

Covid -19 pandemic lockdown, an endowment for the Ecosystem Health of the Rivers?

A Comparative case study of River Ganga: role of the anthropogenic activities, Governmental interventions, GAP, Pre and Post Lockdown Scenarios, their implications on riverine and human health and the lessons learned.

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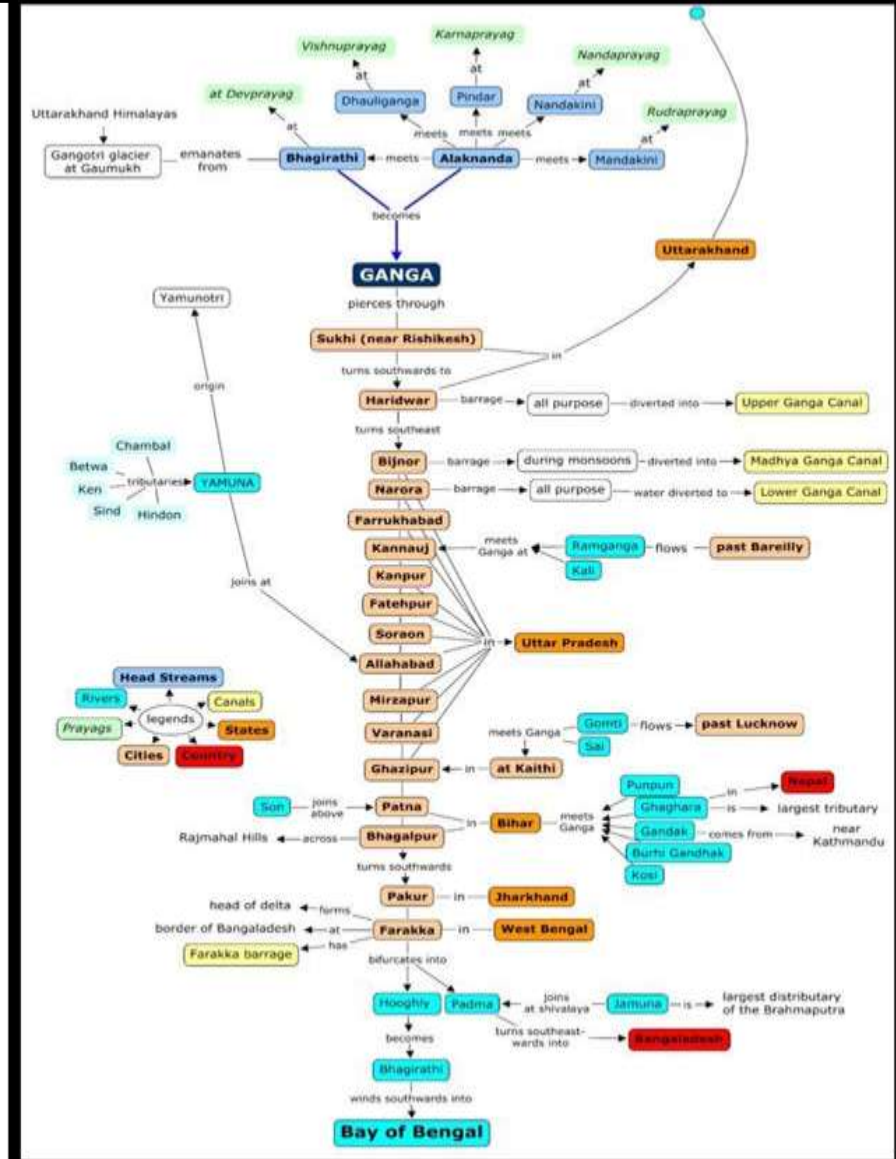


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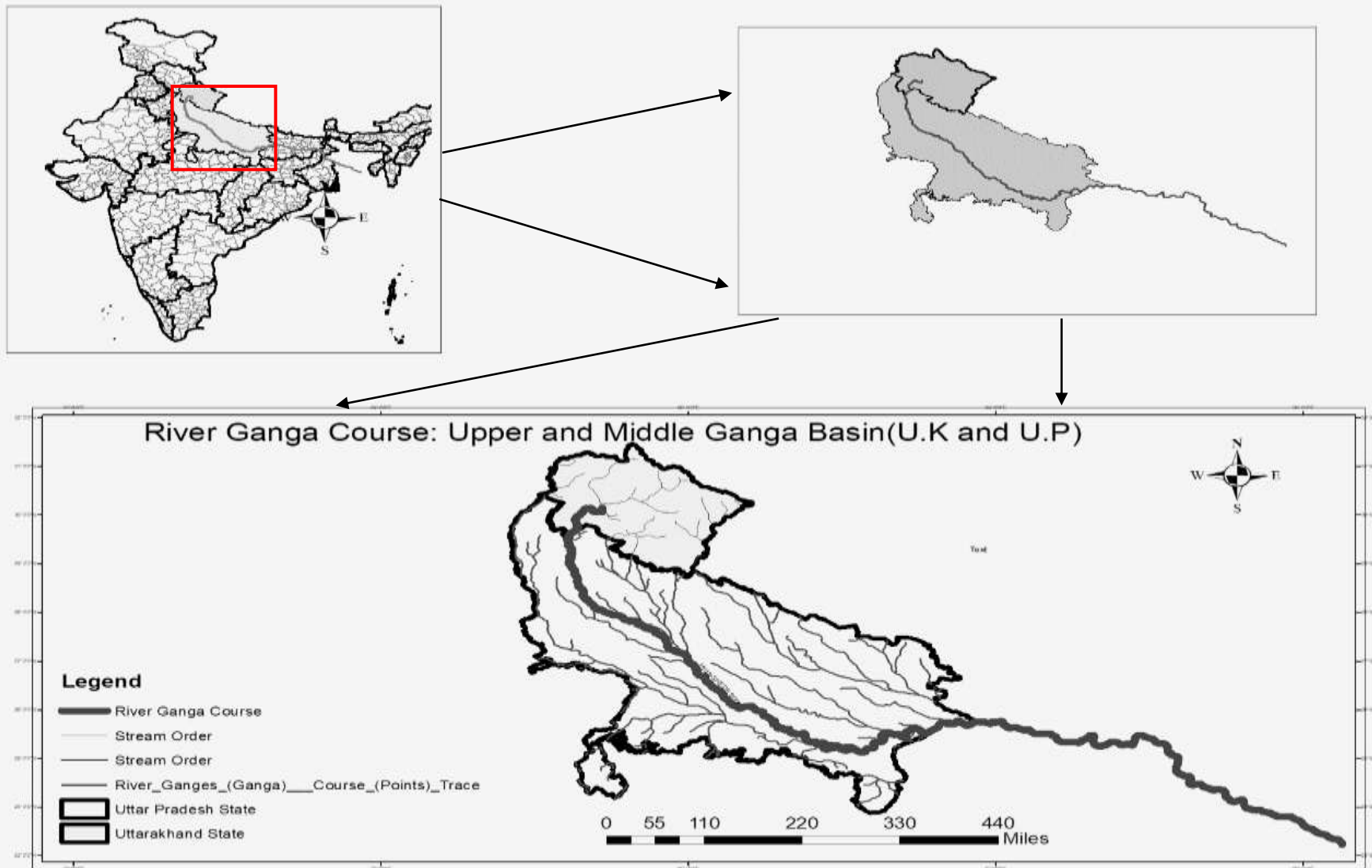


River Ganga :Facts, Importance and Course

- ❖ River Ganga holds great importance in India's rich cultural heritage.
- ❖ Geographical Origin: Gangotri Glacier (GAUMUKH) in Uttarakhand
- ❖ Ganga basin catchment area, constitutes 26% of the country's land mass (8,61,404 Sq. km).
- ❖ The basin covers 11 states viz., Uttarakhand, U.P., M.P., Rajasthan, Haryana, Himachal Pradesh, Chhattisgarh, Jharkhand, Bihar, West Bengal and Delhi.
- ❖ Distance Traversed :2525Km
- ❖ One of the densely populated River basins of the world sheltering an area of about 1,086,000 Sq.Km extending over India, Nepal and Bangladesh.
- ❖ About 79% area of Ganga basin is in India.
- ❖ Houses approximately 40% Population of the country.
- ❖ Contributes to more than one-third of India's surface water resources, out of which 90 percent is used for irrigation.



