Journal of Climate Change, Vol. 9, No. 3 (2023), pp. 41-50.
DOI 10.3233/JCC230023

Modelling of Pollutant Transport in Yamuna River from the Najafgarh Drain, NCT Delhi Using Matlab Software

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Received April 17, 2023; revised and accepted July 18, 2023

Abstract: When the river Yamuna leaves the National Capital Territory of Delhi, its situation further deteriorates. Despite accounting for only 1% of the river's overall catchment area, this region is responsible for more than half of the pollutants discovered in the Yamuna. The river Yamuna, on the other hand, is Delhi's only natural resource for maintaining all forms of life. The Yamuna River is currently experiencing a significant level of pollution problem, and in order to control pollution in the Yamuna River, continual analysis is essential. The Yamuna River is contaminated by the discharge of untreated municipal sewage and industrial effluent through seven major drains: Najafgarh, Yamunapur, Sen Nursing Home, Barathpula, Maharani Bagh, Kalkaji, and Tuglakabad. In terms of people and chemicals, continuous sampling takes time and money. The primary objective of this study is to analyse the wastewater samples collected by sub-drains and STP's to predict the pollutant transportation in river Yamuna from Najafgarh Drain. The study focusses on the only pollutant, i.e., Biochemical Oxygen Demand from the starting point to after the confluence of Najafgarh Drain into river Yamuna. The prediction is to be done by using MATLAB software. This study would help to identify the main sources of sub-drains which are polluting Najafgarh Drain and eventually the river Yamuna. This shows how MATLAB may be used to calculate the pollution load caused by organic waste in the Yamuna River as it flows through Delhi, India's National Capital Territory. The model numerically solves a series of differential equations to simulate the dissolved oxygen and biochemical oxygen demand parameters in two dimensions. MATLAB is an interactive programming language that may be used to develop algorithms, graphics, and user interfaces in other computer languages. MATLAB helps estimate future water quality using present data, which saves time, labour, and other costs associated with the continuous study. There are various software programmes available in the market for predicting river water quality, however, MATLAB GUI provides an accessible and convenient user interface (Graphical User Interface).

Keywords: River Yamuna**;** Najafgarh drain**;** Sub drains**;** Biochemical oxygen demand**;** MATLAB; Mathematical modelling.

Introduction

India is part of the continent of Asia divided into 28 Governorates. India's total area is about 3,287,590 km^2 (1,269,345 m^2). The current population of India is 1,400,309,632 based on world metre elaboration of the latest United Nations data. The per capita availability of water is estimated to decline further to 1465 m^3 by 2025 and 1235 m^3 by 2050. The per capita annual water availability has declined to 1508 m^3 in 2014 from 5177 m^3 in 1951. The Rapid population growth in India results in a significant increase in the size

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of industries due to increased demand for Industrial products. Delhi is the capital of India with three major drainage basins in the national capital territory of Delhi, i.e., Najafgarh, Barapulla and trans-Yamuna basin. NCT Delhi covers an area of about 1484 km^2 (573 mi^2) and the current population of Delhi is 31,181,376. Surface water pathways in India are exposed to pollution due to industrial activities in this region resulting in harm to human and aquatic health in addition to the negative impact on the environment. It is estimated that 75-80% of water pollution comes from domestic wastewater discharged into untreated local water bodies. Delhi produces approximately 550 million gallons of purified water (MGD) per day from wastewater through its Sewage Treatment Plant (STP), but only 89 MGD is used less than 20% and the rest can be dumped. This significantly increases the proportion of contaminants such as BOD, Cr, oil, Hg, *E. coli* and heavy metals (Figure 1). In India, only 38% of municipal wastewater is treated (CPCB, 2015). Moreover, 80% of freshwater sources are contaminated (Dey, 2015). Two of India's most revered rivers, the Ganges and Yamuna, are no exception but are considered goddesses by Hindus (Haberman, 2006; Alley, 2002). In both 2007 and 2017, the Ganges River was included in the list of the 10 most dangerous rivers in the world (Wong, 2007; Sawe, 2017). One of the most polluted Ganges tributaries is the Yamuna. Pollution in this river could cause the Yamuna to "nearly die," researchers claim. The total length of the Engender from Himalayan is 1,376 km, and the catchment area is 366,220 km^2. The annual flow of the river is about 10,000 Kumek. Annual consumption is 4400 cubic meters, 96% of which is for irrigation (MoEF, 1994). Over 70% of Delhi's drinking water supply comes from the Yamuna River (CPCB, 1996; Upadhyay et al., 2010). An estimated 57 million people depend on the water of the Yamuna River. The capital region, Delhi, generates about 76% of the total pollutants in Yamuna (PTI, 2018), effectively diverting rivers into "sewer channels" (Datta, 1992). National Capital Territory (NCT) Delhi is one of the fastest-growing metropolitan areas in the world. It faces a serious problem of volumetric wastewater generation. These effluents are mainly supplied by Delhi SKT's numerous effluents, which have a significant impact on the surface and groundwater systems of the area. The effect on surface water can be seen in the Yamuna River, where the water colour of the river is turquoise upstream of Wazirabad, and the Najafgarh runoff turns to dark gray downstream of Wazirabad where it enters the Yamuna River. Henceforth, a series of 19 drains joins the river Yamuna, making it a giant drain (Figure 2). 95% of the Yamuna pollution in Delhi is resulted due to discharge of wastewater through seven major drains, viz., Najafgarh, Yamunapur, Sen Nursing Home, Barathpula, Maharani Bagh, Kalkaji and Tuglakabad. The major outfall is the Najafgarh drain which contributes nearly 70% of the total pollution load to Yamuna in Delhi. The Najafgarh Drain is the capital's most polluted body of water due to the direct inflow of untreated sewage from surrounding populated areas i/c sewage from Gurugram. Assessing the water quality of wetlands in wildlife habitats, a January 2005 report by the Central Pollution Control Board rated the

