

# Trends in Organic Contamination in River Yamuna: A Case Study of Delhi Stretch (2007-2016)

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## Case Report

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# Abstract

The river Ganges largest tributary is river Yamuna and it is the longest tributary in India serving millions of individuals. It is emerging from the glacier known as Yamunotri that has a height of 6,387m that travel through Uttarakhand to Allahabad. The water from river is abstracted as well as in stream used for irrigation, power generation, domestic water supply, industrial use, etc., because of which the after affects are many. In India, an alarming situation exists since quite a long time in river pollution. When river Yamuna enters Delhi, it meets the water quality guidelines with respect to Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) but during its exit the water quality deteriorated. The main reasons of deterioration of the river water are sewage discharge and industrial effluents and mis utilization of fresh water. The dilution capacity of the river also gets reduced due to significant water abstraction. The chief contributor of contamination is National Capital Territory (NCT) of Delhi followed by Agra and Mathura by either point or non-point sources.

In this paper we investigated the ongoing trends in basic water quality guidelines of the River Yamuna which show huge deviation in Delhi segment. Due to the influence of industrialization, urbanization and horticultural advances the Delhi segment gets severely contaminated. Yamuna Action Plan (YAP) was undertaken by the government for the restoration and preservation of the river Yamuna. The DO, BOD in the Delhi segment and eutrophicated segment investigation, the water quality parameter trends in the river Yamuna represent that regardless of the considerable number of endeavors the water quality isn't fit for assigned best utilizations. The outcomes require inventive points of view in the advancement of a refreshed comprehensive preservation technique for the river Yamuna.

## Introduction

The river water quality has been decaying alarmingly in perspective on the fast growth of urban populace, industrialization and deficient infrastructure. Perceiving the gravity of the issue, Government of India propelled enormous deals for protecting rivers across the nation. In 1985 river Ganga was acknowledge for interference as it is the most blessed and biggest river in India. Further the river Yamuna was considered significant as it is the major tributary of river Ganga and it passes through Delhi. The river Yamuna can be considered into an open drain getting discharge from domestic, industrial and horticultural wastewaters which often results in death of fish's upto Etawah. The government figured Yamuna Action Plan (YAP) to reduce the water contamination from the important urban focuses. Majorly the energy efficient treatments like Upflow Anaerobic Sludge Blanket (UASB) reactor followed by an oxidation pond were used in 14 Class-I cities to treat the sewage during 1993 to 2003. Many imaginative advancements and pilot plants were developed and implemented for treating the sewage. After UASB reactor a polishing unit Downflow Hanging Sponge reactor was developed giving exceptionally promising outcomes in Haryana and Agra [19]. Japanese government invested 141 million US dollars to install sewage treatment plant to treat sewage of 3.5 million populace counterparts. Moreover, arrangement was made on making minimal effort sanitary offices for low-income group, on education, on sanitary needs, advanced crematoria, river front development, etc. [2] [3].

## ***The Yamuna River.***

The river Yamuna at the Banderpoonch top in the Uttarkashi area of the Himalayan Mountains in Uttarakhand 6384 meters begins from the Yamunotri glacier above the mean sea level. It is the largest tributary of the river Ganga. The river Yamuna passes through the stretches of Himachal Pradesh, Delhi, Uttar Pradesh, Haryana, Rajasthan and Madhya Pradesh travelling a length of 1,376 km and having 366,220 km<sup>2</sup> of catchment area. Tons, Chambal, Sindh, Betwa and Ken are the chief tributaries of the river Yamuna [17]. Around 10,000 cumecs is the yearly flow of the river out of which about 4400 cumecs is used mainly constituting 96% for agriculture. It isn't much the same as another river because it has a significant spiritual and social noteworthiness. The river Yamuna is categorised into five different segments based on different geological, hydrological and natural characters [7]. The different segments are organized underneath in Table 1 and the equivalent is diagrammatically portrayed in Fig. 1. From Hathnikund, Tajewala and Okhla barrage a huge amount of water is abstracted from the river. The river not just gives an employment to category living in the basin yet additionally offers an actual existence backing to irrigation, industrial and urbanisation. Along its course it is the principal resource of drinking water. Around 85% of the total water supply of Delhi is taken from the surface water mainly from river Yamuna [14]. Nearly about 57 million individuals are reliant on the river water of Yamuna. The annual abstraction from different locations is listed below in Table 2.

The industrial towns up and down the river, releases huge measures of wastewater into it. The river Yamuna turns into a drain in the lower stretch accepting all types of effluents from irrigation, industries and municipal [1]. In Haryana, Delhi, Uttar Pradesh there are countless industries like paper, sugar, leather, chemical, power, pharmaceuticals, etc., which are legitimately releasing and contaminating the river [4]. Modern urban areas like Yamuna Nagar, Delhi, Agra, Mathura lies on its bank. Because of broad anthropogenic weight it is quickly decaying into a sewage channel [22] [18]. 95% of the contamination by treated or untreated municipal and industrial waste is mainly released in Delhi segment through twenty-two significant drains like Najafgarh, Yamunapur, Barapullah, Maharani bagh, etc. In Delhi the river is contaminated to the point that past Okhla, it scarcely bolsters any type of life. The natural organic matter, supplements, pesticides, heavy metals have additionally been found at disturbing levels.

