DO Modeling for the Yamuna River, Delhi

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Abstract- **Yamuna River Delhi stretch is a severely polluted reach with dissolved oxygen concentration below the detected limit almost the entire length with a higher concentration of oxygen-demanding substances. This stretch needs a management tool to predict the conditions and management of the river with the contributing load. QUAL2Kw is used to simulate the parameter DO. The framework has been calibrated and validated for the secondary data of February data of 1999-2006 and 2007-2009 respectively. DO prediction was done by keeping BOD and COD for all outfalling drains 10 mg/l and 50 mg/l as the effluent standard set for this reach. The scenarios have been developed changing the upstream flow. With the fixed pollutant load, it was observed that if the flow is increased by 50 cumecs of the minimum suggested flow, the reach could not attain the required minimum DO concentration.**
Keywords- **Dissolved Oxygen, Water Quality Model, QUAL2Kw, Urban river reach, Biochemical Oxygen Demand**

1. INTRODUCTION

Yamuna River originated from the Yamunotri, north of Haridwar in the Himalayan Mountains. After flowing total length of 1386 kilometers covering five states Uttaranchal, Uttar Pradesh, Himachal Pradesh, Haryana, Rajasthan, Madhya Pradesh & NCT – Delhi with a watershed area of 366223 km^2, its confluence with the river Ganga at Prayag Raj, Uttar Pradesh. Before reaching the Delhi stretch, the river water diverts and controls by a weir to produce electricity in Uttaranchal. In Tajewala / Hathnikund in Haryana state. During the dry season, the river becomes dry in some portions of the Tajewala and Delhi segment and regains by groundwater discharge and Som Nadi, a seasonal stream.

The river enters Delhi near Palla village and courses through Delhi for about 22 km. In Delhi, the river is tapped at Wazirabad through a barrage for supplying drinking water in the city, and no water is allowed to flow downstream during the dry season beyond the Wazirabad barrage to fulfill the water supply requirement in the capital Delhi [1]. After the Wazirabad barrage, in the Delhi stretch, the river is fed by 16 major drains along with the water transported by Haryana Irrigation Department from Western Yamuna Canal to Agra Canal via Najafgarh Drain, with partially treated or untreated domestic and industrial wastewater from different places and the river becomes a sewer line [1]. In the Delhi stretch, wastewater from the National Capital Region contributes about 80% of the pollution of the total river length [1] and becomes a sewerage line. This massive pollution is due to the enormous abstraction of water for irrigation, water supply for drinking and industrial purposes, and also the outfalling of untreated or partially treated industrial and domestic wastewater. it is an urgent requirement to develop a proper waste load allocation process to maintain the ecological health of the river and the sustainable development of society. Data from WRIS, India, at Delhi Railway Bridge station - pH value is7.65, DO is around 0.37 mg/l (In few years, it was not detectable), Biochemical Oxygen demand 38.78mg/l, fecal Coliform 2201851.85 in the year 2019, and Ammonia 10.75 mg/l (the last 10-year average value is very higher than the acceptable limit of 0.5 mg/l).

The diminishes of DO mainly occur in the low flow season. A high concentration of Biochemical Oxygen and Chemical oxygen demand with nutrients reduces the DO and consequently, the reach becomes anoxic. Hence it requires developing management options that can predict the DO concentrations and manage the required standard throughout the reach.

QUAL2kw which originated from QUAL2k, and modified versions of QUAL2E or QUAL2E- UNCAS [2] which was deliberated as a water quality assurance tool to interact with algal growth, nutrients, and dissolved oxygen, boundary conditions, nonconservative constituents with input-output consideration for steady and dynamic states and uncertainty analysis like sensitivity analysis [3] and deterministic tool for waste load allocation, as well as total maximum daily load analyses[4]. Applications of QUAL2Kw are found in various research works such as [5][6][7][8] and successfully determined the waste load allocation and Total maximum daily load allocation. The present study develops a modeling approach using the QUAL2Kw framework to maintain the DO concentration of the urban reach of Yamuna, Delhi.

