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# ANALYSIS OF VARIATION IN WATER QUALITY OF YAMUNA RIVER IN PASSING THROUGH DELHI USING FUZZY MODELLING

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ABSTRACT. River Yamuna, a tributary of river Ganges has been acclaimed as the lifeline of northern India. From the past few decades Yamuna has been exposed to extensive deterioration and pollution. The 22 km Delhi segment of Yamuna River is established as the leading contributor and is responsible for more than three quarters of the total pollution load. Untreated waste water discharge into the river is the major reason behind this and multiplying population, extensive industrialisation and endless anthropogenic exercises has worsened the situation. In spite of numerous continual endeavours the river's health is still disappointing. The present study aimed to analyze the variation in the water quality of Yamuna after passing through its most polluted stretch. In this study CPCB data of critical water quality parameters of Yamuna before entering Delhi at Sonepat and before exiting Delhi at Okhla have been considered. Fuzzy Inference System of MATLAB has been used for this analysis. The results reveal that water quality is in good to medium category before entering Delhi and after passing through Delhi the holy river has turned into a sewer. Persuasion of an imperishable management plan along with appropriate sewerage planning and preserving minimum ecological flow is needed to retrieve the ailing river.

## 1. INTRODUCTION

Fresh water is one of the key elements responsible for sustaining life on earth. India is a country which is graced with fairly good land, huge water and

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TABLE 1. Table (a)

| Segment | Distance | Kilometers |
|---|---|---|
| Himalayan segment | From origin to Tajewala barrage in Haryana | 172 kms |
| Upper segment | Tajewala barrage to Wazirabad barrage | 224 kms |
| Delhi segment | Wazirabad barrage to Okhla barrage | 22 kms |
| Eutriphicated segment | Okhla barrage to Chambal concurrence | 490 kms |
| Diluted segment | Chambal concurrence to Ganga concurrence | 468 kms |

mineral resources. In India, rivers are the major source of fresh water and there are seven major rivers with more than four hundred rivers in total. The river Yamuna, also known as Jamuna is the longest as well as second largest tributary of the river Ganges. Similar to Ganges the river Yamuna too has been hailed as one of the sacred rivers in Indian mythology. Arising from the glacier Yamunotri at a height of 6387 meters in the Garhwal Himalayas in Uttrakhand this beautiful river travels a length of about 1376 kilometres before merging with the Ganges at Triveni Sangam in Allahabad [1]. With a catchment area of 366,223 square kilometres which is around 40.2% of entire Ganga Basin, the Yamuna flows through several states. The river travels from Uttrakhand, U.P., Haryana going across H.P. and then Delhi. Table (a) and fig (i) shows catchment area of Yamuna river basin. With an estimated 57 million people directly or indirectly dependent on Yamuna's water, the river is of paramount importance. We are glorified with the holy water of Yamuna, however it is displeasing that we care expressing our thankfulness and gratitude towards river by considering it as a sewer.

It has been projected that Delhi is the major contributor to this plight (fig (ii)). The river enters the city 1.5 kilometres upstream of village Palla and leaves at Jaitpur, downstream of the Okhla Bridge. Around 19 drains of the capital are discharged into the river and accounts for around 96 percentage of the total pollution load of Yamuna. Merely, 5 percentage of the total discharged

sewage is treated and thus is posing a serious threat to population. Besides this increasing industrialization, expanding population and religious activities are making the river health more worsening. Effectively and efficiently evaluation of Water Quality (WQ) status of the river is need of the hour and one of the crucial subject matters for water authorities. A lot of studies for pollution mapping of Yamuna have been conducted [2–5]. The conventional and deterministic methods to evaluate water quality of river systems have a major limitation of inability to deal with uncertainties and vagueness encountered within WQ management. A lot of studies revealed that using Artificial Intelligence in framing of river WQ management [6–14]. Zadeh [15, 16] developed Fuzzy logic in 1965 and introduced the notion of linguistic reasoning. The Fuzzy logic has demonstrated a great promise in many emerging fields including engineering, applied sciences and many others. Many researchers applied fuzzy logic in water resource management [17–24].

