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The physical analysis of Yamuna River and study of socio-economic issues: A case study of Delhi

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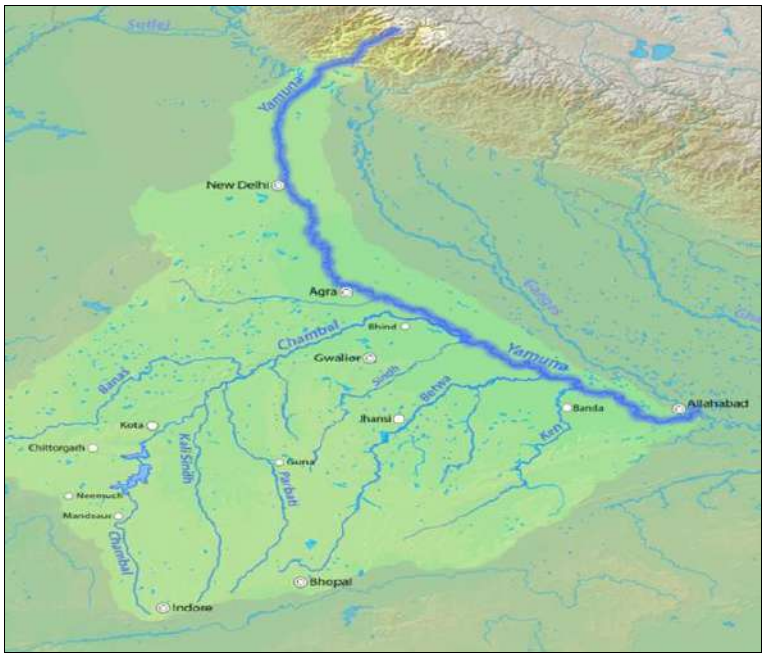
Abstract
This paper majorly focused upon the physical characteristics of the river Yamuna in all the five states through which the river flows i.e. Uttrakhand, Haryana, Delhi, Uttar Pradesh and Himachal Pradesh which includes the morphology of the river, the Yamuna plain, river's environmental flow, its water quality, annual flood etc. and the impact of human activities on these characteristics which mainly have caused change in river course, deteriorated its water quality, increase in pollution level due to agricultural and domestic and industrial waste that is going directly into the river, draining of many small and big drains into the river, inability of the authorities to manage the sewerage waste and regulating idol immersion during festivals. The paper also analyze the efforts of government in this regard and shows the importance of state to revive some natural entity.

Keywords: Flood, biodiversity, environmental flow and morphology

Introduction

Study area

The study area includes a detailed analysis of all the characters including river course, environmental flow, water quality, biodiversity and annual flood in river Yamuna which will be examined thoroughly here in this report.



***Source*:** https://images.app.goo.gl/zQwmhLypca9X92pE9

Map 1: Map of study area

Statement of the problem

As rightly quoted by Mahatma Gandhi "be the change that you want to see in the world" I consider it my personal and moral responsibility to delve into the problems that my surroundings suffer from. Being a native of Delhi and living near River Yamuna the changes that I have seen are disturbing. Hearing news like Yamuna is dead seems extremely unnatural to me which is why I wanted to study the river in depth for which I had to delve

into the physical characteristics of the river to understand the socio economic impact on the river.

This paper majorly focused upon the physical characteristics of the river Yamuna in all the five states through which the river flows i.e. Uttrakhand, Haryana, Delhi, Uttar Pradesh and Himachal Pradesh which includes the morphology of the river, the Yamuna plain, river's environmental flow, its water quality, annual flood etc. and the impact of human activities on these characteristics which mainly have caused change in river course, deteriorated its water quality, increase in pollution level due to agricultural and domestic and industrial waste that is going directly into the river, draining of many small and big drains into the river, inability of the authorities to manage the sewerage waste and regulating idol immersion during festivals. The paper also analyze the efforts of government in this regard and shows the importance of state to revive some natural entity.

To make this point valid that the river can be revived from a dead state to a live one I have added some case studied that show that a systematic effort can bring some good results that are for the benefits of the human as well as environment.

Apart from this the annual flood though bring numerous benefits and a revival to the Yamuna floodplains but it also brings many problems that are faced by people residing in these floodplains. The annual flood is supplemented by annual migration of people residing here. The most important thing to note here is that this migrated population is the lower class, poor, deprived people who have to settle on temporary shelters during floods. This paper also analyze this aspect to understand deeply the relationship between a natural service provider and human community. So overall the paper focuses upon the physical morphology of the river and how this nature's gift is being modified through some anthropogenic activities.

Objectives

1. To study physical attributes of Yamuna river.
2. To study socio-economic attributes of Yamuna River.
3. To study Yamuna plains and annual flood.
4. To study the ecological flow of the river.
5. To study the problem of pollution in Yamuna river.
6. To study the government actions taken for wellness of the river.

Data base

The data collected is secondary data collected mainly through various government sites and various articles published online, a lot of literature scrutiny has been done to maintain the authenticity of the paper, and the secondary data is complemented by primary data collected mainly through personally interviewing people and getting a lot of information through the people living near study area.

River Yamuna

The River Yamuna is the largest tributary of River Ganga. This river is as prominent and sacred as the great River Ganga itself. There are various pilgrimage centers e.g. Yamunotri (Uttaranchal), Paonta Sahib (Himachal Pradesh), Mathura, Viridian, Bateshwar & Allahabad (all in Uttar Pradesh) are located on the banks of this river.

Large urban centers e.g. Yamuna Nagar, Sonepat, Delhi (the political nucleus of India), Gautam Budh Nagar, Faridabad, Mathura, Agra and Etawah are also established on its banks. Large industrial centers have also been developed either on banks or in its basin.

In agriculture front also the Yamuna basin is one of the highly fertile and high food grain yielding basin, especially areas in Haryana and Western district in Uttar Pradesh. All this reflects that the River Yamuna not only flows in the hearts of India but also plays a significant role in the economy of the country.

The total length of Yamuna River from origin at Saptrishi Kund to its confluence with Ganga at Allahabad is 1,376 km traversing through five states. The main stream of river originates from the Yamunotri glacier (Saptrishi Kund) near Bander punch peaks (380 59' N 78027'E) in the Mussoorie range of the lower Himalayas at an elevation of about 6,320 meter above mean sea level in Uttarkashi district of Uttaranchal. The head waters of Yamuna river are formed by several melt streams, the chief of them gushing out of the morainic smooth at an altitude of 3,250 m, 8 km North West of Yamunotri, hot springs at the latitude 310 2'12" N and longitude 780 26' 10".

The river enters into the plains at Dak Patthar in Uttarakhand where the river water is regulated by a weir and is diverted into canal for power generation. From Dak Pathar, the Yamuna flows the famous Sikh religious shrine of paonta sahib. Flowing through Paonta Sahib, it emerges from the foothills of Kalesar, north of Tajewala. It reaches Hathnikund in Yamunanagar district of Haryana state, where the river water is diverted into Western Yamuna canal and Eastern Yamuna canal for irrigation. During dry season, practically no water flows in the river downstream of Tajewala barrage and river remains dry in several stretches between Tajewala and Delhi. Ground water accrual and contributions from seasonal streams again regenerate the river. Yamuna River enters Delhi near Palla village after traversing for about 224 km. Further downstream there is a barrage at Wazirabad which supplies drinking water to the city of Delhi. Generally, the flow in the river downstream of the Wazirabad barrage is almost nil in dry season because the available water is not adequate to meet the demand of Delhi. About 22 kilometers downstream of the Wazirabad barrage, the Yamuna water is diverted into the Agra Canal for irrigation through the Okhla barrage. Generally, the water flows through barrage during dry season is nil. Whatever water flows in the river beyond the Okhla barrage is contributed through domestic and industrial wastewaters generated by East Delhi, Noida and Sahibabad and joins the river through the Shahdara drain. Further downstream, Yamuna flows through the Agra city and reaches Mathura. The total length of the Yamuna from its origin to Allahabad is 1,376 kilometers and the drainage area is 366,223 square kilometers.