## ***Yamuna River Pollution and its sources***

The river Yamuna along its bank supports all types of life, different social and business exercises rely upon it [23]. It supplies significant amount of drinking water to a huge number of populace and has numerous different usage [1]. River Yamuna is of incredible financial criticalness because of its richness and high profitability, especially to numerous parts of Haryana and Uttar Pradesh [18]. Few all around assigned usages of water are drinking, bathing, irrigation, livestock, washing, industrial, esthetics, recreation, religious, cultural, etc. In monsoon time frame i.e. from July to September the accessibility of water of the river Yamuna differs enormously with reality, with 80% of the water streaming in it though accessible water in the non-storm period i.e. from October to June is broadly utilized for water system leaving almost no flow in the river [16].

### ***Point sources of pollution***

These are organised sources of contamination with quantifiable contamination load [15]. These incorporate surface channels bringing domestic sewage through open channels or potentially from sewerage framework or industrial effluent, sewage siphoning stations etc. 85% of the total pollution of river Yamuna comes from domestic level of the urban communities besides the river [16]. The domestic wastewater constitutes of organic matter, microorganisms, salts, chemicals, supplements, oil and grease, etc. Many industries besides the river release their wastewater into it without appropriate treatment or release halfway treated or untreated wastewater containing organic and inorganic pollutants further degrading the quality of water.

### ***Non point sources of pollution***

These are various subtle and vague sources of contamination as contamination created by different source is very less and non-measurable. These incorporate organic matter, deposits of dead plants, microorganisms, topsoil, chemicals, minerals, etc [7]. These sources are affected by the general land use in watershed and incorporate regular procedures and the anthropogenic data sources [20]. Non point sources like Horticultural runoffs, solid waste dumping, dead bodies of humans and animals, fascination of idols, botanical contributions, ashes, contamination due to in-stream utilization of water, for example washing, bathing, cattle's swimming, open defecation etc, are the chief sources of contamination.

## **Methodology**

For the assessment of water quality status of river Yamuna the 22 km stretch of Delhi was considered i.e. from Wazirabad barrage (point at which the river Yamuna enters into Delhi) to Okhla barrage (point at which the river Yamuna exists Delhi). The water quality of river Yamuna is assessed and classified according to its different uses like raw water fit for drinking purpose, raw water fit for bathing purpose, raw water fit for agriculture purpose as discussed in the following section. The classification of river water for various purposes is based on certain parameters like Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Fecal Coliform (FC), Total Coliform (TC) and pH. The present paper assessed these parameters for the period from 2007 to 2016 in the Delhi segment of river Yamuna.

## **Results & Discussion**

### ***Yamuna River Water Quality Status***

The quality of river can be investigated by evaluating nutrients, chemicals and microorganisms. A river is considered healthy if it contains dissolved oxygen at least 5 mg/L which is essential for sustaining aquatic life and Biochemical Oxygen Demand around 3 mg/L, moreover the pathogens i.e., disease causing bacteria should be less than 500/ 100 mL of water. In India river water characteristics have been classified as follows:

**Class A:** The river water is fit for drinking after proper disinfection by adding chlorine or bleaching powder,

**Class B:** The river water is fit only for bathing,

**Class C:** The river water is fit for drinking only after proper treatment (screening to remove physical matters or particulate such as paper, plastic, etc.,

**Class D:** The river water is fit only for fish and wildlife and

**Class E:** The river water is suitable only for industrial cooling, irrigation, etc.

These classes as per water quality parameters are organized underneath in Table 3.

## 3.1 Yamuna River Water Quality Trend from 2007 to 2016

The river water quality is evaluated and categorized concerning its assigned uses. The above expressed categorization of water depends on essential parameters like DO, BOD, faecal coliform and total coliform (TC). In this paper the patterns of two basic parameters viz. DO and BOD of river Yamuna for the timeframe of 2007 to 2016 in Delhi segment were studied [5-14]. The statistical summary of Yamuna River water quality data for the Delhi stretch from 2007 to 2016 is given in Table 4.

## 3.2 Dissolved Oxygen (DO) Trends from 2007 to 2016

DO is essential for the endurance of aquatic life forms, for example, plants, microorganisms, invertebrates and for fish. It is commonly obvious that if the water is sustaining aquatic life then the quality of water is good and meeting most guideline parameters. A decrease in the DO level reduces the self-purifying capacity resulting in weakening of living beings and eventually death occurs [21]. Estimation of oxygen is important, and it is estimated in its dissolved state as DO. When DO level is reduced in water it shows substantial contamination due to presence of domestic, industrial or agricultural wastewater. The DO is regenerated in the water naturally from atmosphere or from photosynthesis by aquatic plants and organisms. DO present in the water varies seasonally, by physical, chemical and biochemical reactions [9]. In Fig. 2 the trends in the DO for the Delhi segment of the river Yamuna from 2007 to 2016 are shown.

