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Water quality assessment of River Yamuna from origin to confluence to River Ganga, with respect to Biological water quality and Primary Water Quality Criteria

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ABSTRACT

Clean to slight pollution in biological water quality was observed in River Yamuna at Yamunotri and Hanuman chetti, in terms Biological Water Quality Criteria. River Yamuna was moderately polluted from Okhla Barrage to Allahabad throughout the year. At Etawah, the water quality became severely polluted during summer season. Water quality of River Yamuna at Yamunotri, meets the Primary Water Quality Criteria in terms of pH of 8.1, DO of 7.8 mg/l, BOD of <2 mg/l and Total Coliform count of <2 MPN/100 ml used for drinking water without conventional treatment but after disinfection Class A and Outdoor bathing Class B and Class 'C' and drinking water source after conventional treatment. Average Total Coliform counts of 24775 – 66357500 MPN/100 ml did not meet the criteria of Total Coliform counts of 5000 MPN/100ml for drinking water source with conventional treatment followed by disinfection(Class 'C') in River Yamuna at downstream Yamunotri. Free Ammonia levels of 1.4-6.6 mg/l were unsuitable for propagation of wildlife, fisheries under Class 'D' in River Yamuna from Okhla Barrage to Etawah. Entire stretch of River Yamuna was found to meet the desired criteria for irrigation, industrial cooling and controlled waste disposal (Class 'E') in terms of conductivity levels of 83-1087 $\mu\text{mhos/cm}$.

Keywords: Biological Water Quality, Primary water quality criteria, Flow velocity, designated best-uses.

1. Introduction

River Yamuna, the largest tributary of River Ganga, originates from the Yamunotri glaciers in Uttarkashi district of Uttarakhand state. The river travels a distance of 1376 Km, from its origin at Yamunotri at an elevation of 3291 msl to its confluence with River Ganga at Allahabad at an elevation of 74 msl. During its travel, the river passes through, Uttarakhand, Himachal Pradesh, Haryana, Delhi, Gautam Budh Nagar, Mathura-Vrindavan, Agra. Bateshwar and Allahabad etc, located on its bank. River Yamuna is regulated by six barrages. Out of these, Hathnikund Barrage, Wazirabad Barrage and Okhla Barrage are significant as little or no water is released downstream of these barrages particularly in dry season (almost nine months a year) As a result, the entire river stretch can be divided into four independent segments. Yamunotri to Hathnikund Barrage (Dakpatthar), Hathnikund Barrage (Dakpatthar) to Wazirabad Barrage, Wazirabad Barrage to Okhla Barrage and the downstream Okhla Barrage up to its confluence with River Ganga at Allahabad. The river water is generally used for various purposes and accordingly Primary Water Quality Criteria has been laid down for various designated best uses of river water such as; a) Drinking water source without conventional treatment but after disinfection, b) Outdoor bathing organized, c) Drinking water source with conventional treatment followed by disinfection, d) Propagation of wildlife, fisheries and e) Irrigation, industrial cooling, controlled waste disposal^[1]. The critical parameters used for compliance of water quality of River Yamuna, such as; pH, DO, BOD, Total Coliform, Free Ammonia, Electrical /conductivity, SAR, and Boron have been included to support the water quality. However, these parameters of Primary Water Quality Criteria are not sufficient to indicate the wholesomeness of the water quality. Biological Water Quality Criteria (BWQC) has been introduced to assess the actual health of water bodies, for water quality evaluation^[2]. Biological monitoring provides an effective, easy to understand less time consuming and cost effective method to determine cumulative impact of pollution. The frequent response of a community to pollution is that some species increase in abundance, other (usually the majority) decrease and the population of some species remain stable^[3].

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Among various organisms, benthic macro-invertebrates are more popularly used as bio-indicator for water quality assessment of surface waters^[4]. The present study gives a biological scenario of River Yamuna from 2009 to 2011 with Compliance of water quality of River Yamuna with respect to Biological Water Quality Criteria and Primary Water Quality Criteria.

