1500	192	64	12	6	6265	1570	6727	1682
	2011	0	0	3492	579	821	197	714	58	5027	834	8249	1169
Malaria	2001	1196	0	94524	15	4108	0	145053	191	244881	206	2085484	1005
	2005	1242	0	105303	0	2733	1	185964	175	295242	176	1816342	963
	2011	1162	2	56438	0	2390	0	66465	14	126455	16	1278760	463
Dengue	2001	0	0	21	0	0	0	0	0	21	0	3306	53
	2005	0	0	121	4	0	0	6375	34	6496	38	938	8
	2011	100	0	147	5	21	0	510	0	778	5	18059	119

Source: National Health Profile of India Reports (2005-2011)

Note: NR- Not Reported, NA- Not Available

Table A4: District-wise No. of Sub Centres, PHCs, CHS per 1000 Population in Bihar, 2011

Districts	Sub Centres	PHCs	CHCs	Districts	Sub Centres	PHCs	CHCs
Begusarai	10.29	72.06	1477.18	Gopalganj	13.12	73.09	852.68
Bhojpur	10.04	72.20	1010.74	Jamui	6.29	30.81	585.36
Bhagalpur	10.54	38.31	906.72	Jehanabad	12.22	27.42	562.09
Buxar	11.62	48.79	(-)	Kaimur (Bhabua)	8.89	54.23	813.45
Katihar	9.30	49.49	3068.15	Kishanganj	12.43	105.68	845.47
Khagaria	9.69	63.75	1657.60	Madhepura	7.33	55.41	(-)
Lakhisarai	9.81	45.49	1000.72	Madhubani	10.31	50.86	1492.01
Munger	9.00	45.30	(-)	Muzaffarpur	9.96	50.84	4778.61
Patna	14.92	67.92	1924.27	Nalanda	7.68	43.52	957.51
Samastipur	11.75	65.46	4254.78	Nawada	6.82	33.08	1108.33
Saran	9.55	62.59	1314.37	Purnia	9.80	74.39	1636.56
Vaishali	10.43	74.37	1165.08	Rohtas	15.93	58.09	1481.30
Araria	14.10	85.04	1403.10	Saharsa	12.48	45.17	(-)
Arwal	10.93	24.98	(-)	Sheikhpura	7.47	27.61	634.93
Aurangabad	11.63	35.87	837.08	Sheohar	22.65	54.74	656.92
Banka	7.66	47.19	676.45	Sitamarhi	16.13	63.33	1709.81
Darbhanga	15.14	71.31	1960.99	Siwan	9.04	54.40	1106.06
Champaran**(E)**	15.54	69.63	5082.87	Supaul	12.52	71.88	1114.20
Gaya	9.95	61.68	2189.69	Champaran (W)	10.66	74.01	1961.39

Source: RHS Bulletin, Ministry of Health & Family Welfare

Table A5.1: Medical Colleges in Uttar Pradesh with No. of Beds Attached (2011)

District/city/town	Government	Private	No. of Beds in Attached Hospital
Agra	1	0	1047
Aligarh	1	0	NA
Allahabad	1	0	850
Ambedkarnagar	1	0	NA
Barabanki	0	1	350
Bareilly	0	2	1250
Etawah	1	0	750
Farrukhabad	0	1	350
Ghaziabad	0	2	700
Gorakhpur	1	0	NA
Hapur	0	1	500
Jhansi	1	0	700
Kanpur	1	0	1825
Kanpur	0	1	1000
Lucknow	1	2	3900
Meerut	1	1	1840
Moradabad	0	1	550
Muzaffarnagar	0	1	500
Noida	0	1	500
Varanasi	1	0	1200
Uttar Pradesh	**11**	**14**	**17812**
Source: National Health Profile, 2011			

Table A5.2: Medical Colleges in Uttarakhand with Number of Beds (2011)

District/city/town	Government	Private	No. of Beds in Attached Hospital
Nainital	1	0	600
Dehradun	0	2	1450
P. Garhwal	1	0	300
Uttarakhand	2	2	2350
Source: National Health Profile, 2011			

Table A5.3: Medical Colleges in Bihar with no of Beds (2011)

District/city/town	Government	Private	No. of Beds in Attached Hospital
Patna	3	0	2927
Gaya	1	0	544
Lakhisarai	1	0	1030
Bhagalpur	1	0	659
Kisanganj	0	1	NA
Katihar	0	1	NA
Saran	0	1	500
Muzaffarpur	1	0	500
Bihar	**7**	**3**	**6160**

Source: National Health Profile, 2011

Table A5.4: Medical Colleges in West Bengal with Number of Beds (2011)

District/city/town	Government	Private	No. of Beds in Attached Hospital
Bankura	1	0	1217
Burdwan	1	0	NA
Kolkata	6	1	1966
Purba Medinipur		1	500
Paschim Medinipur	1		561
Maldah	1		600
Nadia	1	0	440
Darjeeling	1		599
West Bengal	**12**	**2**	**5883**

Source: National Health Profile, 2011

Table A6: Proportion of households treating water before drinking and per 1000 distribution of such households by type of water treatment, Uttarakhand (2004)

Districts	Sectors	Ultra-violet/ resin/reverse osmosis	Filter	Boiling	Others	No. per 1000 Treating water Before drinking
Dehradun	Rural	(---)	(---)	(---)	(---)	(---)
	Urban	33.61%	25.05%	23.38%	17.97%	199
Pithoragarh	Rural	(---)	(---)	(---)	(---)	(---)
	Urban	0.00%	98.92%	1.08%	0.00%	900
Champavat	Rural	(---)	(---)	(---)	(---)	(---)
	Urban	0.00%	0.00%	100.00%	0.00%	19
Almora	Rural	(---)	(---)	(---)	(---)	(---)
	Urban	0.00%	7.81%	92.19%	0.00%	777
U S Nagar	Rural	(---)	(---)	(---)	(---)	(---)
	Urban	0.00%	100.00%	0.00%	0.00%	5
Hardwar	Rural	100.00%	0.00%	0.00%	0.00%	1
	Urban	12.10%	5.83%	82.07%	0.00%	90
UK	Rural	100.00%	0.00%	0.00%	0.00%	1
	Urban	6.03%	40.83%	50.47%	2.67%	305

Source: NSS 60th round Unit level data, 'Morbidity, Health Care and the Condition of the Aged, Jan.-June, 2004

Table A7: Proportion of households treating water before drinking and per 1000 distribution of such households by type of water treatment, Bihar (2004)

Districts	Sectors	Ultra-violet/ resin/reverse osmosis	Boiling	Filter	Cloth screen	Others	No. per 1000 Treating water Before drinking
Champaran(W)	Rural	(--)	(--)	(--)	(--)	(--)	(--)
	Urban	0%	0%	100%	0%	0%	22
Champaran(E)	Rural	(--)	(--)	(--)	(--)	(--)	(--)
	Urban	0%	0%	100%	0%	0%	54
Purnia	Rural	(--)	(--)	(--)	(--)	(--)	(--)
	Urban	0%	0%	100%	0%	0%	69
Katihar	Rural	0%	100%	0%	0%	0%	1
	Urban	(--)	(--)	(--)	(--)	(--)	(--)
Muzaffarpur	Rural	0%	100%	0%	0%	0%	7
	Urban	0%	0%	100%	0%	0%	180
Siwan	Rural	0%	0%	11%	0%	89%	12
	Urban	(--)	(--)	(--)	(--)	(--)	(--)
Saran	Rural	(--)	(--)	(--)	(--)	(--)	(--)
	Urban	0%	0%	100%	0%	0%	161
Vaishali	Rural	50%	50%	0%	0%	0%	2
	Urban	(--)	(--)	(--)	(--)	(--)	(--)
Samastipur	Rural	0%	77%	23%	0%	0%	12
	Urban	(--)	(--)	(--)	(--)	(--)	(--)
Bhagalpur	Rural	0%	100%	0%	0%	0%	8
	Urban	0%	0%	100%	0%	0%	8
Munger	Rural	(--)	(--)	(--)	(--)	(--)	(--)
	Urban	0%	1%	99%	0%	0%	182
Patna	Rural	0%	0%	0%	100%	0%	28
	Urban	0%	1%	97%	0%	2%	67
Kaimur (Bhabua)	Rural	0%	0%	0%	100%	0%	4
	Urban	(--)	(--)	(--)	(--)	(--)	(--)
Gaya	Rural	(--)	(--)	(--)	(--)	(--)	(--)
	Urban	0%	100%	0%	0%	0%	37
Bihar	Rural	2%	41%	6%	38%	13%	3
	Urban	0%	4%	95%	0%	1%	63

Source: NSS 60th round Unit level data, 'Morbidity, Health Care and the Condition of the Aged, Jan.-June, 2004

Table A8: Proportion of households treating water before drinking and per 1000 distribution of such households by type of water treatment, WB (2004)

Districts	Sectors	RO	Boiling	Filter	Cloth Screen	Any disinfectant	Others	No. per 1000 Treating water Before drinking
Darjiling	Rural	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	52
	Urban	0.00%	28.40%	67.30%	0.00%	0.00%	4.31%	249
Jalpaiguri	Rural	0.00%	76.97%	23.03%	0.00%	0.00%	0.00%	61
	Urban	0.00%	0.00%	33.29%	0.00%	3.14%	63.57%	271
Koch Bihar	Rural	0.00%	89.81%	10.19%	0.00%	0.00%	0.00%	21
	Urban	(--)	(--)	(--)	(--)	(--)	(--)	(--)
Uttar Dinajpur	Rural	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	6
	Urban	0.00%	5.49%	94.51%	0.00%	0.00%	0.00%	126
Dakshin Dinajpur	Rural	(--)	(--)	(--)	(--)	(--)	(--)	0
	Urban	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	59
Maldah	Rural	0.00%	2.73%	0.00%	0.00%	19.27%	78.00%	17
	Urban	(--)	(--)	(--)	(--)	(--)	(--)	0
Murshidabad	Rural	0.00%	27.15%	2.10%	27.04%	4.51%	39.20%	35
	Urban	9.67%	0.00%	84.72%	5.62%	0.00%	0.00%	304
Birbhum	Rural	0.00%	0.00%	8.91%	87.05%	0.00%	4.04%	43
	Urban	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	39
Barddhaman	Rural	0.00%	0.00%	9.32%	0.00%	90.68%	0.00%	14
	Urban	0.00%	2.23%	95.53%	2.24%	0.00%	0.00%	166
Nadia	Rural	0.00%	0.00%	2.51%	15.52%	36.53%	45.44%	28
	Urban	0.00%	5.10%	86.47%	8.43%	0.00%	0.00%	74
North 24-Parganas	Rural	0.00%	12.61%	87.39%	0.00%	0.00%	0.00%	9
	Urban	14.53%	10.13%	71.86%	0.22%	3.25%	0.00%	241
Hugli	Rural	0.00%	0.00%	12.27%	6.98%	0.00%	80.75%	11
	Urban	17.06%	23.13%	59.81%	0.00%	0.00%	0.00%	129
Bankura	Rural	0.00%	12.12%	6.94%	44.38%	36.56%	0.00%	125
	Urban	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	324
Puruliya	Rural	0.00%	32.00%	1.03%	60.65%	6.32%	0.00%	47
	Urban	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	77
Medinipur	Rural	8.24%	55.23%	36.08%	0.00%	0.45%	0.00%	40
	Urban	8.02%	8.80%	75.02%	0.00%	0.00%	8.16%	366
Howrah	Rural	0.00%	31.95%	68.05%	0.00%	0.00%	0.00%	94
	Urban	17.36%	10.57%	72.07%	0.00%	0.00%	0.00%	123
Kolkata	Rural	(--)	(--)	(--)	(--)	(--)	(--)	(--)
	Urban	31.29%	1.20%	64.42%	2.85%	0.25%	0.00%	227
South 24-Parganas	Rural	0.00%	0.00%	65.36%	34.64%	0.00%	0.00%	34
	Urban	3.59%	9.86%	74.36%	12.19%	0.00%	0.00%	70
West Bengal	Rural	1.36%	29.75%	25.33%	21.46%	11.51%	10.59%	35
	Urban	16.20%	6.92%	72.22%	1.88%	1.10%	1.68%	188

Source: NSS 60th round Unit level data, 'Morbidity, Health Care and the Condition of the Aged, Jan.-June, 2004

Table A9 : Distribution of Households by Main sources of Latrine (2011) , Bihar

	Districts	Water Closet	Pit Latrine	others	No latrine
Bank Districts	1. Begusarai	25.58%	5.24%	0.50%	68.69%
	2. Bhagalpur	27.02%	5.96%	0.74%	66.28%
	3. Bhojpur	24.71%	1.87%	0.61%	72.81%
	4. Buxar	22.86%	1.39%	0.46%	75.29%
	5. Katihar	13.23%	3.86%	0.42%	82.49%
	6. Khagaria	18.78%	4.39%	0.65%	76.18%
	7. Lakhisarai	26.61%	4.62%	0.59%	68.18%
	8. Munger	33.05%	4.77%	1.00%	61.18%
	9. Patna	48.66%	3.52%	0.83%	46.99%
	10. Samastipur	16.31%	2.18%	0.26%	81.25%
	11. Saran	19.82%	1.16%	0.45%	78.57%
	12. Vaishali	23.52%	3.28%	0.38%	72.83%
	Districts	**Water Closet**	**Pit Latrine**	**others**	**No latrine**
Non-Bank districts	1. Araria	7.62%	1.48%	0.26%	90.64%
	2. Aurangabad	19.98%	1.32%	0.48%	78.22%
	3. Banka	10.97%	1.04%	0.24%	87.75%
	4. Darbhanga	21.72%	2.95%	0.46%	74.87%
	5.Champaran (E)	16.50%	1.43%	0.31%	81.76%
	6. Gaya	20.77%	2.74%	0.72%	75.78%
	7. Gopalganj	18.14%	1.38%	0.50%	79.98%
	8. Jahandab	23.56%	2.04%	0.55%	73.85%
	9. Jamui	11.96%	2.43%	0.44%	85.17%
	10. Kaimur	15.31%	0.99%	0.42%	83.27%
	11. Kisangan	8.10%	1.98%	0.30%	89.62%
	12.Madhepura	10.56%	2.23%	0.28%	86.94%
	13. Madhubani	16.27%	1.88%	0.38%	81.48%
	14.Muzzarfarpur	24.42%	2.26%	0.38%	72.94%
	15. Nalanda	26.31%	3.71%	0.70%	69.29%
	16. Nawada	18.69%	3.13%	0.47%	77.71%
	17. Purnia	10.81%	2.57%	0.32%	86.30%
	18. Rohtas	26.38%	1.19%	0.65%	71.78%
	19. Saharsa	13.89%	2.47%	0.37%	83.27%
	20. Seikhpura	22.78%	5.57%	0.58%	71.07%
	21. Sheohar	16.94%	3.08%	0.40%	79.58%
	22. Sitamarhi	18.61%	1.77%	0.40%	79.21%
	23. Siwan	20.74%	1.66%	0.48%	77.12%
	24. Supaul	9.31%	1.32%	0.20%	89.17%
	25. Champaran (W)	13.95%	1.51%	0.41%	84.13%

Sanitation in India

A Review of Current Scenario

GRBMP: Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay	IIT Delhi	IIT Guwahati	IIT Kanpur	IIT Kharagpur	IIT Madras	IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. A list of persons who have contributed directly and names of those who have taken lead in preparing this report is given on the reverse side.

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There is considerable awareness about community water supply needs, but the problems of excreta and sewage disposal, i.e., sanitation, has received less attention in India. The effects of poor sanitation seep into every aspect of human life be it health, welfare, economy, dignity, empowerment or environment.

To meet the country's sanitation challenge there is an urgent need to focus on proper collection and treatment of excreta and sewage and to build and maintain appropriate toilets for all. Government has spent and is still spending a lot of money to improve the state of sanitation, but majority of systems have failed due to various reasons.

In this report the currently available sanitation solutions have been critically assessed and analyzed to determine their relative merits and demerits, especially with regard to Indian conditions and sensibilities. The minimum requirements of an effective sanitation system have also been identified.

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Contents

1. Introduction

Sanitation is the most neglected sector in India. The general tendency is to just transport the waste out of sight; nobody is concerned about the fate of that waste, believing that that nature will automatically take care. But unfortunately that's not true; the effects of poor sanitation seep into every aspect of human life.

In India only 30% of urban households have access to sewer lines, while this percentage is almost zero in rural areas. Growing volumes of untreated sewage contaminate ground water and surface water. Rivers and drainage channels are carrying raw sewage. A large portion of the population has no access to toilets. These people cannot defecate in privacy and are forced to go out to defecate in open fields, near rivers or on railway tracks. To meet the country's sanitation challenge there is an urgent need to focus on building appropriate toilets, ensuring their quality, use and maintenance and further treat the waste from these toilets properly before disposal.

In the last few years, substantial funds have been spent by both central and state governments on building of the sanitation infrastructure in the country. However due to a variety of reasons including inappropriate sanitation solutions adopted, the results from such initiatives have been less than heartening, Even now, an unacceptably large percentage of Indian population have no access to toilets and hence practice open defecation.

There is an obvious need for good sanitation systems, which are complete in themselves, i.e. these systems should not compromise at any end. Therefore such systems must have certain important properties,

- **Disease prevention:** A sanitation system must be capable of destroying or isolating pathogens.
- **Environment protection:** A sanitation system must prevent pollution and conserve valuable water resources.
- **Nutrient recycling:** A sanitation system should return nutrients to the soil.
- **Affordability:** A sanitation system must be accessible to the poorest people.
- **Acceptability:** A sanitation system must be aesthetically inoffensive and consistent with cultural and social values.
- **Simplicity:** A sanitation system must be robust enough to be easily maintained with the limitations of the local technical capacity, institutional framework and economic resources.

Since a large number of sanitation options are currently available, it is important to do a critical evaluation of these in order to identify optimal solutions for a given scenario. In subsequent sections of this report, the currently available sanitation solutions have been analyzed to determine their relative merits and demerits, especially with regard to Indian conditions and sensibilities. The minimum requirements of an effective sanitation system have also been identified.

2. Sanitation

A WHO Study Group in 1986 formally defined 'sanitation' as "the means of collecting and disposing of excreta and community liquid wastes in a hygienic way so as not to endanger the health of individuals and the community as a whole". Safe disposal of excreta is of utmost importance for health and welfare of society and also for the social and environmental effects it may cause to the communities involved.

Ownership of a toilet does not always lead to better adoption of sanitation and hygiene practices. Often error in design, improper or no maintenance, lack of knowledge of proper usage of toilet and insufficient running water in the vicinity are the causes of dissatisfaction amongst users, resulting in a return to open defecation. Open defecation is practiced in India more than anywhere in the world (more than 600 million individuals) [1].

Most of the sanitation systems prevalent today are either based on storing human excreta in pits ('drop-and-store') or on flushing it away with water ('flush-and discharge'). Drop-and-store systems can be simple and relatively economical but have many drawbacks. Often they cannot be used at all in crowded areas, on rocky ground, where the groundwater level is high or in areas periodically flooded. They require access to open ground and the digging of new pits every few years. Flush-and-discharge systems require large amounts of water for flushing, and in many cases, unaffordable investments in pipe networks and treatment plants. Over a year for each person some 400-500 liters of urine and 50 liters of feces is flushed away with 15,000 liters of pure water.

According to World Health Organization, Sanitation can be classified as 'improved' and 'unimproved' as shown in Fig.2.1.

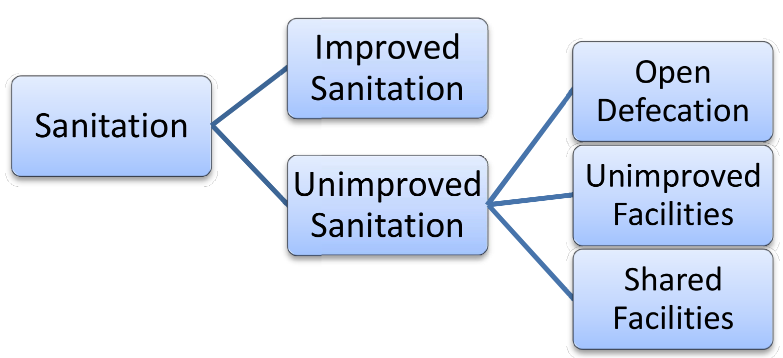


Figure 2.1: **Classification of Sanitation according to WHO**

2.1 Unimproved Sanitation

Systems which are unhygienic and/or lack proper technological inputs to facilitate a minimum comfort level are termed as unimproved sanitation. Following systems fall into this category:

2.1.1 Open Defecation

When human feces is disposed of in fields, forests, bushes, open bodies of water, beaches or on railway tracks or other open spaces or disposed of with solid waste [2].

2.1.2 Unimproved Facilities

These facilities do not ensure hygienic separation of human excreta from human contact. Unimproved facilities include pit latrines without a slab or platform, hanging latrines and bucket latrines [2].

2.1.3 Shared Sanitation Facilities

Sanitation facilities of an otherwise acceptable type shared between two or more households. Only facilities that are not shared or not public are considered improved, by WHO [2].

2.2 Improved Sanitation

Only facilities that are not shared or not public are considered improved, by WHO [2]. These are likely to ensure hygienic separation of human excreta from human contact. They include the following facilities [2]:

- Flush/pour flush to:
    - piped sewer system
    - septic tank
    - pit latrine
- Ventilated improved pit (VIP) latrine
- Pit latrine with slab
- Composting toilet

3. Toilets: Front End of a Sanitation System

The front end of a sanitation system should consist of a toilet or a urinal. A toilet should act as a user interface where people can defecate at ease. It is important to understand the working principle of different types of toilets; some toilets help in conveying the excreta safely, others even treat it on site. Some are dry whereas others use water to convey the waste. In this section different types of toilets are described and their advantages and disadvantages are discussed.

3.1 Pit Latrine

The pit latrine is one of the cheapest and most widely used toilets. It is essentially a pit in which excreta and anal cleansing water are disposed. The pit is enclosed by a superstructure to ensure privacy (see Fig. 3.1). To prevent people of falling into the pit, increase convenience and reduce odor, a slab with a hole is used to cover the pit. A toilet seat can be installed over the slab. [9] As the pit fills, two processes limit the rate of accumulation; leaching and degradation. Urine and anal cleansing water percolate into the soil through the bottom of the pit, while microbial action degrades part of the solid excreta. For this reason, the bottom of the pit should be necessarily unlined [3].The pit latrine needs no water for its function. This is a big advantage in water scarce areas.

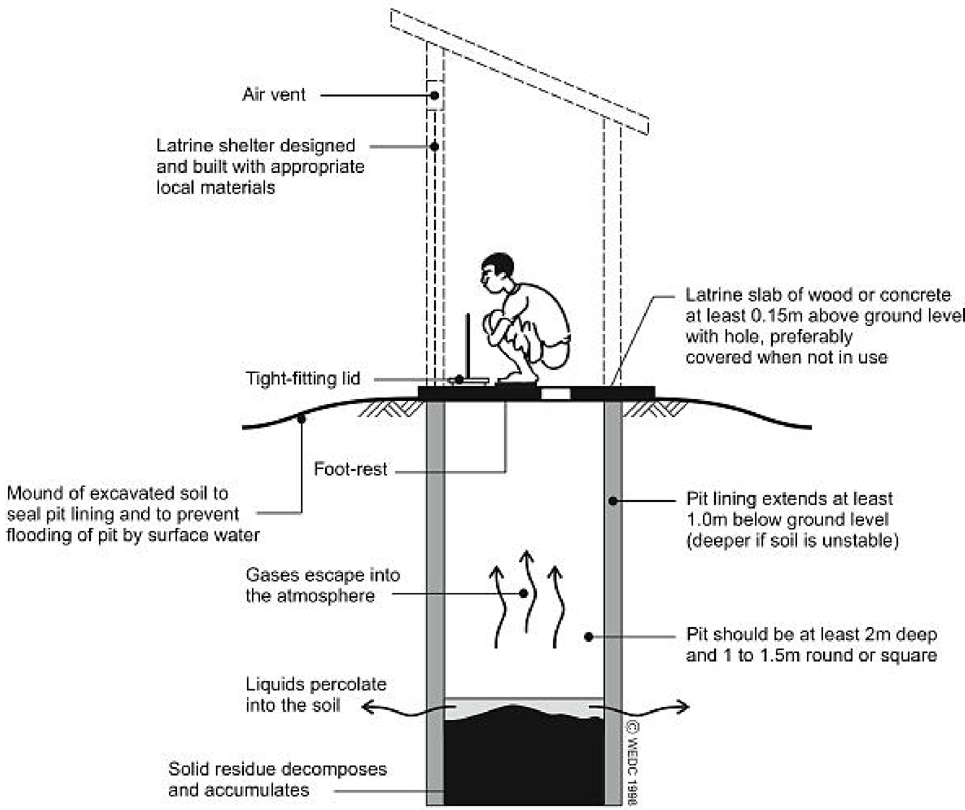


Figure 3.1: Schematic diagram of a simple pit latrine. Source: Harvey et al. 2002 [12]

The depth of the pit is at least 2 m, but usually more than 3 m [4].The depth is usually limited by the groundwater table or rocky underground. Lining the pit walls prevents it from collapsing and provides support to the superstructure [13].Because of the static properties, a round pit with a diameter of more than 1.5 m guarantees a stable construction and avoids a collapse [10].A horizontal distance of 30 m between the pit and a water source like a shallow tube well is recommended to limit chemical and biological contamination of water [3].The WHO (1992) advises a minimum of 15 m distance between a pollution source and a downstream water abstraction point. In densely populated areas with many pit latrines, the risk of a groundwater contamination remains extremely high [11].

A pit latrine has to be closed after the pit fills up. After six months or so, the degraded fecal matter in the pit may be removed and the latrine put back in operation. A twin-pit latrine is a slight improvement on the pit latrine. In such a latrine, two adjacent pits are constructed. When one pit fills up, it is closed and the second pit is put in operation. The first pit may be cleaned after some time and put back into operation after the second pit fills up. In this way, the latrine is in constant use. However in general, the pit latrine represents a primitive technology and other better non-flush systems are available [3, 13].Advantages and disadvantages of pit latrines is summarized in Table 2.1.

Table 3.1 Advantages and disadvantages of a Pit Latrine [9]

Advantages	Disadvantages
✓ Does not require a constant source of water ✓ Low (but variable) capital costs depending on materials ✓ Can be used immediately after construction ✓ Can be built and repaired with locally available materials	❖ Flies and odors are normally noticeable ❖ Low reduction of pathogens ❖ Costs to empty may be significant compared to capital costs ❖ No specific reuse of feces and urine ❖ Pits are susceptible to failure/overflowing during floods ❖ Stagnant water in pits may promote insect breeding ❖ Sludge requires secondary treatment and/or appropriate discharge

3.2 Ventilated Improved Pit (VIP) Latrine

A ventilated improved pit (VIP) is slightly more expensive than a pit latrine, but greatly reduces the nuisance of flies and odors, while increasing comfort and usability [3]. Fly and odor nuisance may be substantially reduced if the pit is ventilated by a pipe extending above the latrine roof, with fly-proof netting across the top (see Fig. 3.2). The inside of the superstructure is kept dark. Flies that hatch in the pit are attracted to the light at the top of the ventilation pipe. When they fly towards the light and try to escape they are trapped by the fly-screen and die. A small gap above the door or a louver in the door allows the air to enter. The flow of air is increased if the doorway of the superstructure faces the prevailing wind [10].

The VIP design can be used for both single and double pit latrines. Single pits need to be emptied or relocated when full. When double pits are used, one side is used at a time until it is full and then the second side is used. In this way, no new pits need to be constructed [10].Also, it should be possible to dig out a filled pit only after it has stood for a year or more resulting in an advanced degradation of the content and thus reduced odor and health risk during the emptying. A urine diversion slab could be added to collect and store urine and reuse it in agriculture. If the emptied fecal sludge is composted it may be also reused in agriculture [11].

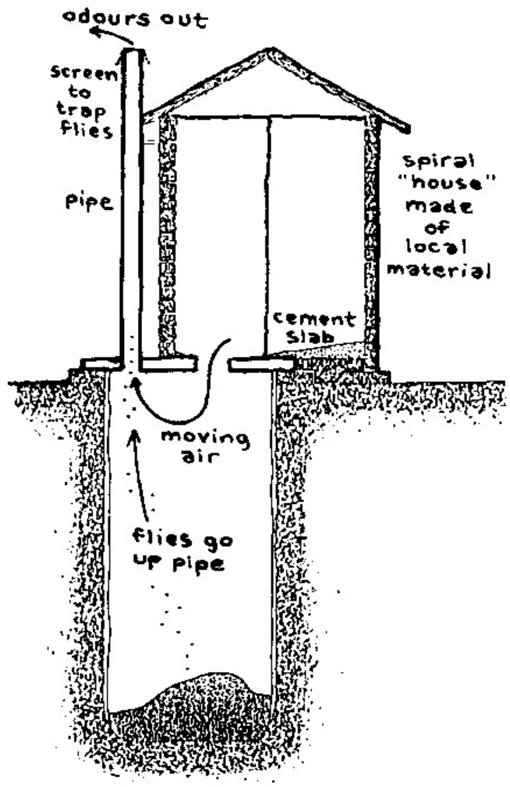


Figure 3.2: Schematic diagram of a Ventilated Improved Pit Latrine
Source: http://www.ugandanetwork.org.uk

Pathogen reduction and organic degradation is very low in such latrines. However since the excreta is confined, pathogen transmission to the user is limited. This technology is a significant improvement over single pit latrines or open defecation [11]. The advantages and disadvantages of a VIP latrine is summarized in Table 3.2.

3.3 Composting Toilet

Composting toilets minimize water use and recycle nutrients contained in excreta. There are various systems i.e. pits or vaults; urine diversion or normal; low-tech and high-tech; single-vault continuous or multiple vault batch. The functioning of the various different composting toilet systems is basically the same (see Fig. 3.3). Fecal matter and toilet paper or other dry cleansing material is dropped into a composting chamber. Organic household waste can also be added. Good ventilation serves to prevent excessive humidity and odor.

Table 3.2 Advantages and disadvantages of a Ventilated Improved Pit Latrine [11]

Advantages	Disadvantages
✓ Flies and odors are significantly reduced (compared to non-ventilated simple pit latrines) ✓ Can be built and repaired with locally available materials ✓ Can be used immediately after construction ✓ Low (but variable) capital costs depending on materials ✓ Does not require a constant source of water	❖ Pits are susceptible to failure/overflowing during floods ❖ Stagnant water in pits may promote insect breeding ❖ Sludge requires secondary treatment and/or appropriate discharge ❖ Leachate can contaminate groundwater ❖ Costs to empty may be significant compared to capital costs ❖ Health risks from flies, if not completely removed by ventilation ❖ No specific reuse of feces and urine ❖ Manual emptying of the pit poses severe health hazard

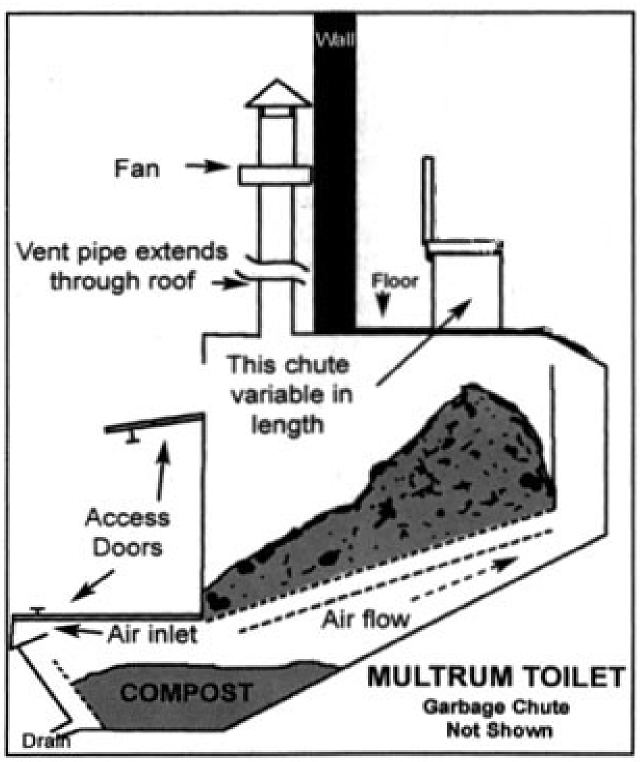


Figure 3.3 General schematic diagram of a Composting Toilet
Source: Adapted from the Humanure Handbook

To increase composting properties, dry material, such as sawdust or ash are added. This regulates the carbon to nitrogen ratio (C/N) and enhances the composting process. If ash and lime are used as bulking material, there is the additional beneficial effect of raising pH, which leads to improved pathogen die-off [14].

Often, composting toilets also have a drainage system to allow the drainage of liquids. This leachate has very high concentrations of nutrients, organics but also contain pathogens. It needs to be collected, treated and if possible reused. Urine diversion usually reduces leachate production [15].The end product of composting toilet is an odorless (and generally stabilized) material, called humanure, which is a valuable as soil conditioner (improving nutrient content, structure and water retention capacity of the soil). Depending on the local conditions, humanure can be harvested after some weeks or years. After this, it may be directly reused or may require a secondary treatment for complete pathogen removal [16].

Ventilation of composting toilets is important in order to maintain low moisture content of the compost and to prevent odor. It can be done naturally or mechanically. Mechanical ventilation requires a fan or another mechanical device and power/solar energy. For natural ventilation, a difference of pressure (or temperature) is required inside and outside the vaults. This can be given by wind or a stack effect. The stack effect can be achieved by installing the ventilation pipe outside and expose it to the sun (it may also be painted in black). When the air in the pipe heats up, it rises upwards out of the vent; a downward draught of cooler air of higher density then flows in through the squat plate hole, replacing the vacuum space created after warm air rising [17].

Composting latrines may be classified as shown in Fig. 3.4 into single vault and multiple vault systems.

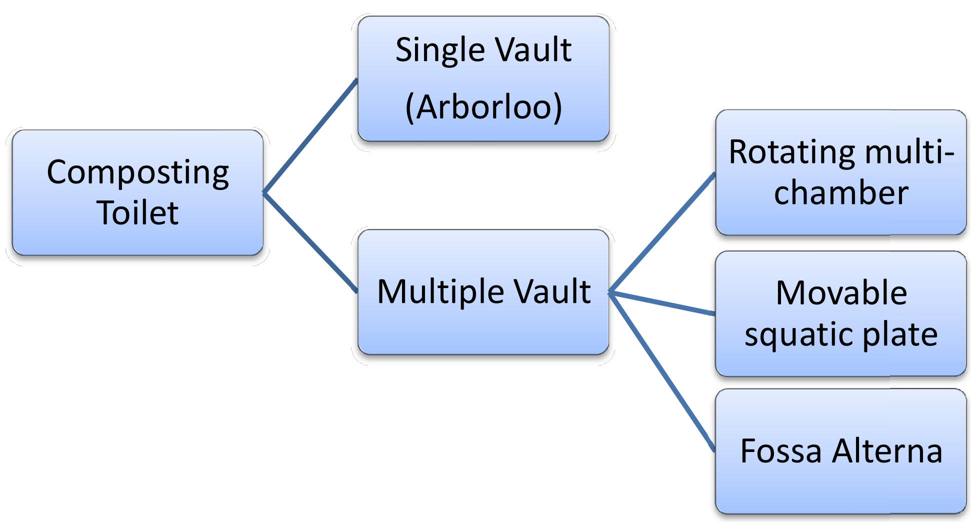


Figure 3.4 Classification of Composting Toilets, according to GTZ, 2010 [15]

3.3.1 Arborloo

This is an extremely simple, low cost version of the single vault composting toilet and has been developed for rural African regions [18]. The Arborloo (see Fig. 3.5) dispenses with the need to remove the compost and instead uses a shallow pit with a depth of up to 1.5 m to collect and compost feces, soil, wood ash and dry leaves. When the pit is almost full the contents are covered with a thick layer of soil. A young fruit tree is eventually planted within the pit. At the same time another shallow pit will be dug and the toilet superstructure moved to the new pit.

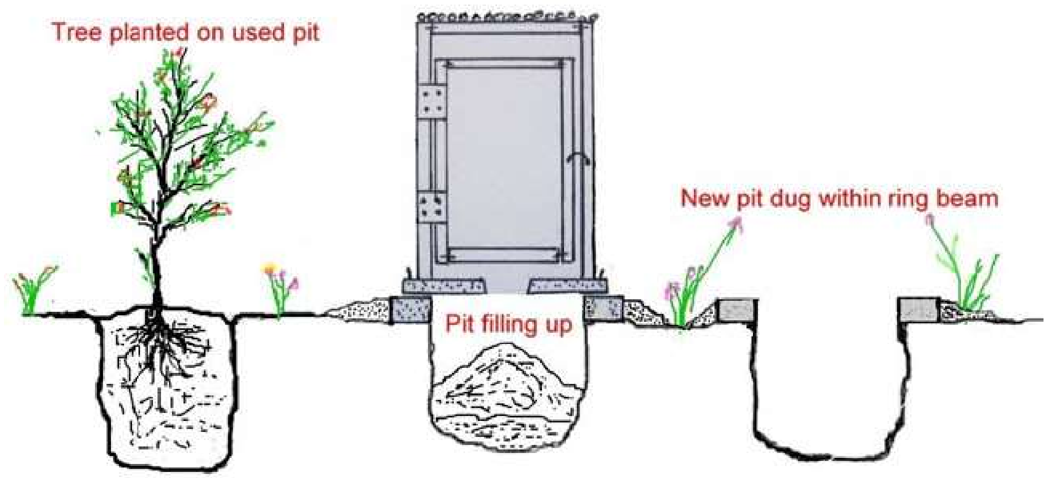


Figure 3.5 The simplest single pit compost toilet–Arborloo, Source: Morgan, 2007[18]

3.3.2 Rotating Multiple Chamber

This is a multiple-vault toilet that can be constructed from an under-floor processing vault with a cylindrical outer housing in which a slightly smaller inner tank is able to rotate. The inner tank is divided into four (or more) chambers (see Fig. 3.6). The vault in use is positioned directly below the down pipe of the toilet. When the vault in use is filled, the inner tank is rotated, whereby the next vault is positioned below the toilet. In this way each vault is filled in sequence. After filling all the vaults, the material in the first vault is removed and emptied through an access door [15].

3.3.3 Movable Squatting Plate

This is a multiple-vault toilet that can be constructed from an under-floor processing vault with a cylindrical outer.In these specially designed double vault systems, the toilet itself is movable. Usually these toilets are squat toilets with a movable squatting plate. The squatting plate is placed above the vault in use, and has an opening for the feces. At the same time the opening of the second, remaining vault remains covered by the squatting plate. Once the first vault is filled the squatting plate of the toilet is turned by 180°, whereby it closes the first vault and opens the second vault for further use [15]. In toilets where urine is not diverted, liquid can drain into a collection tank by means of a sieve bottom or a slope. If not treated and used as a fertilizer, the leachate should be discharged into an evapo-transpiration bed or a wastewater treatment process. The covering lids of the vaults can face the sun for additional heating. This increases evaporation of leachate as well as the temperature of the composting process [15].

Figure 3.6 Rotating multi-chamber bin, Source: Ekolet, Finland

3.3.4 Fossa Alterna

A low-cost double vault composting toilet, the “Fossa Alterna”, has been developed for rural Africa, which functions in exactly the same manner as more expensive systems, only that the composting vaults are shallow pits and the toilet superstructure is moved back and forth between the pits as they are used in alternation [18].

The advantages and disadvantages of composting toilets are summarized in Table 3.3.

3.4 Urine Diversion Dehydration Toilet (UDDT)

Present-day designs of double-vault Urine-Diversion Dehydration Toilets (UDDTs) are based on the Vietnamese double-vault dry toilet, which was developed in the 1960s by local authorities [19].UDDTs divert all liquids i.e. urine and anal cleansing water, from the feces to keep the processing chamber contents dry. UDDTs make use of desiccation (dehydration) processes for the hygienically safe on-site treatment of human excreta. Typical UDDT toilets are shown in Fig. 3.7. Adding wood ash, lime, sawdust, dry earth etc. after defecation helps in lowering the moisture content and raising the pH. The system thus creates conditions of dryness, raised pH and pathogen die-off [19].If wet anal cleansing habits prevail in a community, anal cleansing water must be diverted (by providing a separate washbowl) from the feces.

Table 3.3 Advantages and disadvantages of a Composting Toilet [16]

Advantages	Disadvantages
✓ Considerable reduction in the volume of fecal matter (upto 30 %, GTZ 2006) ✓ Considerable reduction in the volume of solid waste, as organic waste can be added to the toilet ✓ Urine can be collected separately ✓ There is no need to dig pits or to install sewers in the case of vault composting toilet ✓ The humanure (end product) is a valuable soil conditioner	❖ Needs careful operation and requires bulking material ❖ Proper moisture and temperature needs to be maintained ❖ Secondary treatment of leachate is required ❖ Costlier than ordinary pit latrine

Urine is collected in containers for direct use, storage and further processing (e.g., desiccation, struvite production, etc.). Disinfected urine can be used at small or at large scale, or locally discharged by infiltration into the soil (e.g. evapo-transpiration bed). Feces collected in UDDTs can either be dehydrated (storage and dehydration) or composted (co-composting small-scale or large scale) before they are used as soil amendment [20].

With double-vault UDDTs, fecal matter is collected and stored in twin-pit compartments, which are used alternately. Daily deposits are made into one of the compartments. After each use, a handful of cover material (wood ash, sawdust, soil, lime, etc.) is sprinkled over the feces to absorb moisture and help in speeding up the dehydration process. When one vault is full (which should take roughly one year), the respective compartment is sealed while the other compartment is put in use. The storage time is counted from the date of the last fecal matter contribution to a compartment, and should be at least one year to provide sufficient time for desiccation and disinfection [20].

Plant ash, lime, dried soil or sawdust is added after every defecation as bulking agent to enhance the drying process [14]. The immediate coverage of the fresh feces with an additive material can considerably lower nuisances caused by odor or flies. Faster drying also means that the biological degradation is small if sufficient additive is used and thus, the losses of organic matter and N from the feces to the air are small [14].Ash and lime have the additional beneficial effects of raising pH, which leads to improved pathogen die-off [14].

(a) (b) (c)

Figure 3.7: (a) Double-vault urine diversion dehydration toilet, Vietnamese style, Bhutan. Source: WAFLER (2009); (b) Urine-diversion squatting pan with anal cleansing water collection bowl (made from fibre-reinforced plastic). Source: WAFLER (2010); (c) Ceramic urine-diversion pedestal with separate bowl for collection of anal cleansing water. Source: UNESCO-IHE

UDDTs are waterless systems that are particularly suitable for conditions where water is scarce or expensive. The products of UDDTs, collected urine and humanure, are both valuable fertilizer and need to be either reused correctly on-site or transported to a site where they can be reused or discharged correctly. Therefore, UDDTs are particularly adapted for households or communities with need for such types of fertilizing products. The advantages and disadvantages of UDDT systems are summarized in Table 3.4.

Table 3.4: Advantages and disadvantages of UDDT [20]

Advantages	Disadvantages
✓ Suitable for hard rock soil areas, high ground water levels and areas prone to flooding ✓ No contamination of groundwater sources due to contained processing of human feces ✓ UDDTs allow for an easy treatment and reuse of excreta ✓ Urine can be directly used as a fertilizer ✓ Single vault is easy to construct ✓ Saves a lot of water	❖ Double-vault UDDTs require large surface area for construction ❖ Possibility of smell if not well operated and too much liquid (urine, anal cleansing water, etc.) enters the processing compartment ❖ Transport of human excreta to secondary storage and/or processing site may be required ❖ Regular shifting of containers from single-vaults ❖ It is difficult to use for small children

3.5 Flush Toilet

A flush toilet is a toilet that disposes off human excreta by using water to flush away the excreta through a drainpipe to another location. It consists of a toilet bowl and a cistern which stores water (see Fig. 3.8). By pushing or pulling lever water is released into the bowl, which mixes with the excreta and carries it away. There are different low-flush toilets currently available that use only a minimized amount of water per flush. A good plumber is required to ensure that all valves are connected and sealed properly, therefore minimizing leakage [3]. To save water, there are dual flush toilets available, with two different flush volumes to reduce water use [4]. But generally the user ends up flushing twice in case of low flush volume. There are also flush toilets in the market that collect the urine separately and use a very low flush volume to flush the urine away [5].