The present study addresses analysis and evaluation of variation in WQ of river Yamuna in passing through Delhi. A WQ model is developed utilizing MATLAB Fuzzy Inference System to measure variation.

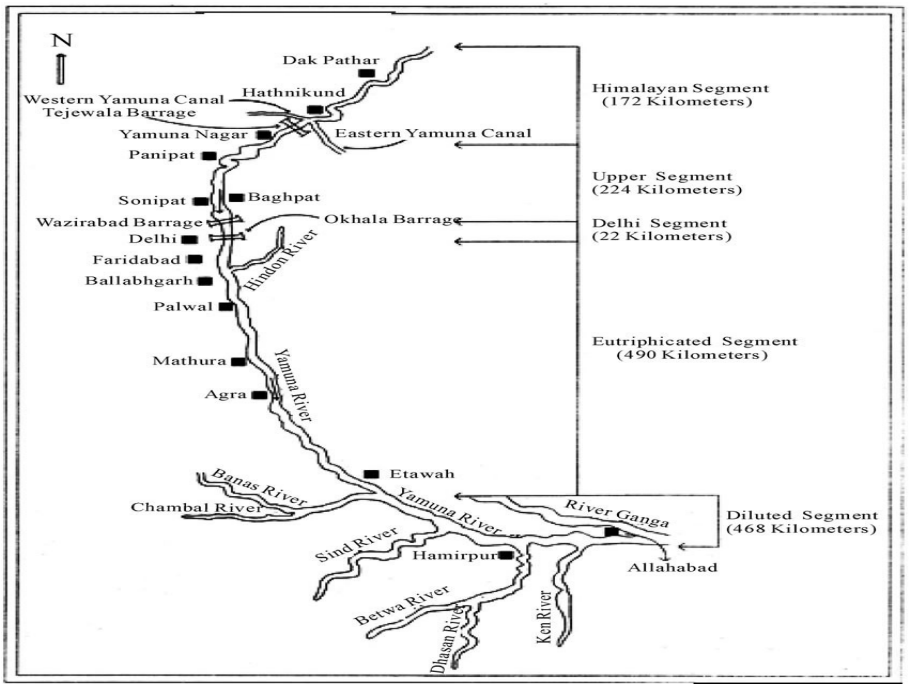



Figure (i): Catchment area of Yamuna River Basin

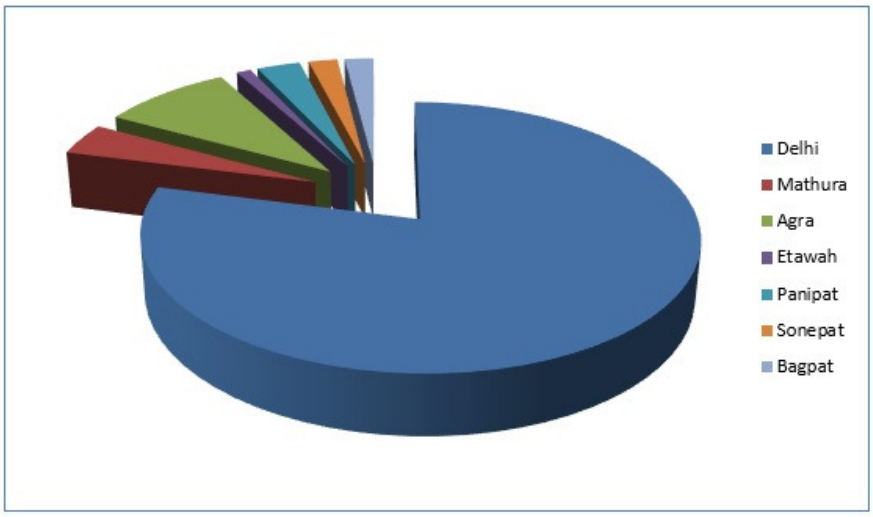



Figure (ii) Contribution to pollution load of Yamuna by various cities (Source CPCB)

## 2. Methodology

In this study a Fuzzy Inference Rule based technique known as Mamdani method has been used which involves following four steps:

**Step 1.** Fuzzification of crisp (non-fuzzy) input variables with the help of linguistic variables and using membership functions.

