WASTEWATER MANAGEMENT IN NAJAFGARH DRAINAGE BASIN

– KEY TO WATER QUALITY IMPROVEMENT IN RIVER YAMUNA

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Abstract
During last decade a number of sewage treatment plants (STPs) and pumping stations have been constructed in Delhi, however there are severe limitations in the sewerage network which are attributed to excessive silt deposition and settlement, inadequate pumping capacity etc. As a result, a large quantity of sewage is divert to storm water drains while the STPs are under utilised to the extent of 43%. Besides, almost 45% of the population in low-income areas is not covered by sewerage system. Najafgarh Drain (NjD) is the largest of all drains in the National Capital Territory and carries a total flow of over 2000 mld and BOD load of around 195 t/d. Due to the unique situation found on the 22 km long stretch of river Yamuna in NCT Delhi, apparently it is necessary to achieve a BOD of as low as 3.5 mg/l at the outfall of NjD itself if the stipulated water quality of 3 mg/l in the river is to be achieved. Under the given circumstances, it is found that conventional measures alone can not help in achieving this objective. A sizable investment of over Rs. 70 billion phased over 20 years is required, which may be difficult to materialise. To address such a situation an integrated strategy involving conventional and unconventional environmental engineering interventions is developed. The conventional measures will focus on rehabilitating the sewerage system including desilting, laying of new lines, strengthening the pumping capacity etc. While the unconventional measures will consist of implementation of (1) small bore sewerage with decentralised treatment and/or on-site sanitation in low income communities, (2) augmenting the self purification capacity of trunk sewers/rising mains (3) augmenting the self purification capacity of the open channel of NjD and (4) creation of a wetland wastewater treatment system in northern part of the city. The latter set of interventions can be implemented independently in the short-term; they have the potential to reduce a sizable fraction of organic load reaching the river and can serve as back up in case the conventional system does not function effectively. Such a combined strategy is expected to provide a cost effective and sustainable solution.

INTRODUCTION

The 22 km long stretch of Yamuna along National Capital Territory of Delhi (NCT) is in a unique situation because of two barrages located on its upstream and downstream ends at Wazirabad and Okhla respectively. In order to meet the drinking water demand of the city, no fresh water is released from the upstream barrage at Wazirabad while a large quantity of wastewater is discharged on its downstream through over 18 drains into the river. Due to a combined discharge from domestic, industrial and agricultural activities this stretch is considered to be highly polluted and it has become critical from public health point of view. Typically, BOD in this stretch varies between 15 to 33 mg/l while the *Total Coliform* is estimated to be of the order of a million MPN /100 ml.

Najafgarh Drain (NjD) is the largest among all the surface drains joining the river in NCT. Its sewered catchment area is around 374 sq.km. Because of severe constraints in the sewerage system in its drainage basin, NjD carries a very large quantity of raw sewage. In addition, it receives treated effluent from various STPs and freshwater from Western Yamuna Canal. The combined discharge is over 2000 mld, while the BOD load varies between 80 t/d to 195 t/d and; this alone represents 50% of hydraulic load and over 25% of organic load from NCT Delhi in to the river Yamuna. Looking at the perennially high level of flow in NjD, it will not be inappropriate to consider this channel as a typical polluted river. In view of the magnitude of the organic load carried by NjD and the path traversed by it through a major part of the city, it gains tremendous significance in the overall strategy for control of pollution in river Yamuna.

As per the directions of the Supreme Court, maintaining a BOD level of 3 mg/l in the Yamuna waters in NCT has been made mandatory. However, under the given circumstances where complete sewage treatment is not feasible and dilution water (from upstream barrage) in the river is not available, achievement of this target appears to be difficult. While the discharges from rest of the surface drains are planned to be trapped and diverted for treatment, this strategy will not be feasible for NjD because of sheer volume of wastewater. In this context, there is a need to develop an integrated plan exclusively for the NjD basin with the objectives of identifying:

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- Key constraints in utilising full carrying capacity of the sewerage system
- Short and medium term measures for prevention of entry of sewage in to NjD, and
- Long term innovative measures for augmenting the purification capacity of the entire system including the STPs and the conveyance system.

From this point of view a study was commissioned during the later part of Yamuna Action Plan, Phase-I to develop a road map for management of wastewater in the NjD basin. This paper is derived out of the said study.

DRAINAGE PATTERN IN THE NAJAFGARH DRAIN BASIN

NjD originates somewhere in Alwar – Rewari region of Rajasthan and Haryana in the Arawali Hills. It enters NCT on the south western side and traverses a length of 40 km before joining Yamuna in the north. NjD used to be a natural channel known by the name of 'Sahibi River' and it was essentially serving the purpose of drainage of storm water for the adjoining areas of Haryana and Delhi. It was channelised in 1978 with the objective of integrating into the storm water drainage system of the city and was renamed as 'Najafgarh Drain'.

There are two dominant drainage directions in NCT characterized by river Yamuna and NjD. The river flows from north to south dividing Delhi in two halves. Other topographical feature affecting the drainage pattern is the ridgeline in the western half which runs diametrically through the city from southwest to northeast and terminates on the right bank of Yamuna. NjD flows almost parallel to the ridge draining the entire western and north western parts of the city and joins Yamuna in the north. About 48 secondary channels running in NW-SE direction join NjD from both sides.

As a result of the distinct topographical boundaries on the city landscape, four watersheds can be demarcated viz. (1) trans Yamuna part of the city (2) area bounded by the river and the ridge (3) area bounded by the ridge and the NjD, and (4) area on the north-western side of NjD. The sewerage and drainage planning for the city has been done on the basis of these watersheds. With respect to NjD basin, the latter two watersheds are of relevance.