The toilet bowl consists of a siphon including the water seal against bad odors from the effluent pipe. Major advantage of flush toilet is that the smelly feces and urine is easily eliminated by simply using the flush and a water seal [6].

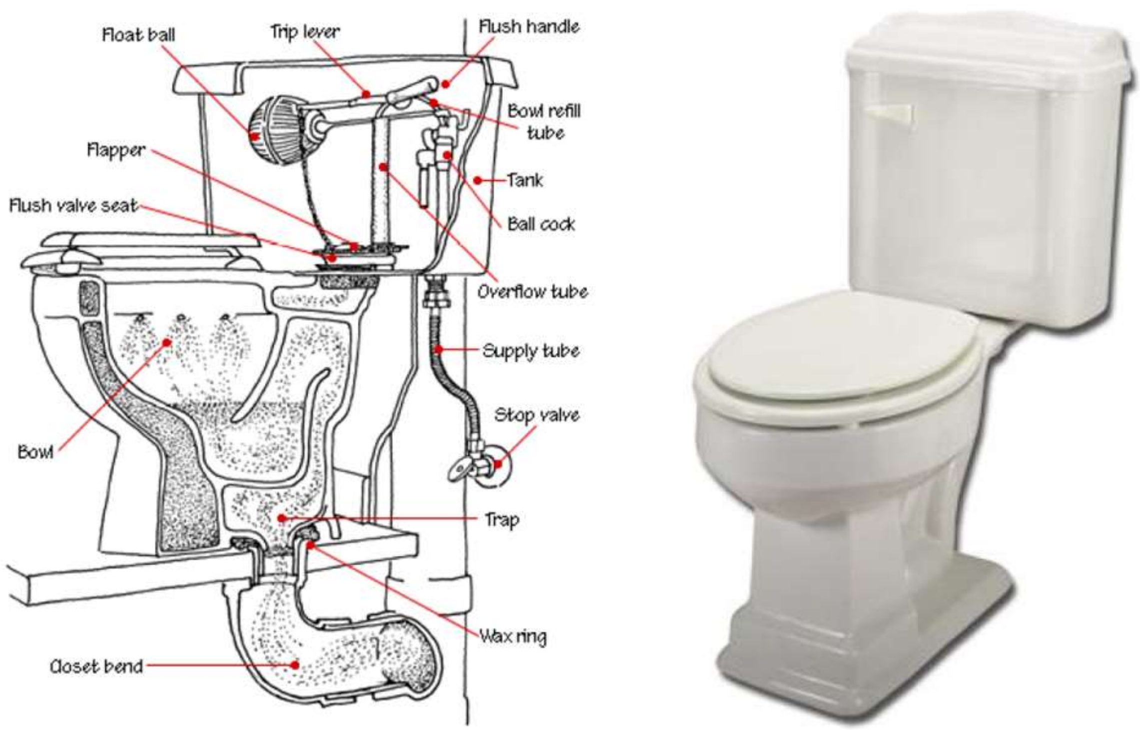


Figure 3.8: Design of a Flush Toilet, Source EAWAG/SANDEC, 2008 [13]

The flush toilet has a good user interface, is hygienic and hence is widely used. However, proper treatment of the sewage generated through flushing is an ecological necessity, which is overlooked in many cases. Besides the fact that a huge amount of freshwater is required for flushing, in many instances there is no treatment plant at the end of a sewerage system.

Consequently, sewage flows directly into water bodies like rivers, lakes, sea or infiltrate into the groundwater and contaminate these water sources [6].

In an article Sunita Narain, a prominent environmentalist in India, describes cistern flush toilets and sewerage as a part of the environmental problem and not as a solution: "Consider the large amount of clean water that is used to carry even a small quantity of human excreta. In India, flushes are designed to be particularly water-wasteful. So with each flush, over 10 liters of clean water goes down the drain. We build huge dams and irrigation systems to bring water to urban areas. This water which is flushed down the toilet goes into an equally expensive sewage system, all to end up polluting more water — invariably our rivers and ponds. Most of our rivers are today dead because of the domestic sewage load from cities. We have turned our surface water systems into open sewage drains" [7].

The various advantages and disadvantages of flush toilets have been summarized in Table 3.5.

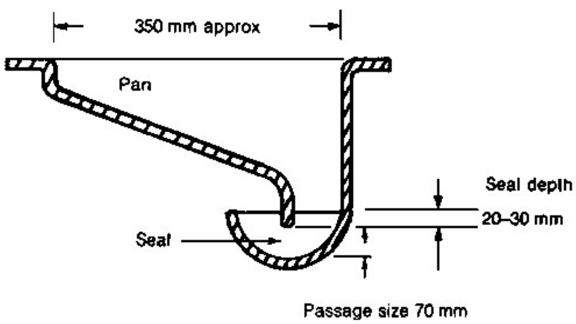
Table 3.5: Advantages and disadvantages of a Flush Toilet [6]

Advantages	Disadvantages
✓ The excreta of one user is flushed away before the next user arrives ✓ If used properly, there is no real problems of odor ✓ Suitable for all types of users namely sitters, squatters, wipers and washers [3] ✓ Easy to use and clean	❖ Capital investment is high; operating cost depends on the price of water and the price of wastewater treatment ❖ It will not function without a constant source of water ❖ Cannot be built and/or repaired locally with available materials ❖ Generates a large volume of sewage to be discharged ❖ There is a high risk of water pollution due leakage in sewer system or if there is no treatment of discharged toilet wastewater

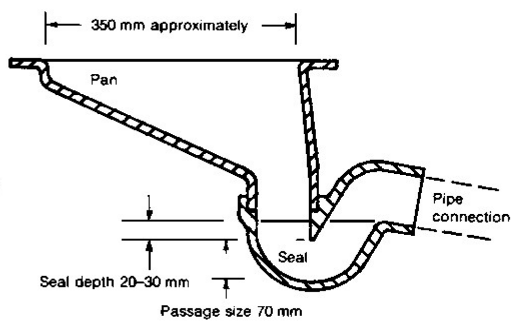
3.6 Pour Flush Toilet

A pour-flush toilet is like a regular flush toilet except that instead of the water coming from the cistern, user has to pour it (see Fig. 3.9). When the water supply is not continuous, any cistern flush toilet can become a pour-flush toilet [8].There is a water seal in such toilets that prevents odors and flies from coming back up the drain pipe. The pan may be of the squatting type or of the pedestal variety where the user can sit.

The amount of water needed for flushing depends on the design of the pan or pedestal, the depth and volume of the water seal, and the minimum passage size through the seal. For a water seal directly above the pit about 1 liter of water is normally sufficient for flushing. For an improved pedestal pan and offset pit, a minimum of 3 liters for water is necessary.



(a)



(b)

Figure 3.9 Design of a pour flush toilet. (a) Direct Pour Flush; (b) Offset Pour Flush Source: WHO, 1992[10]

The pour-flush toilet prevents users from seeing or smelling the excreta of previous users. Thus, it is generally well accepted. Provided that the water seal is working well, there should be no odors and the toilet should be clean and comfortable to use [8]. Advantages and disadvantages of pour-flush toilets have been summarized in Table 3.6.

Table 3.6: Advantages and disadvantages of a Pour Flush Toilet [8]

Advantages	Disadvantages
✓ The water seal effectively prevents odors ✓ The excreta of one user is flushed away before the next user arrives ✓ Suitable for all types of users (sitters, squatters, wipers and washers) ✓ Low capital costs; operating costs depend on the price of water	❖ Requires a constant source of water (can be recycled water and/or collected rain water) ❖ Cannot be built and/or repaired locally with available materials ❖ Requires some education to be used correctly

3.7 Zero Discharge Toilet (ZDT) System

This technology, developed by IIT Kanpur, concerns a flush toilet that is also zero discharge. The toilet is identical to conventional Flush Toilet System, difference being it uses recycled water to flush. A solid liquid separator is fixed underneath the toilet seat, which separates the solid and liquid. The separator allows formation of a thin water film that adheres to the surface of the separator and flows outwardly while most of the solids gravitate into the central retention compartment of the Retention cum Polishing (RCP) tank (see Fig.3.10).

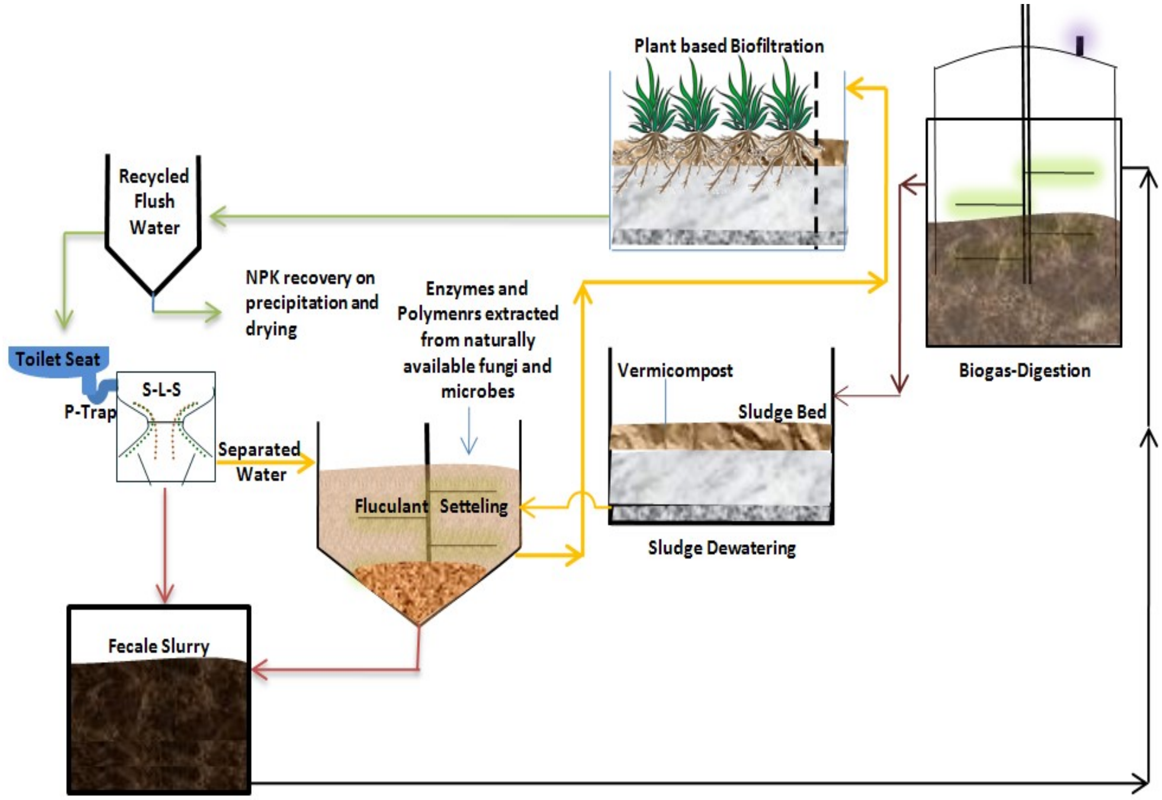


Figure 3.10: Schematic diagram of Zero Discharge Toilet System

Specially developed microbial culture, enzymes and polymers, extracted from naturally available fungi, is added to the separated liquid to eliminate any foul odor. Green non-toxic dye is also added to improve aesthetics of the water. This liquid is then recycled for flushing the toilet, thus avoiding the excessive use of fresh water for flushing while no compromise is done on using adequate liquid for completely flushing the toilet pan.

The solids gradually disintegrate to form slurry, which is then evacuated from the tank under gravity. The fecal slurry is converted into quality organic manure using activated aerobic composting and vermin-composting for rapid and effective utilization of valuable organics and nutrients.

The entire scheme is implemented in a most compact fashion in the vicinity of the toilet avoiding long distance conveyance of water and wastes. The advantages and disadvantages of a ZDT system are summarized in Table 3.7

Table 3.7: Advantages and disadvantages of a Zero Discharge Toilet System

Advantages	Disadvantages
✓ Saves a lot of fresh water, only uses 1/10 of water as compared to conventional flush toilet system ✓ Recovery of valuable by products in the form of organic manure and inorganic fertilizer ✓ No need of sewerage system, soak pit or septic tank and can be easily installed in congested colonies ✓ User comfort and hygienic conditions at the same level as in conventional water borne systems	❖ One dedicated attendant is required for smooth running of the system ❖ Proper maintenance is required otherwise flush water may start smelling

4. Disposal: Back End of a Sanitation System

The back end of a sanitation system can be onsite storage and treatment of excreta or conveyance of excreta to a treatment plant. Following are some of the examples of back end solutions of a sanitation system.

- Piped Sewer System
- Septic Tank
- Anaerobic Baffle Reactor
- Soak Pit
- Composting
- Small Bore Sewer System

4.1 Piped Sewer System/ Conventional Sewers

Conventional gravity sewers are large networks of underground pipes that convey black water, brown water and grey water from individual households to a centralized treatment facility by gravity. Sewer networks are mostly found in urban areas. The sewage from one or more buildings is collected using laterals, usually of 100 mm in diameter. Laterals lead to branch sewers, then main sewers and finally trunk sewers, which is connected to a sump well. Water from the sump well is pumped to the sewage treatment plant [22].

Conventional gravity sewers do not require on-site pre-treatment or storage of the wastewater. Because the waste is not treated before it is discharged, the sewer must be designed to maintain self-cleansing velocity (i.e. a flow velocity that will not allow particles to deposit in sewers). Self-cleansing velocity is taken as 0.6 m/s corresponding to the peak flow rate in the sewer. A constant downhill gradient must be guaranteed along the length of the sewer to maintain such flows. When the sewer depth becomes too large, intermediate pumping stations are required.

Sewers are laid beneath roads, at minimal depths of 1.5 to 3 m to avoid damages caused by traffic loads. Sewers can be accessed through manholes for cleaning purposes. Manholes are provided at regular intervals along the sewer, at pipe intersections and at changes in pipeline direction. The sewer network requires robust engineering design to ensure that a self-cleansing velocity is maintained, that manholes are placed as required and that the sewer line can support the traffic weight. The advantages and disadvantages of a piped sewer network are summarized in Table 4.1.

Table 4.1: Advantages and disadvantages of a Piped Sewer Network [22]

Advantages	Disadvantages
✓ Convenience to the end user ✓ Health risk is reduced ✓ No nuisance from smells, mosquitoes or flies ✓ Moderate operation and maintenance costs ✓ No problems related to discharging wastewater	❖ High capital investment ❖ Needs a continuous and reliable supply of piped water ❖ Difficult to construct and costly to maintain in high-density areas ❖ Problems associated with blockages of pipes and breakdown of pumping equipment may occur ❖ Recycling of nutrients and energy becomes difficult

4.2 Septic Tank

The septic tank is the most common small-scale decentralized treatment unit for grey water and black water from cistern or pour-flush toilets. It is basically a sedimentation tank in which settled sludge, i.e., fecal matter is stabilized by anaerobic digestion (see Fig.4.1). Dissolved and suspended matter leaves the tank more or less untreated. The shape of a septic tank can be rectangular or cylindrical.

Septic tanks are used for wastewater with a high content of settleable solids, typically for effluent from domestic sources, but they are also suitable for other wastewater with similar properties [23].

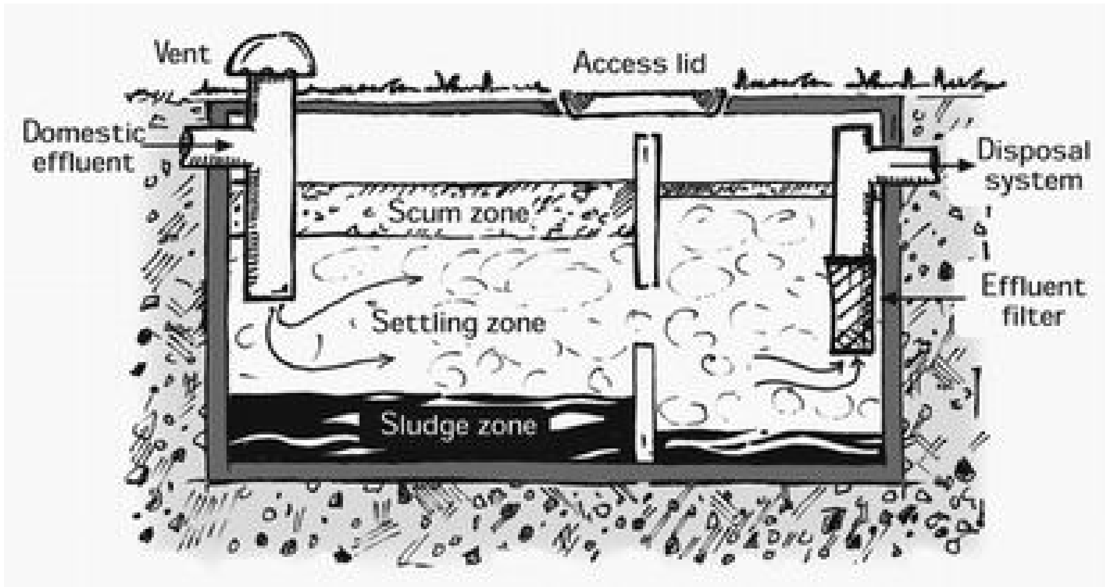


Figure 4.1: Schematic of a Septic Tank, Source: http://www.nrc.govt.nz

A septic tank consists of a minimum of 2 compartments made out of concrete or bricks. Pre-fabricated concrete rings, PVC or fiberglass septic tanks are also available and may be less expensive in some contexts [24].The first compartment occupies at least half of the total volume, because most of the sludge accumulates here [23],while scum (oil and fat) floats to the top. When there are only two chambers, the first one should be 2/3 of the total length [3]. The following chamber(s) are provided to calm the turbulent liquid. A baffle, or the separation between the chambers, is provided to prevent scum and solids from escaping with the effluent [3]. A T-shaped outlet pipe, the lower arm of which is at least 30 cm below water level [23], will further reduce the scum and solids that are discharged. Normally, the chambers are all of the same depth (between 1.5 to 2.5 m), but sometimes the first chamber is made deeper as the others.

Over time, anaerobic bacteria and microorganisms start to digest the settled sludge anaerobically, transforming it into CO_2 and CH_4 (biogas) and some heat. Optimal physical treatment by sedimentation takes place when the flow is smooth and undisturbed. A septic tank will remove 30 to 50% of BOD (Biological Oxygen Demand), 40 to 60% of TSS (Total Suspended Solids) [25]and result in an abatement of 1 log units *E. coli* (a fecal indicator bacteria)[3]although efficiencies vary greatly depending on the influent concentrations and climatic conditions. Hydraulic Retention Time (HRT) is generally 24 hours [27].

The advantages and disadvantages of septic tanks are summarized in Table 4.2.

Table 4.2: Advantages and disadvantages of a Septic Tank [26]

Advantages	Disadvantages
✓ Can be built and repaired with locally available materials ✓ No real problems with flies or odors if used correctly ✓ Little space required due to underground construction ✓ Low investment costs, low operation and maintenance costs depending on the availability of water and the requirement for emptying ✓ No energy required ✓ Long service life	❖ High cost compared to dry or composting toilet systems ❖ Constant and sufficient amounts of piped water required to bring the waste to the treatment unit ❖ Low reduction in pathogens, solids and organics: Secondary treatment for both effluent and fecal sludge required ❖ De-sludging required: Manual de-sludging is hazardous to health and mechanical de-sludging (vacuum trucks) requires the infrastructure and may be rather costly ❖ Only suitable for low-density housing in areas with low water table and not prone to flooding

4.3 Anaerobic Baffle Reactor

Anaerobic baffled reactors (ABR), also called baffled or improved septic tanks, are upgraded septic tanks which aim to enhance the removal efficiency for non-settleable and dissolved solids [27]. An ABR consists of a tank and alternating hanging and standing baffles that compartmentalize the reactor and force liquid to flow up and down from one compartment to the next, enabling an enhanced contact between the fresh wastewater entering the reactor and the residual sludge containing the microorganisms and responsible for anaerobic digestion of the organic pollutants (see Fig. 4.2). The compartmentalized design increases the solids retention time is comparison to the hydraulic retention time, making it possible to anaerobically treat wastewater at short retention times of only some hours [28].The baffled design of the ABR ensures a high solid retention resulting in high treatment rates, while the overall sludge production is characteristically low [29].Such tanks are simple to build and simple to operate, as well as very robust to hydraulic and organic shock loading [23].Yet, both sludge and effluent from ABR still need further treatment before safe discharge into the environment.

It has a settling chamber for larger solids and impurities[23]followed by a series of at least 2 [27], and sometimes up to 5 [23]up-flow chambers. Treatment performance of ABRs is in the range of 65% to 90% COD (Chemical Oxygen Demand) removal, corresponding to about

70% to 95% of BOD (Biological Oxygen Demand) removal [23, 27, 30].This is far superior to that of a conventional septic tank (30 to 50 %) [25].

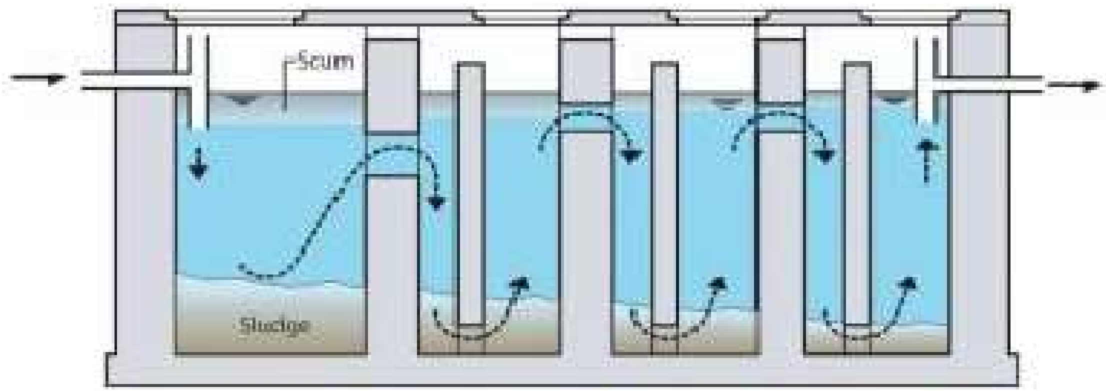


Figure 4.2: Schematic cross-section of an Up-Flow Anaerobic Baffled Reactor Source: Morel and Diener, 2006 [27]

ABRs are typically applied in Decentralized Wastewater Treatment Systems (DEWATS), usually in combination with several other treatment steps. A typical DEWATS could be a five component system of three anaerobic steps consisting of a biogas settler/digester; an ABR and an anaerobic up-flow filter; followed by an aerobic treatment unit such as a constructed wetlands and a maturation pond [31].ABRs are easy to const, low cost and robust [23],yet having higher treatment efficiency than septic tanks. The advantages and disadvantages of an ABR system are summarized in Table 4.3.

Table 4.3 Advantages and disadvantages of an Anaerobic Baffle Reactor[26]

Advantages	Disadvantages
✓ Good treatment performance for all kinds of wastewater ✓ Stable to hydraulic shock loads ✓ Simple to construct and operate, construction material locally available ✓ Low capital and operating costs ✓ Low sludge generation, reduced clogging ✓ Biogas can be recovered, low HRT, long biomass retention time	❖ Needs expert design and construction, Clear design guidelines are not yet available ❖ Long start-up phase ❖ Needs strategy for fecal sludge management (effluent quality rapidly deteriorates if sludge is not removed regularly) ❖ Effluent requires secondary treatment and/or appropriate discharge ❖ Needs water to flush ❖ Low reduction of pathogens

4.4 Soak Pits

Soak pits consist of a simple pit, generally 1m^3 in volume. The effluent received by a soak pit is allowed to infiltrate into the surrounding soil. The soak pits are either left empty & lined with porous material to provide support and prevent collapse; or they are unlined and filled with coarse rocks and gravel to provide support and to prevent collapsing. In both cases a layer of sand and fine gravel has to be spread across the bottom to facilitate the dispersion of the flow. The depth of a soak pit should be between 1.5 and 4 m. The bottom of the soak pit has to be more than 1.5 m above the groundwater table [32].

As the effluent percolates through the soil from the soak pit, small particles are filtered out by the soil matrix and organics are digested by micro-organisms present in the soil. The effluent is absorbed by soil particles as it moves both horizontally and vertically through the soil pores. Sub-soil layers should therefore be water permeable in order to avoid fast saturation. High daily volumes of discharged effluents should be avoided [33].

A well-sized soak pit should work for about 3 to 5 years without maintenance. To extend the life of a soak pit, care should be taken to ensure that the effluent has been clarified and/or filtered well before it is discharged into the pit. This prevents an excessive build-up of solids. The soak pit should be kept away from high-traffic areas so that the soil above and around it is not compacted. When the performance of the soak pit deteriorates, the material inside the soak pit can be excavated and refilled. To allow for future access, a removable (preferably concrete) lid should be used to seal the pit until it needs to be maintained. Particles and biomass will eventually clog the pit and it will need to be cleaned or moved. As long as the soak pit is not used for raw sewage, and as long as the previous collection and storage/treatment technology is functioning well, health concerns are minimal. The soak pit is located underground and thus, humans and animals should generally have no contact with the effluent [32].

It is important however that the soak pit is located at a safe distance from a drinking water source (ideally at least 30m). As long as the soak pit is not used for raw sewage, and as long as the previous collection and storage/treatment technology is functioning well, health concerns are minimal [32].

The advantages and disadvantages of a soak pit are summarized in Table 4.4.

4.5 Composting

Composting is a process of decomposing organic matter by microorganisms under controlled conditions. In developing countries the main component of municipal waste is organic matter such as food waste and yard waste. Fecal sludge can also be composted after it has been dewatered using drying beds, thickening ponds, or mechanical dewatering.

Table 4.4: Advantages and disadvantages of a Soak Pit [32]

Advantages	Disadvantages
✓ Low capital cost and requires minimal operation & maintenance ✓ Can be built and repaired with locally available materials and by the community ✓ Small land area required ✓ Simple technique with a high acceptance	❖ Pre-treatment (e.g. settling) of the incoming effluent is required to prevent clogging and limit health risk, although eventual clogging is inevitable ❖ Applicable only where soil conditions allow infiltration, the groundwater table is at least 1.5 m below the soak pit, there is no risk for flooding and any water well is in a distance of at least 30 m ❖ Difficult to realize in cold climates ❖ Should be avoided for high daily volumes of discharged effluents

Dewatered sludge may be mixed at a volumetric ratio of approx. 1(sludge):3 (solid organic material), whereas more liquid sludge (TS of 5 %) may be mixed at ratios between 1:5 to 1:10 [34, 35]. To ensure aerobic conditions, the compost pile is turned twice a week for the first two weeks and then once every 10 days. The temperature of the pile rises to about 65ºC in the first week and then goes down to 40 °C over the next few weeks. After about 21 to 60 days [37],the composting process enters the maturing or curing phase when the pile is left without turning for some weeks or more depending on the local conditions. There are three fundamental types of composting techniques: open or windrow composting; box or bin composting or trench and pit composting [34].

4.5.1 Windrow Composting

This is a slow but simple process. The material is piled up in heaps or elongated heaps (called windrows). The size of the heaps ensures sufficient heat generation, and aeration is ensured by regular turning, addition of bulky materials, passive or active ventilation [34].Systems with active aeration by blowers are usually referred to as forced aeration systems and when heaps are seldom turned they are referred to as static piles. Sloped and sealed or impervious composting pads (the surface where the heaps are located) control the leachate with a surrounding drainage system.

4.5.2 Box Composting

The compost is placed in boxes made out of bricks, wood or mesh boxes with holes in between and a screen at the bottom. Box composting requires less space and is less labor intensive than the windrow system as the aeration is more passively and the compost does not to be turned. But the initial capital cost required for a box system is slightly higher.

4.5.3 Trench and Pit Systems

Theseare characterized by heaps, which are partly or fully contained under the soil surface [34].This allows to save space and to reduce construction cost (in comparison to boxes). Structuring the heap with bulky material or turning is usually the choice for best aeration, although turning can be cumbersome when the heap is in a deep pit and leachate control is difficult in trench or pit composting [34].

4.5.4 Vermi-composting

It involves using special types of earthworms to convert organic waste into worm casting, and can also be done in decentralized composting [36].In a vermi-composting plant, the waste is first composted aerobically for about two weeks as in an ordinary plant. Then, the semi-decomposed waste is put in boxes with special types of worms, such as *Eisenia fetida, Lumbricusrubellus*, and *Eiseniahortensis.* Vermi-composting results in better quality compost, but the worms need more care than aerobic composting. For vermi-composting, the pile does not need turning, but the temperature and moisture needs to be suitable for the worms at all times to ensure their survival.

The advantages and disadvantages of the composting process are summarized in Table 4.5.

Table 4.5: Advantages and disadvantages of Composting [38]

Advantages	Disadvantages
✓ Reduces common problems with organic wastes, such as smell, leachate, flies and rodents, and emissionof methane ✓ Large-scale composting reduces the amount of waste that needs to be transported to final disposal sites, thus reducing the cost of solid waste management ✓ Production and sale of compost will encourage the use of organic farming and gardening and reduce the need for chemical fertilizers	❖ If not done properly, household composting can cause problems such as smell, leachate, flies and rodents ❖ Large-scale composting requires a professional collection, operation and maintenance and marketing ofthe compost ❖ Requires space

4.6 Small Bore Sewer System (SBS)

Small bore sewer system, also known as solids free sewer, divides the sewage into two components at the source itself using an interceptor. One is the decanted liquid fraction (supernatant of the sewage) and the other is settled sewage solids (sludge). The solids which accumulate in the interceptor tanks should be removed periodically for safe disposal. Sewer lines are designed to receive only the liquid portion of household wastewater for off-site treatment and disposal.

The interceptor tanks are generally designed as septic tanks with minimum two chambers and have to provide space for four separate functions:

(a) Interception of solids;
(b) Digestion of settled solids;
(c) Storage of digested solids; and
(d) Storage of scum

SBS system requires small diameter piping because it conveys only liquid, hence it is economical. Its major advantages and disadvantages are summarized in Table 4.6. Because of the lower costs of construction and maintenance and the ability to function with little water, small bore sewers can be used where conventional sewerage would be inappropriate.

Table 4.6: Advantages and disadvantages of Small Bore Sewer System [39]

Advantages	Disadvantages
✓ Reduced water requirements, since sewers are not supposed to carry any solids	❖ Needs periodic evacuation and disposal of solids from each interceptor tank in the system
✓ Reduced excavation costs, since sewers don't require that much slope, as in the conventional sewer lines	❖ Since the bore is small, there is a possibility of pipe getting choked with floating material
✓ Reduced material costs, as pumps and pipes required are economical as dealing with only liquid	❖ Requires expert design and construction supervision
✓ Reduced treatment requirements, as pretreatment occurs at the interceptor itself	

5. Current Global Sanitation Scenario

Sanitation coverage has lagged behind water provision since the first International Decade of Water and Sanitation (1980-1990). In 2011, almost two thirds (64%) of the world population relied on improved sanitation facilities, while 15% continued to defecate in the open. Since 1990, almost 1.9 billion people have gained access to an improved sanitation facility. The world, however, remains far from the Millennium Development Goal (MDG) sanitation target, which requires reducing the proportion of people without access from 51% in 1990, to 25% by 2015, as agreed upon in the Monterrey Consensus and reinvigorated as part of the "Water for Life" Decade (2005-2015) [2].

By the end of 2011, there were 2.5 billion people who lacked access to an improved sanitation facility. Of these, 761 million use public or shared sanitation facilities and another 693 million use facilities that do not meet minimum standards of hygiene (unimproved sanitation facilities). The remaining 1 billion (15% of the world population) still practice open defecation. The majority (71%) of those without sanitation live in rural areas, where 90% of all open defecation takes place [2].

The toll that unsanitary conditions and contaminated drinking water take on both the health of the human population and the environment is crippling. Besides the indignity suffered by those lacking sanitation facilities, millions of people in the developing world die from diseases contracted through direct and indirect contact with pathogenic bacteria found in human excreta. Infectious diseases such as cholera, hepatitis, typhoid, and diarrhea are waterborne, and can be contracted from untreated wastewater discharged into water bodies. More than half of the world's rivers, lakes, and coastal waters are seriously polluted from wastewater discharge [4].The cost of inadequate sanitation translates into significant economic, social, and environmental burdens.

Some key facts about global sanitation scenario are listed below:

- More than one in six people worldwide - 894 million - don't have access to safe water [2].
- Globally, diarrhea is the leading cause of illness and death, and 88 per cent of diarrheal deaths are due to a lack of access to sanitation facilities, together with inadequate availability of water for hygiene and unsafe drinking water [2].
- Today 2.5 billion people, including almost one billion children, live without even basic sanitation. Every 20 seconds, a child dies as a result of poor sanitation. That's 1.5 million preventable deaths each year [40].
- In Sub-Saharan Africa, treating diarrhea consumes 12 percent of the health budget. On a typical day, more than half the hospital beds in are occupied by patients suffering from fecal-contamination related disease [40].
- A recent study by the Water and Sanitation Program of the World Bank estimates that inadequate sanitation costs India the equivalent of 6.4% of its GDP. A 2008 UNICEF study points out that a mere 21% of rural India uses improved sanitation facilities. But sanitation is no one's priority [41].
- Public health and environmental policies have frequently become exercises in crisis intervention rather than preventive measures that improve the health and well-being of the whole urban population [42].
- Most Asian cities do not have effective wastewater treatment systems. In the Philippines, for example, only 10% of wastewater is treated while in Indonesia the figure is 14%, in Vietnam 4%, and in India 9% [43].

6. Current Indian Sanitation Scenario

In India only 30% of urban households have access to sewerage systems [44].Cities plan for water but not for waste. Growing volumes of untreated sewage leads to contamination of ground water due to leaching. Rivers and tributaries are becoming drains as the time goes by. In 2011 around 40% of urban population did not have access to improved sanitation, and 66% of rural population still practiced open defecation (see Table 6.1). There is no privacy for women who are forced to go out to defecate in open fields, near rivers or on railway tracks at odd hours.

Table 6.1 Use of Sanitation Facilities in terms of percentage of population of India[2]

		Year	1990	2000	2011
		Population (x1000)	873785	1053898	1241492
		Percentage of Urban Population	26	28	31
Urban		Improved	50	54	60
	Unimproved	Shared	17	18	20
		Unimproved	5	6	7
		Open Defecation	28	22	13
Rural		Improved	7	14	24
	Unimproved	Shared	1	3	4
		Unimproved	2	4	6
		Open Defecation	90	79	66
National		Improved	18	25	35
	Unimproved	Shared	5	6	7
		Unimproved	3	5	6
		Open Defecation	74	63	50

Figure 6.1 also clearly depicts the state of sanitation of India in terms of kind of toilets being used, if used at all. By 2011, though there is a rise in percentage of households using better toilet facilities, it is not a significant increase, but the population has increased significantly since 2001 (from Table 6.1). Hence the number of people without improved sanitation facilities is still very high.

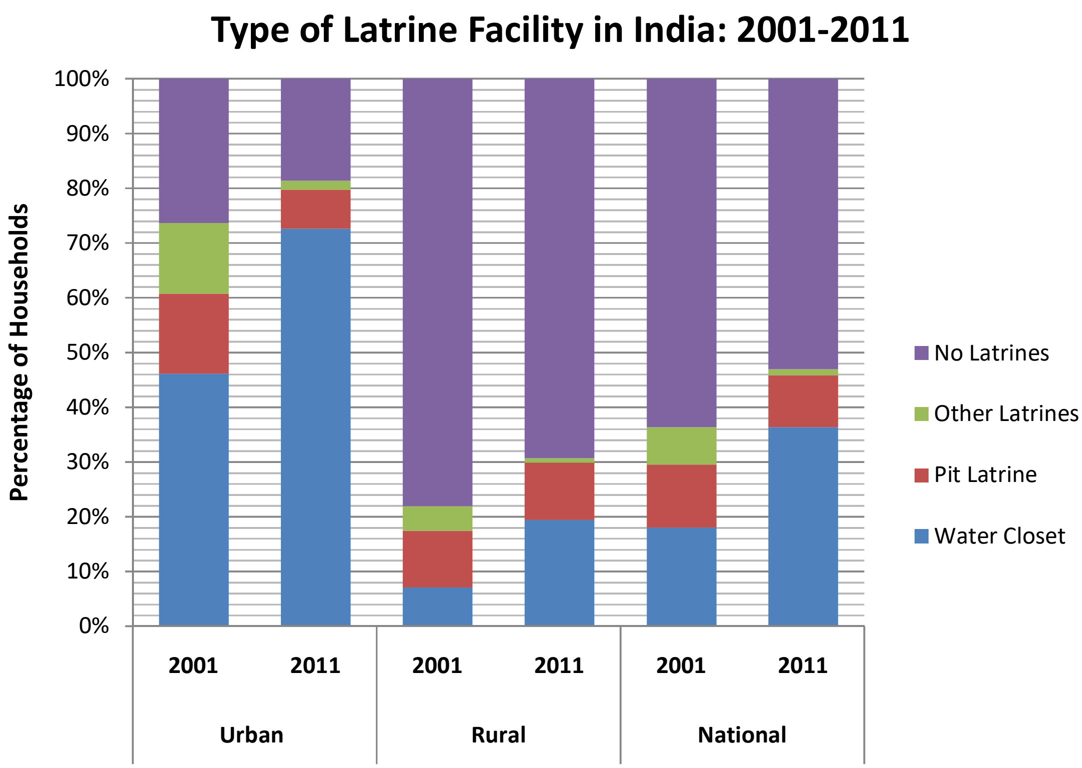


Figure 6.1: **Comparison of toilets being used by Indian households in year 2001 and 2011, Source: Census, 2011**

7. Crisis in the Making

In India high strength domestic wastewater discharges after no or partial treatment through sewage treatment plants or septic tank seepage have resulted in a large build-up of groundwater nitrates in Rajasthan, India [45]. A study on water handling, sanitation and defecation practices in rural southern India showed that, among 97 households interviewed, 30 (30.9%) had toilets (Septic Tank) but only 25 (83.3%) used them. 74.2% of respondents defecated in fields. This led to serious diarrhea during monsoon and other diseases due to unsafe water [46]. A field survey was conducted in four slums, squatter and pavement dweller communities of Mumbai City, India with a total sample size of 1,070 households. The study revealed extremely low water consumption pattern averaging merely 30 L/capita/d and no sewerage and safe excreta disposal facilities manifested by high occurrence of water-borne diseases. The annual diarrheal, typhoid and malaria cases were estimated to 614, 68 and 126 per thousand populations respectively. At point of prevalence scale, at least 30% of all morbidity could be accounted for by water-related infections [47].

A study was conducted on toilets in elementary and senior secondary schools located in rural areas of six districts of Uttarakhand state in India. In the six districts there were a total of 705 schools, of which only 372 schools (52.7%) used septic tank. Also, the study revealed that the toilets with septic tanks are 46.2 and 94.2% respectively in economically developed district of Pithoragarh and Udham Singh Nagar. But in economically backward districts of Nainital and Champawat, only 28.6 and 41.9% of elementary and senior secondary schools respectively have toilets with septic tanks. Another finding from the study is that lack of awareness in pupils regarding sanitation was main reason for adverse health effects [48].

Another study discussed the concept of ‘’healthy city’’ which promotes physical, mental, social, and environmental well-being of people [49]. They prioritized urban health and environmental challenges in eight major Indian cities, including Delhi, Mumbai, Kolkata, Chennai, Hyderabad, Meerut, Indore and Nagpur. Based on this criteria different cities in India were evaluated and it was found that Sanitation in Delhi’s slums was recorded 23.9% and total of 64%,Mumbai’s slums recorded 21.4% and total of 32%, Kolkata’s slums recorded 24% and total of 47.1%, and Chennai’s slums recorded 19% and total of 34%. The study clearly concludes that there is inadequate sanitation facility in slums and this situation has to change so that the concept of “Healthy City” is achieved [49].

In Assam, the Public Health Engineering Department (PHE) is implementing the Total Sanitation Campaign. The main goal of the Total Sanitation Campaign is to eradicate the practice of open defecation by 2017. Villages that achieve the ‘open defecation free’ status receive monetary rewards and high publicity under a programme called Nirmal Gram Puraskar. Still there are more than 12 lakh households in Assam which have no access to toilets, as on April 2013. Despite the Total Sanitation Campaign, the practice of open defecation continues in the State. The PHE Department must work rapidly to provide sanitation facilities to these households in order to achieve the ambitious sanitation target under the Total Sanitation Campaign [50].

In an article in the newspaper Hindustan Times about the city of Gurgaon, it is stated that “Poor sanitation leads to rise in diarrhea cases”: The first monsoon showers have led to a spurt in diarrhea cases in the city, doctors said. According to private and government hospitals, about eight such cases, along with complaints of gastroenteritis and vomiting, are being reported daily. “The number of patients suffering from water-borne diseases has increased in the past 10 days. We see about 10 patients every day, out of which eight are admitted. These are mostly residents of Sector 14 and areas near the railway tracks where sanitation is a major issue,” said DrRakesh Kumar, medical officer, Gurgaon Civil Hospital [51].

An article “Sanitation Shortage Hurts Health, Education of India’s Girls and Women” published in GPI[52]states that, “Inadequate sanitation forces women in both rural and urban areas of India to defecate in the open, leaving them vulnerable to sexual violence. Lack of toilets or maintenance of them also creates health hazards. It forces girls to drop out of school and women to quit their jobs'. Jairam Ramesh, minister of drinking water and sanitation, recently stated in the Parliament that 60% of India's population and 70% of women don't have access to a toilet. In July 2012, he deemed India the world's capital of open defecation, according to local media. He also tempered the excitement about successful missile tests by lamenting that there is no use launching missiles if there are no toilets for women.

The capital of India is also not exempt from the toilet troubles. New Delhi has only 132 public toilets for women, while men have 1,534, according to a 2009 report by the Centre for Civil Society, a nongovernmental research and educational organization devoted to improving citizens' quality of life. Suman Chahar, an expert in environmental sanitation and public health says on open defecation: "This is a very grave and daily issue, particularly for these women, it concerns their security, health and dignity. Along with shocking incidents of rape and molestation and lewd remarks, I have heard shocking stories of what all these women go through if accidentally they found a man from their community 'sitting' next to them in the row." Inadequate sanitation facilities in rural and urban India endanger the safety and health of girls and women as well as force them to drop out of school and quit their jobs. Advocates demand that the government and community prioritize this basic need before pursuing further technological advancements in the country.

8. Concluding Remarks

The discussion presented so far clearly shows that the sanitation problem is far from being solved in India. It is a matter of shame that in our country a large number of people still practice open defecation or have to defecate in conditions that do not provide a minimum amount of dignity and comfort. The matter of scientific disposal of excreta is another area of concern. Currently, unscientific disposal of excreta into water bodies and into the ground is resulting in both our surface and ground water bodies being polluted. Sewage can be plainly seen flowing or accumulating in water bodies and surface depressions and excreta can be seen on the ground in plain view. These things not only violate our aesthetic sense, they also cause odour problems, lead to breeding of disease vectors and are a threat to public health.

The overall sorry state of sanitation facilities in India arises only partly from the fact that a large segment of our population is poor and lack access to toilets. There are considerable doubts regarding which sanitation technologies are suitable for Indian conditions. In recent years, both central and state governments in India have spent enormous resources to provide "improved" sanitation facilities as elucidated in the "Millennium Development Goal" targets. Large numbers of pit latrines were constructed to prevent open defecation. However, many of these pit latrines became defunct and people returned to open defecation.

