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Correlative Assessment of Water Quality and Qualitative and Quantitative Fish Production from River Yamuna, In the State NCT Delhi

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ABSTRACT:
River Yamuna originates from the Yamunotri Glacier at a height 6,387 Metres. Earlier, the waters of the Yamuna were distinguishable as "clear blue", as compared to the silt-laden yellow of the Ganges. However, due to high density population growth and rapid industrialization, today Yamuna is one of the most polluted rivers in India, especially around New Delhi, the capital of India, which dumps about 58% of its treated or partially treated waste into the river. Hence, water quality of river Yamuna has widely been studied with regard to physico-chemical characteristics. The paper presents their impact of pollution on the production of fishes in the state of NCT Delhi. The river Yamuna has been reduced to a small stream due to sewage and industrial effluents draining into it. Even though, the Govt. of India is taking stringent measures to assuage these pollution loads to save an ailing river to flourish the aquatic life, revival is not so eminent. Due to that the production and quality of fish is affected badly. Economical aspects of the state NCT Delhi has also impacted.

Keywords: Yamuna, Delhi Segment, Pollution, Biochemical Oxygen Demand, Chemical Oxygen Demand, Dissolved Oxygen, Faecal Coliform, Total Coliform, River Water Quality, Fish, Fish Production.

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INTRODUCTION

Apart of being a traditional water source, the river Yamuna has been worshipped as a goddess in Indian Culture as cultural icon and also has been a part of timeless civilization. River Yamuna is the largest tributary of the River Ganga in North India. Total length of the river Yamuna is approximately 1370 kilometres. The river Yamuna originates from the Yamunotri glacier near Bander Poonch peaks in the Mussoorie range of the lower Himalayas at an elevation ofabout 6387 Meters above mean sea level in district Uttarkashi (Uttaranchal). River Tons and Giri are the principal source of water in mountainous ranges and important tributaries of river Yamuna.

On the basis of hydrological and ecological conditions, the river Yamuna has been

segmented into five segments (shown in Table 1 and Figure 1): Himalayan Segment, Upper Segment, Delhi Segment, Eutrophicated Segment and Diluted Segment. After origin, Yamuna River flows through several valleys for about 200 km in lower Himalayas and appears into Indo-Gangetic Plains. Water quality of the river Yamuna from Yamunotri Glacier to Tajewala Barrage In the (Himalayan Segment) is good and meets all the prescribed standards of water quality parameter also. Within this segment, river water is diverted into Eastern Yamuna Canal (EYC) and Western Yamuna Canal (WYC) in Hathnikund/Tajewala in Yamuna Nagar district of Haryana state. Forcatering the water demand of the surrounding districts, no water is allowed to flow in the downstream of the Tajewala Barrage especially during summers and winters that leaves the river remains dry in many areas between Tajewala and Delhi. Majorly, water from the untreated or partially treated domestic and industrial effluents discharge by several drains flows in the river Yamuna between Tajewala Barrage and Delhi. After a flow of 224 km of upper segment Yamuna enters Delhi.

Here again, the Yamuna water is trapped by Wazirabad barrage to cater the domestic supply of water to Delhi and no water or extremely little water is allowed to flow downstream of this barrage during lean seasons. At 22 km downstream there is another barrage named Okhla barrage. This segment from Wazirabad barrage to Okhla barrage is called Delhi segment, whichis considered as the most polluted segment of the river Yamuna. This segment receives water from twenty-two (22) sewage drains of Delhi, Najafgarh drain. From here, Yamuna water is diverted into Agra canal for irrigation. River water is not allowed to flow downstream beyond the Okhla barrage during summers. Thereafter, water flow in Yamuna River is, the domestic and industrial wastewater generated from east Delhi, Noida and Sahibabad and joins the river through Shahdara drain (CWC, 2009).

Based on the water quality, the entire Yamuna River stretches may also be segmented into five distinguished stretches i.e., Himalayan stretch, Upper stretch, Delhi stretch, Mixed stretch and Diluted stretch (CPCB, 2006-07). Delhi segment, which is barely 2 per cent of the length of the river Yamuna basin, continues to contribute over 80 per cent of the pollution load in the entire stretch of the river. Virtually, there is no water in the river Yamuna for nine months (CSE, 2009). Gokul barrage, Mathura is also a reason of low flow and increased pollution of the river. The river Yamuna confluences the river Ganga and the underground Saraswati at Prayag (Allahabad) after traversing about 950 km.

Table 1: Different Segments of the River Yamuna

Sl. No.	River Segments	Segment Area		Approx. Segment Length
		From	To	
1.	Himalayan Segment	Origin	Tajewala Barrage	172 km
2.	Upper Segment	Tajewala Barrage	Wazirabad Barrage	224 km
3.	Delhi Segment	Wazirabad Barrage	Okhla Barrage	22 km
4.	Eutrophicated / Mixed Segment	Okhla Barrage	Chambal Confluence	490 km
5.	Diluted Segment	Chambal Confluence	Ganga Confluence	468 km