The catchment of the Yamuna river system covers parts of Uttar Pradesh, Uttarakhand, Himachal Pradesh, Haryana, Rajasthan, Madhya Pradesh and Delhi. The area of Yamuna catchment lying in different states is shown below in Table 1.

Table 1: The Catchment Area of Yamuna River in Various States [1]

Name of the state	Catchment area in the state (sq.km)
Uttar Pradesh (including Uttarakhand)	74,208
Himachal Pradesh	5,799
Haryana	21,265
Rajasthan	102,833
Madhya Pradesh	12,028
Delhi	1,485

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Photo 1: Bandarpunch Glacier

Photo 2: Saptrishi Kund [2]

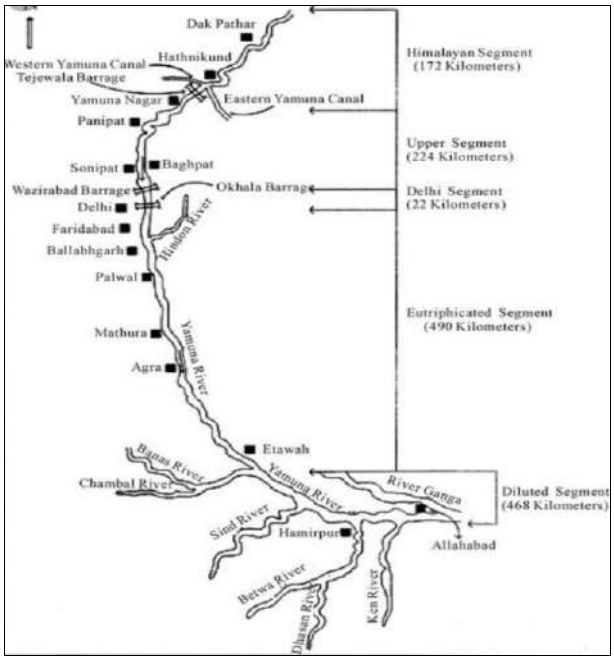
Photo 3: Origin of yamuna river: yamunoutri [3]

Segments of the River

The Yamuna river can be segmented in five distinguished independent segments due to characteristic hydrological and ecological conditions, that are Himalayan segment from origin to Tajewala barrage, upper segment from Tajewala barrage to Wazirabad barrage, Delhi segment from Wazirabad barrage to Okhla barrage, eutrophic segment from Okhla barrage to Chambal confluence and undiluted segment from Chambal confluence to Ganga confluence. The table 2 shown below shows these segments:-

[4] **Table 2:** Different Segments of Yamuna River

Name of the segment	Location	Length (Kilometres)
Himalayan segment	From origin to Tajewala barrage	172
Upper segment	Tajewala barrage to Wazirabad barrage	224
Delhi segment	Wazirabad barrage to Okhla barrage	22
Eutriphicated segment	Okhla barrage to Chambal confluence	490
Diluted segment	Chambal confluence to Ganga confluence	468



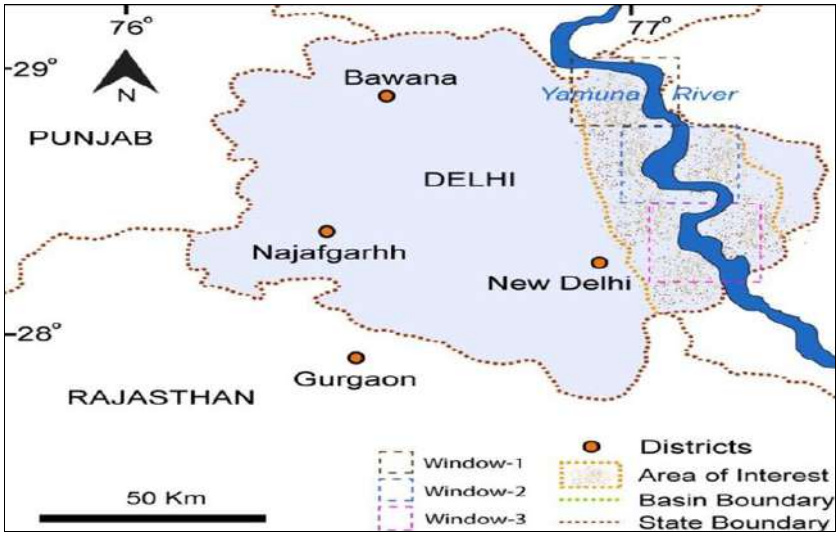
Map 2: Segments of Yamuna River [5]

River Migration

In the natural domain, rivers have tendency to migrate along their floodplains under favourable conditions, i.e., high discharge, availability of free space, regional slope, eroding agents, natural levees, extensive floodplains and a thick alluvium. In river growing stages whenever the natural boundary conditions are violated, rivers start to behave unpredictably in terms of maintaining discharge, sediment load, course shifting, flowing conditions and seasonal flooding. Below is the case study of Delhi that shows the changes in river course in Delhi.

[1] CPCB report 2006
[2] Source:- https://images.app.goo.gl/FkmbZCbavJ1u3GsKA
[3] https://images.app.goo.gl/d2jsQ72mmKCF1Lzj8
[4] CPCB report 2006
[5] Source:-CPCB report 2006

Case Study



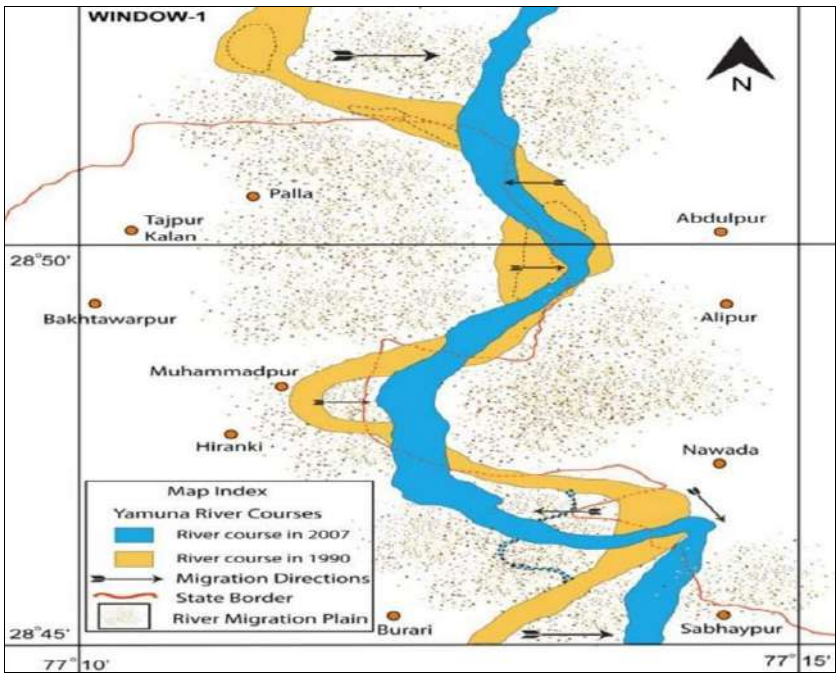
***Source*:** International journal of research in engineering and technology

Map 3: Index map of study area within Delhi region showing three windows (1, 2, 3) orange dotted borders mark the area of interest in which three windows are taken for detailed studies on river courses and floodplains

The detailed observations of the satellite images and Toposheets have been carried out to determine the relative shift of the channel and meander loops in terms of distance and direction in general to understand the dynamic behaviour of the Yamuna River. Morphology of Yamuna River has changed through the last few decades due to onset of the rapidly growing land use / land cover of the region. Due to commence of heavy urbanization within Delhi in last few decades, floodplain areas have been extensively used for the settlements. The Yamuna River has shown temporal variations both in channel position and geometry since the onset of 19th century.

