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Research Paper

Role of Decision Support System for River Pollution Control

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ABSTRACT -

Due to continuous population growth and industrialization along with intensive agriculture to meet food demand, good quality water has become rare in most of the basins of India. Up to the last decade, to solve the water related issues in India, water quantity and quality were considered individually; and it was realized that individual consideration of these parameters will not solve the problem for long term. Therefore, at present, a concept of integrated water resources management has been encouraged to manage the water resources and pollution control in the rivers. In the present study, an efficacy of a decision support system (DSS) has been presented for the Yamuna River to augment the good quality of water as environmental flows, which include the hydrology, natural resources, pollution, socio-economics, infrastructural development, etc of the basin. Using the DSS, numbers of possible scenarios were tested and it is revealed that installation of sewage treatment plants (STPs) alone cannot improve the water quality of the river when river is highly intercepted. To ensure the environmental flows in the river, integrated water resources management has become important at micro-watershed level.

Keywords: Decision support system; River pollution; Yamuna river; India.

INTRODUCTION

Good water management in requisite quantity and of acceptable quality constitutes a major challenge and calls for integrated and holistic planning. Decision made now affects all and will have great impacts on generations to come. Planners and water managers must focus on obtaining a thorough understanding of the available water resource and potential impacts in order to meet current and future demands. Many aspects have to be considered in order to respond to changes in natural phenomena, increase in demands, and provision of adequate and good quality water at a reasonable cost to the public. The increased competition for a finite resource requires that water managers also consider conservation and wise use of water. New and improved water management tools provide water managers the means to consider and assess all these complex issues as they plan for the future. Further to this, due to exponential population growth, pressure on the food, adequate water supply and sanitation has been increased. Under such circumstances, to meet out the consumptive demands, river ecosystem is often overlooked. This leads to the ecological disturbance of the river. In many cases, wastewater either domestic or industrial is being discharged in to the river, which accelerated further damage of the river eco-system.

Looking into these facts, the concept of Integrated Water Resources Management (IWRM) has been encouraged during this decade. The Technical Advisory Committee of Global Water Partnership has adopted the definition (GWP, 2000) *IWRM is a process, which promotes the co-ordinated development and management of water, land and related*



resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. In a simplified manner, the IWRM can be defined as optimal utilization and allocation of water resources to meet out the sectoral water demands either actual or virtual without affecting the socio-economic and environment.

In order to achieve a more efficient management and sustainable development of water resources for multiple uses according to the principles of IWRM, a suitable instrument is required that provide the better insight into the system as well as the possible solution of the water related problem for decision processes. No doubt, the integrated decision support system (DSS) will play as a good instrument (Bach et al., 1989; Kaden et al., 1989; Harvno et al., 1995).

DSS provides a custom, flexible and dedicated management system, to assist managers, decision makers and policy makers to: (i) provide timely, transparent, well informed and reproducible answers to important questions; (ii) quickly and effectively streamline workflow, reduce time and cost requirements; (iii) transform data and information into knowledge and produce understandable results and decisions. Considering the aforesaid facts and requirement, in the present study, a case study has been presented for Yamuna River Basin, which includes the components of integrated water resources management followed by development of the DSS. This DSS has been developed for the Yamuna Action Plan having objectives of pollution abatement and ensure the additional flows for achieving the environmental flows. A brief description of Yamuna river basin is presented in the following section.

MATERIALS AND METHODS

Study Area

The Yamuna River is a prominent and sacred river as the great Ganga River itself. The total length of the Yamuna River from its origin at Saptrishi Kund to its confluence with Ganga at Allahabad is 1,376 km traversing through five states. The main stream of the river originates from the Yamunotri glacier (Saptrishi Kund) near Bander punch peaks ($38^{\circ}59'N$ $78^{\circ}27'E$) in the Mussoorie range of the lower Himalayas at an elevation of about 6320 meter above mean sea level in Uttarkashi district of Uttarakhand. The head waters of the Yamuna River are formed by several melt streams, the chief of them gushing out of the morainic smooth at an altitude of 3250 m, 8 km Northwest of the Yamunotri hot springs at a latitude $31^{\circ}02'12''N$ and longitude $78^{\circ}26'10''E$. In the upper reaches, the Rishi Ganga (right bank), and Unta and Hanuman Ganga (left bank) join the Yamuna River. In the lower Himalayan ranges the Yamuna River receives water from Kamal, Tons, Giri and Bata on its right bank and on its left bank it receives the Aglag and Asan River tributaries.