2. Materials and methods

The critical parameters such as pH, DO, BOD, Total Coliform, Free Ammonia, EC, were used for Primary Water Quality Criteria: (Table 1). Total Coliform count in water quality of River Yamuna was done by Multiple Tube Fermentation Technique^[5]. The data on physico-chemical and bacteriological parameters, was collected for Year 2010. Biological water quality assessment of River Yamuna was done using Saprobic score and Diversity score of benthic macro-invertebrates using Biological Water Quality Criteria (Table 2). A total of 10 numbers of locations were selected on entire stretch of River Yamuna. The details of sampling location are given in Table 3 and the sampling locations are depicted in Map 1. Sampling was carried out during November 2009, May 2010, November 2010 and in May 2011.

3. Results and Discussion

The flow velocity of River Yamuna varies from Yamunotri to Allahabad with respect to Altitudinal variation ranging from 3291 msl to 74 msl (Table 3). River Yamuna is not a continuous river especially during about 9 dry months a year. As a result there are three independent segments of river i.e. river stretch downstream of Hathnikund Barrage to Wazirabad Barrage in between Haryana and Delhi state, downstream of Wazirabad Barrage to Okhla Barrage in Delhi state. Flow velocity in River Yamuna from Yamunotri to Allahabad, was measured during November 2009, May 2010, November 2010 and again in May 2011. Maximum flow velocity of 1.66 m/s was recorded in River Yamuna at Wazirabad during May 2011. This abrupt increase in flow velocity was due to release

of excess quantity of water from Tajewala barrage at upstream, as a result of heavy monsoon. Due to impact of monsoon on River Yamuna, maximum flow velocity of 0.93 meter/second was observed in Himalayan segment followed by 0.622 m/s in eutrophicated segment and 0.322 m/s in diluted segment^[6].



Map 1: Sampling locations on River Yamuna

Table 1: Primary Water Quality Criteria

Designated Base Use	Class of Water	
Drinking water source without conventional treatment but after disinfection.	A	1. Total Coliform organism MPN/100ml. shall be 50 or less. 2. pH between 6.5 and 8.5. 3. Dissolved Oxygen 6 mg/l or more. 4. Biochemical Oxygen Demand 5 days 20 °C 2 mg/l or less.
Outdoor bathing (Organized)	B	1. Total Coliform organism MPN/100ml. shall be 500 or less. 2. pH between 6.5 and 8.5. 3. Dissolved Oxygen 5 mg/l or more. 4. Biochemical Oxygen Demand 5 days 20 °C 3 mg/l or less.
Drinking Water Sources after conventional treatment	C	1. Total Coliform organism MPN/100ml. shall be 5000 or less. 2. pH between 6 and 9. 3. Dissolved Oxygen 4 mg/l or more. 4. Biochemical Oxygen Demand 5 days 20 °C 3 mg/l or less.
Propagation of Wild Life Fisheries.	D	1. pH between 6.5 and 9.5. 2. Dissolved Oxygen 4 mg/l or more. 3. Free Ammonia (as N) 1.2 mg/l or less.
Irrigation, Industrial Cooling Controlled Waste.	E	1. pH between 6.5 and 9.5. 2. Electrical Conductivity at 25-mg/cm max. 2250. 3. Sodium absorption ratio Max. 26. 4. Boron Max 2 mg/l.

Minimum flow velocity was observed in upper segment (0.055 m/s) and there was no flow velocity in River Yamuna in Delhi segment at Okhla barrage during October –November, 2009. 1.25 m/s flow velocity was observed at Etawah during November 2009, Hanumanchetti during November 2010 and at Lakhwar Dam during May 2011. Minimum flow velocity was observed at Dakpatthar, Wazirabad and Okhla Barrage mainly due to impact of barrages (Figure 1). The issues related with water quality of River Yamuna due to regulated flow which has transformed the river into various segments in dry seasons. Intermittent release of water from barrages due to unpredictable rainfall cause significant change in the water quality at downstream reaches of barrage. Flow regulation in upper segment of River Yamuna was affected both in terms of quality and quantity, which has resulted into Moderate (Class ‘C’) to Heavy Pollution (Class ‘D’) at downstream Tajewala Barrage to Kalanur during winter of 2004 whereas at the same location, the water quality improved to Class C during 2009, 2010, 2011.