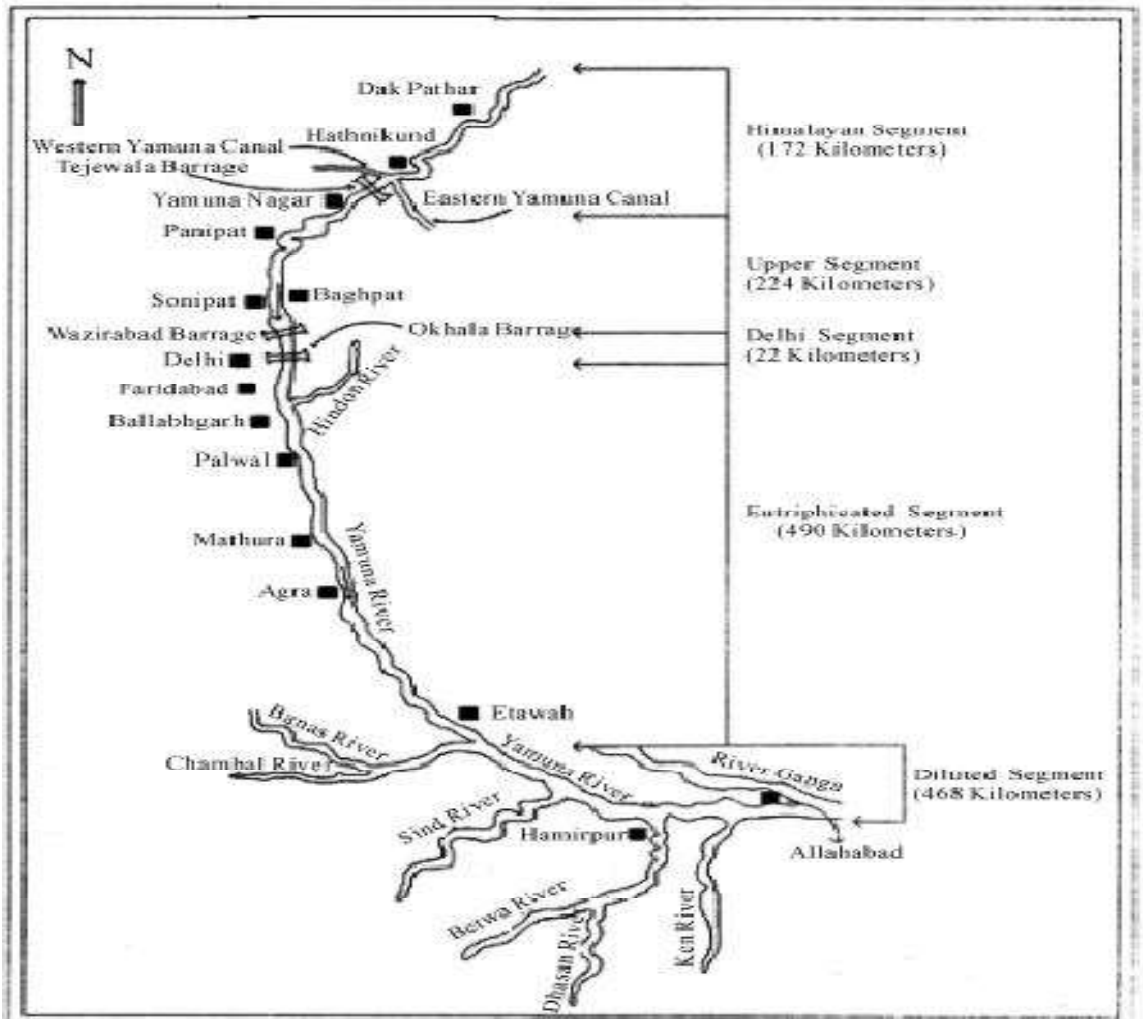

Figure 1: Segmentations of the river Yamuna

MATERIALS AND METHODS

All the data are collected from Central Pollution Control Board, Delhi, and the Office of the Director: Animal Husbandry Unit, Govt. of NCT of Delhi, Old Secretariat. New Delhi and Office of Warden of Fisheries: Govt. of NCT of Delhi, G. T. Road, Seelampur, Delhi and from official websites through the internet. All the data are secondary data used for the analysis of the above-mentioned topic of this paper.

RESULTS

Status of Yamuna Water Quality

Firstly, the criteria for a healthy river prescribed by Central Pollution Control Board, Delhi are;

1. Dissolved Oxygen: At least 5 mg/l
2. Biochemical Oxygen Demand: About 3 mg/l
3. Faecal Coliforms counts should not exceed 500 per 100 mL of water.

Table 2: Indian River water qualities have been categorized in five classes

Designated-Best-Use of water	Class	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 20°C 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 20°C 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 20°C 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 25°C micro mhos/cm Max. 2250 Sodium absorption Ratio Max. 26 Boron Max. 2mg/l
	Below-E	**Not Meeting A, B, C, D & E Criteria**

Water quality monitoring and analysis of Yamuna River is regularly carried out by Central Pollution Control Board (CPCB) since 1977. According to the Central Pollution Control Board (CPCB) the water quality of Yamuna River falls under the category "E" which makes it fit only for recreation and industrial cooling, completely ruling out the possibility for under-water life. The pollution of the Yamuna River from domestic discharges from Delhi, Ghaziabad, Noida, Faridabad, Mathura and Agra has rendered the river unfit for any use. In Delhi, around 3800 MLD (million litres per day) of sewage falling in the river Yamuna. Due to different barrages reasoning low flow and huge quantity of wastes from neighbouring cities discharging into the Yamuna River, Central Pollution Control Board (CPCB)have categorised one of the worst polluted rivers of the country. According to the status of water quality in India (2007) released by CPCB the Yamuna water quality at Okhla and Nizamuddin bridges has been described as the worst affected. Table 3 shows the diversion of Yamuna Water at various places all along its length. These barrages blocked the flow of the river and formed the lentic (stagnant) environment. Generally, most of the sludge get deposited at upstream of the barrages. This settled polluted materials moves to downstream along with sudden release of water from the barrages and increases the river pollution.

Table 3: Diversion of Yamuna River water EYC (Eastern Yamuna Canal) WYC (Western Yamuna Canal)

Sl. No.	Location	Construction	State	Purpose	Status of River
1.	Dak Patthar	Barrage	Uttarakhand	Power Generation	Water diverted into canal
2.	Asan	Barrage	Uttarakhand	Power Generation	Water diverted into canal
3.	Hathnikund	Barrage	Uttar Pradesh / Haryana	Irrigation and drinking water	Water diverted into canal (WYC and EYC) No water flow downstream in dry season
4.	Wazirabad	Barrage	Delhi	Drinking water	Generally, no water flow downstream in dry season
5.	ITO bridge	Barrage	Delhi	Water supply to power plant	Water available mainly from drains
6.	Okhla	Barrage	Delhi / Uttar Pradesh	Water supply into Agra canal	Generally, no water flow downstream in dry season

As per the report of CPCB, 2019 Yamuna River water quality in Delhi stretch is affected by various other factors along with wastewater received from various drains, such as, quantity of water received from Western Yamuna canal through Najafgarh drain, input from Hindon cut canal, quantity of fresh water released from Wazirabad and Okhla barrage, fluctuations in the intensity and duration of rainfall etc.

