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Status of pollution of Yamuna waters and remedial measures for its prevention

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Abstract

River Yamuna, a tributary of river Ganga, is one of the sacred rivers of India. Unfortunately, of late it has turned into such a state that no one would like to dip even his hand in its water. Specially downstream of Delhi City, and particularly below Okhla barrage during lean season the flow in the river is almost negligible, and consists mainly of sewage disposal and industrial effluents from Delhi and Noida. Central Water Commission (CWC) is collecting water samples of river Yamuna at 10 sites for analyzing water quality comprising 24 parameters for past two decades. Critical analysis of the data reveals that at Delhi, Mathura, Agra and Etawah, the water is unfit for human consumption. Two basic remedial measures for making Yamuna waters suitable for human consumption are (1) to increase the inflow in the river to dilute and digest the pollution load and (2) to prevent the incoming of the highly polluted waste/effluents by treating the same as per standard norms. Studies carried out to assess the quantum of water required to dilute the present incoming pollution load indicate that it is not possible to provide such huge quantity of water in the river round the year. However, a mixed solution is practicable where the effluents are treated to the minimum desired level and some minimum quantum of water as may be available by constructing reservoirs in the upstream of Delhi city, is released in the river at specified period of the year.

YAMUNA BASIN

River Yamuna originates from the Yamunotri glacier in Tehri-Garhwal district of Uttar Pradesh. After flowing in the hills for about 200 km, it emerges into the Indo-Gangetic plains in Saharanpur district of UP. Flowing further down, it reaches Tajewala where the Western and Eastern Yamuna canals take off from the Tajewala Headwork. Before Tajewala, Tons is the main tributary of the Yamuna. River Firi joins the Yamuna downstream of Dakpatthar. From Faizabad near Tajewala, the river flows 104 Km in a southwesterly direction and receives the Maskara stream on its left bank. Near Biauli in Muzaffarnagar district of UP, the river turns southwards for a distance of 128 km. to reach Delhi. From the Okhla headwork in the National Capital Region of Delhi, the Agra canal takes off from its right bank. Beyond Delhi, the river flows towards Mathura in south direction for a distance of about 205 km. From Mathura onwards it flows in a southeasterly direction through Agra, Etawah, Kanpur and Allahabad district before joining the Ganga at Allahabad.

A map of the Yamuna basin showing water quality observational sites on the main river Yamuna being maintained by the CWC is at figure 1.