The Chambal, Betwa, Sind and Ken are the important tributaries joining the Yamuna on the right bank in the plain, and the Hindon River on the left bank. Among all these tributaries, the Tons at the hills and the Chambal at the plains are the most important tributaries in terms of their discharge. The Tons is the principal source of water in the mountainous range and generally carries more water than the mainstream. In the plains, during the non-monsoon period, the Chambal River contributes about 5-10 times more water to the Yamuna than its own flow. However, since 2003, there is a significant reduction in the discharge of the Chambal River. In the basin, most of the rainfall occurs during the monsoon season. The impact of this rainfall pattern mostly influences flooding. The Yamuna River carries almost 80% of the total annual flow during the monsoon period. During the non-monsoon period the river flow is reduced significantly and some river stretches become dry.

Due to large abstractions at the Hathinikund barrage, the downstream part of the river is almost dry, though the 4.5 cumec water is allocated for the downstream release during December to June. However, after traversing a few kilometers, this water disappears and the river becomes dry up to the Palla. After the Wazirabad barrage near Delhi,



there is no release during the dry period (i.e., December to June). The water available in the Wazirabad barrage to the Okhla barrage stretch is due to wastewater outfalls of more than 30 cumecs with recorded BOD of more than 30 mg/l. After the Okhla barrage, a similar situation persists and the river has little water all the way up to Etawah when the Chambal River joins. However, due to base flow, the river does not get dry. After Etawah, the river quality gets improved and up to the confluence with Ganga River, it becomes environmentally good.

As stated above, in general the Yamuna River is very critical and requires better integrated water resources management and planning. Therefore, the Ministry of Environment and Forests was keenly interested to develop a DSS of IWRM for Yamuna basin.

Components of DSS

The Yamuna DSS links the MIKE Basin model, Mike 11 Hydrodynamics and Water Quality model and the Point and Non-point Sources Pollution load calculator. The components of the DSS are: (i) dashboard, (ii) Water allocation model, the MIKE BASIN (iii) load calculator, MIKE BASIN (iv) Hydrodynamic and water quality model, MIKE 11, (v) User Interface. The Data flow between the models is shown in Fig. 1. Brief description of individual components is given as follows:

The MIKE Basin model: include the rainfall-runoff process, water allocation from surface and groundwater resources as well as the water quantity in the overall system, while the Pollution Load Calculator is used for the calculation of point and non-point sources pollution (DHI, 2009). The entire outputs in the form of net runoff and pollution load are form the inflow to the MIKE 11 hydrodynamics and water quality module. However, the human influenced inputs for the MIKE BASIN Model such as water supply, irrigation abstraction, population, possible infrastructure development like installation of sewage treatment plants; diversion of wastewater for other uses is directly supplied through the user interface. Addition to the above, it has the potential to: (i) integrate the analyses of the water balance of the basin under various abstraction scenarios and reveal if the foreseen abstractions from groundwater are sustainable; and (ii) generate scenario of water surplus and deficit under various mitigations.