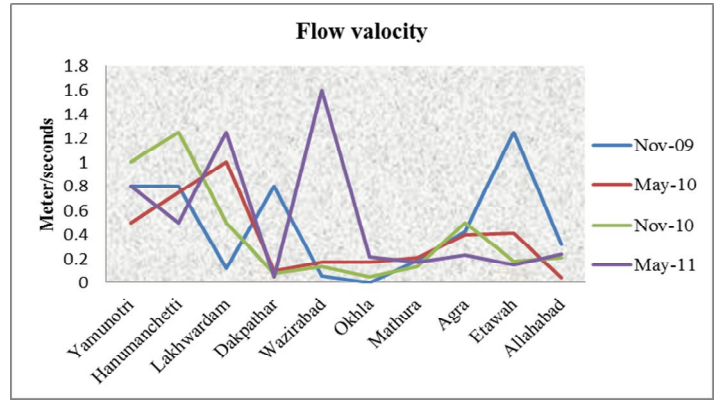


Fig 1: Seasonal variation in flow velocity of River Yamuna

Loss of biological life at Panipat downstream indicating severe pollution in water quality (Class E) mainly due to discharge from drain number 2. Whereas at Sonapat, Severe Pollution was due to non-availability of water in River Yamuna^[7].

Table 2: Biological Water Quality Criteria (BWQC)

S. No	Taxonomic Groups	Range of saprobic score (BMWP)	Range of diversity Score	Water quality characteristic	Water quality class	Indicator Colour
1	Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Diptera	7 and more	0.2 - 1	Clean	A	Blue
2	Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Planaria, Odonata, Diptera	6 – 7	0.5 - 1	Slight Pollution	B	Light blue
3	Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Odonata, Crustacea, Mollusca, Polychaeta, Diptera Hirudinea, Oligochaeta	3 – 6	0.3 - 0.9	Moderate Pollution	C	Green
4	Mollusca, Hemiptera, Coleoptera, Diptera, Oligochaeta	2 – 5	0.4 & Less	Heavy Pollution	D	Orange
5	Diptera, Oligochaeta No animals	0 – 2	0 - 0.2	Severe Pollution	E	Red

Table 3: Location description of River Yamuna

Sl. No.	Name of station (State)	Altitude in meter	Location Distance	Significance of station	Present use of river water
1.	Yamunotri (Uttarakhand)	3291	278 km from Dehradun	Impact of high altitude, reference location.	Drinking and bathing, religious
2.	Hanumanchetti (Uttarakhand)	3256	14 Km from Yamunotri	Impact of high altitude, reference location.	Drinking and bathing, religious
3.	Lakhwar Dam (Uttarakhand)	790	40 Km from Hanumanchetti	Impact of abrupt change in altitude	Drinking and bathing,
4.	Dak Pathar (Uttarakhand)	790	15 Km from Dehradun	Impact of abrupt change in altitude	Drinking and bathing,
5.	Wazirabad (Delhi)	224	25 Km from Palla	Reflects water quality of river water at Haryana -Delhi border and impact of Drain No. 8 (Sonapat)	Drinking water source
6.	Okhla Barrage (Delhi)	213-305	22 Km from Wazirabad	Indicates water quality at Delhi after receiving 14 major drains of city	Propagation of wild life and fisheries
7.	Mathura (Uttar Pradesh)	174	167 from Delhi	Indicates impact of various urban centers Delhi, Haryana and UP	Religious, bathing
8.	Agra (Uttar Pradesh)	169-171	58 Km from Mathura	Indicates river water quality at Taj Mahal.	Tourism, Bathing
9.	Etawah (Uttar Pradesh)	130	119 Km from Agra	Indicates river water quality before confluence to tributaries	Religious, bathing
10.	Allahabad (Uttar Pradesh)	74	357 Km from Etawah	Indicates water quality before confluence to River Ganga	Religious, bathing

Table 4: Biological Water Quality in River Yamuna

S. No.	Sampling Locations	Seasonal variation in Biological water quality of River Yamuna			
		November, 2009	May, 2010	November, 2010	May, 2011
1.	Yamunotri	B	A	A	A
2.	Hanumanchetti	B	A	A	A
3.	Lakhwar Dam	C	C	A	A
4.	Dak Patthar	A	C	B	B
5.	Wazirabad	C	C	B	B
6.	Okhla Barrage	C	C	C	C
7.	Mathura	C	C	C	C
8.	Agra	C	C	C	C
9.	Etawah	C	E	C	C
10.	Allahabad	C	C	C	C