As per the data available on website and reports of CPCB, different water quality parameters of Yamuna River during last 15-16 years are as follows:

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand is the amount of dissolved oxygen used by aerobic biological organisms in the water body to decompose the organic matter polluted by sewerage or industrial effluents. Higher level of BOD indicates that the level of dissolved oxygen is falling which is hazardous forbiotic life and biodiversity of the river. It may be caused due to the higher level of organic pollutants and nitrate in the water body. From Wazirabad to Agra canal downstream the BOD level ranges from 2 to 22 mg/L. Table 4 and Figure 2 shows the average BOD levels in Yamuna River at different locations of river Yamuna in the state NCT Delhi during the period of 2005 to 2020.

Table 4: Biochemical Oxygen Demand (BOD) at different locations of River Yamuna in NCT Delhi

Locations / years	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Palla	1.92	3.50	3.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.3	5.8
Wazirabad	NA	NA	NA	1.50	2.33	1.33	2.18	2.00	3	2.4	4.5	5	4	2.5	NA	4.65
Nizamuddin	21.55	36.00	23.83	25.70	23.42	16.83	15.45	21.50	14	17.2	22.5	24.5	20.5	31.5	21.2	31.3
Okhla Bridge (inlet of Agra Canal)	14.82	30.50	1.87	12.80	14.50	13.82	13.00	22.00	17	17.3	21.5	26	17.5	26.5	17.4	16.3
Okhla (after Shahdara Drain)	29.73	94.80	47.67	61.80	51.30	33.58	NA	NA	31	NA	62	35.5	44	34	35.7	60.85

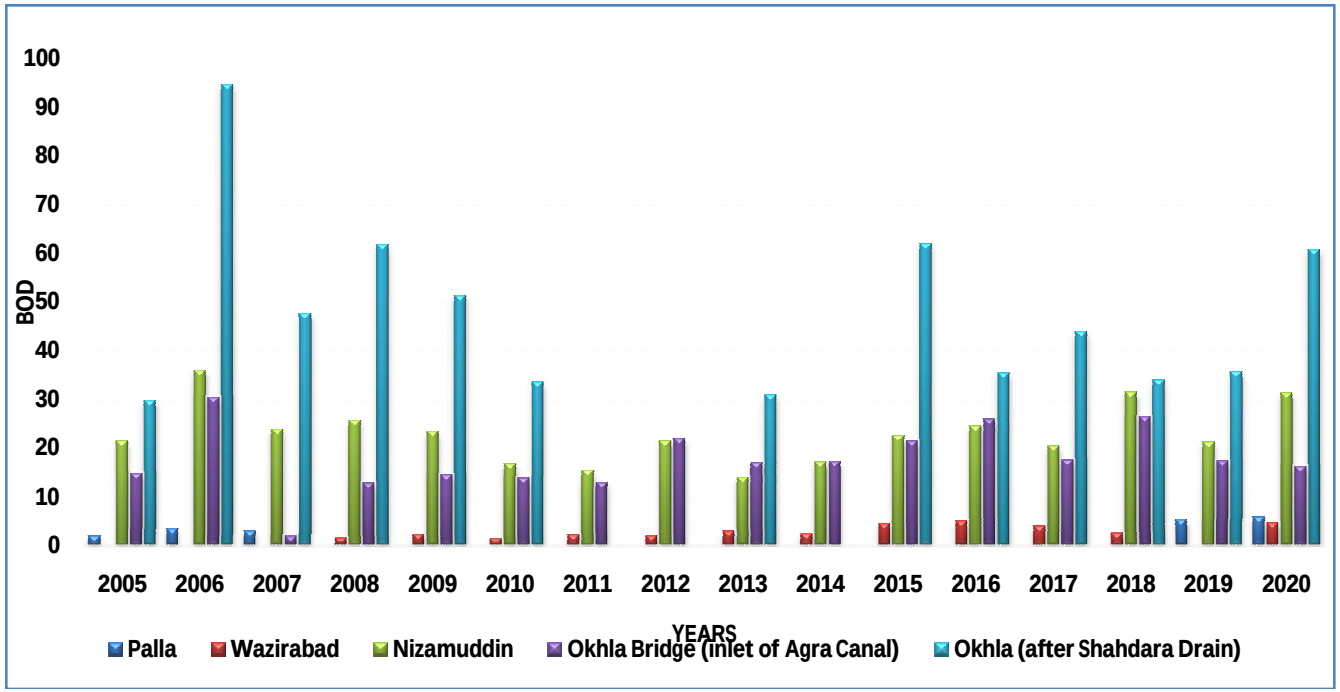

Figure 2: Biochemical Oxygen Demand (BOD) at different locations of River Yamuna in NCT Delhi

Chemical Oxygen Demand (COD)

The level of Chemical Oxygen Demand beyond the permissible limit is the indicator of the organic and inorganic pollutants in the water body. From Nizamuddin Bridge to Okhla downstream COD of River Yamuna found above the permissible limits (ranges from 20 to 188 mg/L). Table 5 and Figure 3 shows the average COD levels in Yamuna River at different locations of river Yamuna in the state NCT Delhi during the period of 2005 to 2007.

Table 5: Chemical Oxygen Demand (COD) at different locations of River Yamuna in NCT Delhi

Locations/years	2005	2006	2007
Palla	11.875	10.25	13.91
Wazirabad	NA	NA	NA
Nizamuddin	51.571	88.75	66.58
Okhla Bridge (inlet of Agra Canal)	37.429	92	20
Okhla (after Shahdara Drain)	85.182	188	NA

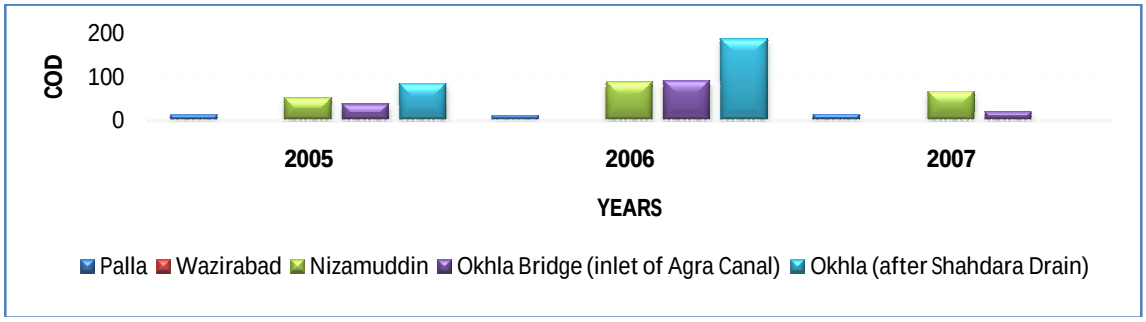

Figure 3: Chemical Oxygen Demand (COD) at different locations of River Yamuna in NCT Delhi