From the graph it is clear that in the Delhi segment DO levels are very less, sometimes its value is zero mg/L at Okhla barrage during the year from 2007 to 2010. It is also less than the 4 mg/L i.e., the standard value given by CPCB to support aquatic life which is because of the fall of untreated wastewater directly into the river by various drains. This discharge into the river is responsible for higher oxygen demand in this segment. The river being detrimental continues to be septic and have eutrophic condition and has no self-purification capacity. However, the trends from the year 2011 to 2016 there is increase in DO level but it is still below the standard limit. The DO levels trends decrease from 2007 to 2016 indicate that there is

increase in pollution in the Delhi segment. DO levels in river Yamuna starts decreasing drastically after Wazirabad and remains low in the Delhi downstream segment.

### 3.3 Biochemical Oxygen Demand (BOD) Trends from 2007 to 2016

It is the measure of amount of oxygen consumed by microorganisms present in water to decompose the organic matter supplied by wastewater. Decrease in dissolved oxygen indicates higher BOD levels indicating higher contamination in the water which results threats to aquatic life [22]. Chemical oxidation can also be measured for inorganic matter. The higher concentration of BOD is inversely proportional to lower concentrations of DO present in water. In water higher BOD levels indicate more amount of organic matter present in it. In Fig. 3 the trends in the BOD for the Delhi segment of the river Yamuna from 2007 to 2016 are shown.

Fig. 3 clearly depicts that in the Delhi Segment BOD levels are extremely high. The observed values of BOD extend between 3 mg/L to 50 mg/L exceeding the desired levels for bathing in Delhi segment. This is fundamentally because of the release of untreated wastewater into the river through various drains in this segment. Before Delhi the BOD levels are from 1 to 3 mg/L supporting aquatic life but past the outfall sewers in the river Yamuna after Wazirabad BOD levels do not meet the desired guidelines downstream Delhi segment. From 2007 to 2010 and 2013 to 2016 the graph shows an increase in BOD levels because of increase in organic matter in the river.

### 3.4 Total Coliforms (TC) Trends from 2007 to 2016

Coliform bacteria are microorganisms present in the surroundings, in the faeces of warm-blooded animals and humans. In water their presence indicates contamination and the presence of pathogens. Coliform bacteria are of three different groups, each having different risks. Presence of Total coliform, fecal coliform, and *E. coli* indicates quality of water. A vast kind of bacterias comes under TC and FC comes under TC mainly exists in faeces and *E. coli* comes under FC. If TC is confirmed in a water sample than FC and *E. coli* are tested. TC is harmless bacteria present in soil or vegetation, FC is pathogenic and their presence indicates fecal contamination, *E. coli* are also harmless but some causes diseases, they are present in intestines of humans and animals and their presence also indicates fecal contamination. In Fig. 4 and 5 the trends in the Total Coliform and Faecal Coliform for the Delhi segment of the river Yamuna from 2007 to 2016 are shown respectively.

Fig. 4 & 5 clearly depicts that in the Delhi Segment TC and FC levels are extremely high. In the Delhi segment the observed values of TC extends from 10000 to 920000000 MPN/100 mL exceeding the desired levels of standards. The presence of TC and FC in the river water indicates contamination from the environment as well as faeces, it means that pathogens are present at higher risk in river Yamuna. This is again also because of release of untreated wastewater through various drains in the Delhi

segment. The graph shows TC and FC levels with an increasing trend from 2007 to 2016 due to presence of organic matter. TC and FC in the Delhi stretch is horrific making it unfit even for bathing.

## 3.5 pH Trends from 2007 to 2016

pH of Yamuna river water was found alkaline in nature and varied from 7.2-8.8. The change in pH effects all the aquatic organisms because most of the metabolic activities of them are pH dependent. For the sustainable aquatic life, the optimal range of pH is 6.5 to 8.2. It was also noted that pH was the only parameter which was meeting the standard for water quality in the Delhi stretch, only sometimes it was found out of limit. In Fig. 6 the trends in the pH for the Delhi segment of the river Yamuna from 2007 to 2016 are shown below.