River Ganga: Basin and Study Area

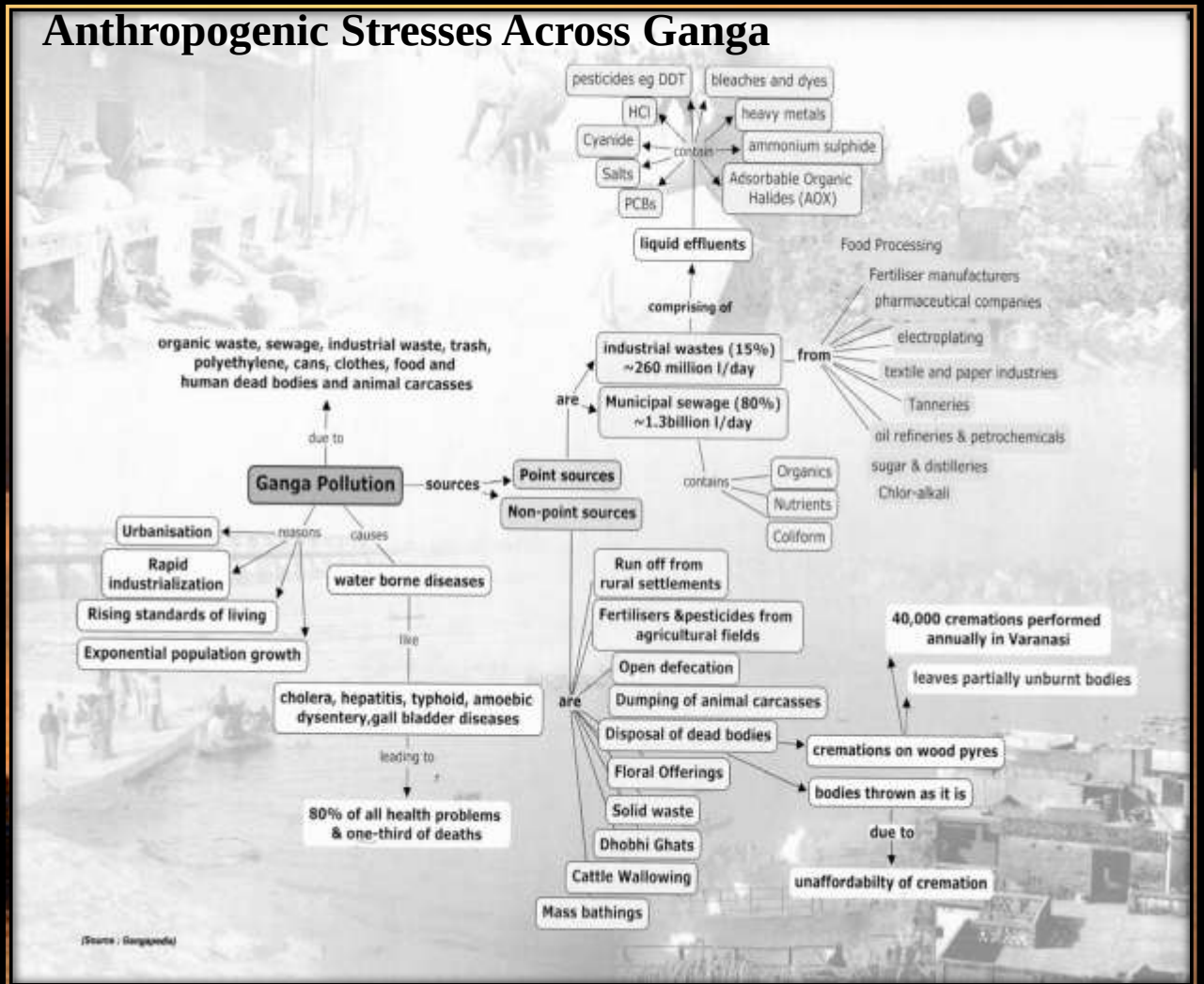


MAJOR CAUSES OF POLLUTION

1. Booming population.
2. Mass scale emigrations from rural to urban areas.
3. Inefficiently planned urban and industrial sectors.
4. Construction of dams and barrages across the river reaches.
5. Discharge of untreated municipal and industrial wastes.
6. Floral and religious offerings.
7. Cremation of the dead bodies on the river banks.
8. Inescapable increment in the waste production {Approx.12000MLD waste is generated everyday in the river basin, whereas the present treatment capacity is just one-third of it.)
9. Discharge of the industrial pollutants that are non-biodegradable and toxic in nature.



Anthropogenic Stresses Across Ganga



PURPOSES FULFILLED BY RIVER GANGA

Supporting Services : The services that are necessary for the production of all other ecosystem services including soil formation, photosynthesis, primary production, nutrient cycling and water cycling.



Provisioning Services: The products obtained from ecosystems, including food, fiber, fuel, genetic resources, biochemical's, natural medicines, pharmaceuticals, ornamental resources and fresh water.

- ✓ **Source of drinking water, source of water for industrial use, sanitation, transportation.**
 - ✓ **Sustains a list of towns and cities.**
- ✓ **Sustains Agriculture by being the source of Irrigation.**
- ✓ **Provides source of energy in the form of electricity.**
 - ✓ **A Sin Purifier.**
- ✓ **Opens door for many water sports such as rafting and kayaking.**
- ✓ **Ganga shores are home to many indigenous and migratory birds.**
- ✓ **Provides livelihood options to those residing in the basin.**
 - ✓ **Promotes ecotourism.**

Regulating Services: The benefits obtained from the regulation of ecosystem processes, including air quality regulation, climate regulation, water regulation, erosion regulation, water purification, disease regulation, pest regulation, pollination, natural hazard regulation.