Dissolved Oxygen (DO)

After Wazirabad, the level of Dissolved Oxygen starts decreasing drastically and majority of times the level of Dissolved Oxygen was found Nil at Delhi downstream locations. Shahdara drain and Hindon River discharge wastewater at these locations. Almost every year, mass death of fishes is reported from these locations and now the situation is that, rarely the presence of fishes is reported in Yamuna River between Delhi to Agra. Table 6 and Figure 4 shows the average levels of Dissolved Oxygen in Yamuna River at different locations of river Yamuna in the state NCT Delhi during the period of 2005 to 2020.

Table 6: Dissolved Oxygen (DO) at different locations of River Yamuna in NCT Delhi

Locations/years	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Palla	8.375	7.05	8.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	10	12.15
Wazirabad	NA	NA	NA	8.1	7.33	7.79	7.8	8.75	10.5	9.3	10.5	9.3	7.75	7.7	NA	11.35
Nizamuddin	2.1	NA	0.32	0.5	NA	0.77	0.82	2.7	.6	1.2	1.2	1.5	2.75	3.6	2.4	1.35
Okhla Bridge (inlet of Agra Canal)	1.517	NA	7.4	0.2	0.05	0.31	0.54	2	.7	1.4	NA	1.1	1.8	2.95	3.1	1.45
Okhla (after Shahdara Drain)	2.94	NA	0.042	NA	NA	0.51	NA	NA	.6	NA	1.7	.85	1.85	3.5	3.3	2.95

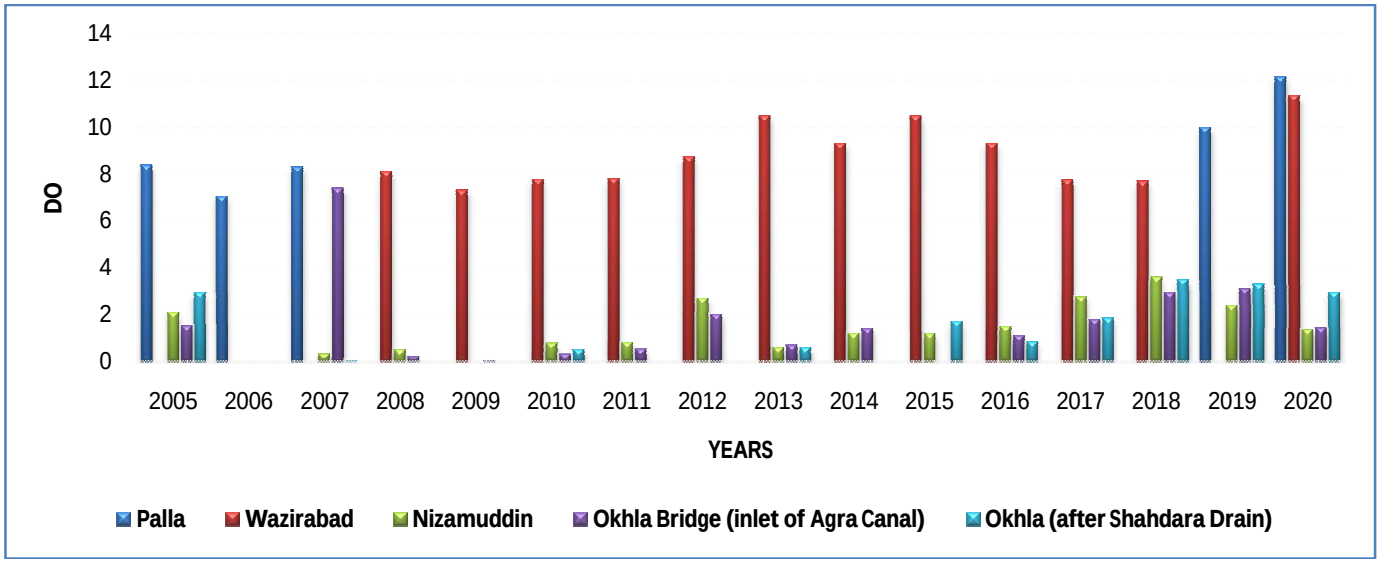

Figure 4: Dissolved Oxygen (DO) at different locations of River Yamuna in NCT Delhi

According to the Centre for Science and Environment, approximately 75 to 80 percent of the river's pollution is the consequence of raw sewage, industrial runoff and the garbage disposed into the river and it aggregates over 3800 MLD of waste per day (CSE, 2009).Due to heavy drainage, the faecal coliform and total coliform is drastically increased in river Yamuna which make it unfit even for bathing and other day to day use.Despite the huge investments made by subsequent governments in cleaning up the river the situation is alarming and our survival and that of rivers is at stake. There are twenty-twodrains situated at the left and right bank (upstream and downstream) of the rivercarrying the sewage to the river Yamuna in the state of NCT Delhi as per record of Central Pollution Control Board. All the drains are listed in the table7 as upstream and downstream drains directly meeting to River Yamuna .

Table 7: List of drains out falling into River Yamuna

UPSTREAM	DOWNSTREAM
Najafgarh Drain	Barapulla Drain
Metcalfe House Drain	Maharani Bagh Drain
Khyber Pass Drain	Kalkaji Drain
Sweeper Colony Drain	Sarita Vihar Drain
Magazine Road Drain	Tekhand Drain
ISBT Drain	Tughlakabad Drain
Tonga Stand Drain	LPG Bottling Plant Drain
Civil Mill Drain	Sarita Vihar Bridge Drain
Power house Drain	Shahadra Drain
SN Home Drain	Sahibabad Drain
Drain No.14	Indrapuri Drain

The serious water quality problems are there in the, cities, towns and villages using Yamuna Rivers as a source of their water and the Yamuna is under serious threat from record escalation in urbanization and industrialization. All the data of FC and TC are beyond the prescribed standards by the CPCB at all the locations of River Yamuna in the state NCT Delhi. Table 8 and Figure 5 shows the average FC levels and Table 9 and Figure 6 shows the average TC levels in Yamuna River at different locations of river Yamuna in the state NCT Delhi during the period of 2005 to 2020.