One of the main reasons for failure of sanitation programs in India is the adoption of solutions which are incompatible with the expectations and cultural sensibilities of the population. Based on the discussion presented about the peculiarities of traditional sanitation practices and present sanitation conditions in India, certain conclusions can be arrived at regarding sanitation practices in Indian conditions,

1. Open defecation cannot be recommended under any circumstances. This practice does not allow defecation with dignity and privacy and may be unhygienic if done improperly.
2. Toilets that need daily manual cleaning are not recommended under any circumstances since they are against human dignity and contravene the Manual Scavenging Act.
3. Hanging toilets, i.e., toilet constructed directly over water bodies or cesspools cannot be recommended under any circumstances. Such toilets create extremely unhygienic conditions.
4. Indian habit of using anal cleansing water renders the use of pit latrines difficult. The pits cannot be maintained dry and this leads to odor and fly problems. Defecation under such conditions becomes uncomfortable, and people soon abandon pit latrines and revert to open defecation.
5. Use of UDDTs is difficult, since the present models require following a certain discipline during defecation. An improved version of UDDT, specially attuned to Indian conditions is required.
6. Flush and pour-flush latrines connected to open drains are problematic. Since the open drains follow the contours of the ground, in flat areas slopes cannot be maintained for flow of sewage at self-cleansing velocities. This leads to the deposition of sewage solids in the drain and subsequent choking and overflowing of the drains, creating unhygienic conditions.
7. Flush and pour-flush latrines connected directly to soak pits or connected to septic tanks followed by soak pits is problematic in congested areas, especially when water table is high. The chances of groundwater pollution are very high under such conditions.
8. Shared or communal toilet facilities must be given due importance. Such facilities may be the only workable solutions under certain conditions.

Hence there is an urgent need for evaluation of all sanitation technologies currently available and to identify and select the best technologies applicable to Indian conditions both urban and rural which should follow a certain level of hygiene and maintain human dignity. Some underlying principles for such analysis can be identified as:

1. The acceptable system must allow defecation in privacy and with dignity and a minimum amount of comfort. In other words, the system must provide a good "front end" solution.
2. The effluents from the sanitation system should not be a threat to general aesthetics of the area, i.e., seen flowing or accumulating in open view or create odor problems. Such effluents should not become a threat to public health, either by allowing proliferation of flies and other disease vectors or by pollution of groundwater.
3. The effluent from the sanitation system must be treated to render it harmless before disposal. In other words, the system must have a good "back end" solution.
4. It is also desirable that the effluent from the sanitation system is treated such that nutrients present in feces and urine can be recycled for land application.

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Sanitation in India

Recommendations for Optimal Practices

GRBMP: Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay	IIT Delhi	IIT Guwahati	IIT Kanpur	IIT Kharagpur	IIT Madras	IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. A list of persons who have contributed directly and names of those who have taken lead in preparing this report is given on the reverse side.

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Contents

Summary

There is considerable awareness about community water supply needs, but the problems of excreta and sewage disposal, i.e., sanitation, has received less attention in India. The effects of poor sanitation seep into every aspect of human life be it health, welfare, economy, dignity, empowerment or environment.

To meet the country's sanitation challenge there is an urgent need to focus on proper collection and treatment of excreta and sewage and to build and maintain appropriate toilets for all. Government has spent and is still spending a lot of money to improve the state of sanitation, but majority of systems have failed due to various reasons.

Through assessment and analysis of prevalent sanitation issues in various types of human settlements in the country, this report recommends workable sanitation models for various situations. For this purpose, urban sanitation and rural sanitation issues are analyzed separately. Areas of concern are identified and problems faced are discussed, followed by formulation of the recommendations.

Sanitation models suggested in this report for various situations have certain common characteristics. They allow people to defecate with dignity and a minimum amount physical comfort. Further, these proposed models also incorporate methods for the safe disposal of the resultant excreta and sewage. In short, they provide both acceptable "front-end" and safe "back-end" solutions. These models completely discard the prevalent objectionable practices in the sanitation sector, i.e., manual scavenging, open defecation, conventional dry latrines, open drains, direct defecation into water bodies (cesspools) and soak pits in areas with high ground water table or rocky strata.

Finally, cost analysis of various sanitation models show that the cost of defecation and safe disposal of the resultant excreta and sewage ranges between Rs. 3.50 and Rs 5.50 /person/day, irrespective of the model adopted. Our country must be aware of this cost and willing to pay for it for a systemic solution to the sanitation problem.

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1. Introduction

Sanitation is the most neglected sector in India. The general tendency is to just transport the waste out of sight; nobody is concerned about the fate of that waste, believing that that nature will automatically take care. But unfortunately that's not true; the effects of poor sanitation seep into every aspect of human life.

In India only 30% of urban households have access to sewer lines, while this percentage is almost zero in rural areas. Growing volumes of untreated sewage contaminate ground water and surface water. Rivers and drainage channels are carrying raw sewage. A large portion of the population has no access to toilets. These people cannot defecate in privacy and are forced to go out to defecate in open fields, near rivers or on railway tracks. To meet the country's sanitation challenge there is an urgent need to focus on building appropriate toilets, ensuring their maintenance and further treat the waste from these toilets properly before disposal.

In the last few years, substantial funds have been spent by both central and state governments on building of the sanitation infrastructure in the country. However due to a variety of reasons including inappropriate sanitation solutions adopted, the results from such initiatives have been less than heartening, Even now, an unacceptably large percentage of Indian population have no access to toilets and hence practice open defecation.

There is an obvious need for good sanitation systems, which are complete in themselves, i.e. these systems should not compromise in any aspect. Therefore such systems must have certain important properties,

- **Disease prevention:** A sanitation system must be capable of destroying or isolating pathogens.
- **Environment protection:** A sanitation system must prevent pollution and conserve valuable water resources.
- **Nutrient recycling:** A sanitation system should return nutrients to the soil.
- **Affordability:** A sanitation system must be accessible to the poorest people.
- **Acceptability:** A sanitation system must be aesthetically inoffensive and consistent with cultural and social values.
- **Simplicity:** A sanitation system must be robust enough to be easily maintained with the limitations of the local technical capacity, institutional framework and economic resources.

A critical assessment of traditional sanitation practices and present sanitation conditions in India leads to following observations,

1. Open defecation cannot be recommended under any circumstances. This practice does not allow defecation with dignity and privacy and may be unhygienic if done improperly.
2. Toilets that need daily manual cleaning are not recommended under any circumstances since they offendbasic human dignity and contravene the Manual Scavenging Act.
3. Hanging toilets, i.e., toilet constructed directly over water bodies or cesspools cannot be recommended under any circumstances. Such toilets create extremely unhygienic conditions.
4. Indian practice of using anal cleansing water renders the use of pit latrines difficult. The pits cannot be maintained dry and this leads to odor and fly problems. Defecation under such conditions becomes unhygienic and uncomfortable, and people soon abandon pit latrines and revert to open defecation.
5. Use of Urine Diversion and Dehydration Toilets (UDDT) is difficult, since the present models require following a certain discipline during defecation. An improved version of UDDT, specially attuned to Indian conditions is required.
6. Flush and pour-flush latrines connected to open drains are problematic. Since the open drains follow the contours of the ground, in flat areas slopes cannot be maintained for flow of sewage at self-cleansing velocities. This leads to the deposition of sewage solids in the drain and subsequent choking and overflowing of the drains, creating unhygienic conditions.
7. Flush and pour-flush latrines connected directly to soak pits or connected to septic tanks followed by soak pits is problematic in congested areas, especially when water table is high. The chances of groundwater pollution are very high under such conditions.
8. Shared or communal toilet facilities must be given due importance. Such facilities, which are conceptually different from public toilets, may be the only workable solutions under certain conditions.

This report,at first, developsbenchmarks for the minimum requirements of an acceptable sanitation solution in Indian context and then proposes acceptable sanitation solutions for all categories of human settlements, both in urban and rural areas. It also tries to determine the cost of implementation of these solutions.

2. Benchmark for an Acceptable Sanitation Solution

Minimum requirements for an acceptable solution in Indian context can be identified as:

1. The acceptable system must allow defecation in privacy and with dignity and a minimum amount of comfort. In other words, the system must provide a good “front end” solution.
2. The effluents from the sanitation system should not be a threat to general aesthetics of the area, i.e., seen flowing or accumulating in open view or create odor problems.

Such effluents should not become a threat to public health, either by allowing proliferation of flies and other disease vectors or by pollution of groundwater.

3. The effluent from the sanitation system must be treated to render it harmless before disposal. In other words, the system must have a good “back end” solution.
4. It is also desirable that the effluent from the sanitation system is treated such that nutrients present in feces and urine can be recycled for land application.

No sanitation solution that contravenes the first three points above is acceptable. Solutions which allow adherence to all four of the above conditions should be generally preferred.

3. Recommendations for Urban Sanitation

Urban areas in India are defined using the criteria mentioned below,

a. All statutory places with a municipality, corporation, cantonment board or notified town area committee, etc.
b. A place satisfying the following three criteria simultaneously:
   i. a minimum population of 5,000
   ii. at least 75 per cent of male working population engaged in non- agricultural pursuits
   iii. a density of population of at least 400 per sq. km. (1,000 per sq. mile)

An urban area can be classified as metro cities or class 1, class 2 and class 3 towns. The sanitation issues in all urban areas are of similar nature and can be classified as shown in Fig.3.1.

In urban areas with existing sewer lines, the issues are relatively simple. In such areas, care must be taken to ensure that all households and establishments in the area are connected to the sewer lines. In urban areas without sewer lines, the general policy should be to install sewer lines in all areas, except in, a) very congested areas with narrow road width, b) in slum areas and, c) in newly developed or developing colonies and apartment complexes. Further, all sewage collected must be necessarily conveyed to a sewage treatment plant (STP) for treatment. Ideally the STPs must be decentralized, such that the sewage conveyance and pumping costs can be minimized, however this may be impossible in some already developed areas due to space constraints and other local opposition.

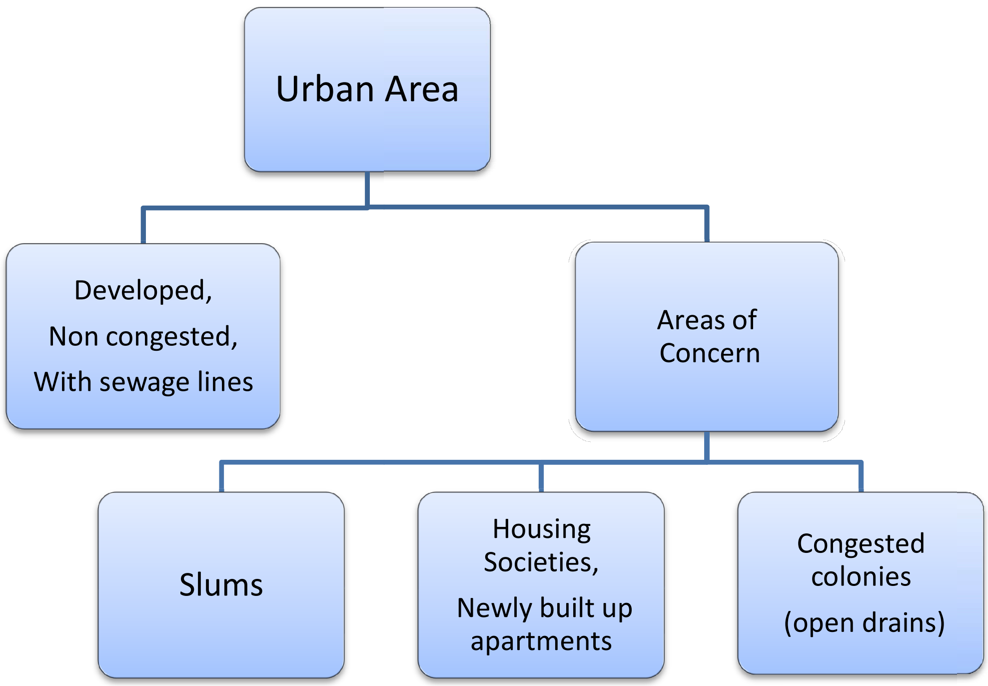

Figure 3.1: **Classification of Urban Area, with respect to areas of concern in view of sanitation**

The proposed sanitation solutions in those parts of urban areas where conventional sewers lines are impossible or are not recommended are given in subsequent sections.

3.1 Congested Colonies

Congested colonies with narrow lanes are quite common in urban areas. In many Indian urban landscapes, such congested colonies constitute the major form of human settlement. Most houses in such colonies have either flush or pour-flush toilets. The sewage from such toilets flows in open drains and then on to some low lying area or water body in the vicinity of the colony. Alternatively, some houses in the colony may have septic tanks, which are connected to soak pits or to open drains.

Neither open drains nor soak-pits constitute an adequate solution to the "back end" sanitation problems in congested urban colonies. A viable solution to the "back-end" sanitation problems in such cases is a small-bore sewer network, which may be constructed inside the open drain network existing in such colonies. In a small bore system, the sewage must pass through an interceptor before being released into small bore closed pipes. Such interceptor tanks, which are similar to septic tank, may be constructed in suitable locations inside the colony. If possible, an interceptor tank may receive sewage from several households. The sewage flowing through the small-bore system may be released into existing sewer lines outside the colony. Alternatively, the sewage from the small-bore system may be treated in a decentralized STP before disposal.

Compared to conventional sewer systems, small bore sewers can be significantly less costly to construct, and yet provide a similar level of service. Such systems are in successful operation in many countries. Blockages in such small bore systems can be largely eliminated through proper designing of the interceptor tanks. The provision of interceptor tanks also result in flow equalization, considerably reducing peak flows in the network. The sustainability of the system however depends on the regular evacuation of the interceptor tanks and systems for this must be put in place. The sludge from such tanks must be further treated before disposal.

Since the solids load is considerably reduced in the effluent from the interceptor tanks, small bore sewers need not be designed for self-cleansing. Pipe gradients can be reduced and sections depressed below the hydraulic grade line. This reduces the sewer depth requirements and such sewers may also run along existing open drains. Also, manholes are not necessary in such networks. Provision of hydraulic flushing must however be available to remove any blockages.

Since such networks have not been installed in India, cost analysis of this system was done by studying a pilot project proposed for a small congested colony near Delhi. This colony has 1200 households and a population of around 6000. Water consumption is around 100 lpcd, hence sewage generated is around 80 lpcd. If the effluent from the proposed small-bore system is discharged in the nearest sewer line, then the amortized capital and O&M cost of the system is Rs. 4.51 /cap/d. In case the amortized capital and O&M cost of an STP is included, the cost rises to Rs. 5.13 /cap/d. The relevant calculations are presented in the Appendix (see Table A1**).**

3.2 Slums

Slums in urban areas are distinguished by the fact that individual households in such areas generally do not have toilets. The inhabitants in such areas either practice open defecation or use other toilet facilities like hanging latrines over cesspools, public latrines provided by municipalities, etc.

It is not practical to have separate toilets for each household in slum areas. Therefore a community toilet system is the best possible solution. The proposed alternatives for slum areas include the following,

- Community latrines based on Zero Discharge Toilet (ZDT) technology as developed at IIT Kanpur.
- Community pour-flush latrines connected to a small bore system and discharging to sewer line outside the slum
- Community pour-flush latrine discharging directly to sewer line outside the slum

Alternatives such as pit latrines, latrines connected to septic tanks and then soak pits etc. were considered inappropriate considering the possibility of groundwater contamination. Composting toilets are generally inappropriate in Indian conditions due to the practice of using water for anal cleaning. Presence of excess water makes composting difficult. Alternatives such as UDDT are also considered inappropriate since the discipline required for using such toilets is difficult to maintain in communal/shared toilets. Calculations show that the amortized capital and O&M cost of a ZDT system for 750 persons is approximately Rs. 4.90/cap/d. The relevant calculations are presented in the appendix (see Table A2).

Community toilet systems are common in India. An organization devoted to the setting up such toilets is Sulabh International, which has evolved a business model for the operation and maintenance of such toilets. Assessment of the model adopted by Sulabh International shows that their model has a good "front end", i.e., users can defecate in privacy and with a minimum physical comfort. However, the 'back end" of their system is not so efficient. The most commonly adopted "back end" solution for such systems is a septic tank followed by a soak pit, which is clearly unacceptable in congested slums. However, the Sulabh Model can readily be improved by connection of toilets to sewers, either directly, or through a small-bore system. Calculations show that the amortized capital and O&M cost of a pour-flush community toilet system for 750 persons is approximately Rs. 4.71/cap/d, when proper "back end' solution is incorporated. The relevant calculations are presented in the appendix (see Table A3).

3.3 New Townships/ Housing Society/ High Rise Building Complexes

The guiding principle regarding sanitation in such units is the fulfilment of the zero discharge criteria, at least in the dry season. All sewage produced in such units must be treated on site and re-used for a) horticulture purposes, b) cooling purposes, c) for flushing purposes, d) fire-fighting demand, and d) to maintain surface water bodies within the premises. Such a policy will have dual benefits, the fresh water demands from such units will be considerably reduced and there will be no additional demand on the urban sewage network.

The entire cost for this should be borne by the township/society concerned. A market survey was done to understand the costing of a decentralized STP of a housing society. For a typical society in the NCR region, the operation and maintenance cost of a 500 kld plant was found around Rs. 25.6/ kL (refer appendix, Table A4). Assuming that a household of 5 generates 800 L sewage per day, the amortized cost of treatment is about Rs. 5.24 /cap/d including the capital cost of STP. However, in cases where an existing STP is already available, the amortized cost is Rs. 4.09 /cap/d (refer appendix, Table A5). Analysis of the costs in a society in the NCR region with a functioning STP showed that the cost of running the STP contributed only around 4.50 % of the total user charges paid by households to the society (refer appendix, Table A6).

4. Recommendations for Rural Sanitation

In India, human settlements with population less than 5000 are generally known as rural areas. Many households in rural areas do not have toilets and practice open defecation. Most toilets in rural households are of the pit latrine type. In rare cases, households have flush or pour flush latrines. Such latrines are sometimes connected to soak pits, either with or without a septic tank. Communal toilets are mostly absent in rural areas.

Based on the description of the current scenario concerning rural sanitation in India, it is clear that most of the practices followed are unacceptable as per the minimum sanitation benchmarks identified. Current government policy recommends the construction of pit latrines in rural areas to prevent open defecation. However, due to the Indian practice of anal cleaning with water after defecation, pit latrines are never dry and hence do not satisfy the minimum comfort criteria (smell, flies etc.) that is expected from a latrine. Hence many pit latrines constructed in rural areas have been abandoned and people have reverted to open defecation. Furthermore, pit latrines and soak pits are unsuitable in areas with high water table, rocky strata etc. and may be the cause of groundwater contamination or general decline in public hygiene due to overflowing.

4.1 Sanitation in Rural Areas with Population less than 1000

In small villages with well drained soil and relatively low water table, the acceptable sanitation solutions are the following,

- A pour flush latrine for individual households, with a septic tank followed by a soak pit. A group of 4-5 households can have one septic tank installed with the septage discharged into the ground through a soak pit. Construction of a double pit system is recommended to enhance system reliability and so that the soak pits can be used in turns and cleaned when not in use. Regular evacuation and maintenance of septic tank is also required. The amortized cost of the above system is Rs. 4.19 /cap/d, which includes the cost of the toilet. Calculations are shown in a tabular form in the Appendix (see Table A7). The existing toilets in households may be converted to the above system relatively easily.
- A community toilet system for each cluster of household with an attached septic tank and a soak pit can be a good option in settlements where majority of households lack toilets. A community toilet could be a pour-flush latrine similar to that described previously, or a ZDT system (similar to that developed by IIT Kanpur).

In small villages with high water table, periodic flooding or with rocky strata, soak pits are not recommended. Acceptable sanitation solutions in such situations are the following,

- For individual households, an improved version of the UDDT system with provisions keeping the feces separate from urine and anal cleaning water. Such systems suitable for Indian conditions are currently not available and development of such systems should be encouraged.

- A community toilet system for each cluster of household based on ZDT technology similar to that developed by IIT Kanpur.

4.2 Sanitation in Rural Areas with Population between 1000 and 5000

In large villages, provision of a soak pit is not recommended even when the topography is favourable. Provision of a soak pit enhances the threat of water borne diseases in the area and hence must be avoided even in areas with moderate population density. The proposed sanitation solutions in large villages include,

- Pour flush toilets in individual households connected to small-bore system transporting the effluent to a lined constructed wetland for further treatment. 4-5 households can have a common interceptor tank. The amortized cost of such a system, including the wetland, but not including the toilet is approximately Rs. 4.18 /capita/d. Detailed cost calculations are provided in the Appendix (see Table A8).
- Community toilet system of the pour-flush type connected to small-bore system transporting the effluent to a lined constructed wetland for further treatment before discharge.
- Community toilet system employing ZDT technology similar to the system developed by IIT Kanpur

4.3 Sanitation in Rural Areas with Population greater than 5000

There may be some settlements with population more than 5000 but still designated as rural area due to predominantly agricultural occupation of the people and/or low population density. The sanitation solutions in such areas are similar to villages with population between 1000 – 5000. However, other types of STPs, i.e., pond systems and aerobic lagoons may be considered in such areas in lieu of wetland systems.

5. Concluding Remarks

The overall sorry state of sanitation facilities in India arises only partly from the fact that a large segment of our population is poor and lack access to toilets. There are considerable doubts regarding which sanitation technologies are suitable for Indian conditions. In recent years, both central and state governments in India have spent enormous resources to provide “improved” sanitation facilities as elucidated in the “Millennium Development Goal” targets. Large numbers of pit latrines were constructed to prevent open defecation. However, many of these pit latrines became defunct and people returned to open defecation.

Through analysis presented in this report, the sanitation practices that are undesirable in Indian conditions have been identified. Further the desirable aspects of any sanitation solution in India have been highlighted. Subsequently, sanitation solutions have been proposed for various kinds of human settlements prevalent in India, in both urban and rural areas. The approximate cost for adopting these technologies has also been worked out. These results are summarized in tabular form in Tables6.1 and 6.2.

From Tables6.1 and 6.2 it can be concluded that amortized cost of sanitation facilities are in the range of Rs. 4.00 to Rs. 6.00 /capita/day. Further all proposed sanitation solutions require provisions for regular operation and maintenance, including deputation of skilled/unskilled workforce for this purpose. Our country not only needs to adopt the correct technological solutions, but must also be willing to arrange and plan for the funds required to provide sanitation for all.

Table 6.1: Summary of Urban Sanitation

Urban Sanitation									
					Components covered in costing				
S.No.	Category	Proposed Solution		Cost (Rs.) /head/day	Front end	Conveyance cost	Capital investment in treatment	Operation and Management cost	Remarks
1	High rise buildings/ Townships/ Housing Societies	a	New Buildings with an in house STPs installed	4.1		√		√	The treated water is used for purposes like flushing, horticulture etc., which further reduces the demand of fresh water of the society
		b	An in-house STP proposed if not already installed, as it would reduce a lot of load from municipal sewer lines	5.24		√	√	√	This cost includes the cost of STP, this is the best possible solution as recycling of wastewater is a necessity nowadays
2	Congested Colonies	a	Small bore sewer system connected to a STP	5.13		√	√	√	Considering 80 L of wastewater generated per head per day
3	Slums	a	Zero Discharge Toilet system: a mobile community toilet system	4.9	√	√	√	√	ZDTS is a complete solution but would need extra land for composting. Cost of toilet included as nobody has a personal toilet in slums
		b	Community toilet (SulabhShauchalya type) connected to STP	3.88	√			√	Wastewater is supposed to be dumped in nearest sewer line, only cost of treatment considered. 40 L wastewater assumed per head per day

Table 6.2: Summary of Rural Sanitation

Rural Sanitation										
S. No.	Population		Proposed Solution		Cost (Rs.) /capita./day	Components covered in costing				Remarks
						Front end	Conveyance cost	Capital investment in treatment	Operation and Management cost	
1	Less than 1000	a	Septic tank with soak pit		4.19		√	√	√	For households already having toilets, only if topography allows
		b.	Community toilet	Pour flush toilet attached to septic tank and soak pit	4.71	√		√	√	To cater households without toilets, a community toilet is a must
			Community toilet	Zero Discharge Toilet System	4.9	√	√	√	√	ZDTS is a complete solution, would need extra land for composting
2	More than 1000 but less than 5000	a	SBS connected to a wetland		4.18		√	√	√	Considering 80 L of wastewater generated per head per day
		b	Community toilet	Pour Flush toiletconnected to wetland via SBS	4.71	√			√	Capital cost of wetland not considered in case of community toilet, 40 L wastewater assumed per head per day
			Community toilet	Zero Discharge Toilet System	4.9	√	√	√	√	ZDTS is a complete solution, would need extra land for composting though

Table 6.2: Summary of Rural Sanitation (continued)

Rural Sanitation											
S. No.	Population	Proposed Solution			Cost (Rs.) /capita./day	Components covered in costing				Remarks
						Front end	Conveyance cost	Capital investment in treatment	Operation and Management cost	
3	More than 5000	a	SBS connected to a STP		5.13		√	√	√	Considering 80 L of wastewater generated per head per household, including cost of STP
		b	Community toilet	Community toilet (SulabhShauchalya) connected to STP via sbs	4.71	√			√	Capital cost of STP not considered, as the wastewater is supposed to be dumped in nearest sewer line, only cost of treatment considered. 40 L wastewater assumed per head per day
				Zero Discharge Toilet System	4.9	√	√	√	√	ZDTS is a complete solution, would need extra land for composting though

Appendix

Table A1: Costing of a Small Bore Sewer System installed in a congested colony

Small bore system for a congested colony (population: 6000)			
S.No.	**Particulars**	**One time Cost**	**Per month**
1	Pipe laying cost	7,756,801	
2	Cost of Manholes	0	
3	System Access Points	2,300,256	
4	Clarigester (Septic Tank)	10,160,000	
5	Surface Reinstatement	1,372,800	
6	Low pressure and cctv testing after commissioning	2,215,300	
7	Clarigester internal components	20,888,400	
8	Intermediate Pumping Station	0	
	Total	**44,693,557**	**431365.00**
9	O & M of the conveyance system in 20 years		20850
	Total Monthly expenditure		452215.00
Per head per day cost of safe disposal of waste water to a nearby sewer line			2.51
Per head per day cost of including conveyance in sewer line and treatment			**4.51**
Per head per day cost of conveyance and treatment including cost of onsite STP			**5.13**
Assumptions and considerations			
1	Total capital cost amortised on monthly basis assuming rate of interest as 10 % for a period of 20 years		
2	Detailed costing has been taken from a proposed pilot project by EIL		
3	Assuming 80 liters of wastewater generated per head per day		

Table A2: Costing of Zero Discharge Community Toilet System

ZDTS for Slum (Population: 750)				
S.No.	**Particulars**	**One time (Rs.)**	**Monthly (Rs.)**	**Annual(Rs.)**
1	Toilet Structure (30 toilets) + Mixer + Mini Evacuation Trolley + Composting Yard	3240000	42817	513804.00
2	Chemicals and other toiletries		5000	60000.00
3	Diesel + Electricity etc.			54750.00
4	Supervisor / Local Representative incentive @10000 per month			120000.00
5	Sweeper/Operator (6 Nos.) @6000 per month		36000	432000.00
6	Contingency/Repairs/Servicing/Standby			162000.00
	Total			1342554.00

	Cost of treatment per day	3678.23
	No. of Users	750.00
	Cost per user per day	**4.90**

Assumptions and considerations	
1	Total capital cost amortised on monthly basis assuming rate of interest as 10 % for a period of 10 years
2	Cost of chemicals and toiletries taken from market survey
3	Assuming Rs. 150 expenditure on fuel and electricity per day
4	Considering contingencies to be 5 % of the total capital investment, annually
5	Considering 25 users per toilet system per day

Table A3: Costing of Sulabh Shauchalya with proper treatment of wastewater

Sulabh Shauchalya in Slum (Population:750)				
S.No.	**Particulars**	**One time (Rs.)**	**Monthly (Rs.)**	**Annual(Rs.)**
1	Toilet Structure (3 units of 10 toilets each)	3000000	39645	475740.00
2	Toiletries and Electricity charges			54750.00
4	Supervisor / Local Representative incentive @10000 per month			120000.00
5	Sweeper/operator(3 Nos.) @ 6000 per month		18000	216000.00
6	Contingency/Repairs/Servicing/Standby			150000.00
	Total			1016490.00

	Cost of defecation per day	2784.90
	No. of Users	750.00
	Cost per user per day	3.71
	Cost of conveyance and treatment of sewage per user	1.00
	Total cost of treatment per user per day (excluding cost of land)	4.71

Assumptions and considerations	
1	Total capital cost amortized on monthly basis assuming rate of interest as 10 % for a period of 10 years
2	Cost of toiletries wages of labor taken from market survey
3	Assuming expenditure of Rs. 150 on electricity and toiletries per day
4	Considering contingencies to be 5 % of the total capital investment, annually
5	Assuming 40 liters of wastewater per person per day
6	Considering 25 users per toilet system per day

Table A4: Costing of a 500 kld treatment plant including capital cost of STP

	Operation & Maintenance Cost of a 500 kld treatment plant including capital cost of treatment plant	One time investment	Tentative existing expenditure / month	Cost /KL
1	**Capital cost (for supply, installation, testing and commissioning of electro-mechanical items including civil work)**	**10000000**	107461	**7.16**
2	**Break-up of Non-Comprehensive Offer**	-		
i	Manpower (4 Nos) + Administrator		45000	**3.00**
ii	Site expenses (Room Rent, Uniform, Staff welfare, Conveyance,Safety appliances, Tools & tackles, Stationery, Internet, telecommunication, etc)		15000	**1.00**
iii	Maintenance cost		170000	**11.33**
iv	Electricity cost		95000	**6.33**
2	**Chemicals**	-		
i	Chlorine		3000	**0.20**
ii	Polymer		1300	**0.09**
iii	Oil, grease/lubricant		1500	**0.10**
iv	MGF Media/ Activated Carbon		53000	**3.53**
	Total cost (treated water)		**491261.00**	**32.75**

Approximate expenditure per household per day	26.201
Cost of treatment of wastewater per person per day	**5.240**

	Assumptions and considerations
1	Total capital cost amortised on monthly basis assuming rate of interest as 10 % for a period of 15 years
2	Cost of chemicals taken from market survey
3	Assuming an average of 5 persons per household
4	Assuming 800 liters of wastewater generated per household

Table A5: Running cost of a 500 kld STP

Operation & Maintenance Cost of a 500 kld treatment plant			
S.No.		Tentative existing expenditure / month	Cost /KL
1	**Break-up of Non-Comprehensive Offer**		
i	Manpower (4 Nos) + Administrator	45000	**3.00**
ii	Site expenses (Room Rent, Uniform, Staff welfare, Conveyance, Safety appliances, Tools & tackles, Stationery, Internet, telecommunication, etc)	15000	**1.00**
iii	Maintenance cost	170000	**11.33**
iv	Electricity cost	95000	**6.33**
2	**Chemicals**		
i	Chlorine	3000	**0.20**
ii	Polymer	1300	**0.09**
iii	Oil, grease/lubricant	1500	**0.10**
iv	MGF Media/ Activated Carbon	53000	**3.53**
	Total cost (treated water)	**383800.00**	**25.59**

Approximate expenditure per household per day	20.469
Cost of treatment of wastewater per person per day	**4.094**

Assumptions and considerations	
1	Assuming an average of 5 persons per household
2	Cost of chemicals taken from market survey
3	Assuming 800 liters of wastewater generated per household

Table A6: Maintenance charges of a typical housing society

Freedom Park Life Housing Society (B.P.T.P.)							
S.No.	**Month**	**Maintenance charge per month**	**No. of Flats**	**Maintenance charge per month per household**	**Running cost of STP/ month**	**Cost incurred to user per month, due to STP**	**% of total maintenance charge**
1.00	Apr	3992000.00	453.00	8812.36	200000.00	441.50	5.01
2.00	May	4976000.00	453.00	10984.55	200000.00	441.50	4.02
3.00	Jun	5310000.00	453.00	11721.85	200000.00	441.50	3.77
4.00	Jul	5128000.00	453.00	11320.09	200000.00	441.50	3.90
5.00	Aug	4486000.00	453.00	9902.87	200000.00	441.50	4.46
6.00	Sept	4463000.00	453.00	9852.10	200000.00	441.50	4.48
7.00	Oct	3630000.00	453.00	8013.25	200000.00	441.50	5.51
8.00	Nov	3808000.00	453.00	8406.18	200000.00	441.50	5.25
9.00	Dec	3956000.00	453.00	8732.89	200000.00	441.50	5.06
Total		**39749000.00**	**453.00**	**87746.14**	**1800000.00**	**3973.51**	
Average		**4416555.56**	**453.00**	**9749.57**	**200000.00**	**441.50**	**4.53**

Table A7: Cost of septic tank and soak pit attached to toilets of 5 households

S. No.	Particulars of toilet systems	Cost (Rupees)	Monthly(Rs)
	Septic tank and soak pit for 5 households(30 members)		
1	Pourflush toilet systems including superstructure (5 no.s)	75000	
2	Septic Tank(good for 30 people) attached to soak pit	100000	
	Total	175000	1689.00
	Maintenance and cleaning charges per year	25000	2083.33
	Total		**3772.33**
	Cost of Sanitation per head per day including cost of toilet		**4.19**

Assumptions and considerations

1	Total capital cost amortised on monthly basis assuming rate of interest as 10 % for a period of 20 years
2	Cost of chemicals and toiletries taken from market survey
3	Cost of toilet systems and septic tank taken from market survey

Table A8: Costing of a Small bore sewer system installed to a village

Small bore system for a village (population: 5000)			
S.No.	**Particulars**	**One time Cost**	**Per month**
1	Pipe laying cost	7,756,801	
2	Cost of Manholes	0	
3	System Access Points	2,300,256	
4	Clarigester (250 Septic Tanks) including internal components	25,873,667	
5	Surface Reinstatement	1,372,800	
6	Low pressure and cctv testing after commissioning	2,215,300	
7	Intermediate Pumping Station	0	
	Total	39,518,824	381365.00
8	O & M of the conveyance system in 20 years		20850
	Total Monthly expenditure		402215.00
Per head per day cost of safe disposal of waste water to a nearby sewer line			2.68
Per head per day cost of conveyance and treatment in wetland			4.18
Assumptions and considerations			
1	Total capital cost amortised on monthly basis assuming rate of interest as 10 % for a period of 20 years		
2	Detailed costing has been taken from a proposed pilot project by EIL		
3	Assuming 80 liters of wastewater generated per head per day		

Cremation Practices

Analysis and Recommendations

GRBMP: Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay | IIT Delhi | IIT Guwahati | IIT Kanpur | IIT Kharagpur | IIT Madras | IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. A list of persons who have contributed directly and names of those who have taken lead in preparing this report is given on the reverse side.

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Contents

1. Introduction

In several towns located on the banks of sacred rivers across the country, and more so in the northern part, the poorest of the poor often resort to disposal of dead bodies in rivers. This method of disposal is resorted primarily on account of relatively higher expenses involved in conventional wood based cremation. Although Hindu scriptures suggest this mode of disposal as one of the options in very rare circumstances, increasing instances due to higher population loads have made it an environmental/ river water quality and public health concern. In order to address this issue, over the years a number of agencies have attempted to introduce alternate methods of cremation apparently termed 'environment friendly' and claimed to involve lower expenses e.g., electric furnace or metallic perforated grills for wood cremation. However for a variety of reasons virtues of the alternative methods have not appealed to the society at large. The reservations could be attributed to socio-religious beliefs, customs and traditions or plain technical issues related to their performance and cost.

In this context, it is appropriate to review these issues and develop a fresh perspective on the places of cremation as integral part of social infrastructure for any community, town, city or village - be it on river banks or otherwise. However, it is pertinent to recognize that in view of the matter of 'life-and-death', and the socio-cultural and religious dimensions attached to it, the subject of cremation is quite nebulous. For a rationalist with scientific/ technology perspective, prima facie the arguments based on religion and beliefs may appear unacceptable. However for any new alternative on offer for a subject as sensitive as cremation, it would have to gel with the beliefs, customs and traditions of the target society before it could be promoted at a wider scale. In this respect, this report commences with a description of the sensitive subject of religious beliefs to help develop a perspective, then takes on issues related to technology, analyses lessons from successful initiatives in the past in selected towns and finally presents a set of recommendations for possible future initiatives.

At the outset it is to be mentioned that this report is based on a comprehensive research study which was carried out by the Foundation for Greentech Environmental Systems back in 2004 at the behest of the Japan Bank for International Cooperation (now JICA) and for the Ministry of Environment and Forest. This study was conducted under the context of the Yamuna Action Plan to identify issues associated with societal resistance towards use of alternate technology based crematoria which were constructed along the River Yamuna and to identify ways for their promotion.

2. Religious Beliefs and Socio-Cultural Aspects

The custom of cremation of a dead body is practised mainly in the Hindu religion and those religions which have emerged out of it i.e., Jainism, Buddhism and Sikhism. Among others, these oriental religions are characterised by strong presence of rituals and undoubtedly the process of cremation is also dominated by a series of rituals. The rituals are in turn determined or governed by the belief system of a religion or society. In this context, the following paragraphs offer an overview on the origin and persistence of rituals in the Hindu religion.

2.1. Hindu Rituals and Identity

'Rituals' - meaning patterning of actions strongly characterise Hindu religion and the society as a whole. Hindu ritual patterns are considered to constrain life from birth, through childhood, to marriage and finally to death and therefore are followed during the course of various religious and social activities and prayers performed to mark special occasions. Depending on geography and other factors, ritual behaviour can be extremely diverse, however it is also stable in a certain way in behaviour patterns which are passed through generations and which give shape and a degree of unity to the Hindu traditions. Ritual action also gives people a sense of deeper identity and belonging. Therefore rituals have seldom been abandoned within Hindu traditions and this is particularly true for the ceremonies performed at the time of birth, marriage and death.

Many rituals can be traced to very early Hindu texts such as *Vedas* and *Upnishads* and therefore they have been performed for several millennia. Hindu rituals have existed under diverse social and political contexts and therefore have exhibited high degree of persistence which has survived great political upheavals, colonial repressions and ecological catastrophes. In some sense, ritual structures with links to the *vedic* solemn (*srauta*) seem to have defied history. Changes, if any have come over the generations at a very slow pace.
Rituals also cut across theological distinctions. In the rich variety of Hindu ritual, there are cultural forms which do not demand belief in any particular doctrine, but rather demand action in certain ways. Therefore different sections of the Hindu society can be found to follow same or similar rituals.

Rituals can be compared to a language as a system of communication – they have a structure, a syntax, and for a believer some meaning.While the formal meaning of *vedic* rituals may not be explicitly obvious and may not stand the scrutiny of a scientific rational analysis, however with respect to the domestic rituals, the *grhya* (householder's) rites involving birth, marriage and death are considered important and sacred activities.

2.2. Belief in Rebirth and Transmigration

In Hindu religion it is believed that the soul is distinct from the body and it goes through a long cycle of birth and death according to the *karmic* credits or debts accumulated during its various lifetimes – human and other species. It is also believed that birth in human form is the highest level of evolution of a soul which offers it an opportunity to 'escape' the unending cycle. This 'escape' represents attainment of *moksha* or *mukti* which a soul may strive to achieve (and therefore the name *moksha-dhma* or *mukti-dham* typically given to cremation grounds) and which is then related to the 'rites of passage' of an individual. It is also believed that upon death the astral body (*sukshm* sharer, comprising *maan*, *budhi* and *ahankar*) carries the *karmic* account of a soul for its onward journey.

2.3. Rites of Passage

In Hinduism 'rites of passage' are believed to constrain a soul's passage through time from birth to death by moulding and helping construct social identities. The Sanskrit term for 'rites of passage' is *samskara*, implying the putting together of a person as a social actor. The closest meaning for *samskara* is sacrament which connotes sanctifying the soul in its human form. In other words *samskaras* are believed to make a person cultured, disciplined and conditioned as a complete being. It is believed that *samskaras* also help a person in facing difficulties in life and enable achievement of the ultimate purpose of attaining *moksha*.

According to *ManuSmriti*, there are sixteen *samskaras* which are recommended at specific stages of a soul's journey from the stage of conception to death. Among the sixteen, the most important *samskaras* are performed at the time of birth (*Jatkarma*), initiation (*Upanayana*), marriage (*Vivahasamskara*) and funeral (*Antimsamskara*) – the latter two marking the beginning and end of a householder's life. In general all *samskaras* are performed in ritualistic and elaborate ceremonies typically involving worshiping of fire and other elements of nature, with the accompaniment of chanting of sacred mantras. The mantras are supposed to have profound effect of invoking the cosmic powers and receiving blessings of the Gods.

2.4. Funeral Rites

Funeral rites performed at the time of cremation are called *antyesthisamskara*, which mean not the absolute 'end' but encoding for the next life. Unlike other religions wherein upon death the soul is believed to rest in peace, in Hindu religion it is believed that its journey will go on, and therefore the purpose of the cremation ceremony is to pray for it to be peaceful and evolutionary. The purpose of performing a ritualistic ceremony is therefore for the soul to either get a superior human form in its next birth or attain *moksha*. Evidently to the extent possible the next-of-kin want to perform the ritualistic ceremony as per the scriptural prescriptions without any compromises so as to facilitate the ultimate, i.e., attainment of *moksha* for the departed soul.

The *antyesthisamskara* in particular and rest of the 15 other *samskaras* in general have evolved over the millennia. Therefore in general, the structure of the *antyesthisamskara* including the preceding and following rites and rituals is fairly uniform among different sections of the Hindu society located in different parts of the country and the world. Among the three broad versions, the toughest to perform is called *shastrachar* which is strictly based on the scriptures. Two simplified versions are called *lokachar* and *kulachar* which are evolved at the level of a society and family/community respectively, according to the local social, cultural, geographical and environmental circumstances.

2.4.1. Preceding and Following Rituals

Before cremation invariably a corpse is bathed, anointed with sandalwood paste, shaved if male and wrapped in a red cloth. Significance of the first two rituals is to reduce or suppress odour during the time the corpse is kept at home and during the cremation. Use of red cloth signifies positive feeling or blessings for the onward journey of the soul as red is considered to be the colour of life.

Death in Hinduism, as in many other cultures, is believed to be fraught with the danger of an ominous influence for the bereaved and their being haunted by a malevolent ghost. This belief in after-life and/or danger of transmigration into a ghost spirit leads to performance of a set of rites immediately before and after the cremation which are called *pinddaan* and *sraddha* respectively.

Pindadan is performed to facilitate migration of the spirit from the realm of ghosts to the realm of the ancestors or *pitras*. This ritual is symbolic of seeking peace for the soul or the astral body. It comprises offerings of five balls (*pinda*) made of flour of barley, wheat or rice to the deceased at various stages during its last journey from home to the cremation ground. First *pinda* is offered at home, second is offered outside the home, third is offered at a square or cross road, fourth is offered at a resting place before the crematoria and the last *pinda* is burnt along with the dead body in the pyre.

On the same lines, *sraddha* is performed as the final rites over several days immediately following the cremation, as the family members are considered to be under the inauspicious influence. These again involve offerings of *pinda* to the deceased which are believed to construct a virtual body in an intermediate realm - the world of the ghosts (*preta-loka*). These daily offerings continue for ten days, recapitulating the ten lunar months of the embryo's gestation, at which time the ghostly body is complete and with the rite known as *sapindikarana*, transmigrates into the realm of the ancestors (*pitra-loka*) for its onward journey.

Therefore the *antyesthisamskara* and the preceding and following rites in totality are believed to control the inauspicious influence of death. In several communities invariably a feast is organised on the 11th or 13th day after the death to mark end of the mourning period and getting the family back into the routine life.

2.4.2. Belief in Cremation

In Hindu religion it is believed that the human body is made of five basic elements of the nature i.e., earth, water, air, fire, and *aakash* (sky) and in the end it should merge with the same elements in their micro form. In conformity with this belief, for time immemorial Hindus have followed the practice of cremation which enables merging with the elements in the shortest possible time. There are several references to cremation in the scriptures, particularly in the *Rigveda* - considered to be the oldest scripture in the world. According to some, it is believed that along with the smoke of the burning firewood the soul rises to the heavens while another belief is that after burning of the body its link with the departed soul is severed and therefore the latter would not wander.

2.4.3. *Antim Samskar* - The Process of Cremation

This section describes salient features of the process of cremation which offers an understanding of the significance of certain rituals and how the traditional arrangement of a pyre made of wooden logs is found to be in compliance for their performance. This description is also intended to help in appreciating the limitations of alternative systems on offer and their general lack of acceptance by the society at large.