Flow regime in Najafgarh drain

The flow along NjD can be classified under three different stages. The background flow, i.e., before entry into NCT is 164 mld which comprises untreated and treated sewage from the towns of Jhajjar, Bahadurgarh, Rohtak and Gurgaon in Haryana. Almost 40% flow is untreated while the rest 60% is discharged after conventional treatment (TEC, 2002).

Next stage represents flows originating in Delhi. Due to various limitations in the sewerage system in NCT, a large quantity of sewage is diverted into secondary drains which eventually join NjD. As per a field study, 38 out of the identified 48 secondary drains carry significant flows (WAPCOS, 1999). These drains are shown in Exhibit 1. There are fifteen secondary drains on the left hand side, out of which Supplementary drain (180 mld), Nangloi Sayed drain (98 mld) and Shakurbasti drain (74 mld) are considered major. Supplementary drain needs special mention because of its large catchment area, high flow and BOD load. It brings treated flow from several STPs as well as untreated sewage from residential areas in the north. On the right hand side, there are 23 major secondary drains including Dariyai Nala (98 mld), Palam drain (68 mld), Phanka Road drain (54 mld) and Keshopur drain (51 mld) which carry major flows.

The aggregate measured flow from these secondary drains is 946 mld. In addition there are non-point sources of wastewater from habitations along the drain. It is estimated that the total flow of wastewater joining NjD from the NCT is around 1550 mld.

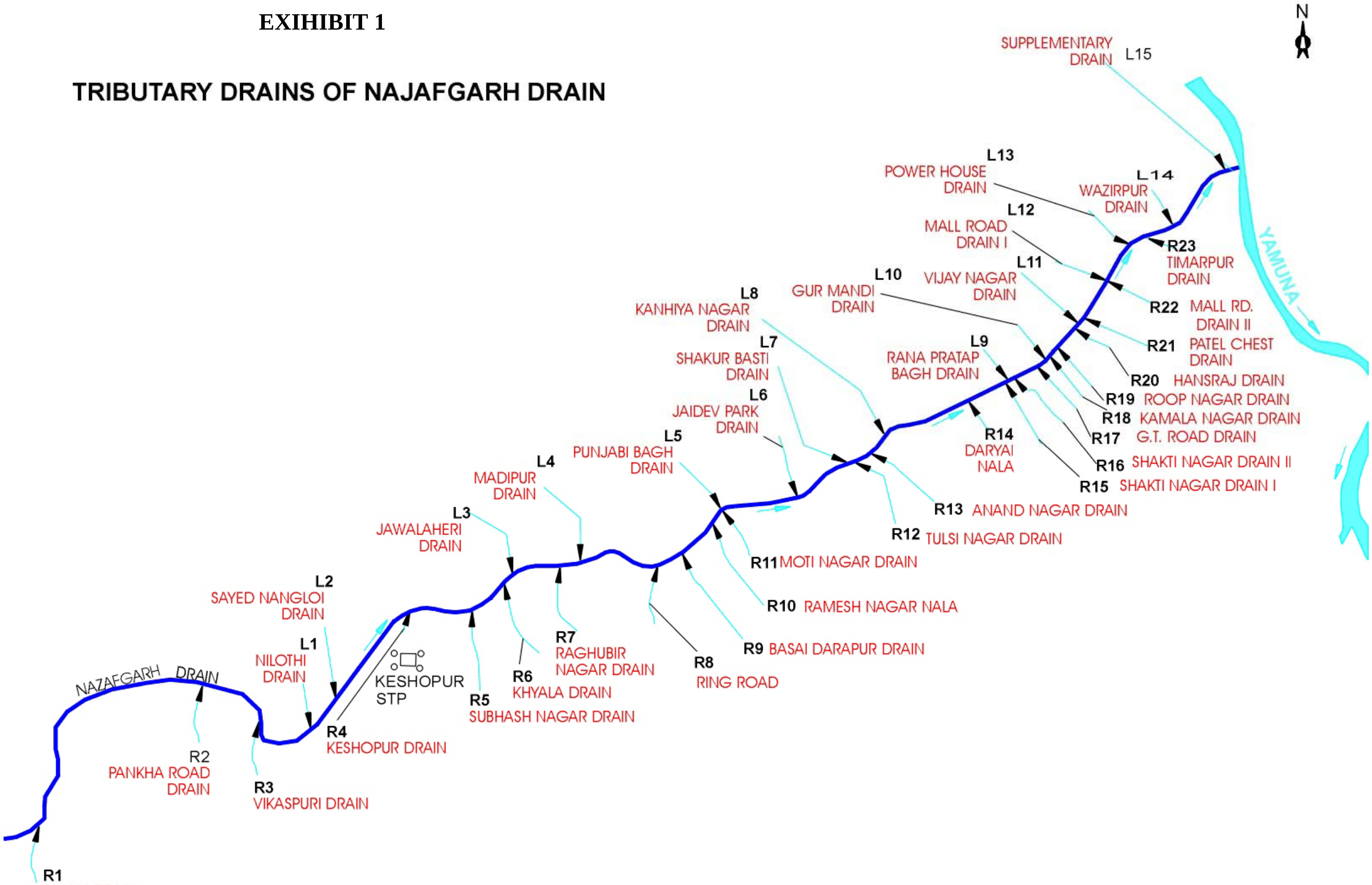
Next stage represents increased and diluted flow in NjD as a result of entry of almost 450 mld of fresh water which is routed through the Western Yamuna Canal (WYC). This transfer is done under a sharing agreement for irrigation water between the five riparian states of river Yamuna. Exhibit 2 shows the build up of flow along the length of NjD. Please note that the starting point of the graph is somewhere in the middle reach in NCT and not really the origin or entry point of NjD in NCT.