Table 8: Faecal Coliform (FC) at different locations of River Yamuna in NCT Delhi

Locations/years	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Palla	2930	4025	5616.667	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2060	39555
Wazirabad	NA	NA	NA	18600	16116.7	3948.33	9125.45	165922	NA	NA	2	12100	27070	460000	NA	39539
Nizamuddin	2351938	1772500	3757583	1064545	5799167	4893333.3	42000000	1900000000	NA	NA	NA	2713000	55030000	19525000	4850000	5605000
Okhla Bridge (inlet of Agra Canal)	943273	1670000	NA	709900	3094546	3541090.9	110000000	1900000000	NA	NA	NA	46020000	8085000	2340000	5534000	1689000
Okhla (after Shahdara Drain)	1691455	4068000	7441667	4788333	2.16E+08	7628166.7	NA	NA	NA	NA	NA	2720000	11000000	17110000	24610000	3984000

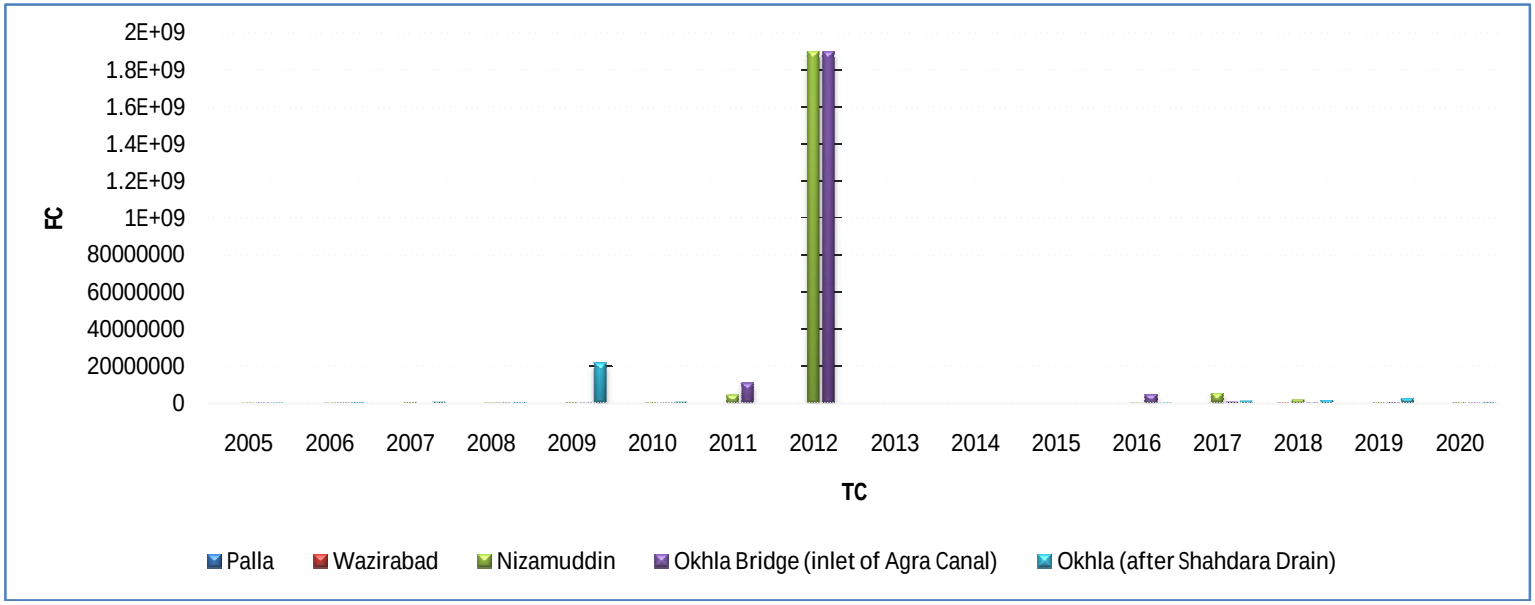

Figure 5: Faecal Coliform (FC) at different locations of River Yamuna in NCT Delhi

Table 9: Total Coliform (TC) at different locations of River Yamuna in NCT Delhi

Locations/years	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Palla	40842	112250	1643667	-	-	-	-	-	-	-	-	-	-	-	17050	85245
Wazirabad	-	-	-	146727	311166.7	27666.67	45763.6	418356	2500	10003	8501	27245	80000	800000	-	175165
Nizamuddin	31786556	36225000	50172000	8918182	97191667	17945083	2.5E+08	1.9E+09	9200000	12000000	9200000	9220000	70100000	19620000	12250000	14350000
Okhla Bridge (inlet of Agra Canal)	13986000	11150000	300	6512000	38727273	9528182	1.9E+08	1.9E+09	2850000	23800000	5800000	9220000	8085000	3620000	8534000	8175000
Okhla (after Shahdara Drain)	51313636	62640000	64875000	48683333	2.48E+09	66357500	-	-	6350000	-	-	800020000	11020000	80250000	24745000	17745000

