TOWARDS BETTER MANAGEMENT OF THE URBAN WATER AND WASTEWATER: A CASE STUDY

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1. Introduction

Our country is blessed with a large number of rivers. There are fourteen major rivers, each having basin area more than 20,000 sq. km., which occupy 83 percent of total drainage basins, contribute 85 percent of total surface flow and house 80 percent of country's population. They are: Brahmaputra, Ganga, Indus, Godavari, Krishna, Mahanadi, Narmada, Cauveri, Brahmani, Tapi, Mahi, Subarnarekha, Pennar and Sabarmati. Over and above, there are 44 medium rivers (basin area between 2,000 and 20,000 sq. km. each) and 55 minor rivers (basin area less than 2,000 sq. km. each). There are also several small non-basin coastal rivers besides a few rivers, which originate and get lost in the desert after traversing some distance. But the irony of fact is that these rivers starve for water except for the brief monsoon period of three to four months. As a result, most of the cities and towns, barring the metropolitan cities, which rely on surface water source in the form of rivers/lakes for their massive requirement, have to be dependent on groundwater as a perennial source for quenching their requirement for drinking water. However, the quality of these scarce water resources are being increasingly threatened due to man-made abuses, like discharges of untreated municipal wastewater and industrial effluents into water bodies, or utilisation of such wastes on land for irrigation, thereby polluting them. There is, therefore, an imminent need for proper management of urban water resources.

2. The Problem in General

2.1 Water availability

Cities and towns, which derive water from surface source, suffer from non-availability of steady flow as the river discharge diminishes considerably, particularly during summer months. To add to the miseries, adequate quantity of water is also not available to dilute/assimilate the polluted industrial effluent or municipal sewage discharged into the river from urban centres upstream. Hence, during summer months, water requirement increases, while river discharge decreases to its minimum flow. Cost of treatment of river water to make it potable also increases because of presence of contaminants. Under such a scenario, municipal authorities are hard pressed to provide adequate quantity of treated drinking water and to maintain its quality.

Due to rapid urbanisation, the major cities/towns are experiencing unbridled growth of population even at a rate of 40-50 percent in a decade, outpacing the required rate of growth in infrastructure development in terms of housing, roads, transportation, communication, power supply, water supply & sewerage systems, sanitation etc. to accommodate the population in a healthy environment. As a result, the backlog of providing adequate services is mounting, not to speak of the expected level of satisfaction, which could be a distant dream.

To tide over the crisis, quantity of water supplied by the municipal bodies is reduced; and in extreme cases, water is supplied at alternate days or even at reduced frequency. Severe doses of disinfectants, like chlorine, used to protect/maintain the quality of water from bacteriological contamination during its journey from the water treatment site to the farthest consumer end, make the pipes and sanitary fittings vulnerable to corrosion and also contamination from their metallic constituents.

2.2 Water distribution system

Rivers being the lifeline of human civilisation, most of the cities start growing along the riverbanks. Indian cities are also no exception. Water services in such growth patterns adopt branching system of water distribution network from a long trunk main. As the distance increases from the water treatment plant or the intermittent elevated reservoirs to the consumer end, equitable water head/pressure is difficult to provide in such networks. The more the distance from the Head works, the lesser is the available water pressure. More often than not, individual consumer has the tendency to install booster pump at his house connection directly from the water main although such actions are prohibited and also punishable under the Municipal Act. Such selfish actions create further imbalance in water distribution system. In metropolitan cities with population approaching millions, it is beyond the capacity of any management to detect such illegal activity when it cannot provide the basic necessity of adequate quantity of water.

Grid system of water supply could be a solution to the problem of unequal distribution, but renovating the present system and at the same time meeting the future requirement by augmenting the system is a herculean task, particularly when the rate of growth of city population is unpredictable and of tall order.

Leakage in the water transmission system and unaccountable unauthorised tapping are also cause of concern for almost all the municipal bodies in the country.

2.3 Wastewater collection, conveyance, treatment and disposal

The problem of water supply in urban centres has arisen out of mis-management of this scarce resource; while the dismal scenario in respect of wastewater collection, conveyance, treatment and disposal in these areas is a matter of gross neglect. The sewerage system is non-existent in most of the cities. Wherever it is there, it is choked due to lack of maintenance. As a result, the untreated sewage ultimately finds its way to the rivers or streams through storm water drains.

The status of water supply vis-à-vis wastewater generation and treatment in class-I cities and class-II towns, as surveyed by the Central Pollution Control Board, Delhi, is presented in Table 1. The study revealed that only about 22 percent of the total sewage generated in the country is treated before it is discharged to water bodies. With regard to the degree of treatment provided in the sewage treatment plant (STP), the picture is even more dismal, as most of these are operated by un-skilled persons having no formal training. The supervisory staff are also not aware of the concept of conventional biological treatment, not to speak of modern technologies of treatment, to impart necessary training, as they are, more often than not, drawn from the civil construction department. As a consequence, the treated sewage from STPs fail to achieve the effluent standards set by the government for discharge into water bodies, or the untreated/partially treated sewage is by-passed to storm water channels. The pollution Control Agencies/Boards are also reluctant to deal with the municipal bodies as they play truant not to treat their sewage on the plea of paucity of funds.

Table 1 Status of Water Supply and Wastewater Generation & Treatment in Class I Cities and Class II Towns of India

Parameters	Status as on 1995-96
Number of class I cities	299
Population (million)	128.1
Distribution of population of class I cities according to catchment area (million)	
• Major river basins	97.4
• Non-basin coastal	23.3
• Non-basin, non-coastal	7.4
Water supply (million litres/day, mld)	20,545
Per capita water supply (litres/day)	182
Wastewater generated (mld)	15,772
Wastewater treated (mld)	3,740
Number of Class II towns	245
Population (million)	22.4
Distribution of population of class-II towns according to catchment area (million)	
• Major river basin	17.2
• Non-basin coastal	1.0
• Non-basin, non-coastal	4.2
Water supply (mld)	1,936
Per capita water supply (litre/day)	103
Wastewater generated (mld)	1,650
Wastewater treated (mld)	61.5

Source: *Central Pollution Control Board, Delhi- 110 032*

Under such a scenario, the cities/towns suffer from scarcity of surface water for supply and also pollute this resource by discharging untreated sewage/ industrial wastewater unabated. Groundwater resource is also threatened due to over-exploitation and discharge of polluted wastewater on land for irrigation and also due to indiscriminate disposal of municipal solid waste or hazardous industrial/bio-medical waste with-out taking proper precautions against percolation of leachate to ground water.

The problems of metropolitan cities are the same, but because of the scale of operation, it is more severe. An example is given in the following paragraphs to highlight the scenario in the capital city of Delhi to focus attention on areas to be looked into for providing relief to the citizens in terms of solving their perpetual problem.