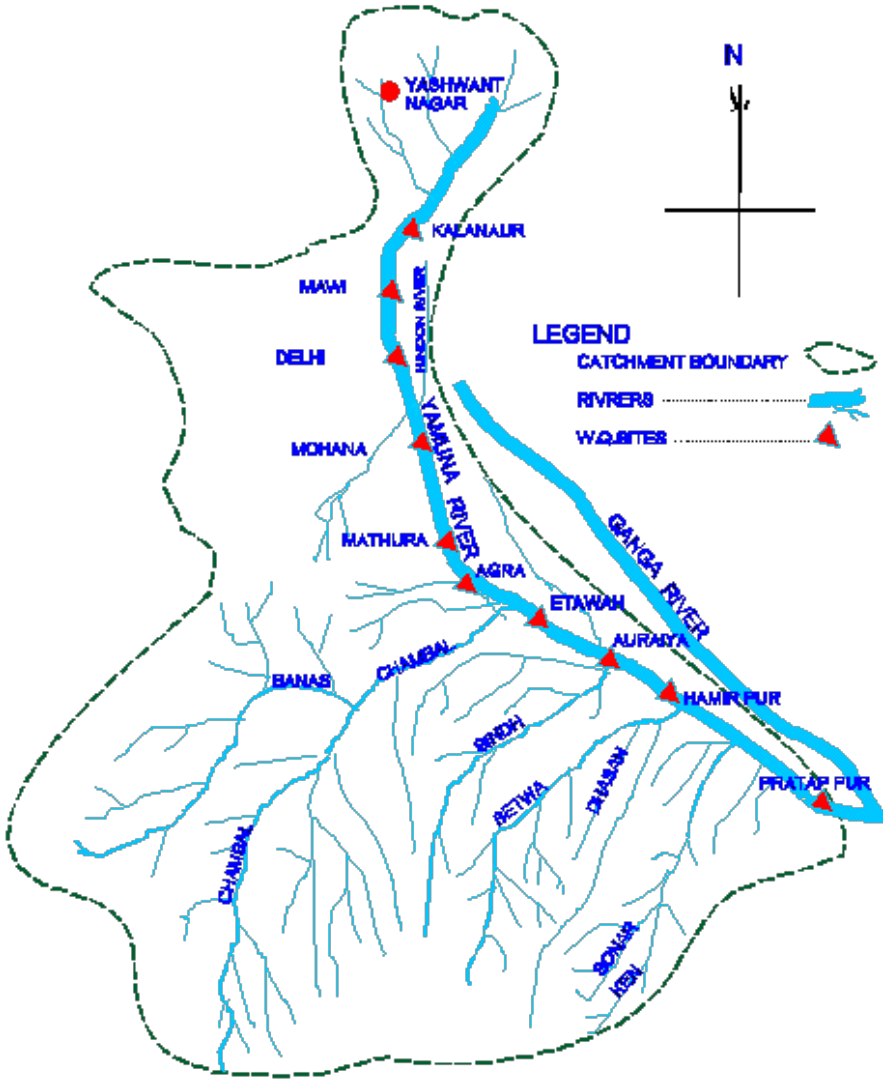

Figure 1. Map of the Yamuna basin showing water quality sites on the main river Yamuna.

WATER AVAILABILITY AND REQUIREMENT FOR DIFFERENT USES IN THE BASIN

The total water availability of the entire Yamuna basin based on the discharge data being maintained by the CWC as assessed by the 'Inter Disciplinary Working Group' consti-

tuted by the Government of India for the study of requirement of minimum flows in the Yamuna river who submitted their report in May 1989 is as given below:

Table 1. Water availability of Yamuna basin.

S. No.	Water Availability	Monsoon (June – Oct.)	Non Monsoon (Nov. – May)	Total (Annual)
1	Average availability	81957	7838	89795
2	At 75% dependability	54821	6002	60823

(Quantity in Million Cubic Meters/MCM)

Availability of flows

Study of the observed flow data of the river for 32 years (1951-82) for Tajewala and 22 years (1960-82) for Okhla for non monsoon period (Nov. to May) shows that for about 70% to 80% of the time, the discharge downstream of Tajewala and Okhla is less than 5 cumec. For a considerable period there is no flow. At Mathura and Agra, the 90% dependable flows are less than 5 cumec for at least two months (May and June) and 75% dependable follows are less than 5 cumec in May. At Etawah, the minimum flows during the period November to May vary from 2.45 cumec to about 15 cumec. Flows at 90% dependability in May are less than 5 cumec and 75% and 90% dependable flows at about 146 cumec and 97 cumec respectively during May. Further lower down at Hamirpur, the flows dwindle and the minimum flows reduce to about 48 cumec (June) and 75% and 90% dependable flows reduce to about 109 cumec and 82 cumec respectively. Downstream of Hamirpur the flows again increase at Pratappur near Allahabad where the minimum, 75% and 90% dependable flows are 75 cumec, 144 cumec and 113 cumec respectively.

Water balance of Yamuna basin

Surface Water Resources : The surface water balance by the year 2000 AD as assessed by the working group as mentioned in para 2.0 is as follows:

	Quantities in MCM
Net availability including imports, export and storage regulation	78452
Utilization for irrigation by 2000 AD	52992
Domestic, non domestic and industrial	1787
(Including use of ground water potential)	
Balance	23673
Ground Water	
Total utilizable water	58533
Irrigation utilization by 2000 AD	36375
Balance	22158

HYDROLOGICAL OBSERVATIONS FOR WATER QUALITY STUDIES

In order to assess the quality of water at sites for different uses of Yamuna waters, hydrological observations are being carried out for about 2 decades by the Central Water Commission. Details are as given below:

Table 2. Availability of water quality data.