## Conclusion

The quality of river Yamuna follows the drinking water standards before entering Delhi and comes under Class C of river classification having BOD and TC below 3 mg/L and 5000 MPN/100 mL respectively. The river Yamuna gets dirty with all the pollutants during the Delhi stretch. The river water quality and quantity both are over exploited in this segment. It is our duty to preserve the water quality as a huge populace depends on it. During 2% of whole stretch traverse in Delhi from Wazirabad to Okhla barrage it receives about 70% of the total contamination. After Wazirabad the DO decreases drastically and remains drastic downstream, it was observed most of the time well below the prescribed limit of 4 mg/L and ranges from 0.0 – 10.5 mg/L. The BOD values were also critical in the Delhi segment usually not meeting the prescribed limit of 3 mg/L and ranges from 1.3 – 61.8 mg/l. The TC values were significantly superior to the prescribed limit of 5000 MPN/100 ml and ranges from 10000 - 920000000 MPN/100 mL. Analysing the values of DO, BOD and TC according to river classification the river Yamuna comes under Class E. The major reason of worsening of water quality is predominant discharges from domestic from domestic and industrial sources in Delhi segment. Eighteen drains out of twenty-one wastewater drains in Delhi joins river Yamuna downstream of Wazirabad barrage and rest joins Agra or Gurgaon canal are the biggest polluter of river Yamuna. During non-monsoon period the fresh water is not available in the river after Wazirabad which is the reason for not maintaining the rivers self-purification capacity. Therefore, river Yamuna is more of drain in the Delhi segment.

## Declarations

### Acknowledgement

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### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Tables

**Table 1: Major segments and reaches of river Yamuna**

No.	Segment	Reach	Length (Km)	Tributaries/drains	Dam/Barrage	Canal
1	Himalayan	From origin to Tajewala Barrage	172	Kamal, Giri, Tons, Asan	Dak Patthar, Asan	Dak Patthar, Asan
2	Upper	From Tajewala Barrage to Wazirabad Barrage	224	Som, Choti Yamuna, drain no. 2 & 8	Hathnikund	Western & Eastern Yamuna Canals
3	Delhi	Wazirabad Barrage to Okhla Barrage	22	22 drains, Hindon	Wazirabad, Yamuna	Agra
4	Eutrophicated	Okhla Barrage to Chambal Confluence	490	Hindon, Bhuria Nala Mathura - Vrindavan drain, Agra Drain	Okhla	Agra, Gurgaon
5	Diluted	Chambal Confluence to Ganga Confluence	468	Chambal, Ken, Sindh, Betwa	-	-

Source: CPCB, 2009; Central Inland Fisheries Research Institute, 2014

**Table 2: Water abstraction from the river Yamuna**

Location/ Barrage	State	Purpose	Water abstracted and its use
Dak Patthar	Uttarakhand	Power generation	abstracted into canal
Asan	Uttarakhand	Power generation	abstracted into canal
Hathnikund	UP/ Haryana	Irrigation, Drinking, others	20,000 MLD diverted into Western and Eastern Yamuna canals, no flow downstream in dry season.
Wazirabad	Delhi	Drinking	1,100 MLD, no flow downstream in dry season.
ITO bridge	Delhi	Cooling units of power plant	Abstracted into drains
Okhla	Delhi/UP	Irrigation, others, diverted into Agra canal	5000 MLD abstracted between Wazirabad to Okhla, no flow downstream in dry season.
Etawah	Delhi/UP	Irrigation, Drinking, others	400 MLD abstracted between Okhla to Etawah, no flow downstream in dry season.
Prayagraj	UP	Irrigation, Drinking, others	475 MLD abstracted between Etawah to Prayagraj, no flow downstream in dry season.

Source: CPCB, 1999

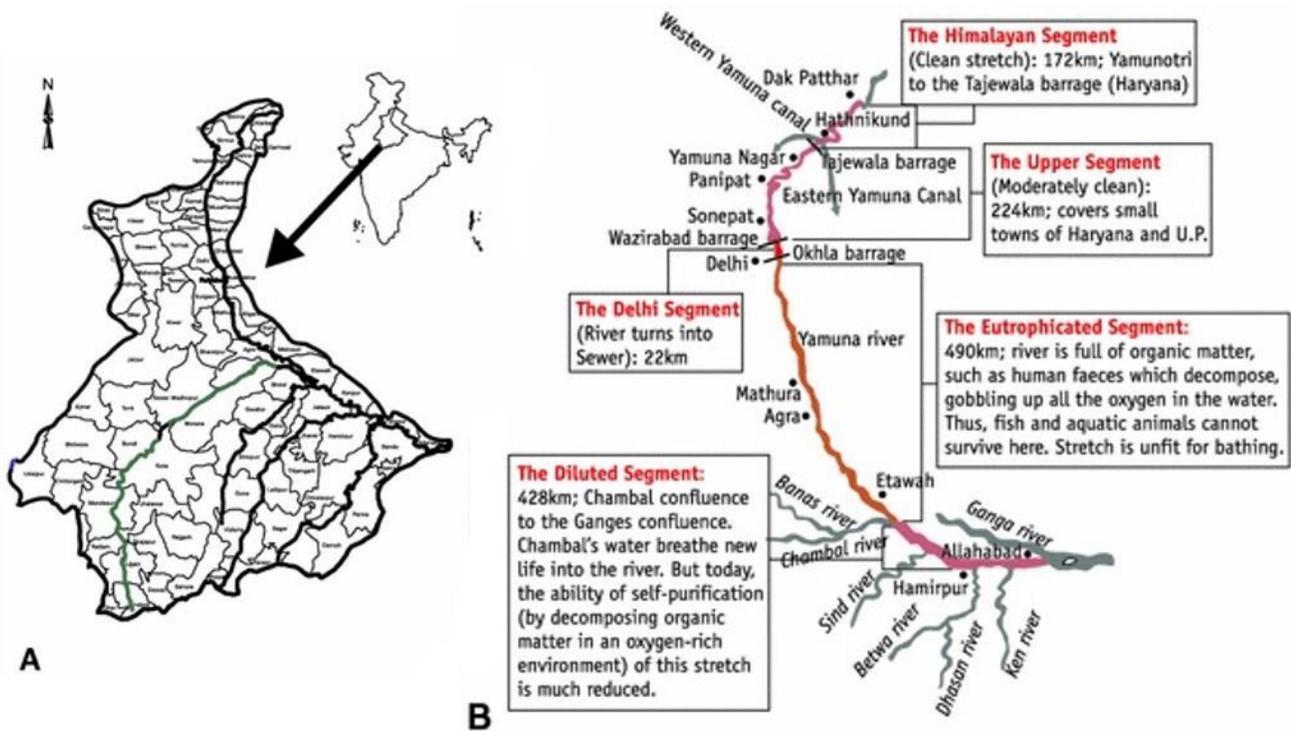
**Table 3: River water quality classification under different categories**