Preparation of a pyre

A conventional pyre comprises a pile of wooden logs wherein the body is placed in the middle. There are no scriptural prescriptions for the quantity of wood to be used but depending on size of the body and other factors, traditionally 5, 7, 9 or 11 *mann* are used, where one *mann* is 40 kg. Dung cakes are also used in varying quantity to supplement wood.

The process of cremation is also considered as performance of a *havan* or *yajnya* which involves worshiping the fire and invoking the cosmic powers through chanting of mantras. As in the case of a *havan* in normal times, here also the process is carried out with frequent offerings (*ahuti*) of ghee and *samagri* (a mixture of herbal additives). Other materials such as camphor, forest-gum, etc. are also used. While there are no rules for the quantity of these additives, customs have evolved based on local circumstances. Generally quantity of ghee is about the weight of the body and that of the *samagri* is about twice as much. However given the high cost of *ghee*, affordability is a major factor and variations are common.

The purpose of addition of these materials is two fold. Firstly they act as catalysts for the fire and secondly the fragrance that pervades in the surroundings helps in suppressing the odour released from burning of the body. For the latter, at times sandal wood is also used, albeit in small quantity. Addition of these materials also imparts an element of sanctity to the whole process.

Depending on the *lokachar* and *kulachar*, members of the family and the community also make an offering (*ahuti*) of wood and *samagri* into the pyre. In rural areas it is a common practice for every attendee to bring along offering of small log of wood or dry dung cake for the pyre. Purpose of this custom is to ensure adequate quantity of fuel for complete burning of the body and show solidarity with the bereaved.

The ritualistic process is considered sacred, purifying and in conformity with the natural laws of blending the gross body with the five elements described earlier. It represents a hygienic disposal method which is also safe from environmental health point of view as it does not leave behind any objectionable or infectious residues or does not involve blockage of land/space, etc. If looked scientifically, the burning of wood and the body does not constitute a polluting activity in the sense that it does not lead to emission of any hazardous or poisonous gases.

Orientation of the body

As a rule, the body is laid along north–south direction. The head points in the north as it is believed to be the direction of light, dominant of fire and source of knowledge. It is also considered to be the realm of *Kubera*, the demigod of wealth. The feet point towards the south as it is considered to be the realm of *Yama*, the demigod of death and connotes the direction of darkness.

Generally the body is kept slightly tilted, with head being about 6 inches higher. More wood is placed on the head side and less towards the feet as the former requires more heat to burn completely and this arrangement enables optimal use of wood.

Pinda dan

As stated earlier, the fifth *pinda* brought from the home is placed on the pyre and is burnt along with the dead body. This is considered to be one of the important rituals.

Mukhagni

This ritual comprises offering fire to the pyre by the eldest son or closest relative which signifies deliverance of one of the obligations towards the deceased. Moreover, among the *pouranik* Hindus it is the fire brought from the home which is used for lighting the pyre. As per the scriptures, it is believed that the use of kitchen fire leads to the accumulated good karmas of the person in this life time (*prarabdh*) getting attached to the transmigrating astral body and carried forward into the next life.

Another interpretation of this ritual is related to the importance of fire and its ability to take the soul to the *swargloka* (heavens). The person offering the *mukhagni* is asked to chant a specific mantra which means ‘the deceased was born out of this fire and this all pervading fire should reappear and it should take the deceased to the *swargaloka*.’

Kapal Kriya

Kapal Kriya is one of the rituals performed about half an hour or one hour after lighting the pyre. The actual practice and its significance vary among communities. In some communities it comprises merely touching the skull with a long bamboo. It is believed that the astral body carries the 'engrams' i.e., trace of the past life in the memory, which may be misused by evil spirits or it might interfere with the life in its next birth. Touching of scull with a bamboo is symbolic of erasing this memory.

On the other hand in some north Indian communities, *Kapal Kriya* involves breaking of the skull by hitting it with a bamboo. It is believed that the soul escapes through the top of the head and unless the skull is broken it will not have a smooth passage for the next life.

2.5. Reasons for Rigidity in Cremation Procedure

From the above description it is evident that the rituals associated with cremation of a body have certain significance and the Hindu society has deep belief in them. People do not view cremation as a mere process of combustion of organic material or dead biological cells, tissues and bones, and considerations of economy are secondary. To the extent possible the rich and the poor alike prefer to carry out the *antim samskara* as per the scriptural rules or prescriptions of the supervising priests. Moreover, as death is 'once in a life time' event, resources permitting, the bereaved family members do not like to compromise on rituals if they are believed to 'guarantee salvation' for the soul. Among the poor and especially rural communities, there is a tendency to even borrow or collect community contribution so as to be able to carry out all the rituals including the following rituals and rites over the next 13 days.

One of the reasons for this ritualistic process is that it is being followed since ancient periods (for over 5000 years) as it is believed to be originating from the *Vedas* (believed to be revelations straight from the God and not written text of recent origin). It is believed that if the process is carried out as per the scriptures, it leads to salvation of the deceased and also ensures peace, harmony and happiness in the family. Among the *Pouranik Hindus* it is a strong belief that the above described rituals of *Pind Daan*, *Mukhagni* and *Kapal Kriya* are integral and it is only by following them the soul of the deceased attains *moksha* and reaches the heavens. Accordingly the traditional wood based cremation process has evolved which has been more suitable for their performance.

In addition, there is social pressure to follow the rituals and carry out subsequent rites. One of the purposes of this is to maintain the so called prestige in the community. Particularly in the semi-urban and rural areas people would not like to be perceived to be cutting cost on such obligations. On the other hand, elaborate cremation procedures followed among the better section of the society, for eminent leaders and persons of prominence have also served as a deterring example for middle class and the poor to take initiatives for alternate methods.

For a rationalist, while the traditional Hindu process of cremation may not fit into a scientific analysis, however on account of the above described factors there is inherent rigidity within a large section of the society in adhering to it.

2.5.1. Flexibility Among Selected Communities

It is understood that those societies which have undergone social reforms have been able to adopt a degree of flexibility in various rituals including the process of cremation. This effect is observed in the state of West Bengal where reformers like Raja Ram Mohan Roy, Ishwar Chandra Vidyasagar, Debendranath Tagore, and others had taken radical initiatives in early nineteenth century for removing several deep rooted ill practices of sati, child marriage, and disapproval of marriage of widows. Similarly the followers of Arya Samaj have also adopted several reforms to simplify the overall process, for instance reverting to normal life within three days of death. However, it needs to be noted that this flexibility can not be attributed to short-term public participation and awareness creation campaigns of recent origin but to social reforms spread over couple of centuries.

Certain degree of unorthodoxy is also observed in a small section of the urban society of the country. Particularly in large cities like Mumbai, Kolkata and perhaps to a limited extent in Delhi exigencies of urban life have reduced the scope for conducting ritualistic cremation and subsequent rites over an extended period. People like to get over with the obligations and get back to routine at the earliest. However, a large part of the society across the country still adheres to the traditional way of cremation which apparently gives to the bereaved family member a sense of consolation of having performed their obligations towards the deceased.

2.6. Variations in Cremation Procedure

As stated earlier, rituals evolve along *lokachar* and *kulachar* depending on the local circumstances. As Hinduism is not just a religion but a way of life, there are several sects and groups in different parts of the country. Accordingly there are significant variations in the rituals performed by the followers of different sects, however their structure may remain by and large same. For instance in rural communities use of dung cakes for cremation is very common while in urban communities this is limited to carrying the *mukhagni* and igniting the initial fire in the pyre as their availability may be limited.

On the other hand, *sanyasis* and children are usually buried. A holy man is buried in a tomb or *Samadhi*, indicative of the belief that the body and the soul is absorbed into a higher state of consciousness. On the other hand body of a renouncer, who is believed to have undergone his own funeral during the rite of renunciation, might simply be placed in a river. The latter practice originates from the belief that while alive the body did not serve any purpose, upon death it should at least serve as a source of food to the aquatic life. However, scriptural reference or justification for this practice is not available.

With regard to protection of the tree stock, there is the case of the Bishnoi community in western Rajasthan which is fiercely protective of its forests. In order to prevent cutting of trees this community has adopted an extreme form of *lokachar* of inhumation or burial as practices in other religions. It is understood that there is another Hindu sub-caste in the state of Tamilnadu in southern India which also follows this custom. These practices are not in conformity with the *shastrachar* and in fact are considered as violations.

It is also learned that due to financial reasons the poor often resort to use of 'inferior' fuels. For instance in order to minimise expenses on wood, there is a tendency to use waste tyres in the pyre. Moreover, as the ritual of offering the *ahuti* of ghee is unaffordable, addition of kerosene is not a rare practice either.

The latter three illustrations have been included only to present the extent of variation that exist in the society and are in no way indicative of alternatives with which the larger society would be comfortable or would approve of.

2.7. Social Responsibility of the Business Community

In the context of the costs involved in a traditional cremation process and thereby the poor resorting to disposal of dead bodies in rivers, it is interesting to learn what the scriptures have to say. The scriptures exhort the business community to take this as its social responsibility and bear the burden of the poor. Extending financial help to a poor family towards deliverance of its obligation for a dignified cremation of its deceased member is considered to be a social duty of a very high order.

In view of this, it is often found that in several large and small towns alike, the crematoria are managed by civil society, trusts, etc. which are in turn financially supported by the local trading or business community. Invariably the infrastructure at the crematoria is built through donations received from local business houses, industries, etc. The entire establishment is run on no-profit basis which provides selfless service, firewood and other materials required for cremation at affordable prices.

2.8. Significance of Trees and Environment in Hindu Religion

Hindu religion is one of those oriental religions in the world which has accorded very high value to preservation of environment and it has a designated presiding deity called the demigod *Dattatray*. With such belief several traditions and customs have evolved wherein components of the ecosystem such as rivers, ponds and trees are revered and worshiped. Respect towards nature and environment is ingrained in the Hindu religion in the form of the principle of sanctity of life for both human and non-human.

This principle translates into accordance of high importance to trees/forests and plants, whereby several species e.g., *Pipal, Amala*, *Banyan*, and *Tulsi* are worshiped regularly. In this respect it is interesting to note that some of the dense patches of forests across the country have survived due to this value and which are recognised as 'sacred groves'.

According to scriptures planting of trees is considered a very sacred duty and cutting of trees is forbiddenned. Planting of a tree is considered to be equivalent to giving birth to 10 sons and it is also recommended that during his/her entire life time a person should plant at least one tree for every completed year. Such scriptural injunctions characterise *Hindu* religion with a value system enabling harmony with the ecosystem. Drawing from this, many civil society organisations have promoted the concept of *SmritiVan* along side cremation grounds.

3. Technology Options for Cremation

On account of concerns related to high costs involved in wood based traditional cremation and those related to conservation of forest, various agencies have tried to develop alternate solutions based on a variety of fuels. In terms of technologies and fuel, the available alternatives are listed as follows:

- Conventional pyre on ground
- Improved wood cremation system (IWC)
- Electric crematorium (EC)
- Diesel, LPG or CNG fired crematorium
- Combined gas and wood fired crematorium
- Biomass gassifire based crematoria, and
- Solar crematorium

Salient features of these technologies vis-à-vis their compatibility with the traditional procedure of cremation are described in the sections that follow.

3.1. Conventional Pyre

A conventional pyre is about 6-8 ft long, 3-4 ft wide and about 3-4 ft high. In lay man's terms, size of such a pyre is defined as that corresponding to a person of normal size with both arm stretched out. A margin of about a foot on either side along the length is preferred for complete covering of the body. The pyre is prepared on a slightly raised ground by placing bigger/heavier wooden logs at the bottom and smaller logs at the top. This arrangement provides for effective circulation of air through the pyre and improves combustion. To this effect in some parts of the country pyres are also made on a platform of large lose stones and boulders. In order to prevent falling of the upper logs and spreading of the fire, it is a common practice to put some logs in inclined position on the two long sides of the pyre. The body is placed at about mid-height. Depending on size of the body, moisture content of the wood and weather conditions, traditionally 5, 7, 9 or 11 *mann* are used, where one *mann* is equal to 40 kg. Average consumption is between 300 to 400 kg and in rare cases it could be as much as 500 kg. Readily combustible biomass e.g., dry grass, bamboo, etc. are also placed to facilitate the fire.

In some parts of the country it is a common practice to use dung cakes as main fuel and straw for start up. This alternative biomass could be cheap as it is available in-house or can be procured from neighbours. Typically 200 kg of dung cake is required for one cremation.

Typically in urban areas, a platform and a shed are constructed to designate and safeguard the place of cremation and to offer protection against rains, etc. The shed typically has openings for creation of draught and thereby facilitate ventilation.

3.2. Pyre in a Vedi

As the process of cremation is symbolic of performing a *havan* or*yajnya* among the follower of the *Arya Samaj*, the layout of the location for the pyre also corresponds to a *vedi* – a fire altar typically used for performing a *havan*. For this purpose ideally a 4 ft deep trough with sloping sides (2v:1h) is made. At the bottom, the trough length and width are same as for a traditional pyre on ground as described above. Steps are provided for easy access for arranging the pyre and cleaning. A schematic of this type of pyre arrangement is shown in Figure 1. Although this arrangement is not very common it offers following advantages:

- Unlike a pyre on a raised platform the fire in a pit is not affected by wind and therefore it is contained.
- As a result, in this case the fire grows slowly which is apparently convenient for performance of initial rituals while standing close by and offer *ahuti*.
- As the fire grows slowly, the rate of burning of dry wood is not disproportionately high compared to the body which takes longer to initially dehydrate primarily due to 80-90% moisture content and then start combusting. From these points of views, compared to a conventional pyre this arrangement is considered to be optimising consumption of wood. However there are no data available to support this claim.
- The trough does not allow spread of foul matter if any, released from the body and thus helps in maintaining the place clean.

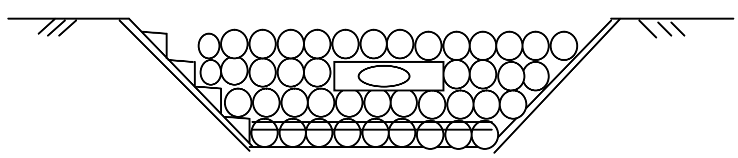

Figure 1: Arrangement of Pyre in the form of a *Vedi*

3.3. Improved Wood Cremation System

An improved wood cremation system (IWC) comprises raised metallic perforated platform with two flanges. It is designed with the objective of optimisation of combustion by augmenting the air to fuel ratio wherein it is claimed that fire wood requirement can be brought down by 100 kg and the complete cremation process can be completed in 3-4 hours.

Amongst all available options this IWC comes closest to the traditional process of cremation followed in the Hindu religion as it allows performance of the last rites in the prescribed ritualistic manner. IWCs were developed with the objective of reducing consumption of wood by as much as one third and were piloted under, among others, the Ganga and the Yamuna Action Plans with the objective of offering an option of lower cost cremation for the poor. However the response from the society has not been encouraging for a variety of socio-religious and technical reasons.

3.3.1. Principle of IWC

In its most basic form, an IWC comprises a metallic grill as in the case of a furnace. It is designed on the principle of increasing the air to fuel ratio by providing openings in the bottom. In addition, side flanges are provided to contain the wood and the heat from spreading out. The heat gradient creates a draught and as a result the perforations in the bottom and sides allow entry of plenty of air at a rapid rate. These features apparently lead to improvement in the rate and efficiency of combustion.

3.3.2. Forms of IWC

Different forms of IWCs have been introduced by various agencies. As shown in Figure 2, in its most basic form an IWC comprises the following four components:

(a) A perforated bottom plate about 7-8 feet long and 3 feet wide
(b) Perforated flanges along the two long sides of the bottom plate
(c) Six short columns supporting the fire place and enabling movement of air from underneath
(d) Hearth underneath the bottom plate for collection and retention of ashes

The bottom plate is made of either thick cast iron blocks or welded grill of angle iron and mild steel bars. The side flanges are again made of either cast iron blocks or fire bricks. The columns are made of either steel or cement concrete. The hearth is typically paved with clay bricks or cement concrete.

Where fire bricks are used instead of the iron plates, fire brick walls are joined by fire clay. Openings are provided in the lower part of the walls below the bottom plate and there are no openings in the upper parts. Thus the air flow takes place only from the bottom while the brick walls act to restrain the wood logs from spreading out and prevent heat loss.

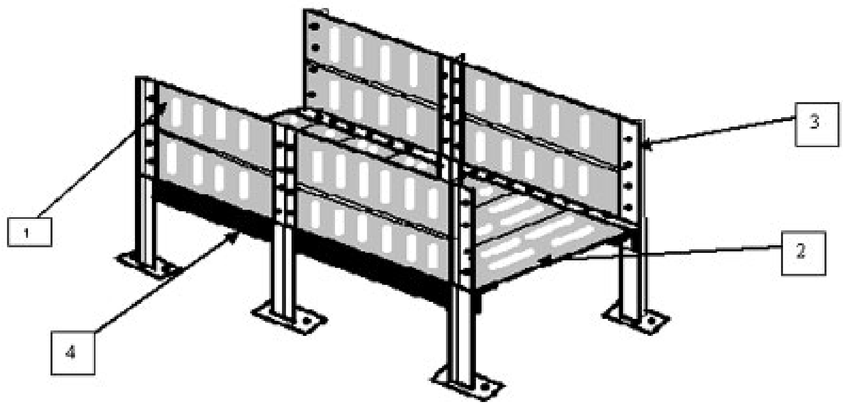

Figure 2: Basic Form of an Improved Wood Crematorium

The IWC is installed on a raised concrete/masonry platform and a steel shed is provided for cover. In relatively new installations a hood and chimney are also provided for improved ventilation which afford a degree of convenience to the attendees. At some locations mild steel trays are provided underneath for ease in collection of ashes and performance of multiple cremations on a single installation.

3.3.3. Performance and Benefits

In a conventional pyre which is lit on the ground, typically about 300-350 kg of wood is required and the ashes are collected next day. As against this, it is claimed that a cremation on the IWC requires about 200 kg of wood. In addition, complete cremation takes about 3-4 hours which enables early collection of ashes. Thus from cost and time point of views it is claimed that the IWC offers economy and ease of operation, and the two advantages together hold promise mostly for the urban poor.

3.3.4. Reservations of the Community

It is understandable that the subject of cremation is rather sensitive matter and any community which follows the traditional ritualistic procedures is likely to have reservations against any procedural changes or technological interventions. Some of the identified reservations which are entirely attributed to beliefs and none whatsoever to a scientific argument are as follows:

- Lack of contact of the pyre and therefore the body with the ground is not a desirable feature.
- Iron as the material of construction is not a sacred or auspicious metal.
- Presence of holes in the place or mat or mattress (*aasan*) used for worship/prayer, etc. and for that matter the IWC is considered inauspicious.

3.3.5. Limitations

Some of the functional and technology related limitations associated with IWCs are listed below:

- One of the most serious reported limitations is the inability to achieve complete burning of the body within the claimed lower quantity of wood. This is attributed to, among others, falling of cinders through the perforated bottom plate which otherwise help in complete burning of bones and other body parts in a conventional pyre.
- On account of exposures to multiple cycles of rapid heating (up to 1000º C) and cooling (due to spraying of water for removal of ashes for next operation) the structural elements (comprising cast iron or refractory bricks) experience thermal stresses and as a result rapid damage.
- Along with the above, the bottom plate is also subjected to corrosion leading to creation of holes and thereby falling of larger wooden pieces and cinders. This again leads to inefficient use of fuel value of the wood.
- Combined effect of corrosion and deposition of black soot leads to poor aesthetics which puts off people to use them.
- Maintenance and replacement of damaged plates is not easy as very few mechanics or blacksmiths are ready to accept work related to objects associated with cremation/ death. Moreover, lack of spares makes replacement of damaged metallic parts difficult.
- At open installations, lack of security makes iron parts prone to pilferage. Likewise when the joints loosen the fire bricks in the side flanges are also prone to pilferage.
- Difficulty in placing a body on the pyre due to the height of the side flanges.

3.3.6. Evolution of IWC

Based on the above experience, some of the agencies involved in promotion of IWCs subsequently considered incorporation of some of the following improvements in their deigns and specifications:

- Use of *Ashtha Dhatu* (an alloy of eight metals) for the platform, flanges and other metallic parts which is apparently considered sacred and is expected to have improved heat, elongation and corrosion resistance.
- Use of appropriate high grade steel for all other metallic components e.g., bottom tray, hood and chimney, etc.
- Use of heavy duty corrosion proof galvanized steel for columns, trusses and corrugated sheets for the shed which could withstand harsh operating environment.

3.4. Electric Crematoria

Electric crematoria (EC) have been around for a much longer time in large urban centres of the country. First EC was installed way back in 1960s in Kolkata and by now there are more than 125 installations across the country. Under the Yamuna Action Plan two such facilities were installed in Delhi.

3.4.1. Principle

An electric crematorium is essentially an electric furnace where the body is heated to a temperature of over 600 ^{o}C with the help of a series of resistance elements in a closed chamber. Fresh air is drawn from one end which helps in combustion and the exhaust is released from the other end. The fats contained in the body add to the process which raises the temperature to as much as 1000 to 1200 ^{o}C and to a large extent the subsequent combustion becomes self sustaining. However, unlike a conventional pyre and an IWC, in electric crematoria no herbal additives or *Ghee* are added and therefore there is an unavoidable aspect of odour emission.

3.4.2. Forms

Unlike an IWC, an EC is technology intensive system involving electrical and mechanical components, and requires dependable supply of electricity. There are very few technology suppliers in the country and the available options are limited.

Conventional model

The commonly used EC model has 12 resistance elements of 4.5 kW each, representing a total load of 54 kW. These are grouped into two circuits of 6 elements each. In addition, there are ancillary electrical components e.g., blowers, etc. which take the total power load to about 64 kW.

The air passed in 'once through' mode and the exhaust air is taken to a scrubber for removal of volatiles and suspended particles. The gases are released through a chimney which is generally 15 m high.

The wastewater from the scrubber is stored in a tank and released intermittently into a drain or a sewer. The settled solids are removed as necessary and disposed off in land fill. Besides plain sedimentation, the effluent does not receive any other treatment.

After burner model

In this model, a secondary combustion chamber is provided after the main furnace. This chamber essentially heats up the exhaust gases to a temperature of over 1000 ^{o}C and thereby helps in removal of odorous volatile organic compounds. As a result, this model does not require a scrubber and wastewater storage system. Instead the height of the chimney is increased to 30 m. Because of additional heating and taller chimney, the total electric load of this model is about 81 kW. However, due to comparatively higher capital costs fewer installations of this model are found.

3.4.3. Operations

As the arrival of bodies at a crematorium is uncertain, and the heating up of a cold furnace to the required temperature of 600 ºC takes inordinately long time, the system is required to be kept switched-on round the clock. It takes about 1-2 hours for cremation of one body including initial preparations and collection of ashes, etc. In view of the practice of cremation only during day light hours, the crematoria are typically kept open between 6 am to 8 pm and therefore the possible daily throughput for one EC is only about 4-5 bodies. However, in some large cities, e.g., Kolkata where average daily arrival is high, the crematoria are operated round the clock.

3.4.4. Performance and Benefits

One of the benefits of electric crematoria is the apparent saving of fire wood and therefore the claim of its being 'environment friendly'. This may be relevant in urban areas where fire wood has to be brought from long distances, however in view of low energy efficiency on account of long idling hours, this claim does not hold.

Another claimed benefit is its lower potential for air pollution compared to a conventional pyre as the system is equipped with scrubber and/or after burner. However, this needs to be verified as emission data from a conventional pyre in terms of hazardous, poisonous or corrosive substances (which might otherwise endanger life of human beings, flora and fauna or structures in the vicinity) are not available.

3.4.5. Reservations of the Society

In spite of a number of installations of this alternative system in large cities and efforts by municipal bodies and other agencies to promote their usage, the society in general has not accepted ECs for various reasons. Some of the reservations are discussed below:

- Inability to perform *Mukhagni* and *Kapal Kriya*.
- Inability to offer *ahuti* of *ghee* and *samagri* by the attendees and thereby derive a sense of having performed a sacred *havan*.
- Uncertainty of collecting ashes as higher temperature often leads to charring of bones.
- Unacceptable odour of ashes due to inability to blend herbal additives.
- Poor aesthetics of the furnace.

However, these reservations are subjective and would vary among sections of society depending on their background and circumstances at that point of time.

3.4.6. Limitations

ECs have both technical and financial limitations, and some of the key issues are summarised in the paragraphs that follow.

Technical aspects

ECs require dependable power supply as power failure during the course of a cremation would constitute a horrendous experience. However, to avoid such untoward incidences, typically a diesel generator is provided as a standby.

Considering the requirement of round the clock heating of the furnace, generally both circuits of heating elements (27 kW each) are kept on. Energy consumption during idling is unavoidable and turns out to be significant, leading to very high expenses on electricity. On this account, an EC may not necessary qualify as an 'environment friendly' alternative.

While it is possible to switch-off one of the circuits during idling, municipal operators seldom do so. Similarly, sensors and circuit breakers to cut off electricity when temperature rises above a certain limit are commonly not included apparently due to capital cost consideration.

The insulation material typically comprises glass wool while an efficient alternative of ceramic fibre is not used again due to cost considerations. The former leads to higher energy losses and thereby higher operating costs.

Often the wastewater treatment unit attached to the scrubber is not operated, instead the effluent is let out into a drain or a sewer. This leads to creation of unaesthetic and undesirable conditions.

Financial aspects

In large cities, typically two ECs are installed at a facility to take care of more than one body at a time. This leads to a total installed load of over 130 kW which, being higher than 100 kW entails a dedicated high tension power connection. Although high tension power supply is reliable and stable, it comes at a higher price. Secondly, irrespective of the actual energy consumption, the monthly bill from the utility corresponds to the total installed load which turns out to be high.

The overall energy charges due to idling and the above factors turn out to be in the range of Rs. 125,000 to Rs. 150,000 pm, however generally the user charges are reported to be only at around 50%. After including other typical operation and maintenance costs of the facility, a typical urban local body finds it difficult to sustain the operations on its own. On account of these reasons, it is understood that the Municipal Corporation of Delhi has been considering to convert its existing ECs into gas fired crematoria.

3.4.7. Evolution

As described earlier, electric crematoria are now available in two models i.e., conventional and with 'after-burner'. In addition, other features include energy saving measures e.g., sensors, circuit breaker system and insulation, etc.

3.5. Other Technologies

A number of agencies in the country have been working on developing alternative fuel based cremation systems. Some of these developments are profiled in the paragraphs that follow.

3.5.1. Biomass Gassifier Based Crematoria

The Tata Energy Research Institute (TERI) and other agencies have developed biomass gassifier based cremation systems where the producer gas derived from wood chips is used for combustion. It comprises primary and secondary combustion chambers where the operating temperature is 800 and 1100 °C respectively. The system is equipped with necessary controls to optimise and economise operations, a venturi scrubber for emission control and an effluent treatment unit.

It is claimed that this system requires 150-200 kg of wood chips for one cremation which is about half of what is required in a conventional pyre. Average time taken for full cremation is reported to be 60 – 90 minutes and at the end it enables collection of ashes for performance of subsequent rites.

First such system was installed in Ambarnath in Thane district in February 2002. Subsequently more such plants have been installed in Goa and Tamil Nadu (Ambattur, Alandur and Pallavaram). However, information on their performance, social acceptance and current status is not available.

3.5.2. Gas and Diesel Based Crematoria

On the same lines as above, LPG/ CNG and diesel based crematoria have been developed. A diesel based crematorium was installed by the Pune Municipal Corporation in 2001 which is claimed to be cheaper than an electric crematorium in terms of capital and operating costs. Current status of this facility is not known.

Likewise it is claimed that a CNG based crematorium takes about 2 hours for complete cremation and in terms of operating costs involves about half that of a wood based conventional pyre. In view of these advantages, in recent years the Municipal Corporation of Delhi (MCD) has installed CNG based crematoria at some of its main cremation grounds and it has also been planning to convert the existing electric crematoria into CNG based facilities. However it is understood that some of these installations have experienced technical problems relating to gas supply, burner, control system, etc. and are reported to be out of order.

3.5.3. Solar Energy Based Crematoria

M/s Ghadia Solar Energy Systems Pvt. Ltd. Gujarat has been involved in developing a solar energy based cremation system since late nineties. Its prototype comprises a metallic pyre box/ furnace 2m long and 60 cm wide which is heated by two reflectors. The latter comprise

50 sqm parabolic shape scheffler mirrors made in acrylic. The pyre box is kept about 6 m above ground and the reflectors are about 7 m away on the sides. The system is designed to generate a temperature of about 700 °C.

Initial R&D work has been carried out at the Goraj Ashram, near Vadodara in Gujarat. However it is understood that further work is required to be carried out to make it foolproof and before it could be promoted for wider installation.

4. Experience from Selected Towns

In the context of the special class of social infrastructure that is being discussed in this report, it is worth covering experience from selected towns where commendable work has been carried out by the local civil society organisations. These towns are among others, Rajkot, Jamnagar and Sidhdhapur in Gujarat, Mathura in UP and Kinshangarh in Rajasthan. The objective of portraying experience from these towns is to present some of the innovative measures, which are well accepted by the community making the operations sustainable, and thereby offer a perspective for similar developments elsewhere. For the sake of brevity, key lessons are presented collectively.

In all the above mentioned towns the civil society organisations in collaboration with the local business community and the respective urban local bodies have established conducive institutional mechanisms demonstrating successful public private partnerships. The resources thus mobilised have been utilised for development of good quality basic infrastructure and create an aesthetic, congenial and pious environment at a place which is associated with death and which otherwise arouses repulsive or depressing feelings among visitors and passers by alike.

Common features in varying degree at the crematoria in all these towns comprise a majestic entrance, wall paintings depicting religious/scriptural messages of profound significance on the repetitive cycle of birth and death, mythological fables, text from *Bhagwat Geeta* and the four *Vedas*, depiction of the 'wheel of life' highlighting its cyclic nature; clean pathways and resting places with appropriate sheds; amenities for washing, bathing; landscaping and water fountains, suitably located office, prayer and assembly rooms, storage for wood, etc.

At Rajkot this paradigm has been taken to an artistic level whereby the otherwise gloomy and desolate setting of a typical crematorium is replaced by beautiful ambience, converting it into a kind of a tourist spot and a source of inspiration. On a typical weekday visitor count (comprising all age groups) is around 2000 which rises to 5000 during weekends. Similar works have been carried out at Mathura and Jamnagar in varying degrees. Selected photographs of the Rajkot and Mathura crematoria are presented in Figures 3 to 6.

At all these locations the operations are managed by a local civil society organisation in partnership with the local business community and the urban local body. A dedicated team of workers/volunteers offers a range of services and helps in maintaining a high level of cleanliness and aesthetics. Part of the operation costs are met through user charges and grants from the ULB and the rest through donations from the local business community and philanthropic organisations. It is noteworthy that for poor families, the agencies provide free or subsidised services and also offer to send ashes for immersion into the Ganges at Haridwar free of cost. Such costs are borne particularly out of the corpus created through donations from the business community. Such partnerships epitomise the scriptural prescriptions on the subject and help create the necessary social framework to support the poor of the society.

Figure 3: The Ambience at Sadguru Muktidham, Rajkot

Figure 4: Amenities at Sadguru Muktidham, Rajkot

Figure 5: The Tourists at Sadguru Mukti Dham, Rajkot

Figure 6: Aesthetics at Mathura and Jamnagar Crematoria

An interesting observation at some of these locations is the fair degree of acceptance of alternate technologies for cremation, particularly the improved wood cremation system. As shown in Figure 7 the IWCs installed here are found to be well designed with high material specifications and effective in operation. Apparently the congenial ambience created at these cremation grounds could be one of the factors in lowering reservations towards their usage.

Figure 7: Simple Cot Shaped IWCS in Use at Rajkot

5. Conclusions and Recommendations

For a typical Indian city cremation grounds constitute part of the essential social infrastructure and their provision and maintenance are the responsibility of the respective urban local bodies. Instead of viewing cremation grounds as sites for merely consigning mortal remains of a person to flames, ULBs need to adopt a paradigm shift and view them as the 'last resort' of a human life. In this respect beyond their physical elements, the facilities, ambience and the services at the cremation grounds need to be planned and developed such that they blend with the value and belief systems of the Hindu society at large.

Further, in the context of the Ganga River Basin Management Plan (GRBMP) one of the main objectives of developing cremation grounds is to facilitate the poorest strata of the society and thereby prevent disposal of dead bodies into the rivers. From environmental conservation point of view, another objective would be to reduce pressure on forest resources.

Based on the above considerations a set of recommendations are evolved which can be classified broadly into four categories viz., socio-religious aspects, institutional aspects, infrastructure requirements, and finally technological aspects. Each of these is described in the paragraphs that follow.

5.1. Socio-Religious Aspects

Hinduism is greatly characterised by rituals which offer a sense of identity to its followers. Rituals which have persisted for millennia have scriptural basis and carry significance in relation to the belief system propounded by the *Hindu* philosophy. As the followers of *Hindu* religion believe in reincarnation of the soul - the cycle of birth and death and *moksha* (salvation), these beliefs govern the rituals performed at the time of cremation i.e. the final rites of passage. Therefore the underlying belief behind *Anthyesthi samskara* - the way it is performed, is to achieve purification of the migrating soul for its onward journey in next life form with an enlightened and easy passage.

Given the sensitive and profoundly socio-religious considerations associated with performance of last rites in Hindu society at large, a key factor for success of any intervention in this area would be to adopt a holistic approach wherein the technical inputs are necessarily preceded by eliciting perceptions and opinions, creating awareness and exploring participation from different sections of the respective local communities. The infrastructure, the facilities and the services should be planned and developed in consultation with the local community, keeping in consideration the subtleties behind performance of a range of rituals and associated specific requirements. Figure 8 attempts to capture and summarise this paradigm through a diagram and the relevant features are described in the sections that follow.

It is of utmost importance that the ambience created at the cremation grounds is soothing not merely to the physical senses of the distressed visitors but it should also invoke their spiritual side. It should help them connect with the profound tenets of Hinduism pertaining to the theory of *Karma*, the repetitive cycle of birth and death, the significance of living a virtuous life and performing good deeds with the ultimate objective of salvation. The ambience from the point of view of aesthetics as well as religious/spiritual setting should invoke the conscience being of every visitor such that he/she gets an opportunity for introspection on the profound significance of human life and how it relates to day to day activities.

With regard to the concern on depleting forest resources arising out of fire wood requirements for cremation, it would be desirable to take advantage of scriptural prescriptions on afforestation and tree conservation. In their respective geographical areas, the urban local bodies and other concerned agencies could promote the institution of *smriti van* (memorial forests) which signify ***Vrikshanjali***as a form of***Shradhanjali*** (condolence through afforestation). Similarly residents in their respective areas can be motivated to adopt the practice of plantation on any solemn occasions, leading to improvement in the local ecosystem and in the long run augmenting the supply of wood.

5.2. Infrastructure Requirements

Besides a shed and a place for making a pyre, a cremation ground should ideally have among others the following infrastructure and facilities:

- A boundary wall with a gate for protection from anti-social elements and stray animals.
- A covered place for resting, washing, bathing, urinals and toilets separately for male and female attendees.
- Platform for performing a set of rites prior to cremation.
- Multiple raised platforms for making pyres.
- Adequate arrangement for lighting and power supply.
- An office room for the operating agency.
- A hall for holding condolence/prayer meeting which is usually performed immediately after the cremation.
- A storage yard for stocking firewood and other necessary materials.
- Lawns and paved pathways.
- Parking ground.

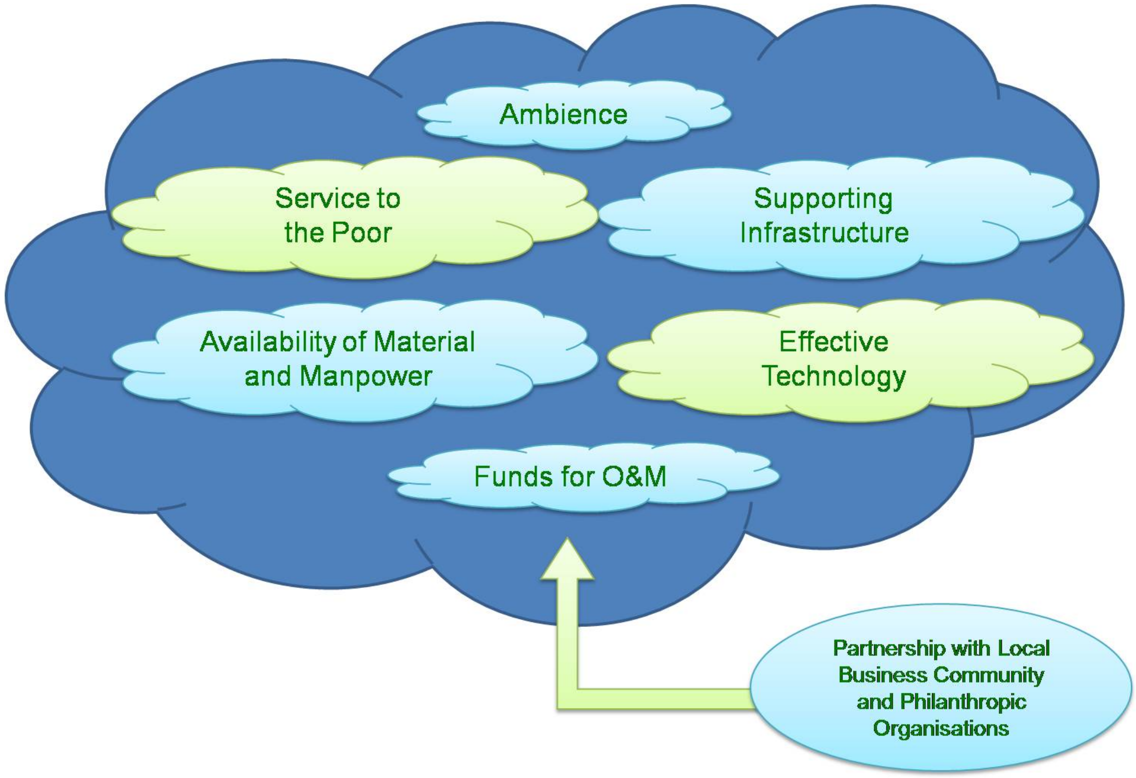

Figure 8: Combination of Enabling Factors at a Cremation Ground

The entire facility should ideally be planned and developed in consultation with the local community incorporating considerations of aesthetics, religious sentiments and beliefs, convenience, etc. The size of the facility/infrastructure should be in line with the size of the habitation/population that it is expected to serve. The material specifications and the quality of construction must be in line with the anticipated large footfalls and demanding working conditions such that the infrastructure has long life.

5.3. Institutional Aspects

In order to bring a humane and soothing touch to the services offered at cremation grounds it is recommended that wherever feasible, urban local bodies should establish partnership with a committed local community based organisation (CBO), civil society organisation or non-governmental organisation. This partnership should ideally be established at the time of planning and developing the facility/infrastructure so that the agency finds it convenient to take up its operation and maintenance. It is also recommended that wherever feasible the partner organisation should be asked to mobilise own resources (may be 10-20%, which could be through donations, grants, etc.) towards part of the construction cost so as to impart a sense of ownership. Such an arrangement could be classified as a subsidised DBFO (design, build, finance and operate) arrangement.

With regard to operation and maintenance, it is recognised that user fees alone can not help in meeting entire cost of a typical establishment of a cremation ground. Further, if the facility has to render service at subsidised cost to the poor, it is imperative that other avenues for financial support need to be established. In this respect it is recommended that the ULBs should facilitate capacity building and corpus creation for the operating agency with the help of, among others, the local business/trading community and philanthropic organisations. Through such arrangements, the latter will get an opportunity to discharge their scripturally defined social obligations in this most sensitive matter and the poor will not be forced to resort to undesirable methods of disposal of dead bodies e.g., into rivers.

Lastly, to ensure sustainability of operation, appropriate institutional mechanisms in the form of management committees, etc. with representation for various stakeholders should be put in place.

5.4. Technical Aspects

Recognising that a typical wooden pyre comes closest with regard to compliance with performance of a range of rituals at the time of cremation and considering the customs and traditions followed by different sections of the society, it is recommended to offer options for the same. These could comprise:

(a) Raised platforms for traditional / conventional pyres, and
(b) Pits of about 9'L x 5'W x 5'D for making pyres in the form of a *hawanvedi*

A wood pyre in the form of a *hawanvedi* is more in line with traditional Hindu practices, has a high degree of sanctity, offers comparatively higher combustion efficiency and is free from any structural or material lacunae. Innovative design modifications for increased air supply from the bottom can help in further improving its combustion efficiency.

Improved wood cremation systems in their basic form can be considered as an option however they should be adopted with a fair degree of caution in terms of size, design and material specifications. An IWC should not be perceived to be offering significant economy in wood consumption. An effective IWC should have following construction features:

- A minimum width of 3' for holding required quantity of wood.
- Exclusion of flanges which otherwise entail raising the dead body and cause difficulty in its placement on the pyre.
- Smaller openings (< 3 mm) in the bottom plate to prevent falling of cinders.
- Higher clearance from the ground for convenience of removal of ashes.
- Material of construction comprising alloy steel of high specifications as so as to be able to withstand thermal stresses corresponding to multiple cycles of heating up to 1000 ^{o}C followed by rapid cooling; and prevent corrosion.

Given high energy consumption of electric crematoria during long idling, they cannot be termed 'environment friendly'. Further due to their incompatibility with the ritualistic process of cremation they are found to be 'tradition unfriendly'. Instead of considering EC as an option for meeting the social obligation towards unclaimed bodies and those from poor families, as recommended above, the urban local bodies should arrange to provide subsidised or free cremation service on conventional wood pyres. If at all, improved electric crematoria (with technical features for energy savings) should be adopted with a high degree of caution and only in large metropolitan cities where a net throughput of at least 10 dead bodies per day is expected.

SWOT

Analysis of Ganga Action Plan

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay	IIT Delhi	IIT Guwahati	IIT Kanpur	IIT Kharagpur	IIT Madras	IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. A list of persons who have taken lead in preparing this report is given on the reverse side.

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1. Introduction

Ganga, the longest river in India has a unique position in the Indian psyche. Apart from geographical scale and spread, she has played a vital role in the social, cultural, economic and political life of the country. The socio-economic changes in the post industrialization era have adversely affected the flow and quality of the river water leading to pollution of the river. In order to reduce the pollution of this river the Government of India (GOI) has been implementing a pollution abatement program since last 25 years.

This note is primarily aimed at presenting an analysis of the strengths, weaknesses, opportunities and threats (SWOT) of Ganga Action Plans (GAP I and GAP II) — one of the longest and ambitious government interventions which have significantly influenced policies for controlling water pollution in India. This report is primarily based on the secondary data collected, mainly in the form of papers, articles and reports available on the issue of pollution of the river Ganga. The objective of this report is to consolidate—in a systematic manner—the available knowledge and insights in order to understand nuances and complexity involved in design, implementation and monitoring aspects of the Ganga Action Plan (GAP).

The second section of the report presents the need to conduct a SWOT analysis. The third section outlines the objectives and components of the GAP including the parameters selected to measure the quality of the water. Section 4 present strengths and weaknesses of the GAP, in a classified manner, focusing on its design, implementation, monitoring, and regulation aspects of the GAP. These are drawn from both—reports and articles by government agencies and by independent researchers. Section 5 and 6 briefly discuss the opportunities and future threats or challenges of GAP. Finally, the concluding section summarizes the strengths, weaknesses, opportunities and threats in a tabular form.

2. Rationale for Analysis

The rationale for analysis of the GAP could be stated by presenting two arguments. First, the GAP has been the first-ever multi-state, national-level substantial effort for reducing the pollution of the river. Being the first program it has set the precedence for policy-making and program-designs for other rivers in the country. In other words, analysis of this pioneering, trend-setting, initiative have national-level implications in the area of policies and other interventions for cleaning rivers across the country.