**Step 2.** Formation and Evaluation of Fuzzy Inference Rules.

**Step 3.** Integration or aggregation of rule outputs.

**Step 4.** Defuzzification of the fuzzy output into crisp (non-fuzzy) output.

## 3. Sampling sites and Water Quality Parameters

In this study, first sampling site is Sonepat (Yamuna before entering Delhi) and second sampling site is Okhla A/M of Shahdara drain (Yamuna before exiting Delhi). Two critical WQ parameters Biological Oxygen Demand (BOD) and Dissolved Oxygen (DO) have been evaluated at these sampling sites. BOD is the measure of amount of oxygen consumed by aerobic biological organisms in decomposing organic matter present in the water body at a particular temperature. Pollution results in high BOD level which in turn leads to decreased oxygen level because available oxygen in water is being consumed by aerobic biological organisms. DO represent the amount of free oxygen present in water and is essential for survival of almost all forms of aquatic life

.It is a prime indicator of quality of water. Atmosphere and photosynthesis of green plants are the major sources of DO. Increasing temperature of water body and discharge of organic waste into water body leads to low DO level and this badly impacts aquatic life.

## 4. Variation Analysis using MATLAB FIS

In this analysis, a Fuzzy methodology is suggested to calculate variation in water quality of the Yamuna water is passing through Delhi. The four steps of Fuzzy Inference System in MATLAB are executed taking BOD and DO as inputs and water quality as output. The trapezoidal membership function is used to represent linguistic variables. We have used Excellent(E), Good(G), Medium(M), Poor(P), Very Poor(VP) as linguistic variables for the inputs BOD and DO and Very Good(VG), Good (G), Satisfactory(S), Bad(B), Very Bad (VB) for the WQ depiction. In general the number of rules is given by [number of linguistic variables]number of parameters . Here we have five linguistic variables and two parameters, so we have 52 =25 rules. These rules are formed with expert advice. Some of these rules are shown in Table (b).

| Rules | BOD | DO | WQ |
|---|---|---|---|
| | If | And | Then |
| 1 | E | E | VG |
| 2 | E | G | VG |
| 3 | E | M | G |
| 4 | E | P | S |
| 5 | E | VP | VB |

**Table (b) Few of the Rules formed in this analysis**



These are then aggregated for the determination of final crisp (non-fuzzy) output through Defuzzification. The most prominent centroid method of defuzzification is used in this analysis.

## 5. Simulation results and analysis

The proposed model for prediction of variation in WQ was justified by using MATLAB simulation studies. The Fuzzy Logic Designer of MATLAB is applied to calculate the variation of WQ of river Yamuna before entering Delhi and before exiting Delhi.

| Linguistic Representation | BOD | DO |
|---|---|---|
| E | [0;0;2;3] | [7;7;20;20] |
| G | [2,3,5,7] | [4;5;7;7] |
| M | [3.5;4.5;7;10] | [2;3;4;5] |
| P | [4.8;7.5;10;25] | [0;1;2;3] |
| VP | [7.5;35;40;40] | [0;0;1;1] |

Table (c) Membership Function of BOD and DO

| Linguistic Representation | WQ |
|---|---|
| VG | [80;90;100;100] |
| G | [60;70;80;90] |
| S | [30;35;65;70] |
| B | [10;20;30;40] |
| VB | [0;0;10;20] |