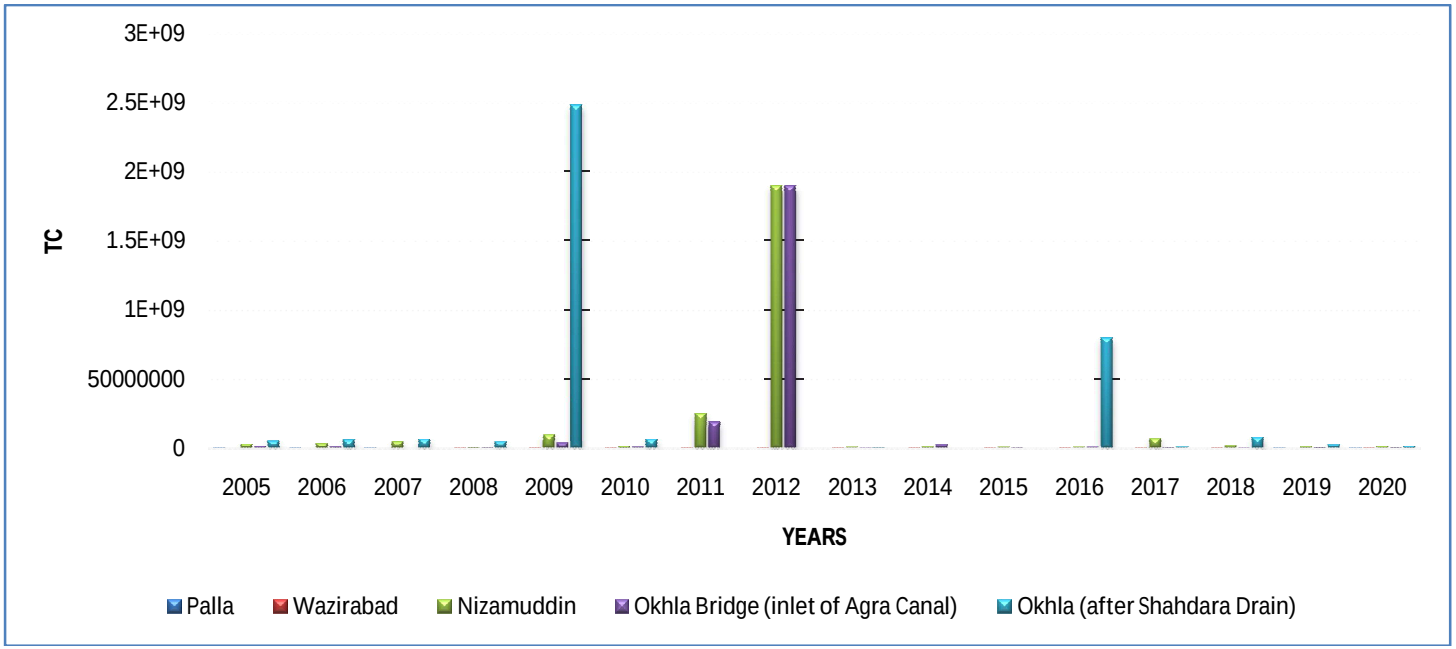

Figure 6: Total Coliform (TC) at different locations of River Yamuna in NCT Delhi

DISCUSSIONS

On the basis of all the above secondary data collected by the author from different sources, it can be said that due to all the pollutions found in River Yamuna, production of fishes is badly affected qualitatively as well as quantitatively. According to the discussion with the Fisheries Extension Officer, Govt. of NCT of Delhi, it came in light that earlier so many species of fishes were found in the river Yamuna. But now-a-days only 15 species of fishes listed below in Table 10 are found in the river Yamuna in which first 4 species namely Common Carp (*Cyprinus carpiosps*), Kharda (*Tilapia mozambica*), Mrigala (*Cirrhinus mrigala*), Rohu (*Labeo rohita*) are predominantly found in it. Singhara (*Mystus singhalasps*.), Chittal/Patola (*Notopterus notopterus*) etc. are the rare species of fishes of River Yamuna. Some of the species like Mahashir (*Tor mahanadicus*) etc. are already extinct from the Yamuna River. If, rarely found, species are not taken care of, it can be extinct from the river like other already extinct species of fishes. It must be taken care by the eminent authority to save the environment of River Yamuna to protect its aquatic life.

Table 10: List of Fishes found in River Yamuna

Sl. No.	Common Name	Scientific Name
1.	Common Carp	*Cyprinus carpiosps. (3)*
2.	Kharda	*Tilapia mozambica*
3.	Mrigala	*Cirrhinus mrigala*
4.	Rohu	*Labeo rohita*
5.	Catla	*Catla catla*
6.	Chilwa	*Chela bacaila*
7.	Pangasius	*Pangasius pangasius*
8.	Malli	*Wallago attu*
9.	Singhara (rare)	*Mystus singhalasps. (3)*
10.	Mangur (highest yield among Mangur)	*Clarias garipinus*
11.	Mangur	*Clarias battracus*
12.	Mangur	*Clarias mangur*
13.	Chittal	*Notopterus chitala*
14.	Chittal/Patola	*Notopterus notopterus*
15.	Bam	*Mastacembelus armatus*

Usually, the production of fishes takes place whole year in the river Yamuna, but most of the production takes place in three months when the volume of water is excess in the river during rainy season (July to September) which is also the breeding period of fish. During this time period, fish is found all over the stretch of river Yamuna i. e. from Wazirabad to Okhla in the state of NCT of Delhi. At this time, fishes also migrate from Gokul Barrage to Okhla Barrage against the current and the production is maximum at Okhla Barrage. According to the Officer, when the volume of water is low during the summer season the production of fish is badly affected. During this period, fish is available, but in low quantity even 1 Kg or 2 kg. The maximum quantity if required is produced upto 50 Kg/Dayonly. During this period, production of fish is maximized through Drag Net in which 2 boats are used, otherwise it is low. Table 11 and Figure 7 show the annual fish production of River Yamuna in the state of NCT of Delhi.

Table 11: Details of annual fish production from River Yamuna in NCT of Delhi

Sl. No.	Year	Total production from R. Yamuna + Ponds (MT)	Total Production from R. Yamuna (MT)
1.	2005 -2006	800	480
2.	2006 -2007	700	420
3.	2007 - 2008	610	420
4.	2008 -2009	720	420
5.	2009 -2010	720	432
6.	2010 - 2011	820	492
7.	2011 - 2012	740	444
8.	2012 - 2013	690	414
9.	2013 - 2014	880	400
10.	2014 - 2015	675	400
11.	2015-2016	710	430
12.	2016-2017	950	432
13.	2017-2018	800	410
14.	2018-2019	790	400