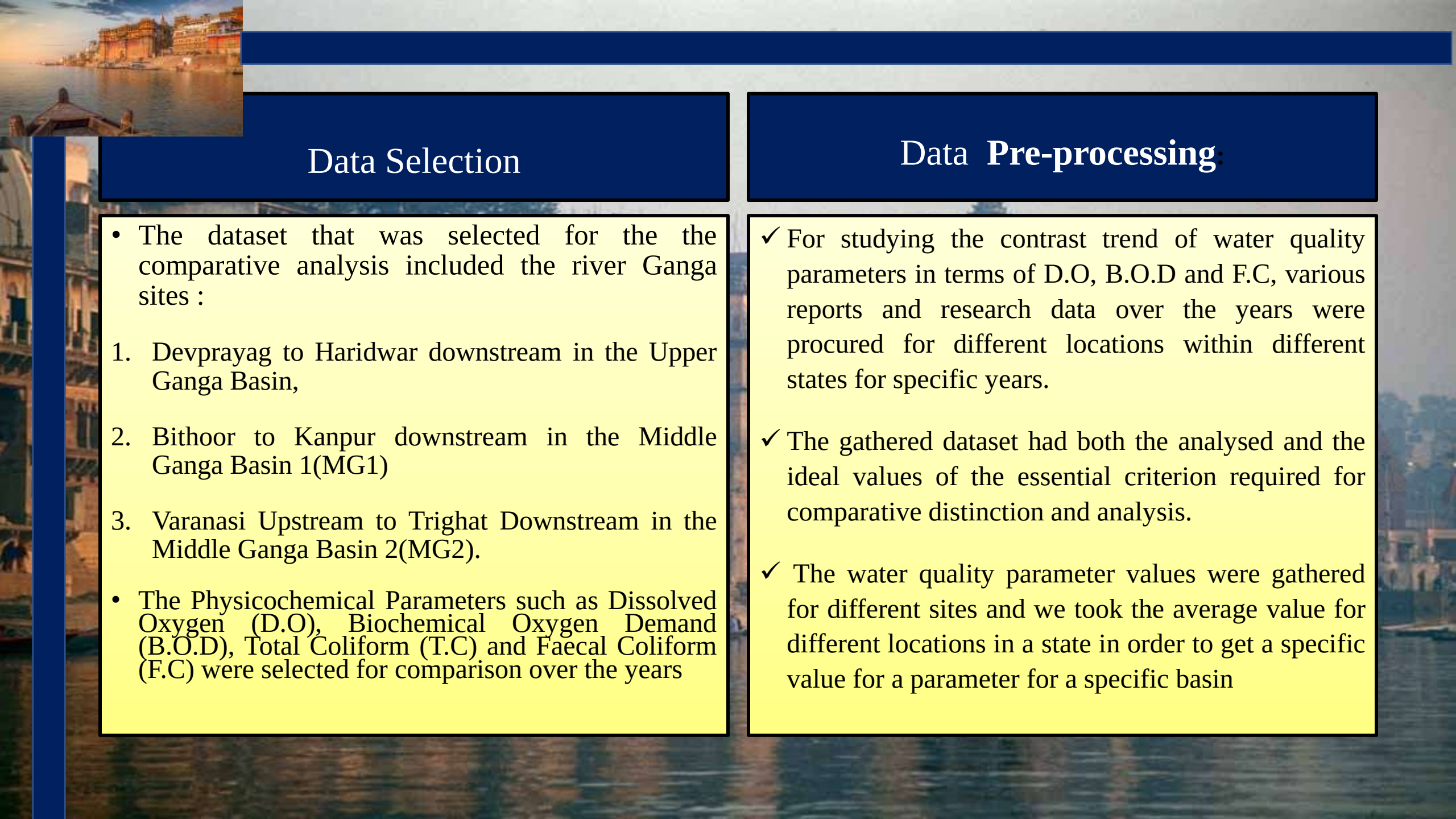
Cultural Services: The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences – thereby taking account of landscape values.

Drivers of Ecosystem Change

Direct Drivers of Change	Indirect Drivers of Change
✓ Dam Construction ✓ Dike and levee construction ✓ Diversions ✓ Draining of wetlands ✓ Deforestation/Land use change ✓ Release of Polluted water effluents ✓ Overharvesting ✓ Introduction of exotic species ✓ Release of metals and acid forming pollutants into the atmosphere ✓ Emission of climate altering air pollutants ✓ Climate change ✓ Technology adaptation and use ✓ Natural, physical and biological drivers ✓ External inputs(e.g. fertilizer use, pest control etc.)	✓ Demographic ✓ Economic (e.g. globalization, trade, market and policy framework) ✓ Socio-political (e.g. Governance, institutional and legal framework) ✓ Science and technology ✓ Cultural and religious (e.g. beliefs, consumption choices)

Ecosystem Services Affected Along the Ganga Stretch

STATES THROUGH WHICH RIVER GANGA PASSES	Ecosystem Services at risk
1. Uttarakhand	provision of habitat for native species, recreational and commercial fisheries, maintenance of deltas and their economies, productivity of estuarine fisheries
2. Uttar Pradesh	habitat, sport and commercial fisheries, natural floodplain fertility, natural flood control habitat, sport and commercial fisheries, recreation, pollution dilution, hydropower, transportation natural flood control, habitat for fish and waterfowl, recreation, natural water purification
3. Bihar	water supply quality and quantity, fish and wildlife habitat, transportation, flood control water supply, habitat, commercial fisheries, recreation
4. Jharkhand	sport and commercial fisheries, waterfowl, other biotic populations
5. West Bengal	sport and commercial fisheries, waterfowl, water quality, fish and wildlife habitat, transportation habitat, fisheries, recreation, water quality water supply, hydropower, transportation, fish and wildlife habitat, pollution dilution, recreation, fisheries, flood control



Data Selection

- The dataset that was selected for the comparative analysis included the river Ganga sites :
 1. Devprayag to Haridwar downstream in the Upper Ganga Basin,
 2. Bithoor to Kanpur downstream in the Middle Ganga Basin 1(MG1)
 3. Varanasi Upstream to Trighat Downstream in the Middle Ganga Basin 2(MG2).
- The Physicochemical Parameters such as Dissolved Oxygen (D.O), Biochemical Oxygen Demand (B.O.D), Total Coliform (T.C) and Faecal Coliform (F.C) were selected for comparison over the years

Data Pre-processing:

- ✓ For studying the contrast trend of water quality parameters in terms of D.O, B.O.D and F.C, various reports and research data over the years were procured for different locations within different states for specific years.
- ✓ The gathered dataset had both the analysed and the ideal values of the essential criterion required for comparative distinction and analysis.
- ✓ The water quality parameter values were gathered for different sites and we took the average value for different locations in a state in order to get a specific value for a parameter for a specific basin

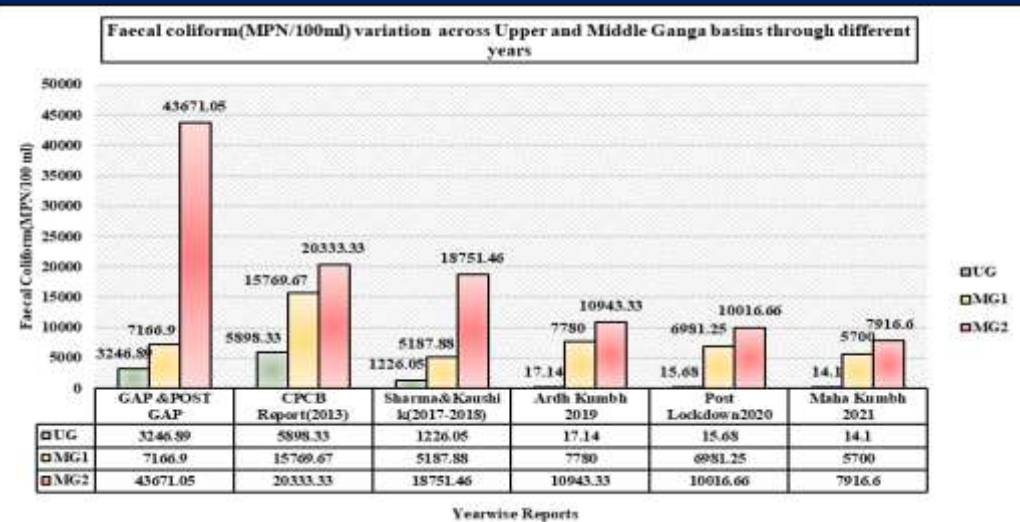
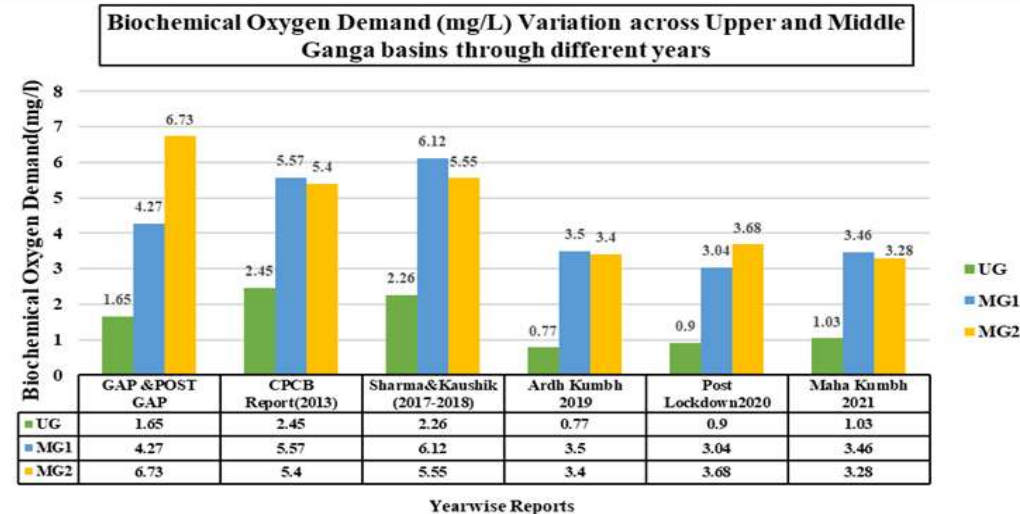
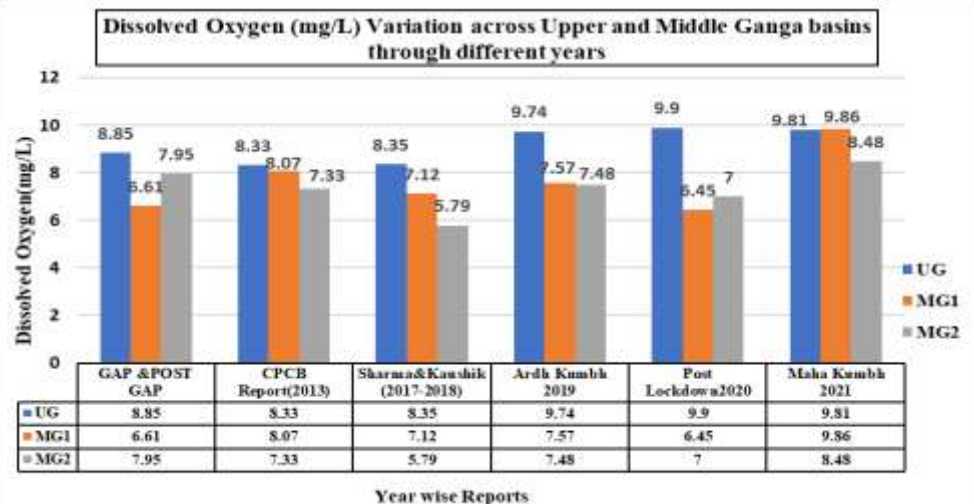
Similar steps were followed in order to have a time line data. The distinguished results involved River Ganga during different phases of Anthropogenic pressures, Governmental and private organisations involvement that has been outlined.