Window-1 (Temporal Changes 1990 – 2007)

It shows wide migration of about 1.2 Km of river towards eastern side before entering into Delhi State which has ultimately reshaped its prominent meander into a straight course. On crossing the borderline, rive regained a shallow meander through bending its course towards Palla on the western side. On moving below near Muhammadpur, river has shown omission of a sharp meander and formation of the straight course through migrating about 0.3 Kms towards eastern side; near Nawada, river has shifted the notch of its next meander about 0.2 Km in the south-east direction. Along the point bar of this meander, a palaeochannel indicated by the dotted black line has formed due to river migration towards the eastern side. At the bottom-most part of this window, river has shifted about 0.5 Km towards Sabhaypur on the eastern side borderline.

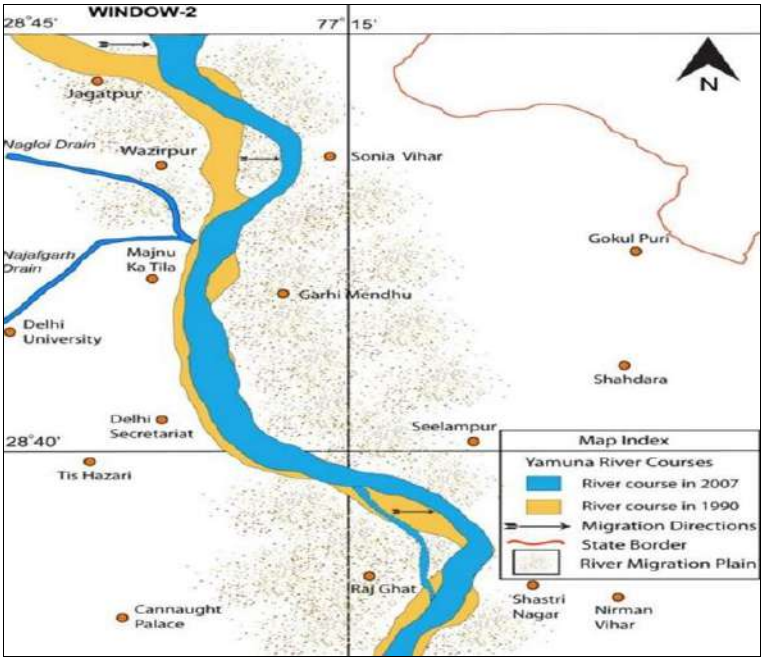


***Source*:** International journal of research in engineering and technology

MAP 4: Map of Window 1

Window-2 (Temporal Changes 1990 – 2007)

Window-2 starts with the mid-point of the meanders last marked in the Window-1, where it shows the similar trend of migration on the eastern side. However the river section between Jagatpur, Wazirpur and Sonia Vihar shows the juxtaposed meanders of similar patterns developed during 1990 and 2007. Previously existing straight course near Wazirpur has curved down into a meander by shifting about 0.2 Km towards Sonia Vihar. Along this portion, a few palaeochannels have resulted due to shifting of the river.

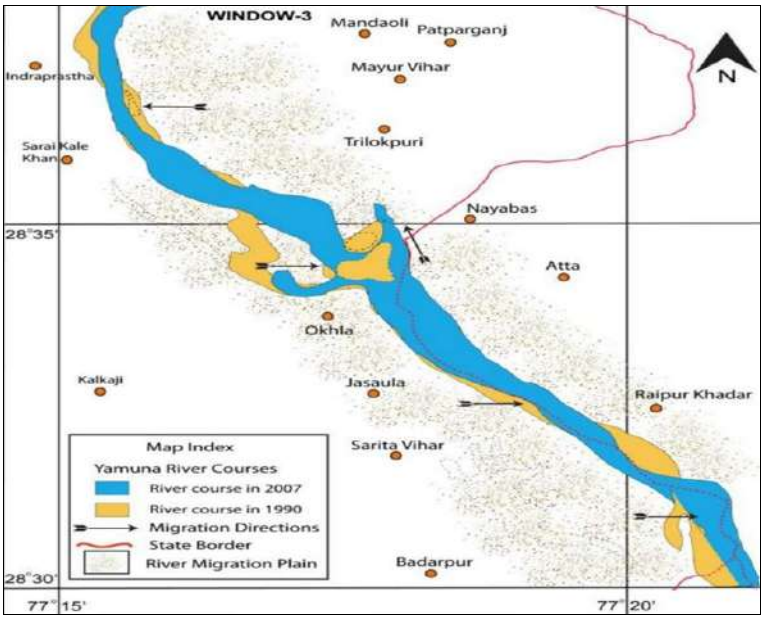


***Source*:** International journal of research in engineering and technology

Map 5: Map of Window 2

Window-3 (Temporal Changes 1990 – 2007)

This window covers the remaining part of an important stretch of the Yamuna River, i.e. from Wazirabad barrage to Okhla barrage which is the most polluted amongst all due to being drained from the heavily urbanized area. Especially in this window river finds itself completely trapped on both the flanks, therefore the river has lost its effective migration plain and forcefully maintaining its straight course. After 1990 a rapid increase in the urbanization in and around Okhla area has affected the western meanders of the river due to which its course has constricted to flow straight at a distance of 0.3 Kms. palaeochannels are left out along this section. In the lower parts of this window, river course passes along Jasaula, Sarita Vihar and Badarpur where it favours to flow congruently with the previous courses, however satellite images show that it is gradually migrating towards Badarpur on the western.



***Source*:** International journal of research in engineering and technology

Map 6: Map of Window 3

Demarcation of Yamuna Flood Plain

Flood Plains play an important role in maintaining the flow of the River, help recharge groundwater and provide a habitat for aquatic biodiversity, the most significant sign of rivers' health because the flood Plains are integral to River hydrology.

The Expert Committee, which gave its report to NGT mentions:-

- In 2014, on the steps needed for demarcation and protection of flood Plains the committee has recommended that demarcation and mapping of the flood plains once in 25 years.
- Flood Plains both in Delhi and UP portion of NCR should be done by DDA and state of Uttar Pradesh.
- It has also been recommended total removal of all encroachments and solid waste and reclaiming possessions of the flood plain, prohibition of growing agricultural crops and vegetables and permitting only floriculture and tree planting and the creation of biodiversity parks in four phases.
- There was recommendations for the creation of constructed wetlands on the flood Plains at the outfall point of all drains before they joined the River.

DDA informed the Yamuna monitoring committee that once in 25 years, flood Plains within Delhi had been demarcated and it removed encroachments that had mushroomed over 400 acres of land. It reported that more than 17,500 tonnes of Malba has been removed.

But there is lack of data or there is no data to prove their claims. There are also no claims or no strategy for the day to day surveillance of illegal activities which were taking place on the flood Plains. Environmental compensation, which was imposed by DDA under polluter pays principle was stated to have been opposed by the people and accepted as ground enough to drop surveillance.

Status of demarcation of Yamuna flood plain in 2018

Picture 1: Enchroachment of Yamuna Flood Plain By Dmrc [6]

The Committee on visit found no identifiable physical boundaries anywhere. Committee also saw large scale encroachments taking place which were visible but were not being stopped by DDA, police or any other authority. However, after 2019 DDA started taking action of installing bollards. Today the flood Plains, stretching from Wazirabad to Hazrat Nizamuddin now stands demarcated by providing 349 + 242 is equals to 591 Bullard's respectively at both stretches.