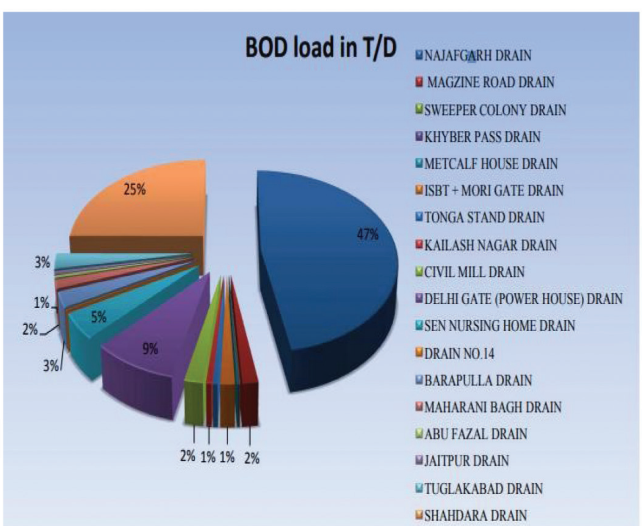

Figure 1: Pie-chart depicts BOD load (T/d) distribution.

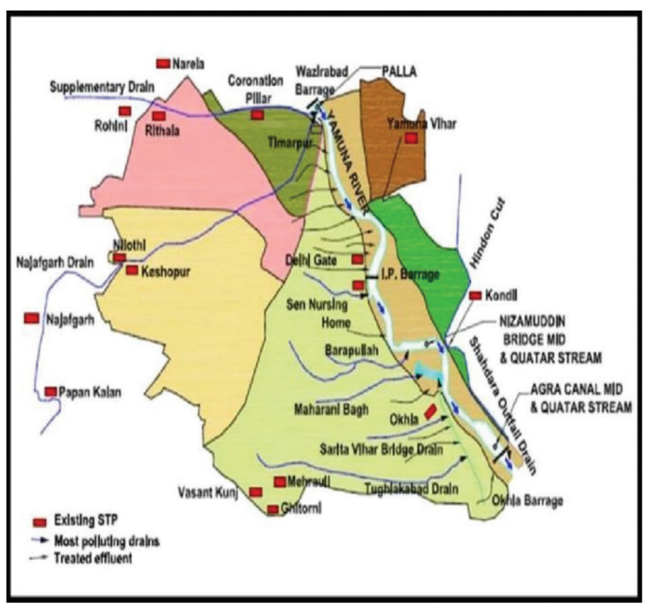

Figure 2: Flow path of river Yamuna and major drains & STPs in Delhi.

Najafgarh Drain under category D, along with 13 other highly polluted wetlands. The Kakkrola Regulatory Unit is beneath. Najafgarh Road has been closed, leaving large amounts of water in this expanded ditch to fill the local water table and make irrigation easier for farmers. Thus, nearly 60% of the length of the Najafgarh drain flows through the southwest district of NCT Delhi and this entire stretch of the drain is unlined. Moreover, very few (probably 2-3 drains) secondary drains from Dhansa to Kakkrola connect to this large drain, and after Kakkrola nearly 38 large and small drains join the Najafgarh drain (WAPCOS, 1999). Therefore (by visual observation), the quality of the water flowing through the drain is better in the section from Dhansa to Kakkrola. Following the Najafgarh runoff from Dhansa to Kakkrola, there have been proposals related to limited ground water extraction combined with an artificial recharge in this area of the aquifer (Bajpai, 2011; INTACH, 2003; Shekhar, 2006). However, it has also been suggested that loose drains in refill areas are a cause of groundwater contamination (Kumar et al., 2006). From this point of view, it becomes important to assess the quality of groundwater in shallow aquifers near Najafgarh drains.