Table 1: List of River Ganga Reports/ Researches carried out through different years involving different parameters listed below.

S.No.	Report Name/ Research Phase/ Year	Parameters Considered	Data Procured from
1.	GAP and Post GAP Phase (2002-2008)	D.O, B.O.D, F.C	MINARS Report (2009-2010)
2.	CPCB Data (2002-2011)	D.O, B.O.D, F.C	CPCB Report (2013- compiled)
3.	Sharma and Kaushik (2017-2018)	D.O, B.O.D, F.C	Ph.D. research data(ongoing)
4	Ardh Kumbh, 2019, Prayagraj, (January,2019- October,2019)	D.O, B.O.D, F.C	State Pollution Control Board's (Uttarakhand Pollution Control Board (UKPCB) and Uttar Pradesh Pollution Control Board (UPPCB))
5.	Post Lockdown Phase,2020 (June, 2020- September, 2020)	D.O, B.O.D, F.C	State Pollution Control Board's (Uttarakhand Pollution Control Board (UKPCB) and Uttar Pradesh Pollution Control Board (UPPCB))
6.	Maha Kumbh ,2021 UG: (January,2021-March,2021) MG1 and MG2:(January,2021-April,2021)	D.O, B.O.D, F.C	State Pollution Control Board's (Uttarakhand Pollution Control Board (UKPCB) and Uttar Pradesh Pollution Control Board (UPPCB))



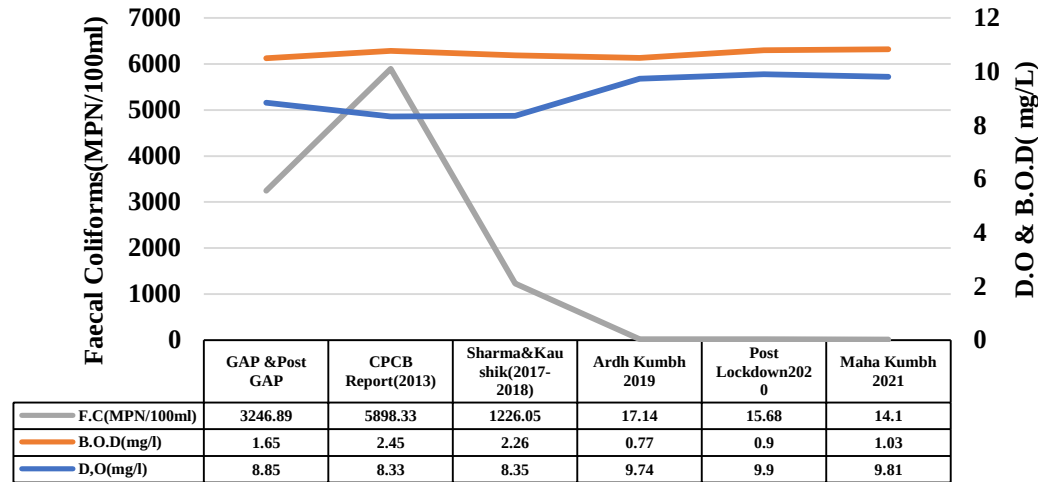
The results depicting the comparative trend of distinguished water quality parameters of River Ganga through different years has been shown below in Fig. 1, 2 and 3 respectively.



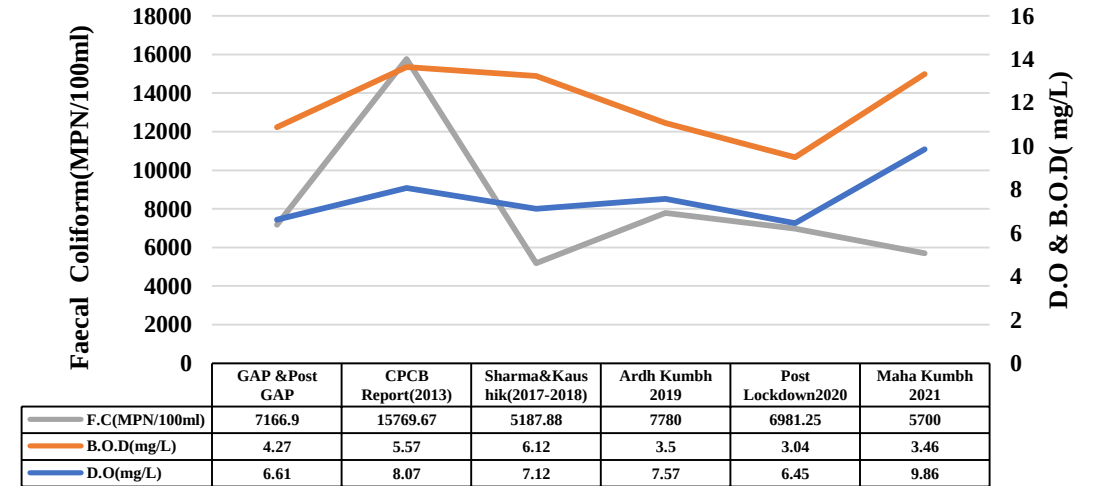


The concentrations of contrasting water quality parameters in River Ganga after comparison showed an inconsistent trend that has been indicated in Fig.4, 5 and 6 respectively.