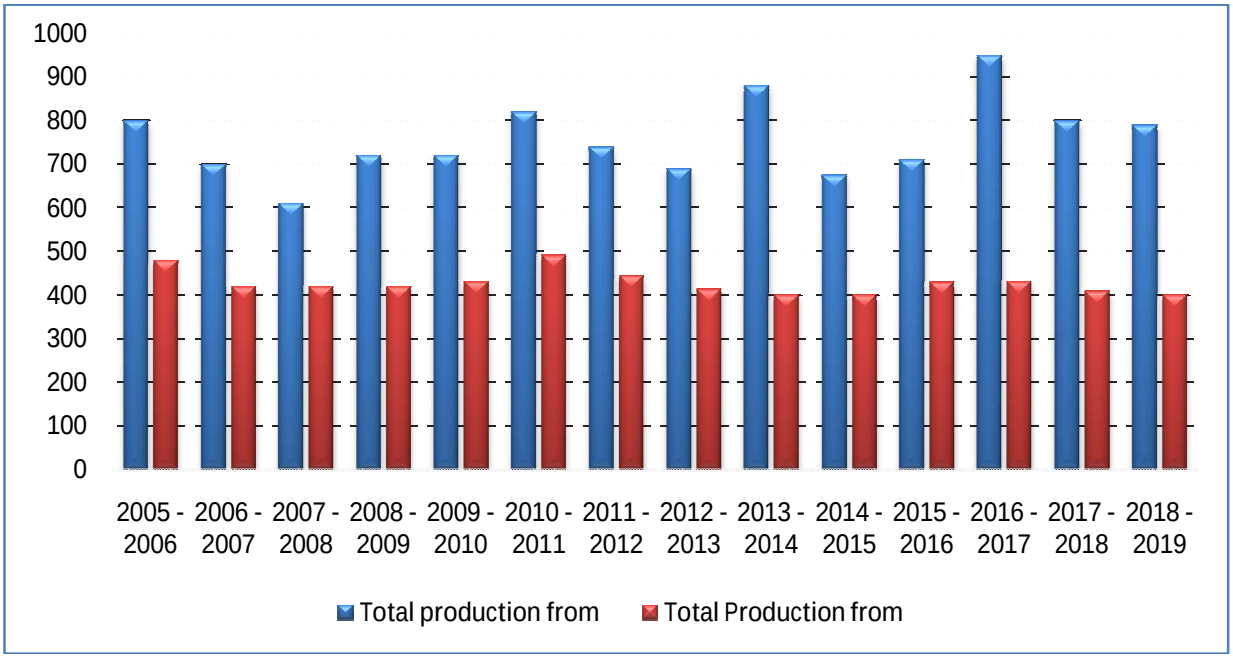

Figure 7: Annual fish production from River Yamuna in NCT of Delhi

During this period fishes are only found in the area Palla to Wazirabad and Old Okhla to Okhla barrage. Even some fishes are also produced in Chilla area which is reserved as Bird Sanctuary near Hindon Canal. However, fishing is not allowed in this reserved area, but some illegal fishing is sometimes reported from here. As per information regarding issuance of license for fishing, Department had issued total 1355 license in the year 2013-14 and 1135 for the year

2014 to January 2015. Some illegal cases are also found every year. But the most important thing is to note that no fish is found in the stretch from Wazirabad to Okhla Barrage i. e. production of fish is Nil in this particular stretch of River Yamuna. And the obvious reason was stated that low flow of water during the period due to which pollution level becomes higher and no species of fish is able to survive in that region. Data of BOD (ranges from 22 to 93 mg/l), COD (ranges from 20 to 188 mg/l) and DO (ranges from 0 to 2 mg/l) of these areas are not found feasible for the survival of fishes. Fishes are sensitive species and acts as Bio indicator for the river water ecosystem. This is an alarming situation and indicates the pollution status of the Yamuna River especially in the state of NCT of Delhi.

Quality of fish is also degraded by the polluted water of River Yamuna. It may confer as Sinha S., Singh R., Kumar S. and Singh C. P. in 2008, observed deviating consequences on the metabolic pathways in different tissues in the fishes of the river Ganga nearby Patna, Bihar. It was observed that protein content decreased by 25% in muscles and 32% in liver of the experimental fishes in comparison to standard fishes, which indicates degradation of dietary value of consumption of fishes. Along with this, pollutants especially heavy metals enter into the fish and finally enter into the food chain of Human being by the process of biomagnification. This process lasts at the cost of human health. It must be checked through thick and thin. For that we have to know the different sources of pollution of River Yamuna which are as follows:

Different Sources of Pollution of River Yamuna

- Effluents discharged by Industries
- Domestic Waste Water
- Pollution due to Agricultural Activities
- Improper disposal of Solid Wastes
- Other Sources such as:
  - Worship materials, polythene bags, clay idols, human excreta, account books and floral offerings are left behind in the river water.
  - Use of catchment areas for defecation by the people deprived of the sanitation facilities.
  - Dumping unburnt bodies of human beings and animals into the river due to various reasons.

Policies and Strategies for Improving Yamuna Water Quality

River Yamuna is facing acute water pollution problems same as other rivers of India. We need to develop awareness among masses to apply the strategies effectively. Some of the following important measures that can be very effective for the improvement Yamuna water quality status:

- **Appropriate Management and Treatment of Wastewater**

  Appropriate management and treatment of wastewater is necessary to improve the water quality as it is required before discharged to river water. Otherwise, it is harmful for aquatic lives. Around 3,800 MLD of sewage water is contributed by Delhi itself in the river Yamuna (Yamuna Action Plan, 1993). Therefore, it is essential to take necessary action and implementation of the following strategies:

  - **Conservation and Effective Use of Water**

    Shortage of water has become a common problem now a days in both urban and rural areas. High grade treatment of river water is required before use for domestic purposes due to severe pollution, which is expensive and not feasible in the developing country like India. Therefore, the conservation and effective use of water is necessary. Further, there is scarcity of open area due to developmental activities which has less scope for water infiltration and recharge of groundwater aquifers. In the rural and urban areas, the rainwater and floodwater quickly flow to the nallas and rivers, which then dry up soon after the rains stop, as we have lesser arrangements to hold this longer to seep into the ground and recharge the groundwater bodies. For the same we need to promote and develop water harvesting system at the maximum.
  - Encourage Wastewater Treatment & Technologies which should be cost effective and feasible.
  - Management and Treatment of Drainage Water strictly.