The DDA reported in 2020 that the entire flood plain now stands demarcated by providing bollards at a distance of 7200 metres between each Bullard. The physical signage boards are under fabrication and will be up to a vertical height of nine metres with the flags at a height of six metres.

Repossession of the land given to other departments

DDA has reported that 12.11 hectares of land has been repossessed from DMRC and 7.5 hectares is in the process of being handed over to DDA.

Action taken on prevention of dumping of solid waste

- Security of flood plain and installation of CCTV cameras.
- Engaged engineer to undertake foot marches along the bollards in his jurisdiction and even small encroachments are removed there and then.
- The completion of handing over by DMRC and other Department needs follow up.
- Delay in handing over 35,00,00,000 to DDA by UP government strict action should be taken on this. As the funds are connected with the rejuvenation of the River system.
- 954 hectares are still under cultivation which needs to be evicted NGT issued strict guidelines to DDA to solve this problem.
- Dumping of construction and demolition waste should be strictly regulated through CCTV cameras.

At ground level, NGOs should be taken help.

***Source*:** photo taken by me

Picture 2: Waste dumping site enchroachment

[6] Source:-picture taken by me

***Source*:** photo taken by me

Picture 3: Waste dumping in protected area of yamuna plains

Annual Floods in River Yamuna

The river faces the hazards of annual floods, susceptibility to erosion and adverse impacts. The tributaries contribute 70.9% of catchment area and balance of 29.1% accounts for direct drainage into the Yamuna River or to the smaller tributaries. On the basis of area, the catchment basin of Yamuna is estimated to be 40.2% of the Ganga basin. The river faces the hazards of annual floods, susceptibility to erosion and adverse impact of anthropogenic factors. Nature cannot take more abuse. Hence the degradation caused to the environment of the city has to respond in terms of its wrath. A case study of Delhi is presented below in this regard.

Flood in Yamuna

Keeping in view the topography, Yamuna catchment upto Delhi is divided in two parts - (1) The upper catchment from source in Himalayas to Kalanaur in Haryana - which comprises parts of Himachal Pradesh and hills of West Uttar Pradesh and (2) the lower catchment from Kalanaur to Old Delhi rail bridge which consists of West Uttar Pradesh and Haryana. The flow of Yamuna within Delhi is by and large influenced by discharge from Tajewala Headwork 240 kms upstream. In the event of heavy rain in the catchment area excess water is released from Tajewala. Depending upon the river flow level downstream, it takes about 48 hours for Yamuna level in Delhi to rise. The rise in water level also causes backflow effect on the city's drains. The city also experiences floods due to its network of 18 major drains having catchment areas extending beyond the city's limits.

The city has been experiencing floods of various magnitudes in the past due to floods in the Yamuna and the Najafgarh Drain system. The Yamuna crossed its danger level (fixed at 204.83 m) twenty five times during the last 33 years. Since 1900, Delhi has experienced six major floods in the years 1924, 1947, 1976, 1978, 1988 and 1995 when peak level of Yamuna River was one meter or more above danger level of 204.49m at old rail bridge (2.66 m above the danger level) occurred on sixth September 1978. The second record peak of 206.92 m was on twenty seventh September 1988.

As per the map of the flood prone areas of Delhi, it has been classified into thirteen zones based on the flooding risk in relation to incremental rise in the water level of the Yamuna (DDA, 1993). These cover a range from 199 m to 212 m level of water in the Yamuna. This zoning map covers parts of North Delhi on the West bank of the Yamuna and almost the entire Trans Yamuna Area on the East bank.

Although the unprotected flood prone area is only 1.7% or 25 km only towards the south east and about 5% or 74 sq km in the north eastern parts which is protected by earthen embankments, every year water level ruses in Yamuna above danger level and large population has to be evacuated to the top of the bunds and Delhi highways.

As already stated, main reasons for this rise of water level is not natural but release of excess water from Tajewala head works upstream to the two canals one on left and other on the right bank of the river. Rise in water levels also cause back flows in the connecting drains and have effect on the city drain network causing overflow, cause of many monsoon related diseases.

Local Flooding

A significant phenomenon which has been increasing during recent years is that of local flooding. Urban areas are characterized by a high area under impervious surfaces (Roads, pavements, houses etc). High rates of development along with the resultant loss of soft landscape has led to high surface water run-off rates. This results in flash floods in the low lying areas even after moderate precipitation. Another factor adding to this effect is that of river because the river is already flowing at a higher level within its embankments. Thus, the water gets logged in the city areas and it takes several days to mechanically pump it out and bring the situation under control. Similarly, during the past few years, flooding due to the city's 18 major drains has also become a common phenomenon. Already under the pressure of the city's effluent discharge, these drains experience reverse flow from the Yamuna, which is in spate, and as a result they tip their banks, flooding the neighbouring colonies.

Picture 4: Delhi Iron Bridge in normal conditions

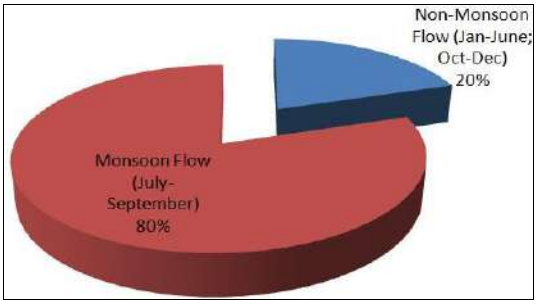
***Source*:**http://revenue.delhi.gov.in/wps/wcm/connect/DOIT_DM/dm/home/vulnerabilities/hazards/floods#:~:text=This%20is%20very%20clear%20from,to%20choked%20drains%20of%20Delhi

Picture 5: Delhi Iron Bridge during flood conditions

River Flow

The river has extremes of dry as well as flood conditions during a year. Due to high population density of the

catchment, the river remains almost in dry state during January to June in many parts of its stretch and under flooded conditions during July-September. The river is dissected at 5 barrages during its course i.e. at Dak Patthar (about 160 km from origin in Uttaranchal); at Hathnikund (172 km distance from origin, just at foothills in Haryana); at Wazirabad (in NCT Delhi, 396km distance from origin); at Okhla (in NCT – Delhi, 418 km distance from origin); and at Mathura (Near Gokul village in U.P. about 570 km distance from origin). These barrages are the major water abstraction locations on the river. The water is contributed into the Yamuna River, not only through its tributaries but also by the canals and drains from various urban centres.



***Source*:** CPCB report 2006

Fig 1: Flow of Yamuna during monsoon and non-monsoon period

Uses of Yamuna River Water

The river water can be used either in abstracted form or as non-abstractive or in-situ water uses.

Abstractive Uses

The river water is abstracted at different locations for varied uses. At two places i.e. Hathnikund / Tajewala and Okhla, the water abstraction is significant.

Domestic Water Supplies

Significant use of Yamuna water for domestic water supply is found in urban agglomerations like Delhi, Mathura, Agra and Allahabad.

Irrigation

Irrigation is an important use of Yamuna river water. It has been estimated that about 92% of Yamuna river water is used for irrigation. In the entire Yamuna basin the irrigated land is about 12.3 million hectares and approximately half of it (about 49%) is irrigated exclusively from surface water. At present there are four irrigation canals transporting the Yamuna river water to the command areas.

In stream uses

Hydropower: The total potential for hydropower development in the entire Yamuna basin is about 1300 MW. The present utilization is only one third of total potential.

Fisheries

The Pisciculture is neither practiced on large scale nor undertaken in organized manner in the area. However, the entire river stretch and tributaries is being utilized for fishing in unorganized manner.

Growing aquatic plants

The most prevalent aquatic plant in River Yamuna is the water hyacinth, mostly found near barrages.

Navigation

River Yamuna and its tributaries are not suitable for Navigation. Low flow of river further restricts this activity. However, some potential exists to use the stretch between Agra and Allahabad for navigation.