Organic load along NjD

Water quality profile along the length of NjD is also shown in Exhibit 2. The background flow brings a BOD of 98 mg/l (16 t/d). All 38 drains put together contribute as much as 168 t of BOD/d into the NjD. Fresh water discharge from WYC leads to a drop in BOD concentration as shown in the graphs in Exhibit 2. At this stage, BOD dilution to the extent of almost 65 % takes place. Just before the outfall into Yamuna, the measured BOD is 125 mg/l (WAPCOS, 2002) and the corresponding BOD load is estimated to be of the order of 147 t/d.

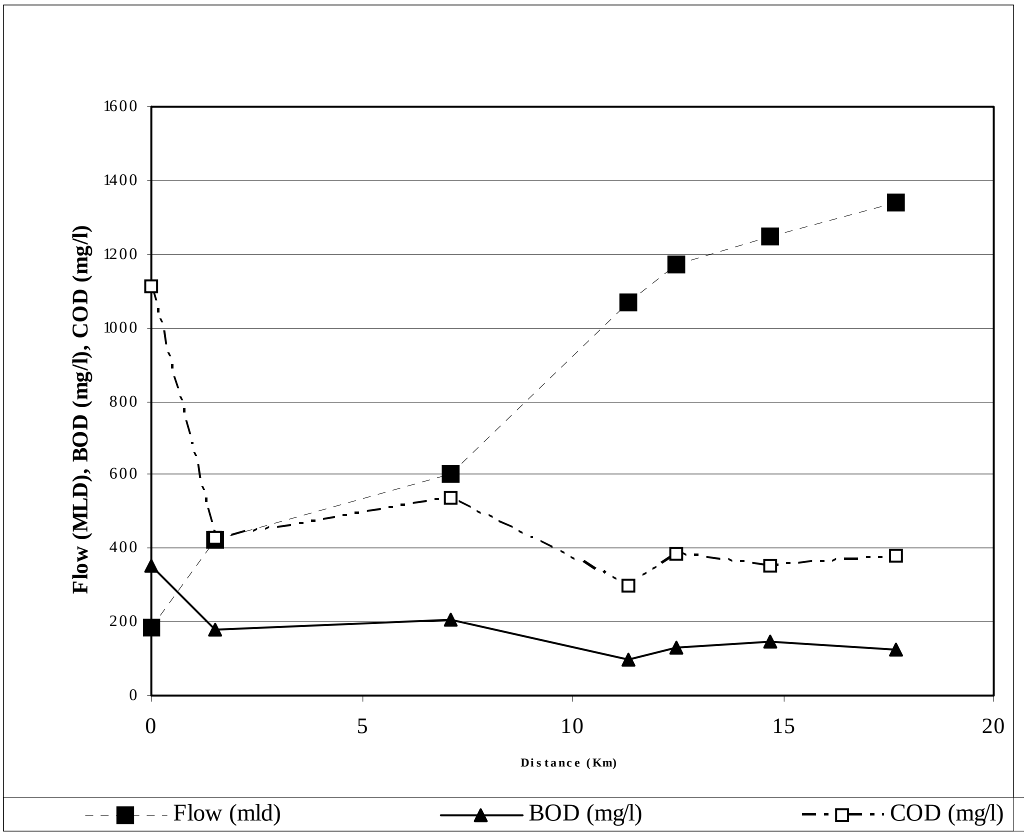
EXIHIBIT 1

TRIBUTARY DRAINS OF NAJAFGARH DRAIN



(Source: WAPCOS, 1999)

EXHIBIT 2 : WASTEWATER CHARACTERISTICS ALONG NjD



(Source: WAPCOS,1999 and TEC,2002)

MAIN SOURCES OF WATER POLLUTION

Activities in all the three sectors i.e., domestic, industrial and agriculture are contributing to wastewater loads in NjD. Their relative contributions are shown in Exhibit 3. Total wastewater flow in NjD is estimated to be close to 1500 mld (excluding WYC freshwater discharge) while the total BOD load discharged by it into the river is estimated to be 195 t/d. By far the largest contribution is from the domestic sector corresponding to a basin-wide population of about 7.62 million. Total sewage generation is estimated to be 1340 mld and the BOD load is estimated to be 305 t/d. Out of this, about 55% of sewage is getting treated in existing STPs and on this basis, the net discharge of BOD from domestic sector is estimated to be 152 t/d. Average sewage discharge is found to be 176 lpcd which is higher than what is typically considered for urban areas in the country. Schematic distribution of treated and untreated sewage flows is shown in Exhibit 4.

Direct assessment of the extent of water pollution from industrial sources is not available, however an estimate is made from the designed capacity of 11 common effluent treatment plants (CETPs) planned in various industrial estates in NjD basin. Total flow and BOD load from this sector is estimated to be 150 mld and 15 t/d (@ 100 m/l) respectively.

NjD basin also supports 6 large authorized dairy farms and a number of unauthorized dairy farms located mostly in the northern and western parts of the city. Total number of dairy cattle is estimated to be around 184,000 and the corresponding BOD is estimated to be 28 t/d. Moreover, based on a mass balance for the entire NjD, the flow from agriculture sector is estimated to be around 89 mld.