3.0 Problems in Metropolitan Cities: A Case Study

The magnitude of the problem in management of water resources in metropolitan cities, like Delhi, is all the more complex. The capital city is experiencing acute water shortage almost throughout the year, and in summer season in particular. The groundwater being saline, contaminated in industrial areas and fast-depleting due to large-scale unauthorised abstraction by individual households by shallow tubewells in spite of its being of inferior quality, its use as a supplement source is going to be restrained / regulated in near future by the newly constituted Central Groundwater Authority. The city would, therefore, have no option of conjunctive use of surface water and groundwater to quench the thirst of the metro-populace, but to be solely dependent on surface water source. The factors contributing to the problems of Delhi with special reference to water supply and wastewater management is discussed in the following paragraphs.

3.1 Population to be served for water supply & drainage

This city has a historical background of several centuries. However, the significance of this city started growing when the British Rulers shifted the capital from Calcutta to Delhi in 1911. The population of this city increased several folds after the partition (1947), making this ancient city, one of the largest cities of the world. Rapid urbanisation in turn enhanced the thrust on basic amenities to cope with the living standards.

According to the Census Report of India, the population of Delhi was 9.42 million in 1991, registering an increase of 51.45% in the decade 1981-1991. This rate of increase was more than double the rate registered for the whole of the country (23.79%). The population of Delhi in 1998 has been estimated to be 11.5 million, which includes 4 to 5 lacs of floating population. It is likely to cross 13 million as it enters the new millennium. The population growth of Delhi is depicted in **Fig 1.**

Of the total population, 90% is residing in urban areas and the remaining 10% in urban villages. The water supply, wastewater collection and treatment facilities to urban

population are served by the Municipal Corporation of Delhi (77%), the New Delhi Municipal Corporation (3%) and the Delhi Cantonment Board (1%).

3.2 Water supply

3.2.1 Historical evolution of water treatment plants

Before partition in 1947, potable water to Delhi was supplied from the dug wells near Wazirabad by the Municipal Corporation of Delhi. The first water treatment plant with a capacity of 158.9 MLD was commissioned at Chandrawal Water Works (CWW), behind the Old Secretariat. In the fifties, water supply capacity was further augmented through construction of a 27.24 MLD treatment plant at Okhla and 249.7 MLD treatment unit at CWW. In the sixties, a 181.6 MLD water treatment plant was installed at Wazirabad. Subsequently, to meet sharp demand for water supply due to geometric growth of population, water treatment plants have been constructed at Haiderpur (North-West Delhi) and Bhagirathi (East Delhi). The present water treatment capacity in the city is 2,655.9 MLD (including Raney Wells and tube-wells managed by the Delhi Jal Board). By overloading the plants, approximately 2,724 MLD of potable water is being produced and distributed. The status of water treatment plants (existing and proposed) is given in Table 2.

Table 2 Status of Water Treatment Plants

S.No.	Source of raw water
1.	Yamuna river
2.	Yamuna river
3.	Western Yamuna Canal
4.	Upper Ganga Canal
5.	Ground Water (aquifer)
6.	Tehri dam/Renuka dam
7.	Western Yamuna Canal
8.	Western Yamuna Canal
9.	Western Yamuna Canal

S.No.	Source of raw water
10.	Western Yamuna Canal

The above Table reveals, broadly, that the total water treatment capacity would be approximately 4,540 MLD by the end of 2001.

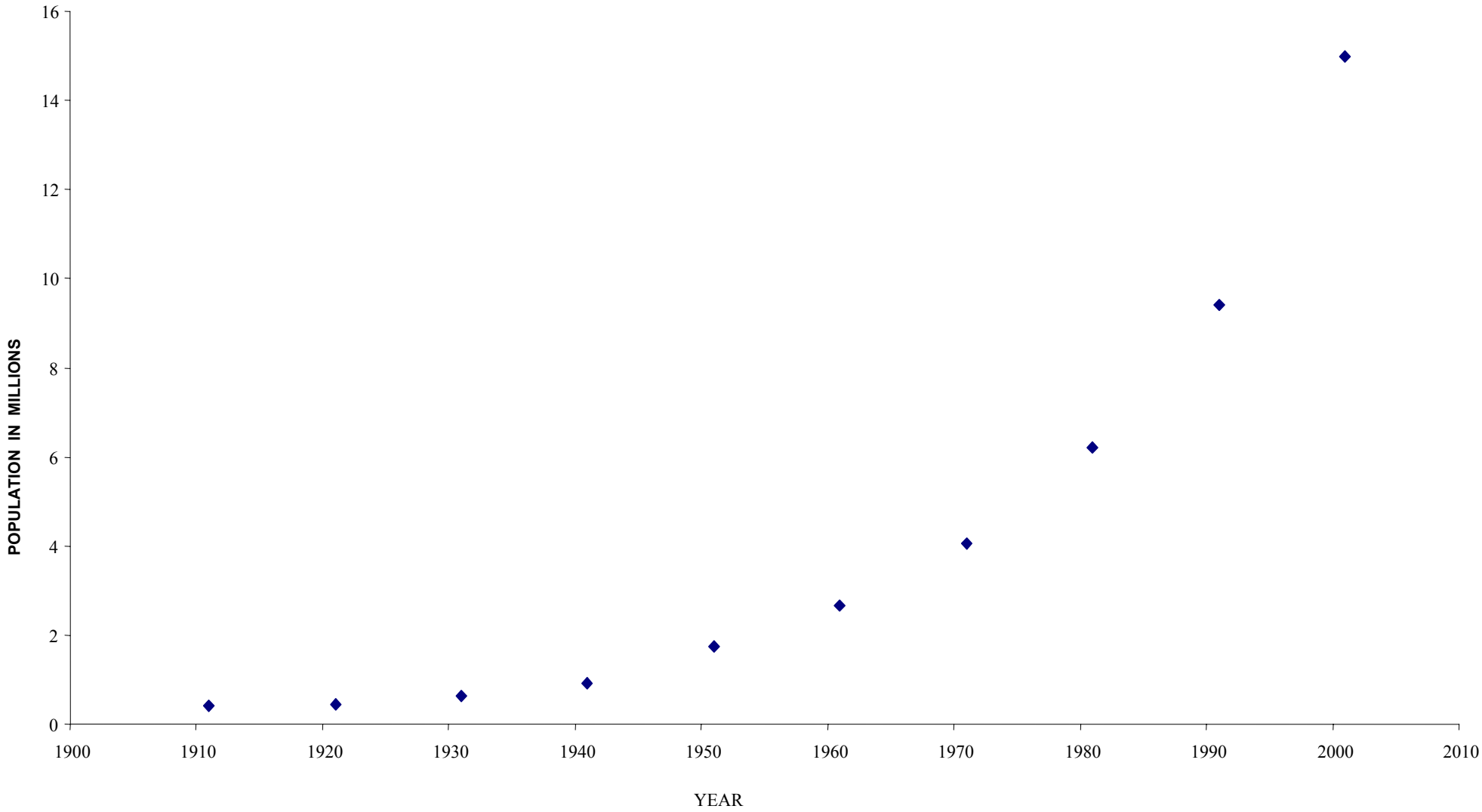


FIG. 1 POPULATION GROWTH IN DELHI

3.2.2 Distribution of potable water

The statistics show that till April, 1997, there were 9,13,295 metered water connections, 2,84,917 un-metered water connections and 2,679 bulk water connections. In addition, water is distributed to a number of public hydrants and public toilets. Water tankers are also used to distribute water in emergencies/festivities, which come under unaccounted use of treated water. It has been estimated that out of the 2724 MLD of drinking water produced today, only 2163.31 MLD is distributed in an accounted way, and approximately 20.5% of water produced are unaccounted in term of unauthorised tapping or losses. A considerable portion of drinking water produced by the Delhi Jal Board is supplied to NDMC, Delhi Cantonment and Delhi Development Authority (DDA) for onward distribution. Besides this supply, DDA and Group Housing Societies draw groundwater for drinking and other purposes. The region-wise distribution of water and groundwater extraction vis-à-vis total requirement as on January, 1999 are given in **Table 3.**