The biological water quality of River Yamuna showed clean (Class ‘A’) to slightly polluted (Class ‘B’) at Yamunotri and Hanumanchetti. Water quality at this location can be used for drinking and bathing purposes throughout the year. However, the water quality of River Yamuna from Lakhwar Dam to Wazirabad was clean to slightly polluted during November to May (Table 4). The water quality of River Yamuna was moderately polluted (Class ‘C’) from Okhla Barrage to Allahabad throughout the year. At Etawah the water quality became severely polluted (Class ‘E’) during summer season. Study on the status of water quality of River Yamuna biologically clean-slight pollution water quality Class ‘A-B’ supported by Plecoptera> Tricoptera> Ephemeroptera> Diptera> Odonata> Coleoptera> Mollusca> Hemiptera In Himalayan segment. In upper segment at Lakhwar Dam downstream, the biological water quality gradually deteriorated from Class ‘A’ to Class ‘C’ at Wazirabad supporting benthic invertebrates belonging to Crustacea> Odonata> Hemiptera> Mollusca> Diptera> Coleoptera> Ephemeroptera. Biological water quality of Moderate pollution Class ‘C’ was observed in Delhi segment of River Yamuna at upstream Okhla barrage, with dominance of Hemiptera> Coleoptera> Mollusca> Dipter. Okhla Barrage has been constructed near village Madanpur Khadar and Jaitpur, 20 km downstream from Wazirabad Barrage upstream. Okhla Pakshi Vihar is situated in Ghaziabad district of Uttar Pradesh near Delhi on River Yamuna in between Okhla barrage and Okhla Weir. The area of Pakshi Vihar was developed in year 1990 when River Yamuna near Delhi was identified as internationally important wetland and declared as Ramsar site^[9]. The ancient literature records indicate that River Yamuna has been rich habitat for variety of bird during winter months. Flamingo is one of the most beautiful and endangered bird in the world. It appears sporadically or irregularly. The bird was last observed in the water of river Yamuna date back in the month of October and November 1971 near Okhla Barrage in the early part of the morning. Recently hundreds of Flamingo have been again observed at Okhla Barrage on November 22, 2002. According to bird watchers, a flock of these bird was observed near Okhla, but the bird did not stay for long time and soon flew off to new destination^[8]. Moderate – Sever Pollution in Water Quality Class ‘C-E’ was observed in Eutrophicated segment, supported by dominance of Hemiptera> Odonata> Coleoptera> Mollusca> Diptera> Crustacea>Ephemeroptera. There was an abrupt increase in pH 7.55-8.25 and Conductivity 790.5-1171.5 micro mhos/cm in this segment^[9]. There was no change in biological water quality from moderate pollution Class ‘C’ in diluted segment of River Yamuna supporting dominance of Mollusca> Odonata> Hemiptera> Coleoptera> Diptera> Ephemeroptera.

3.1 Compliance of water quality of River Yamuna with respect to Biological Water Quality Criteria and Primary Water Quality Criteria.

The average water temperature in River Yamuna increased gradually from its origin at Yamunotri to Its confluence with River Ganga at Allahabad. The minimum water temperature of 4.0⁰C was observed at Yamunotri and maximum of 40 ⁰C was observed at Agra (Figure 2) Average pH in water quality of River Yamuna was almost similar at its origin at Yamunotri (8.1) and before its confluence to River Ganga at Allahabad (8.2). The minimum average pH in water quality was observed at Okhla Barrage in Delhi (7.6).

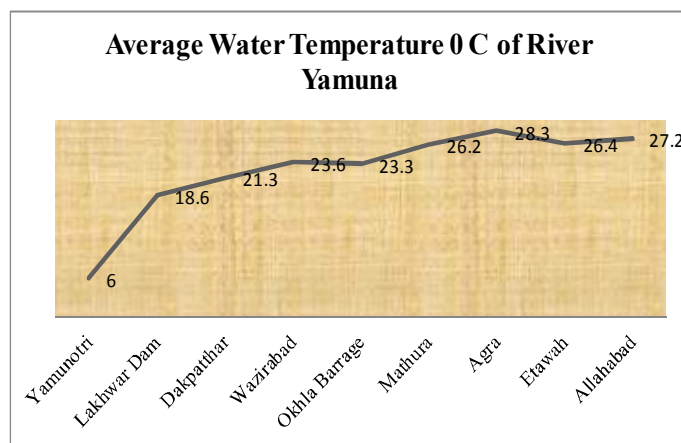


Fig 2: Water temperature variation in River Yamuna.