Materials and Methods

Study Area

The *Najafgarh Drain* or *Najafgarh Nallah* once called Sahibi River, continues its flow through Delhi where it is channelised for flood control purposes. It drains into the Yamuna River as a tributary. The Najafgarh Drain is named after the once-famous and massive Najafgarh Lake, which is located near the town of Najafgarh in southwest Delhi.

Najafgarh drain starts in Delhi with Dhansa Border and after traversing around 56 km, it meets Yamuna River near Wazirabad Barrage. Figure 3 explains the description of study area.

SITE 1 (28.53492” N 76.87043” E): Najafgarh Drain starts at Dhansa Border in Delhi. The latitude of the Dhansa Border is 28.53492 and the longitude is 76.87043. Furthermore, Dhansa Dam which is around the Dhansa border meets Najafgarh Jheel. It travels a distance of 7.92 km where it meets Badshahpur Jheel.

SITE 2 (28.53492” N 76.87043” E): At this point, Badshahpur Jheel meets Najafgarh drain which is at latitude and longitude of 28 and 76 respectively.

SITE 3 (28.56864” N 77.03031” E): Najafgarh Drain meets with a sub-drain of Badshahpur Jheel, after confluence Najafgarh Drain goes further and meets with a sub-drain with the name Drain No. 2 (Trunk Drain) with distance 11.1 km between them.

SITE 4 (28.57884” N 77.03778” E): Then after sector 16D a drain across Dwarka (Palam drain) meets with Najafgarh Drain and goes further with the distance between them 1.35 km.

SITE 5 (28.58779” N 77.02535” E): Along with the drain at Pappankalan STP is present of 40MGD capacity After meeting with Palam drain and getting some treatment from Pappankalan STP it flows further with the distance between them 1.57 km.

SITE 6 (28.60812” N 77.00678” E): After this Najafgarh STP of 5MGD treats the drain water which is about 2.90 km from Pappankalan STP.

SITE 7 (28.62644” N 77.02173” E): After getting treatment from Najafgarh STP the Najafgarh Drain submerges into the Mungashpur subdrain at Prem Vihar with a distance of 2.51 km. At Prem Vihar, a new major drain started which is called the supplementary drain along or parallel with Najafgarh Drain and this supplementary Drain gets turned towards Sultanpuri at Paschim Vihar.

SITE 8 (28.65775” N 77.05254” E): After merging with Mungashpur Drain, Najafgarh Drain meets with Nilothi STP of 60MGD with a distance of 4.60 km.

SITE 9 (28.63895” N 77.06011” E): Najafgarh drain goes further and where Vikaspuri sub drain is submerging in this drain having a distance of 2.22 km from Nilothi STP.

SITE 10 (28.68038” N 77.18467” E): After meeting with Vikaspuri Subdrain, Najafgarh Drain goes to Keshopur STP of 72 MGD with a distance of 2.94 km.

SITE 11(28.70839” N 77.21828” E)): It further meets with Daryain Nallah near Gulabi Baghhaving a distance of 10.1 km between them.

SITE 12 (28.70943” N 77.22806” E): It is going further and at Jahangirpuri a subdrain is submerging with Najafgarh Drain with a distance of 4.53 kms between two of them.

SITE 13 (28.70943” N 77.22806” E): The Jahangirpuri sub-drain and supplementary drain which is another major drain in Delhi meet Najafgarh drain whereas the distance between them is about 961 m.

SITE 14 (28.7078” N 77.23063” E): At last a supplementary drain meets with Najafgarh Drain at