S. No.	Location of the site on main river Yamuna	Date from which data is available
1	Kalanaur	01.09.1976
2	Panipat	01.09.1976
3	Delhi	01.02.1979
4	Mohana	01.09.1976
5	Mathura	01.07.1976
6	Agra	30.07.1976
7	Etawah	01.02.1972
8	Auraia	01.01.1981
9	Hamirpur	01.01.1981
10	Pratappur	01.01.1981

It may be seen from the above table that common period or the data availability for almost all the sites is from 1981-82 onwards. However, the scrutinized data as printed in the water Yearbooks is available from 1986 –87 to 96-97. Moreover, data of Panipat site is found to be sufficient to study various parameters and thus the data of upstream most Kalanaur site has not been considered. Hence, the present study is based on the water quality data of aforesaid 9 sites from S. No. 2 to 10 for the period from 1986-87 to 1996-97.

ANALYSIS AND STUDY OF WATER QUALITY DATA

Parameters considered for study

The number of parameters being analyzed by the CWC at present is 24; however, only following 7 important parameters have been considered for the study in this paper.

1. Dissolved oxygen (D.O.)
2. Biochemical Oxygen Demand (B.O.D.)
3. Electrical Conductance (EL)
4. Fluorides (F)
5. Chloride (Cl)
6. Sulphate (SO4)
7. Hardness No. (As $CaC0_3$)

A brief description of these 7 parameters is as given below:

Dissolved oxygen (D.O.): Oxygen has some solubility in water that depends on concentration of dissolved material and temperature. Solubility of oxygen decreases with the rise in temperature. The maximum amount of oxygen in normal river water is between 9-11 ppm (excluding sea water) in the temperature range varying from 20^o to 30^o C. Dissolved oxygen is responsible of sustaining various aquatic fauna. It is also responsible for presence and absence of various microorganisms in water.

Bio-chemical oxygen Demand (BOD): Bio-chemical oxygen demand is the amount of oxygen consumed by bacterial activities under standard conditions of time and temperature. Its value depends on the amount of material that can be degraded by bacteria and the

bacterial population in the sample. Some times toxic chemicals do not allow the bacteria to grow, even though the other conditions are favorable for their growth. **This is a very important parameter for assessment of level of pollution and its nature.**

Electrical Conductance (EL): Conductance is a numerical expression of the ability of a conductor to carry electric current. The reciprocal of resistance is conductance. This ability in an aqueous solution depends on the presence of ions, their total concentration, mobility, valency, and on temperature at the time of measurement. The conductivity is determined at 25^{o}C as this temperature is taken as standard temperature for most of the works.

Fluoride (F): It is the one of the essential elements that should be present in drinking water but in a very limited quantity. The optimal concentration for human being is 1mg/litre. Lower concentration of water can cause dental caries and even mottling of teeth. Larger concentrations also have very serious effects on bones of animal and human beings. The bones become hard and still due to which even children stoop and are not able to walk straight. Ground water in certain areas has high fluoride concentration. Such waters have to be de-fluoridated before consumption.

Chloride (Cl): It is one of the major inorganic anions in water and wastewater. In potable water, the salty taste produced by chloride concentrations is variable and dependent on the chemical composition of water. The chloride concentration is higher in wastewater than in raw water because Sodium Chloride is a common article of diet and passes unchanged through the digestive system. A high Chloride content may harm metallic pipes and structures as well as growing plants. Some waters containing 250 mg Chloride/liter may have detectable salty taste if the cation is Sodium. The typical salty taste may be absent in waters containing as much as 1000 mg Chloride/liter when the predominant cations are Calcium and Magnesium.

Sulphate (SO_4): Sulphur is widely distributed in nature and it is present in air also in the form of its oxides. Much of this Sulphur is dissolved in water and appears at sulphates. The other sources of sulphates in water are leaching from sulphate bearing minerals such as epsom and gypsum, domestic washing containing detergents, degradation of organic proteins and oxidation of sulphide. Sulphate up to 300-500 mg/lire does not harm. The higher concentration is reported to have purgative action.