Table 3 Region-wise Water Supply and Demand

S.No.	Region	Accounted water supply, MLD	Estimated ground water extraction by agencies other than MCD, MLD	Total requirement, MLD
1	Okhla	712.78	348.44	1061.225
2	Trans-Yamuna	408.6	306.45	715.05
3	Keshopur	385.9	193	578.85
4	Rithala	367.74	96.5	464.215
5	Coronation pillar	288.29	86.26	374.55
	Total	**2163.31**	**1030.65**	**3193.89**

The above Table shows that 1030.58 MLD of groundwater is being extracted from the aquifer by the individuals and group housing societies of Delhi. This extraction is in addition to the dug wells and Raney wells operated by the Municipal Corporation of Delhi (MCD). This huge extraction of groundwater needs urgent attention to avoid increase in groundwater salinity and other catastrophic impacts due to lowering of groundwater table below the water level of the polluted Yamuna River, leading thereby to contamination of groundwater aquifer due to recharge from the polluted river.

3.3 Sewage generation

The conventional way is to estimate wastewater generation at 80% of the water supplied. However, as discussed in earlier chapters, it will not be applicable to the National Capital Territory (NCT) Delhi, as a huge amount of groundwater is being extracted. In view of this, the Central Pollution Control Board (CPCB) has studied all the major drains in the city to estimate actual sewage generation. The extensive monitoring conducted by the Board reveals the following:

- There are eight drains in Okhla region carrying significant amount of wastewater and discharging into the river Yamuna;
- A number of drains emanating from the Keshopur, Rithala and Coronation Pillar regions are joining the Najafgarh drain leading to the river Yamuna downstream of the Wazirabad barrage;
- A portion of sewage generated in Rithala and Coronation Pillar regions is carried by the Supplementary drain to the river Yamuna joining in between Wazirabad barrage and Najafgarh drain confluence with the Yamuna; and
- Entire sewage generated in Trans-Yamuna region is carried by the Trans-Yamuna (Shahdara) drain, which passes through Noida to discharge downstream of Okhla barrage.

A line diagram indicating the pollution loads carried by various drains and falling into the river Yamuna is depicted in **Fig 2.** The wastewater additions to the two major drains viz. Najafgarh drain and Trans-Yamuna drain were studied in-depth. The line diagrams showing the wastewater and BOD load additions to the main drain along the length are presented in **Figs. 3 and 4.** The wastewaters flowing in the drains and collected through the sewerage network are added to get the total wastewater generation. This exercise shows that 2546.94 MLD of sewage is being generated from the NCT of Delhi. The region-wise wastewater generation, as on January, 1999 is given in **Table 4.**

Table 4 Region-wise Sewage Generation

S.No.	Region	Sewage generation, MLD	Sewage collected through sewerage network, MLD	Sewage flowing in drains, MLD
1	Okhla	849	435.84	413.14
2	Trans-Yamuna	572.04	18.16	553.88
3	Keshopur	463	274.67	188.41
4	Rithala	363.2	81.72	281.48
5	Coronation pillar	299.64	74.91	224.73
Total		**2546.88**	**885.3**	**1661.64**

The above Table shows that 1661.64 MLD of sewage is being discharged untreated, into the river Yamuna. However, the actual flow in the drains is more than 1661.64 MLD due to sources other than sewage.

3.4 Sewage collection, treatment & disposal

3.4.1 Sewage collection

Mutually exclusive departments are involved in laying of sewers in different parts of Delhi *i.e.* DDA and NDMC; and the Cantonment Board lay sewers in their respective areas and hand over to the Delhi Jal Board (DJB). DJB is responsible for the area under the Municipal Corporation of Delhi. It has been seen that co-ordination among the implementing agencies is very much lacking.