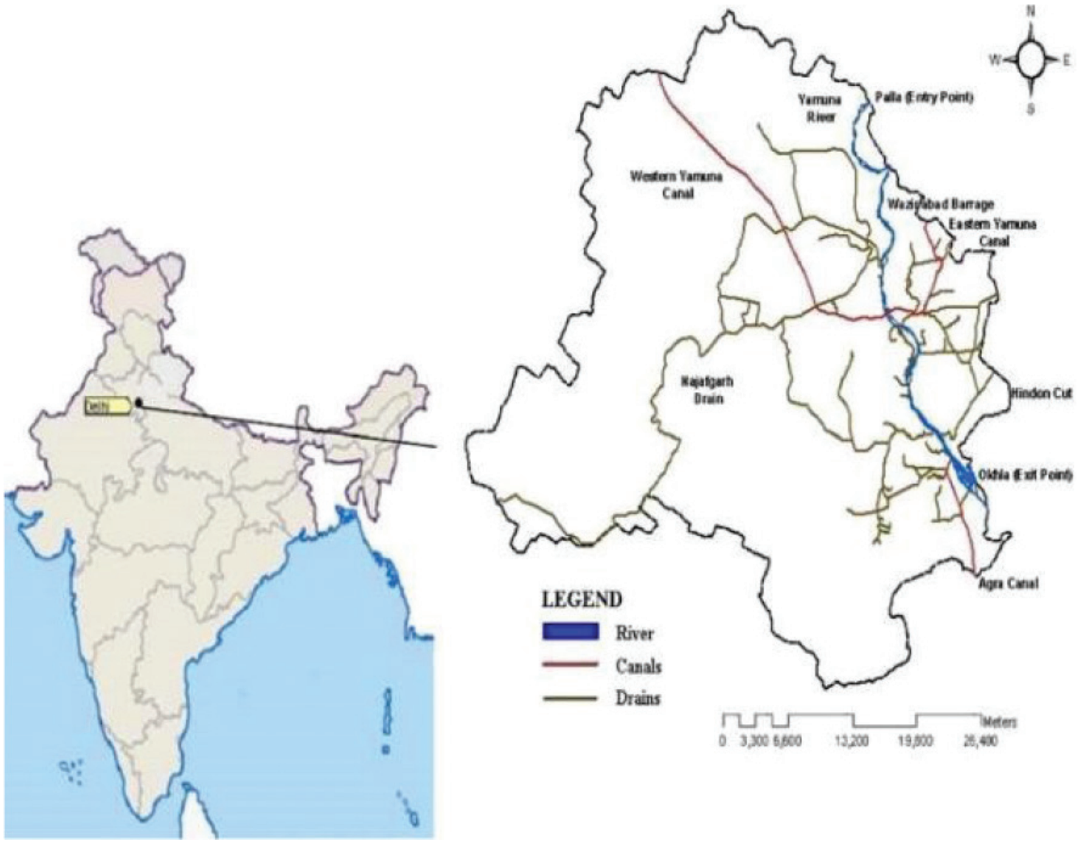

Figure 3: Description of study area.

Wazirabad Barrage at a distance of 311 m. At Wazirabad Barrage, this large drain eventually reaches the Yamuna River. Table 1 refers to sampling areas.

Table 1: Sampling areas

Sampling areas	*Longitude*	*Latitude*	*Distance, m(x)*
Dhansa Border	28.53492	76.87043	0
Badshahpur Drain	28.50452	76.94359	7920
Drain No.2	28.56864	77.03031	11100
Palam Drain	28.57884	77.03778	1350
Pappankalan STP	28.58779	77.02535	1570
Najafgarh STP	28.60812	77.00678	2900
Mungashpur STP	28.62644	77.02173	2510
Nilothi STP	28.65775	77.05254	4600
Vikaspuri Drain	28.63895	77.06011	2220
Keshopur STP	28.65275	77.08576	2940
Daryainala	28.68038	77.18467	10100
Jahangirpuri Drain	28.70839	77.21828	4530
Supplementary Drain	28.70943	77.22806	961
Meeting Point	28.7078	77.23063	311

Sampling Sites and Procedures

Samples were collected during the month of July on different dates making a total of 25 sampling campaigns considering three samples at a location (one at sub-drain or STP, after confluence and before confluence). Figure 4 refers to sampling areas along the Najafgarh drain using GoogleMyMaps. At each sampling point, waste water samples were collected using a portable water sampler from the surface in sterilised bottles. Acid was used to clean the bottles, which were subsequently rinsed numerous times with de-ionised water and the water sample itself. To avoid microbial decomposition of solids, samples were stored at 4°C and delivered to the laboratory within two hours of collection, and all waste water measurements were completed within 24 hours per test or no more than 7.0 days following sampling. Figure 5 explains the spatial distribution of sampling points: A comprehensive drain map.

Analytical Procedures

The entire collection of 25 samples was examined. The flow of discharge, pH value, total alkalinity, total suspended solids, biochemical oxygen demand, chemical oxygen demand, ammonia, phosphate, hydrogen