2. METHODOLOGY

The present study developed DO profiles for the Yamuna River, Delhi, which is from Palla to Wazirabad. In Palla, the river enters Delhi and after 22 km it reaches Wazirabad. At Wazirabad, the water is collected and supplied to Capital City, and after Wazirabad, 16 drains dispose of the partially and untreated water into the river, and at Okhla 22 km downstream from Wazirabad river leaves Delhi. This study includes four monitoring stations Palla (M1), Old Railway Bridge (M2), Nizamuddin (M3), and Okhla (M4), and 16 drains were taken as point sources. The upstream flow was taken constant for both calibration and validation Two abstraction points are taken as Wazirabad and Agra Canal. The data for water quality was collected from secondary sources for the year 1999-2009 and the month of February. The average data of the first seven years has been used for calibration and the last three years have been used for validation. The O'Conner -Dobbins equation has been used to determine the reaeration coefficient [6]. Root mean square values have been calculated. The total 44 km stretch of river was segmented into 20 reaches. The model was calibrated and validated manually to get minimum RMSE values. The model has been run to determine the minimum load for maintaining the required minimum DO concentration (4 mg/l) throughout the reach. In the DO modeling for this stretch, the flow of water has been kept minimum at 10 cumecs at Wazirabad to Okhla, and BOD and COD have been kept at 10 mg/l and 50 mg/l for all contributing drains as directed by NGT, Delhi. The flow has been increased 10 cumecs intervals to attain the required DO concentration.

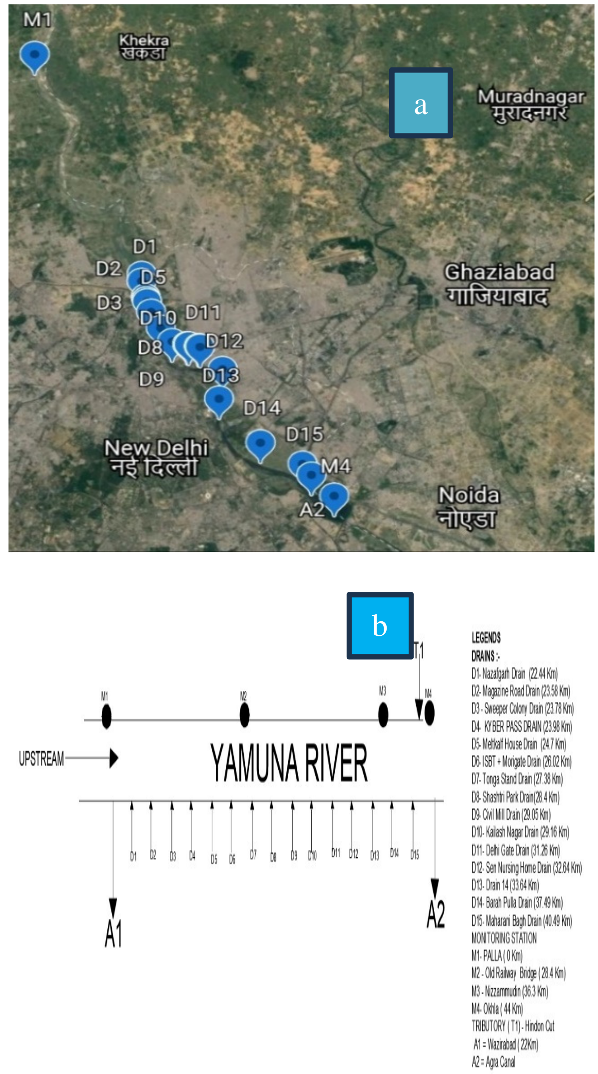


Fig.1a-b Outfalling drains locations and name [10]

TABLE I
Head Water Input

Parameter	Calibration	Validation
Temperature	15.18°C	14.5°C
DO	8.47 mg/l	8.65 mg/l
BOD	1.61mg/l	1.75mg/l
COD	5.51 mg/l	5.13 mg/l
pH	7.82 s.u.	7.85 s.u.