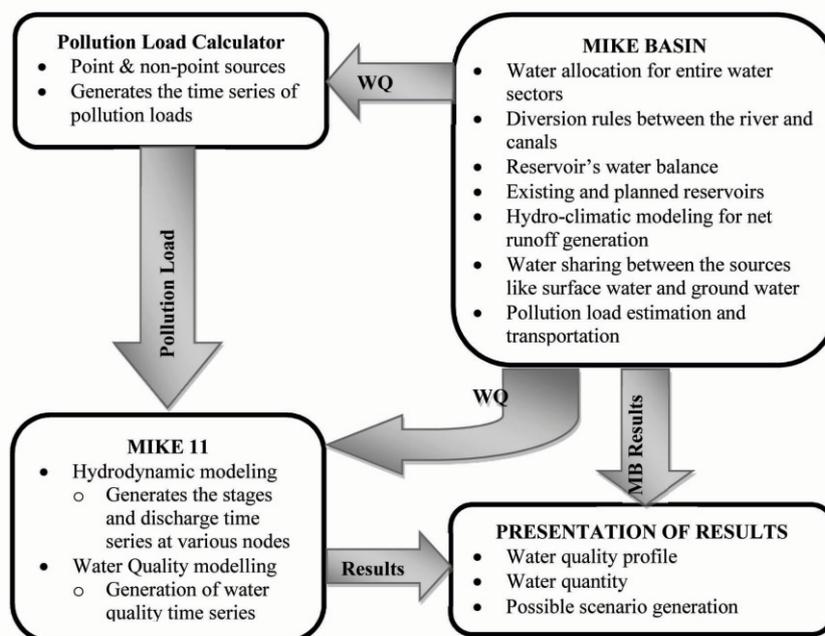


Fig. 1 Schematic structure and data flow in the DSS



The load calculator: plays a crucial role in the DSS by controlling the input of pollutants and drainage water into the river system. The load thus calculated are fed directly into the MIKE11 water quality model and the drainage flows generated by the calculator is directed via the MIKE Basin model which must at all times keep an account of all water volumes being distributed within the basin.

The MIKE11 models: serve to the hydrodynamic computations and the transportation of pollutants in the river (DHI, 2009). A suitable value of decay factor for individual water quality parameter is considered in the analysis. The interaction of polluting components with flow characteristics is also included in the MIKE 11 WQ modelling. This is the final stage of the DSS computation which gives water quality profile and water quantity to the users end.

The DSS dashboard: The Dashboard is the user interface of the DSS. It can handle the tasks: (i) of viewing the input data and results of the Scenarios; (ii) to copy and create a new scenario under a new name and then edit the input data of this new scenario to construct further scenarios; (iii) to run the new scenario, MIKE Basin, Load Calculator and MIKE11 will be run internally by the DSS; and (iv) to compare the results of a new scenario with other simulation. The results are also available for the user further analysis outside the DSS.

Table 1 List of secondary data

Sl. No.	Data Item	Sl. No.	Data Item
1	Climatic data: <ul style="list-style-type: none"> • Daily rainfall (1951-2003) • Meteorological data: Max, Min and Mean Temperature (1951-2003) 	7	Agriculture data: <ul style="list-style-type: none"> • Land use (Area) • Cropping pattern (Area): Kharif, Rabi • Cropping intensity • Irrigation sources • Livestock • Fertilizer & Pesticides • Protected area: National forest
2	Hydrological data: <ul style="list-style-type: none"> • Daily discharge at different sites (2002-07) • Monsoon (June-July) • Groundwater data (2000-2006) 	8	Industries: Type and Number
3	Irrigation data: Canal discharge (1995-2008)	9	Water Supply & Sanitation: <ul style="list-style-type: none"> • Water supply criteria (Urban, Rural) • Wastewater generation • Wastewater treatment facility • Water treatment facility
4	Soil data: Soil type		
5	Water Quality data		
6	Socio-economic data: <ul style="list-style-type: none"> • Population: Total, Urban, Rural (1991, 2001) • Population density: 1991, 2001 • Population decadal Growth rate 		



Application of the DSS

The developed DSS was applied on the Yamuna River basin for integrated water resources management and water quality analysis. To run the DSS various data are required, and can be categorized into two parts: (i) calibration and validation of MIKE BASIN, and MIKE 11 model for water quantity and quality; and (ii) population projection, diversion of wastewater flow, installation of sewage treatment plants for wastewater management, adaptation of clean technology for wastewater management, adaptation of best irrigation methods, allocation of additional water for river by construction the upstream reservoir, etc for generation of various scenarios. List of secondary and primary data are given in Table 1 and 2, respectively.

RESULTS AND DISCUSSION

Modelling Components

Before running the DSS, the components of the DSS especially the MIKE BASIN and MIKE 11 Hydrodynamic and Water Quality models were adequately calibrated using the require information of hydro-climatic variables and catchment's physiographic characterises as well as the river's hydraulic characteristics. The example calibration of MIKE Basin model is shown in Fig. 2. It is observed that the MIKE BASIN model gives reasonably good calibration of the catchment physiographic and flow characteristics.

Table 2 List of primary data

Sl. No.	Item	Remarks
1	Cross-sections	Cross-section of the Yamuna River (Hathnikund to the Allahabad); Western Yamuna Canal (WYC); WYC Power canal; Hindon and Kali River; and Najafgarh drain were surveyed. In totality 195 cross-sections were surveyed.
2	Structures along the river	Dimension of all the structures installed across the river were surveyed.
3	Flow and water quality monitoring	<ol style="list-style-type: none"> 1. To know the quality of the river Yamuna during the lean period, discharge were measured at different locations starting from the Hathnikund to the Allahabad before the river joins to the river Ganga. The concentration of different parameters was measured by taking the samples at the same time and location. 2. These measurements were also carried out for the major tributaries at their terminal points (i.e. near the confluence with river Yamuna) such as Hindon, Chambal, Sind, Betwa and Ken. 3. Relatively higher attentions were given to the critical stretches of the river Yamuna, such as Delhi, Mathura and Agra. At these stretches, round the clock (i.e. 24 hours) monitoring of major polluting drains was conducted for four consecutive weeks. 4. For non -point source estimation above three items were repeated after the first rainfall storm.