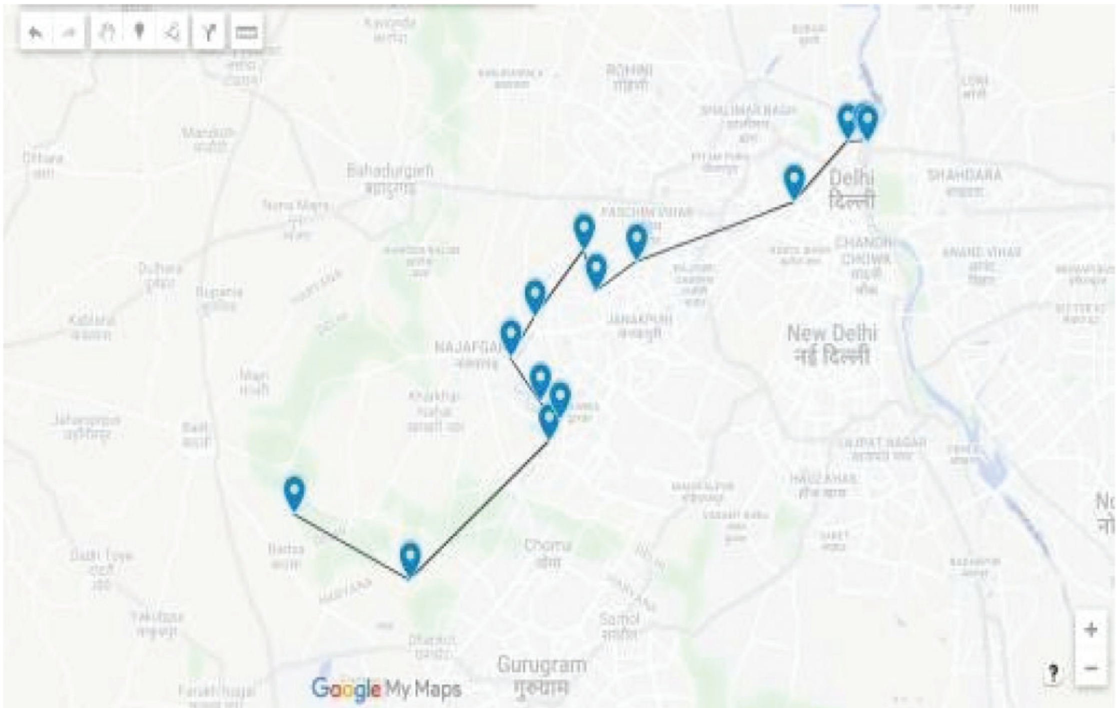

Figure 4: Sampling areas along the Najafgarh drain using GoogleMyMap.

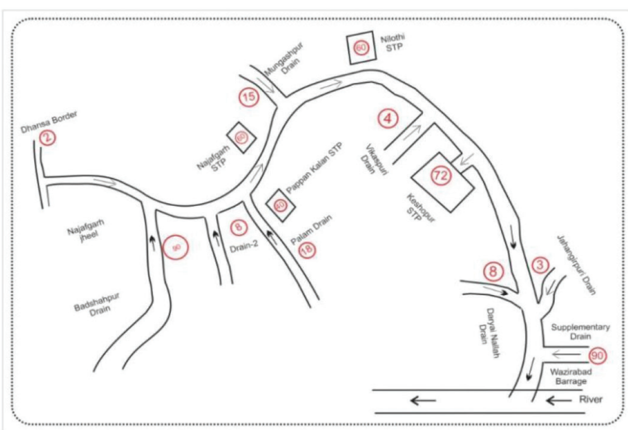

Figure 5: Spatial distribution of sampling points: A comprehensive drain map.

sulphide (H_2S), and total coliform are the waste water quality parameters. By multiplying flow velocity by cross-sectional area, the flow rate at the commencement of the Najafgarh drain was estimated. Subsections were created from the cross-sectional. Each subsection's discharge was determined separately, and the total discharge was calculated by adding the subsections' discharges (Egypt Nile). The pH was measured in situ with the Hydra Lab-Surveyor multi-probe system, while the remaining parameters were measured in the lab using normal procedures. A sterilised "Millipore" membrane with a pore size of 0.45 m and a diameter of 47 mm was used to filter water samples.

Data Treatment

Mass balance (mixing zones) were involved to simulate/estimate the concentrations of the various pollutants in the river on a seasonal basis. As a simple example, below are the two mass-balance equations for two-point sources discharging their waste directly into the Najafgarh drain.

Component Mass Balance

q1* C1 + Qriver, upstream* Criver, upstream = Qriver, downstream* Criver, downstream (1)

q2* C2 + Qriver, downstream* Criver, downstream = Q3* (2)

Overall, balance

Qriver, upstream + q1 = Qriver, downstream

Q3 = Qriver, downstream + q2 (3)

A steady state concentration and a complete mixing vertically and laterally were assumed. A first order decay of organic pollutants was also assumed. The pollutant concentration at any point after the point source can be calculated by using the following equation:

$$C = C_0 * e\ (-k*x/v)$$

where C = pollutant concentration at any point after point source, mg/L; C_0 = pollutant concentration directly downstream the injection point, mg/L; k = first order decay, day^{-1}; x = distance downstream the injection point, m; v = velocity in the river, m/day.

The mass balance helps predict the mass loading at the end of the sub-drains meeting the Najafgarh drain before discharging in the river Yamuna. Waste water samples were collected at the end of each sub drain to compare the predicted values of the model with the actual data. Consequently, this model allows us to obtain mass balance closure and helps in identifying the dispersion level and mixing condition.