Hardness No. (as $CaCO_3$): Total hardness is defined as the sum of the Calcium and Magnesium concentrations; both expressed as Calcium Carbonate in mg/liter. Water hardness is understood to be a measure of the capacity of water to precipitate soap.

Tolerance Limits for various uses: As per Indian Standard Institute (Now known as Bureau of Indian Standard) – IS2296 –1982, the tolerance limits of various parameters had been specified as per classified use of water. The classification as given in table 3, has been adopted in India.

Table 3. Tolerance limits of various parameters.

Parameters	Units	Class A	Class B	Class C	Class D	Class E
Dissolved Oxygen	Mg/L	6	5	4	4	-
Biochemical Oxygen Demand (BOD)	Mg/L	2	3	3	-	-
Electrical Conductance	Micro-mhos/ CM	800	2000	2400	1000	2250
Fluorides (F)	Mg/L	1.5	1.5	1.5	-	-
Chlorides (Cl)	Mg/L	250	-	600	-	600
Sulphate (SO_4)	Mg/L	400	-	400	-	1000
Hardness No. ($CaCO_3$)	Mg/L	300	-	-	-	-

Classification **Type of use**

Class A Drinking water source without conventional treatment, but after disinfecting.
Class B Outdoor bathing
Class C Drinking water source with conventional treatment followed by disinfecting
Class D Fish culture and wildlife propagation
Class E Irrigation, industrial, cooling etc.

The Central Board for the prevention and control of pollution, New Delhi has prescribed certain norms for various industries for keeping various parameters influencing the quality of water to the desired limits before releasing water into the natural streams. Similar guidelines have also been issued by UP Pollution Control Board, Lucknow. Details of some important parameters are as given below:

Table 4. Tolerance limits prescribed by UP Pollution Control Board.

Characteristics	General Tolerance Limits prescribed	Caustic Soda Industry	Sugar Industries	Breweries & distilleries	Pesticides and formulation industry	Straight phosphate fertilizer industry	Small paper and pulp industry
BOD for 5 days (20 ^{o} C)	30	-	30	30	30	-	30
Total suspended solids in PPM	100	100	100	100	30	100	100
Fluoride (F) in PPM	20	-	-	-	-	10	-

CRITICAL REVIEW OF WATER QUALITY DATA

Scrutinized available common data of 9 sites on the Yamuna, as mentioned in para 3.0 for the period from 1986-87 to 1996-97, i.e. for 11 years has been compiled. Critical val-

ues for 7 parameters selected for studies for all the 9 sites for 1986-87, 1996-97 and average of past 11 years (1986-87 to 1996-97) during non monsoon period is as given below:

Table 5. Observed data for water quality analysis.

Site /Parame-ter		Panipat	Delhi	Moha-na	Mathura	Agra	Etawah	Au-raiya	Hamir-pur	Pratap-pur
D.O.	I	06.02	00.95	05.52	09.69	09.81	07.28	08.19	08.49	08.66
	II	07.05	00.00	02.37	07.94	12.09	09.37	07.96	06.30	07.44
	III	06.75	01.43	03.31	08.82	09.15	09.39	09.30	00.69	08.19
B.O.D.	I	04.25	43.21	49.58	08.52	09.00	07.45	01.38	06.00	03.54
	II	02.73	67.15	48.90	43.89	23.02	18.94	05.34	04.77	03.27
	III	03.93	37.65	35.64	18.45	13.99	10.63	05.02	05.36	04.97
E.L.	I	266.0	569.0	788.0	1106	1090	1094	481.0	475.0	451.0
	II	391.0	1027	1338	1188	1242	1117	708.0	628.0	545.0
	III	341.0	746.0	1126	1218	1275	1212	645.4	654.5	585.2
F	I	00.02	00.37	00.22	00.24	00.14	00.18	00.15	00.10	00.12
	II	00.27	01.03	00.51	00.41	00.41	00.22	00.22	00.15	00.14
	III	00.19	00.52	00.56	00.52	00.44	00.33	00.33	00.30	00.29
CL	I	17.96	96.43	152.3	224.8	282.7	271.7	46.35	55.48	47.94
	II	06.97	135.4	195.2	182.9	211.6	179.2	51.93	66.53	43.19
	III	08.69	86.19	150.2	173.0	196.3	191.3	53.86	60.02	46.37
$S0_4$	I	10.17	09.86	12.73	16.84	55.87	60.53	01.43	05.41	04.94
	II	30.00	79.33	68.83	72.00	94.33	75.00	42.83	44.17	35.67
	III	26.99	67.08	64.74	90.11	98.56	99.06	44.68	42.35	33.52
H. No.	I	201.7	227.4	293.9	361.7	389.9	311.2	218.9	205.3	170.8
	II	167.0	264.2	321.4	278.4	322.6	284.4	181.9	199.6	163.4
	III	184.2	211.1	287.1	308.2	302.6	273.4	184.4	194.0	170.2