- ❖ Encourage Recycling and Reuse of Wastewater by creating awareness.
- ❖ Framing and Financing Wastewater Management Schemes which are feasible and cost effective.
- ❖ Improving the Sewerage System by upgrading in existing areas and constructing in newly constructed areas.
- ❖ Upgradation of Sewage Treatment Plants (STPs) and Common Effluent Treatment Plants (CETPs) having capacities to cater the need of increasing population.
- ❖ Proper Disposal of Sewage
  Disposal of sewage effluents is a big problem in almost every big city which must be taken into account. Approximately 2,322 million litres of untreated sewage are disposed in Yamuna from Delhi itself. It is dangerous to dispose of sewage water simply into river due to their microbiological and chemical characteristics. Prescribed norms and standards by CPCB, Delhi must be followed and implemented strictly. Only after complete treatment sewage water can be discharged into river. Hence, untreated or partially treated sewage should be banned to discharge into the river Yamuna.

- ➢ **Upgradation and Technical Advancement of Agricultural Practices**
  Farmers are needed to be aware and educated and skilled regarding the agricultural practices. As, they are using large quantities of pesticides, insecticides and chemical fertilizers without knowing the required quantities which pollutes the lakes, ponds and rivers by runoff during rainy season and cause eutrophication, which decreases the dissolved oxygen level and threaten animal and plant health. Encouragement and promotion of the use of bio-fertilizers having least chemical constituents is needed to prevent such situation and to accelerate the efforts to prevent the soil erosion through vegetation cover especially along the either side of the river.

- ➢ **Environmental Management**
  Ecological health of a river reflects the environmental management system and facilities of any place directly or indirectly. Hence, to protect river Yamuna from the pollutants some of the important steps should be taken immediately such as:

  - ❖ **Solid Waste Management**
    Various Rs such as Reduce, Reuse, Recycle, Rethink, Refuse etc. has been suggested, so that, we can reduce the Solid waste generation in our daily lives which may also be helpful in the management of solid wastes. Recycling units of solid wastes are used to manage it effectively.
  - ❖ **Construction and maintenance of Public Toilets**
    As per report, approximately 30% to 40% of urban population have the practice of open defecation as they stay in slums without sanitation facilities. Water contaminated with faecal matter causes various diseases among the residents. The risk level can be dropped by 40 percent with proper sanitation. The construction and maintenance of public sanitation facilities especially in the slum areas situated near either side of the river is the best solution to prevent further deterioration of water quality.
  - ❖ **Construction of Electric Crematorium and Create Awareness**
    Numerous cremations performed at the bank of Yamuna River cause water pollution. In addition to this, several carcasses of dead cattle disposed into the river each year. Due to the lack of adequate cremation facilities large number of partially unburnt corpses are dumped into the Yamuna.

  The only solution of these problems is construction of electric crematoria. Both central and state government should accelerate it and afford it to aware, convince and guide people to use electric cremation. It is eco-friendly as well as cost effective.

- ➢ **Construction of Holy Bathing Ponds near River Ghats**
  In India, holy bathing at religious occasions is common. It affects river water quality badly. This problem may be addressed by constructing holy bathing ponds, near the ghats filled with river water along with artificial ground water recharge techniques. This will prevent river

pollution as well as help to recharge the groundwater resources.

- **Afforestation**

  Afforestation along the either side of the banks of the river Yamuna would help in reducing the soil erosion and controlling the agricultural runoff, which would finally help to control the pollution. Further, it can also reduce the rise in river water temperature by preventing the direct exposure of river water with sunlight. This would also oxygenate the river water which increases the Dissolved oxygen to enhance the water quality.

- **Legislation and Fines**

  Stringent rules and regulations are necessary to be formulated and compulsory to be implemented fully to control the intensifying pollution in the river Yamuna. Monitoring and surveillance at the major pollution sites of the river must be started immediately. Disposal of domestic wastes in river must be banned and fine and imprisonment must be imposed to the various polluters as per recommendations and guidelines of National Green Tribunal (NGT) as Polluters Pay Principle (PPP).

- **Awareness and skill development among the People**

  People's participation is compulsory to achieve the desired goals regarding the control and prevention of pollution of the river Yamuna, as without their contribution this is simply impossible. Therefore, this is important to create awareness among the people regarding the ways of river pollution and its consequences. People must be aware, taught and skilled about various protective measures to control the increasing pollution levels in the river.

CONCLUSIONS AND SUGGESTIONS

River Yamuna acts as the life line for the majority of the cities including Delhi. Cities located at the bank of it contribute enormously in polluting the river Yamuna. Flow of the river Yamuna is restricted through several barrages. Water quality and aquatic ecosystem of the river is directly or indirectly affected by these barrages. Polluted sludges get deposited at the upstream of the barrages and their sudden release in the downstream of the river water suddenly increases the pollution level so high that led to the mass death of fishes especially in Delhi and other eutrophicated segment frequently.

Nearly 15 km upstream of Wazirabad barrage, the river Yamuna enters Delhi near the Palla village, which acts as a reservoir for Delhi. Installed capacity of sewage treatment is1,478 MLD in Delhi, (Yamuna Action Plan, 2003) however, sewage generation is approximately 3296 MLD (Yamuna Action Plan, 1993) or more recently may be 3800 MLD (CSE, 2009). Thus, about 1818 MLD to 2,322 MLD of untreated sewage and a substantial amount of partially treated sewage pass into the river every day. The inadequate sewage system of Delhi can be blamed for the same. In Delhi, river water appears black and it is almost stagnant. Trapping and treatment of all the generated wastes, legal and illegal, sewered and un sewered is highly essential. Due to high transportation cost, treatment facilities need to be constructed nearby the source of sewage generation to make it cost effective. Catchment area demarcation is also an important component of water quality management. It is necessary to check and improve the water use practices in the areas where pollutants originate, in order to reduce pollution load at an outfall.

Several highly expensive water treatment technologies are prevailing in Western countries, but the country like India it is not easily affordable and viable. Emphasis and encouragement must be given to the economically feasible techniques capable of removing or minimizing the pesticides content from the water instead of conventional water treatment processes.

The quality restoration of the river Yamuna is complex and interdisciplinary endeavour. The strategy for pollution control of the river Yamuna must be a multi-line, multidimensional and multidisciplinary approach withfool proof action plan. The possible strategies to restore this ailing river to its pristine status must be thoroughly planned, examined as well as effective and enduring solutions established and implemented to trap the various sources of pollution in the river Yamuna.

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