Second, the GAP initiative has attempted to address the most complex dynamics around the issue of river pollution. One of the issues is the vast and socio-culturally complex civilization of over 300 million people, out of which a large population live in densely populated cities directly along its banks. Most of the urban centers lack proper sewage treatment facilities. The average population density in the Ganga basin is 520 persons per square km, while the national average is 325. Major cities of Delhi, Kolkata, Kanpur, Lucknow, Patna, Agra, Meerut, Varanasi, and Allahabad are situated in the basin. These cities have large and growing populations and a rapidly expanding industrial base[1]. Between 1991 and 2001, urban population in the basin has increased by 32%. Population pressures, lack of proper investment in water quality infrastructure, governance problems, and a lack of empowerment of the people all continue to contribute to the deteriorating state of the Ganga. Against this complex background, it is highly important to take a critical look at the strengths, weaknesses, opportunities and threats arising from implementation of the GAP.

Third, GAP is entering into a new phase by adapting a river basin approach. The Central Government itself has accepted that, despite having spent more than 2500 crores of rupees on abatement of the pollution of Ganga in the earlier phases, it has been ineffective and there is a need to revamp the GAP. Revamping of GAP needs a critical assessment of the success and failures of GAP, in an in-depth manner and from various points of views. This document is an effort for presenting a critical analysis of the GAP.

3. Ganga Action Plan: Components and Objectives

3.1. Initial Vision

The idea of cleaning river Ganga was initiated by Government of India (GOI) in 1979; however the GAP could only be initiated in 1985 after a comprehensive survey of the river Ganga by Central Pollution Control Board (CPCB). CPCB had published two comprehensive reports on the pollution issues in the river (CPCB, 1982; CPCB, 1984). These reports formed the basis of intervention activities under GAP. The GAP was aimed at controlling the pollution of this most significant river in a systematic and planned manner.

The core objective of the GAP was to abate pollution and improve water quality. Although GAP also gave importance to: (a) conserve biodiversity, (b) developing an integrated river basin management approach, (c) conducting comprehensive research to further these objectives, and (d) gaining experience for implementing similar river clean-up programs in other polluted rivers in India.

3.2. Program Design

The studies by CPCB indicated that a large proportion of pollution load in the river came from the municipal wastewater generated in twenty-five Class I towns located on the banks of the Ganga, each with a population exceeding 100,000 (NRCD, 2009). It constituted around 75% of the pollution from all point-sources. Remaining 25% of the pollution from point-sources was mainly due to untreated industrial effluent. Therefore, emphasis under the GAP was given on **interception and diversion of wastewater and its treatment in Sewage Treatment Plants (STPs)**, before discharging into river. This strategy involved arresting sewage at the end of the disposal system by intercepting the *nalas* (carrying sewage into the river) and diverting them towards STPs. Similarly, industries releasing

[1]During the course of her journey, the river receives municipal sewage from 29 Class-I cities (cities with population over 1, 00,000), 23 Class II cities (cities with population between 50,000 and 1,00,000) and about 48 other smaller towns. In addition, effluents from industries and polluting wastes from several other non-point sources are discharged into the river Ganga resulting in her pollution.

effluent directly in the river were mandated to establish effluent treatment plants (ETPs) both, in-house as well as common ETPs. In addition to the point-source, non-point sources were also identified, such as disposal of dead bodies, surface run-offs from fields containing residues of fertilizers and pesticides, and crematorium ash. Works were also undertaken to prevent pollution of the river from the non-point sources. These include: introducing electric crematoriums, improving aesthetics of the *ghats*, and promoting public participation. Under the GAP, the schemes corresponding to the point-sources were categorized as 'core schemes' whereas the schemes taken up to address the pollution created by non-point sources were categorized as 'non-core schemes'.

BOX 1: Components of GAP

Core Schemes:

- Interception and diversion (I&D) of sewage, reaching the Ganga-river. (52.32%)
- Installing treatment facilities to treat the intercepted sewage. (36.66%)

Non Core Schemes

- Providing facilities of Low Cost Sanitation (LCS) at community and individual levels at identified locations (7.22%)
- Installation of Crematoria (electric as well as wood based improved crematoria) (0.62%)
- River Front Development (RFD) including bathing Ghats (1.13%)
- Afforestation
- Public awareness and participation (0.32%)

(Source: Presentation to NAC members by NRCD, 2006)

GAP was divided in two phases. Phase-I started in 1985 and covered the then three states, Uttar Pradesh (UP), Bihar and West Bengal (WB). It consisted of core and non-core components listed in Box 1. The choice and design of the core components of the GAP I was entirely based on the survey of CPCB. As mentioned before, the focus in GAP I was on sewage interception and treatment facilities. The classification of the core and non-core components is given in the Box 1 (the percentage-figures indicate the contribution of the particular component in the overall budget).

Thus a large portion of the budget was dedicated to the treatment of urban sewage. Implementation of GAP I started in 1986 and ended in 2008, delayed by 10 years. On the basis of the review of GAP and the felt need of expansion of the program, GOI declared and launched phase-II of GAP in 1993, when the implementation of GAP-I were even not reached halfway. Implementation of GAP-II is still under progress in five states, viz. Uttarakhad, UP, Bihar, Jharkhand and WB. The components of GAP-II were same as the GAP-I, as it was just an extension of GAP-I. Together, GAP-I and GAP-II targeted interception, diversion, and treatment of sewage of more than 37 cities located on the banks of the river Ganga. The relevant data reveal that, until recently, an amount of Rs. 1612.38 crores has been spent on the GAP (MoEF, 2011). [refer Annexure 1 for state-wide details of issues in implementation of GAP-I and GAP-II]

3.3. Institutional Arrangements for Implementation and Monitoring

Development of dedicated and specialized institutional structure was one of the deliberate strategies that the GOI implemented, in order to ensure the effective implementation of the GAP. These institutions were created at all levels, such as the Central Government, the State Governments, as well as, at the level of local governments, i.e. towns and cities. A brief review of the same is presented below.

3.3.1. Institutional Arrangements at the Central Level

Environment, being a subject under the purview of the union/central government, the Ministry of Environment and forests (MoEF) was made in charge of the overall design and implementation of GAP. Central Ganga Authority (CGA) came into existence under the Environment Protection Act 1986, headed by the Prime Minister of India. The CGA, under the chairmanship of the PM, was constituted to finalize the policy framework and to oversee the implementation of GAP-I. The Chief Ministers (CMs) of the concerned states, union ministers and secretaries of the concerned central ministries and experts were its members. An additional agency called Ganga Project Directorate (GPD) was set up with adequate financial and administrative powers in order to implement projects under GAP-I.

As GOI decided to expand its program to all major rivers in India, the GPD was later transformed into National River Conservation Directorate (NRCD), along with transformation of the CGA into National River Conservation Authority (NRCA) in 1995. These changes took place after the commencement of GAP II in 1993. The NRCD designed and is still looking after the implementation of National River Conservation Plan (NRCP) in which the GAP II was merged in December 1996.

3.3.2. Institutional Arrangements at the State Level

At the state level, State River Conservation Authorities (SRCAs) were constituted in all the four concerned states, viz., Uttarakhand, Uttar Pradesh, Bihar, and West-Bengal. These authorities are mandated to function mainly as coordinating as well as monitoring agency for Ganga Action Plans.

Different para-statal agencies were brought in at the state level to actually carry out physical implementation of the drainage interception and diversion work, as well as erection, commissioning and operation and maintenance of treatment plants. For example, in the state of Uttar Pradesh, Uttar Pradesh Jal Nigam (UPJN) has been responsible for building and maintenance of assets under GAP I and II. In Bihar, Bihar Rajya Jal Parishad (BRJP) and in West Bengal, Public Health Engineering Department (PHED) has been given the responsibilities, respectively.

Multiple institutions were responsible for monitoring of the implementation and operations of the sewage treatment. In addition to the SRCAs, state level offices of the para-statal agencies/state departments and State Pollution Control Boards, Regional Commissioner, District Magistrates also were involved in the monitoring functioning. In addition to different government agencies, autonomous academic institutions were appointed exclusively for monitoring of river-water quality and performance of sewage treatment plants, such as IIT Kanpur and Patna University. These institutions were given the responsibility of monitoring quality of the river-water for different stretches. However, this arrangement came into existence at a very late stage after GAP started.

3.3.3. Institutional Arrangements at the Town Level

At the local level, the responsibilities of respective implementation, operation and maintenance were rested with mostly the local offices of the para-statal agencies. For example, in Kanpur, the local office of the U.P. Jal Nigam was renamed as Ganga Pollution Control Authority which looked after creation and O&M of the assets. The role of the municipal councils was limited to overseeing the implementation and operation.

For monitoring of industrial pollution, the regional offices of the State Pollution Control Boards (SPCBs) were made responsible. In addition to the SPCBs, 'Citizens' monitoring committees' (CMPs) were an important part of the institutional arrangement. These committees were thought of for monitoring of GAP at the local level. CMPs were to be mainly constituted for monitoring of STPs and sewage related issues of pollution.

3.4. Standards for Water Quality

The objective, at the time of launching the Ganga Action Plan in 1985, was to improve the water quality of Ganga to acceptable standards by preventing the pollution load from reaching the river. The acceptable standards were not defined in particular for GAP. However, in 1987, as per the recommendations of the Menon-Committee constituted for monitoring of GAP, the standards were redefined (See Table I).

Table 1: The Class 'B' Water Quality Standards set by Menon Committee (sourced from NRCD, 2009)

No.	Indicator	Unit
1	Bio-Chemical Oxygen Demand	Maximum 3 mg per liter or less
2	Dissolved Oxygen	Minimum 5 mg per liter or more
3	Faecal Coliform	500 (as most probable number) per 100 ml
4	Total Coliform	2500 (as most probable number) per 100 ml (Maximum permissible)
5	pH	6.5 to 8.5

4. Strengths of GAP

Since beginning, GAP has been criticized on many fronts. Some of the important points of criticisms were: inordinate delays in implementation, irregular release of funds, confusions over roles of government institutions, weak monitoring, and irregular and inadequate operation and maintenance of the assets (Ahmed, 1985; Divan, 1995). On the other hand, the government institutions involved have also been justifying the utility and effectiveness of the efforts taken under GAP, by showing progress on various indicators; and some of the results have also been corroborated by independent researchers. Since beginning, the environmental quality of the water has been the most severely debated issue among the proponents and critiques of the effectiveness of the GAP. This was mainly because the 'quality' and 'purity' of the water carry different interpretations by people, researchers, implementers, and other stakeholders. These interpretations are influenced by different factors, ranging from religious perceptions to physical-scientific parameters (Alley 1994). Issues over achievement of set quality-related parameters (in terms of DO and BOD), adequacy of parameters, and the technology have also been at the center of the debate among the scientific community. This sub-section summarizes the main points from the critique of the GAP covering the major strengths of the Ganga Action Plan as well as its weaknesses.

4.1. Strengths of Design aspects of GAP

4.1.1. The Strategy of Interception and Diversion of *Nalas*

The strategy of diverting the sewage-flows towards STPs by intercepting *nalas* and constructing a conveyance system with pumping-stations was very important and relevant strategy under the design of the GAP. It was relevant because, the task of treatment of sewage did not need to wait until entire sewage network is established in the cities and towns located on the banks of the river Ganga. Thus, it must be viewed as an important strength of the GAP, as the interception-diversion strategy attempted to hit the origin of the problem on an urgent basis and aimed at controlling further pollution of the river.

4.2. Strengths of Implementation Aspects of GAP

4.2.1. Creation of Institutional Structure

The pollution abatement program under GAP has created and restructured many governing agencies at central, state as well as at the local levels. Establishment of this fairly broad institutional structure (though with many internal lacuna) indicates the willingness and commitment of the government to implement the program.

4.3. Strengths of Operation and Maintenance Aspects of GAP

Although, forcing state and local governments for taking over the financial responsibilities pertaining to O&M through judicial interventions (mainly inspired by civil society) cannot be called as strength of the design of the program alone, it is strength of the GAP in a different sense. Such interventions create the basis for future policy designs about tariff policies of the ULBs as well as funding responsibilities of the state governments with respect to Ganga.

Initiatives such as providing diesel pump-sets to keep STPs running during load-shading schedules and in the times of absence of electricity supply was an important step too.

4.4. Strengths of Monitoring, Evaluation and Regulation Aspects of GAP

4.4.1. Peer Review and Monitoring through Various Stakeholders

The responsibilities of monitoring and evaluation of GAP were assigned to different agencies at different levels. It includes: right from the top level CGA, CPCB and NRCD, at the state level, SRCDs and para-statal agencies such as UPJN, SPCBs and other ministerial agencies (eg. a special agency created by UP government which acts as a link-agency between UPJN and Cabinet Ministry), Regional Commissioner at the regional level, as well as, District Collector, ULBs and local offices of the SPCBs and para-statal agencies. Establishment of institutions itself was a strength as it followed the peer-review principle within the government institutions.

4.4.2. Appointment of Independent Agencies for Water Quality Monitoring

Monitoring of river water quality by different academic as well as public institutions was the integral part of monitoring mechanisms of GAP. Accordingly, many autonomous institutions (such as IIT Kanpur, University of Patna) have been monitoring river water quality (sample collection and testing) as per the methods prescribed by CPCB/NRCD by collecting sample in different stretches of the river Ganga. In order to assess the quality of river 44 parameters were selected for monitoring. These assignments have been given to these institutions on research and development (R & D) basis by the government. This has resulted in creation of database on river water quality and may be viewed as an important strength of the monitoring mechanism, and shows willingness and openness of the government for transparent and third party monitoring.

4.5. Other Achievements/Strengths of GAP

4.5.1. Creation of Knowledge Base

GAP also gave rise to many studies of different pollution aspects of the river Ganga. These studies were conducted by various national and international institutions of high repute. Many researchers with high level caliber were engaged in the analysis of different aspects of pollution including ways for abatement of pollution, institutional structures for it, as well as assessment of the GAP. There is a great scope for drawing from these reports, including the court interventions in order to learn from the past efforts and their successes and failures.

4.5.2. Awareness Building among Different Government Agencies

The GAP has now a history of almost 25 years. The two consecutive plans for pollution abatement have kept various governments (viz. local, state, and central) and their agencies functional on this issue for almost two decades. Officials and employees of the state departments are aware of many issues and, now, possess a wealth of knowledge regarding the pollution of the Ganga-river. Agencies such as pollution control boards have been made far more functional on this issue, which is one of the important outcomes of the Ganga Action Plan.

4.5.3. Awareness and Activity among the Non-Government Actors

GAP although initiated by various central and state government agencies, the contribution of civil society organizations has been significant. The civil society organizations have brought many aspects of the pollution to the fore as well as forced government agencies to take effective action. Involvement of the judicial institutions, though not much effective, was a result of relentless efforts by the civil society organizations. Their involvement has kept the issue alive at different levels as well as on different forums. This might not be viewed strictly as one of the achievements of the GAP, however, it can certainly be viewed as an important opportunity that could be utilized for future efforts under GRB EMP.

4.5.4. Improvements in River Water Quality

The report on the status of GAP published by MoEF (NRCD, 2009; prepared by AHEC, IIT Roorkee) is the only comprehensive document which argues for improvement in river water quality against the parameters prescribed by Menon Committee, except the coliform levels. The main arguments mentioned in the report are briefly presented as follows.

Dissolved Oxygen (DO):

The report states that "[i]n 22 years of monitoring at 16 stations, the value of DO below 5.0 mg/l was recorded only in 2.6% cases. In these cases, the values were between 3.2 and 4.9 mg/l. These were observed between Kannauj and Kanpur. A comparison of results with pre-GAP period shows that there is a marginal increase in DO values indicating improvement in water quality" ……. (NRCD, 2009)

Biochemical Oxygen Demand (BOD):

The report suggests higher variation in BOD values as compared to those of DO. It shows that, in 27% of total samples, BOD values were more than the prescribed norm of 3 mg/l. All these samples were mainly taken during lean flows from the middle stretch that starts from Kannauj and ends at Allahabad. The data collected from autonomous monitoring agencies and compiled by CPCB shows that even in the middle stretch, the summer averages of the BOD values in 2010 are reduced to almost half of those recorded in 1986 (CPCB, 2010).

5. Major Weakness of GAP

5.1. Weakness of Design aspects of GAP

The design of the GAP is said to suffer from five important lacunas. These are briefly summarized as follows.

5.1.1. Limited Scope of Issues Addressed

The design of the GAP placed activities such as diversion and treatment of the sewage at the core of its interventions. The non-core schemes under GAP, which attracted meager funding, revolved around crematoria and beautification of bathing *ghats*. It is argued that, although extremely important, excessive emphasis on sewage collection, conveyance and treatment shows lop-sidedness of thinking as well as strategizing underlying GAP. This has proven inadequate because it overlooked the fact that, in different stretches or segments of the river (viz. upper, middle, and lower) issues and problems are different and are caused by different types of natural conditions and human interventions.

Intervention activities designed under the GAP also betray failure in considering issues that apparently are not connected with the pollution of the river or are indirectly connected. The first such important issue is diversion of the water from Ganga for industrial and agricultural uses in huge quantities. The upper and lower Ganga canals have diverted almost entire amount of the river flow in Uttar Pradesh. This diversion has reduced the capacity of the river to absorb pollution as absence of adequate flows has affected the process of dilution.

Similarly, the pollution from non-point sources was also not adequately addressed in the design of the GAP. For example, the entire set of core and non-core activities does not contain any activity to control the pollution from run-off from agricultural fields, which brings non-biodegradable pesticides into the river.

5.1.2. Inadequacy of Standards of Water Quality

Experts argue that, the discharge standards prescribed by the CPCB (refer Table 2) and those set by the M. G. K. Menon committee (Refer Table 1 given in subsection 3.4) for monitoring of water-quality in the river Ganga are inconsistent with each other. In fact the standards stipulated by CPCB are based on scientific investigations (refer Table 2, Row-2 for comparison). However, according to experts the norms prescribed by the Menon Committee are fixed rather arbitrarily and do not hold scientific justification.

Secondly, the experts argue that the very idea of fixing standards to the 'bathing-class' indicates that this thinking is exotic, imported from the western developed countries, and is rather inadequate on the background of religious rites practiced along the banks of the river Ganga. Western countries fix standards for water-quality up to the 'bathing-class', because, river-water is seldom used directly for 'human-contact uses'. Whereas in India, pilgrims and even the dwellers on the banks of Ganga take a holy dip in the water and practice religious offering, even drink water (called '*arghyam*' and '*achman*'). Many villages located on the banks of the river Ganga use river water directly for drinking purpose in rural areas. Obviously the objective, considering these religious and other practices, should be to keep river-water clean or pure to its pristine level of purity and norms should set up, up to a level of 'drinking-class' that is Class-A from consideration of faecal contamination (see Table 2, Row 1).

Table 2: The Designated Best-Use Classification for Inland Waters (by CPCB) ***(Source: NRCD 2009)***

Class	Designated Best Use (DBU)	Criteria	
A	Drinking Water Source without conventional treatment but after disinfection	pH	6.5 to 8.5
		Dissolved Oxygen (DO)	6 mg/l or more
		Biochemical Oxygen Demand (BOD)	2 mg/l or less
		Total Coliform	50 MPN/100 ml
B	Outdoor bathing (Organized)	pH	6.5 to 8.5
		Dissolved Oxygen (DO)	5 mg/l or more
		Biochemical Oxygen Demand (BOD)	3 mg/l or less
		Total Coliform	500 MPN/100 ml
C	Drinking Water Source With Conventional treatment followed by disinfection	pH	6.5 to 8.5
		Dissolved Oxygen (DO)	4 mg/l or more
		Biochemical Oxygen Demand (BOD)	3 mg/l or less
		Total Coliform	5000 MPN/100 ml
D	Propagation of wild life and fisheries	pH	6.5 to 8.5
		Dissolved Oxygen (DO)	4 mg/l or more
		Free Ammonia	1.2 mg/l
E	Irrigation, industrial cooling and controlled waste disposal	pH	6.5 to 8.5
		Electrical Conductivity	2250 mhos/cm
		Sodium absorption ratio	26
		Boron	2 mg/l

5.1.3. Influence of Aid on Choice of Technology

One of the important issue in the debate is the choice of technology for sewage treatment under the GAP, especially the Up-flow Anaerobic Sludge Blanket (UASB) technology introduced with the Dutch development aid which was an important financial source for the GAP-I. The critics argue that while adapting the technology, the MoEF did not carry out any comparative assessment of the sewage treatment technologies on the criteria of suitability or efficiency (Menon, 1988). Further they argue that the choice of UASB was highly influenced by the Dutch aid and resulted into a mere waste of resources.

5.1.4. Inappropriate Technological Choices for Treatment

The other technologies adapted by GAP such as Activated Sludge Processes (ASP) were capable of treating sewage only up to the standards prescribed for DO, BOD and COD. They were opted because; the standards themselves were set to achieve water quality up to the 'B Class-Bathing' standards. However, these technologies are highly incapable in terms of removing pathogens and coliform, i.e. the bacterial contamination. The water quality data show high level of presence of pathogens and coliform across all the stretches of the river Ganga, despite implementation of GAP (NRCD, 2009). Disinfection as an important way to kill pathogenic organisms could be achieved by employing several methods using two approaches: (a) by using chemicals and (b) by employing filtration techniques. Importantly, under GAP all these methods such as chlorination, ultra-violate treatment; solar-based techniques (sodies), ozonation were used after secondary treatment of the sewage. However, all methods proved ineffective. All these methods had limitations in disinfecting the sewage water after secondary treatment. For example, chlorination process has limitation, as the extent of the chlorine used for disinfection could not be increased beyond a certain value. If it is used more than prescribed norm it can be harmful to aquatic life. Similarly, the UV technology has limitations as it is expensive and ineffective on secondary effluents. There are certain limitations with sun based methods as well as ozonation too[2]. This gives more substance to the argument for adapting different standards and level of treatment.

Comparison between conditions of water in Indian rivers with the water in western rivers would be helpful in this context. The rivers in Europe and other western countries are either snow-fed and/or rain fed for at least 120 days in a year, whereas, flows in Indian rivers last merely for 30-60 days during monsoon. Despite having adequate flows for dilution of the discharged effluent, western countries treat water up to the tertiary level. The Indian model of treatment proposes treatment up to secondary level only, despite having lean season of water flows of 10 months. This results in further degradation of the water quality of the river in terms of fecale contamination. Thus, the case for tertiary level treatment of the effluent and sewage finds further substantiation due to these experiences with the technologies adapted for eliminating or reducing microbial contamination, and western practices of tertiary level treatment despite adequate flows in the rivers.

5.1.5. Inappropriate Policy of Discharging Water into the River

Discharging partially treated sewage or effluent in the river is an acceptable practice as far as the following conditions are met: (a) The river-flows are substantial; (b) The sewage or effluent treatment plants are operated with full capacity and diligence under effective regulation. First, the adequate water flow in the river is particularly required for dilution of effluent, which reduces the danger of further degradation of the quality of the water. Second, the treatment plants should also treat the entire sewage and effluent that is diverted or directed to them. It means STPs and ETPs should never be set up on a by-pass mode. This requires effective operation and maintenance of assets, as well as equally effective monitoring and regulation of the same. However, in the case of the assets created under GAP, both these conditions are not met. Due to large scale diversion of water for industrial and agricultural purposes the middle stretch of the river becomes almost dry in the lean season, which intensifies the pollution (Gyawali, 1999). Similarly, the irregular operation and inadequate maintenance of assets have been an important issue with the GAP-assets, which has resulted into further degradation of the quality.

[2] For details refer: Compendium of sewage and effluent treatment technologies, could be sourced from www.moef.nic.in

5.1.6. Lack of a Clear Policy-Legal and Institutional Framework

A loose and vague policy and legal framework, especially the lack of clarity about the roles of various stakeholders involved in the implementation of the GAP, have been important weaknesses of the very design of GAP. The lacunas and gaps in the existing pollution abatement laws create many ambiguities and gaps which allow departmental discretions to play a decisive role in implementation of the program. These ambiguities have also paved the way for many weaknesses of the GAP itself.

Similarly, multiplicity of institutions is another result of the lack of clear policy-legal framework. The failure of institutional mechanisms created by Ganga Action Plan could be traced to the overlaps and conflicting jurisdictions of the government agencies (departments, para-statals, government-agencies working at various levels). These have caused many problems (as discussed in 2.4.1) for decision-making and implementation of GAP (CDP-Kanpur, 2006).

5.2. Weakness of Implementation

5.2.1. Political Motivations behind the GAP

Since very beginning, this ambitious plan was perceived as highly politically motivated, especially in choosing Ganga as the first river to be cleaned up (EPW, 1985). It was perceived that the official references to the importance of controlling pollution in Ganga have been invariably couched in the appeal to the religious sentiments of Hindus. However, the very effort of appealing the religious sentiments seems to have proven mis-directed because of the wide-spread and deep-rooted cultural belief that this sacred river can never get polluted. The politicians soon realized the futility of GAP in terms of appealing the sentiments of Hindus and gaining political mileage from it. The large scale apathy from the common citizenry about the GAP despite large-scale aggressive media/civil society campaigns as well as court interventions could be attributed to these reasons. This situation underlines the importance of the political motivation in implementing programs such as GAP, but the future course of action does not consider this element in its design.

5.2.2. Inordinate Delays in Creating Assets

Many reasons have been cited for inordinate delays in implementation of GAP. The Public Accounts Committee (PAC) appointed by the *Lok Sabha* to assess the performance of GAP came out with instances and references for many administrative and other delays. The most common reasons cited by the committee are (PAC, 2004):

1. Confusions and tensions among the central and state governments over the issue of funding for assets to be created under GAP. For GAP-II, initially, the arrangements were 50:50 cost-sharing basis, then it was changed to 70:30 pattern and, finally the central government provided 100% funding (except the land costs). Even after these changes, the funding pattern was again changed many times under the 10th Five Year Plan.

2. The selection of towns under GAP II was completely left to the state-level decision making, which resulted in non-uniformity in the selection as well as delayed the process of preparation of project-proposals.

3. Majority states could not acquire or provide land for constructing the sewage treatment plants and pumping infrastructure within the prescribed time which delayed the implementation of the program.

4. The state governments could not prepare the Detailed Project Reports (DPRs) in time, and according to the guidelines issued by the NRCD, MoEF. The quality of the DPRs was poor, and due to the discrepancies in them, the sanctioning process could not be conducted in the stipulated time.

5. Problems created by court-cases, contractual issues, and inadequate capacities in the local bodies/implementing agencies came in the way of speedy implementation.

6. Cost-overruns and re-sanctioning of the schemes also led to time-wastage and further delayed the process.

5.2.3. Partial Coverage for Collection, Conveyance and Treatment of Sewage across Cities in the River-Basin

Issues related to coverage by sewage collection, conveyance and treatment systems have been largely responsible for partial treatment of sewage. These issues seem to be present at different levels, such as: (i) coverage of *nalas* within the cities, (ii) coverage of cities and towns (iii) coverage of rural population. Some of these issues are discussed briefly in the following paragraphs.

1. *Coverage of nalas within the cities*: Under the GAP-I, in many of the Class-1 cities interception and diversion works did not cover all the *nalas* that discharged sewage into the river. Due to partial coverage, remaining sewage was allowed to be released into the river through *nalas* and, thus pollution continued. Moreover, it is said that among all the STPs constructed under GAP roughly 20% of the STPs were overloaded, which could not treat all the sewage conveyed to them and some untreated sewage polluted the river. These factors resulted in partial treatment of the sewage reducing the effectiveness of the interventions of GAP. Speedy, amorphous, and unplanned urbanization was not accounted for in the GAP-I as well as GAP-II. It was necessary to undertake specific measures for prevention of pollution of the river water, while planning new settlements or expansion of the present ones, which remained neglected.

2. *Coverage of cities and towns*: The coverage was restricted to only 25 Class-I cities during GAP-I. Later, GAP was expanded to cover 27 more Class-I cities. However, Class-II, Class-III and Class-IV towns were left uncovered as far as collection and treatment of sewage was concerned.

3. *Coverage of rural settlements*: The decision not to cover rural settlements was also considered a major hurdle to the success of GAP.

5.2.4. Over-Designed STPs

Generally the STPs were designed considering the following three main factors (a) population of the cities and towns, (b) projections of the growth of the population, and (c) standards based on per capita sewage generation. In many cases these calculations resulted in STPs with large capacities. As a result, in practice, sufficient amount of sewage could never reach to the STPs, largely due to inadequacy of the sewer networks as well as the inadequate interception and diversion of sewage flowing through the *nalas* (CSP- Kanpur, 2009). Roughly, it is said that, 80% of the STPs remained 'under-loaded', which resulted in dead-investment on the STPs.

5.3. Weakness of Operation and Maintenance

5.3.1. Irregular Maintenance

Operation and maintenance of GAP-assets has been the responsibility of Urban Local Bodies (ULBs) or state government agencies. However, ULBs did not have enough resources for this purpose and states were inconsistent in releasing the money for operation and maintenance. The critics further say that states never give due importance in their funding for operation and maintenance of GAP assets. Even after court-interventions, states addressed the issue with limited seriousness. Municipal councils faced problems raising required financial and human resources to ensure proper operation and maintenance (Shaw, 2006).

5.3.2. Sub-Optimal Functioning of the Assets

Irregular maintenance of the assets and failure to ensure a full coverage by the sewage-collection network led to sub-optimal functioning of the assets installed for sewage and effluent treatment. Irregular electricity supply kept the pumping stations in an 'On & Off' mode for many years after installations. Finally, in response to a writ petition filed in Allahabad High-court by an NGO and subsequent directions by the HC, the state government of UP provided diesel-engine sets to operate pumps during load-shading schedules. Nonetheless, it has been alleged that many times diesel engine sets also do not work because of irregular supply of diesel by the state authorities (Biswas, 2002). Suboptimal functioning of ETPs and STPs also has forced the farmers around Kanpur to irrigate their farmlands with partially treated, polluted water casing health problems to the farming dependent population (Singh, 2001).

5.3.3. Unclear, Unviable Financial Models

The policies and programs implemented under GAP lacked clear financial models, and did not have a balanced arrangement of effective incentives, disincentives and penal provisions. In fact, the entire funds put in the GAP hitherto should have been viewed as *investment.* Nonetheless, the funds should have been multiplied 20 times in the form of a turnover of a treatment sector, from the initial figure of investment, through an appropriate finance and business model. However, this did not happen and the government agencies today are left with eroded assets with no more life remaining. This did not happen precisely because it lacked a clear arrangement of financial incentives wherein all concerned stakeholders (both, from public and private spheres) could be engaged in a business activity which would have served interests of all the engaged through achieving the basic objective of treatment of sewage. This involves creating a proper mix of incentives and disincentives with effective regulatory arrangements. For example, incentives and disincentives for establishing a treatment market, or for establishing a decentralized sanitation systems, or for proper arrangements for buy and sell of treated sewage and so on, as indicated in the 'DBFO' model (Consortium of 7 IITs, 2010: Report No.: 004_GBP_IIT_EQP_S&R_03_Ver 01 Dec 2010).

5.4. Weakness of Monitoring, Evaluation and Regulation

5.4.1. Neglect of Monitoring of Important Aspects Other Than the River-Quality

The Government did not make any arrangements to monitor many important issues associated with the river and contamination of its water such as, erosion, tree cover. For example, tree cover in the Ganga basin has reduced considerably and land-use patterns have changed, which has led to an increase in soil erosion. This seriously affects flows in the river. The monitoring mechanisms also missed aspects such as sediment yield and sediment deposition on the river bed, as well we some key areas such as watershed development and interaction of surface-water and groundwater.

5.4.2. Failure to Utilize Available Monitoring Data

The data collected hitherto was neither put together in a cohesive manner nor analyzed independently. Because of this neglect of data-analysis, lessons could not be drawn for further analysis of O&M as well as for designing new initiative in order to reduce the pollution. Thus, this neglect led to not utilizing the lessons learned from past experiences in an effective manner and has raised questions on government spending on monitoring programmes.

5.4.3. Failure in Controlling Industrial Pollution

By the end of the first phase, only about 45 per cent of the grossly polluting industrial units had installed ETPs. Over 18 per cent of those did not function properly, and did not meet the technical standards. These units discharged industrial effluent of 2667.16 MLD into the rivers. The NRCD had no mechanism to ensure that the installed plants functioned satisfactorily, other than SPCBs (PAC, 2004). The participants in the debate over tackling the industrial pollution also argue that GAP has failed to tackle the issue of industrial pollution effectively, especially because of its thrust on the sewage treatment plants.

The monitoring of construction of ETPs, operation of ETPs and discharge of industrial effluent is marred by weak mechanisms for monitoring under GAP. Due to the sub-optimal operation or non-operation of the ETPs, discharge-standards were rarely met as far as the industrial effluents are concerned. In fact, CPCB and SPCBs have sufficient powers to close down the operations of the polluting industries; however, PCBs could not take effective actions due to the political interventions. For example, paper and pulp industries, sugar factories and distilleries along the banks of the rivers Ramganga and Kali near Kannuaj have continuously been discharging industrial effluent into Ganga which, despite repeated complaints have not been closed down or forced to construct and run the ETPs. This has created a major problem of color in the river-water, and has been a major cause of suffering of the people at Allahabad during religious gatherings and mass-bathing events.

5.4.4. Weak Monitoring by Central Institutions

Failure of government institutions in monitoring of the program was one of the major critiques. As the Public Accounts Committee pointed out in its report, the apex body headed by the Prime Minister to monitor the plan, viz. National River Conservation Authority, met only twice, in 1994 and 1997 (PAC, 2004). The states were asked to set up Citizen Monitoring Committees which were supposed to ensure public participation in the schemes. Haryana, Bihar and Delhi governments did not constitute such committees in any of the towns and West-Bengal constituted committees only in 5 out of 42 towns. The constituted committees in West Bengal and Uttar Pradesh met only infrequently. Thus, both at the central and the state level, monitoring of the plan was highly inadequate (CAG, 2000).

5.4.5. Failure in Establishing Citizen's Monitoring Committees

The participation of stakeholders has not been effective in implementation of the GAP. There were provisions to constitute the citizens monitoring committees; however, in practice, these committees either were not constituted at all or did not function effectively (PAC, 2004). This situation occurred partly because of the political aspects of constituting committees and partly because of the low repose from the citizens.

5.4.6. Flaws in the Design of Citizen's Monitoring Committees

The very design of the Citizen's monitoring committees (CMC) was flawed. The CMCs were constituted at the city or town level, in which, Mayor of the town was made an ex-officio chairperson of the CMC. This provision assigned a key role to the mainstream political forces and caused concentration of powers in the hands of dominant sections. Further, critics argue that, this provision reduced the strength of third-party monitoring as it mixed the responsibilities with the powerful local government.

Another observation shows that there was little sense of ownership among the stakeholders due to their limited participation in formulating schemes and in implementation. In public perception, the plan continues to be seen as a government scheme.

6. Opportunities for Future

6.1. Experiences with Technologies

A variety of treatment technologies have been experimented under the GAP. Up-flow Anaerobic Sludge Blanket (UASB), Activated sludge Process (ASP) and the Stabilization Pond

Technology are the three main technologies used for treating sewage. Government authorities have a fair understanding of strengths and weaknesses of these technologies by now. For example, it is known that UASB technology is land-intensive and has constraints in treating the sewage with varying values of DO, BOD and coliform in the treated effluent. Similarly it is also clear that the ASP technology demands more energy. The effectiveness of these technologies, in terms of improving the quality of the water is also varied. The ministry has come out with a compendium of sewage treatment technologies recently (Tare and Bose, 2009). This experience has to be leveraged upon while employing new technologies.

6.2. Adaption of River Basin Approach

Adoption of the River Basin Approach (RBA) is an important perspective-level shift in the thinking around cleaning the Gaga-waters. This is important particularly because it addresses the question of pollution in a much broader sense and considers all possible sources of pollution in the basin by basing itself on the principles of a watershed. It is important to consider the vast expanse of the Ganga River Basin and give importance to both quantity (*aviral dhara*) and quality of water (*nirmal dhara* or un-polluted flow). The river Ganga travels for more than 2500 km, and the geographical area of the basin accounts for 26 per cent of the country's landmass, 30 per cent of water and 40 per cent of the population (Dharmadhikary, 2011).

6.3. GOIs Commitment to Raise Adequate Funds

The government, in the paper written by NRCD, has explained commitment to raise funds for subsequent phases of Ganga Action Plan. The strategy described in the future course of action assures approaching all possible agencies for raising financial resources such as, ULBs, state governments, central government as well as the bilateral and multilateral funding.

6.4. Awareness and Inclination to Contribute

Though the efforts to form the citizens committees failed, the participation of the civil society organizations in diverse modes was very crucial in implementation of GAP. These modes included: numerous court interventions, setting up of *Ganga-Praharies* to promote vigilance on the banks of Ganga, awareness campaigns on pollution of the river, participation of academia and independent researchers in the research activities such as monitoring of water quality, innovating with the decentralized sanitation systems, etc. The contribution of CSOs in terms of awareness building as well as analysis and monitoring of government interventions is unmatched. There is a great opportunity to leverage these initiatives and participation of CSOs even in development and monitoring of future phases of the GAP.

7. Threats and Challenges

7.1. Divergence of River Action Plan with Broader Development Policies

Despite adoption of the broader river basin approach, the danger of divergence of River Action Plans (RAPs) with the broader development policies (such as policies for industrial development, urbanization as well as sectoral policies like irrigation) is looming ahead. Considering that the central objective of the GAP is cleaning of Ganga, there is a great need to integrate it appropriately with the other broader development policies. If the GAP continues to be implemented without ensuring such integration, many of the deeper problems underlying pollution of water of Ganga will remain unaddressed. Perhaps this is the most challenging threat to address.

7.2. Challenge in Experimentation with Newer Institutional Models

After 1990 reforms, the GOI has been following the policy of private sector participation in almost every sector. The JNNURM scheme is an instance of the same and which aims at addressing different urban problems including the sewage disposal. There is scope for introduction of these reforms in the very design of the activities under Ganga Action Plan in future. However, there is also an equally great threat of failure of reform-models (such as the Public Private Partnership - PPP model) as these models are yet to be proved as robust and effective enough to implement widely.

7.3. Influence of Bilateral/Multilateral Financers on the Program Component

Bilateral and multilateral funding has been an important source for many developmental programs in India. However, there has been a great debate over role of international Funding Institutions (IFIs) and unwarranted influence over policy-making and structuring of programs. One of the former Project Director of GAP in one of the forums commented that accepting funding from IFIs including World Bank was one of the mistakes. Even the testing of UASB technology under GAP financed through the Dutch aid attracted criticisms for the same reason. This threat still looms over the future policy-making and program design in the next phases of Ganga Action Plan.

7.4. Capacities and Incentives Structures for ULB

The capacity of the ULBs has been a critical issue. Though the ULBs have very little role in implementation of the GAP hitherto, the ownership of the assets rests with the ULBs. The implementation and operation and management of the assets, have been kept out of the purview of ULBs with the excuse of their weak capacities. The institutions such as city development authorities, (e.g. Kanpur Development Authority) have been blamed for further weakening of ULBs' role in the local governance. This is said to create problems for the construction, operation and maintenance of the assets in the Ganga Action Plan too.

This calls for a robust incentive structure for ULBs. If this factor is not addressed with sufficient gravity and seriousness at the policy level, the threat of failure of future GAP efforts would persist.

7.5. Wastage of Funds

Misuse and wastage of funds is one of the serious challenges. Even today the implementation of projects under the JNNURM program, especially sewerage-projects is facing similar problems. It seems that the central government is not able to exercise effective control over the decisions and actions at the state and local levels, especially pertaining to budget preparation, cost-over runs and quality of the works done. In fact this is the larger governance related problem, which would decisively affect GAP and its objectives.

7.6. The Complexity in Monitoring of Technical Parameters

Failure in utilizing monitoring data (refer subsection 4.4.2) also highlights the important issue of complexity in monitoring of methodological rigor in collecting samples, and testing them in the laboratories. An expert from IIT Kanpur reported that, there are differences of opinions among the autonomous agencies and government officials regarding the reliability of the data-samples and lab test-results. This complexity creates confusions about the validity and acceptability of the values of parameters (or standards) tested, and further complicates the process of monitoring river water quality. The expert further argues that, the Citizen Monitoring Committees (CMCs), though established at one or two instances (for example, once in Kanpur) could not understand these technical complexities and soon lost their interest in monitoring of GAP. This experience highlights the need and the challenge in setting up such norms and parameters that the monitoring mechanisms with no technical background or capacities could also monitor them easily.

7.7. Inadequate Analytical Foundations of Future Plans

The chapter titled 'Critical Analysis of GAP' presented by NRCD in the Status Paper on GAP shows that NRCD has accepted the flaws, mistakes, and gaps in implementation of GAP with an apologetic undertone. The acceptance of limitations of GAP by NRCD, although commendable, is preliminary in nature and lacks an in-depth analysis, especially from the standpoints of different stakeholders involved in implementation of GAP. It misses many aspects such as, the need for analyzing policy and legal aspects of centre-state relationships, implementation of 74^{th} amendment, and State Government-ULBs relationships, as well as, the convergence of policies adapted for implementing GAP with the broader developmental policies.

Despite such severe inadequacy of the analytical foundations, the government is continuing with the implementation of big-budget, flag-ship programs such as Jawaharlal Nehru National Urban Renewal Mission in the Ganga basin. Sewerage schemes and STPs of large capacities are being constructed under these programs in all major cities located on the banks of the river Ganga. Importantly, the government agencies are committing same mistakes in planning and implementation of the programs such as: over-designing of STPs, choosing and employing UASB technology for STPs, implementing programs without elaborate and detailed process of planning, and implementing programs without clarity of financial models for operation and maintenance. The implementation of these programs without integrating the lessons in the policy and program designs also poses serious threat of wastage and misuse of funds.

7.8. Evolving a Robust Regulatory Framework and Institutional Arrangement

The threats posed by programs such as JNNURM are not only limited to repetition of mistakes committed earlier or wastage and misuse of funds. This is because, JNNURM scheme is not only an infrastructure development program, but also a program which is expected to bring fundamental economic and governance reforms in the functioning of state governments and more importantly in the functioning of local governments. Important reforms such as Private Sector Participation (PSP), principle of cost-recoveries, restructuring of para-statal bodies and establishment of effective regulatory mechanisms have close linkage with the performance of agencies concerned with the GAP. The effectiveness of these reforms largely depends on the designs of institutional structures and time lapses involved in adaptation of reforms at the local level. Especially against the background of the sorry state of implementation of reforms, and complexities involved in restructuring of para-statal agencies, evolving a robust regulatory framework still remains a great challenge before the policy makers of GAP.

8. Conclusion

Table 3 summarizing the strengths, achievements and weaknesses shows that there is a great imbalance in the both strengths and weaknesses of the GAP if looked at critically. The core weaknesses of the GAP in all aspects of design, implementation, monitoring, evaluation, and regulation has defeated the very purpose of the GAP and there is a great scope for learning from these weaknesses in preparing Ganga River Basin Environment Management Plan, and implementation of the same by National Ganga River Basin Authority.

Table 3: Strengths, Achievements and Weaknesses of the GAP

Aspects	Strengths	Weakness
Design of the GAP	• Initial Vision • The Strategy of Interception and Diversion of *Nalas*	• Limited scope of issues addressed • Inadequacy of standards for assessing water-quality • Influence of aid on planning in general, and prioritization of programmes and selection of technologies in particular • Inappropriate choices of treatment technologies • Inappropriate policy of discharging treated effluent and sewage into the river • Lack of a clear policy-legal and institutional framework
Implementation of the GAP	• Creation of the institutional infrastructure	• Political motivations behind GAP • Inordinate delays in creating assets • Partial coverage in collection, coverage and treatment of sewage across cities in Ganga Basin • Overdesigned STPs
Operation and Maintenance of the GAP	• Forcing ULBs and state-governments to pay for the O&M	• Irregular maintenance • Sub-optimal functioning of Assets • Unclear, unviable finance models
Monitoring, Evaluation and Regulation of the GAP	• Peer review and monitoring by various stakeholders • Appointment of independent agencies for water quality monitoring	• Neglect of monitoring of other aspects other than river quality • Failure to utilize available monitoring data • Failure in monitoring and regulating, thereby controlling industrial pollution • Weak monitoring by central institutions • Failure in establishing Citizen's Monitoring Committees • Flaws in design of Citizen's Monitoring Committees
Other aspects of strengths / Achievements		
• Creation of knowledge base • Awareness building among government agencies • Awareness building among civil society actors		

This analysis also points at the different dimensions of broader problem of governance failure, despite some of its achievements. Several issues such as delays in implementation of the program, confusion over funding, technological issues, operation and maintenance of the assets do not only indicate typical governance failures but also clarify the gaps in policy and program design. These gaps also highlight the weakness in program planning/implementation/monitoring/evaluation, center-state coordination, state-ULB coordination, etc. The issues such as multiplicity of institutions, especially at the local level and their conflicting/overlapping roles place the need for a deeper institutional analysis. Opaque implementation and low levels of citizen's participation pose broader challenges for the future design and intervention and demand greater transparency. This calls for a detailed analysis of the governance-related factors affecting effectiveness of the GAP both within government agencies as well as outside.