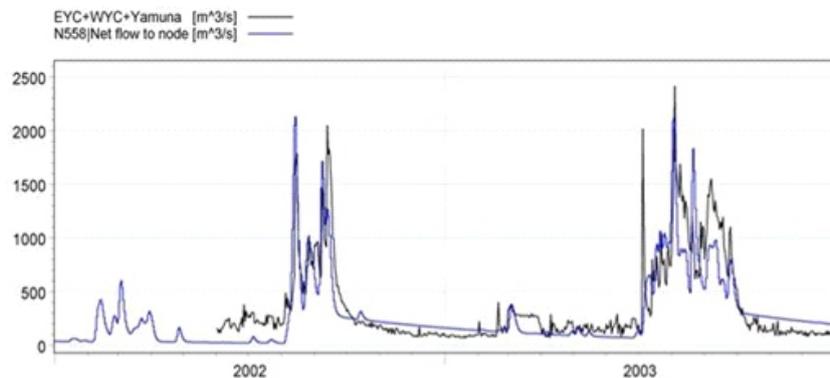


Fig. 2 Example calibration of MIKE BASIN model

As stated above, the MIKE 11 ECO lab, a system of differential equations which have causal linkage between the physical, chemical and biological characteristics and hydrodynamic characteristics. The parameters considered in the modelling were BOD, DO, Ammonia, Nitrate, Phosphorous, Coliform and biomass. After calibrating the model, the results in the form of water quality profile for various indicative parameters are shown in Figs. 3 and 4. Fig.3 shows the variation of BOD and DO, and Fig. 4 shows the variation of Ammonia, Nitrite, Nitrate and Phosphate in the various reaches of Yamuna for the existing conditions.

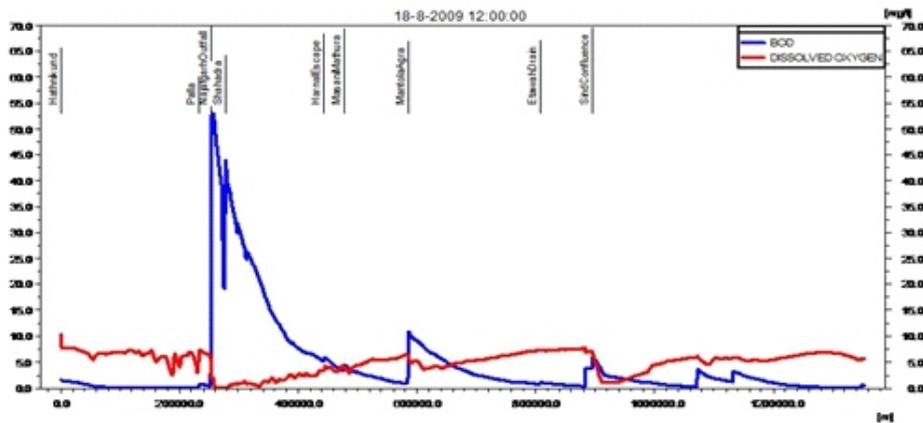


Fig. 3 Variation of BOD and DO along Yamuna

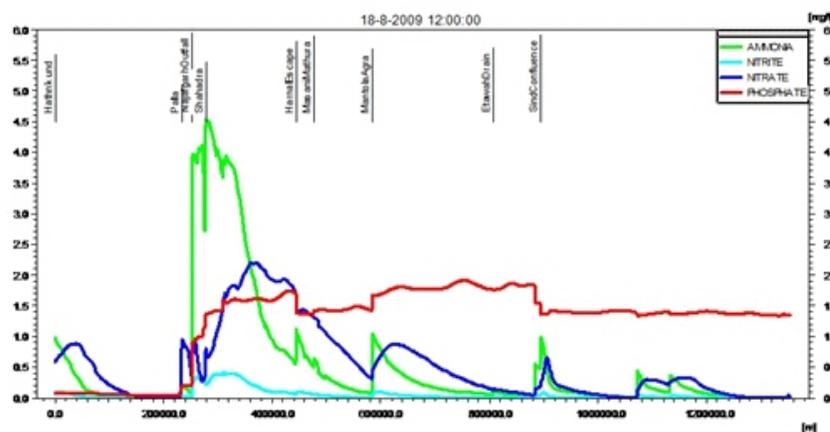


Fig. 4 Variation of Ammonia, Nitrite, Nitrate and Phosphate along Yamuna

Scenario generation

Considering the various implementation and proposed schemes for pollution control under Yamuna Action Plan Phase II and III, various scenarios have been generated to analyse the impact on the river water quality. Assumptions of example scenarios are listed in Table 3. A brief description of type of scenarios is given as follows:

Baseline Scenarios B-0, B-1 and B-2: These scenarios refer to what could be called “business as usual”. These scenarios provide for increased population as projected by the literature, projected increases in industrial pollution load but no further proactive measures being taken to increase the level of treatment except insofar as to cater to the increased population in each category treated in scenario B-0. Each drain will be serviced by the same technologies that were in use in 2010. While such a set of scenarios are extremely unlikely to take place, it is useful to have for comparison the situation that could arise if the agencies responsible maintain a completely passive posture. It was assumed that no attempt was made to increase the priority surface water demand supplied to waterworks. This water thus had to be taken from the groundwater.

Existing Development Trajectory Scenario E-1: This is not a set of scenarios that could attract universal agreement on what this trajectory is. It is therefore necessary to specify clearly what assumptions are made to create these scenarios.

This scenario assumes the same population projection as for B-1 and that they are distributed among the 26 drain catchments in exactly the same way. The most important assumption is that all interceptor sewers are in place and that no sewer discharges (except for the 15 percent population engaged in dry defecation) reach the drains without treatment. It also assumes that the sewage captured by the interceptors are treated to level equivalent to 10 mg/l BOD and released in to the drain system or directly into the river. This includes a part of the 28 percent unsewered discharge which would also be captured by the interceptor.

The existing sewage treatment plans will carry on at the same level on treatment as in 2010. This scenario assumes that 50 percent of industries comply with the CPCB requirement. The water demand from (provided as the top priority) from the WYC was increased to the waterworks specified in the Master Plan.

Najafgarh Diversion Scenario N-1: This is type of intervention is considered by many to approach the final solution of preventing any polluted water entering the Yamuna at all. This involves the construction of a right bank parallel canal that will intercept and diversion all right bank drains between Wazirabad and Okhla and send this water, after treatment – to (say) 10mg/l BOD - to the Agra Canal for use in irrigation of specified crops. As this exercise would leave the riverbed dry and fully exposed – it was thought that some amount of clean water (say 10 cumecs) could be released over the barrage at Wazirabad. This scenario would still allow the release of polluted water through the Hindon Cut to cross Okhla Reservoir to Agra Canal. The outcome of the DSS runs for these scenarios are presented in Figs. 5 through 9.

It is clear from Fig. 5 (i.e. BOD profile under scenarios B0, B1 and B2) that if no special interventions are made (Baseline-Business as Usual Scenario) the stretch of the Yamuna between Wazirabad Barrage and Chambal Confluence (approximately 500 km) will continue to remain under heavy pollution and its intensity will continuously increase at all the locations in the next 20 and 30 years. The other segments of the river generally remain under acceptable condition even after this period. However, implementation of interceptor project and treatment of wastewater up to 10 mg/l BOD