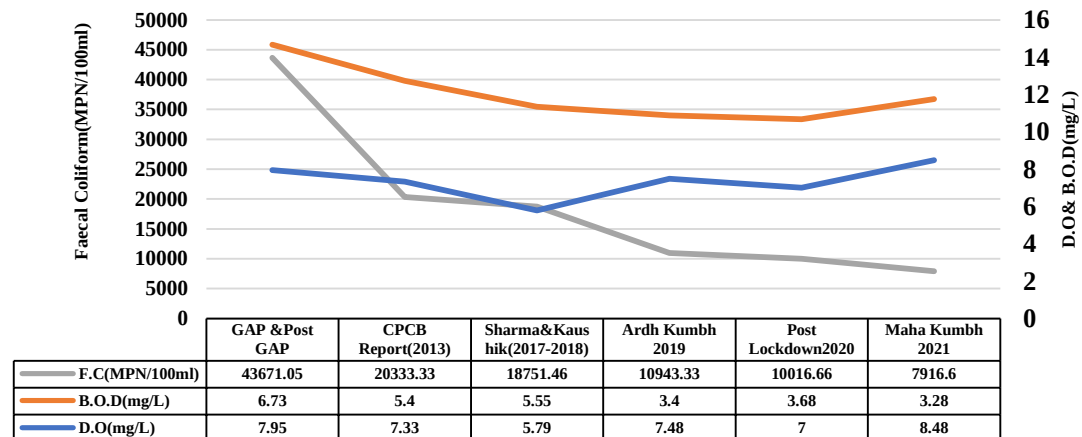
Trends of D.O, B.O.D and F.C in the Upper Ganga basin(Devprayag- Haridwar) through different years



Trends of D.O, B.O.D and F.C in the Middle Ganga 1 basin(Bithoor- Kanpur) through different years



Trends of D.O, B.O.D and F.C in the Middle Ganga 2 basin(U/S Varanasi- D/S Tarighat) through different years





Further in order to analyse the inclination of water quality characteristics during specific mass -bathing years, with respect to D. O, B.O. D and T.C, the reports generated by State Pollution Control Boards of the Upper and Middle Ganga Basin were gathered. The average values of different locations for a specific parameter were calculated.

- The results illustrated the comparative trend of river Ganga through different mass-bathing years. The varied reports data with reference to a specific mass -bathing festival that was taken into consideration has been displayed in the Table.
- Table2: List of River Ganga Reports involving data from different mass -bathing events through years incorporating different parameters listed below

S.No.	Mass Bathing Events Name/Location/Year/ Data Months	Parameters considered	Report Procured from
1.	Ardh Kumbh (2016), Haridwar (January,2016-May,2016)	D.O, B.O.D, T.C	State Pollution Control Board's (Uttarakhand Pollution Control Board (UKPCB) and Uttar Pradesh Pollution Control Board (UPPCB))
2.	Magh Mela (2018), Allahabad, New Name: Prayagraj (January,2018-April,2018)	D.O, B.O.D, T.C	State Pollution Control Board's (Uttarakhand Pollution Control Board (UKPCB) and Uttar Pradesh Pollution Control Board (UPPCB))
3.	Ardh Kumbh (2019), Allahabad (January2019-April,2019)	D.O, B.O.D, T.C	State Pollution Control Board's (Uttarakhand Pollution Control Board (UKPCB) and Uttar Pradesh Pollution Control Board (UPPCB))
4.	Maha Kumbh Mela (2021), Haridwar UG: January, 2021- March,2021 MG1 and MG2: January,2021- April,2021)	D.O, B.O.D, T.C	State Pollution Control Board's (Uttarakhand Pollution Control Board (UKPCB) and Uttar Pradesh Pollution Control Board (UPPCB))



The water quality can become adversely affected if these parameter values are found to be exceeding the ideal value over the years that has been shown in the Table 3:

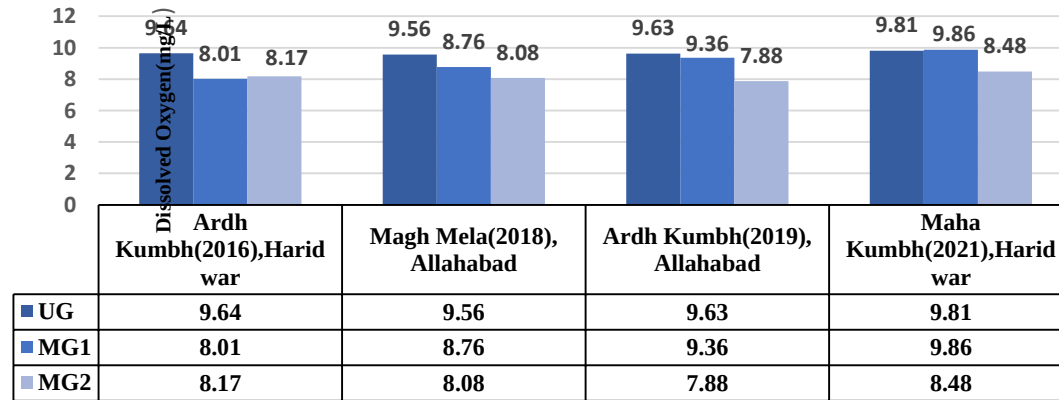
S.No.	1.	2.	3.	4.
Parameters	Dissolved Oxygen (D.O)	Biochemical Oxygen Demand (B.O.D)	Total Coliform (T.C)	Faecal Coliform (F.C)
Units	mg/L	mg/L	MPN/100 ml	MPN/100ml
Definition	Quantity of oxygen dissolved in water	Amount of oxygen needed by the living organisms	Coliform bacteria derived from human and animal waste	Coliform bacteria derived from animal waste
Ideal Value	>4 mg/L	<3mg/L	<500MPN/100 ml	Nil/100 ml



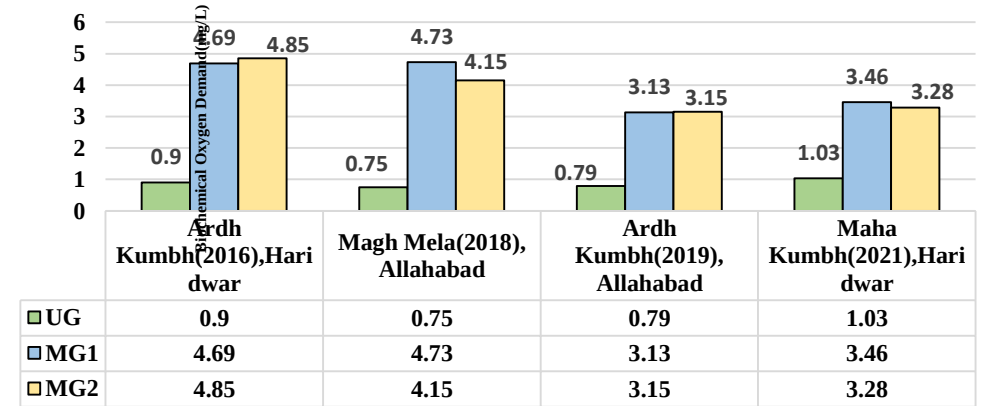


The outcomes showcasing the comparative analysis of specific water quality characteristics during different mass-bathing events has been illustrated in the Fig. 7, 8 and 9 respectively.