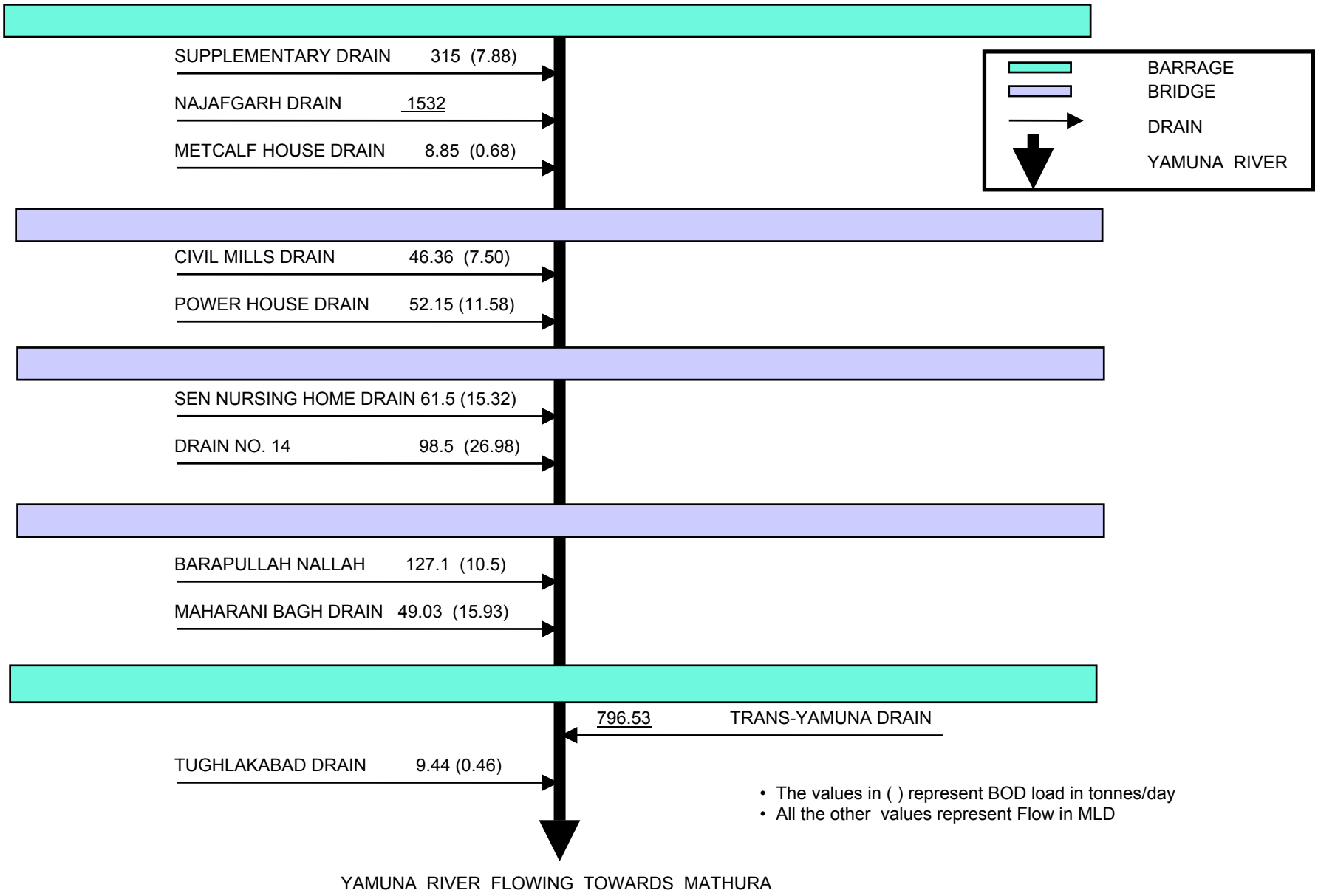


FIG. 2 LINE DIAGRAM SHOWING POLLUTION LOAD ADDITION BY THE MAJOR DRAINS IN DELHI TO RIVER YAMUNA

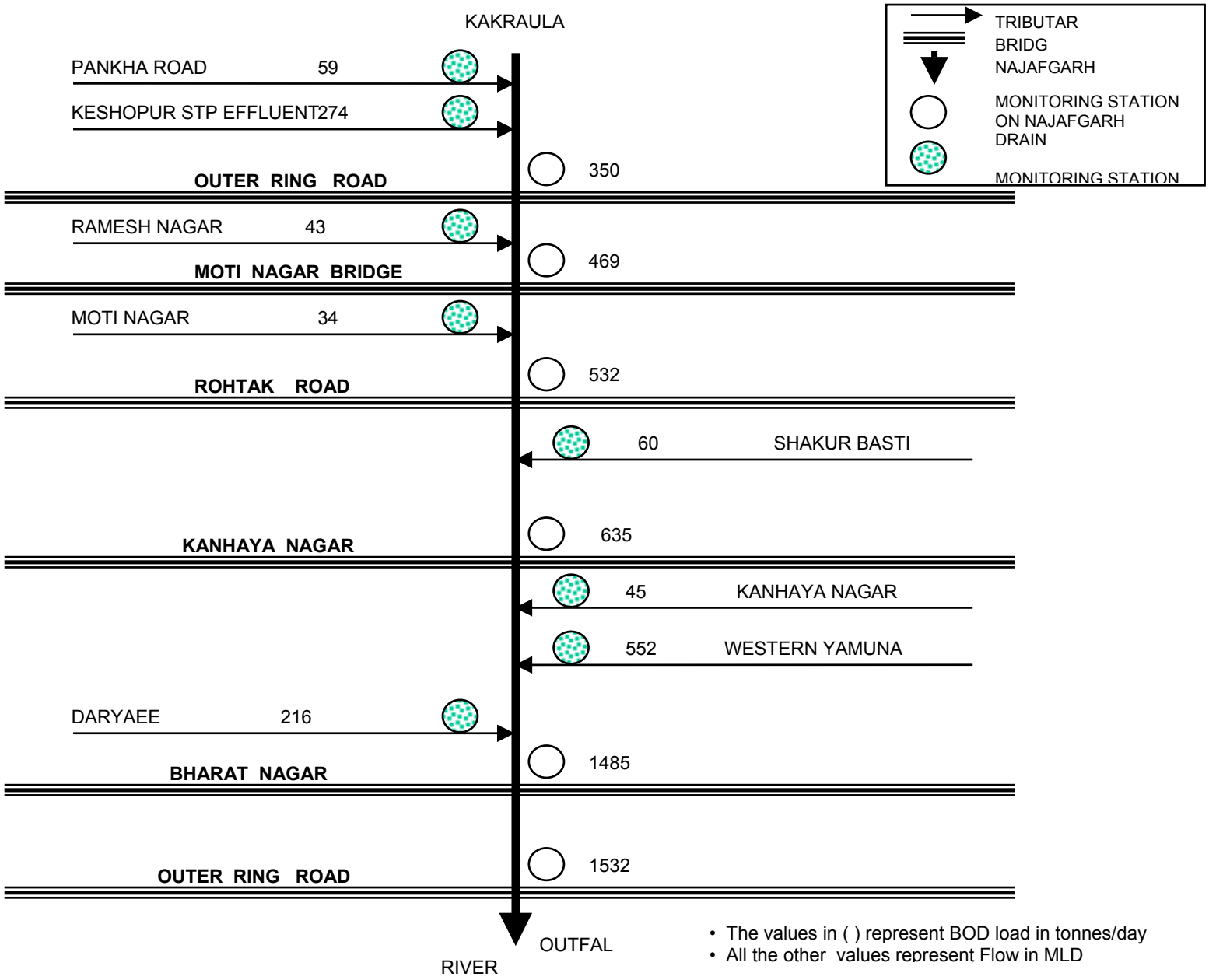


FIG. 3 LINE DIAGRAM SHOWING POLLUTION LOAD ADDITION BY MAIN TRIBUTARIES TO

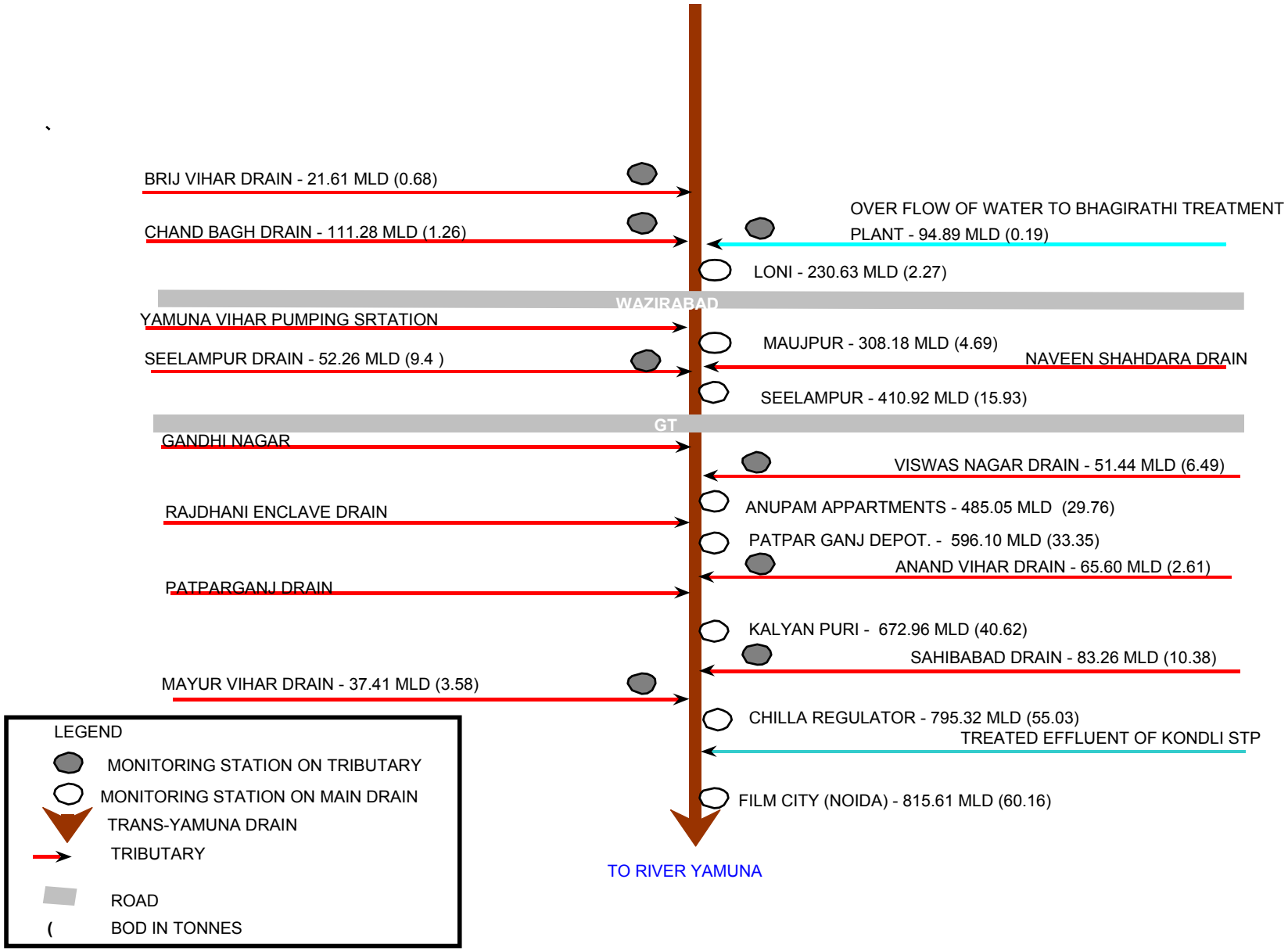


FIG. 4 LINE DIAGRAM SHOWING MEAN DRY WEATHER FLOW AND BOD LOAD ALONG THE TRANS-YAMUNA DRAIN

Thus, the objective of sanitation and protection of health and hygiene is getting defeated. The developmental work is often not synchronised with the entire network. If any part of the network is not connected or under repair, the entire sewage is pumped into the nearby storm water drain. The discharge through the open drains in Delhi speak for themselves the efficiency of collection of wastewater.

Around 75% area of urban Delhi is sewered, and mostly, the rural areas are unsewered. Some villages are likely to come on the map of sewered area with the construction of STPs at Najafgarh, Ghitorni, Narela etc.

Delhi has been classified into several categories of pockets, *i.e.* authorised colonies, unauthorised colonies, unauthorised but regularised colonies *etc*. The status of sewage collection network provided in the habitation of above categories is given below:

i) **Approved colonies**:

- All the approved colonies have been provided with sewerage facilities.

ii) **Unauthorised but regularised colonies:**

- There are 567 such colonies;
- sewerage facilities exists in 292 colonies;
- Sewers have been laid but not made functional in 67 colonies;
- The schemes have been prepared for 91 colonies; and
- It has been planned to extend sewerage facility in all the remaining 117 colonies progressively depending upon feasibility.

iii) **Resettlement Colonies:**

- There are 54 resettlement colonies;
- Sewerage facilities exists in 22 colonies;
- work is in progress at Khichripur, Nandnagari, Gokulpuri and Seelampur; and
- The work in remaining colonies will be completed progressively alongwith construction of sewage pumping stations and trunk services.

iv) **Urban Villages:**

- There are 126 villages (excluding two under the Cantonment Board and one deserted village);
- Sewerage facilities exists in 83 villages;
- Sewerage facilities for three villages are in commissioning stage; and
- Work is in progress in four villages, namely Khiripur, Krishngarh, Masudpur and Badarpur.

v) **Unauthorised Colonies:**

- There are 1500 such colonies; and
- According to the present policy of DJB, it is not intended to extend sewerage system to these colonies.