Source:[9];[1]

TABLE II
Water Quality for Different Stations

Station Name	Distance Km	DO mg/l	BOD mg/l	COD mg/l	pH
For Calibration					
M2	28.4	0.085	42.9	65.43	7.06
M3	37.5	0.01	35.91	49.67	6.82
M4	44	0	22.7	40.43	6.88
For Validation					
M2	28.4	0.0825	34.025	63.33	7.2
M3	37.5	0.02	22.5	39	6.93
M4	44	0.03	19.66	29	6.975

Source:[9][1]

TABLE III
RMSE Values for Calibration and Validation

RMSE	Calibration	Prediction
DO	0.021	0.021
BOD	0.4167	0.3568
COD	0.3755	0.411

TABLE IV
Headwater Input for DO Modeling

Parameter	Values
Dissolved Oxygen	8.40 mg/l
BOD	2.40 mg/l
COD	12.00 mg/l
pH	7.9 s.u.

Source: DPCC domain

TABLE V
Point Source Input

Drain No	Flow m^3/s *	BOD, mg/l	COD, mg/l
1	24.91	10	50
2	0.22	10	50
3	0.43	10	50
4	0.150	10	50
5	0	0	0
6	0.16	10	50
7	0.45	10	50
8	0.09	10	50
9	0.58	10	50
10	0.79	10	50
11	0.58	10	50
12	1.07	10	50
13	1.81	10	50
14	0.81	10	50
15	10.69	10	50

* DPCC domain

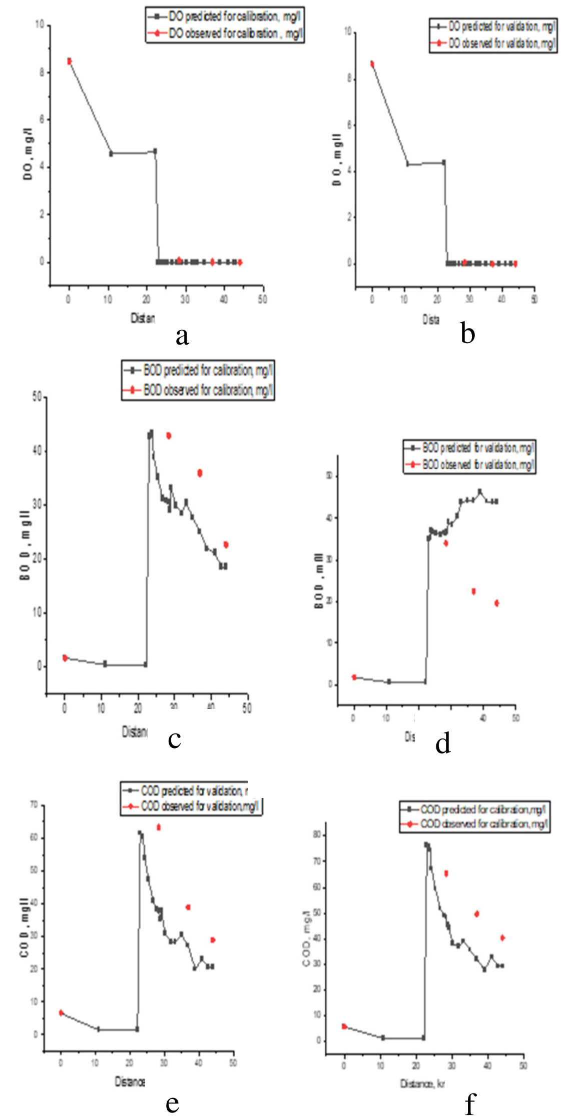
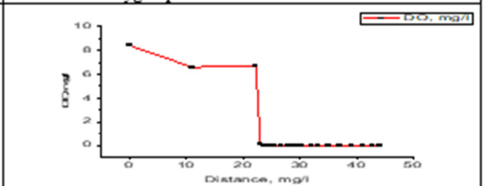