The average pH in water quality of entire stretch of river Yamuna is meeting the drinking water quality class ‘A’ and Class ‘B’ of primary water quality criteria (6.5-8.5) for drinking water without conventional treatment but after disinfection, and Outdoor bathing, Organized (Figure 3).

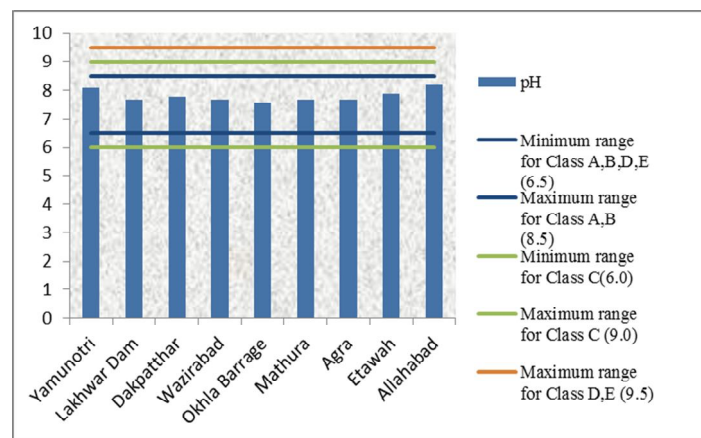


Fig 3: pH levels in water quality of River Yamuna

Average Dissolved oxygen level in River Yamuna was good in entire stretch (5.4-8.7 mg/l) except at Okhla Barrage (0.5 mg/l) in Delhi. The average Dissolved Oxygen levels in water quality of River Yamuna is meeting the desired levels of Class 'A' (6.0 mg/l) and Class 'B' (5.0 mg/l) of Primary Water Quality Criteria for drinking water without conventional treatment but after disinfection, and Outdoor bathing (Organized) respectively (Figure 4).

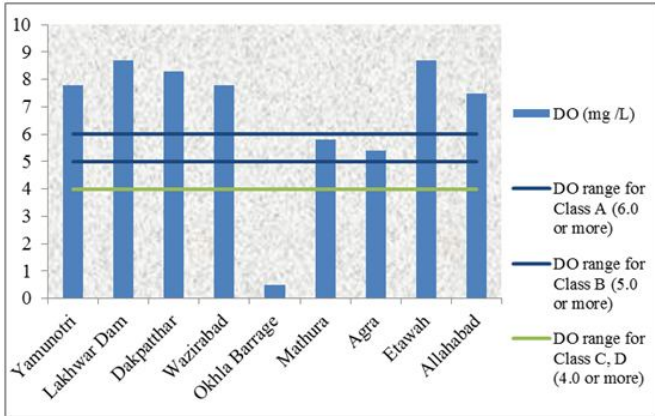


Fig 4: DO levels in water quality of River Yamuna

The average BOD levels in water quality of River Yamuna from Yamunotri to Wazirabad was <1 mg/l. There was an abrupt increase in BOD levels of 33.6 mg/l at Okhla Barrage in Delhi. Average BOD levels decreased to 6.8-7.8 mg/l in the river stretch of Mathura to Etawah. At Allahabad the average BOD level decreased to 3.0 mg/l. The average BOD levels in water quality of River Yamuna from Yamunotri to Wazirabad, is meeting the desired levels of 3.0mg/l in Class 'A' of Primary Water Quality Criteria for drinking water without conventional treatment but after disinfection and Class 'B' for Outdoor bathing at Allahabad (Figure 5).