vi) **JJ clusters:**

- According to the present policy of DJB, it is not intended to extend sewerage system to these colonies. Presently, these are under the purview of the Slum department, MCD, which is providing localised facilities.

vii) **Rural Villages:**

- There are 201 such villages where the drinking water availability is approximately 55 to 68 litres per capita per day. Unless this quantity increases to a minimum of 135 litre per capita per day, the DJB felt it is not technically feasible to install sewerage facilities in these villages.

Even though, around 75% area of Delhi is sewered, the Table 4 reveals that only 34.7% of sewage generated are collected through sewerage network and rest is disposed untreated. This can be attributed to unsynchronised developmental activities, such as sewers laid but not connected to sewage pumping stations (SPSs), SPSs constructed but not the sewer lines, sewers and SPSs laid but house-hold connections yet to be provided *etc.*

3.4.2 Sewage treatment

Delhi is having 6 Sewage Treatment Plants (STPs) in operation. However, there are several STPs either in construction phase or planned. The status of sewage treatment plants in Delhi is presented in **Table 5**. The present sewage treatment capacity is 1153.16 MLD in total, whereas only 885.3 MLD is being collected by the sewerage network to the STPs that implies STPs are under utilised. Region-wise statistics as on January, 1999 are given in **Table 5.**

Table 5 Region-wise Sewage Treatment

S. No.	Region	Sewage generation, MLD	Available sewage treatment capacity, MLD	Sewage collected through sewerage network, MLD	Additional capacity requirement, MLD	The capacity can be utilised by enhancing collection efficiency, MLD
1	Okhla	848.98	572.948	435.84	276.032	137.108
2	Trans-Yamuna	572.04	45.4	18.16	526.64	27.24
3	Keshopur	463.08	326.88	274.67	136.2	52.21
4	Rithala	363.2	181.6	81.72	181.6	99.88
5	Coronation pillar	299.64	27.24	74.91	272.4	_
Total		**2546.94**	**1154.068**	**885.3**	**1392.872**	**316.438**

Note:

- *At Coronation pillar STP, 72.64 MLD of sewage is being bye-passed by giving only screening and grit removal.*
- *The over-all efficiency of Keshopur STP is poor.*
- *STPs at Rithala and Kondli are under-loaded.*
- *STP at Okhla is nearer to satisfaction level.*

The above Table reveals that there is an immediate requirement of 1,392.8 MLD additional treatment capacity; and by enhancing the efficiency of sewage collection network, about 316.438 MLD can be treated in the existing sewage treatment plants.