Model Description

MATLAB: A Programming Tool

MATLAB (matrix laboratory) is a fourth-generation programming language and numerical computing environment. It was created by the company Math Works. Matrix manipulation, plotting functions and data, implementing algorithms, creating user interfaces, and interacting with programmes written in other languages such as C, C++, Java, and Fortran are all possible with MATLAB. MATLAB is a graphical and numerical computing software system that is user-interactive. It can be extended with programmes written in its programming language and has a wide range of

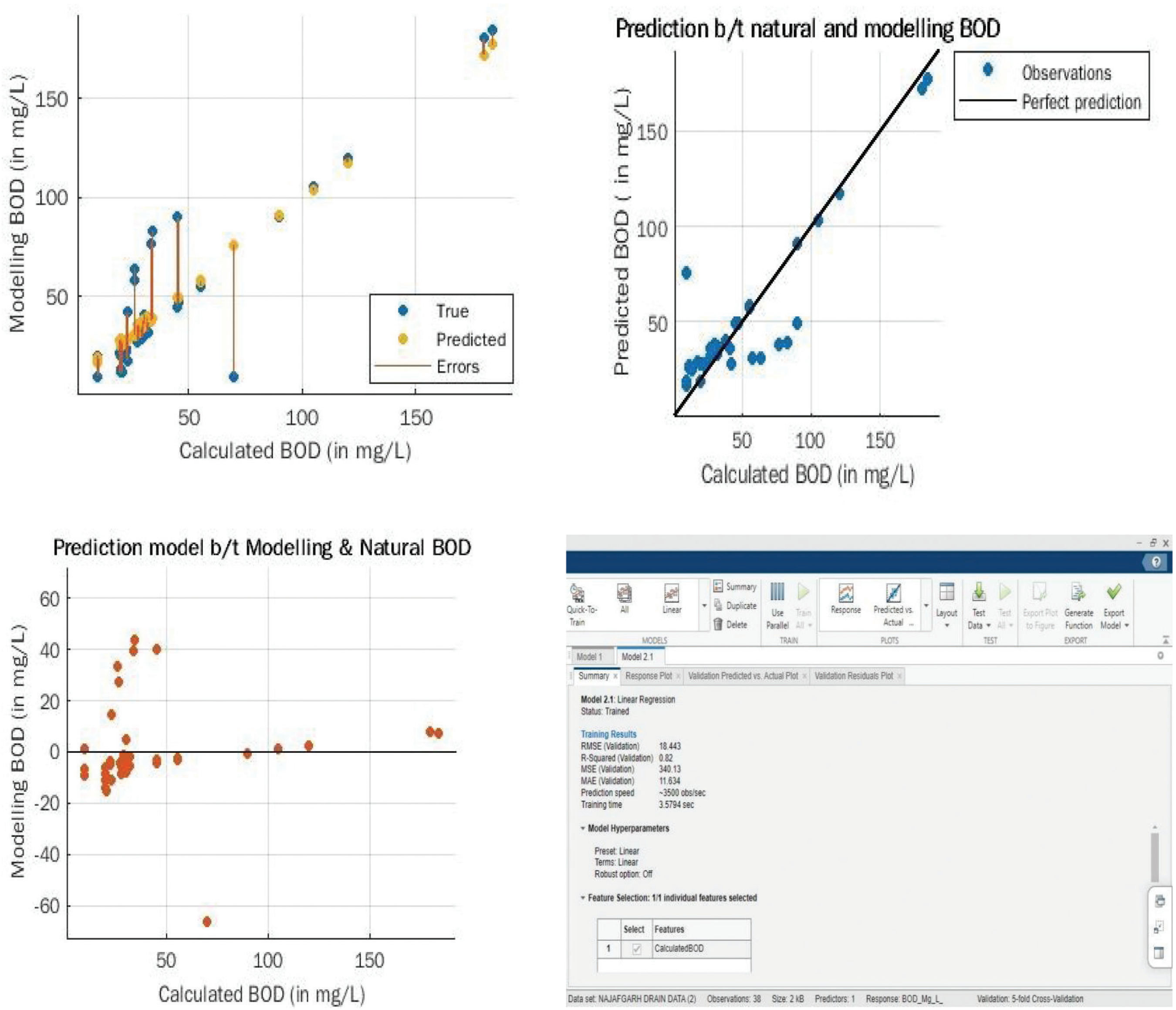

Figure 6: Relation between actual and predicted BOD using Regression Learner in MATLAB.

graphical capabilities. Many of these programmes are included with the system, and some of them extend MATLAB's capabilities to non-linear problems like solving initial value problems for ordinary differential equations. MATLAB is a programming language that is used to solve problems numerically, or with finite precision arithmetic. Therefore, it produces approximate rather than exact solutions.