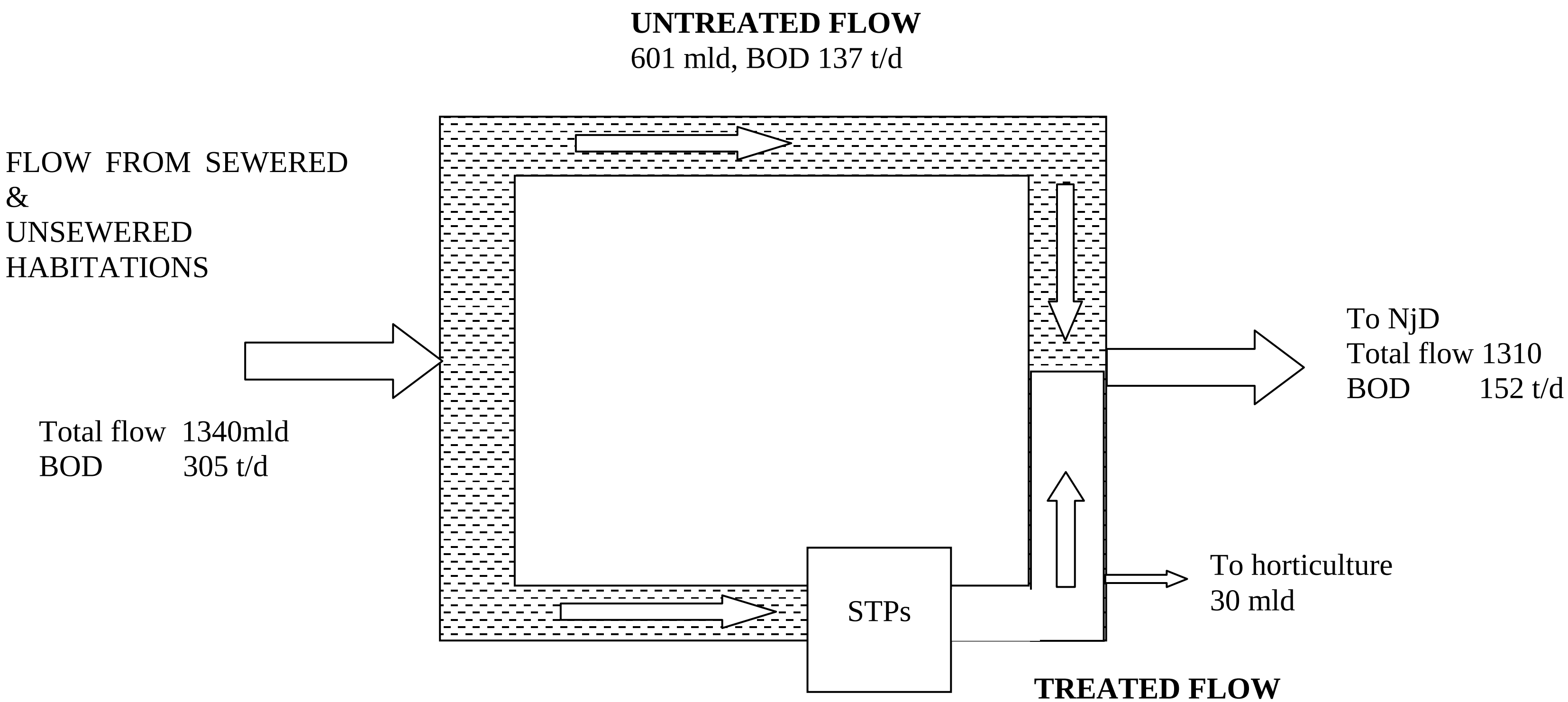
EXHIBIT 3 : WATER POLLUTION FROM DIFFERENT SECTORS IN NjD BASIN

Particulars	**Units**	**Sectors**			**Total**
		Domestic	Industrial	Agriculture	
Wastewater flows	mld	1340	150	NA	> 1490
BOD loads	t/d	152	15	28	195
Relative BOD contribution	%	78	8	14	100

EXHIBIT 4

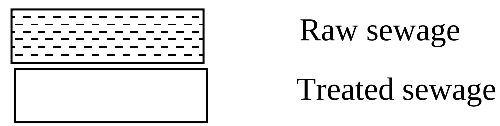
DISTRIBUTION OF TREATED AND UNTREATED DISCHARGE

OF SEWAGE IN NjD BASIN



Notes:

1. Per capita BOD contribution considered @ 40g/c/d
2. Flow values adopted from ECFA, 2000
3. Hydraulic capacity utilization of STPs as per information available from DJB.
4. STP effluent BOD assubed to be 20mg/l.



SEWERAGE SYSTEM IN THE NjD BASIN

There are four sewerage zones in the NjD basin viz. Coronation Pillar (CP) zone, Rithala Rohini (R&R) zone, Keshopur zone and Outer Delhi zone which have been carved out based on the drainage pattern described earlier and depending on the presence of external discontinuities e.g., railway lines, major roads etc. As per the current policy of Delhi Jal Board and Municipal Corporation of Delhi, population residing in rural villages, unauthorised non-regularised colonies and slum clusters is not covered by sewerage system. This constitutes almost 45% of the total population which resort to open defecation or has on-site sanitation arrangement. Coverage is complete in planned colonies, while it is partial in regularised colonies, resettlement colonies and urban villages.

The sewerage system comprises of 55 km of trunk sewers, 45 main pumping stations and a large number of smaller pumping stations. Numerous surface drains have also become an 'integral part' of the network which help in channelling about 946 mld of combined wastewater in to NjD. There are nine sewage treatment plants (STPs) in the basin, some of which were constructed more than 30 years back. The aggregate treatment capacity available in the basin is around 1296 mld. Individual STP capacity utilisation varies between 0 to 100% with a basin wide average of 57%. From hydraulic load point of view this amounts to an idle STP of almost 3.2 million population equivalent (PE). Status of STPs in NjD basin is shown in Exhibit 5 and key constraints faced by the system are summarised below :