The quality of sewage generation in Delhi varies with the location, as the living standards of inhabitants and efficiency of collection network are not similar throughout. Therefore, the raw sewage received at STPs is also getting varied. It has been observed that raw sewage at Okhla STP, Keshopur STP, and Rithala & Kondli STPs represent fresh, septic and settled sewage characteristics respectively.

The Central Pollution Control Board conducted performance evaluation studies in four sewage treatment plants. The findings of the extensive studies in terms of operational parameters and efficiency are summarised in **Table 6.** These findings require appropriate action to be taken by the Delhi Jal Board to enhance the operation and efficiency of the plant.

3.4.3 Disposal of wastewater

River Yamuna is being treated merely as the wastewater disposal sink for the NCT Delhi. Thus in the lean period the river becomes virtually a open sewer carrying sewage all through its stretch, starting from the confluence point of Najafgarh drain, the biggest polluting drain from the Delhi. The spatial distribution of various drains adding wastewater to river Yamuna in the Delhi stretch (Wazirabad barrage to

Kalindi barrage) and incremental pollution load (BOD in tonnes) are shown in **Fig 5.** The treated sewage from the STP at Okhla is disposed directly into Agra Canal, and that from Vasantkunj is utilised for gardening. All other STPs' treated effluent ultimately joins the river Yamuna.

4.0 Issues to be Addressed

The issues, which need to be reviewed by the policy makers/ planners/ local government to achieve the prime objective of water management and pollution control in National Capital Territory of Delhi, are described below:

4.1 Water supply

- Looking at the rate of growth of population in Delhi, there is an urgent need to plan for augmenting the availability of water from river source by construction of reservoir up-stream of Delhi within a reasonable period.

- The National Capital Territory of Delhi is receiving on an average 80 cm rainfall per year and it has an area of 1055.37 sq.m, i.e. 844 $X10^3$ MLD of rain water per year. This huge amount of water can be harvested for better utilisation. However, until the sewage/wastewater entry into storm water drains is prevented, the storm water may not be re-utilised for any application without use-specific treatment.

- A serious drive is necessary in providing equitable quantity of water to the residents of Delhi. For new development areas, grid system of water supply could be adopted.

- Illegal tappings from water mains have to be stopped through surveillance and penal action.

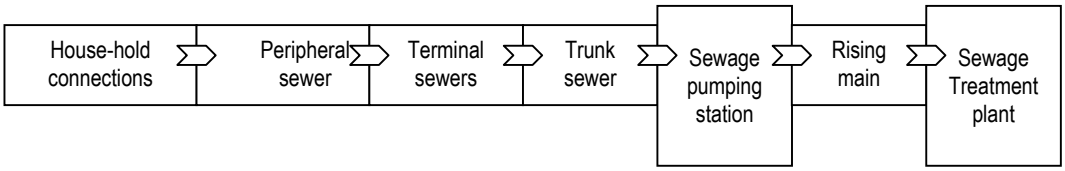
- Insufficient potable water supply by the concerned departments is leading to extraction of huge amount of groundwater, estimated at 1,030.58 MLD in addition to the quantity extracted from Raney wells operated by MCD. This huge amount of water withdrawl from the aquifer may be attributed to the salinity rise, contamination of aquifer etc. In particular, shallow bore wells in the areas adjacent to the storm water drains, which are at present carrying sewage due to the lack of sewerage network, are being contaminated considerably. Even the presence of coliforms is detected. There is a need to visualise the problem and a holistic approach is to be evolved in attacking the problem.

Table 6 Comparative Statement of Operational Parameters of Sewage Treatment Plants in Delhi

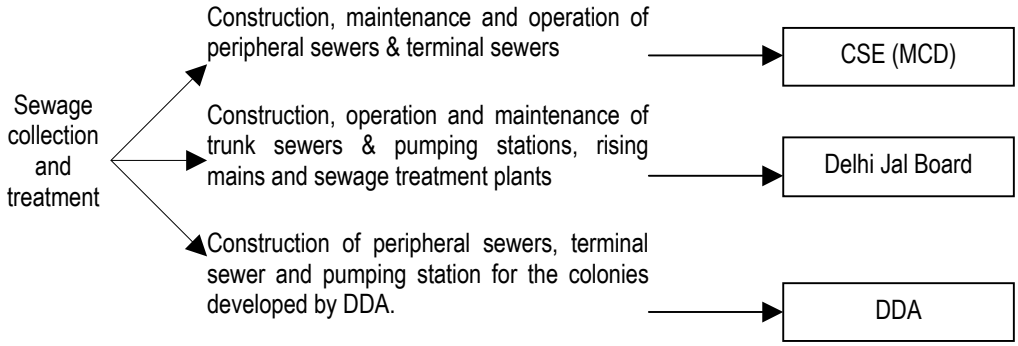
S.No.	Operational Parameter		167.98 MLD STP at Okhla	45.4 MLD STP at Kondli	181.6 MLD STP at Rithala	90.8 MLD STP at Keshopur	Recommended values as per CPHEEO Manual
1	Period of monitoring		30.10.95 - 4.11.95	19.5.97 – 21.5.97	July 25, 26 & 28, 1997	17.11.97 - 19.11.97	-
2	Flow (m^3/hr)		2083 - 5100	407 – 871	1915 - 7003	3216 – 3777	-
3	Quality of incoming sewage	SS	375	378	289	679	-
		BOD	200	162	121	312	-
PRIMARY CLARIFIERS							
4	Retention Time (hrs.)		3.7 - 4.9	2.53 - 3.0	3.52 - 3.75	2.36 - 2.70	2 - 2.5
5	Hydraulic Surface Loading (m^3/m^2/day)		13.6 - 18.3	24.14 - 28.34	19.95 - 21.25	22.3 - 24.5	25 - 30
6	Percent Reduction in Solids		67.8 - 85	52 - 82.5	42.6 - 82.6	70.6 - 77.5	45 - 60
7	Percent Reduction in BOD		38 - 52	30 – 78	37.7 - 50.7	47.1 - 54.1	30 - 45
ACTIVATED SLUDGE PROCESS							
8	F/M ratio d^{-1}		0.076 - 0.126	0.02 - 0.029	0.61	-	0.2 - 0.5
9	MLSS (mg/l)		2680 - 3848	380 – 462	470 - 1410	497 - 3624	1500 - 3000
10	MLVSS (mg/l)		1925 - 2509	341 – 373	263 - 838	344 - 1978	1200 - 2400
11	MLVSS/MLSS		0.60 - 0.75	0.80 - 0.85	0.43 - 0.59	0.55 - 0.69	0.8
12	SS in Return Sludge (mg/l)		8000 - 10500	≈ 7500	4000 - 6000	8000 - 12000	10000
13	Recycle Ratio		0.42 - 0.71	0.06 - 0.066	0.15	0.10 - 0.15	0.25 - 0.50
SECONDARY CLARIFIERS							
14	Retention Time (hrs)		3.0 - 3.58	3.44 - 7.37	4.66 - 4.96	3.70 - 4.00	1.5 - 2.0
15	Hydraulic Loading (m^3/m^2/day)		22.25 - 26.28	20.9 - 24.7	20.20 - 21.54	18.5 - 20.1	15 - 35
16	Overall Percent Reduction	SS	34.5 - 96.2	93.9 - 97.7	86.7 - 93.20	76.9 - 87	-
		BOD	45.6 - 96.0	89.7 - 95.7	89.7 - 94.8	81.7 - 83	85 - 95