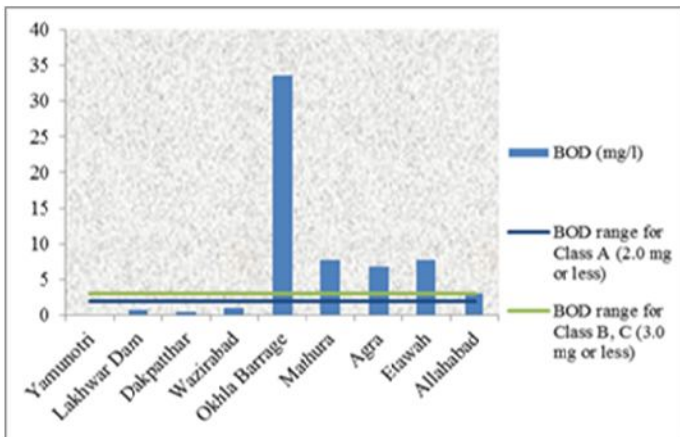


Fig 5: BOD levels in River Yamuna.

Total Coliform count in river is very important parameter to ascertain the drinking and bathing water quality. One has to take utmost care while using proper methodology for suitability to water quality criteria. The method of Total Coliform estimation used in Primary Water Quality Criteria is by MTF technique and the standards are expressed in MPN/100 ml. The results reported with respect to Total Coliform estimation done by MF technique did not comply with the water quality standard prescribed by CPCB^[10]. The average minimum Total Coliform numbers in River Yamuna was <2 MPN/100 ml at Yamunotri and Maximum of 66357500

MPN/100ml at Okhla Barrage in Delhi stretch. The average Total Coliform numbers in water quality of River Yamuna at Yamunotri is meeting the desired levels of Class 'A', Class 'B', and Class 'C' of Primary Water Quality Criteria of 50 MPN/100 ml, 500 MPN/100ml and 5000 MPN/100 ml or less respectively for drinking water without conventional treatment but after disinfection, and Outdoor bathing (Organized) and drinking water source after conventional treatment respectively (Figure 6).

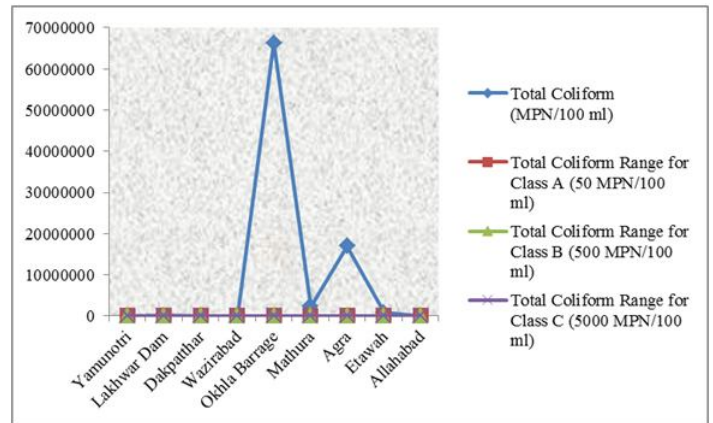


Fig 6: Total Coliform count in River Yamuna

The average free ammonia in water quality of River stretch of Yamuna from Yamunotri to Wazirabad (0.0- 0.13 mg/l) is meeting the primary water quality criteria of 1.2 mg/l of Class 'D' for Propagation of wildlife and fisheries. From Okhla Barrage to Etawah the river stretch did not support water quality use for propagation of wildlife and fisheries as the Ammonical nitrogen level ranged between 1.4 to 6.6 mg/l in this stretch. Ammonical nitrogen level of below detection limit in water quality of River Ganga was suitable for conservation of rare and endangered Gangetic Dolphin (*Platanista Gangetica*) in 82 km stretch of River Ganga declared as Ramsar site from Garhmukteshwar to Narora at Garhmukteshwar. Dolphins were commonly observed in biological water quality of Moderate Pollution Class 'C'. Habitat degradation due to construction of Dam/Barrages, extraction of water, siltation, pollution due to hazardous chemical and other human activities are the main cause of its decline in the river^[11].