Table 4 summarizes the opportunities and threats before the government for designing the river restoration programmes. For example, the adaption of river basin authority is an opportunity; however, it is equally important to develop an understanding of various problems with respect of to Ganga according to its three important stretches viz., the upper, middle and lower stretches of its flow in order to design the future course of action. Each of its stretch is characterized by different types of problems, having different physical conditions as well as dynamics created by distinct political economy. Similarly the cause and effect relationships and inter-linkages of the problems in the upper stretches with the lower stretches also need to be understood. For example upper stretch is characterized by high flows, steep gradients and soil-erosion which demands for different kind of technological interventions than in the lower stretches.

A similar example in the context of diversion of broader development policies with pollution of the river could be cited as: the huge amount of water diversion for irrigation purposes in the upper stretches causes intensification of the pollution in the middle-stretch of the Ganga by reducing flows even below the levels of minimum environmental flows in non-monsoon season. While the decisions to divert water seems highly irreversible considering the influence of high level of political-economy, the failure of STPs in treatment of sewage call for different approaches. Similar inter-linkages in other problems within different stretches needs to be understood properly which calls for evolving a detailed classification of the problem-classification that should be interdisciplinary in nature.

Apart from understanding the inter-linkages among the problems and their social, political, economic and technological aspects, there is a need to understand the institutional aspects of the problems with respect to the GAP too. Here, institutions do not signify mere formal structure of the government agencies (departments and authorities) and their way of functioning alone, but also the ways adopted by government and non-government actors for using gaps and loopholes in the provisions in a diverse manner that cause interventions to be ineffective. It implies developing an understanding of informal ways of decision-making by using the loopholes in the existing laws, rules, and provisions in the laws as well as their interpretation reflected in the functioning of the government agencies as well as implementation of the programs such as GAP.

Table 4: Opportunities and Threats before River Restoration Progrmmes

Opportunities	Threats
• Opportunity to learn from experiences of technologies such as UASB • Adoption of river basin approach • GOIs commitment to raise adequate funds • Awareness and inclination of civil society to contribute	• Divergence of river action plans with broader development policies • Challenges in experimenting with newer institutional models such as regulatory authorities • Influence of Bilateral and Multilateral financers on program and policy- design • Capacity issues and lack of incentive structures for ULBs • Wastage of Funds • The complexity in monitoring of technical parameters • Inadequate analytical foundation for future plans • Evolving a robust regulatory framework and institutional model

Annexure I

State-wise Status of GAP-I and II

Table A1.1: Interception, Diversion and STPs under GAP-I

State	Interception and Diversion				Sewage Treatment Plants			
	Schemes		Sewer Lines, kms		Schemes		Sewage Treatment, mld	
	T	A	T	A	T	A	T	A
Uttar Pradesh	40	40	136.00	136.00	13	13	375.09	375.09
West Bengal	31	31	173.14	173.14	15	14	371.60	341.60
Bihar	17	17	53.71	53.71	7	5	135.50	118.00
Total	88	88	362.85	362.85	35	32	882.19	834.69

[Source: CAG 2000]

Table A1.2: Status of the schemes sanctioned and completed under GAP-II

Status of Progress Under GAP –II				(As on 31-12-2009)			(Rs. In lakh)
No.	**Action Plan/State**	**Cost of Schemes 31-12-2009**	**Schemes Sanctioned**	**No. of Schemes Completed (30-09-2009)**	**Funds Released By GoI (31-12-2009)**	**Funds Released During 2009-10**	**Expenditure Incurred (Inclusive of State Share) (30-09-2009)**
A	**Ganga Action Plan Phase-II (Ganga River and its tributaries)**						
(I)	**Yamuna Action Plan**						
1	Delhi	18064.08	12	12	17714.54	0.00	16069.53
2	Uttar Pradesh	28266.50	146	146	24001.50	0.00	27323.02
3	Haryana	24220.27	111	111	17870.40	0.00	24826.00
	Total	**70550.85**		**269**	**59586.44**	**0.00**	**68218.55**
	Yamuna Action Plan Phase-II						
	Delhi	46935.45	11	0	12183.72	3000.00	11094.97
	Uttar Pradesh	11507.94	5	1	5852.00	0.00	6644.88
	Haryana	6342.97	16	9	4890.23	1490.00	4949.62
	Sub Total	64786.36	32	10	22925.95	4490.00	22689.47
	Total (Yamuna)	**135337.21**	**301**	**279**	**82512.39**	**4490.00**	**90908.02**
(ii)	**Gomati Action Plan**						
	Uttar Pradesh	5575.09	31	29	4314.72	0.00	5214.66
	Total	**5575.09**	**31**	**29**	**4314.72**	**0.00**	**5214.66**
	Gomati Action Plan Phase-II						
	Uttar Pradesh	26304.22	30	7	16743.46	8023.00	22442.57
	Total	**26304.22**	**30**	**7**	**16743.46**	**8023.00**	**22442.57**
	Total (Gomati)	**31879.31**	**61**	**36**	**21058.18**	**8023.00**	**27657.22**

Status of Progress Under GAP –II				(As on 31-12-2009)			(Rs. In lakh)
No.	**Action Plan/State**	**Cost of Schemes 31-12-2009**	**Schemes Sanctioned**	**No. of Schemes Completed (30-09-2009)**	**Funds Released By GoI (31-12-2009)**	**Funds Released During 2009-10**	**Expenditure Incurred (Inclusive of State Share) (30-09-2009)**
(iii)	**Damodar Action Plan**						
4	Jharkhand	41.44	4	4	19.81	0.00	36.99
5	West Bengal	398.41	10	10	10.74	0.00	392.20
	Total	**439.85**	**14**	**14**	**30.55**	**0.00**	**429.19**
(iv)	**Mahananda Action Plan**						
	West Bengal	5488.23	3	0	500.00	0.00	1803.36
	Total	**5488.23**	**3**	**0**	**500.00**	**0.00**	**1803.36**
(v)	**Ganga Action Plan-II**						
	Uttar Pradesh	19811.76	45	32	15099.77	1357.00	15967.97
6	Uttarakhand	11486.04	52	29	4907.42	1769.00	3947.42
	Jharkhand	20.67	2	2	0.00	0.00	24.57
7	Bihar	395.18	18	14	315.13	0.00	297.54
	West Bengal	23560.84	202	140	19206.63	2000.00	16250.90
	CETP (West Bengal)	8292.00	4	2	4224.00	0.00	3952.00
	Total	**63566.48**	**323**	**219**	**43752.95**	**5126.00**	**40440.41**
	GAP-II (Total)	**236711.09**	**702**	**548**	**147854.07**	**17639.00**	**161238.20**

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Measures for Ecological Revival of River Ganga

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay	IIT Delhi	IIT Guwahati	IIT Kanpur	IIT Kharagpur	IIT Madras	IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who have contributed directly and those who have taken lead in preparing this report is given on the reverse side.

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Contents

1. Introduction

The river Ganga is home to a vast variety of living organisms from simple microscopic flora and fauna to a large assemblage of higher invertebrates(Arthropods, Annelids, Molluscs) and vertebrates (Fishes, Reptiles and Mammals). The biodiversity of the river Ganga is uniqueas it synthesizes three major eco-regions of India situated along different climatic gradients -the Himalayan mountainous region, the Gangetic plains and the Estuarine region including Hooghly-Maldah delta. These regions have different geologic and evolutionary history and hence the biota is diverse.

The main problems of Ganga river basin arise by unsustainable use of water resources; obstruction in flows resulting in river fragmentation and loss of longitudinal connectivity on account of exploitation of its hydro-electric potential in the Himalayan segment;abstraction of large quantities of water for irrigation in plains; and ever increasing water pollution in the middle and lower segments. These issues have been addressed as missions "Aviral Dhara", "Nirmal Dhara" and "Eco-restoration" in the Ganga River Basin Management Plan (GRBMP).

A healthy, self sustaining river system provides important ecological and social goods upon which human life depends (Postel and Richter,2003). Efforts in mitigating damages done to the river system and promote ecosystem goods and services and achieve a healthy, stable and sustainable ecosystem is referred as **Eco-restoration**. Palmer *et al*.(2005) have proposed criteria for measuring success of eco-restoration steps referred to as standards for ecological successful river restoration (Figure 1).

1.1 Goals and Objectives of Eco-restoration

The following goals and objectives have been comprehended:

- **i.** Provide space to endemic flora and fauna for survival by maintaining longitudinal and later connectivity.
- **ii.** Assure pollution free (stress free) environment for existence of sensitive and endemic flora and fauna.
- **iii.** Eco-restoration measures implemented in defined stretches to conserve aquatic biodiversity; sustain breeding sites for fish and aquatic vertebrates; restrict overexploitation of fish; eliminate invasive species; and replenish and rejuvenate endemic biota.

2. Aquatic Biodiversity in River Ganga

The biodiversity in terms of species richness of different communities, phytoplankton, periphyton, zooplankton, zoobenthos, fishes and higher aquatic vertebrates is spelled out in the form of four reports (refer Table 1) prepared by the Ecology and Biodiversity (ENB) thematic group of the Consortium of 7 IITs (IITC) involved in preparation of the Ganga River Basin Management Plan (GRBMP). A snapshot of the type of communities identified and reported in river Ganga is provided in Figure 2. The details and stretch wise interrelationship of communities and the desired levels of characteristic/keystone species are depicted in Table 2 and 3, respectively.

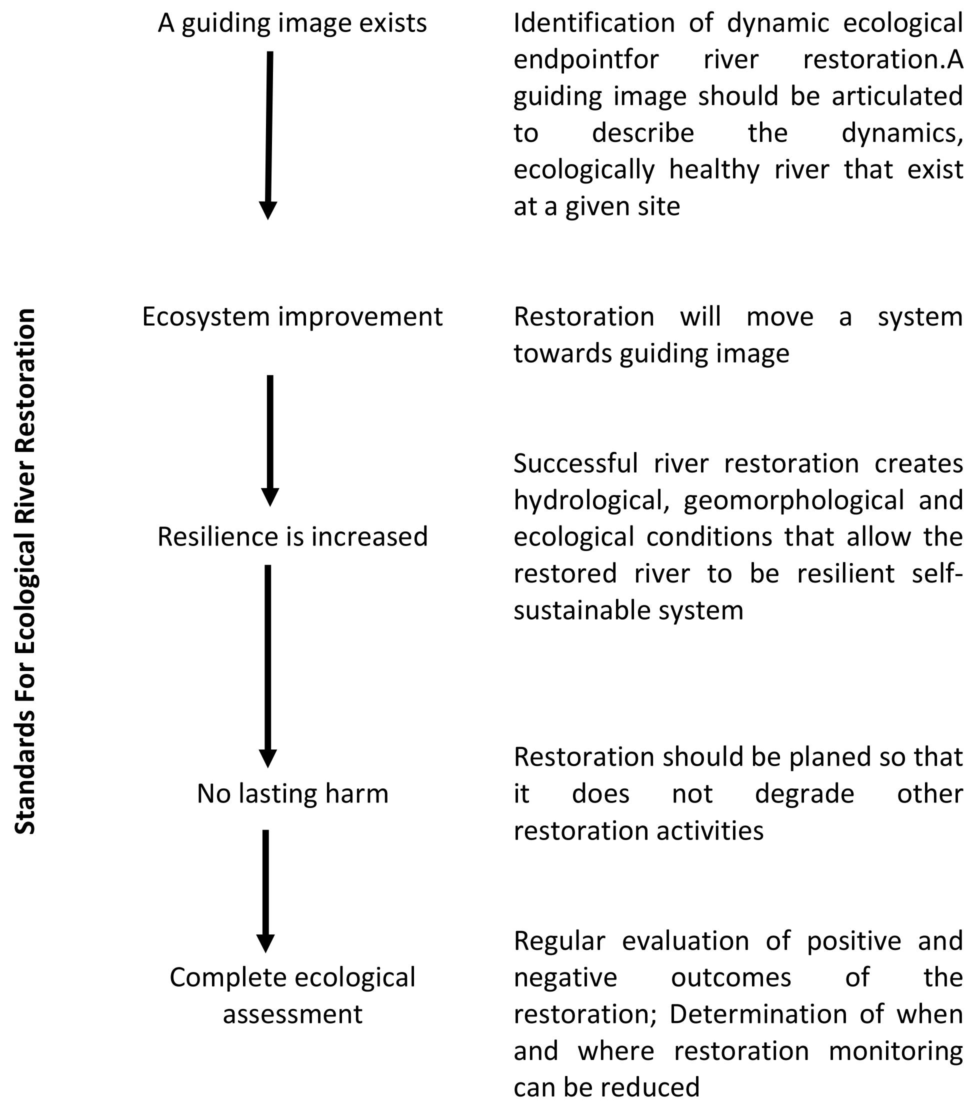
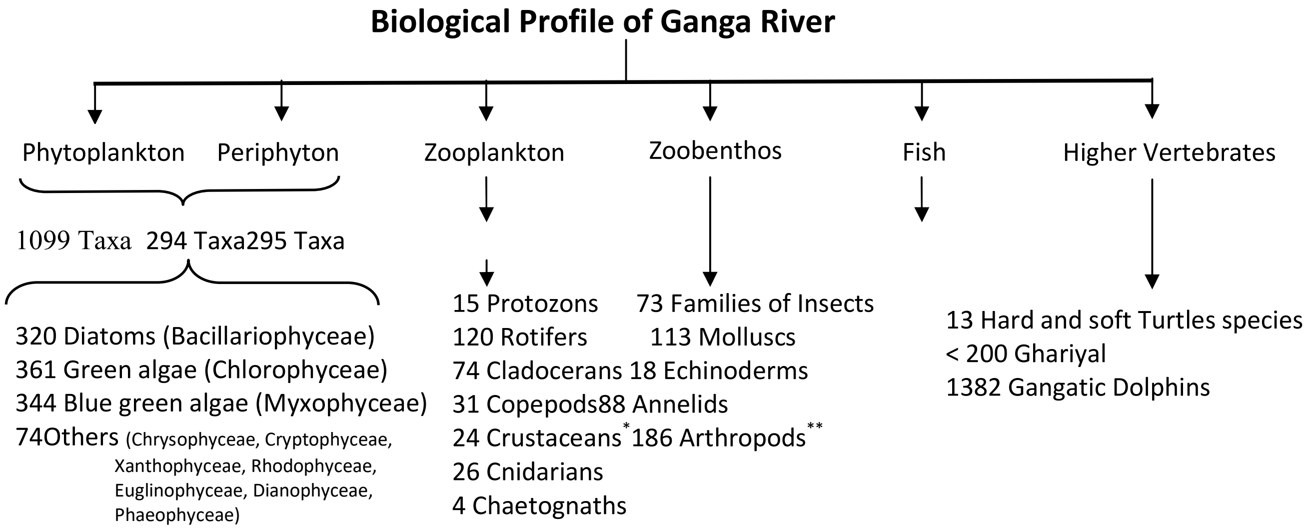


Figure1: Standards for Ecological Restoration

Table 1: List of Relevant Reports Prepared by ENB Group of IITC

S No	Title of the Report	Report Code
1.	Floral and Faunal Diversity in Upper Ganga Segment: Gangotri – Haridwar (Upstream Bhimgoda Barrage)	020_GBP_IIT_ENB_DAT_01_Ver 1_DEC 2011
2.	Floral and Faunal Diversity in Middle Ganga Segment: Haridwar – Varanasi	025_GBP_IIT_ENB_DAT_03_Ver 1_SEP 2012
3.	Floral and Faunal Diversity in Lower Ganga Segment: Varanasi – Farakka	026_GBP_IIT_ENB_DAT_03_Ver 1_JUN 2012
4.	Floral and Faunal Diversity in Lower Ganga Segment: Farakka – Gangasagar	027_GBP_IIT_ENB_DAT_04_Ver 1_JUN 2012



* Other crustaceans; ** Arthropods including (Crustacea, Ostracoda and Arachnida)

Figure 2: Aquatic Biodiversity in River Ganga at a Glance

Table 2: Biological Profile of Different Stretches in River Ganga

River Stretch	Algal ratio D* G* BG*	Specific Zoobenthos	Fish Families/ RET Species	Carps/ Cat Fishes / All Fish taxa	Characteristic Fish Species	Higher Vertebrates
Upper Ganga **UG1 (Gangotri to Gangnani)**	100:6:0 (33, 2, 0) Total: 36 Other: 1	Plecoptera, Tricoptera, Ephemeroptera, Diptera	✧/✧	✧	✧	No Vertebrates
UG2 (Gangnani to Devprayag)	100:17:5 (123, 21, 6) Total: 151 Other: 1	Plecoptera, Tricoptera, Ephemeroptera, Diptera, Coleoptera	4/ 14	(23/6/35)	Snow Trout (*Schizothorax richardsonii*)	No Vertebrates
UG3 (Devprayag to Haridwar)	100:14:13 (95, 13, 12) Total: 123 Other: 3	Tricoptera, Ephemeroptera, Diptera, Odonata	12/ 8	(25/7/42)	Golden Mahseer (*Tor putitora*)	No Vertebrates
Middle Ganga **MG1-MG3 (Haridwar to Fatehgarh)**	100:36:15 (100,36, 15) Total: 154 Other: 3	Tricoptera, Ephemeroptera, Diptera, Odonata	25/ 15	(46/14/109)	Indian Major carps, Catfishes	Soft and hard turtles,Gariyal, GangeticDolphins
MG4-MG5 (Fatehgarh to Varanasi)	100:67:36 (149, 100, 54) Total: 322 Other: 119	Tricoptera, Coleoptera	24/ 12	(34/28/92)	Indian Major carps, Catfishes	Gangetic Dolphins,Turtles
Lower Ganga **LGA (Varanasi to Farakka)**	100:118: 105 (81, 96, 85) Total: 285 Other: 23	Tricoptera, Ephemeroptera, Diptera, Coleoptera, Annelids, Mollusca	35/ 16	41/31/121)	Indian Major carps, Catfishes	Dolphins, Turtles
LGB (Farakka to Ganga Sagar)	100:161: 220 (127, 205, 279) Total: 652 Other: 41	Thysanura, Collembola, Annelids, Mollusca, Echinoderms	37/ 12	(16/27/172)	IMC, Catfishes, Hilsa, *Polynems paradiseus*, *Liza parsia*, *Harpodon neherus*	Turtles, Gariyal, Gangetic Dolphins, Porpoise, Chrocodile

✧A couple of brown trout *Salmo trutta fario* were cited by Nautiyal (2007); D* G* BG*= Diatoms, Green algae, Blue green algae; RET= Rare, Endangered, Threatened; IMC= Indian major carps; CF= Cat fishes

Table 3: Desired Levels of /Conditions for Characteristic/Keystone Species

River Stretch	Characteristic/ Keystone Species	Desired Conditions/Levels
Upper Ganga		
UG1 (Gangotri to Gangnani)	No Fish	
UG2 (Gangnani to Devprayag)	Snow Trout (*Schizothorax richardsonii*)	Trout should be able to migrate for feeding and breeding
UG3 (Devprayag to Haridwar)	Golden Mahseer (*Tor putitora*)	Mahseer should be able to migrate for feeding and breeding

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… … … …*Table Continued from previous page*

River Stretch	Characteristic/ Keystone Species	Desired Conditions/Levels
Middle Ganga		
MG1-MG3 (Haridwar to Fatehgarh)	Indian Major carps, Catfishes, Dolphins	Indian Major carps-40-50% Catfishes-10-15% Dolphins sighting
MG4-MG5 (Fatehgarh to Varanasi)	Indian Major carps, Catfishes,Dolphins	Indian Major carps-40-50% Catfishes-10-15% Dolphins sighting
Lower Ganga		
Lower Ganga LGA (Varanasi to Farakka)	Indian Major carps, Catfishes, Hilsa	Indian Major carps-40-50% Catfishes-10-15% Hilsa
LGB (Farakka to Ganga Sagar)	Indian Major carps, Catfishes, Hilsa,Irrawaddy Dolphin *Polynemusparadiseus*, *Liza parsia*,*Harpadon nehereus*	Indian Major carps- 15-25% CF-10-15% Hilsa-30% Irrawaddy Dolphinsighting *Polynemusparadiseus*, *Liza parsia*,*Harpadon nehereus*

3. Gaps in Available Information

The GRBMP reports related to biodiversity of Ganga River Basin (GRB) are based on secondary data collected from published literature, reports of different organizations (e.g. MoEF, CIFRI, CSIR, NGO's), undergraduate, master's and doctoral projects and dissertations/thesis, etc. Perusal of the data collected reveals that it is available in fragments in geospatial terms and there are distinct gaps in information. The information is in different time domain and isolated stretches largely governed by the period of study and proximity of a river stretch/ water body to the investigating institutions, organization or individuals involved in the study. Due to lack of any definitive biomonitoring program by the concerned agencies (e.g. Central Pollution Control Board, State Pollution Control Boards and National River Conservation Directorate, etc.) the analysis is based on extrapolation of scattered, mostly qualitative data/ information. Most of the data collected relate to periods prior to construction of dams/ barrages in upper Ganga mountainous segment. The procedures followed did not reveal in-depth scientific information and missed out many small organisms in sediments and/ or sediment water interface.

4. Role and Impact of Riparian Vegetation in Eco-restoration

Riparian ecosystem is a connecting link between stream environment and terrestrial catchment. Riparian forest is an area of trees accompanied by shrubs and herbs that is adjacent to the water body. It influences the structure of both aquatic and upland terrestrial community. The components influenced by riparian ecosystem are modifying storage capacity and aquifer recharge, in-channel primary and secondary productivity, organic matter quality and quantity, biodiversity and migratory patterns, and biogeochemical pathways and rates (Sharitz *et al*., 1992). Riparian flora also helps in trapping pollution, filtering and converting sediments, nutrients and other chemicals. They absorb periodic flood fluxes and supply food cover and thermal protection to biota. Ecological buffers that are important to riparian ecosystem are mentioned as follows.

- ✓ Predominance of wood plant community.
- ✓ Presence of surface water and abundant soil moisture.
- ✓ Diversity interspersion of habitat features.
- ✓ Corridor for dispersal and migration.

Riparian ecosystem has many functional characteristics. They are highly productive because of convergence of energy and material, and unique hydrological conditions.Existing riparian systems have economic, social and biological values(Kauffman *et al*., 1997) (Figure 3).

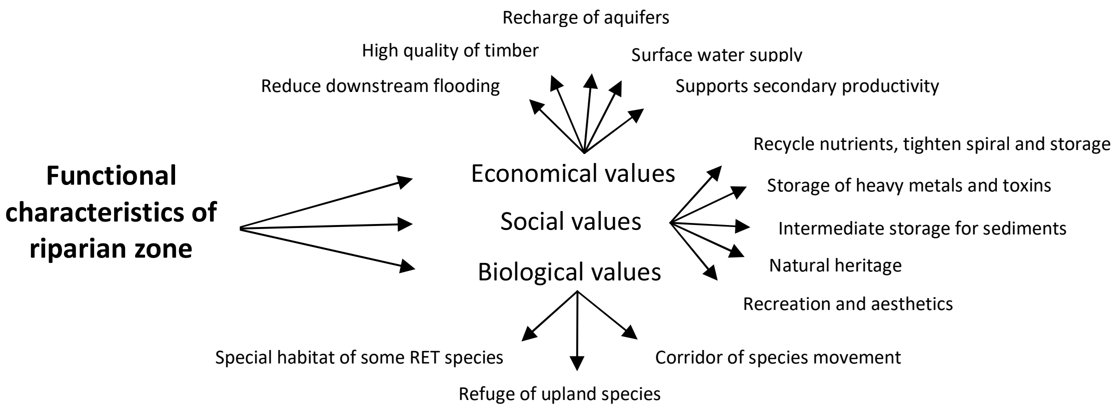

Figure 3:Functional Characteristics of Riparian Zone

Riparian zones hampered regularly by various anthropogenic activities to achieve multiple objectives such as channelization, road construction, timber harvesting, livestock grazing, mining, and water diversion. Degradation of riparian zones and streams diminishes their capacity to provide critical ecosystem functions, including the cycling and chemical transformation of nutrients, purification of water, attenuation of floods, maintenance of stream flows and stream temperatures, recharging of groundwater, and establishment and maintenance of habitats for fish and wildlife. To conserve and maintain ecological integrity and pristine nature of the river, our strategy of ecological restoration requiring holistic approach of activities and conditions should also include the riparian zone restoration.

5. Major Threats on River Ganga Ecosystem

The riverine ecosystem has been exploited for meeting human needs. Major threats to the Ganga basin as well as other river basins in the country affecting/disturbing ecological integrity are briefly described as follows.

5.1 Changes in the Flow Regime

Obstruction: The flow patterns in the river Ganga have been altered due to number of run-of-the-river (ROR) hydro-electric projects in the Bhagirathi and Alaknanda head streams. Some of the projects which have been completed and under operation arelisted in Table 4.

Table 4:Hydro-electric Projects on the River Bhagirathi and Alaknanda

Project	Installed Capacity (MW)	Status	River
Vishunprayag	400	On	Alaknanda

Maneri Bhali I	99	On	Bhagirathi
Maneri Bhali II	304	On	Bhagirathi
Tehri	1000	On	Bhagirathi - Bhilangna confluence
Koteshwar	400	On	Bhagirathi

In addition to the mentioned projects, six projects on Alaknanda and four projects on Bhagirathi are under construction and twenty four projects on Alaknanda and nine on Bhagirathi are proposed (Tareand Mathur, 2010).

These hydro-electric projects have fragmented the river and obliterated the migration routes of some important fishes *viz.,Schizothorax* sp. and *Tor* sp. The salient features of two keystone migratory species *Schizothorax richardsonii* (Snow trout)and *Tor putitora* (Golden mahseer) are indicated in Table 5.

Table 5:Ecological Requirements of *Schizothorax richardsonii* and *Tor putitora*

Organism	Snow trout	Golden Mahseer
Zoological name	*Schizothorax richardsonii*	*Tor putitora*
Size	200-255 mm (maximum 509 mm)	200-260 mm (maximum 610 mm)
Water temperature	7.2-22°C	18.5-27.6°C
Current speed	Swift	Moderate
Water shed	Snow covered hills and spring	Lower reaches of snow fed streams and springs
Substratum	Boulders and stones covered with slimy algal material	Pitted rocks and stones covered with periphytic and filamentous algae
Spawning period*	August-October	May-September
Food and feeding	Herbivorous: feed on algae, periphyton, inferior mouth with hard cartilaginous disc adopted for scrapping; Diatoms (>90%), Green algae (≤6.0%), Desmids (≤1.0%); bottom feeder	Omnivorous (Green algae, insects); Diatoms (≥85%); Green algae (≤4.0%), Desmids (≤3.0%); Water column feeder
Benthos	May fly (≥40%), Caddis flies 30%, Diptera and Coleoptera	May fly (≥25%), Caddis flies 30%, Diptera and Coleoptera
Other requirement	Adult prefers deep pools and runs (1-3 m); It migrates to lower reaches of the stream for breeding	Adult prefers deep waters (pools and runs 1-3 m), while brooders migrate to shallow stream for breeding; Breed at graveled surface depth 0.5-1.0 m

* Period including the migration; Shrestha and Khanna (1976); Singh and Sharma (1995); Kishor *et al*. (1998); Bhatt et al. (2004)

Abstractions: Downstream of Rishikesh (Veerbhadra), Pashulok Barrage diverts nearly all the water in lean season into power channel for Chilla power station. The tail water of this power station joins the river near Bhoopatwala into river Ganga. A stretch of about 15 km from Pashulok Barrage to the confluence of the tail waters to the riveressentially has no flowduring the lean season (Plate 1). Further downstream, at Bhimgauda Barrage nearly all water is diverted to Upper Ganga Canal through Har ki Pauri at Haridwar. The flow of this diverted section is regulated at Mayapur Head Works and let off in the Upper Ganga Canal. The water in excess of requirements is passed through an escape channel which joins Ganga at Kankhal. Thus the stretch between Bhimgoda Barrage to Kankhal is nearly water less except some flow on account of leakage.The movement of major fishes including mahseer is intercepted and growth of other flora and fauna is impeded.

Water abstraction at Bijnor into Madhya Ganga Canal (KharifCanal) and at Narora into Lower Ganga Canal further creates obstacle for biota.Further downstream Farakka Barrage has blocked the migration route of an anadromous fish called Hilsa which migrates from sea to fresh water for spawning.

Plate 1: Comparative Conditions of Flow Upstream and Downstream of Pashulok barrage

5.2 Habitat Alterations

In addition to changes in the flow regime,the river morphology and habitat are also altered steadily. Large scale gravel and sand mining, dumping of construction wastes and other solid wastes have lead to changes in flow direction causing erosion, channelization and river realignment. This reduces stream width, altering flood plains and riparian vegetation. The ecology is seriously impairedwith changes in habitat. The alteration in habitat, changes benthic flora and fauna,fish breeding sites and egg laying sites, for soft and hard shellturtles (*Kachuga smithii*, *K. tecta*, *K. tentoria*, *K. dhongoka* and *K. kachuga*, *Aspideretes gangeticus* and *A.hurum*).

5.3 Emergence of Invasive (Exotic) Species

Exotic species of fish especially common carp *Cyprinus carpio* and Tilapia *Oreochromis niloticus* have invaded Ganga water downstream of Allahabad. These fishes have gained access through water of Yamuna at Sangam. Downstream Allahabad upto Bhagalpur and beyond they have grown in large numbers. They compete with Indian Major Carps (IMC) and haveout grown them due to their adaptability in variable flows.Seven species of exotic fish have been reported in river Ganga (Singh and Lakra, 2006) including Thai magur, (*Clarias gariepinus*) and Grass carp (*Ctenopharyngodon idella*). The CIFRI has reported their presence now upto Narora. Sighting of brown trout *Salmo trutta fario*- an exotic fish, at Jhala downstream (Nautiyal, 2007) is an important signal of the presence of invasive species reaching all the way upto Bhagirathi.

5.4 Introduction and Proliferation of Invasive Species in the River Ganga

Exotic species is an introduced species intentionally or accidently in the system creating various problems including extinction of local species. The other problems such as food and habitat competition, preying upon native species, inducing of new diseases and parasites, result in the production of hybrids and cause genetic erosion of indigenous species.More than 300 exotic fishes are reported in India. Some of them escaped from confinement and are reported in river Ganga and have become invasive to the ecological equilibrium.A snapshot of exotic species found in the river Ganga is presented in Table 6.

Table 6: Exotic Species Found in River Ganga

S No	Exotic Fish	Status	Rivers	Reservoirs	Lakes	Wetlands
1.	*Cyprinus carpio*	Introduce for aqua culture	Ganga	Most reservoirs	Most lakes	Bihar, West Bengal, U.P.
2.	*Hypophthalmichthys molitrix*	Introduce for aqua culture	Ganga Yamuna	Some reservoirs	Some lakes	Bihar, West Bengal, U.P.
3.	*Ctenopharyngodon idella*	Introduce for aqua culture	Ganga Yamuna	Some reservoirs	Some lakes	Bihar, West Bengal, U.P.
4.	*Aristichthys nobilis*	Illegally introduced (banned sp.)	Ganga Yamuna	Some reservoirs in U.P.	Some lakes	Bihar, West Bengal, U.P.
5.	*Clarias gariepinus*	Illegally introduced (banned sp.)	Ganga Yamuna	Some reservoirs in U.P.	Some lakes	Bihar, West Bengal, U.P.
6.	*Oreochromis niloticus*	Introduce for aqua culture	Ganga Yamuna	Many reservoirs	West Bengal	West Bengal, Bihar
7.	*Salmo trutta fario*	-	Asi Ganga	-	-	-
8.	*Gambusia affinis*	-	Ganga	-	-	-
9.	*Pterygoplichthys perdalis* and *P. disjunctivus*	-	Ganga	-	-	-

Singh *et al*. (2013); Kumar (2000)

Cyprinus carpio is widely spread in eutrophic waters. Wild populations are considered vulnerable to extinction. It is a very destructive fish being included in the list of l00 worst invasive species.*Oreochromis niloticus*, Tilapra is an omnivorous fish which devours on most of the living forms (plankton and macrophytes). Breeds in slow moving warm waters. The fecundity and feeding habits are deleterious to indigenous population.It has made Ganga second home where it competes with Indian Major Carps whose production has reduced to nearly half. In order to sustain the wild population it is necessary to control, if not eliminate the growth of exotic species. Natural hybrids have also been reported in the system.

A concerted strategy to curb the introduction to middle and upper Ganga and reduce proliferation in lower Ganga is needed. This requires research and development. Central Inland Fisheries Research Institute and National Bureau of Fish Genetic Resources alongwith other Academic/Research Institutes may be given the responsibility of working out the approach and strategy for control.

5.5 Pollution

Pollution from domestic and industrial wastes is rampant in Ganga river downstream of Haridwar though it is not very serious upto Fatehgarh (Farukhabad) but assumes higher and alarming proportions downstream of Kannauj after the confluence of Ram Ganga and Kali rivers. It remains high at Kanpur and Allahabad, and upto Varanasi. On the basis of long term water quality monitoring of river Ganga undertaken by various organizations on behalf of NRCD (1986-2010), it is apparent that microbial pollution is increasing in the river. Water quality corresponding to Class-I and Class-II (as per the Designated Best Use of CPCB)is reported only in the upper Ganga stretch upto Devprayag and upto Garhmukteshwar respectively; while further downstream all the way down to the estuarine regions water quality is very poor (Tare *et al.*, 2012).

Partially treated and untreated wastes is discharged in the river through about 36 Class-I towns and 14 Class-II towns. As per CPCB report on pollution assessment 2013, 2723.3 MLD wastewater is generated from these towns out of which 1208.8 MLD is partially treated, which is only around 40%. The maximum input in the river is in West Bengal followed by Uttar Pradesh, Bihar and Uttarakhand. In addition 138 storm water drains - natural or manmade also discharge 6087 MLD either in rivers/lake/sea. In this respect maximum volume of wastewater is contributed by Uttar Pradesh (45 drains, 3289 MLD) which is followed by West Bengal (54 drains, 1779 MLD), Bihar (25 drains, 579 MLD) and Uttarakhand (14 drains, 440 MLD).

Residues of organochlorine including HCH (hexachlorocyclohexane), DDT (dichlorodiphenyl-trichloro-ethane), endosulfan and their metabolites are common in the river water (Vass *et al*., 2011). High concentrations were reported by Nayak *et al*. (1995) near Varanasi. There are reports on presence of organophosphates (Ray, 1992). Heavy metals are also reported in the river water and sediments (Vass *et al*., 2011). Some toxic metals which are reported comprise Cd, Cr, Cu, Mn, Ni, Pb and Zn (Saikia *et al*., 1988; Joshi, 1991;Mohammad*et al*., 1987; Israil, 1991; Singh *et al*., 1993).The pollutants can be traced to industrial wastes, agriculture run off and domestic wastes from point and nonpoint inputs.

5.6 Impact on Inland Fisheries

There has been conspicuous reduction in the fish yield, fish catch, fish size and fish composition in the Ganga river due to combined effect of changes in flow, changes in rainfall, loss of breeding sites, pollution and juvenile fishing. It has been generally observed that the size of fish has undergone reduction. Hamilton (1885) had reported Mahseer with maximum size of 2.74 mat Haridwar while in current times the reported maximum size varies between 1.0-1.5m. The maximum size of Indian Major Carps hasalso reduced. The fish yield from the river Ganga is also declining gradually (reported at Allahabad) from 1344 kg/km in 1950 to as low as 362 kg/km in 2000 and a mere 300 kg/km in 2010. The catch composition has also changed. The percentage of IMC has gone down and there is increase in otherspecies as depicted in the Figures4and5.

In addition fish spawn of Indian Major Carps has also declined in the middle stretch due to destruction of spawning sites. The fish spawn availability index which used to be 281 ml in 1970 has declined to 27 ml as recorded during 1996-2000.

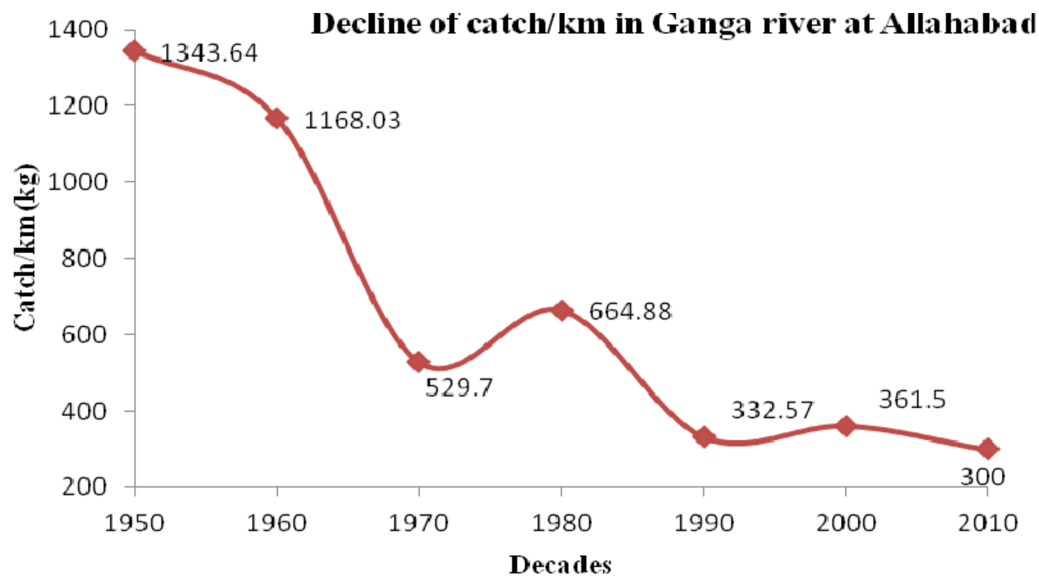

Figure4: Decline of Fish Catch per km at Allahabad During 1950s to 2010s

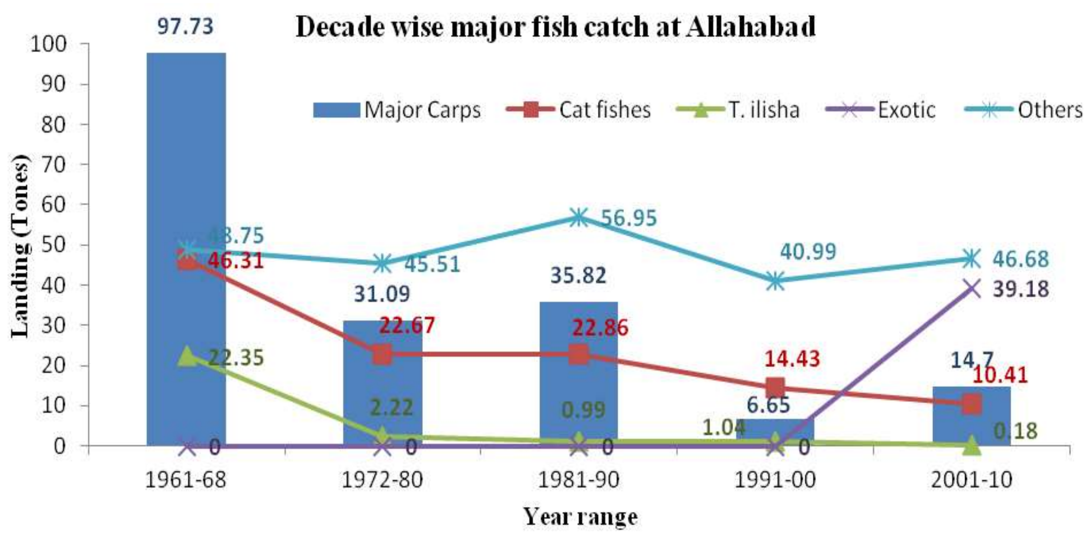

Figure5:Fish Landing at Allahabad (CIFRI Annual Reports 1961-2010)

6. Restoration Measures

The following restoration measures seem inevitable in river ecosystem including research and data validation to bring river Ganga to sustainable, stable and healthy condition.

a) Longitudinal, lateral and vertical connectivity by maintaining Environmental Flows (E-Flows) in the entire stretch of Ganga system. This would provide enough space for endemic species of both flora and fauna for growth and migration. It will also provide connectivity with wetlands. Restoration of wetlands may be made point of focus so as to ensure breeding sites of fish and other aquatic animals.

b) To maintain wholesome quality under mission Nirmal Dhara, concerted efforts are needed to provide stress free, toxic free conditions to promote and sustain endemic flora and fauna. The two measures (longitudinal connectivity and maintaining desired water quality) are the focal points under the missions ‘Aviral Dhara’ and ‘Nirmal Dhara’.

c) Rivers as a fishery resource are almost neglected by state governments. Over exploitation of fish in certain states with open or access fishing rights has reduced the fish catch/yield. Fishing is found to continue even in periods of breeding. Through legislation in River Act (proposed) fishing should come under regulated and restricted category. Broods and juvenile should be protected from exploitation. Fishing during May-August (breeding season) should not be permitted.

d) Identify all the species including zoobenthos, fish and aquatic higher vertebrates which come under rare, endangered and threatened category and conserve them to maintain the ecological integrity.

e) Breeding sites for fish and other higher aquatic vertebrates may be identified and conserved. Soft and hard shelled turtles lay eggs in the flood plains during the post monsoon period which coincides with the growth of pelage, a local phenomenon in U.P. and Bihar.

f) To assess and monitor river health, primary data collection for all parameters including biomonitoring from selected stretches should be done by recognized and reputed research institutions through empowering and involving local riverside communities.

g) Use of chemical fertilizers and pesticides in agricultural in flood plains and riparian zone be regulated and restricted.

h) The Gangetic dolphin *Platanista gangetica gangetica* was declared a National aquatic animal by Ministry of Environment and Forest on May 10, 2010 and a Conservation Action Plan was published for 2010-2020 (Sinha *et al*., 2010).The document provides general and scientific information of the Flagship species including preference for habitat and conservation status. The threats to its population include Human-Dolphin conflict (Poaching, accidental killing, use of dolphin products), habitat degradation, pollution and riverine resource extraction.Strategy for conservation as per principles elucidated in the IUCN Workshop held in 1997 in Bangladesh on water development and Cetacean were adopted.

   - Gangetic Dolphin requires sufficient year round water flow to move, forage and carry out activities that ensure reproductive success and recruitment into breeding population.
   - Large daily fluctuations in flow should be avoided.
   - Equilibrium between sediment erosion and deposition is necessary to maintain essential habitat features.
   - Access to flood plains should be preserved to ensure natural spawning and rearing habitat for fishes which are prey base of the dolphins.
   - Information on the pre development ecological conditions of a river is essential for evaluating migration efforts and to implement future development decisions.

- Post development empirical studies are needed to monitor the operational aspects as well as the effects on upstream and downstream populations of cetaceans and their habitat.
- Cumulative and synergistic impacts of multi development should be considered in assessment of environmental impact.
- Enhancing the capacity and governance frame work for Gangetic Dolphin conservation is needed.

Some areas of Ganga river system, identified as a critical stretch for Dolphins, are mentioned as follows.