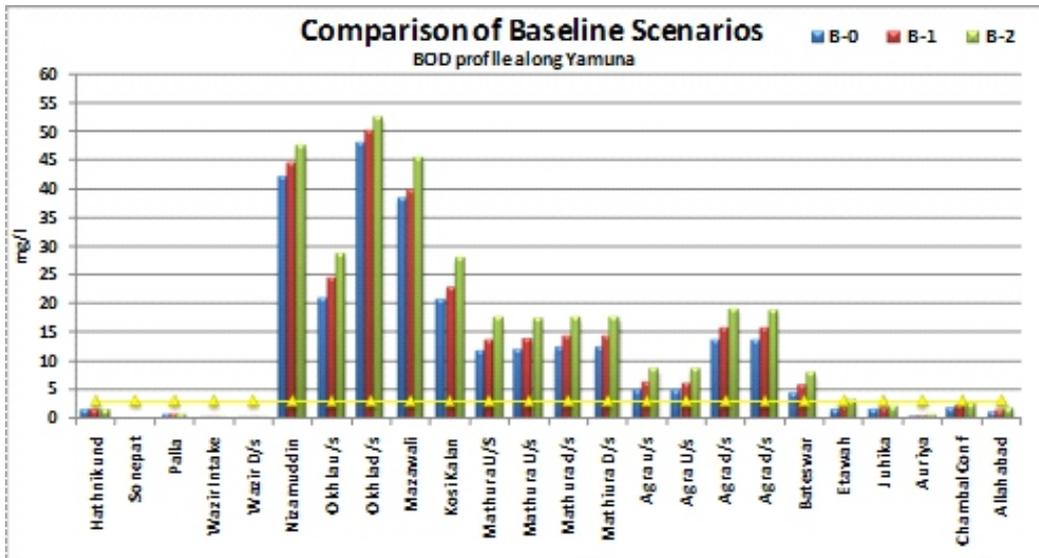


Fig. 5 Comparison of Baseline Scenarios

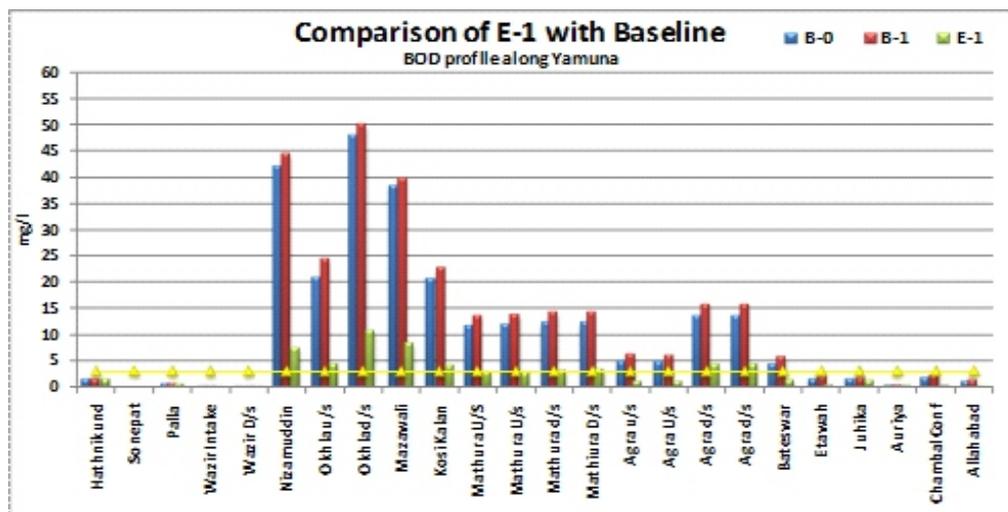


Fig. 6 Comparison of E-1 with Baseline – BOD

(Scenario E-1), the water quality will improve significantly (Figs. 6 and 7). The BOD at Nizamuddin Bridge and Okhla d/s will come down from 40-50 mg/l to 7-10 mg/l by 2020 as shown in Figs. 6 and 7. This will be a significant achievement. However, the BOD does not still reach its desirable level. Still the Delhi segment of the Yamuna does not meet the desired quality with respect to DO (Fig. 7). The DO will continue to remain low in Delhi stretch. With implementation of conditions of scenario N-1 (i.e. Najafgarh along with other six major drains will be diverted to the Agra canal for other uses; and additional 10 cumecs of fresh water will be released from the Wazirabad barrage to maintain the river flow), the BOD of Delhi Stretch will further improve (Fig. 8).

However, the BOD of Yamuna downstream to the Okhla barrage will continue to remain high due to contribution of Shahdara Drain. The DO will also improve significantly and meet the desired level except in Delhi Stretch (Fig. 9). Complete diversion of Najafgarh Drain (Scenarios N-1) has very positive impact on water quality of the river in Delhi Stretch and downstream as evident from Figs. 8 and 9, except DO in Delhi Stretch. A comparison was made of DO and BOD profiles of the Yamuna River for 2020 and 2030 using results of different scenarios i.e. E-1, and N-1. It is observed that they will have almost similar benefits in terms of improvement in BOD and DO.

Beside the water quality profile generation under different mitigation, the comparison of different scenarios at specific locations has been developed. Example comparison at Nizamuddin Bridge is depicted in Figs. 10.