4.2 Wastewater collection, conveyance and treatment

➠ The collection of sewage from the point of generation to the treatment plant comprises a number of sequential stages, i.e. household connections, peripheral sewers, terminal sewers, trunk sewers, sewage pumping station and the rising main, as shown below:



Absence or malfunctioning at any stage in the above sequence leads to pumping of sewage into open storm water drains. Unfortunately, Delhi is facing such unsynchronised development, thereby resulting in situations where required treatment capacity is available but less or no sewage is reaching to the treatment plant. This unsynchronised development in-turn defeats the prime objective of sewage collection for the purpose of treatment. This can be attributed to the dichotomy among the multiple organisations, involved in laying of components of sewage collection and transportation system. While the terminal sewers & peripheral sewers are laid and maintained by the Conservancy and Sanitary Engineering (CSE) Department of the Delhi Municipal Corporation (MCD), the trunk sewers, sewage pumping stations & rising mains are laid and maintained by the Delhi Jal Board (DJB). The Delhi Development Authority (DDA), while developing colonies, lay down peripheral & terminal sewers and later on hand over to CSE department of MCD. Similarly, trunk sewers & sewage pumping stations constructed by DDA are later handed over to the DJB. DDA is responsible for maintenance of these works till these are handed over to the respective departments. The department-wise responsibilities are depicted below:



The multiplicity of authorities create mismanagement. Therefore, there is a need for assigning the entire responsibility of sewage collection, treatment and disposal to a single authority.

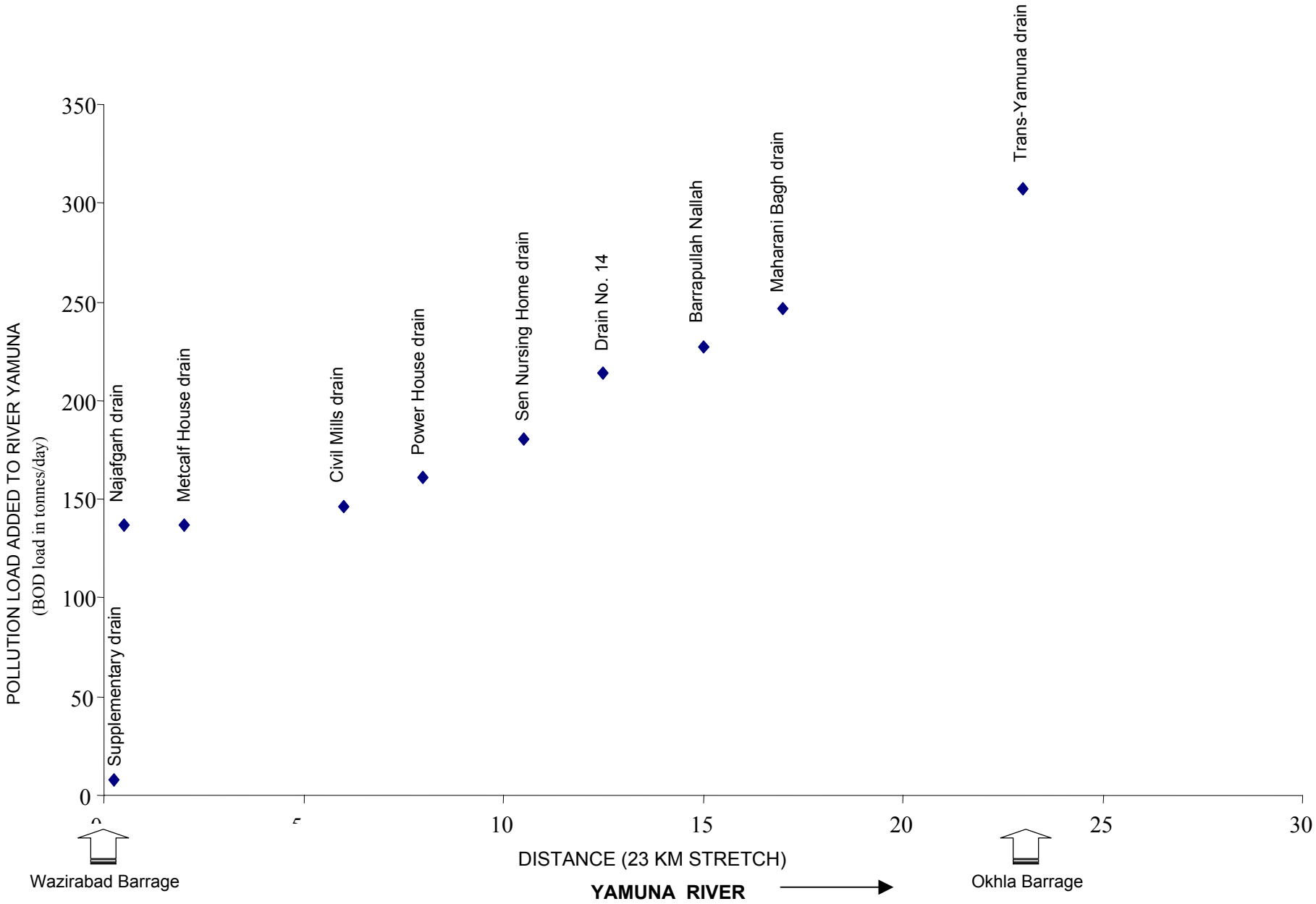


FIG. 5 CUMULATIVE POLLUTION LOAD ADDITION TO RIVER YAMUNA AT VARIOUS POINTS BY THE DRAINS CARRYING WASTEWATER FROM DELHI

- In many unauthorised colonies and unauthorised-regularised colonies, though the water supply is being provided, no provision has been made for sewage collection, which is attributed to the non-payment of development charges. As such, there is no internal sewage network provided in Jhuggi Jhopri Resettlement (JJR) colonies. There is, therefore, a need for providing sewerage facility to the citizens residing in unauthorised, regularised-unauthorised and JJR colonies. In cases, where payment is not made by the residents towards development charges, the charges for the same may be linked according to the water charges.

- From the Table 4, it can be seen that the deficit in collection of sewage through network is 1661.64 MLD. Therefore, this huge amount of sewage is finding its way to river Yamuna through the storm water drains and making the sacred river virtually an open sewer in lean period. The gap is to be reduced within a reasonably short period.