1. Uttar Pradesh:-

Madhya Ganga Barrage at Bijnor to Lower Ganga Canal at Narora (165 km)
Fatehpur to Mirzapur (150 km)
Chambal Yamuna confluence near Etawah
Ganga Yamuna confluence at Allahabad

2. Bihar:-

Gangi-Ganga confluence near Sinha Ghat (20 km)
Upstream of Ghaghara-Ganga confluence at Doriganj, Chhapra to Fatuha (80 km)
Barh to Mokama to Manihari Ghat (Katihar) (210 km) (This includes Vikramshila Dolphin Sanctuary~50 km)
River Gandak from Triveni Barrage at Indo-Nepal border to Ganga-Gandak confluence at Patna (332 km)

i) Invasive species of fish like Chinese carp (*Cyprinus carpio*), Chinese grass carp (*Ctenopharyngodon idella*) and Tilapia (*Oreochromis niloticus*) have made Ganga their second home where it competes with IMC,and need to be control. The protocol and procedure required needs to be worked out through the concerted efforts of Central Inland Fishery Research Institute and other scientific bodies.

j) Regulations and restriction of certain activities through legal instruments:

- Sand and gravel mining should be regulated and dumping of solid wastes must be prevented which are responsible for habitat modification and channelization.
- Cultivation of “pelage” (Cucurbitaceous crops) in the flood plains of the river needs to be restricted to protect breeding sites of higher aquatic vertebrates and prevent contamination from fertilizers and pesticides
- Fishing during the breeding period of commercial fish, brood and juveniles (spawn, fry and fingerlings) should be prohibited or restricted.

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Implementation of Ganga River Basin Management Plan

Recommendations on Legal and Institutional Aspects

GRBMP: Ganga River Basin Management Plan

by

Indian Institute of Technology

IIT Bombay	IIT Delhi	IIT Guwahati	IIT Kanpur	IIT Kharagpur	IIT Madras	IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 "Indian Institute of Technology"s (IITs) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who have contributed directly and those who have taken lead in preparing this report are given on the reverse side.

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Contents

1. Introduction

The Ganga River Basin Management Plan (GRBMP) relates to diverse domains and therefore it is multi-dimensional. Based on inputs from a multi-specialty team, the Plan has identified need for wide ranging interventions – both technical and non-technical, in terms of among others, policies, programmes and infrastructure. The Plan recommendations are far reaching, transcend short-, medium- and long-terms and as regards implementation pertain to multiple agencies.

Moreover, during the process of developing the Plan one of the domains that have been investigated comprises legislative framework applicable in the Ganga River Basin, specifically for managing and harvesting of water resources, protection and conservation of river water quality, utilising the water courses for gainful applications, etc. This mapping of the legislative framework establishes focus on 'exploitation of resources' aspect over the last two centuries whereas considerations towards their protection and conservation are of rather recent origin, which have not necessarily received the priority that they deserve. Given the long stretch of River Ganga transcending several provincial jurisdictions, existence of a number of legislations relating to different subject matters and the corresponding authorities (may be with overlapping authority or jurisdiction), as regards implementation of the Plan, the mapping of legislations exercise has also led the investigators to inquire into the need for evolution of a comprehensive legislation which is specific to the National River Ganga and 'her' basin.

In this context, this brief report summarises findings of the investigations, available constitutional/ legal provisions and institutional mechanisms, and attempts to develop justification for a new/ alternate legislation and mechanism including the philosophy or premise of the proposed legislation. In addition, the report also includes as an annexure a draft bill for the proposed legislation which needs to be discussed and deliberated among wider stakeholders.

2. Key Findings out of the Mapping of Existing Legislations

Based on geomorphology, broadly the 2500 km long stretch of River Ganga is classified into three distinct stretches, viz., upper-stretch comprising the state of Uttranchal; middle-stretch comprising states of Uttar Pradesh, Bihar and Jharkhand; and lower-stretch comprising the state of West Bengal. In the upper stretch characterised by hilly topography, deep gorges, high turbulence, low temperature glacial melt; comparatively lower density of population and lower industrialization, the extent of contamination of the river due to anthropogenic activities is not perceived to be as much of an issue as maintenance of natural flow in the river and ensuring its continuity. On account of prioritising exploitation of water resources for energy (and irrigation), construction of number of hydroelectric projects in the upper-stretch (e.g., Tehri Dam, etc.) has led to severely fragmented streams. As a result, the natural flow of River Ganga has been disrupted which has adverse impacts on ecology and socio-cultural practices on the downstream stretches.

An analysis of legislations in the upper-stretch[1] brings out provisions for, among others, basin-wide planning with the objective of optimum utilisation of natural resources. There are specific interventions to, among others, promote flora and fauna, control and mitigate soil erosion and regulate commercial mining of building materials, however it is noted that none of the legislations provides for basin contamination measurement system, maintenance of minimum and/or environmental flows or measures to address issues relating to hydrology. Given the fragile nature of the ecosystem in the upper-stretch it is imperative that all the concerns related to the quality and health of the ecosystem, socio-cultural aspects as well as public health are addressed appropriately.

In the middle and the lower stretches of Ganga all the issues come to the fore – be it contamination due to anthropogenic activities; water requirements for irrigation; navigation; dams and diversions; ecology and fisheries; and inter-state river management. In these stretches, given the topography and geomorphology, the river has been more manageable and water resources amenable for consumptive uses and accordingly there is plethora of legislation in the domains of irrigation, dams and diversions, and navigation.

A mapping exercise in the middle-stretch establishes existence of several legislations[2] out of which about 60%, which is not surprising, pertain to 'resource exploitation' aspect i.e., infrastructure and services for consumptive use of water resources for crop production and thereby enabling livelihood for millions of rural people in the fertile Gangetic planes. By and large these legislations deal with regulation of flows, operation and maintenance of infrastructure to that effect and to a fair degree on levy of user charges. In this domain it is interesting to note that while a number of legislations originated during the British era there are also some progressive legislations of recent origin which deal with the subject of participatory management of water resources,

[1]The legislations mapped in the upper-stretch comprise Uttranchal Sanshodhan Act, 2001; Uttar Pradesh Panchayat Raj Act 1947 (Uttranchal Amendment) Act, 2002; Uttranchal River Valley (Development and Management) Act, 2005;and Uttar Pradesh Bhagirathi River Valley Authority Act, 1999.

[2]The legislations mapped in the middle-stretch comprise, among others, the Uttar Pradesh State Ganga River Conservation Authority, vide SO 2493(E), 30th Sep. 2009 (a Central Notification); Uttar Pradesh Water Supply and Sewerage Act, 1975; Bihar Irrigation Act, 1997; The Uttar Pradesh State Tube-Wells Act, 181936; The Uttar Pradesh Minor Irrigation Works Act, 1920; The U.P Fisheries Act, 1948; The Ganges Tolls Act, 1867, etc.

optimising usage of water by involving farmers - the ultimate beneficiaries, as regards irrigation demand.

There are few legislations on enabling institutional framework for exploitation of water resources for domestic and industrial water supply; as well as creation and operation of infrastructure for mitigation, control or monitoring of pollution from domestic and other sources. A set of legislations also deal with the subjects of ecology (fisheries) and navigation. Given the recent origin of the State of Uttarakhand, it is implicit that prior to the division of UP, legislations of this stretch were also applicable in the upper stretch of the river as well.

However, as in the case of state legislations in the upper-stretch, certain gaps are identified in this stretch as well. For instance, some of the important areas that are unaddressed comprise sand mining activities in the river basin and the channel with potential to cause soil erosion; unregulated usage of water from river basin for agriculture; hydrology and hydrogeology; basin flow monitoring system; usage of ecological and marine resources, etc.

As the river approaches its mouth on the Bay of Bengal, evidently the subject of navigation and 'commercial use of waterways' gain importance and accordingly one finds a number of legislations related to these domains in the state of West Bengal. Evidently under these legislations the focus is on regulation of activities either within river beds or issues related to the Ganga basin i.e., utilising and maintaining water channels – natural and/or manmade, from the point of view of movement of man and materials and not on the quality of the ecosystem per se. Here again it is noted that that there are several legislations which were enacted during the British period and which are still in force in West Bengal. The state government has also enacted a set of laws regarding urban sanitation and municipal activities, water supply, sewerage and irrigations[3]. However, it is noted that major factors contributing to pollution of the river are not addressed in any of the state legislations. Other important gaps comprise, among others, lack of a measurement system to assess basin contamination, measures for prevention of soil pollution and restrictions on industrial usage of river water, etc.

As stated earlier, a number of legislations are from British period going back to the 19th century and it is evident that they do not respond to the current or emerging challenges- in terms of relevance or commensurate powers, in the changed socio-economic setting. In some cases the recommended monetary penalties are

[3]The legislations mapped in the lower-stretch comprise The Howrah Municipal Act, 1980; The Kolkata Municipal Corporation Act, 1980; The West Bengal Irrigation (Imposition of Water Rates) Act 1974; The West Bengal Irrigation (Imposition of Water Rates for Damodar Valley Corporation Water) Act, 1958; The Bengal Waterways Act, 1934; The Bengal Ferries Act, 1885; The Bengal Fisheries (Requisition and Acquisition) Act, 1965; The Calcutta Port Act, 1890; The Bengal Embankment Act, 1882.

insignificantly low which do not constitute the necessary economic disincentive or punishment for violators.

It is also evident that given the long stretch of the river transcending over diverse provincial /administrative boundaries, there are multiple governments and agencies involved and it has been a challenge to have them on a single platform and achieve synergy of action from the point of views of either sustainability or the health of the river ecosystem.

Recognising the limitations of the then prevailing state level legal and institutional framework, in early seventies and mid eighties the Government of India introduced comprehensive central legislations to safeguard the environment and water bodies. Among others, The Water Act, 1974 and the EPA, 1986 represent landmarks in the Indian environment management domain which have helped a great deal in addressing diverse issues related to protection of the water quality of River Ganga. Among others, EPA enables framing of rules and constitution of regulatory authorities in response to specific challenges in any part of the country and can therefore enable necessary interventions at central and/or state levels. The Wildlife Protection Act, 1972 - a precursor to these legislations, grants considerable powers to take necessary measures as may be required to protect, conserve and improve the river water quality for, among others, protection of 'Gangetic Dolphin' which is accorded highest protection on account of being classified as an 'endangered species'.

Above all the legislations, the provisions of the Indian Constitution, especially under Article 32 offer a major tool in the hands of the common man and the judiciary to proactively take legal recourse through Public Interest Litigation and seek redressal of violations that undermine the larger public good.

However, given the current status of the river and its ecosystem, it is evident that as regards the existing legislative framework around River Ganga there are wide ranging issues that need to be addressed and which pertain to efficacy, coverage, implementation and/or monitoring. It is also noted that apparently there are no legislations which deal with issues related to non-point pollution from agricultural fields, soil erosion and excessive public use of river water for different purposes, etc. Many issues concerning river management do not fall within the present legislative frame, such as maintenance of environmental/ ecological flows, protection of river basin ecology and biodiversity, maintenance of ground water table, consolidated plans for diversion of river waters in different stretches, discharge of sewage from urban centres, obstructions to river flows and loss of connectivity, use of floodplains and active floodplains, etc. There are also issues with the capacity of the relevant institutions as regards their roles in handling and addressing social, economical and technical matters pertaining to the Ganga.

Given the increasing complexities arising out of the pressures of rising population in the entire basin of River Ganga, and given the recent pronouncement of the Government of India according her the status of a 'National River', there is an urgent need to develop clarity on these aspects. In this respect, it is imperative that policies and legislations embracing new paradigms are evolved which address hitherto unaddressed subjects.

3. Need and Justification for New Legislation

Ganga travels through many states and sustains life and livelihood of millions, all the way from her origin at Gangotri in the Himalayas to Gangasagar – its mouth on the Bay of Bangal. Being a legend and part of the Vedic civilisation, Ganga also binds all people living on or off her banks on the spiritual platform. Being an inter-state river, Ganga has met with varied treatment under the legislations of central and state agencies as regards use of riverbed and appropriation of water and mineral resources, abatement of pollution and regulation of industrial activities. In addition to numerous laws, after 35 years of independence, in the year 1985 on realization of deteriorating health of Ganga, the Government of India made a beginning towards restoration of her water quality and ecosystem under the Ganga Action Plan I (GAP-I). Another endeavour was made in the year 1993 under the GAP-II and under Yamuna Action Plan – the latter targeting another sacred Indian river which is one of the major tributaries of Ganga in north India and which joins her in the middle stretch at Prayag/Allahabad.

However, it is evident and increasingly recognised by all stakeholders that the policy, legislative or infrastructure interventions of last two decades to restore water quality of River Ganga have not been able to bring about desired results. In response to this exigency, the Government of India has attempted to revamp its conservation strategy by declaring River Ganga as the 'National River', thus officially according a distinctly higher status in comparison to other water bodies. Additionally, the idea underlying the creation of National Ganga River Basin Authority, 2009 is to approach the worsening situation of Ganga River and her basin in comprehensive and holistic manner. The problem confronted by Ganga requires all-inclusive solution which would ensure maintaining the desired level of minimum ecological flows besides implementing pollution abatement activities (i.e., prevention or control of discharge of domestic and industrial wastewaters). The problem also comprises pollution from non-point sources e.g., run off from rural settlements comprising, among others, fertilizers and pesticides from agricultural fields, open defecation, waste from dairy farms, leachates from open dumps of urban solid waste, dumping of animal carcasses and disposal of human dead bodies which together significantly contribute to pollution of the river and render her waters unsuitable for varied uses – among others, her perceived sacredness which otherwise helps mobilise socio-cultural practices over the entire stretch. Equally important is the issue of dams and barrages for storing and diverting water for irrigation, domestic consumption and industry, which affect the flow, particularly during dry season and determine the health of the riverine ecosystem.

Myriad factors are contributing to decline of Ganga and her basin. As the contributors are numerous and fall under the purview or in the domain of different jurisdictions of the executive and the legislature at the central and the state levels, there is a need to contain the problem of Ganga in an all embracing manner in order to give a solution which would reflect Ganga not just as a geomorphological unit but also as a legend and a spiritual entity as believed by a predominant section of the Indian society *(For instance, as per a reference available in the Bhagvad Gita verse 10:31, Lord Krishna says "Of purifiers I am the wind, of the wielders of weapons I am Ram, of fishes I am the shark and of flowing rivers I am the Ganga")*.

Given the number of legislations at state and central levels with diverse mandates and jurisdictions, it is also evident that there is a need to bring coherence in the laws which touch upon these aspects relating to Ganga River. Unfortunately, it has been observed that environmental legislations have not played the intended role in combating the problem of pollution, especially river pollution.

Therefore it is evident that a specific and comprehensive law to address issues of regulation, conservation and development of the National River Ganga Basin is the pressing need to restore the holy river to her original form.

4. Philosophy and Basic Premise of the Proposed Legislation

In the above context, it is evident that the health of the river depends on the health of the river basin and therefore in the interest of the ecosystem and the public it is essential to adopt an integrated river basin management approach that focuses on not only maintenance and restoration of wholesomeness of all the rivers in the Ganga Basin but also preserves the basin itself. In order to accomplish this objective of wholesomeness of the river and its basin, it is mandated to adopt combination of preventive and corrective approaches which include prohibition and restriction of activities that directly or indirectly affect the wholesomeness of all rivers in the National River Ganga Basin. There is also a need to ensure continuity of the river as a geomorphological, ecological and spiritual entity epitomising 'Aviral Dhara'.

Accordingly, the proposed Ganga River Basin Management Act should aim to prohibit and regulate activities that affect wholesomeness of the river, and creates institutions to regulate the activities thereon. The new legislation would not only propose conservation policies but also promote activities to preserve the Ganga basin. The adoption of a comprehensive legislation would ensure that the law achieves its social, human rights and environmental goals, and principle of public trust throughout the country with proper measures to protect the National River.

5. The NRGBM Act

In the backdrop of the arguments presented in the preceding sections, it is therefore proposed to legislate The National River Ganga Basin Management (NRGBM) Bill, 20XX to provide regulation, conservation and development of the National River Ganga Basin, and for the establishment of necessary institutional framework for effective and expeditious disposal of matters affecting NRGB. The Act will specifically cover issues related to Ganga River Basin and its restoration, restitution, natural flow, ecology, marine environment, etc. For the maintenance of 'wholesomeness' of river Ganga the Bill has taken a preventive approach for the preservation and conservation of Ganga River Basin. The sole focus is on River Ganga from its origin to the mouth and about the preservation and conservation of the Basin. In case of any environmental disputes on River Ganga, necessary action may be taken and remedy granted to river herself and no individual benefits will be granted. Under the legislation, among others, creation of a National River Ganga Basin Management Fund has been proposed for the purpose of meeting partial or full costs towards restoration of the river as well as for research in related fields.

6. Constitutional Provisions and Competence of the Parliament to Enact Such Laws

The Constitution of India provides for realization of fundamental rights and fulfilment of welfare goals in favour of people of this country. It is incumbent upon the Central Legislature to respect the ideals of the Constitution and invoke necessary legislative authority to enact a law on a subject matter which transcends spirituality, faith, belief and socio-cultural practices; geography, geomorphology, water resources and its uses; livelihood; and environment, and which traverses many state boundaries and jurisdictions.

Further, as regards harnessing of water resources while there are a number of successful references of standalone projects in the country, but when it comes to inter-state rivers, it is recognised that India has not been able to effectively develop/exploit the potential through integrated river basin management approaches. There are number of inter-state rivers where the riparian states are at conflict e.g., Delhi and Haryana in the case of Yamuna; Karnataka and Tamil Nadu in the case of Kaveri; Maharashtra and Andhra in the case of Krishna and Godavari, etc. While water is a state subject, it is noteworthy that the Indian Constitution also has provisions which empower the Central Government to regulate inter-state rivers in public interest. In case of a conflict among two or more states on account of sharing of waters of an inter-state river, the powers of states are subject to any law made by the Parliament for the regulation and development of the inter-state river under consideration to the extent the control of the Union is declared by Parliament by law to be expedient in public interest (List-I entry 56)[4]. This means that Parliament can make a law taking over the regulation, development and management of an inter-state river for the common benefit of the riparian states and in overall national interest. It is our firm belief that the prevailing condition of the National River Ganga warrants immediate action on the part of the law-makers of the country for creation of such a law.

For enacting the proposed law, it is important to identify subject matters in List-II which may be seen as being in conflict with entry 56 of List-I. While Clause 2 of Article 246 grants exclusivity to the states to enact laws on subject matters specified in List-II, Article 246 (1) confers exclusive jurisdiction on the central government to enact laws on all subject matters specified in the Union list i.e., List-I. Therefore it is quite clear that the matter of regulation and development of inter-state rivers may not be in conflict with the legislative power of the states if the law refrains from impinging on matters within the domain of state legislatures.

The states have competence to legislate on aspects of water including water flowing through inter-state rivers, subject to certain limitations, viz., a) the control over the regulation and development should not have been taken over by the Union and b) the state cannot pass legislation affecting any aspect of water beyond its territory. Such competence of state legislature in respect of inter-state river water is denuded by Parliamentary legislation. Thereby, if any Parliamentary legislation declares that the control of the regulation and development of an inter-state river (viz. River Ganga) is expedient in public interest, the state(s) will not be entitled to make legislation with respect to that river under Entry 17 of List-II of the Constitution. Furthermore, a legislation under Entry 14 of List-II, relating to agriculture, etc., in so far as it relates to inter-state river water and its different uses, is subject to the provisions of Entry 56 of the Union List. Thus the Parliament i.e., the Central Government has exclusive

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[4]The Inter State River Water Disputes Act 1956 is an Act of Parliament which has been enacted to resolve the water disputes that would arise in the use, control and distribution of an interstate river or river valley. It provides the mechanism to solve the dispute between states. It may be noted that the specific legislation addresses only the issue of conflicts pertaining to use, control and distribution of an interstate river.

jurisdiction to enact laws for regulation and development of inter-state rivers and basin of such rivers.

7. Model for Implementation of the Law

A precise and detailed law on the complicated subject of restoration of the River Ganga shall sustain with in-built enforcement mechanism. Therefore, creation of a dedicated institution in the form of a commission is suggested which shall ensure effective implementation of the law. The commission is expected to carry out a wide range of functions comprising, among others, monitoring and evaluation, investigations, research and development, policy and governance, IEC (information, education and communication), and advocacy. It is also proposed to be a regulatory agency with powers to impose fines on violators. In addition to this, it is proposed to create a tribunal to address grievances of affected parties, if the latter consider penalties are not just. Such a mechanism shall ensure responsible participation of all stakeholders of the Ganga Basin for its efficient management and protection.

8. Rationale for NRGBM Commission

Based on the analysis and arguments presented in the preceding sections, it is evident that a long-term program for implementation, monitoring, review and evaluation of environmental problems and interventions pertinent to National River Ganga Basin (NRGB) is urgently needed. Since these measures cover a wide variety of activities involving continuous monitoring and feedback from diverse sources, institutions and individuals, an independent agency is essential to conduct these activities in a coordinated manner. It is therefore proposed that a nodal agency, tentatively termed "National River Ganga Basin Management Commission" (NRGBMC), with adequate resources and authority be set up to ensure environmental health of NRGB. NRGBMC is proposed to be set up by an Act of Parliament[5] and which should comprise legal luminaries, technical experts, government functionaries and civil society members.

[5]Refer Annexure for the tentative draft of the Bill.

9. Objectives and Mandate of the NRGBMC

NRGBMC is intended to serve as a custodian of National River Ganga Basin (NRGB) and work for its upkeep and improvement on the premise that health of National River Ganga is a key indicator of the health of NRGB as a whole. In this respect its mandate will be as follows:

(1) It shall act as a regulator and protect the interests of River Ganga exclusively.
(2) It shall take all measures necessary for conservation of the environment and sustainable development of National River Ganga Basin in a transparent and inclusive manner.
(3) Such measures shall include, but will not be limited to the following:

  (a) Ensuring that E-Flows are maintained in all rivers of the Ganga River Network at different locations and in different seasons.
  (b) Protecting the geology and ecology of the National River Ganga Basin.
  (c) Use of floodplains in appropriate manner, and after ensuring environmental impact assessment for approval of major projects in flood plains.
  (d) Ensuring both short- and long-term measures for conservation and improvement of aquatic resources in National River Ganga Basin.
  (e) Monitoring, review and dissemination of the National River Ganga Basin's environmental status in the public domain.

It is recognized that all actionable measures proposed under the GRBMP may not be implementable at one go, and the monitoring and review of environmental actions have to be a continuous process. However, the technical reports, database and action plans of the GRBMP being prepared by the consortium of 7 IITs can be taken as the starting point for the proposed NRGBMC.

9.1. Proposed Functions of the NRGBM Commission

The NGRBM Commission is envisaged to perform a wide range of functions which will transcend IEC, 'environment monitoring and impact assessment', investigations, research and development, policy and governance, and advocacy. In addition it is also proposed to take the role of a regulatory agency with powers to impose penalties in case of violations and collect fines towards building a corpus. A set of functions are detailed in the paragraphs that follow.

Information and Communication

- Procure primary and secondary data (both environment-related data as well as socio-economic, cultural, developmental and other data of NRGB) from government and non-government agencies and pre-process the same to address any errors or inconsistencies.

- Compile the above data along with those obtained by NRGBMC itself through environmental monitoring and process them to obtain suitable representations in the form of maps, charts, parametric values, etc.
- Compile all useful environmental reports obtained from various sources in easily usable formats.
- Store all data and reports (soft- and hard-copies) in easily retrievable systems and make them accessible to interested users and other stakeholders.

Environmental Monitoring and Impact Assessments

Conduct or cause to conduct regular environmental measurements in NRGB for such information that is not regularly collected or available from other agencies. The data may be procured through in-house facilities and through outsourced works to technical and non-technical organizations and individuals (such as local governance bodies, schools, colleges, NGOs, community organizations, etc.)

- Conduct or cause to conduct random environmental measurements in the NRGB for specific or sporadic needs e.g., for the purpose of validation or ensuring completeness of the data as mentioned above. The data may be procured through in-house facilities and/ or outsourced as mentioned above.
- Pre-process all data collected for subsequent archiving and use.
- Conduct or cause to carry out environmental impact assessments of on-going and future developmental and infrastructure projects in NRGB as and when the need arises.
- Monitor developmental and infrastructure projects in NRGB for which EIA or preliminary environmental approval was granted by the Commission.
- Carry out field measurements and monitoring that may be needed for investigation purposes.

Investigation

- Investigate issues regarding non-implementation of measures relating to specified prohibition, restriction, conservation and promotion of activities.
- Investigate issues regarding non-compliance of policy decisions and guidelines issued by NRGBMC for environmental preservation of the National River Ganga Basin.
- Investigate issues regarding continuance of existing practices in contravention of NRGBMC's strictures.

Research and Development

- Evaluate national and international research reports on river basins for their pertinence to the NRGB environment.
- Conduct need-based applied research as may be possible by NRGBMC.
- Identify other major research needs of NRGB for communicating to the central and state governments.
- Conduct economic, sociological and cultural analyses and research pertinent to NRGBMC data bank as well as based on information procured from other agencies.
- From time to time review impacts of anthropogenic activities in NRGB.

Policy and Governance

- Review policies and plans of the centre and various state governments which are in force, under implementation or under consideration/ preparation.
- Frame policies to ensure satisfying environmental needs of NRGB.
- Formulate good governance guidelines.

Advocacy and Sensitisation

- Promote overall awareness among diverse stakeholders and the communities regarding environmental aspects and issues as relevant for NRGB; and the role of NRGBMC in addressing the same.
- Educate stakeholders (from rural communities to school students and urban interest groups) on comprehensive understanding of complex environmental processes and their interaction with anthropogenic activities. This will involve, among others, preparation of special educational material, conducting training of field educators, regular delivery of educational programs and getting feedback from diverse stakeholders.
- Conduct advanced level of interactive programmes with stakeholders and domain experts by regularly organising seminars, workshops, conferences, press meetings, etc.
- Conduct special campaigns to sensitize and motivate people to participate in improving health of NRGB.

9.2. NRGB Fund

With the objective of facilitating operations of the NRGBMC it is proposed that the Commission be allowed to generate resources on its own and create a specific corpus called the National River Ganga Basin Fund. In this respect it is proposed that the

NRGBMC must be empowered to impose penalties/ damages on individuals and agencies in the entire basin for any violation of its norms and guidelines on restrictions and prohibitions of environmentally harmful activities in the NRGB. All recoveries out of the penalties thus imposed should be deposited in a specific fund with the Central Government. The said fund should be utilized by the Government on the recommendation and consent of the NRGBMC for improvement of the environment in the NRGB. As an incentive to the public at large, NRGBMC should also be authorised to reward individuals and agencies who contribute exceptionally either by their reformative or watchdog/ investigative actions towards restoration of the health of NRGB.

10. NRGBM Tribunal

10.1. Rationale for Establishing

The proposed legislation is a comprehensive and stand-alone legislation which combines within it matters relating to the preservation, regulation and development of the Ganga River Basin. The objective, scope and extent, permissible and non-permissible activities, institutional frame including grievance redressal mechanism have found mention in the Act. The Commission has been vested with exclusive powers to determine legal rights of various stakeholders relating to the subject matter of the law. It is therefore imperative that a separate appellate body, i.e., a tribunal be established to entertain appeals against the orders of the Commission.

10.2. Powers and Functions of the NRGBM Tribunal

The Tribunal is empowered to entertain appeals from aggrieved parties, to take *suo moto* action on matters relating to River Ganga in the interests of justice and the power to punish for contempt in case of non-compliance with its orders.

10.3. NRGBM Tribunal *vis-a-vis* National Green Tribunal

The object of the National Green Tribunal Act 2010 is to settle disputes relating to environment protection and conservation of forests and other natural resources including enforcement of legal rights relating to environment across the country. The Act also grants relief and compensation for damages to individuals and property related to the matters mentioned therein. As a dispute settlement body, the Green Tribunal has jurisdiction over all civil cases where any infringement of legal rights related to environment takes place. The National Green Tribunal is also an appellate body for all environmental legislations, such as the Water (Prevention and Control of Pollution) Act, 1974, the Forest Conservation Act, 1980, the Environment (Protection) Act, 1986, etc.

In the above context, let this be made clear that the proposed legislation is not seeking any replacement of NGT or discounting its role in any manner whatsoever. Neither is the NRGBM Tribunal being pitted against NGT in the instant legislation. Therefore, the question of overlap/dispute does not arise. Nevertheless the mandate of NGT is limited to settlement of disputes relating to environment whereas the mandates of both the NRGBM Commission and the NGRBM Tribunal relate to every facet of protection and conservation of River Ganga only. Table 1 hereunder seeks to pinpoint salient features of NGT (Column 3) and NRGBM C&T (Column 4). The latter are being taken as one holistic institutional frame within the proposed legislation. The last point on financial corpus in Table 1 relates to the NRGBM Commission on whose advice the central government, as custodian, shall utilise the same.

Table 1: Essential Features of National Green Tribunal and those Proposed for the National River Ganga Basin Management Commission

S No	Particulars	Green Tribunal Act	NRGBM Commission and Its Tribunal
1	Object	Settlement of disputes relating to environment.	Protection and conservation of River Ganga
2	Application	All civil cases relating to environment.	Specific to Ganga
3	Nature	Only dispute Settlement Body.	Coordinated & Self Contained Authority with powers of Investigation/Inquiry and adjudication.
4	Extent of Powers	Applicant to bring grievance before Authority.	*Suo moto* Action
5	Beneficiary	Persons affected victims of environment damage.	Victim is the River Ganga herself - sole focus is on her protection and conservation; There shall be no individual beneficiary per se.
6	Nature of Relief	Pay compensation or relief for death, injury, damage due to accident/ environment hazards.	Restitution, restoration and such other remedial measures for the conservation and protection of the National River Ganga Basin.
7	Applicability vis-à-vis other legislations.	Appellate body for all other environmental legislations.	Exclusive legislation to provide speedy and effective remedy for River Ganga.
8	Financial corpus	No unique or exclusive provision.	Creation of NRGBM corpus out of damages, etc. which will aid research/restoration of the River Ganga and the basin.

The salient points in support of a NRGBM Tribunal may be stated as follows.

- Inbuilt redressal mechanism on appellate matter within the law.
- Time bound disposal of cases.
- Specific subject matter of disputes on which appeals will be heard.
- Focussed object of serving the interests of River Ganga - not individuals affected by accident, disasters, etc.
- Power to take *suo moto* cognisance of matters in interests of justice.
- Vested with powers to undertake appropriate measures for the restoration of the River Ganga

It is to be recognized that establishing NRGBM Tribunal will incur expenditure and it would be quite challenging to get suitable manpower. However, it is expected that in the long-term the likely benefits would outweigh the expenditure to be incurred considering the importance of huge natural resources and critical ecosystem services that will be offered through regulation, conservation and development of the GRB.

11. Epilogue

River Ganga, having been declared as the National River by the Government of India requires prompt and effective measures to contain deterioration of its water quality. The proposed legislation is one such bold attempt towards a comprehensive and self-contained Act which provides for regulation, conservation and development of the basin. This legislation lists out activities which are prohibited, regulated as well as those that needs to be promoted in the basin. It provides for the establishment of National River Ganga Basin Management Commission and National River Ganga Basin Tribunal for effective and expeditious disposal of matters affecting the river basin with a view towards its restoration and conservation. The proposed legislation is a unique instrument which lays emphasis on research and development, continuous impact assessment, advocacy and sensitization as well as punitive action in case of violations.

All the wings of the NRGBMC are intended to work in close coordination and support the technical, scientific, legal and social upkeep of the National River Ganga and her basin. The institutional mechanism with comprehensive power base and wide range of functions seeks to work towards the development and protection of the basin and resolve all disputes arising there from.

The primary object of the legislation is to protect the National River Ganga which in turn attempts to protect the beliefs of a large majority of the country and interests of all other stakeholders. This legislation fulfils the long standing void in current legislative framework on a single measure to protect the river and her basin. Furthermore, it is hoped that successful implementation of this legislation may help in making similar interventions for other major river basins of the country which are severely affected and contaminated as a result of anthropogenic activities and developmental pressure.

Annexure

The National River Ganga Basin Management Bill, 20XX

(An ACT to provide for Regulation, Conservation and Development of the National River Ganga Basin, and for the establishment of National River Ganga Basin Management Commission and National River Ganga Basin Tribunal for effective and expeditious disposal of matters affecting the River Basin with a view to restore and conserve the river basin and for matters connected therewith or incidental thereto)

WHEREAS, the river Ganga is declared as the National River of India on November 5, 2008 by the Government of India considering its unique position in Indian society and world's natural heritage.

AND WHEREAS, it shall be desirable to adopt an integrated river basin management approach that focuses on maintenance and restoration of wholesomeness of rivers of the Ganga Basin in public interest.

AND WHEREAS 'Wholesomeness' in this context shall mean sanctity of the river system as imbibed in the following points:

a. Continuous Flow ("Aviral Dhara") in time and space including maintenance of connectivity of flow in the river systems.
b. Un-polluted Flow ("Nirmal Dhara") meaning that quality of river waters is not significantly affected by human activities.
c. Rivers as Geologic Entities that is, rivers as the earth's creations of ancient times (over geological ages), which may not be recoverable if damaged.
d. Rivers as Ecological Entities that is, rivers as delicately structured ecological balance between various living species and the physical environment achieved over thousands of years and vulnerable to irreversible change.

AND WHEREAS 'Public Interest' in this context shall mean welfare or wellbeing of all beings including the future generations.

AND WHEREAS, to attain the wholesomeness, it is mandated to adopt preventive and corrective approach, the Act shall prohibit, restrict and promote activities that directly or indirectly affect the wholesomeness of all rivers in the National River Ganga Basin.

AND WHEREAS, the Act shall establish appropriate authorities to achieve the objectives of the Act and matters related thereto.

AND WHEREAS the Act shall be enacted to realize fundamental right guaranteed under Article 21 and to give effect to provisions of the Directive Principles of State Policy under Articles 39(b), 48 A, 49 and the Fundamental Duties enshrine under Article 51A (f) and(g) of the Constitution of India.

AND WHEREAS, the Act shall be enacted by Parliament by invoking legislative power under Article 246 read with Entry 56 of the Union List of the Constitution of India.

Chapter I

Preliminary

1. Short Title, Extent and Commencement

1) The Act may be called The National River Ganga Basin Management Act, 2012.
2) It shall extend to the whole National River Ganga Basin.
3) It shall come into force on such date as the Central Government may, by notification in the Official Gazette, appoint and different dates may be appointed for different States.

2. Definitions

In this Act, unless the context otherwise requires –

1) "Active Flood Plain" is the area on the two sides of a river that gets inundated by a flood having a mean recurrence interval of 2.33 years;
2) Afforestation means plantation of trees to restore or re-establish the forest cover;
3) Authority means any authority, board, corporation, council, department, institute, university or any other body corporate, established by or under any Central, State or Provincial Act in force in the territory of India and includes,
   a. The Central Government,
   b. The State Governments,
   c. A Department of the Government,
   d. Local authorities;
4) "Aviral Dhara" (in a river or stream) means continuity of flow in both time and space, including connectivity of flow throughout the river;
5) Basin includes land, water, vegetation and other natural resources on a catchment basis;
6) "Basin" means the entire catchment (of a water body or water course) including the soil, water, vegetation and other natural resources in the area;
7) "Catchment" (or "Catchment Area", or "Watershed", or "Drainage Basin") is the entire land area whose runoff from rain, snow or ice drains into a water body or a water course (before the water course joins another river or discharges into a water body);
8) Class I town means a town whose population is greater than 100,000;

9) Class II town means a town whose population is greater than 50,000 and less than 100,000;

10) "Commercial fishing" means large-scale fishing for commercial purposes by nets, cyanide poisoning, or other modern fishing gear or methods.

11) Commission means National River Ganga Basin Management Commission;

12) "Connectivity" (of a river) means continuity of flow in the three directions, viz. longitudinal connectivity (along the length of the river), lateral connectivity (across the width of river), and vertical connectivity (below the water surface in vertical direction).

13) "Deforestation" means removal or reduction of forest cover, especially when caused by anthropogenic activities;

14) "Degraded Forest" means a forest having loss or reduction of native forest cover and/ or vegetation density;

15) "Direct Injection" (of water) means injection or introduction (of water) directly into subsurface waters through natural or artificial crevices, faults, channels or conduits without the natural passage through porous soil strata;

16) "Ecological Park" is a protected area for conservation of native and endangered species;

17) "Ecology" is the totality of relations between organisms and their environment. It includes the composition, distribution, amount, number and changing states of organisms within and among ecosystems;

18) "Ecosystem" is a community of organisms and their physical environment, considered to function together as a unit, and characterized by a flow of energy that leads to trophic (or nutritional) structure and material cycling;

19) "E-Flows" means Environmental Flows;

20) "Embankment" is a raised wall of earth, stone or other material to hold back water within a water body or water course; it includes levees constructed on either side of a river as a flood protection measure;

21) "Engineered Diversion" means a structure or device constructed or installed to transfer the river water into a canal or other engineering structure;

22) "Environmental Flows" are the regime of flows including sediments and other natural constituents required to maintain the ecological integrity of a river and the goods and services provided by it, computed by Building (Bigger) Block Method;

23) "Flood" means the overflowing of water from a water course or water body that inundates normally dry land;

24) “Flood Plain” is the land area susceptible to inundation by flood waters;

25) “Flood Routing Channel” is a channel designed to carry the excess water of a water course during high flows;

26) “Geologic Entity” is an entity formed by ancient earth processes over geologic ages;

27) “Ghat” is a sloping or cliffed part of a riverbank, often with artificially constructed steps, used for providing easy human access to river water;

28) “Ground Water Recharge” is replenishment (in part or wholly) of water depleted from ground water reservoirs;

29) Hazardous Solid Waste (HSW) includes as provided in the Act;

30) “Hydrological Cycle” is the natural cycle of change through which water moves on earth;

31) Industrial Effluents includes as it is mentioned in the Act;

32) Kharif Canals means Irrigation canals used for crops grown in rainy season;

33) Landfills means a place used for disposal of solid waste on land;

34) Large Scale Industries provided in the Act;

35) Medium Scale Industries provided in the Act;

36) Municipal Solid Waste provided in the Act;

37) “National River Ganga” is the entire length of six head-streams in the state of Uttarakhand namely, Rivers Alaknanda, Dhauli Ganga, Nandakini, Pinder, Mandakani and Bhagirathi starting from their originating glaciers up to their respective confluences at Vishnu Prayag, Nand Prayag, Karn Prayag, Rudra Prayag and Dev Prayag as also the main stem of the river thereafter up to Ganga Sagar including Prayag Raj;

38) “NirmalDhara” or “Un-polluted Flow” means flow in a river or stream that is not significantly polluted by anthropogenic activities;

39) “Paleo-Channel” is the remnant of an extinct river or stream that got filled with sediments deposited in later periods;

40) "person" includes—

a. an individual;
b. a Hindu undivided family;
c. a company;
d. a firm;
e. an enterprise;
f. an association of persons or a body of individuals, whether incorporated or not, in India or outside India;

g. any corporation established by or under any Central, State or Provincial Act or a Government company as defined in section 617 of the Companies Act, 1956 (1 of 1956);
h. any body corporate incorporated by or under the laws of a country outside India;
i. a co-operative society registered under any law relating to cooperative societies;
j. a local authority;
k. every artificial juridical person, not falling within any of the preceding sub-clauses;

41) Ritual Bathing means taking dip in the water for religious or spiritual purposes;
42) River Bed Farming includes seasonal agriculture/farming on the river bed during low flows when the bed is exposed;
43) Rivers in National River Ganga Basin include, but is not restricted to, all major and minor tributaries of the National River Ganga within the basin;
44) River Bank means the land at the side of a river which retains the river in its natural channel, when there is the greatest flow of water;
45) River Bed means dried portion of the river, the place where the river run its course; when it fills with water.
46) River Port means a place on a waterway with facilities for loading and unloading ships;
47) River System means network of rivers rather than a single river;
48) Rivulets includes very small tributaries of a major river;
49) Sand Mining means large scale removal of river sand from the dried channel belt or a part of it;
50) Sewage means as provided in the Act;
51) Small Scale Industries as provided in the Act;
52) Solid Waste as provided in the Act;
53) Sludge as provided in the Act;
54) Tribunal means the National River Ganga Basin Management Tribunal;
55) "Water Body" (or "Surface Water Body") is a depression on land or a lowland area that usually holds water or remains saturated through most of the year, such as a lake, tank, pond, marsh or swamp;
56) "Water Course" (or "Surface Water Course") is an overland channel (natural or manmade) through which water flows, such as a river, stream, rivulet (or "nala") or canal;
57) Water Recharge Structures includes arrangements made for enhancement of sub surface flow and storages of water;

Chapter II

Duty to Ensure Respect and Dignity of National River Ganga

3. Respect and Dignity

Every person shall ensure utmost respect and dignity for the National River Ganga and desist from activities prejudicial to her interests.

4. Duty of State and Citizen

It shall be the duty of the State and every other person to ensure the protection, preservation, conservation and maintenance of wholesomeness of National River Ganga.

Chapter III

Usage of Water in National River Ganga Basin

5. Usage of water shall be determined in accordance with the following

1) The usage of water shall be posterior to nature and ecology.
2) The usage shall have sequential priority from ‘water for life’ to ‘livelihoods’ to ‘developmental activities’.
3) There shall be institutional arrangements for usage of water based on principles of equity, resource-conservation, protection of water resources, and harmonization of water use.

Chapter IV

Prohibition and Restriction of Activities

6. Prohibition of Activities relating to the National River Ganga Basin

Notwithstanding anything contained in any law whatsoever, no person or authority shall indulge in any activity relating to any of the following:

1) engineered diversion and/or storage of water in any river unless E-Flows are maintained in the immediate downstream of the diversion/storage; or

2) discontinuity in the flow due to engineered diversion/storage in any river; or

3) discharge of sewage (either treated or untreated) from Class I towns, either directly or indirectly, into any river; or

4) discharge of industrial effluents (either treated or untreated) from any large, medium or cluster of small industries, either directly or indirectly, into any river; or

5) direct injection of sewage and industrial effluents (either treated or untreated) into the subsurface; or

6) disposal of un-burnt and partially burnt corpses and animal carcasses in any river or riverbank; or

7) open defecation and dumping of municipal/industrial solid wastes or sludge in any river or its active flood plain; or

8) setting up of or continuation in dwellings or other encroachments in the river banks or its active river flood plains; or

9) construction of new permanent structures for residential, commercial and industrial purposes in the active flood plain of any river;

   Provided that construction of bridges and associated roads, jetties/ghats/ports and hydraulic structures for storage/ diversion/ control/ channelization of river waters shall not be thereby prohibited.

10) any other like activities as may be prescribed by the commission.

7. Restriction of Activities relating to the National River Ganga Basin

No person shall indulge in any of the following activities except in accordance with the rules and regulations as may be laid down in this regard from time to time.

1) discharge of sewage (either treated or untreated) from Class II town and smaller towns and villages, either directly or indirectly, into any river; or

2) disposal of sludge derived through treatment of sewage and industrial effluents except in secure landfills/hazardous waste sites; or

3) discharge of industrial effluents (either treated or untreated) from small scale industry into any river; or

4) disposal and/or discharge of mining and construction debris in any river’s flood plain, river bank or the river itself; or

5) construction of bridges and associated roads, jetties, ghats, ports and permanent hydraulic structures for storage/diversion/control/ channelization of waters in any rivers; or
6) withdrawal of ground water by electric/diesel operated shallow and deep tube wells; or
7) sand mining, stone crushing, sediment removal and mining of other minerals from the river bed of any river; or
8) dredging or any other excavation activity on river bed for any purposes threatening the balance of the natural environment; or
9) river bed farming and agricultural activities in the active flood plain of any river; or
10) commercial fishing or aqua culture in any river; or
11) ritual immersion of idols, and floral and other offerings in any river; or
12) wallowing of animals, washing of clothes, vehicles, etc., in any river; or
13) deforestation of hill slopes and notified forest and other sensitive areas; or
14) hazardous or harmful emissions into the atmosphere that can affect terrestrial waters directly or indirectly in any river; or
15) use of chemical fertilizers and pesticides in agriculture, horticulture, aquaculture, animal husbandry, forestry, etc. in any river; or
16) any activity that may lead to geologically disruptive phenomena such as heightened seismic activity, ground subsidence, and leaching or erosion of contaminants into water bodies; or
17) cattle grazing on erodible hill slopes and in over-grazed areas; or
18) any other like activities as may be prescribed by the commission.