River bathing and washing

River bathing and washing is one of the most prevalent uses of river water in the country. Much of this is attributable due to religious rituals.

Recreational uses: The Yamuna River is used very rarely for recreational purpose due to unsuitable conditions like Rocky River bed, low water depth etc. However, at urban centers and at various barrages it has the potential for water sports like boating.

Cattle bathing and washing: It is estimated that about 70% of the total cattle population in the Yamuna basin uses flowing water of river and canals for bathing and watering purposes directly which impacts water quality substantially.

Environmental flow

Environmental flow is the flow needed to support the minimum aquatic life of the river system. As a living River Yamuna should be able to fulfil its ecological function, which includes recharging the groundwater aquifers, carrying nutrient rich alluvial sediment, supporting biodiversity, and aquatic life and providing for social and cultural needs of the riparian populations. The Central Pollution Control Board has specified that the River must achieve at least bathing standards. But at present, influx of domestic sewage and industrial waste it lacks the basic minimum criteria of freshwater. As almost all the water present in the River is diverted for various consumptive uses at the Hathinikund barrage in Yamuna Nagar. The Yamuna monitoring committee directed, state of Haryana shall release of 10 Cumecs water directly into mainstream of River near Hathnikund barrage and maintain E-flow of the River till wazirabad.

The report given by Yamuna monitoring committee states that, in 2018, 10 cumecs of water as ordered by NGT is indeed being released downstream of Hathnikund barrage. However, almost all the freshwater released either evaporates or percolates into the riverbed during the lean season before it reaches Wazirabad. Consequently, no freshwater is released into the River downstream over a bar during the lean season, and whatever flow is present in the River is the domestic sewage and industrial effluent joining the River through 22 storm water drains.

Since 2015 no E-flow study has been undertaken for Delhi stretch of the River. Also, the recommendation of deepening of the water bodies and wetlands upstream over Wazirabad has not been undertaken.

The recommended releases during the lean season months from December to May, are aimed at maintaining required habitat conditions for the indicator fish species of Indian carp, ramus, Bola and Indian trout.

Recommendations given by NGT

- All the stakeholders should treat E-flow as a critical parameter for revival of the River.
- The riparian states of Uttarakhand, Haryana, Himachal Pradesh, Uttar Pradesh and Delhi who are beneficiaries

states under "The water sharing agreement of 1994" to rework the water sharing agreement to permit release of recommended E-Flow at Hathnikund barrage.

- The riparian states should maintain policies and water conservation measures including measures for enhancing water use, efficiency of agricultural practices and promoting cultivation of less water intensive crops through price support mechanisms.

Table 3: Rate of fall of water in Yamuna River

Stretch	Length of stretch (IN KM)	Rate of fall (M/KM)
Upper Himalayan stretch	25	59.0
Himalayan stretch	152	19.1
Total plain stretch	1224	0.2
Lower plain stretch	768	0.08

***Source*:** CPCB report 2006

Biological oxygen demand

- The BOD level in the Yamuna from its origin till Palla has been observed generally between in the rage of 1-3 mg/l with annual average not exceeding 3 mg/l. This is due to the fact that there is no significant wastewater outfall in the river and adequate fresh water available in this river stretch. However, the BOD concentration rises beyond the desired standard i.e. from 3.0 mg/l to 6.0 mg/l between Kalanaur to Palla. This may be either due to accidental discharges of wastewater from urban agglomerations located upstream to these locations or due to human / animal activities in the river e.g. washing, defecation etc.
- There has been significant increase in the BOD level downstream Wazirabad barrage at Delhi immediately after the biggest drain i.e. Najafgarh Drain joins river Yamuna. The BOD has been found exceeding the standards even after Chambal Confluence at Juhika.
- At Nizamuddin Bridge, Delhi the BOD level in the Yamuna River has been in the range of 3 to 51 mg/l with annual average varying from 11 mg/l to 24 mg/l. At Agra Canal the BOD level varied from 3 to 34 mg/l with annual average in the range of 9 – 18 mg/l. At Agra Canal the BOD level has been observed low in comparison to Nizamuddin Bridge, inspite of the fact that the river receives many drains downstream to this location. The possible reason for this trend may be that Okhla Barrage converts river into a big reservoir, which also act as and act as an oxidation pond. Another reason may be that this reservoir gets fresh water from Hindon Cut Canal.
- At Mazawali the BOD level was high and found in the range of 3-39 mg/l with annual average of 10 – 17 mg/l. downstream to Okhla barrages till Etawah, the river having both septic and eutrophicated patches. The abundant algal mass from eutrophicated patches generally flushed down and mixes with septic part of river, which might have interfered in the BOD measurement. Filtration of sample to remove algal contamination also removes organic materials and as such could not be practiced.
- At Mathura there is not much variation in BOD level at upstream and downstream locations. At upstream and downstream BOD level was in the range of 3 – 25 mg/l and 3 - 21 mg/l respectively with similar annual average. The reasons for high BOD level at upstream may be contribution of high BOD load by Vrindavan Oxidation Pond located upstream to river sampling location. Almost same BOD concentration at downstream location is due to Gokul barrage, which transform river again into an oxidation pond similar to Okhla Barrage at Agra upstream the BOD concentration was even higher than Mathura and has been in the range of 2-25 mg/l with annual average of 8 - 12 mg/l between year 1999 and 2005. The reason for higher BOD may be contribution of BOD load from Buria Ka Nagla STP and other wastewater discharges, garbage disposal etc.
- After river location Nizamuddin Bridge, Agra downstream is worst polluted. At this location BOD ranged from 4 – 43 mg/l with annual average of 12-28 mg/l. During the year 2001 the average BOD value at Agra downstream was more than the value at Nizamuddin Bridge. The possible reason for this may be due to significantly low dilution in the river because of prolonged dry season or incomplete diversion of wastewater from source to STP. After Agra downstream there was fall in the BOD concentration though it was higher than the desirable limit except at Allahabad.
- At Bateshwar BOD has been found in the range of 1 – 31 mg/l with annual average of 8-12 mg/l and at Etawah it was in the range of 1 – 24 with annual average of 6-14 mg/l. At Juhika after getting dilution from River Chambal the BOD levels drop significantly and varied between 1 – 10 mg/l with annual average of 3 - 5 mg/l. At Allahabad the BOD level ranged between 1 to 3 mg/l with similar annual average.

Chemical oxygen demand

- It has been observed that besides the wastewater discharges that Yamuna River receives at various places, excessive presence of algal mass (due to Eutrophication) also contributes significantly to COD.
- Upto Palla the COD was in the range of 1 - 49 mg/l. The COD was observed lowest at places located either in hilly stretch or near foothill.
- From Lakhwar dam till Kalanaur the annual average of COD was never exceeded 10 mg/l and was in the range of 2-10 mg/l.
- At Sonepat and Palla the annual average of COD was 9-17 mg/l. From downstream Wazirabad the COD level increased drastically and remained on higher side at Juhika even after receiving Chambal River. The range of COD at this portion of river varied from 3-155 mg/l.
- The maximum COD values observed at stretch between Nizamuddin Bridge to Juhika was more than 60 mg/l. At Allahabad it ranged between 5-18 mg/l. At Nizamuddin Bridge the annual average of COD was 50-76 mg/l, which reduced slightly at Agra Canal after getting higher retention time and also dilution from Hindon cut canal and was in the range of 40-64 mg/l.
- At Mazawali (Palwal) COD exceeded again with annual average in the range of 44-68 mg/l due to persistence of septic or eutrophic condition or the combination of both the COD level.
- At Mathura upstream, downstream and Agra upstream there has been no significant variation in the annual average of COD and it has been observed in the range of 30 to 53 mg/l. The location at Agra downstream is

again the highly polluted in terms of COD location, where it ranged between 11-155 mg/l with annual average of 45-86 mg/l.