Criteria	Class				
	A	B	C	D	E
DO (mg/l)	6	5	4	4	-
BOD (mg/l)	2	3	3	-	-
Total Coliform Organism (MPN/100 ml)	50	500	5000	-	-
pH	6.5-8.5	6.5-8.5	6-9	6.5-8.5	6.5-8.5

**Table 4: Yamuna River Water quality parameters for Delhi stretch (2007 to 2016)**

	DO	BOD	TC	FC	pH
Delhi Stretch	mg/L	mg/L	MPN/100ml	MPN/100ml	
Min	0	1.3	10003	3948	7.2
Max	10.5	61.8	920000000	524650000	8.8
Mean	2.86	18.81	58442117.69	31414796.45	7.81
Median	1.5	16.8	6113666.5	1592500	7.8
Mode	0	3	190000000	-	7.8
Standard Deviation	3.02	13.69	139796081.33	92676615.53	0.31

## Figures



Source: CPCB, 2006

Figure 1

Detailed river Yamuna stretch (A) Basin map (B) Different river segments Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

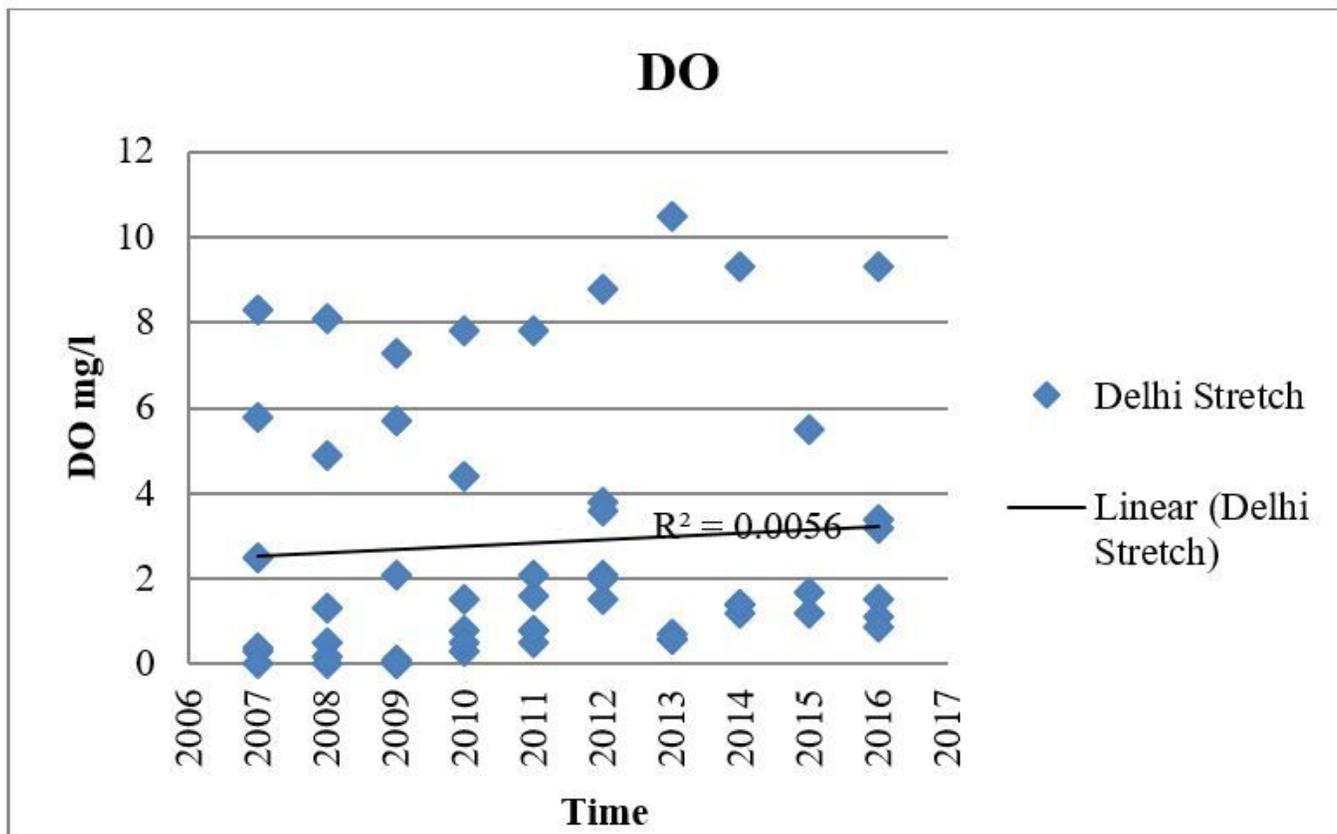


Figure 2

Dissolved Oxygen (DO) Trends in Delhi segment of river Yamuna (2007-2016)

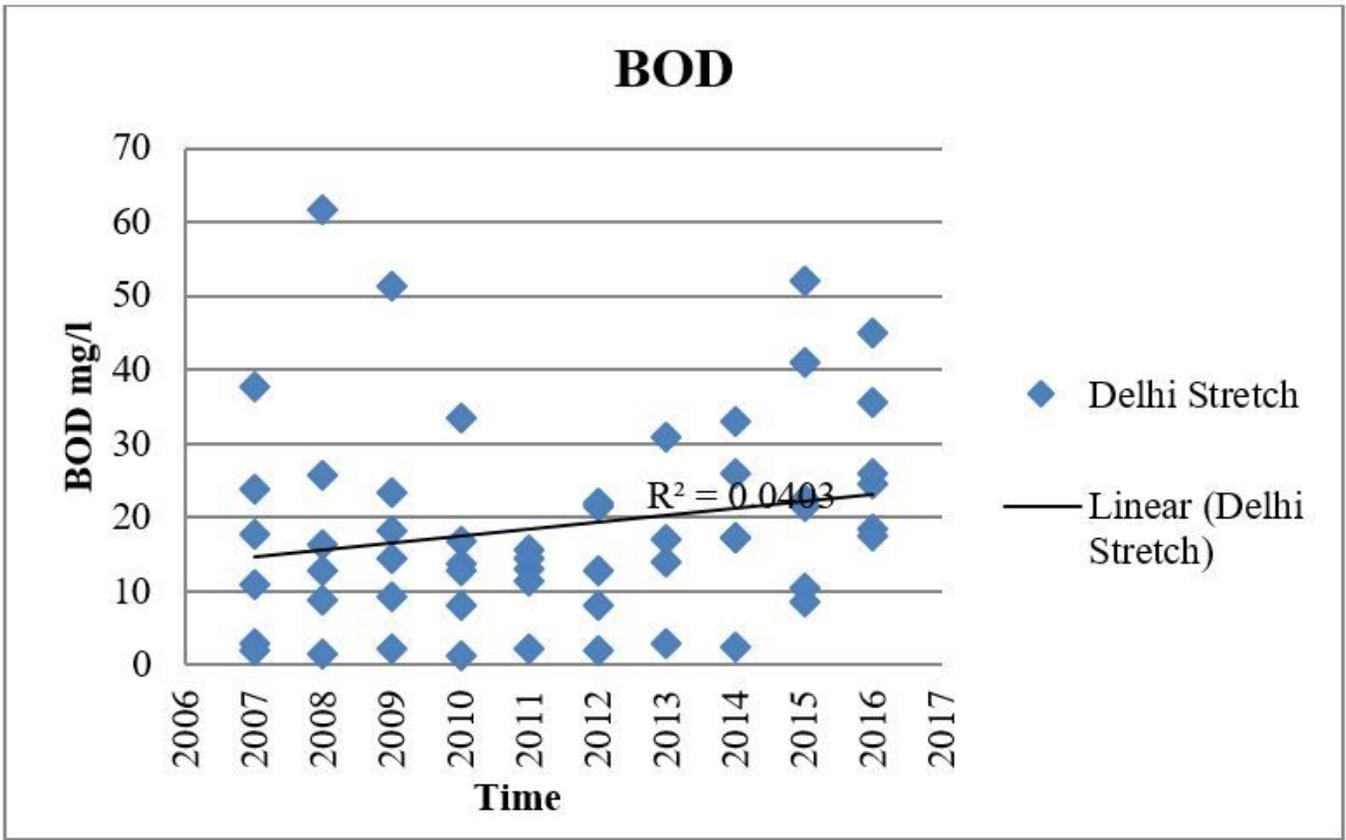


Figure 3

Biochemical Oxygen Demand (BOD) Trends in Delhi segment of river Yamuna (2007-2016)