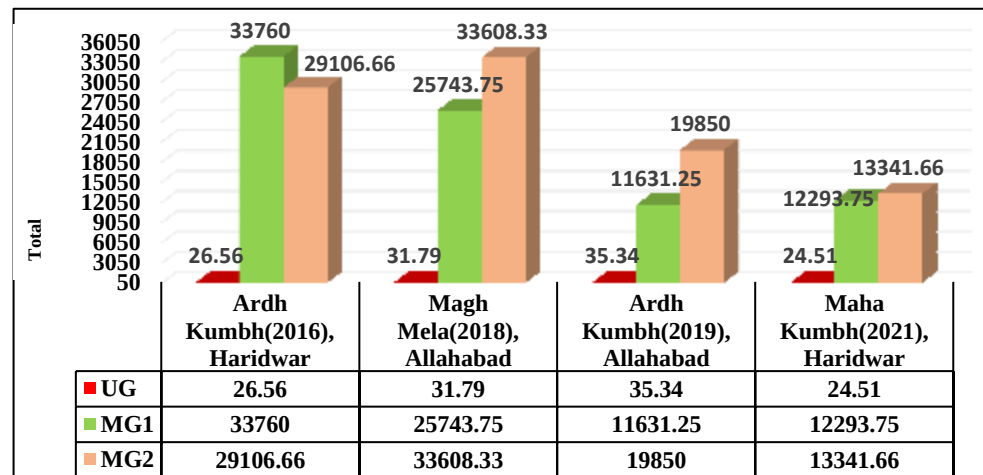
Dissolved Oxygen(mg/L) variation across Upper and Middle Ganga basins(Mass -bathing years)



Biochemical Oxygen Demand(mg/L) variation across Upper and Middle Ganga basins(Mass-bathing years)



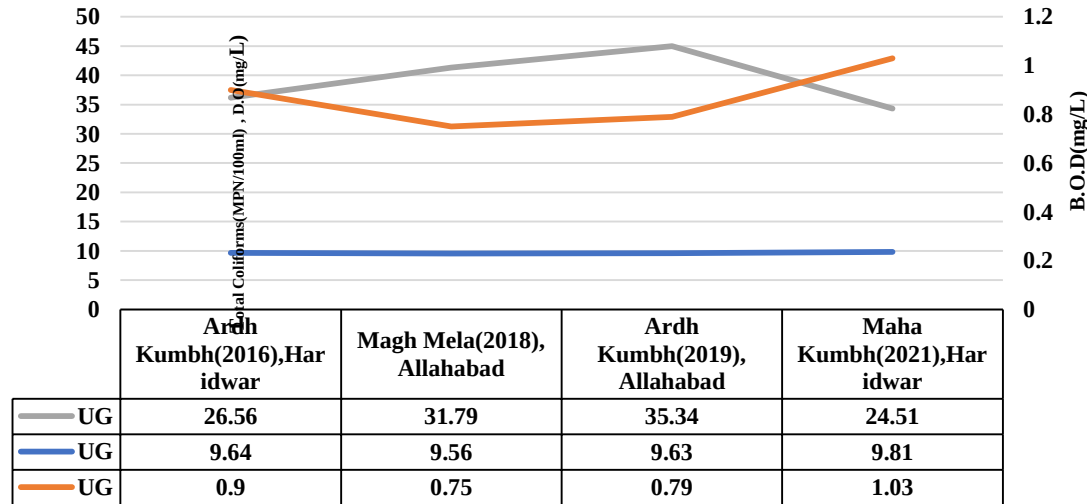
Total Coliform(MPN/100ml) variation across Upper and Middle Ganga basins(Mass-bathing years)



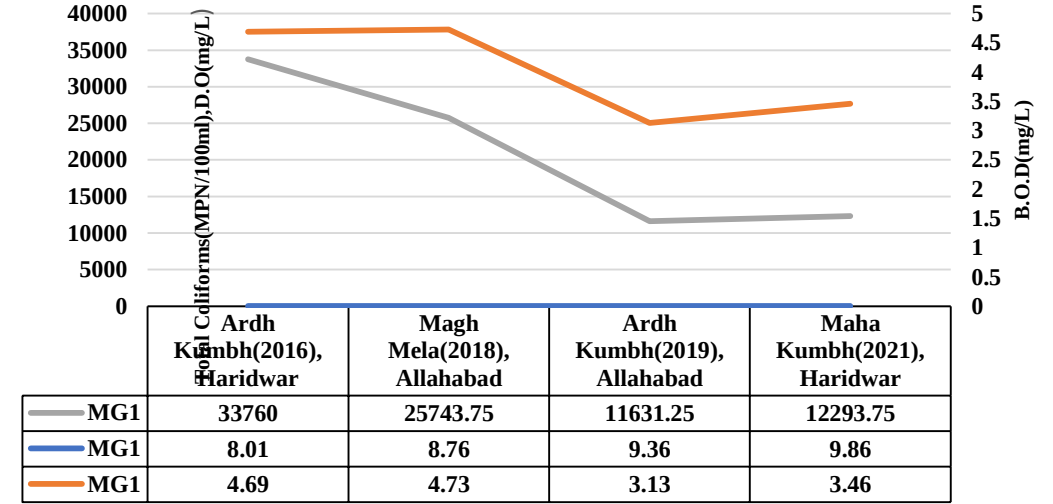


On the basis of the water quality data procured for comparison from different Reports for distinctive mass-bathing events, the findings elucidate a fluctuating yet improving trend that has been displayed in the Fig. 3.4.1, 3.5.1 and 3.6.1 respectively.

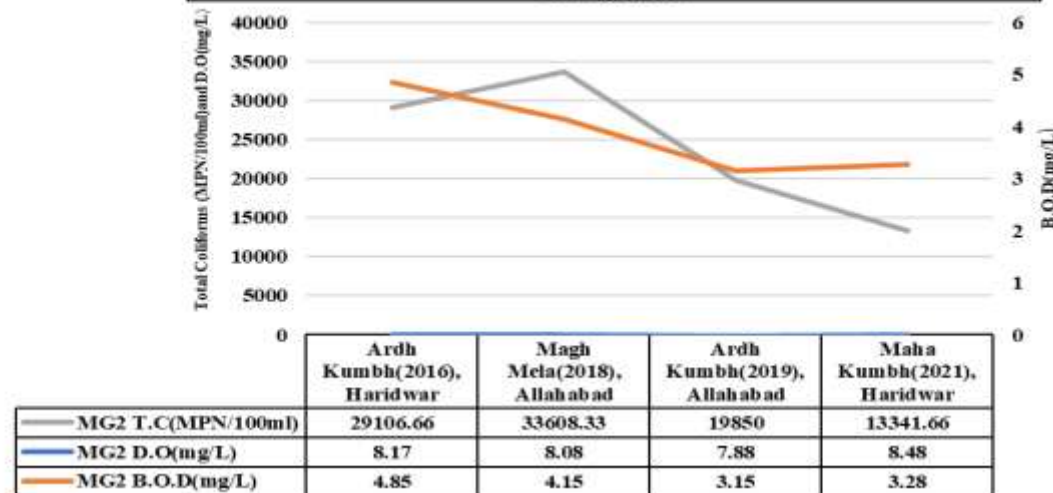
Trends of D.O,B.O.D and T.C in the Upper Ganga basin during Mass-bathing years

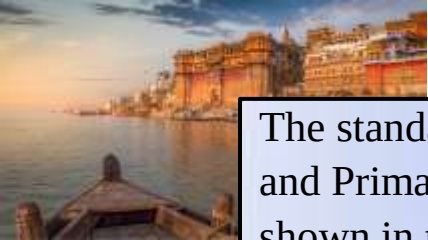


Trends of D.O,B.O.D and T.C in the Middle Ganga basin(MG1) during Mass-bathing years



Trends of D.O, B.O.D and T.C in the Middle Ganga basin(MG2) during Mass-bathing years





The standards depicting Designated Best Use Class of Surface water and Primary Water Quality Criteria for Outdoor bathing have been shown in the Table 4 and 5 below respectively.