Chapter V

Conservation, Development of National River Ganga Basin

8. Conservation and Development

1) The appropriate authority shall take all measures necessary for the conservation and development of the National River Ganga Basin.
2) Such conservation shall include measures relating to the following:
    a. ensuring that E-Flows are maintained in all rivers at different locations and in different seasons;
    b. protecting both geology and ecology in the river basin;

c. using of floodplains in environmentally safe manner, and after ensuring Environmental Impact Assessment for approval of flood plains projects;

d. ensuring both short-term and long-term measures for conservation and improvement of natural resources in National River Ganga Basin;

   Explanation - The term "appropriate authority" in this section and the subsequent one shall be taken to include the Central Government or State Government or such Local authorities responsible for implementation as the context indicates;

e. monitoring, review and dissemination of the National River Ganga Basin's environmental status in the public domain.

9. Promotion of Activities relating to the National River Ganga Basin

The appropriate authority shall adopt special measures to promote the following activities in the National River Ganga Basin:

1) reuse and recycle of treated domestic and industrial sewage and use of products derived from sewage sludge, with mechanism for commercial use/ reuse where feasible;

2) measures including construction of sewer lines, provision of sanitation services, construction of wastewater treatment plants for municipal and industrial effluents, construction of secure solid waste landfills, hazardous waste landfills and other related facilities in the River Basin;

3) facilities for environmentally safe cremation/burial of corpses and measures for disposal of animal carcasses;

4) ground water recharge with unpolluted water (including use of kharif canals, paleo-channels, nalas, check dams, unlined ponds and lagoons, etc.) to increase ground water levels and enhance river base flows;

5) higher efficiencies in irrigation water use (through appropriate irrigation techniques, rationalization of cropping patterns, recycling of return flows, etc.) for agriculture, horticulture, fodder cultivation, etc;

6) higher efficiencies in institutional, commercial, industrial, domestic, municipal and community water uses through minimization of losses, wastage control and provision of adequate water treatment facilities;

7) afforestation and/or grassland development in degraded forest lands, wastelands and denuded hill slopes (for control of surface runoff and erosion, and for enhancing groundwater recharge);

8) activities related to flood control, including development of flood routing channels, embankments and other methods for controlling sediment flows and distribution;

9) protection of breeding areas and natural habitats of indigenous and migratory species of fishes, birds, reptiles, amphibians and mammals, and the prevention of the spread of exotic species;

10) eco-friendly tourism, pilgrimage, recreational and sporting activities in all rivers and riverbanks;

11) use of the riverbank and active flood plains of rivers for development of water-recharge structures and ecological parks;

12) use of bio-fertilizers and bio-pesticides (in place of chemical fertilizers and pesticides) in agriculture, horticulture, aquaculture, forestry, etc., to protect groundwater from agricultural pollutants;

13) any other like activities as may be prescribed by the commission.

Chapter VI
Duties of Central and State Governments

10. Duties of Central and State Governments

1) It shall be the duty of the Central Government to constitute the National River Ganga Basin Management Commission to carry out the provisions of the Act.

2) The Central and State Governments shall render all assistance and cooperation necessary for the effective implementation of the provisions of the Act.

3) The Central Government shall, in consultation with and concurrence of the Commission, make rules and regulations necessary for the effective implementation of the provisions of the Act.

4) In accordance with the directions of the Commission, the Central and the State governments, as the case may be, shall take necessary measures towards prohibition and restriction of activities in any river of the National River Ganga Basin as well as conservation and development of the basin.

Chapter VII

National River Ganga Basin Management Commission Constitution, Power and Functions

11. Establishment of Commission

1) With effect from such date as the Central Government may by notification decide, there shall be established for the purposes of this Act, a Commission to be called the "National River Ganga Basin Management Commission" hereinafter referred to as the Commission.
2) The Commission shall be a body corporate by the name aforesaid having perpetual succession and a common seal with power, subject to the provisions of this Act, to acquire, hold and dispose of property, both movable and immovable and to contract and shall, by the same name, sue of be sued.
3) The Head Office of the Commission shall be at such place as the Central Government may decide from time to time.
4) The Commission may establish offices at other places in India.

12. Composition of Commission

1) The Commission shall consist of the following Members, namely:
   a. A Chairperson,
   b. A Retired or Sitting Judge of the High Court,
   c. Five Independent Members of Civil Society/Academia/Experts having expertise in requisite areas of river basin management.
2) The Chairperson shall be the Chief executive of the Commission and shall exercise such powers and perform such duties, as may be prescribed and he shall be responsible for the business of the Commission.
3) The Chairperson and other members of the Commission shall be persons of ability, integrity and standing and who have special knowledge of and such professional experience of not less than 15 years in scientific, technical, socio-economic, legal or other pertinent areas of river basin management.

13. Selection of Chairperson and other members of the Commission

1) The Chairperson and Independent Members shall be appointed by the Central Government from a panel of names recommended by a selection committee consisting of
   a. The Prime Minister of India : Chairperson
   b. Leader of Opposition : Member
   c. Cabinet Secretary, Central Government : Member Secretary

2) The Retired or Sitting Judge of the High Court shall be selected by the Chief Justice of India.
3) The term of the Selection Committee and the manner of selection of panel of names shall be such as may be prescribed by the Central Government by way of notification.
4) The Chairperson and every other member shall, before entering upon his office, make and subscribe to an oath of office for secrecy and maintain integrity in such form and manner as may be prescribed.

14. Term of Office of Chairpersons and Other Members

The term of office of the members shall be as follows:

1) The Chairperson and every other member shall hold office as such for a term of five years from the date on which he enters upon his office but shall not be eligible for reappointment.

   Provided that the Chairperson and other members shall not hold office as such after he has attained the age of 70 years.
2) A vacancy caused by the resignation or the removal of the Chairperson or any other member or by death or otherwise shall be filled by fresh appointment in accordance with the previous provisions.
3) The Chairperson and every other member shall, before entering upon his Office, make and subscribe to an oath of office and of secrecy in such form, manner and before such Commission as may be prescribed. In the event of the occurrence of a vacancy in the Office of the Chairperson by reason of his death, resignation or otherwise, the senior-most member shall act as the Chairperson till the new Chairperson enters upon his Office.
4) When the Chairperson is unable to discharge his function owing to absence, illness or any other cause, the senior-most member shall discharge the routine functions of the Chairperson till the date on which the Chairperson resumes his Office.

5) No person shall be appointed as Chairperson or member of the Commission who shall have direct or indirect interest in any business or commercial activity related to the River Basin.

15. Resignation, Removal and Suspension of Chairperson and other members

1) The Chairperson or any other member may, by notice in writing, address to the Central Government resign from Office.

   Provided that the Chairperson or any other member shall, unless he is permitted by the Central Government to relinquish his Office sooner, continue to hold Office until the expiry or three months from the date of receipt of such notice or until a person duly appointed as his successor enters upon his Office or until the expiry of his term of Office, whichever is the earliest.

2) Notwithstanding anything contained above, the Central Government may, by order, remove the Chairperson or any other member from his Office if such Chairperson or Members, as the case may be:

   a. Is or at any time has been, adjudged as an insolvent; or
   b. Has engaged at any time, during his term of office, in any paid employment; or
   c. Has been convicted of an offence which, in the opinion of the Central Government involved moral turpitude; or
   d. Has acquired such financial or other interest as his likely to affect prejudicially his functions of a member; or so abused his position as to render his continuance in office prejudicial to public interest; or
   e. Has become physically or mentally incapable as such.

3) Notwithstanding anything contained herein before, no member shall be removed from his office unless the Supreme Court, on a reference being made to it in this behalf by the Central Government, has on an enquiry, held by it in accordance with such procedure as may be prescribed in this behalf by the Supreme Court, reported that the Chairperson or the members, ought on such ground or grounds to be removed.

16. Restrictions on Employment of Members in certain cases

The Chairperson and every other member shall not, for a period of two years from the date which he ceases to hold Office, accept any employment in, or be connected with the Management or Administration of, any enterprise which has been a party to a proceeding under the Act or associate in any capacity or establish any NGO in related field;

Provided that nothing in the section shall apply to any employment under the Central Government or a State Government or Local Commission or in any statutory Commission or any corporation established by or under any Central, State or Provincial Act or a Government company as define in Section 617 of the Companies Act 1956(1 of 1956).

17. Salary and Allowances and other terms and conditions of service of Chairperson and other members

1) The salary and other terms and conditions of service, of the Chairperson and other members including travelling expenses, house rent allowance and conveyance facilities, sumptuary allowance and medical facilities shall be such as may be prescribed.
2) The salary allowances and other terms and condition of service of the Chairperson or any member shall not vary to his disadvantage after appointment.

18. Procedure for Transaction of Business

1) The Commission shall meet regularly at its Office at such time as the Chairperson thinks fit, but four months shall not intervene between its last and next meeting.
2) All decisions shall be taken by majority;

   Provided that in the case of equality of votes, the Chairperson or in his absence the person presiding, shall have to exercise casting vote;
3) The Commission shall observe such rules of procedure in the transaction of its business at a meeting, including the quorum at such meeting, as may be prescribed by the Central Government under the Act;
4) All decisions of the Commission shall be authenticated by the Chairperson or any other officer duly authorised in this behalf.

19. Duties, Powers and Functions of the Commission

1) The powers and function of the Commission shall relate to the following:
   a. To formulate strategies, plans, programmes, policies and guidelines for the due discharge of functions in furtherance of the object of the Act;
   b. To review the working of the Commission and prepare Annual Report;
   c. To review and monitor the working of the Wings under the Act;
   d. To coordinate and strengthen the efforts of the Central and State Governments for conservation and development of the National River

Ganga Basin, and prohibition, restriction and promotion of activities in National River Ganga Basin in consonance with the object of the Act;

e. Issue Directions to the Central and State government;
f. To inquire and investigate into alleged contraventions of provisions of the Act;
g. To direct such investigations and inquiries as may be necessary from time to time;
h. To pass such orders or issue such directions as it may deem fit.

2) It shall be the duty of the Commission to take necessary steps for the elimination of all practices prejudicial to the interests of the National River Ganga Basin and promote the conservation and development of the Basin in consonance with the object of the Act.

20. Power of Superintendence

The Chairperson of Commission shall have the powers of general superintendence direction and control in respect of all matters of the Commission.

Provided that the Chairperson may, for the internal conduct of business of the Commission, delegate such powers relating to administrative matters to any member of the Commission, including the power to monitor the working of the Wings, established under the Act, and such member shall coordinate with the Director, appointed hereinafter, with regard to implementation of the policies of the Commission.

Provided that the Investigation Wing shall, at all times be monitored by the Retired or Sitting Judge of the High Court as specified under Section 12 of the Act.

21. General Administration and Finance Division

1) There shall be a General Administration and Finance Division under the control of the Chairperson of the Commission.
2) Such division shall
   a) Undertake all activities pertaining to the internal management of the Commission;
   b) Create and maintain the National River Ganga Basin Management Fund to be generated from the deposit of damages awarded by the Commission and Tribunal from time to time;
   c) Maintain proper accounts and relevant records;
   d) Prepare annual reports and statement of accounts;
   e) Audit Accounts as may be required by the Central Government.

22. Constitution of Wings

1) The Commission shall constitute the following Wings for the efficient discharge of its duties and functions under the Act:
   a. Information and Communication wing;
   b. Environmental Monitoring and Impact Assessment Wing;
   c. Investigation Wing;
   d. Research and Development Wing;
   e. Policy, Planning and Advocacy Wing.
2) The Commission may constitute such other regional or specialised units under each of the wings, and at such places, as may be necessary from time to time.

23. Composition of Wings

1) Each wing shall consist of the following:
   a. The Director;
   b. Such other Officers and Employees as may be necessary for the efficient performance of the functions under the Act;
2) The Wing shall be headed by the Director who shall be assisted by Additional, Joint, Deputy and Assistant Directors and such other officers or employees as may be decided by the Commission;
3) The Director shall be of the level of Joint Secretary or equivalent of the Central Government;
4) Regional units/branches shall be headed by the Joint Director and he shall report to the Director on all matters relating to the unit/branch.
5) The Director and other officials shall be whole time members.

24. Powers and Functions of Wings

The wings shall discharge the necessary powers, functions and responsibilities in furtherance of its specific subject matter.

1) The Investigation Wing shall investigate matters relating to:
   a) Non-implementation of appropriate measures relating to prohibition, restriction, conservation and promotion activities;
   b) Non-compliance of policy decisions and guidelines in furtherance of integrated River Basin Management;
   c) Continuance of existing practices in contravention of the provisions of the Act; and
   d) Such other matters as the Commission may direct from time to time.

2) The Research and Development Wing shall
   a) Identify research needs of National River Ganga Basin;
   b) Undertake and/or outsource need based specific research;
   c) Conduct economic, social and cultural analysis on National River Ganga Basin;
   d) Prescribe scientific details on measures relating to prohibition, restriction, conservation and promotion activities on National River Ganga Basin, as may be necessary from time to time;
   e) Provide technical know-how related to building of infrastructure on National River Ganga Basin;
   f) Such other matters as the Commission may direct from time to time.

3) The Environmental Monitoring and Impact Assessment Wing shall
   a) Conduct regular and random field measurement of environment related data on river basin;
   b) Monitor developmental and infrastructure projects on the river basin approved by the Government;
   c) Coordinate developmental projects and anthropogenic activities on National River Ganga Basin;
   d) Conduct impact assessment of existing practices, activities and infrastructure on National River Ganga Basin;
   e) Such other matters as the Commission may direct from time to time.

4) The Information and Communication wing
   a) Procure all types of data relating to scientific, technological, economic, social, cultural and such other forms as the commission may determine time to time on river basin;
   b) Preprocess all data collected referred to in clause (a);
   c) Compile data and reports referred to in clause (a);
   d) Store the data and reports in easily retrievable system;
   e) Provide public access to all such data;
   f) Such other matters as the Commission may deem fit.

5) The Policy, Planning and Advocacy Wing shall
   a) Periodically review and frame the environmental strategies, plans, programmes, policies and guidelines on National River Ganga Basin;
   b) Formulate good governance guidelines;
   c) Promote awareness of issues pertaining to National River Ganga Basin;
   d) Conduct advanced interactive Programmes, including Seminars, Workshops and Training of stakeholders;
   e) Conduct special campaigns to sensitize and motivate people;

f) Prepare educational material; and

g) Such other matters as the Commission may deem fit.

25. Appointment and service conditions of Director, officers, inter alia of the Commission

1) The Commission shall appoint the Director, Additional Director, Joint Director, Deputy Director and Assistant Director, officers and other employees required to assist the Commission in the discharge of its functions.

2) The terms and conditions of the service of the Director, Additional Director, Joint Director, Deputy Director and Assistant Director, officers and other employees of the Commission shall be made by the Chairperson in such manner as may be prescribed.

3) The officers and other employees of the Commission shall discharge their functions under the general superintendence of the Chairperson.

4) The salaries and allowances and conditions of service of the officers and other employees of the Commission shall be such as may be prescribed.

26. Power and Functions of Director

The Director shall discharge the following:

a) Be responsible for the overall working of the Wing.

b) Control and Superintend the administration of the Wing

c) Implement the policies, programs, etc. of the Commission, as may be decided, from time to time.

d) Report to the Commission, on regular basis, about the activities of the Wing.

e) Coordinate with the individual member of the Commission, where so appointed under Section 20, the working of the Wing.

f) Prepare Internal Report annually

g) Such other matters as may be decided by the Commission from time to time.

Powers of Inquiry and Investigation

27. Procedure for Inquiry and Investigation

1) On receipt of a complaint by any person or a reference from an Authority or on its own knowledge or otherwise, if the Commission is of the opinion that there exists a prima facie case, it shall direct the Director, Investigation to cause an investigation to be made into the matter.

2) Where however the Commission is of the opinion that there exists no prima facie case, it shall close the matter forthwith and pass such orders as its deems fit and send a copy of its order to the Authority or the person concerned, as the case may be.
3) The Director shall, on receipt of direction, submit a report on his findings within such period as may be specified by the Commission.
4) The Commission may forward a copy of the report to the parties concerned;

   Provided that in case the investigation is caused to be made based on a reference from any authority, the Commission shall forward a copy of the report to the authority as the case may be.
5) If the report of the Director recommends that there is no contravention of the provisions of this Act, the Commission shall invite objections and suggestions from the Authority or the person concerned or any other person, as the case may be.
6) If, after consideration of the objections or suggestions, the Commission agrees with the recommendation of the Director, it shall close the matter forthwith and pass such orders as it deems fit and communicate its order to the Authority or the persons concerned, as the case may be.
7) If, after consideration of the objections or suggestions referred to above the Commission is of the opinion that further investigation is called for, it may direct such further investigation in the matter by the Director or itself proceed with further inquiry in the matter in accordance with the provisions of the Act.
8) On receipt of report of the Director or a further inquiry referred to above, the Commission may close the matter forthwith and pass such orders as he deems fit and communicate its order to the Authority or the persons concerned as the case may be.

28. Power of Commission to Regulate its own Procedure

1) The Commission shall not be bound by the procedure laid down by the Code of Civil Procedure, 1908 (5 of 1908), but shall be guided by the principles of Natural Justice and, subject to the provisions of these Act and of any rules made there under, the Commission shall have powers to regulate its own procedure including the places at which they shall have their sittings, duration of oral hearings when granted, and times of its inquiry.
2) The Commission shall have, for the purposes of discharging its functions under these Act, the same powers as are vested in a Civil Court under the Code of Civil Procedure, 1908 (5 of 1908), while trying a suit.

3) Every proceeding before the Commission shall be deemed to be a judicial proceeding within the meaning of sections 193 and 228 and for the purposes of section 196 of the Indian Penal Code (45 of 1860) and the Commission shall be deemed to be a civil court for the purposes of disposal of the matters pending before it and shall be deemed to be civil court for the purposes of section 195 and Chapter XXVI of the code of Criminal procedure 1973 (2 of 1974).
4) The Commission may call upon such experts, from the field of Science and Technology, Legal Affairs, Economics, Finance, Socio-Cultural, Faith Leaders as it deems necessary, to assist the Commission in the conduct of any inquiry or proceeding before it.

29. Power of Director, Investigation Wing

1) The Director, Investigation shall, when so directed by the Commission, assist the Commission in investigating into any contravention of the provisions of these Act or any rules or regulations made there under.
2) The Director shall have all the powers as are conferred upon the Commission herein before stated.
3) The Director shall have power to direct every person/company/authority against whom the enquiry/investigation is ordered to afford reasonable facilities for the same.

30. Orders by Commission after Inquiry/ Investigation

Where after inquiry or investigation, the Commission finds that any act in contravention of the provisions of the Act has been established on the part of any person or authority, it may pass all or any of the following orders, namely:

a. Direct the immediate discontinuance of the act;
b. Order payment of damages;
c. Order restitution, restoration and such other remedial measures for the conservation and protection of the National River Ganga Basin as may be necessary in the circumstances;
d. Pass such other order as it may deem fit.

31. Power to grant interim relief

1) Where during an inquiry or investigation before the Commission or under the directions of the Commission, it is proved to the satisfaction of the Commission, by affidavit or otherwise, that an act in contravention of the provisions of the Act has been committed or continue to be committed or that such act is about to be committed, the Commission may, by order, grant

a temporary injunction restraining any party from carrying on such act till the conclusion of the inquiry/investigation or until further orders.

2) The provisions of rules 2A to 5 (both inclusive) of Order XXXIX of the first Schedule to the Code of Civil Procedure, 1908, shall, as far as may be, apply to a temporary injunction issued by the Commission under the Act, as they apply to a temporary injunction issued by a civil court, and any reference in any such rule to a suit shall be construed as a reference to any inquiry/investigation before the Commission.

32. Appeal

Any person or authority aggrieved by any decision or order of the Commission may file an appeal to the National River Ganga Basin Tribunal within sixty days from the date of communication of the decision or order of the Commission;

Provided that the Tribunal may, if it is satisfied that the appellant was prevented by sufficient cause from filling the appeal within the said period, allow it to be filed within a further period not exceeding thirty days.

33. Execution of Orders of Commission

1) Any order passed by the Commission under this Act shall be enforced and executable by the Commission in the same manner as if it were a decree or order made by Civil Court in a suit pending therein and for that purpose the Commission shall have all the executing powers of a civil court.
2) For the sake of expeditious disposal or otherwise the Commission if deems fit, may transmit any order or award or decision made by it to a civil court having local jurisdiction and such civil court shall execute it as a decree by that Court.

34. Penalty for failure to comply with orders of the Commission

Whoever fails to comply with any order made by the Commission, he shall be punishable with imprisonment for a term which may extend to 3 years, or with fine which may extend to ten crore rupees, or with both.

35. Members, Officers, etc. of Commission deemed to be Public Servants

All members, officers and other employees of the Commission shall be deemed, when acting or purporting to act in pursuance of any of the provisions of this Act, to be public servants within the meaning of Section 21 of the Indian Penal Code (45 of 1860).

36. Protection of Action taken in good faith

No suit, prosecution or other legal proceedings shall lie against any member, officer or employee of the Commission for anything done or intended to be done in good faith under this Act or rules or regulations made thereunder.

37. Contravention of Order by Companies and Authorities

1) Where any contravention under this Act has been committed by a company, every person, who, at the time, the contravention was committed was in charge of, and was responsible to, the company for the conduct of the business of the company, as well as the company itself, shall be deemed to be liable to be proceeded against in accordance with the provisions of the Act.

   Provided that nothing contained in this section shall render any such person liable, if he proves that the contravention was committed without his knowledge or that he had exercised all due diligence to prevent the commission of the contravention and the contravention was an Act of God.

2) Notwithstanding anything contained above, where any contravention under this Act has been committed with the consent or connivance of or is attributable to, any neglect on the part of any director, manager, secretary or other officer of the company, such person aforesaid shall be deemed to be liable for such contravention and proceeded against.

   Explanation: For the above purposes,

   (a) "company" means any body corporate and includes a firm or other association of individuals; and

   (b) "Director" in relation to a firm, means a partner in the firm and proprietor in a proprietorship firm and in case of trust, cooperative and society the person responsible for management of the same.

3) Where any contravention under this Act has been committed by an authority, every person, who, at the time, the contravention was committed was in charge of, and was responsible to, for the conduct of the business of the authority, as well as the authority itself, shall be deemed to be liable to be proceeded against in accordance with the provisions of the Act.

   Provided that nothing contained in this section shall render any such person liable, if he proves that the contravention was committed without his knowledge or that he had exercised all due diligence to prevent the commission of the contravention and the contravention was an Act of God.

4) Notwithstanding anything contained above, where any contravention under this Act has been committed with the consent or connivance of or is attributable to, any neglect on the part of any superintendent, manager, secretary or other officer of the authority, such person aforesaid shall be deemed to be liable for such contravention and proceeded against.

CHAPTER VIII
NATIONAL RIVER GANGA BASIN TRIBUNAL

38. Establishment of Tribunal

1) The Central Government shall, by notification, establish an Tribunal to be known as National River Ganga Basin Tribunal:
   a. to hear and dispose of appeals against any direction issued or decision made or order passed by the Commission under the Act;
   b. to adjudicate on claim for damages that may arise from the findings of the Commission, or orders for the recovery of damages under this Act.
2) The Headquarter of the Tribunal shall be at such place as the Headquarter of the Commission.

39. Jurisdiction of the Tribunal

Any person or authority, aggrieved by any direction, order or decision passed by the Commission may prefer an appeal to the Tribunal.

40. Limitation

1) Every appeal under sub-section (2) shall be filed within a period of sixty days from the date on which a copy of the direction or decision or order made by the Commission is received by the authority or person referred to and it shall be in such form and be accompanied by such fee as may be prescribed within the rules so framed by the Commission;
2) The Tribunal may entertain an appeal after the expiry of the said period of sixty days if it is satisfied that there was sufficient cause for not filing it within that period.

41. Procedure of the Tribunal

1) On receipt of an appeal, the Tribunal may, after giving the parties to the appeal, an opportunity of being heard, pass such orders thereon as it thinks fit, confirming, modifying or setting aside the direction, decision or order appealed against.

2) The Tribunal shall send a copy of every order made by it to the Commission and the parties to the appeal.
3) The appeal filed before the Tribunal shall be dealt with by it as expeditiously as possible and endeavor shall be made by it to dispose of the appeal within six months from the date of receipt of the appeal and beyond that period on recording the reasons.
4) No appeal under clause (1) shall lie unless the memorandum of appeal is certified with the copy of the order, direction or decision passed by the Commission and with the grounds to the effect that the appellant has plausible defense to be protected against such order. However, while admitting the appeal, the Tribunal may direct to deposit a part or whole of the amount so payable under the direction, order or decision appealed against.
5) The appellant shall get the deposited amount back, with rate of interest fixed by nationalized bank during that time, in case he/it succeeds in the appeal.

42. Composition of Tribunal

The Tribunal shall consist of a Chairperson and at least one Judicial Member and other members to be appointed by the Central Government from the panels of name so recommended by the Selection Committee constituted for that purpose.

43. Qualifications for appointment of Chairperson and Members of Tribunal

1) The Chairperson of the Tribunal shall be a person, who is, or has been a Judge of the Supreme Court of India.
2) The other members of the Tribunal shall be persons of ability, integrity and standing having special knowledge of, and professional experience of not less than twenty years in science and technology, environmental matters, law and policy, public affairs or in any other matter which in the opinion of the Central Government, may be useful to the Tribunal.

44. Selection Committee

1) The Chairperson and Members of the Tribunal shall be appointed by the Central Government from a panel of names recommended by a Selection Committee comprising of:
   a. the Chief Justice of India, Chairperson;
   b. the Cabinet Secretary, Central Government, Member Secretary
   c. the Chairperson, Law Commission of India, Member

d. the Director of any National Institute of importance so nominated, Member

2) The terms of the Selection Committee and the manner of selection of panel of names shall be such as may be prescribed.

45. Term of office of Chairperson and Members of Tribunal

The Chairperson or a member of the Tribunal shall hold office as such for a term of five years from the date on which he enters upon his office, and shall be eligible for re-appointment only for a period of two years and not afterwards;

Provided that no Chairperson or other member of the Tribunal shall hold office as such after he has attained,

1) in the case of the Chairperson, the age of seventy years;
2) in the case of any other member of the Tribunal, the age of sixty-seven years.

46. Terms and conditions of service of Chairperson and Members of Tribunal

1) The salaries and allowances and other terms and conditions of service including the conditions of removal of the Chairperson and other members of the Tribunal shall be such as may be prescribed by the rules so notified by the Central Government.
2) The salaries, allowances and other terms and conditions of service of the Chairperson and other members of the Tribunal shall not be varied to their disadvantage after their appointment.

47. Vacancies

1) If, for any reason other than temporary absence, any vacancy occurs in the office of the Chairperson of the Tribunal, the senior most Member shall act as Chairperson until another person is so appointed by the Central Government in the above stated manner to fill the vacancy and the proceedings may be continued before the Tribunal from the stage at which the vacancy is filled by the Tribunal with that new combination and there shall be no irregularity of law in disposal of such matter pending before the Tribunal.
2) When the Chairperson of the Tribunal is unable to discharge his functions owing to absence, illness or any other cause, the senior-most member or, as the case may be, such one of the Members of the Tribunal, as the Central Government may, by notification, authorize in this behalf, shall discharge the functions of the Chairperson until the date on which the Chairperson resumes his duties.

48. Resignation of Chairperson and Members of Tribunal

The Chairperson or a member of the Tribunal may, by notice in writing under his hand addressed to the Central Government, seek resignationfrom his office;

Provided that the Chairperson or a member of the Tribunal shall, unless he is permitted by the Central Government to relinquish his office sooner, continue to hold office until the expiry of three months from the date of receipt of such notice and until a person duly appointed as his successor enters upon his office or until the expiry of his term of office, whichever is earlier.

49. Removal and suspension of Chairperson and Members of Tribunal

1) The Central Government may, in consultation with the Chief Justice of India, remove from office the Chairperson or any other member of the Tribunal, who;
   a. has been adjudged an insolvent; or
   b. has engaged at any time, during his term of office, in any paid employment; or
   c. has been convicted of an offence which, in the opinion of the Central Government, involves moral turpitude; or
   d. has become physically or mentally incapable of acting as such Chairperson or other Member of the Tribunal; or
   e. has acquired such financial or other interest as is likely to affect prejudicially his functions as such Chairperson or Member of the Tribunal; or
   f. has so abused his position as to render his continuance in office prejudicial to the public interest.
2) Notwithstanding anything contained above, no Chairperson or a Member of the Tribunal shall not be removed from his office on the ground specified in clause (e) or clause (f) of sub-section (1) except by an order made by the Central Government after an inquiry made in this behalf by a Judge of the Supreme Court in which such Chairperson or member had been informed of the charges against him and given a reasonable opportunity of being heard in respect of those charges.

50. Restriction on employment of Chairperson and other Members of the Tribunal

The Chairperson and other members of the Tribunal shall not, for a period of two years from the date on which they cease to hold office, accept any employment in, or connected with the management or administration of, any enterprise which has been a party to a proceeding before the Tribunal under this Act, nor shall they associate or personally establish any NGO in related field.

Provided that nothing contained in this section shall apply to any employment under the Central Government or a State Government or Local authority or in any statutory authority or any corporation established by or under any Central, State or Provincial Act or a Government Company as defined in section 617 of the Companies Act, 1956 (1 of 1956).

51. Staff of Tribunal

1) The Central Government shall frame the rules by way of Notification, in consultation with the Chairperson of the Tribunal, for providing the procedure of appointment of such officers and other employees as it may think fit.
2) The salaries, allowances and conditions of service, including tenure and terms of removal, of the officers and other employees of the Tribunal shall be such as may be prescribed.
3) The officers and other employees of the Tribunal shall discharge their functions under the general superintendence and control of the Chairperson of the Tribunal.

52. Procedures and Powers of Tribunal

1) The Tribunal shall not be bound by the procedure laid down in the Code of Civil Procedure, 1908 (5 of 1908), but shall be guided by the principles of natural justice and, subject to the other provisions of the Act and of any rules made by the Central Government, the Tribunal shall have power to regulate its own procedure including the places at which they shall have their sittings.
2) The Tribunal shall have, for the purposes of discharging its functions under this Act, the same powers as are vested in a Civil Court under the Code of Civil Procedure, 1908 (5 of 1908) while trying a suit in respect of the following matters, namely:
    a. summoning and enforcing the attendance of any person and examining him on oath;
    b. requiring the discovery and production of documents;
    c. receiving evidence on affidavit;
    d. subject to the provisions of Sections 123 and 124 of the Indian Evidence Act, 1872 (1 of 1872), requisitioning any public record or document or copy of such record or document from any office;
    e. issuing summons for the examination of witnesses or documents;
    f. reviewing its decisions;
    g. dismissing a representation for default or deciding it *ex parte*;

h. setting aside any order of dismissal of any representation for default or any order passed by it *ex parte*;
i. any other matter which may be prescribed.

3) Every proceeding before the Tribunal shall be deemed to be judicial proceeding within the meaning of Sections 193 and 228, and for the purposes of Section 196, of the Indian Penal Code (45 of 1860) and the Tribunal shall be deemed to be a Civil Court for the purposes of Section 195 (2 of 1974) and Chapter XXVI of the Code or Criminal Procedure, 1973.

53. Execution of Orders of Tribunal

1) Every order made by the Tribunal shall be enforced by it in the same manner as if it were a Court of appeal, and it shall be lawful for the Tribunal to send, in case of its inability to execute such order, to the court within the local limits of whose jurisdiction:

a. in the case of an order against a company, the registered office of the company is situated; or
b. in the case of an order against any other person, place where the person concerned voluntarily resides or carries on business or personally works for gain, is situated.

2) Notwithstanding anything contained in sub-section (1), the Tribunal may transmit any order made by it to a Court (civil or criminal, as the case may be) having local jurisdiction and such Court shall execute the order as if it were the orders passed by that court.

54. Saving of inherent Powers of the Tribunal

Notwithstanding anything contained in this Act or any other provisions of any enactment in force, nothing shall be deemed to limit or affect the inherent powers of the Tribunal as of the powers of any High Court of India, to make such orders as may be necessary to give effect to any order passed under this Act or to prevent abuse of the process of the Tribunal or otherwise, to secure the ends of justice, needed to impart justice inconsonance of object and reasons and effect to the enactment of the Act.

55. Suo-moto Powers of the Tribunal

Notwithstanding anything contained in this Act or any other provisions of any enactment in force, nothing shall be deemed to limit or affect the Suo-moto powers of the Tribunal as of the powers of any High Court of India or Supreme Court, to make such orders on its own motion if the Tribunal feels in rarest of rare circumstances and on taking cognizance of the facts to be taken by the Tribunal in the interest or relating to the National River Ganga, as may be necessary to give effect to any order passed under this Act or to prevent abuse of the process of the Tribunal or otherwise, to secure the ends of justice, needed to impart by the Tribunal.

56. Power to Punish for Contempt

The Tribunal shall have, and exercise, the same jurisdiction, powers and authority in respect of contempt of itself as a High Court has and may exercise and, for this purpose, the provisions of the Contempt of Courts Act, 1971 (70 of 1971) shall have effect subject to modifications that:

1) the reference therein to a High Court shall be construed as including a reference to the Tribunal;
2) the references to the Advocate-General in Section 15 of the said Act shall be construed as a reference to such Law Officer as the Central Government may, by notification, specify in this behalf.

57. Contravention of Order of the Tribunal

Without prejudice to the Act, if any person or authority contravenes, any Order of the Tribunal, he/it shall be liable for a damages not less than fifty crore or forfeiture of property or imprisonment for a term upto ten years or with both.

58. Vacancy in Tribunal not to invalidate acts or proceedings

No act or proceeding of the Tribunal shall be questioned or shall be invalid merely on the ground of existence of any vacancy or defect in the constitution of the Tribunal.

59. Right to Legal Representation

1) A person or authority preferring an appeal to the Tribunal may either appear in person or authorize one or more legal practitioners or any of its officers to present his or its case before the Tribunal.
2) The Commission may authorize one or more legal practitioners or any of its officers to act as presenting officers and every person so authorized may present the case with respect to any appeal before the Tribunal.

60. Appeal to Supreme Court

Any person aggrieved by any decision, direction or order of the Tribunal, may, file an appeal to the Supreme Court, within ninety days from the date of communication of the decision, direction or order of the Tribunal, to him, on any one or more of the grounds specified in Section 100 of the Code of Civil Procedure, 1908.

CHAPTER IX
MISCELLANEOUS PROVISIONS

61. Power of the Central Government to Make Rules

The Central Government may, by the notification in the Official Gazette, make rules for carrying out the purposes of this Act, however such rules shall be framed only in consultation with the Full House comprising of the Chairman and the Members of the commission and only after confirmation.

62. Bar of Jurisdiction

No Civil Court shall have jurisdiction to entertain any suit or proceedings in respect of any matter which theTribunal constituted under this Act is empowered by or under this Act to determine, and no injunction shall be granted by any court or other authority in respect of any action taken or to be taken in pursuance of any power conferred by or under this Act.

63. Overriding effect

The provisions of this Act shall have effect notwithstanding anything inconsistent therewith contained in any enactment other than this Act.

64. National River Ganga Basin Management Fund

1) Where any amount by way of damages is ordered to be paid under any order made by the Commission or Tribunal, that amount shall be remitted to the National River Ganga Basin Management Fund established under the Act;
2) The National River Ganga Basin Management Fund under sub-section (1) shall be utilized by Central Government on the advice and with concurrence of the Commission.
3) The National River Ganga Basin Management Fund shall be used for,
   a. Environmental development and improvement of National River Ganga Basin
   b. Conduct of research on National River Ganga Basin
   c. Institution of Award
   d. Any other purpose as may be identified and advised by the Commission.
4) Restitution, Restoration and Rehabilitation of the Basin caused due to Natural calamity or disaster shall be done by Government independent of funds being available from the National River Ganga Basin Management Fund established under the Act.

65. Institution of Award

The Central Government shall institute Monetary Rewards for exceptional contributors including Researchers, Academicians, Institutes, Universities, Centres of Excellence and civil society for conservation, development and improvement of the National River Ganga Basin, in conformity with the Commission's goals and guidelines.

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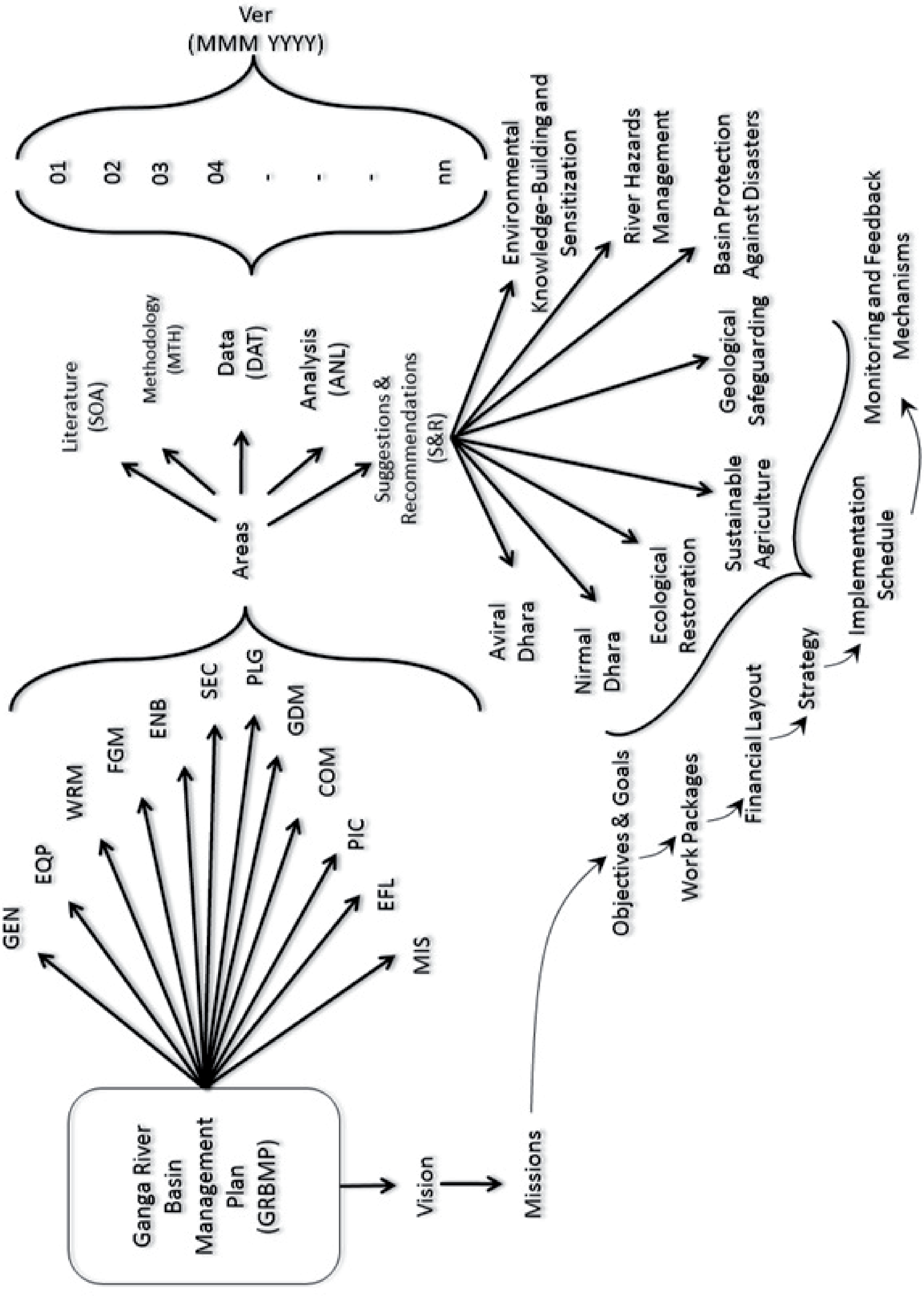
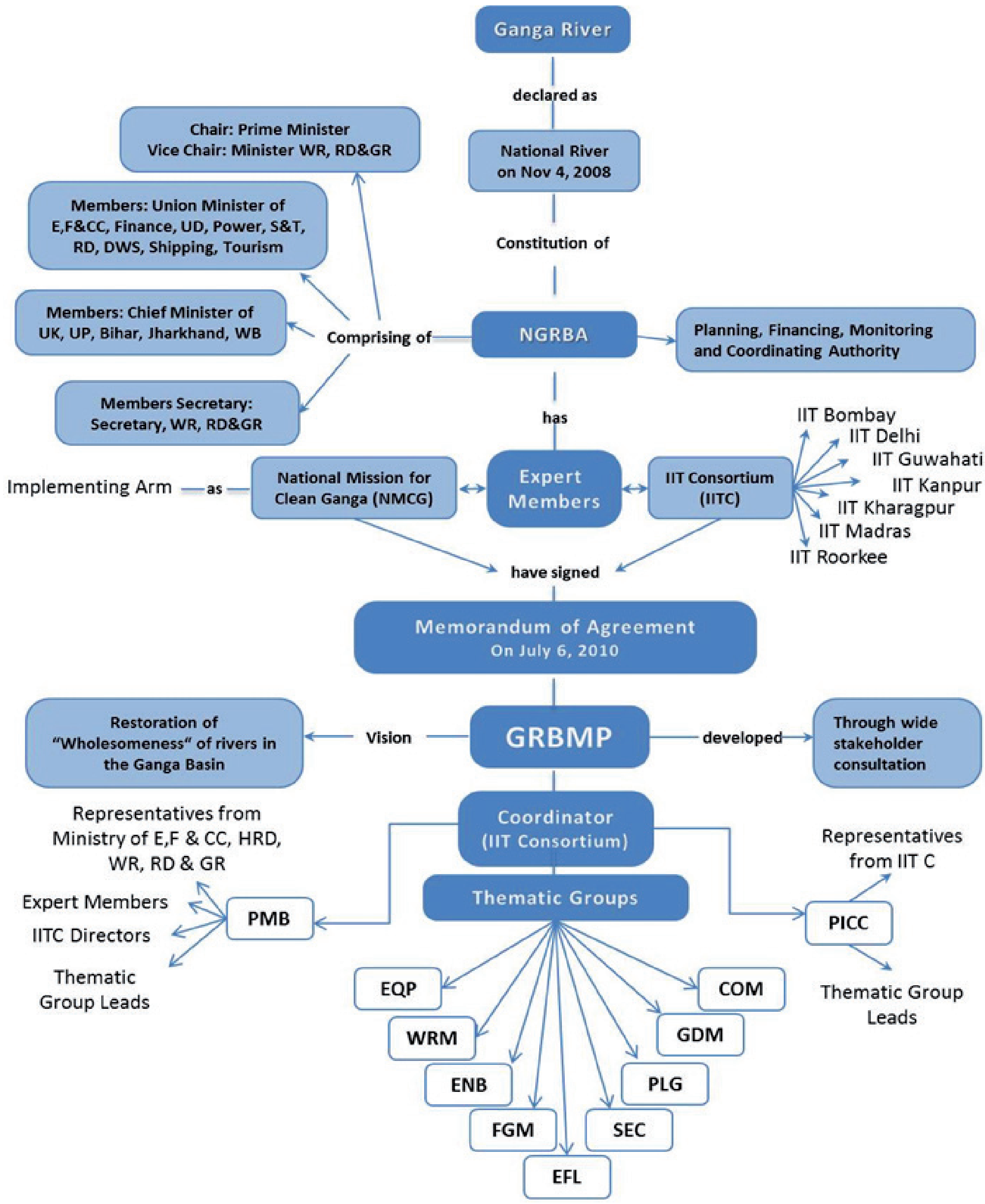


GRBMP WORK STRUCTURE

ORGANIZATIONAL STRUCTURE FOR PREPARING GRBMP



NGRBA: National Ganga River Basin Authority
NMCG: National Mission for Clean Ganga
MoEF: Ministry of Environment and Forests
MHRD: Ministry of Human Resource and Development
MoWR, RD&GR: Ministry of Water Resources, River Development and Ganga Rejuvenation
GRBMP: Ganga River Basin Management Plan
IITC: IIT Consortium
PMB: Project Management Board
PICC: Project Implementation and Coordination Committee

EQP: Environmental Quality and Pollution
WRM: Water Resources Management
ENB: Ecology and Biodiversity
FGM: Fluvial Geomorphology
EFL: Environmental Flows
SEC: Socio Economic and Cultural
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Centre for Ganga River Basin Management and Studies