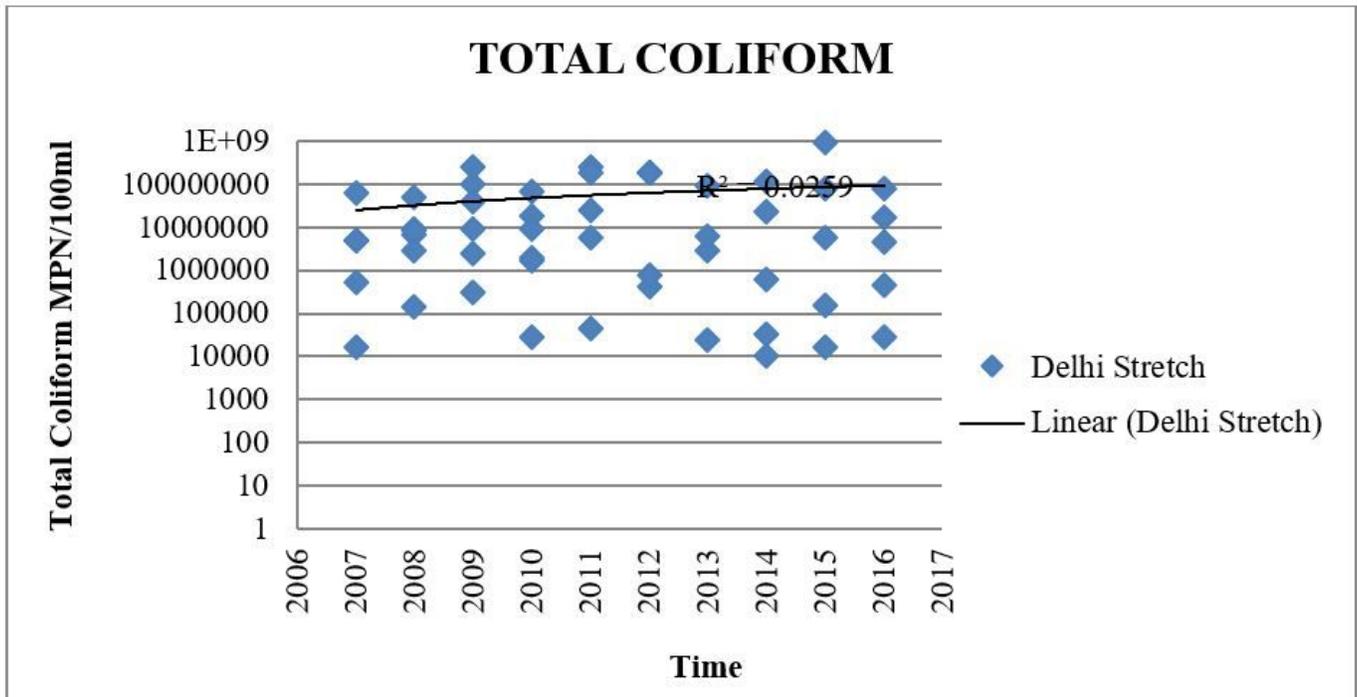


Figure 4

Total Coliform (TC) Trends in Delhi segment of river Yamuna (2007-2016)