Regression Learner

Linear regression models, regression trees, Gaussian process regression models, support vector machines, kernel approximation, ensembles of regression trees, and neural network regression models are all trained with Regression Learner. We may explore our data, select features, set validation schemes, and assess findings in addition to training models. Regression analysis can be used to anticipate energy consumption, financial performance, and industrial process characteristics. It helps people grasp the link between factors and quantitative replies. Fundamentally, regression analysis allows us to design regression models interactively without writing code, test model correctness and performance, and compare the performance of different regression models and features (Figure 6).

Curve Fitter

The Curve Fitter application is used for exploratory data analysis, data pre- and postprocessing, candidate model comparison, and outlier removal (Figure 7).

Results and Discussion

Table 2 refers to sampling values of BOD vs predicted values of BOD at different sampling locations. From the below table, a significant difference in the sampled and predicted BOD has been observed. Also, as we move from the initial sampling point at Najafgarh Drain, i.e., Dhansa Border, towards the other sampling locations an extreme change in BOD levels is observed. The BOD increase or decrease is not constant within two simultaneous locations.

Conclusions

In accordance with the observations, it can be concluded that

1. MATLAB programming can be successfully used as a modelling tool for predicting the fate of pollutants in the river.

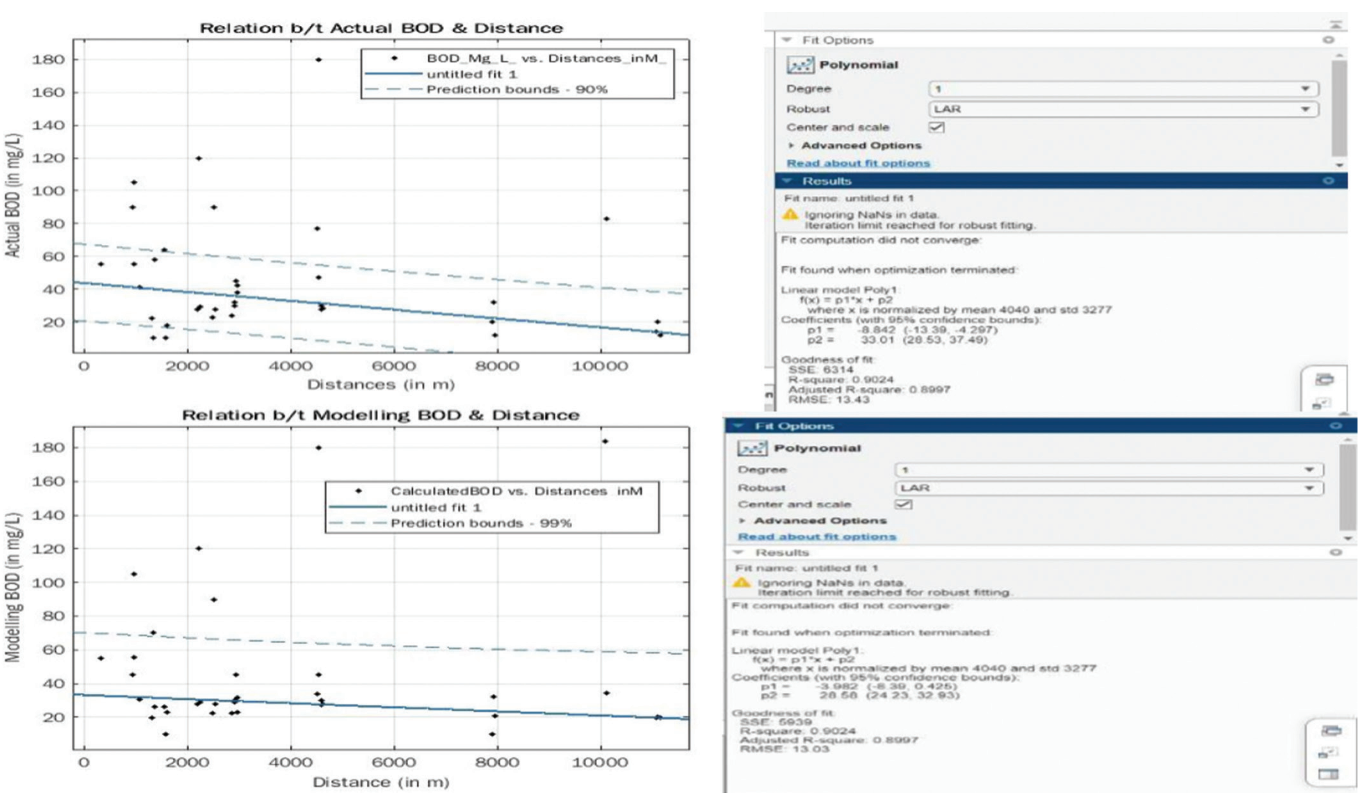

Figure 7: Relation between actual BOD and distance using Curve Fitter App in MATLAB.