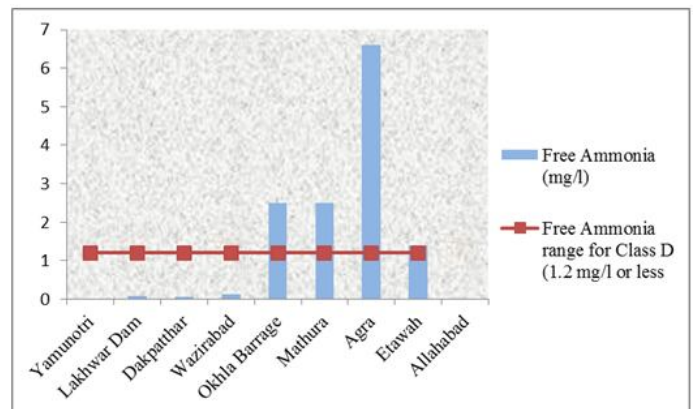


Fig 7: Free Ammonia levels in River Yamuna

Average conductivity in water quality of River Yamuna was minimum of 83 µmhos/cm at its origin at Yamunotri. There was gradual increase in conductivity level (283-324 µmhos/cm) in water quality upto Wazirabad. Thereafter, there was an abrupt

increase in conductivity in river stretch from Okhla Barrage to Etawah (1087-1064 $\mu\text{mhos/cm}$) and then there was sudden decrease in conductivity at Allahabad (593 $\mu\text{mhos/cm}$). The average conductivity in water quality of entire stretch of River Yamuna is meeting the Class 'E' of primary water quality criteria (2250 $\mu\text{mhos/cm}$) for Irrigation, Industrial cooling and controlled waste disposal. Decadal observation indicated that there was an abrupt increase in pH 7.55-8.25 and Conductivity 790.5-1171.5 micro mhos/cm. in water (Figure 7).

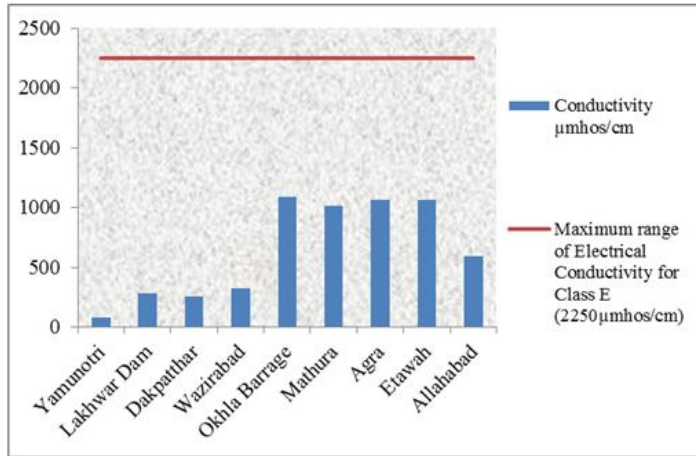


Fig 8: Electrical Conductivity levels in River Yamuna

4. Conclusion

River Yamuna, the largest tributary of River Ganga, travels a distance of 1376 Km, from its origin at Yamunotri at an elevation of 3291msl to its confluence with River Ganga at Allahabad at an elevation of 74 msl. During its travel, flow velocity of River Yamuna varies from 0.0 to maximum of 1.66 m/s. The minimum water temperature of 4.0 $^{\circ}\text{C}$ was observed at Yamunotri and maximum of 40 $^{\circ}\text{C}$ was observed at Agra. The biological water quality of River Yamuna showed clean (Class 'A') to slightly polluted (Class 'B') at Yamunotri and Hanumanchetti. Water quality at this location can be used for drinking and bathing purposes throughout the year. The moderate pollution of (Class 'C') was observed in water quality of River Yamuna was from Okhla Barrage to Allahabad throughout the year. The water quality did not support aquatic life at Etawah during summer season and the water quality was severely polluted (Class 'E'). Water quality of River Yamuna at Yamunotri, meets the Primary Water Quality Criteria in terms of pH of 8.1, DO of 7.8 mg/l, BOD of <2 mg/l and Total Coliform count of <2 MPN/100ml used for drinking water without conventional treatment but after disinfection (Class 'A') and Outdoor bathing (Class 'B') and Class 'C' and drinking water source after conventional treatment respectively. Free Ammonia levels of 1.4-6.6 mg/l were found to be unfit for propagation of wildlife, fisheries under Class D in water quality of River Yamuna at Okhla Barrage. Flamingos have been observed in thousand in the lake formed at Okhla Barrage where they come to feed on fish, insect, seeds and roots of marsh plants. They make their nests in a mound of mud, which look like a depression. There is an urgent requirement to restore the water quality for conservation of habitat of rare and endangered Flamingos at Okhla Barrage.

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