- Trunk sewers in CP and Keshopur zones are more than 30 years old and their capacities have reduced by over 70-90% due to a combination of silt deposition and settlement
- Trunk sewers run in surcharge condition and very often manholes are punctured to relieve the pressure
- Ad-hoc pumps (trolley pumps), special sewers or rising mains are installed as emergency measures to bypass the flow to a nearest surface drain
- Parts of CP, R&R and Keshopur sewerage zones are located on both sides of NjD requiring pumping of sewage across the drain. The siphons and rising mains laid for the purpose are damaged and sewage is discharged directly into NjD
- Rising mains from various pumping stations in CP zone leading to the STP are damaged and discharge into the marshy land, which by default has become a wet land system
- Pump shut down due to power cuts is a common occurrence which leads to deposition of silt, creation of anaerobic conditions in the sewers and associated damage due to crown corrosion etc. Inadequate capacity for pumping of sewage has led to under-utilisation of the capacity of STPs
- In case of some of the new STPs, connecting trunk sewers, pumping stations and rising mains have not been commissioned which again leads to under-utilisation of the capacity of STPs
- Part of the STP at Keshopur is more than 30 years old and is almost defunct. The plant efficiency is reported to be low and a major part of the wastewater is bypassed after primary treatment.
- The existing oxidation pond in a densely urbanised city appears to be incompatible from the point of view of efficiency of land utilisation (per unit volume of treated wastewater)
- The newer STPs in Rohini-Rithala and Outer Delhi zones have not been commissioned either due to weaknesses in the delivery system or lower than planned population growth.

FINDINGS OF WATER QUALITY MODELLING STUDY

Under YAP-I, a comprehensive water quality modelling study was carried out with the objective of developing a strategy for control of wastewater discharges from various tributaries/drains along the river. NjD being one of the major point sources of wastewater in the Yamuna basin, its effect on the river water quality was simulated separately by considering a final BOD concentration of 50 mg/l (However, results of a field study report this value to be around 145 mg/l, ref. Exhibit 2) at the outfall. The results of simulation for the year 2012 are discussed in the context of the value of 3 mg BOD/l in the river water as stipulated by the Supreme Court.

- The current observed values of BOD in Delhi stretch of the river is between 15 to 33 mg/l. For present conditions the model predicts a BOD of 14 mg/l at the Okhla barrage (end point of Delhi stretch), which appears to be a reasonable fit.
- Under Scenario-I with only YAP-I implementation and considering availability of 864 mld of dilution water from upstream barrage or WYC, end point BOD for year 2012 is predicted to be 25 mg/l.
- Scenario-II assumes complete YAP-II implementation, stringent BOD discharge limit of 20 mg/l for all STPs (as against the current limit of 30 mg/l) and no dilution water. In this case the end point BOD is predicted to be 4 mg/l.
- Under Scenario-III with almost same conditions but with 864 mld of dilution water the predicted end point BOD is 3 mg/l.