- At Bateshwar, the river water quality has been almost similar to that of Mazawali and here the annual average varied from 32 – 55 mg/l. The annual average of COD at Etawah was ranged between 32 – 52 mg/l.
- At Juhika after receiving water from Chambal river, annual average of COD reduced and it was in the range of 15-25 mg/l. At Allahabad the annual average values of COD got reduced may be due to effect of dilution and it varied between 7-14 mg/l. There was no significant variation in the COD values at mid and quarter stream at impact locations.

Micro Pollutant Characteristics of Yamuna River Sediment

- Seven heavy metals & five pesticides were monitored on quarterly basis at Palla and impact locations. The micro-pollutants adsorbed by the organic matters present in the river water and settled down at the river bottom as sludge. Flushing of sludge again slowly released them in the water.
- The settlement of the micro pollutants in the riverbed is not uniform, therefore, it is difficult to find out the co-relation of micro pollutants concentration in water & sludge. This is also a reason that accurate sludge sampling to find out true picture of micro-pollutant in sludge is often not possible. Except iron, the concentration of all other studied heavy metals are either not traceable or present with very low concentration.
- In the month of June, 2004 the lead and chromium concentration in March, 2001 was as high as 0.233 mg/g and 0.099 mg/gm at Agra downstream & Mathura d/s respectively. Nickel in June, 2002 & zinc in June, 2004 was high with a concentration of 0.793 mg/g & 3.408 mg/g at Agra d/s.
- The concentration of cadmium was at maximum with 0.232 mg/g in December, 2002 at Agra D/s whereas copper with 1.229 mg/g was at the peak at Agra d/s in June, 2004. Maximum concentration of iron i.e. 57.172 mg/g was observed at Mathura D/s in September, 2002.
- Those metals, which were not traceable or having very low concentration in river water e.g. cadmium, nickel and lead were observed in sediment may be due to their build up concentration at the bottom deposited sludge.
- Among pesticides, Aldrin was not traceable in the year 1999 & 2003 to 2005 and its maximum concentration as 21.13 ng/g was observed in March, 2001 at Mathura d/s. Maximum level of BHC (801.19 ng/g) was observed at Agra downstream (June, 2005), whereas Dieldrin with concentration of 234.07 ng/g was at maximum at Agra D/s (March, 2003).
- Endosulfan was generally not traceable and its maximum concentration (612.18 ng/g) was observed at Agra Canal (December, 2002) DDT reflects its persistence with maximum concentration peak of 79.97 mg/g at Nizamuddin Bridge (September, 2002).

Seasonal Variations in Water Quality

- The physical characteristics i.e. discharge and drainage area of Yamuna river varies significantly during non-monsoon (January to June & October to December) and monsoon period (July to September). Therefore, an attempt is made to find out the variation in river water quality during these two seasons. For four parameters i.e. dissolved oxygen, Biochemical oxygen demand, Total and Faecal coliform, seasonal variations was also analysed year-wise.
- The seasonal variations indicate that in Delhi stretch the DO level was always below the prescribed limit during both the seasons except during the year 2001 when the value just touches the limit at Nizamuddin Bridge.
- After Delhi, the dissolved oxygen generally dropped down slightly during monsoon period, may be due to vanishing of eutrophic condition. The BOD concentration upto Palla was generally below the standards both in monsoon and non-monsoon periods during all the seven years. The value of BOD exceeded the limit afterwards and again meets the standards only at Allahabad.
- However, during monsoon period BOD levels generally reduced & often to meet the prescribed limit after Agra. Though, the values of total and faecal coliforms reduced significantly during monsoon period in the entire Yamuna stretch, but the values were generally high than the prescribed standards. In general it was observed that DO, BOD levels reduced during monsoon period. The total & faecal coliforms reduced in the most polluted stretch i.e. between Delhi and Agra and generally increased at relatively less polluted or clean locations. This may be due to flushing of faecal materials into the river from the catchment areas.
- There was slight decline in the pH value at majority of locations during monsoon seasons. Though from Hathnikund the Nizamuddin Bridge and Mathura downstream there was slight increase in pH values. COD which was observed in the range of 4 mg/l (Lakhwar dam) to 68 mg/l during non-monsoon period reduced (Agra d/s) during monsoon period with a range of 4 mg/l (Lakhwar dam) to 42 mg/l (Agra d/s).
- In most of the locations the ammonia and total kjehldal nitrogen were reduced during monsoon. On the basis of non-monsoon average the ammonia and TKN was in the range of 0.23 mg/l (Hathnikund) to 16.66 mg/l (Mazawali) & 1.14 mg/l (Hathnikund) to 22.86 mg/l (Mazawali) respectively. During monsoon period same were in the range of 0.17 mg/l (Dak Pathar) to 6.99 mg/l (Mazawali) and 1.40 mg/l (Lakhwar Dam & Kalanaur) to 12.77 mg/l (Mazawali) for ammonia and TKN respectively. The conductivity was also fallen down at all locations with a range of 208 (Mathura u/s) to 1403 (Agra D/s) µmhos/cm and 175 (Lakhwar Dam) to 824 (Agra d/s) during non-monsoon and monsoon period respectively.

Water Quality Issues in Yamuna River

The issues related with water quality of Yamuna River are described as follows:

High organic contents

River Yamuna receives significantly high amount of organic matter, which is generally, originates from domestic sources. For biodegradation, this organic waste requires oxygen, causing significant depletion of dissolved oxygen in river water. The oxygen depletion not only affects biotic

community of the river but also affects its self-purification capacity. This problem is critical in the river stretch between Delhi and confluences of river with Chambal. In Delhi stretch, the load of organic matter is so high that it consumes the entire dissolved oxygen available in river water.

High nutrients

The organic matter after biodegradation release nutrients in the water. High nutrients concentration leads to Eutrophication, a condition characterized by significant diurnal variation in dissolved oxygen concentration and excessive algal grown.

Excessive presence of pathogens

Continuous flow of sewage waste, dumping of animal dead bodies etc. and instream uses of water like bathing, cattle wading etc. contribute significant load of pathogens in the river water making it unsuitable for drinking and bathing purposes.

Accumulation of pollutants in the catchment area

Organic, inorganic and toxic pollutants generated from agricultural and industrial sources are accumulated near the source during dry seasons and get mixed with river water posing threat to aquatic life during monsoon or percolated to ground water and making water unfit for human consumption.

Aesthetic value

Yamuna river losing its aesthetic value, glory due to severe odour that releases to the surrounding environment from the anaerobic activities occurring in the river strata and the ugly surface look contributed by blackish water, floating of garbage, plastic bags, dead bodies of animals. The religious activities and tourism are greatly affected because of these transformed characteristics of river water.

Deforestatin in the catchment area

Forest cover in the catchment area of Yamuna is vanishing rapidly. This leads to soil erosion with the rainfall. This result mixing of high amount of silt, mud etc. in the river water, which in turn increases the turbidity. The turbidity of river water is also increased due to direct influx of domestic and industrial wastewater. Increased turbidity has an impact on the productivity of water body besides affecting biotic life of aquatic system.

Reduction in the quantity of water

The fresh water of Yamuna River is over exploited for irrigation use, drinking and industrial uses resulting very little or sometimes no water in the river at certain locations during summer season. The water scarce condition is so severe that to avoid percolation and evaporation losses, the Delhi's share of Yamuna water transported through WJC and added back into the river through Drain No. 2. All this leads to stagnation of water and formation of dry zones in the drainage area of the river. Non-availability of fresh water hampers the purification capacity of the river and causes increase in concentration of pollutants in the river water.

Use of river stream for transportation of water

The Delhi stretch of Yamuna River is being used for transportation of water from one water body to another for irrigation purpose by Haryana and Uttar Pradesh. This transportation activity may dilute or add the pollutants affecting the water quality of river.