Table (d) Membership Function of Water Quality

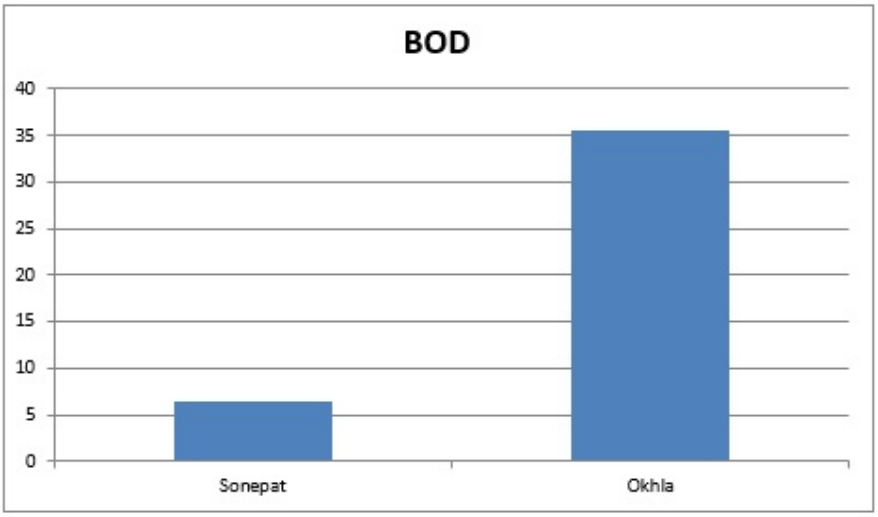
| Sampling Sites | | BOD <3 mg/l | | | DO >4 mg/l | | Output | WQ Status |
|---|---|---|---|---|---|---|---|---|
| | min | max | mean | min | Max | mean | | |
| Sonipat | 1 | 12 | 6.5 | 6.4 | 12.5 | 9.45 | 60.6 | G |
| Okhla | 4 | 67 | 35.5 | 0.1 | 1.6 | 0.85 | 7.52 | VB |

The values obtained using Fuzzy Inference System indicates a drastic variation in the WQ of the Yamuna water after flowing through Delhi. Significant inferences of the analysis are as follows:

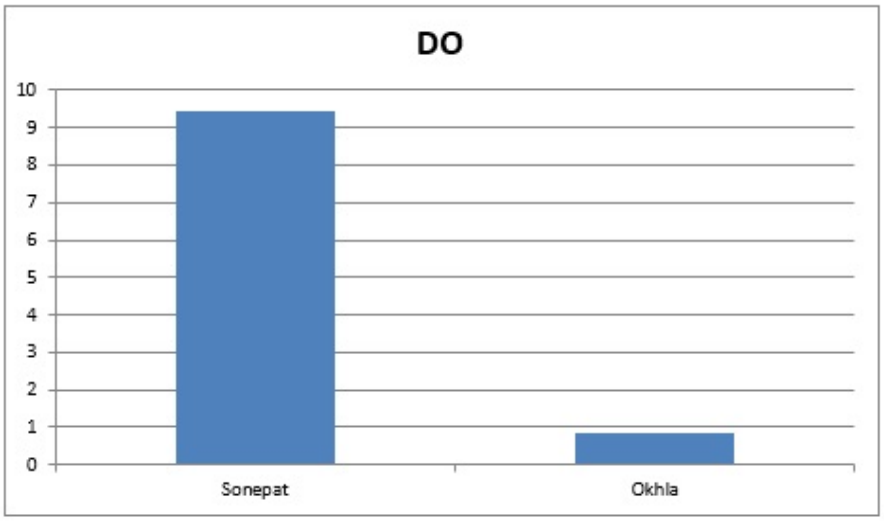
1. BOD at Sonepat falls in good to average category with a value of 6.5 mg/l but at Okhla value of BOD was found to be 35.5mg/l which is much above the prescribed limit. This variation indicates adverse amount of organic matter along this stretch which is due to emission of huge amount of industrial waste and domestic sewage into the river. The variation in BOD levels is shown in Graph (i).

2. DO, the major indicator of WQ was found in a fairly good range at Sonepat whereas DO level touches zero at Okhla. The pollution from Delhi depleted the DO level dreadfully and which in turn has impacted the aquatic life at this

stretch. The variation in DO is shown in Graph (ii).




Graph (i) Variation in BOD values at the sampling sites




Graph (ii) Variation in DO values at the sampling sites

## 6. Conclusion

The proposed model in this analysis affirms the appalling condition of the Yamuna in Delhi. The drastic variation in WQ after flowing through Delhi with escalated BOD and vanishing DO values confirms the contribution of Delhi to this woeful condition of the river. The Yamuna is now called as Delhi's Dying

Holly River. Although there are many plans ongoing for Yamuna's revival but remarkable improvement is still awaited. To improve the condition more Sewage Treatment Plants should be constructed and existing should be upgraded, minimum ecological flow should be maintained and 'zero' discharge into the river should be ensured. The proposed methodology can be applied to other rivers in order to analyse the WQ and formulate sustainable management plans in water resource management.

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