ABBREVIATIONS

I Data for the year 1986-87 **II** Data for the year 1996-97
III. Data as average of 11 years (86-87 to 96-97)
D.O. Dissolved Oxygen in Mg/liter **B.O.D.** Bio-chemical Oxygen Demand
F Fluorides in Mg/Liter **Cl** Chlorides in Mg/Liter
SO4 Sulphates in Mg/Liter **H. No.** Hardness Number
EL Electrical conductance at 25^{o}C in micromhos per cm,

Pollution load in Yamuna Water

It may be seen from table 5 that the value of D.O. at Delhi is 0.95 for the year 1986-87 which has been further reduced to 0.00 during 1996-97, the average value for past 11 years (1986-87 to 1996-97) being 1.43. It indicates that Yamuna water at Delhi is not suitable even for outdoor bathing purposes. Similarly, if we consider BOD parameter, the situation is still worse as the value at Delhi is 43.21 for the year 1986-87 and 67.15 during 1996-97, the average value for past 11 years being 37.65. This reveals that Yamuna water at Delhi is not at all suitable for any kind of use. The presence of Fluorides, Chlorides, Sulphates and Hardness Number as well as Electrical Conductance, although, are within tolerance limits, the state of pollution as indicated by D.O. and BOD parameters which are predominant to all other parameters, reveals that Yamuna water at Delhi is extremely polluted.

The average values for non-monsoon period (December to May) for all the 7 parameters considered for studies for the period from 1986-87 to 1996-97 at Delhi site are as given below:

Table 6. Water quality data for Delhi Site.

S. No	Period	Electrical Conduct-ance micro-mhos/ cm	Chloride in PPM	Fluo-ride in PPM	Sul-phate in PPM	Dissolved Oxygen in mg/l	Bio-chemical oxygen demand at 20^{o} C (5 days) in mg/l	Hard-ness No.
1	86-87	569	96.43	0.37	9.86	0.95	43.21	227.45
2	87-88	456	83.54	0.52	70.34	1.11	54.67	199.24
3	88-89	756	56.25	0.54	65.24	2.75	28.05	213.02
4	89-90	622	48.63	0.29	57.40	2.22	19.26	153.64
5	90-99	588	57.00	0.40	45.67	1.88	23.33	186.17
6	91-92	910	85.67	0.50	70.50	0.22	42.00	175.83
7	92-93	736	66.47	0.35	66.33	5.54	29.36	194.17
8	93-94	833	102.87	0.23	80.00	0.00	44.85	212.02
9	94-95	943	122.36	0.63	105.47	0.07	25.32	244.62
10	95-96	770	93.41	0.91	87.83	0.99	36.94	251.77
11	96-97	1027	135.42	1.03	79.33	0.00	67.15	264.27
Average		746	86.19	0.52	67.08	1.43	37.65	211.11

Considering the tolerance limits for various uses specified in tables 3 and 4 and looking at the values of various parameters, specially D.O. and B.O.D., it is obvious that Yamuna Water at Delhi is highly polluted and is not suitable for safe use of any kind.