Table 2: Sampling values of BOD vs predicted values of BOD

Sampling areas	*BOD (mg/L)*	*Calculated BOD*
Dhansa Border	10	10
Before confluence point of Badshapur drain from Gurugram	20	9.68
BOD of Badshahpur drain	32	32
After confluence point of Badshahpur drain with Najafgarh drain	12	20.72
Before confluence point of drain no. 2	14	19.79
Sample of drain no. 2 before discharging into Najafgarh drain	20	20
After confluence point of drain no. 2 with Najafgarh drain	12	19.8
Before confluence point of Palam drain with Najafgarh drain	22	19.7
waste water from Palam drain	10	70
After confluence point of Palam drain with Najafgarh drain	58	26.35
Wastewater from Najafgarh drain before Pappankalan STP	64	26.18
Waste water from Pappankalan STP	10	10
Wastewater from Najafgarh drain after Pappankalan STP	18	22.91
Wastewater from Najafgarh drain before Najafgarh STP	24	22.64
Waste water from Najafgarh STP	30	30
Wastewater from Najafgarh drain after Najafgarh STP	42	22.86
Wastewater from Najafgarh drain before Mungashpur Drain	22.62	22.62
Waste water from Mungashpur Drain	90	90
Wastewater from Najafgarh drain after Mungashpur Drain	27.86	27.86
Wastewater from Najafgarh drain before Nitholi STP	27.33	27.33
Wastewater from Nitholi STP	30	30
Wastewater from Najafgarh drain after Nitholi STP	27.87	27.87
Wastewater from Najafgarh drain beforeVikaspuri Drain	27.61	27.61
Wastewater from Vikaspuri Drain	120	120
Wastewater from Najafgarh drain after Vikaspuri Drain	29.13	29.13
Wastewater from Najafgarh drain before Keshopur STP	32	28.78
Wastewater from Keshopur STP	45	45
Wastewater from Najafgarh drain after Keshopur STP	38	31.81
Wastewater from Najafgarhdrain before confluence point of Daryainala	41	30.51
Wastewater from Daryainala	184	184
Wastewater from Najafgarhdrain after confluence point of Daryainala	83	34.22
Wastewater from Najafgarh drain before confluence point of Jahangirpuri drain	77	33.6
Wastewater from Jahangirpuri drain	180	180
Waste water from Najafgarh drain after confluence point of Jahangirpuri drain	47	45.41
Wastewater from Najafgarh drain before confluence pointof Supplementary Drain	90	45.23
Wastewater from Supplementary Drain	105	105
Waste water from Najafgarh drain after confluence point of Supplementary Drain	55.32	55.32
At Yamuna	55.25	55.25

2. This study clearly shows that the predicted BODs at different locations are significantly less than Sampled BODs which indicates that there may be some illegal activities such as illegal Dhobi Ghats, Industries in residential areas, illegal slaughtering and illegal dairies, etc. which are influencing the BOD or untreated sewage discharged in the Najafgarh Drain.
3. At Keshopur STP BOD varies between 45 and 80 mg/L which is more than the prescribed norms. As per NGT, Keshopur STP is not working properly. For knowing further details, we approached to DJB official who informed us that Keshopur phase- 20 MGD and Keshopur Phase II 40 MGD are not working to their desired level.
4. In case an adequate quantity of fresh water is not available for dilution downstream of Wazirabad we can decide the output parameter of treated effluent at all the STPs to arise at the bathing quality of river water.

   NOTE:- In total, 23 drains discharge directly into the Yamuna River. Before the wastewater from certain drains is dumped into the river, the appropriate authorities should collect it for further treatment.
5. It is to be noted that sampling at Vikaspuri Drain had a higher BOD value at 120 mg/L.
6. As information gathered from Delhi Jal Board, the wastewater from the drains is being trapped through an interceptor sewer laid along the Najafgarh drain and being conveyed to the nearest sewage treatment plant. The wastewater after treatment at the respective STPs, will be allowed to flow in the Najafgarh drain. Thereby, improvement in the quality of river water.
7. Similarly, Daryainala having the highest BOD with 184 mg/L is also being trapped in the existing interceptor sewer near Shakti Nagar extension, and the wastewater is being pumped to Rithala STP for further treatment.
8. Jahangirpuri Drain with BOD 180 mg/L is also proposed to be trapped at Coronation STP.
9. Therefore, it is concluded that after the commissioning of the above project the quality of the Najafgarh drain and subsequently river water will be improved.
10. However, the river water beyond Wazirabad Barrage can have the bathing quality river water only after the release of adequate fresh water.

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