Table 3 Assumption for the example scenarios

Scenarios	Scenario No.	Year	Flow Scenario	Population	Treatment Scenario	Comments
Business as usual	Bo	2010	Present	Present	Present ¹	This scenario is based on the present condition.
	B1	2020	Present (with increased water supply from groundwater)	Projected	Present with no augmentation of treatment facilities.	Wastewater generation is projected. Both domestic and industrial wastewater was considered.
	B2	2030	Present (with increased water supply from groundwater)	Projected	Present with no augmentation of treatment facilities.	
Existing development trajectory	E1	2020	Present (with increased water supply allocation)	Same as B1	Interceptor working. All sewage being treated. No wastewater discharge without treatment.	All the drains will be intercepted and treated at 10 mg/l BOD.
Najafgarh diversion	N1	2020	Present (with increased water supply) and add 10 cumec fresh water from Wazirabad ²	Same as B1	Najafgarh and Supplementary along with six other drains will be diverted to Agra canal after treatment.	Due to Najafgarh diversion Delhi segment will become dry. To establish the flow in the river, 10 cumecs of water will be added to the river from Wazirabad barrage.

¹Treatment of wastewater up to 30 mg/l BOD

²10 cumecs water is proposed to avoid the dry river in Delhi stretch.

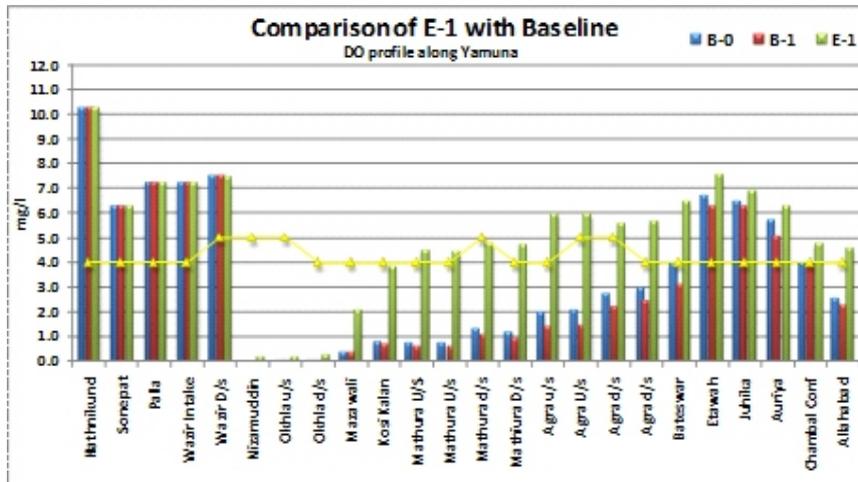


Fig. 7 Comparison of E-1 with Baseline – DO

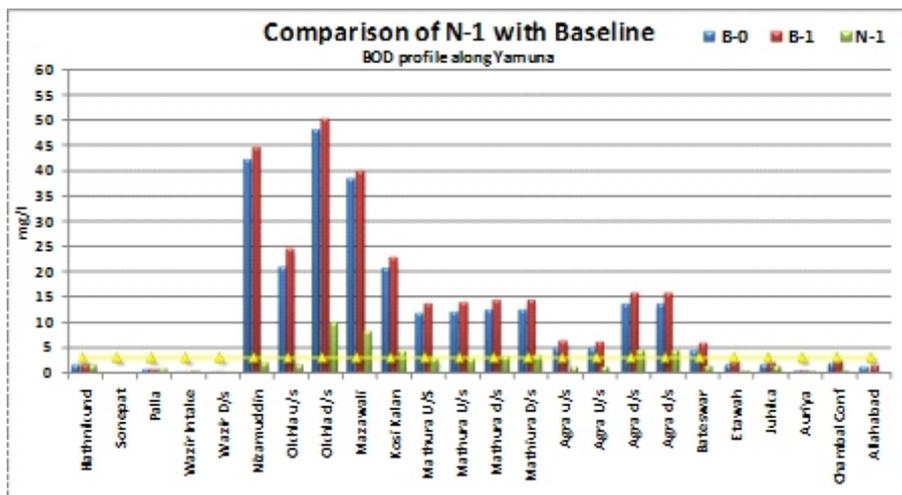


Fig. 8 Comparison of N-1 with Baseline – BOD

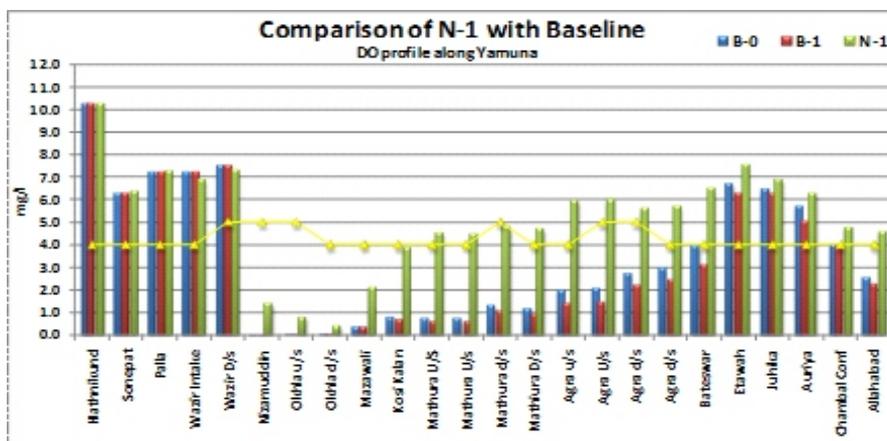


Fig. 9 Comparison of N-1 with Baseline – DO

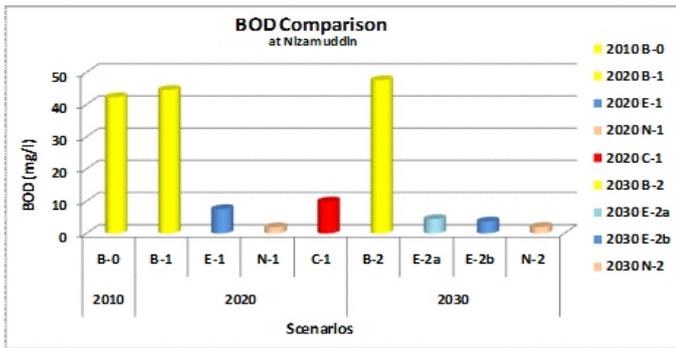


Fig. 10a Comparison of BOD at Nizamuddin Bridge

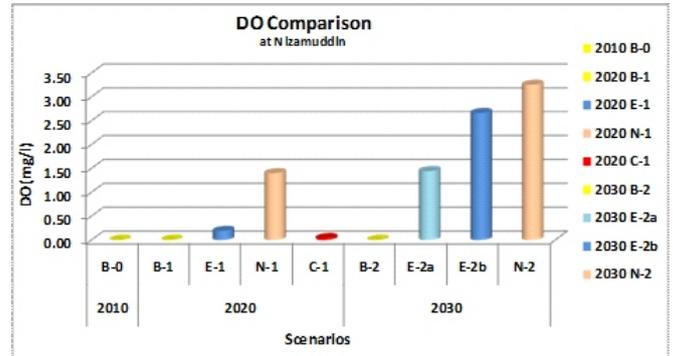


Fig. 10b Comparison of DO at Nizamuddin Bridge

Conclusions :