Discharges from sewage treatment plants into the river

Sewage treatment plants (STP's) have been constructed at various urban centers to conserve the water quality of Yamuna River. The treated, untreated or partially treated sewage from these STP's generally discharged directly or through carrier drain into the river. Prior to installation of STP's the sewage of urban centers was discharged and get mixed with river water at various locations in the wide stretch of river through long & slow transportation system. After installation of STP along with swift collection and transport system, the sewage from urban centers concentrated at few places, where STP's are located. The connection of STP with the river sometimes poses great threat to water quality during non-operation of STP due to unavoidable reasons e.g. power failure, mechanical problems or maintenance of plants. In such cases the collected sewage is generally bypassed and discharged into the river at few locations without any treatment. Such problem is very significant in those stretches of river where the STP's are located upstream of the river e.g. Mathura-Vrindavan and Agra. The discharges from these STP's located upstream from water abstraction point have impact on the water quality making it unsuitable for various human activities occurring down stream of these STP's.

Role of barrages

Presently there are six barrages in the Yamuna River and some other are in planning stage. The barrages have impact on characteristics of Yamuna River:

- Blocking the continuity of the river, which is a prominent characteristic of lotic (flowing) environment.
- Less demand of irrigation water or rainfall in the catchment area leads to intermittent release of water from the barrages and thus affecting the river water quality.
- Sludge containing inorganic, organic, toxic matters are generally get deposited at upstream of barrage. This settled material flushes to downstream along with sudden release of water from the barrages. Thus, pollutants mixed further with the river water at downstream, deteriorating its quality.
- The water generally releases from barrages during monsoon after a gap of 6-9 months. The water releases from the barrage after a considerable gap period, significant amount of deposited sludge in downstream reaches, which is dominantly organic in nature also flushes with it and flow in the river downstream. This sludge after mixing with the water at downstream consumes the available dissolved oxygen rapidly resulting into fish mortality and killing of other fauna of the river.
- Besides the negative impact of barrages on river characteristics, barrages also have one positive impact. Barrage forms some sort of reservoir towards upstream. This reservoir acts as oxidation pond to treat.

***Source*:** https://sandrp.in/2020/07/29/yamuna-river-floodplain-abused-in-delhi/amp/

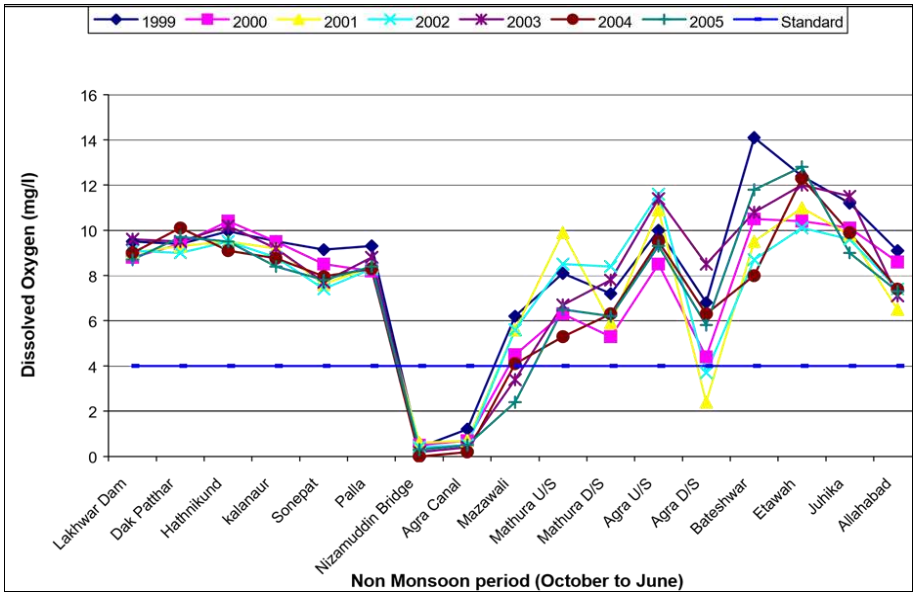
Picture 6: Showing water pollution difference between Delhi section and Haryana section water