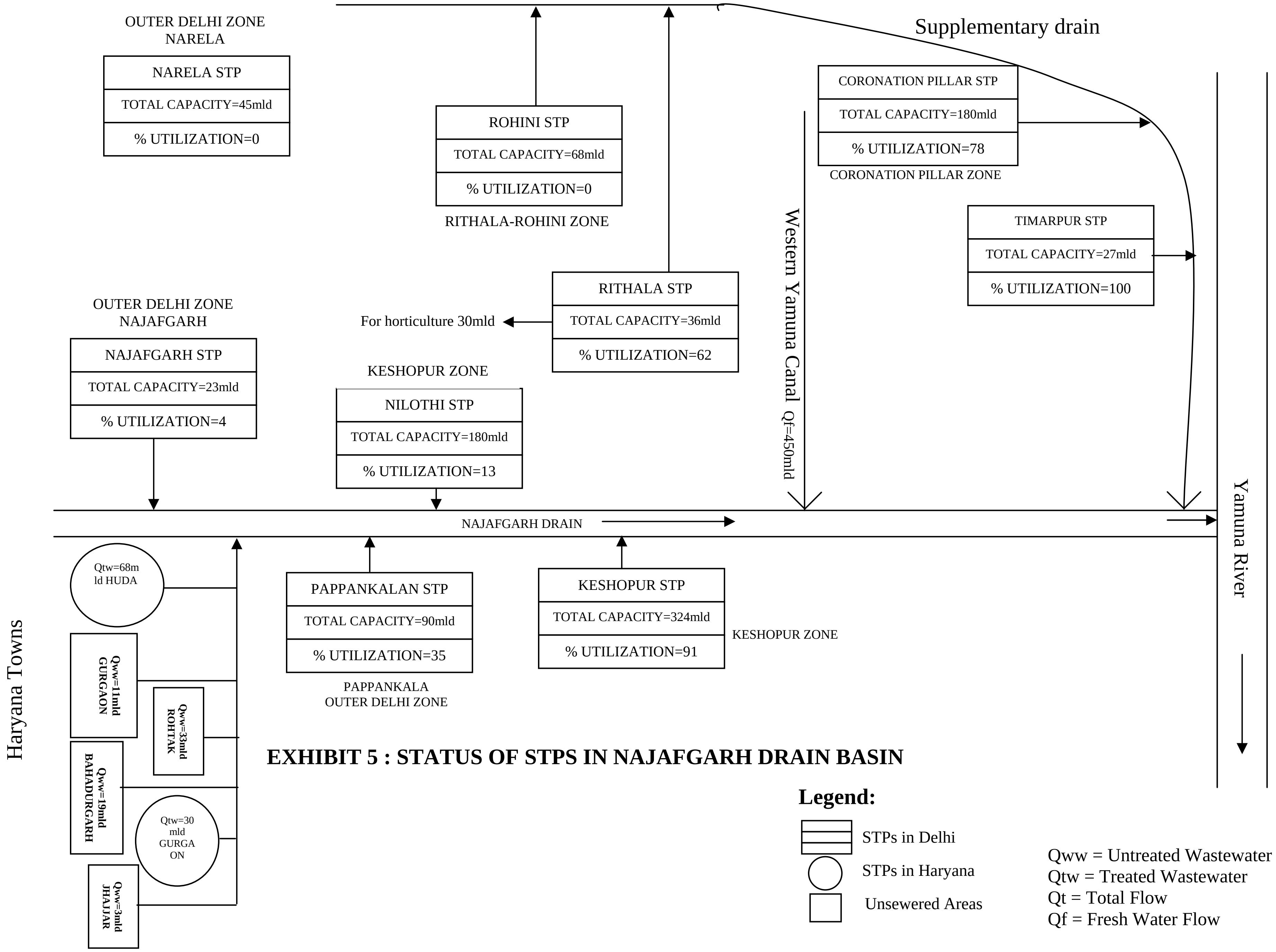


EXHIBIT 5 : STATUS OF STPS IN NAJAFGARH DRAIN BASIN

- Scenario IV is the most severe amongst all, where imposition of a stringent BOD discharge limit of 10 mg/l from all the existing and proposed STPs in the NjD basin is considered and availability of dilution water is also considered. The predicted mid point and end point BOD values are 6 mg/l and 2.5 mg/l respectively.

From the results of Scenario IV it is noted that to achieve the desired water quality of 3 mg BOD/l over the entire 22 km long stretch of Yamuna in Delhi, combined intervention of creation of additional STP capacity and release of much more than 864 mld of fresh water from upstream barrages is required (as of now only 450 mld of fresh water is reported to be reaching NjD through WYC). Therefore, under the current flow conditions/arrangement of sharing of water among the five riparian states and proposed STP capacity, the objective of desired water quality is not achievable. It is all the more difficult considering that the outfall BOD concentration adopted during simulation is almost half of what is found in actual conditions.

NEED FOR FURTHER INTERVENTIONS

In view of the above discussion, and the fact that the flow in the river down stream of Wazirabad barrage is essentially from NjD, it becomes apparent that to achieve a BOD value of 3 mg/l in the river, its concentration in the NjD itself needs to be brought down to not just 10 mg/l, but as close to 3 mg/l as possible ($3 < x < 10$). This conclusion is applicable in all years irrespective of the growth of population and discounting the self purification capacity of the river.

Hypothetically, if the desired river water quality is to be achieved today, there is a need to treat the entire wastewater generated in the NjD basin to a level of 3.5 mg BOD/l after accounting for the dilution effect of WYC. Schematically this computation is shown in the Part A of Exhibit 6. The extent of treatment that would be required in the NjD basin is computed as follows :

	Rest of the wastewater	Only domestic sewage
Required BOD removal	(194.5 – 6) t/d = 189 t/d	(152 – (1340*3.5/1000)) t/d[1] = 147.3 t/d
Per capita BOD load	40 g/c/d	40 g/c/d
PE	189,000/ 0.04	147,300/ 0.04
Required STP capacity	4.725 million PE	3.7 million PE
Required equivalent STP capacity (@176 lpcd)	4.725 * 176 = 832 mld	3.7 * 176 = 651 mld

1 . Refer Exhibit 3.

From sewage treatment point of view, considering that almost 557 mld of the existing STP capacity is unutilised, apparently only about 95 mld (= 651 – 557) of additional capacity is required to be created in NCT for present loads. Besides, additional operation in the form of polishing units would be required at the existing STPs to bring down the effluent BOD from current levels of 30 mg/l to 3.5 mg/l.

From the point of view of the present loads from entire 'rest of the wastewater' in NjD, the strategy will involve commissioning of industrial CETPs as well as installing treatment plants for the dairy farms waste. Total additional treatment capacity that needs to be created in the basin is worked out as follows:

Particulars	Capacity (mld)
Unutilised STP capacity	557
Required STP capacity	832
Required additional STP capacity	832 – 557 = 275

Particulars	Capacity (mld)
STP for domestic wastewater in NCT	95
CETP for industrial wastewater	nil (150 mld will be available in end 2003)
Treatment plant for dairy farm waste	89, say 100
STPs in Haryana towns	91, say 100

Part B of Exhibit 6 schematically represents the entire sewerage system and the broken lines represent the loopholes (diversions to NjD as a result of weaknesses in the system) that need to be plugged. In the backdrop of the baseline conditions in the NjD basin described earlier, it is understood that a large amount of work is required in this direction.