This paper brings out the experience of development of a decision support system (DSS) for managing the river water quality in Yamuna Basin duly considering the developments in the basin for meeting agricultural, domestic and industrial water demands and various options for managing the water quality in the most polluted stretches of Yamuna River. The DSS has been developed as a planning and management tool to evaluate the relative merits and demerits of a range of proposals for development and operation of waste water management systems with the river water quality of Yamuna in focus. The developed DSS by itself can be used by non-specialists but uses sophisticated modeling systems like Mike Basin, Load Calculator and Mike11 HD and ECO lab to predict water quality conditions in the river as a consequence of implementing different scenarios. Based upon the scenarios tested for Yamuna Basin and the consequent projected water quality parameters, it can be inferred that a full diversion of treated sewage effluent to Najafgarh drain into Agra Canal and using this water for irrigation is likely to be the best option for the Yamuna Basin. However this would imply that river will remain dry in the Delhi stretch. To enhance the possibility of receiving more water into the river, suitable crop plan need to be developed which sustain the farmers economy and minimize the crop water demand, as nearly 90% water is being used for the agriculture. Considering this option, a further study has been carried out for better investigation. Based on the study it was inferred that at least 34% of irrigation water can be saved through the appropriate crop planning in the basin. Likewise using rainwater harvesting and such like measures in the catchment can further enhance the availability of water in the river and augment the water table that has been depleting due to over-exploitation. The developed DSS therefore gives an opportunity to holistically consider the quantity and quality aspects of the river Yamuna. Similar DSS can be developed for other river basins and water bodies in India to holistically manage water quantity and quality.

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