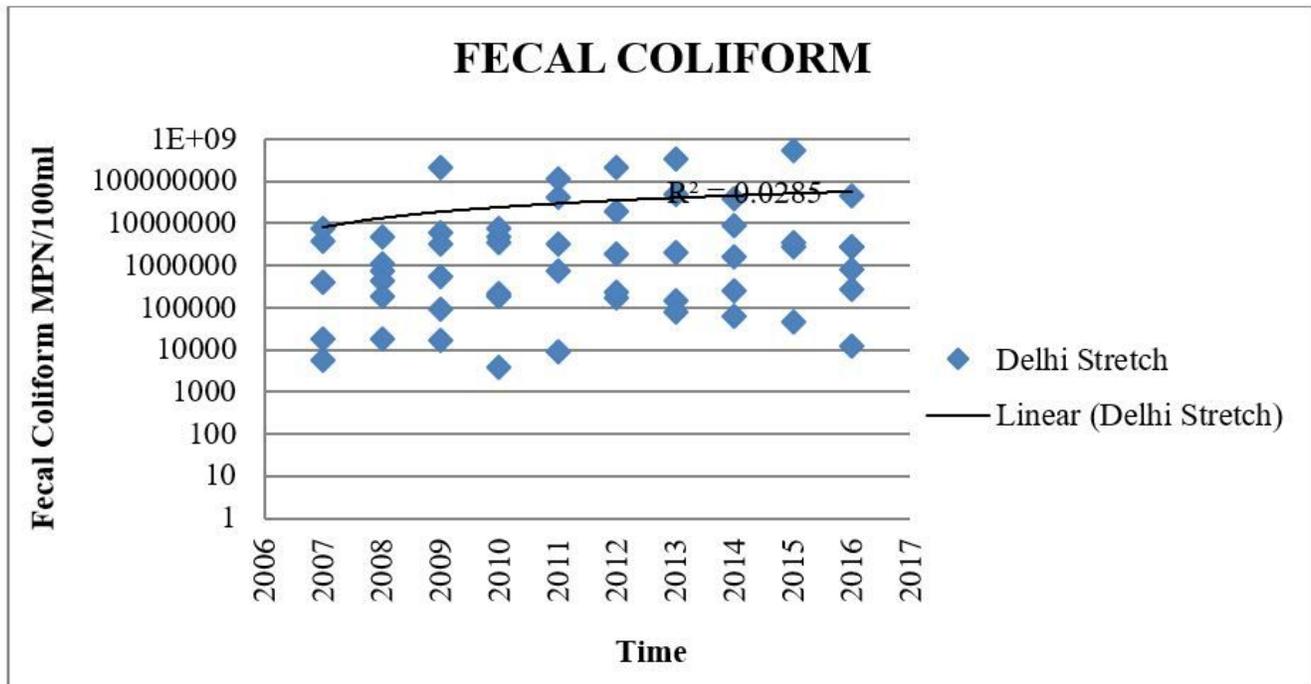
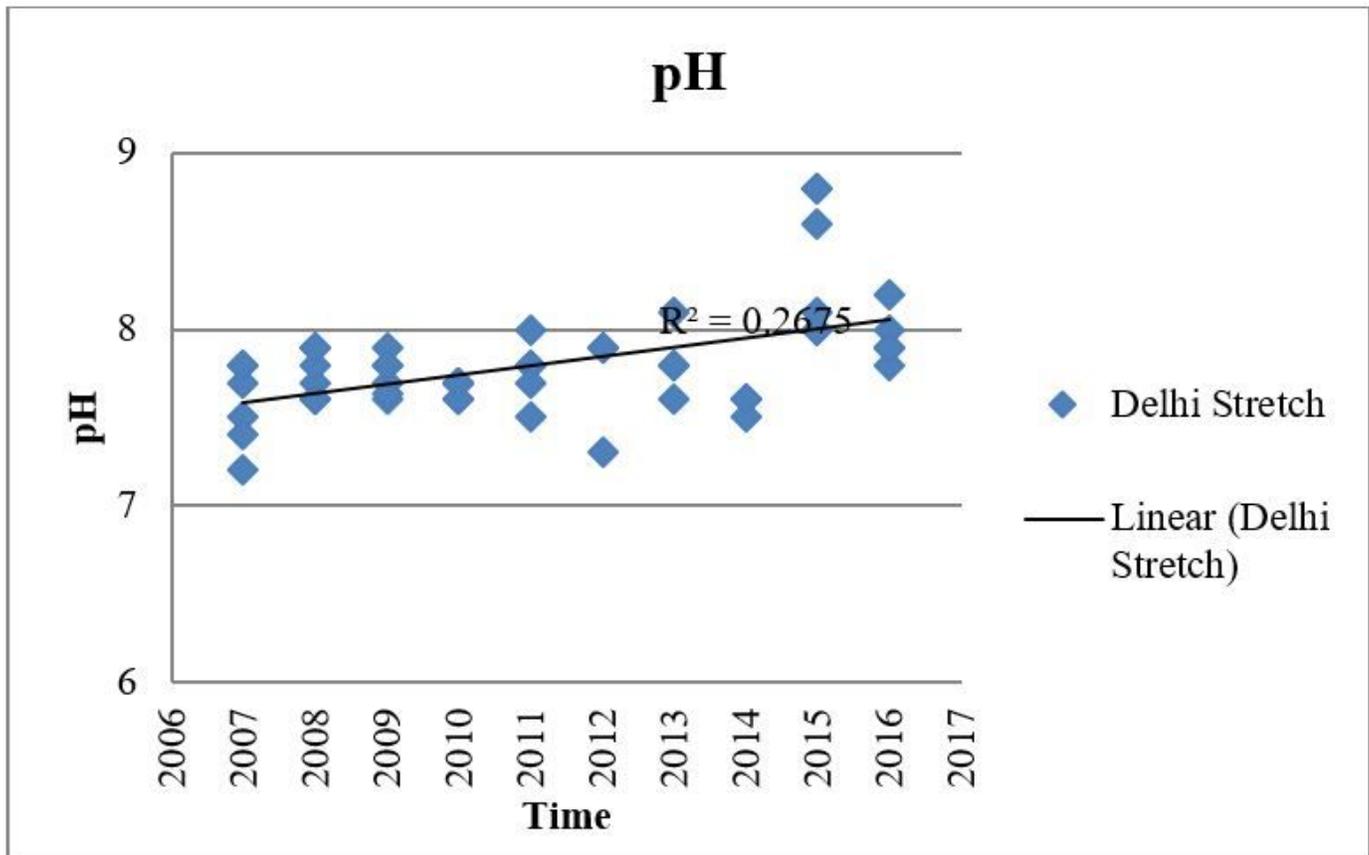


Figure 5

Faecal Coliform (FC) Trends in Delhi segment of river Yamuna (2007-2016)



## Figure 6

pH Trends in Delhi segment of river Yamuna (2007-2016)