EXHIBIT 6: SCHEMATIC REPRESENTATION OF PROPOSED STRATEGY FOR WATER POLLUTION CONTROL IN NJD BASIN

Part A

Current BOD loads

WYC

Q	450 mld
BOD	0.5 t/d
	1 mg/l

Rest of the wastewater

Q	1710 mld
BOD	194.5 t/d
	L_1=114 mg/l

NjD outfall

Q	2160 mld
BOD	195 t/d
	90 mg/l

Desired BOD loads

WYC

Q	450 mld
BOD	0.5 t/d
	1 mg/l

Rest of the Wastewater

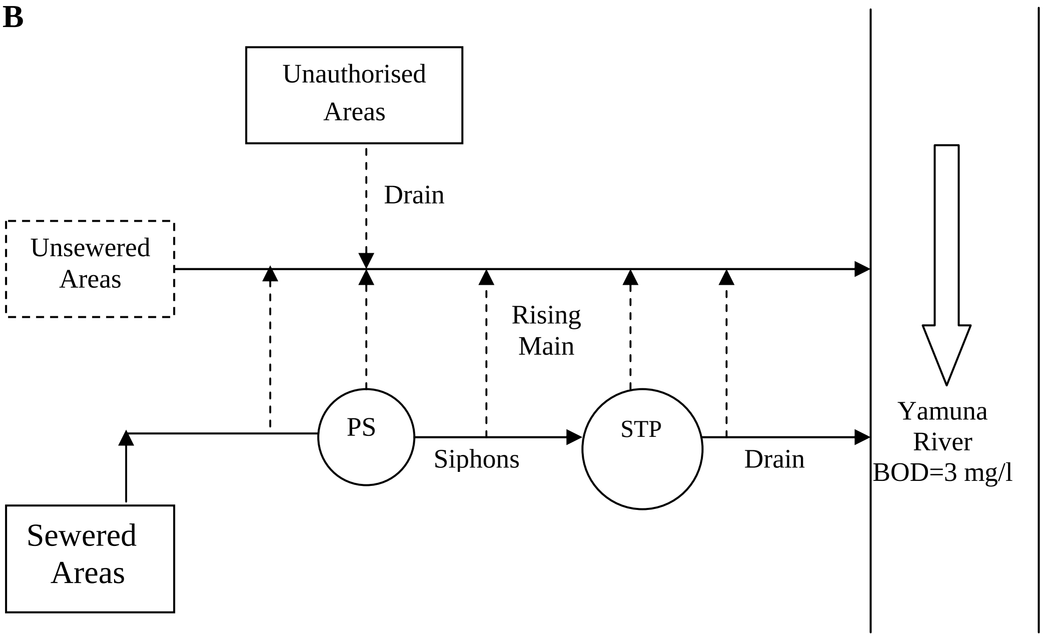
Q	1710 mld
BOD	6 t/d
	L_2=3.5 mg/l

NjD outfall

Q	2160mld
BOD	6.5 t/d
	3 mg/l

Conclusion : BOD in the 'Rest of the wastewater' needs to be brought down from 114 to 3.5 mg/l (or by 189 t/d).

Part B



---- : Loopholes in the system that need to be plugged

THE WAY FORWARD

There is a need to accelerate and strengthen efforts on augmenting the capacity of the existing system for intercepting and treating the discharges from the domestic sector. There are two aspects to it, i.e.:

- Interventions for recovering or renovating the existing sewer lines, pumping stations and STPs under current wastewater load regime, and
- Planning to augment the capacity of the system to meet the expected increase in wastewater loads for next 30 years.

With regard to the first point, an integrated strategy for addressing the current complex situation has been developed. This will comprise of both the conventional sanitary engineering interventions as well as some unconventional environmental engineering measures for wastewater treatment. Salient features of this strategy are described in the sections that follow.

Conventional interventions

In order to achieve a higher capacity utilization at the existing STPs, the strategy involves implementation of following conventional interventions:

- Desilting of sewers
- Repairs and renovation of settled sewers
- Repairs and renovation of sewage pumping stations and rising mains
- Repairs and renovation of siphons across the NjD, and
- Repairs and re-engineering of STPs

The investment required for implementing these measures is estimated to be of the order of Rs. 70 billion which would have to be phased over a period of 20 years (GHK International, 2000).

Unconventional interventions

Considering a large scale of investment and time involved, it may be difficult to achieve measurable improvement in river water quality in the short term. In view of this, there is a need to go beyond the conventional approach and look for alternatives which can help in reducing the stress on the aqueous environment in the short term. Therefore, the strategy proposes paradigm shift to explore the feasibility of introducing some unconventional measures in conjunction with the above cited conventional measures e.g., (a) small bore sewerage with decentralised treatment or on-site sanitation through two pit composting toilets in uncovered areas (b) augmenting self purification capacity of surface drains, long rising mains and surcharged trunk sewers, and (c) creation of a wetland system in existing marshy area.

Implementation of these interventions does not depend on the repairs, renovation or re-engineering of any of the malfunctioning components of the existing sewerage system in the NjD basin. As a result, their implementation can be taken up independently and immediately and they can start showing results in the short to medium term. It must be noted that these unconventional measures involve a paradigm shift and need to be developed and implemented on a different plane.

SPECIFIC COMPONENTS

Based on the above considerations, following set of independent project components have been identified :

1. De-bottlenecking of the existing trunk sewer system in Coronation Pillar and Rithala-Rohini zones
2. De-bottlenecking of the existing trunk sewer system in Keshopur and Outer Delhi zones
3. Preparation of a master plan for coverage of unsewered localities by appropriate sanitation system
4. Pilot study for augmenting self purification capacity of a trunk sewer / rising main
5. Creation of a wetland system at the existing marshy area in CP zone
6. ‘Renaturing’ of Najafgarh drain and augmentation of its self cleaning capacity, and
7. Environment management and monitoring plan

Salient features of only component nr. 3 to 6 are described briefly in the following paragraphs which represent unconventional and innovative interventions.

Appropriate sanitation for unsewered localities

The strategy proposes a paradigm shift for urban low income communities which are not covered by sewer system. It involves exploring the possibilities of installing small bore sewers and providing decentralised treatment ; or moving away from the water based conveyance system to on-site sanitation by promoting two pit latrines and other composting toilets. This shift is called for considering high cost of laying a conventional sewer network and low water availability in most of these localities. However, site specific appropriateness and affordability of sanitation options will need to be assessed.

Augmenting self purification capacity of a trunk sewer/rising main

The problem of sulphide corrosion due to the biological transformation in sewage during its travel down the sewer is well understood. However, what is not so well recognized is the parallel transformation of other complex organic matter as a result of the combined action of attached and suspended biomass in sewers. This is possible due to the presence of a large population of attached bacteria along the walls of the sewers and availability of oxygen. The reaeration coefficient measured in well designed sewer lines varies from 4 to 104 day^{-1} as compared to what is observed in shallow streams (0.05-12 day^{-1}) and rivers (3.4 day^{-1}) (Nema, 1993). By augmenting the supply of oxygen, the biodegradation process can be facilitated right in the sewer/rising main. As a result, the readily biodegradable organic matter and the complex matter can be converted into simpler compounds, carbon dioxide and numerous partially oxidized compounds. Field measurements have shown BOD reduction of as much as 27% in sewers. Measurements made in a sewer upstream of an STP showed a drop of 81% in the redox potential indicating occurrence of a significant biodegradation activity (Metcalf and Eddy, 1981).