Designated-Best-Use	Class of water	Criteria
Drinking Water Source without conventional treatment but after disinfection	A	- Total Coliforms Organism MPN/100ml shall be 50 or less - pH between 6.5 and 8.5 - Dissolved Oxygen 6mg/l or more - Biochemical Oxygen Demand 5 days 20C 2mg/l or less
Outdoor bathing (Organised)	B	- Total Coliforms Organism MPN/100ml shall be 500 or less pH between 6.5 and 8.5 - Dissolved Oxygen 5mg/l or more - Biochemical Oxygen Demand 5 days 20C 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	- Total Coliforms Organism MPN/100ml shall be 5000 or less pH between 6 to 9 - Dissolved Oxygen 4mg/l or more - Biochemical Oxygen Demand 5 days 20C 3mg/l or less
Propagation of Wild life and Fisheries	D	- pH between 6.5 to 8.5 - Dissolved Oxygen 4mg/l or more - Free Ammonia (as N) 1.2 mg/l or less
Irrigation, Industrial Cooling, Controlled Waste disposal	E	- pH between 6.0 to 8.5 - Electrical Conductivity at 25C micro mhos/cm Max.2250 - Sodium absorption Ratio Max. 26 - Boron Max. 2mg/l
	Below-E	Not Meeting A. B. C. D & E Criteria

CRITERIA		RATIONALE
1.Fecal Coliform MPN/100 ml	500 (desirable) 2500 (Maximum permissible)	To ensure low sewage contamination. Faecal coliform and faecal streptococci are considered as they reflect the bacterial pathogenicity.
2.Fecal Streptococci MPN/100 ml	100 (desirable) 500 (Maximum Permissible)	The desirable and permissible limits are suggested to allow for fluctuation in environmental conditions such as seasonal change, changes in flow conditions etc.
3. pH	Between 6.5-8.5	The range provides protection to the skin and delicate organs like eyes, nose, ears etc. which are directly exposed during outdoor bathing.
4.Dissolved Oxygen:	5 mg/L or more	The minimum dissolved oxygen concentration of 5 mg/l ensures reasonable freedom from oxygen consuming organic pollution immediately upstream which is necessary for preventing production of anaerobic gases (obnoxious gases) from sediment.
5.Biochemical Oxygen demand 3 day, 270C	3 mg/L or less	The Biochemical Oxygen Demand of 3 mg/l or less of the water ensures reasonable freedom from oxygen demanding pollutants and prevent production of obnoxious gases".

Water Quality Characteristics: Designated Best Use Class and Trend over the years

DO, BOD, FC and TC are one of the critical indicators of the Ecosystem state of the river.

These parameters imply the true biological health of the river. Thus, in order to study the water quality condition in River Ganga through different phases, the comparative results of these characteristics were gathered and analyzed.

The water quality status of River Ganga in the Upper and Middle Ganga basins in terms of Dissolved Oxygen, Biochemical Oxygen Demand and Faecal Coliform has been shown in Table 6,7 and 8 below respectively

Locations	Upper Ganga Basin-UG (Devprayag- Haridwar)		Middle Ganga Basin 1 - MG1 (Bithoor- Kanpur)		Middle Ganga Basin 2 - MG2 (U/S Varanasi- D/S Tarighat)	
Phases	Water Quality Class	Trend Over Years	Water Quality Class	Trend Over Years	Water Quality Class	Trend Over Years
GAP & Post GAP Phase	A	No trend	A	No trend	A	No trend
CPCB Report (2013)	A	Slightly Decreasing	A	Moderately Increasing	A	Slightly Decreasing
Sharma and Kaushik (2017-2018)	A	Slightly Increasing	A	Decreasing	B	Significantly Decreasing
Ardh Kumbh (2019)	A	Significantly Increasing	A	Slightly Increasing	A	Significantly Increasing
Post Lockdown 2020	A	Slightly Increasing	A	Decreasing	A	Slightly Decreasing
Maha Kumbh 2021	A	Slightly Decreasing	A	Significantly Increasing	A	Moderately Increasing

Locations	Upper Ganga Basin-UG (Devprayag- Haridwar)		Middle Ganga Basin 1 - MG1 (Bithoor- Kanpur)		Middle Ganga Basin 2 - MG2 (U/S Varanasi- D/S Tarighat)	
Phases	Water Quality Class	Trend Over Years	Water Quality Class	Trend Over Years	Water Quality Class	Trend Over Years
GAP & Post GAP Phase	A	No trend	D	No trend	-	No trend
CPCB Report (2013)	B, C	Slightly Increasing	D	Slightly Increasing	D	Slightly Decreasing
Sharma and Kaushik (2017-2018)	B, C	Slightly Decreasing	-	Slightly Increasing	D	Slightly Increasing
Ardh Kumbh (2019)	A	Significantly Decreasing	D	Significantly Decreasing	D	Significantly Decreasing
Post Lockdown 2020	A	Slightly Decreasing	D	Slightly Decreasing	D	Slightly Increasing
Maha Kumbh 2021	A	Slightly Increasing	D	Slightly Increasing	D	Slightly Decreasing

Continued.

Locations	Upper Ganga Basin-UG (Devprayag- Haridwar)		Middle Ganga Basin 1 - MG1 (Bithoor- Kanpur)		Middle Ganga Basin 2 - MG2 (U/S Varanasi- D/S Tarighat)	
	Water Quality Class	Trend Over Years	Water Quality Class	Trend Over Years	Water Quality Class	Trend Over Years
Phases						
GAP & Post GAP Phase	-	No trend	-	No trend	-	No trend
CPCB Report (2013)	-	Slightly Decreasing	-	Moderately Increasing	-	Slightly Decreasing
Sharma and Kaushik (2017-2018)	-	Slightly Increasing	-	Decreasing	-	Significantly Decreasing
Ardh Kumbh (2019)	Agricultural Reuse	Significantly Increasing	-	Slightly Increasing	-	Significantly Increasing
Post Lockdown 2020	Agricultural Reuse	Slightly Increasing	-	Decreasing	-	Slightly Decreasing
Maha Kumbh 2021	Agricultural Reuse	Slightly Decreasing	-	Significantly Increasing	-	Moderately Increasing

The water quality status of River Ganga in the Upper and Middle Ganga basins in terms of Dissolved Oxygen, Biochemical Oxygen Demand and Faecal Coliform across mass-bathing years has been shown in Table 9, 10 and 11 below respectively.																					
Locat ions	Upper Ganga Basin-UG (Devprayag- Haridwar)		Middle Ganga Basin 1 - MG1 (Bithoor- Kanpur)		Middle Ganga Basin 2 - MG2(U/S Varanasi- D/S Tarighat)		Locat ions	Upper Ganga Basin-UG (Devprayag- Haridwar)		Middle Ganga Basin 1 - MG1 (Bithoor- Kanpur)		Middle Ganga Basin 2 - MG2(U/S Varanasi- D/S Tarighat)		Mas s- Bath ing Eve nts	Upper Ganga Basin-UG (Devprayag- Haridwar)		Middle Ganga Basin 1 - MG1 (Bithoor- Kanpur)		Middle Ganga Basin 2 - MG2(U/S Varanasi- D/S Tarighat)		
	Water Qualit y Class	Trend Over Years	Water Qualit y Class	Trend Over Years	Water Qualit y Class	Trend Over Years		Water Quality Class	Trend Over Years	Water Quality Class	Trend Over Years	Water Quality Class	Trend Over Years		Water Quality Class	Trend Over Years	Water Quality Class	Trend Over Years	Water Qualit y Class	Trend Over Years	Water Qualit y Class
Mass - Bathi ng Event s							Mass- Bathi ng Event s							Ardh Kumb h (2016), Haridw ar	A	No Trend	-	No Trend	-	No Trend	
Ardh Kumbh (2016), Haridw ar	A	No Trend	A	No Trend	A	No Trend	Ardh Kumbh (2016), Haridw ar	A	No Trend	D	No Trend	D	No Trend	Magh Mela (2018), Allaha bad	A	Slightl y Decre asing	-	Decrea sing	-	Increas ing	
Magh Mela (2018), Allaha bad	A	Slightl y Decre asing	A	Slightly Increasi ng	A	Slightl y Decre asing	Magh Mela (2018), Allaha bad	A	Slightl y Decre asing	D	Slightl y Increa sing	D	Slightl y Decre asing	Ardh Kumb h (2019), Allaha bad	A	Slightl y Increa sing	-	Signifi cantly Decrea sing	-	Signifi cantly Decrea sing	
Ardh Kumbh (2019), Allaha bad	A	Slightl y Increa sing	A	Signific antly Increasi ng	A	Decre asing	Ardh Kumbh (2019), Allaha bad	A	Slightl y Increa sing	D	Decre asing	D	Decre asing	Maha Kumb h Mela (2021), Haridw ar	A	Decre asing	-	Slightl y Increas ing	-	Decrea sing	
Maha Kumbh Mela (2021), Haridw ar	A	Slightl y Increa sing	A	Slightly Increasi ng	A	Slightl y Increa sing	Maha Kumbh Mela (2021), Haridw ar	A	Increa sing	D	Slightl y Increa sing	D	Slightl y Increa sing								