REQUIREMENT OF MINIMUM FLOWS FOR DILUTING POLLUTION LOAD

Flows required for diluting water pollutants to restrict BOD to the limit of 3 mg/liter, as determined by the '*Inter–Disciplinary Working Group on Study of Requirement of Minimum Flows in the Yamuna*', set up by the Govt. of India, who submitted their report in May 1989, is as given in table 7.

Possible measures for augmentation of flows

In order to meet the flow requirements of desired level of purity at different places for various identified uses, the measures that need consideration may be as given below:

i. Providing monsoon storage reservoirs in the upstream to store monsoon run off.
ii. Encourage conjunctive use of surface and ground water
iii. Full treatment of all waste waters from towns and industries
iv. Use of sewage water for irrigation
v. Providing drainage in the irrigated area
vi. Modernization of irrigation system and efficient water management
vii. Creation of awareness for maintaining sanctity of the holy rivers

Table 7. Requirement of water to dilute pollutants.

Town	BOD of waste water after treatment mg/liter	Waste water flow	Flow required for dilution of BOD to 3 mg/liter	90% dependable flow
Delhi	30	12.36	223	2
	20	12.36	140	
	10	12.36	58.00	
Mathura	30	0.596	16.05	2.31
	20	0.596	10.12	
	10	0.596	4.17	
Agra	30	0.812	21.93	3.40
	20	0.812	13.84	
	10	0.812	5.70	
Etawah	30	0.120	3.24	4.23
	20	0.120	2.04	
	10	0.120	0.84	
Allahabad	30	1.796	32.33	112.79
	20	1.796	20.35	
	10	1.796	8.38	

Flows in Cumec

The availability of surface water is short of its demand for various uses specially upstream of Delhi City. However, the possibility of constructing storage upstream of Tajewala to store surplus monsoon flows may be explored. The scope of proposed Kishau Dam and Renuka dam upstream of Tajewala might be enlarged to include the requirements of water for diluting the pollutant loads and for maintaining minimum flows at different locations. The Ganga waters, after completion of Tehri Dam may also be brought to the Yamuna through the existing Upper Ganga Canal System to increase the flows in the Yamuna.

CONCLUSION

It may be seen from table 5 that the values of BOD are abnormally high at Delhi and at downstream stations up to Etawah. It gets reduced from Auraiya onwards where the Chambal River contributes to the Yamuna. This is further improved at Hamirpur where the Betwa River joins and finally it comes nearer to the permissible limit at Allahabad. In order to bring the value of BOD up to 3 mg/liter at Delhi City, flows amounting to 56 cumec are required even after treatment of waste water up to BOD limit of 10 mg/liter. The depletion of ground water will certainly necessitate the use of surface water for irrigation, and thus it may not be possible to release water in the Yamuna for the purpose of dilution of the pollutants and for the maintenance of the ecology of the river. The requirement of domestic water supplies of Delhi city are so high that perhaps there will be no scope for releasing any amount of water in the river at present. However, the possibility of creating upstream reservoirs for providing regulated releases as well as curtailing irrigation demand in some areas where the conjunctive use of ground and surface water

may be resorted to, may be thought of. The main stress therefore, is to be applied on the treatment of the pollutants before releasing them into the river. The Central Pollution Control Board and the State Pollution Control Boards have already issued guidelines for the industries in this regard. However, the strict compliance is still required to be observed for maintaining the sanctity of the holy river Yamuna. In addition to imposing penalties to the defaulters and closing down such industries which are repeatedly violating the guidelines laid down by the 'Pollution Control Boards', creation of an awareness for not releasing untreated water and industrial waste to the natural streams, amongst various water users is also required. The Central Water Commission, Indian Water Resources Society, and various Water Resources Departments of State Governments are following this in practice in the country by way of observing 'Water Resources Day' each year and by propagating the importance of water in the masses.