Sewer distance upstream of STP, km	15.5	9.7	8.1	4.8	0
Redox potential, mV	+258	+122	+70	+50	+48

STP

In view of the complex sewerage network in NjD basin with long trunk lines and rising mains, the volume available within the pipelines is large and the time required for sewage to reach STPs is long. These wastewater conveying elements can be viewed as extensions of a treatment plant and the holding capacity can be utilised beneficially. From water pollution control point of view, it offers an opportunity to reduce the organic load arriving at an STP and / or joining the surface water bodies at significantly lower capital and O&M costs.

In case of NjD basin, trunk sewers in CP zone and Keshopur zone are 5 km to 7 km long where a pilot study is proposed for re-engineering the system to exploit its self purification capacity. If found feasible, a plan will then be developed for replication on other trunk sewers and rising mains.

Wetland system at the existing marshy area

A large expanse of land in the west of the Coronation Memorial and north of Model Town (CP zone) is demarcated as marshy area. It extends over approximately 300 ha and about 200 ha of this land belongs to DJB. Currently a number of sewage pipelines (pumping mains) are passing through this area for delivering the wastewater to the STP in CP zone. However, very often these pipelines are damaged and the sewage is discharged into the marshy area. As a result, the area serves as an unintended wetland system.

In view of the constraints faced by the existing system of sewage treatment, it would be necessary to explore possibility of developing the marshy area into a sustainable wetland system. This site has a potential to provide sewage treatment to the extent of 150 mld through this natural process. It can receive flows from parts of the CP zones as well as from the Supplementary drain which passes along the northern boundary of the marshy area. Besides, it will have a significant ecological and socio-economic significance. It could serve as a potential site for ground water recharging as well as a site for migratory birds. Inclusion of community managed pisciculture activities would lead to creation of livelihood opportunities for a section of the local population.

In this context, the experience of East Calcutta wetland system (ECWS) is relevant and could be considered. The ECWS has been in existence for last 80 years and is entirely operated and managed by the community. It expands over 4000 ha of land where a network of facultative lagoons treat raw sewage and the farming community produces about 10,000 tonnes of fish every year. It has evolved into an ecosystem of its own and supports a robust pisciculture economy. In view of its tremendous ecological significance, it has also been recently recognized as a wetland of international heritage under the Ramsar Convention.

Renaturing of Najafgarh Drain to augment the self purification capacity

As in case of a sewer line described earlier, it is possible to augment the self purification capacity of an open channel, except that it is much easier. For a natural channel the self purification capacity is a function of not only its reaeration capacity but also the population of suspended biomass and the benthic biomass available along its course. Self purification is pronounced in shallow streams with depth of flow below 1.6 m and where the ratio of wetted area to volume of flow is high (Nema, 1993). The latter parameter represents the availability of benthic bio-mass across the width of a channel which is predominant in carrying out biodegradation in flowing wastewaters.

In case of mountainous streams the natural aeration rate is very high. However, streams in plains have a lower aeration rate due to lesser degree of turbulence. Same is the case with manmade channels and drains in the plains. Moreover, due to a combination of factors e.g., disposal of solid waste, sediment deposits and lack of vegetative bank protection etc. they are found to be ecologically degenerated. One way to regenerate such channels is by desilting and preventing disposal of solid waste. In addition, other innovative approaches for increasing the reaeration rate and the active biomass population are by introducing :

- Smaller impounding structures across the channel at regular intervals
- Ladder for creation of turbulent flow conditions on downstream of the impounding structures
- Root zone treatment along the bed and bank of the channel, and
- Vegetative cover for bank stabilization, etc.

Considering the 40 km long stretch of NjD and its fairly large cross sectional area (top width 28 m, bottom width 23 m, height 3 m, and depth of flow 1 m), there is significant potential for implementing such an innovative project. Once created and maintained properly, the re-natured system will continue to deliver results irrespective of the efficiency of trunk sewers, pumping stations, rising mains and STPs. These conventional engineering systems are vulnerable to several factors e.g., silt deposits, settlements, technical faults, power failure, process disruption etc. While on the other hand, the natural system in the drain, if developed in a robust manner will perform well in all seasons of the year and provide a strong backup in case the conventional system develops malfunctioning.

CONCLUSIONS

NjD is like a medium size perennial river carrying very high BOD load. Unless its BOD is brought down to below 10 mg/l, it will be impossible to achieve the desired water quality in the stretch of Yamuna which is bound by the two barrages at Wazirabad and Okhla has little fresh water coming from the upstream. Water quality modelling shows that even if the existing STPs are upgraded and new STPs are designed to get an outlet BOD of 10 mg/l and unless more than 864 mld of fresh water is brought into the stretch, the BOD over the entire 22 km long stretch does not become 3 mg/l. Considering large investment costs, it may not be feasible to achieve the end objective in the short or medium term at all. In view of this, an integrated strategy involving conventional sanitary engineering interventions and unconventional environmental engineering interventions has been developed. These interventions pertain to (a) promotion of on-sate sanitation and decentralised treatment in uncovered areas (b) augmentation of self purification capacity in trunk sewers/rising mains (c) augmentation of self purification capacity of the NjD and (d) development of a marshy area into a wetland system. The latter set of interventions is independent of the bottlenecks of sewerage system and their implementation can start off immediately. Such measures implemented in conjunction with rehabilitation of the existing sewerage system will help in providing a cost effective and reliable solution for control of organic load entering into the river.

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