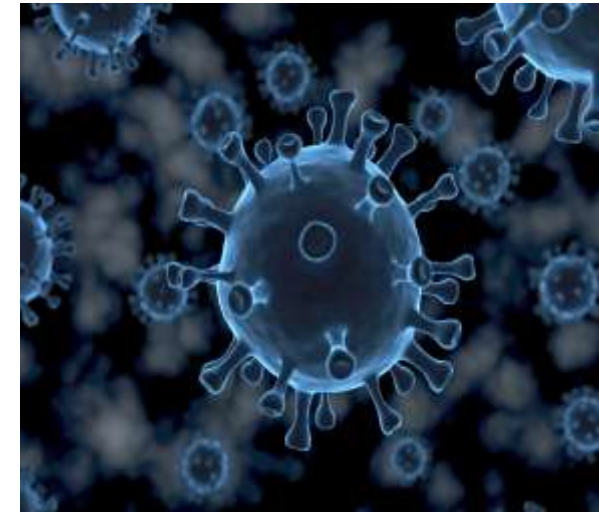


Conclusions

- ❑ Role of Central and State Governments, many private organizations and NGO's (Non-Governmental Organizations) enhanced the water quality of the river at many stretches. The Nanami Ganga Programme under NMCG brought improved success by yielding better results at many regions of river pollution.
- ❑ The river conservation challenges have grown over the years and so is the demand for river water. The river water is being utilized for drinking, bathing, agricultural use, industrial purpose, power generation and others. There has been increase in the amount of pollution load due to population explosion in the expanding cities, lean flow of the rivers as a result of melting of glacial snow, adverse effects on the river ecosystem and human health due to degraded water quality, the violation of the stringent environmental norms by industries and individuals and lack of self-awareness about the importance of rivers has come out to be a major challenge.
- ❑ It can be stated that despite the demographic and other anthropogenic pressures have significantly been increased over the years, the river water quality comparatively improved at many of the sites.
- ❑ However, the analytical parameters of water quality (DO, BOD, FC, TC), that not only effect the ecosystem health of the rivers, but also adversely impact human health and well-being are found to be exceeding the maximum permissible limits at some of the sites making the river water still unfit for potable and bathing purpose.

Covid 19 Pandemic and Environment

- ❖ The Covid-19 pandemic lockdown may have forced us to stay inside, but it has emerged as a boon for the river Ganga and environment. The river ecosystem reclaimed back to its natural state and started its healing process. The results revealed that the water quality improved with regard to the specific parameters for specific regions. The rivers self-purification capacity also increased. The fishes and other aquatic fauna were visible. This all could be witnessed because of the abrupt closure of industries, hotels and other sources along the river banks that dump and discharge their waste into the river. The ritualistic bathing activities that brought many visitors on the Ganga Ghats were also halted due to lockdown. There was decline in the human activities while there was no reduction in the amount of sewage from the households.
- ❖ But these improvements are labelled as a temporary phenomenon, as once the anthropogenic activities resume, the river would return back to its degraded state. What is required is stringent enforcement of regulations. Cessation of activities is not a permanent solution. If the deterioration of the river continues, it would not only hamper the riverine flora and fauna but would hamper the entire ecosystem. As the ecosystem would be affected, it would result in many water borne diseases, potential of causing even death of the humans consuming its contaminated water.
- ❖ Thus, in order to maintain the ecological flows and to continue enjoying the benefits river Ganga provides us with in the form of Ecosystem Services, the water quality needs to be maintained.



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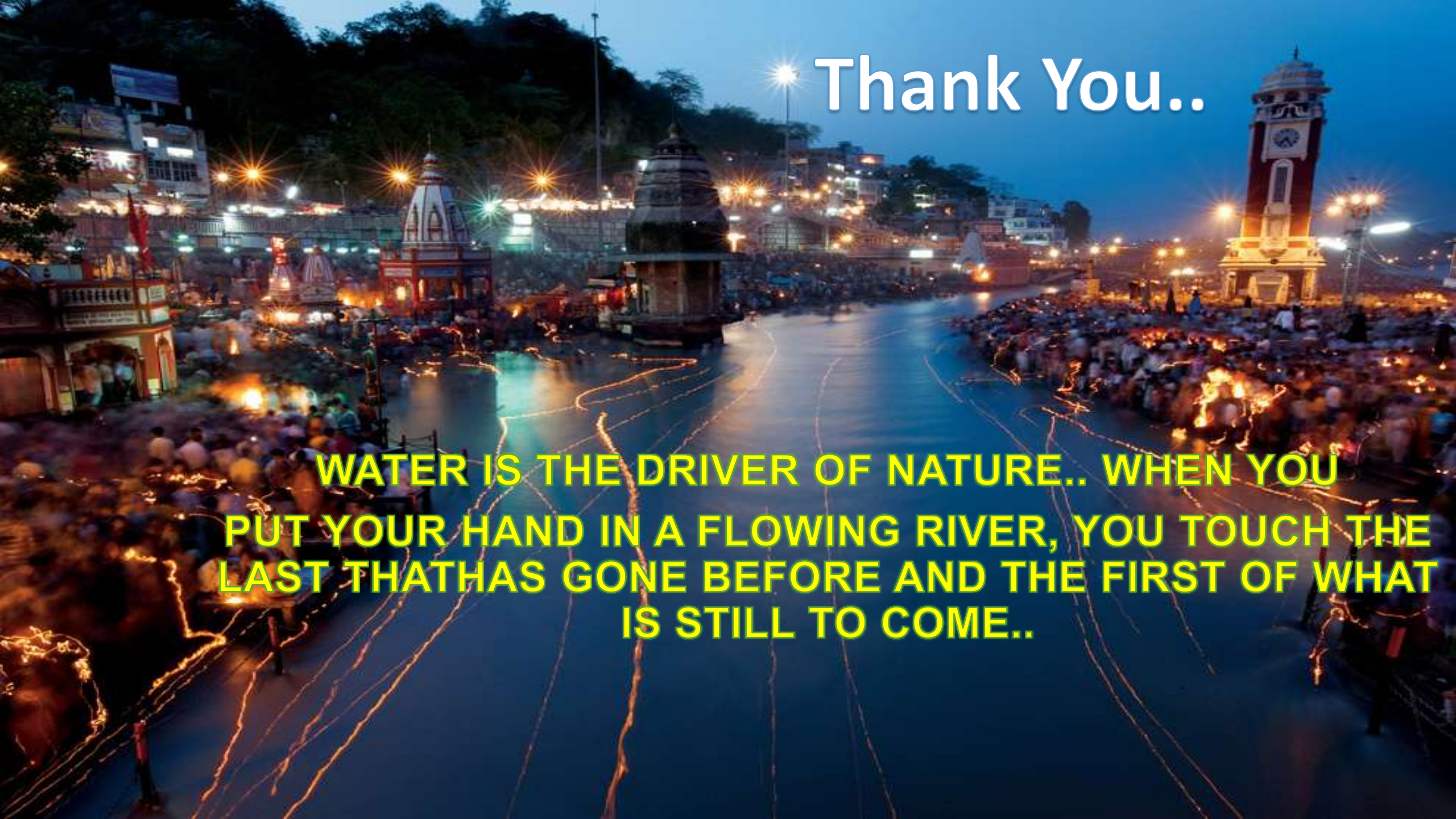
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A night scene of a crowded riverbank, likely in Haridwar, India. The river flows through the center, reflecting the lights. On the right, a tall clock tower stands prominently. On the left, there are several temples and structures, including a large one with a dome. The banks are filled with people, and the scene is illuminated by streetlights and temple lights.

Thank You..

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