***Source*:** photo taken by me

Picture 7: Idol Immersion and Pollution in Delhi Segment of Yamuna

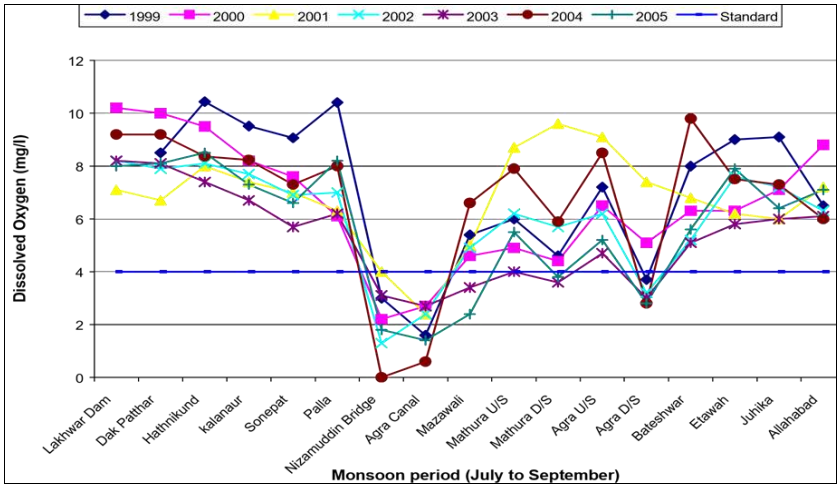
***Source*:** photo taken by me

Picture 8: Pollution of Worship Leftover near Wazirabad Barrage

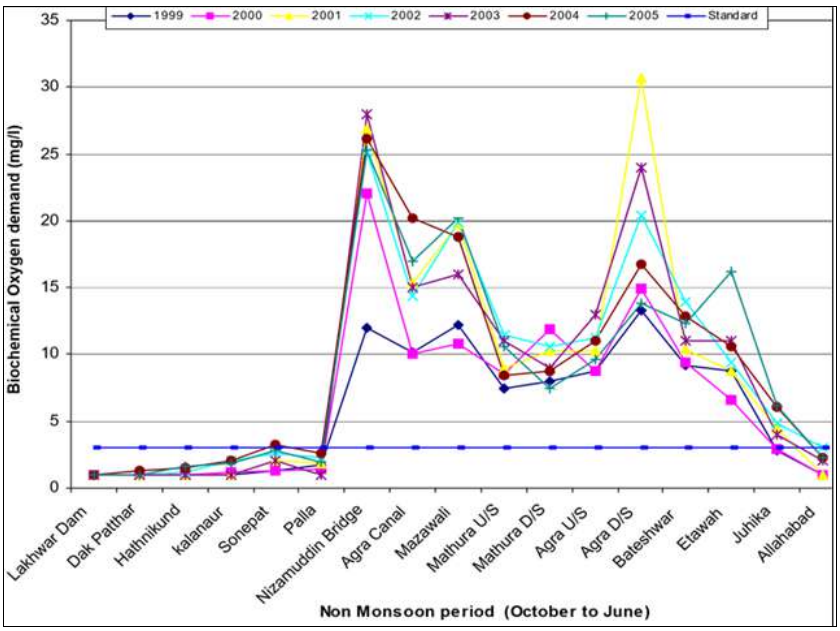


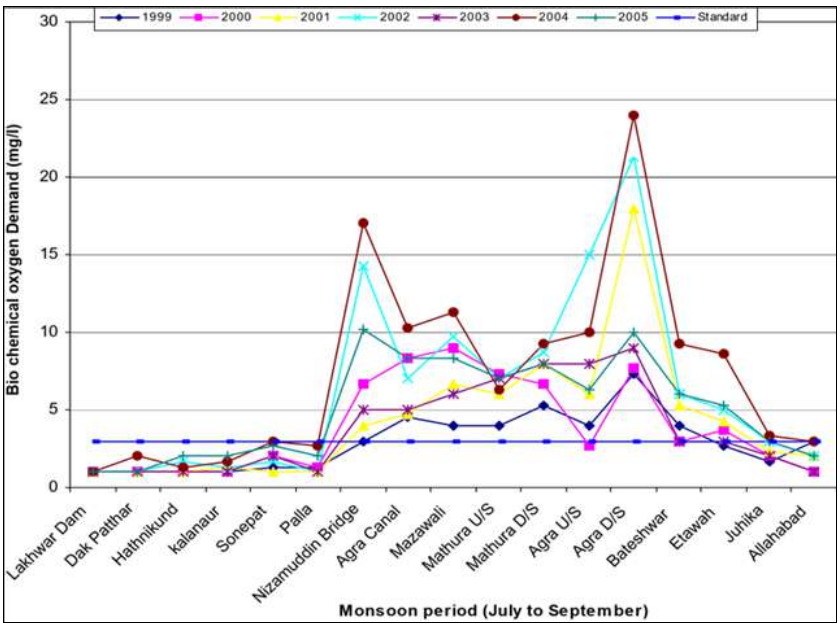
[7] **Graph 1:** Seasonal Variation in Dissolved Oxygen in Yamuna River

[7] CPCB report 2006



[8] **Graph 2:** Seasonal Variation in Bio-chemical Oxygen in Yamuna River





[8] CPCB report 2006

Yamuna action plan

Yamuna Action Plan (YAP) to clean the dirtiest river of the country was formally launched in 1993. The YAP has so far completed two phases as YAP-I and YAP-II. The YAP-I covered Delhi, eight towns in Uttar Pradesh and six towns in Haryana. Under YAP II, emphasis was on the 22-km stretch of Yamuna in Delhi. Now we have YAP-III, phase III of Yamuna Action Plan for Delhi, at an estimated cost of Rs 1,656 crore. In 2013, the YAP-III was initiated and is supposed to be completed by 2015. This is a bilateral project between the Government of India and Japan. The Japanese Government has provided financial grant of 17.7 billion yen to carry out the project, under the Japanese Bank for International Cooperation (JBIC), and this project is being executed by the Ministry of Environment and Forests, National River Conservation Directorate and the Government of India. Under the Yamuna Action Plan Phase III, the Delhi stretch is given prime emphasis as it is the most critical stretches of Yamuna, where most of the city's sewage is dumped.

The main activities covered under YAP were interception and diversion works, pumping stations, STPs, low cost toilet complex, crematorium, plantation, bathing ghat / river front development, public participation and awareness and computer networking system.

The limitation of yap 1

- The STP capacity created remained under-utilised to the extent of 25-45% because of severe limitations in the collection system and power availability.
- The strategy in YAP-I did not adequately address non-point sources.
- Municipalities and agencies which were responsible for Operation & Maintenance (O&M) of sewerage infrastructure were constrained to maximize the operational efficiency of the system due to a combination of factors related to skills, finance, management systems, power cuts and upstream sewerage infrastructure.

Subsequently, the work continued with the launch of YAP phase II (YAP II) in the year 2004 with the senctioned cost of 647 crores. The project was completed in 2008 Under YAP II, emphasis was on the 22-km stretch of Yamuna in Delhi. The Yamuna Action Plan Project Phase II is regarded as the core project under the National River Conservation Plan of Government of India. The project addresses the abatement of severe pollution of the River Yamuna by raising sewage treatment capacity, caused by rapid population growth, industrialization and urbanization. The plan includes building new and expanding capacity of old sewage treatment plants and laying and rehabilitating sewers to enhance the treatment capacity particularly in Delhi and Agra. Public participation and awareness were also a part of project to ensure the residents' recognition of the necessity of water quality conservation in the River Yamuna, and would establish linkage between the river conservation and their own living environments. But, there had been no concrete results even though Rs.1, 500 crore had been spent through phases one and two of the Yamuna Action Plan. It has been observed that despite of the continuous efforts to minimize the pollution load still the BOD is not decreasing.

The Yamuna Action Plan Phase - III project for Delhi has been approved by the Ministry in December, 2011 at an estimated cost of Rs. 1656 crore with loan assistance from Japan International Cooperation Agency. Besides this, two projects have also been sanctioned by the Ministry in July, 2012 at an estimated cost of Rs. 217.87 crore for taking up works for pollution abatement of river Yamuna in towns of Sonepat and Panipat in Haryana which are located on upstream of Wazirabad in Delhi.

NGT rules related to Yamuna River

As a consequence of present deplorable state of the river, NGT has given directions to take up cleaning of Yamuna under Maily Se Nirmal Yamuna Revitalization Plan, 2017. In pursuance of this direction, the Centre and the Delhi government have come together to launch projects under phase three of the Yamuna Action Plan which will cost Rs. 825 crores. This Yamuna Action Plan-3 will be the first plan to comprehensively help with sewage treatment and solid waste management along with river front development and providing a proper Chhat Ghat for devotees.

National Green Tribunal (NGT) ordered that every household in Delhi will have to pay a monthly environmental compensation to clean up Yamuna River. According to the direction, the compensation to be paid will be directly proportional to the property or water tax whichever is higher, paid by a particular household. In case of unauthorized colonies households that do not pay property tax or water bill will have to pay an amount that would be between 100 rupees to 500 rupees.

According to the Tribunal, industrial units within a particular industrial cluster have to pay these amounts on the 'Polluter Pays' Principle, for the pollution already caused by them and even which they are causing presently, as well as to prevent pollution in future on the Precautionary Principle. Major part of such costs, obviously have to be borne by the authorities concerned, let us say 2/3rd, while 1/3rd of the total costs should be borne by the industries.

WAY Forward

- Effective coordination between State and Central government agencies is required in terms of execution. It is necessary to reduce the quantity of water being drawn from the river for irrigation. Efficient irrigation methods like sprinklers or drip method should be used.
- Effective check to ensure in situ treatment of effluents is done before discharge from industries.
- Steps must be taken to relocate the existing settlements and encroachments near the floodplains and no further encroachments should be allowed.
- There should be a ban on construction of new barrages.
- Since there is shortage of landfill sites in Delhi, most wastes are dumped in the river. Keeping this in mind,

immediate action needs to be taken to identify more landfill sites in Delhi.

- Public awareness is most important prevention measure. Effective steps should be taken to enhance public awareness.

Personal experience

- To me going to the field and performing survey was the first opportunity that I got and because due to COVID we had to manage field work alone this was more difficult. But it was interesting to me as this is first time that I got this closer to a population that has seen these changes on their own over years. My methodology of working was to personally go to random people working or touring near Yamuna and asking them about the changes that they have seen over years.
- Mr. Abdul sattar who lives near one of the Yamuna's ghat, who also got many national awards for saving school children in 1997 when in a drastic accident a school bus was fell in the river and he and many others saved many children, says that Yamuna used to be very clean some 20 to 30 years ago but the condition of Yamuna today is very drastic and sometimes they face many problems such as foaming in the Yamuna and bad smell of the river.
- Talking to one fisherman it was revealed that they now earn just 50 to 200 rupees per day whereas some 12 to 20 years ago they used to earn more and there used too many varieties of fishes for example malli, singara, sauli, ek kanta.
- Talking to Inderpal, another fisherman, and the inability of government to provide these fishermen the basic grants of 10-15 thousand that they are promised was exposed.
- Personally going to the field I realized the efforts of the government are seen nowhere. Yamuna is still in a bad condition and it needs a proper strategy to convert this man made filth into a natural living river.

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