Fig.2 Calibration and validation for DO, BOD, and COD (a-f)

3. RESULTS

Fig. 2 depicts the observed and predicted profiles for calibration and validation. Fig 2(a) and Fig 2(b) are shown the DO prediction for calibration and Validation. It was observed that after the meeting of the D1 (Najafgarh drain), the dissolved oxygen became zero for the entire reach. From the simulation results, it has been observed that the predicted values for DO were quite the same as the observed values. BOD values were different from observed values in Fig 2(a) and 2(b). This might be due to the sampling collection time. But RMSEV for the calibration and validation were 0.41 and 0.35 which were very close. Table III shows the RMSE values for calibration and validation which are quite acceptable. Hence, this model can be used to manage urban river stretches like the Yamuna River Delhi [6][10]. Fig. 3 shows the DO profile for different flow conditions. Fig. 3 shows that with an increment of flow, DO conditions got better conditions. Although, it was observed that 50 cumecs increment flow could not attain the required 4 mg/l of DO concentration.

<table>
<tr><th>Flow</th><th>Dissolved Oxygen profile</th></tr>
<tr><td>Q1</td><td>
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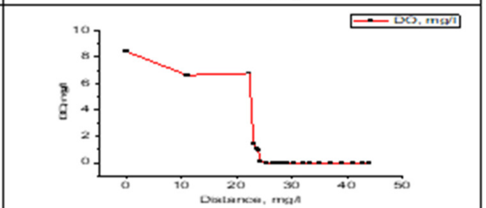
<tr><td>Q1+10</td><td>
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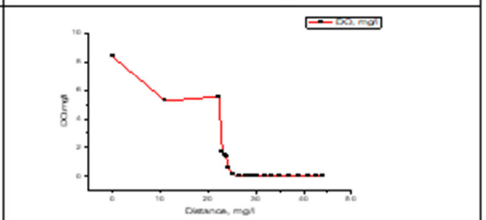
<tr><td>Q1+20</td><td>
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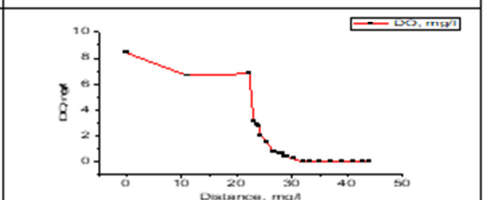
<tr><td>Q1+30</td><td>
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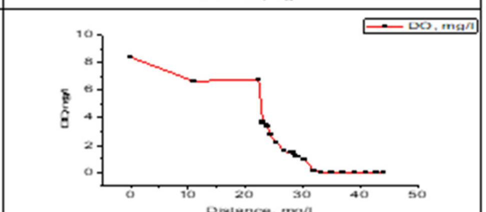
<tr><td>Q1+40</td><td>
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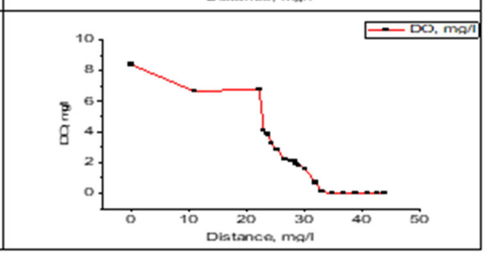
<tr><td>Q1+50</td><td>
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Fig. 3 DO profiles with flow variations

4. CONCLUSIONS

The water quality Model QUAL2Kw is a one-dimensional and less complex model requiring less data. In many developed countries like the USA, South Korea used this model for waste load allocation and Total maximum daily load allocation. For India, which is a developing country can use this model for river management and maintain the ecological health of the river. Although this study shows that DO concentration increased with the flow increase, more management options should be adopted to attain the required DO concentration of this reach. Furthermore, due to data constraints, this study did not include nutrient data, Hence, it is suggested that more parameters need to be monitored and the frequency of the monitoring should be increased.

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