- It is observed that settling (sinking) of sewers is a frequent phenomenon in Delhi, even in case of new sewer lines. There may be many reasons, but faulty work man-ship and irresponsible supervision cannot be ruled-out.

  In view of frequent settlements of sewer lines, it is recommended that MCD and DDA, as the case may be, should explore the alternatives. These authorities may prepare the report in consultation with experts drawn from the universities/institutes. It is feel necessary that the tendering procedure should be reviewed by the concerned authority so that technically competent agencies are assigned the work rather than simply considering the lowest quote.

- Restoration of settled sewer line and laying a loop line takes considerable time, which might even extend upto several years together, resulting in silting of upstream sewers. In order to ensure the timely completion of on-going sewerage and sewage treatment schemes, the concerned authority should adopt the proper project management tools, such as PERT, CPM, updating of bar-charts etc.

- Collection and treatment of sewage require a three-tier maintenance system i.e. preventive, breakdown and routine. Whereas, in Indian cities/towns including Delhi, only break-down maintenance is practised and the procedural delay promotes the usage of pumps (trolleys) to lift the sewage from main sewers to nearby open drains, as a temporary relief. Inventory of spares is not maintained to attend preventive and breakdown maintenance. A schedule for routine maintenance and preventive maintenance alongwith a backup of optimal inventory of spares have to be prepared.

- All the sewage treatment plants (STPs), except those in Okhla & Keshopur, are considerably under-loaded. Due to less flow available at the sewage pumping station (SPS), sewage is being lifted within a few hours instead of pumping throughout the day due to available pump capacities. As a result, the sewage treatment plants are getting excess capacity for a few hours giving shock loads to STPs and no flow during the rest of the day leading to operational difficulties at STP.

  In all the sewage pumping stations, differential capacity pumps may be provided for ensuring continuous lifting of sewage to the concerned STPs. The lowest pump capacity shall however be such that the self-cleaning velocity is maintained in the sewer.

- There is a gap in respect of revenue collection and providing funds for the purpose of water supply and sewage collection & treatment. The Delhi Jal Board is billing and collecting money towards water supply. MCD, NDMC and Cantonment Board are collecting house tax of which a part is allocated towards collection of sewage. This taxation excludes construction, operation and maintenance of trunk sewers, sewage pumping stations, rising mains and sewage treatment plants. The lack of sufficient allocation of fund may be one of the reasons for improper operation and maintenance of sewage pumping stations and sewage treatment plants.

- Sulabh Sauchalaya Complexes are not connected to the sewage collection network. In practice, septic tank and soak pits in sequence are provided to take care of the wastewater. However, due to clogging/choking of distribution system in soak pits, in-sanitary conditions are prevalent. Therefore, all the outlets of Sulabh Sauchalay complexes in the National Capital Territory of Delhi may be connected to the sewerage network.

- Very little emphasis has been given towards the sludge digestion and utilisation of useful bio-gas (methane) which have considerable energy value. Only, Okhla STP is collecting gas in gasholders and being utilised through the network. All other plants are neither using sludge digesters properly nor the gas is being collected for beneficial purposes. Thus, plenty of useful bio-gas, which can be converted into power or fuel, to be utilised for running of the plant or in households, is being wasted.

  The sewage treatment plants in Delhi, which generate primary sludge, should have adequate digestion facilities/digesters and the useful bye-product of the digestion, i.e. bio-gas, should be collected and utilised for beneficial purposes such as conversion into power by employing dual fuel engines and utilisation of the power for running of sewage treatment plants, households connections *etc*.

- It is observed that project management technique such as critical path method (CPM), and project evaluation review technique (PERT) are not being practised in any development work. Application of such techniques can ensure concept of resource rescheduling for optimum utilisation. Even, bar charts have not been updated.

- From the Table 5, it can also be observed that there is an additional requirement of 1392.872 MLD treatment capacity as on January, 1999. However, it is to be noted that the sewage generation is expected to rise in the coming years.

  Due to lack of proper management, absence of appropriate planning techniques/tools, prioritisation of the localities for construction of STPs was not done effectively. Thus, STPs with ample treatment capacities are available in North-West Delhi (Rithala, Rohini and Narela) and South Delhi (Ghitorni and Vasant Vihar), whereas, untreated sewage arising from the colonies of Trans-Yamuna and Central Delhi are being discharged into river Yamuna.

  The Delhi Jal Board should build the sewage treatment plants according to the requirement, *i.e.* where there is more sewage generation, the capacity of the treatment plant should be accordingly higher, for optimum utilisation of available resources, in controlling the pollution. Therefore, the comprehensive plan should take these factors into account in addition to synchronised development of all the components of the plan.

- It is observed that the personnel involved at lower level in operation, maintenance and supervision of STPs are not properly trained and at the higher level, the concept of Environmental/Public Health Engineering is missing.

  There is a need for comprehensive planning of human resource development at various levels. It is suggested that DJB, in consultation with NEERI, Nagpur and All India Institute of Hygiene and Public Health, Calcutta, shall develop training courses. If necessary, DJB may also consult the World Health Organisation (WHO).

- In case of Narela STP, the treated sewage is proposed to be disposed in Drain No. 6, which joins the river Yamuna, upstream of Wazirabad water intake point, which is a sensitive place. The planning and construction authorities should take the prior approval of the pollution control boards to prevent such kind of incidents.

- From the population growth curve, it can be visualised that the demand for water supply and wastewater collection, treatment is on the rise and will have stress to have additional modules of treatment units from time to time.

Therefore, the STPs are required to be planned for at least fifteen years and the required place for future development shall be made ready as the procedure for acquisition of land consume considerable time.

- The sewage treatment plants in Delhi are in general under-loaded. The functioning/ operating parameters of the respective treatment technologies are not being adjusted to the current flow, thereby leading to excessive retention, excessive aeration, sludge bulking, etc. which in turn leading to uneconomical treatment and malfunctioning of the sewage treatment plants.

- Due emphasis has not been given towards the development of the green belt in many of the sewage treatment plants. All the sewage treatment plants should have sufficient green belt within the premises as per the consent conditions of the Delhi Pollution Control Committee.

- Looking at the complexity of the organisation(s) involved in water supply, sewage collection, treatment and disposal system(s), the possibilities for promoting the privatisation may be explored by the government on the built, operate and transfer technique.

- The water supply sanitation services are required to be self-supporting in terms of finance. Otherwise, no amount of government support in the form of subsidy could meet the over-increasing gap between the services required and actual provision.

5.0 Concluding Remarks

5.1 Groundwater being depleted every year, attempts should be made for rain water harvesting. Additional water storage is also required to be developed upstream of Yamuna for arresting of rainwater during monsoon.

5.2 Surveillance activities to be stepped up to stop illegal tapping of water from mains by direct pumping by households.

5.3 Management of urban water resources, especially in metropolitan cities, is a gigantic man-made problem with no apparent easy solution. With the rapid influx of population and unbridled growth of industrialisation in the small-scale sector to support the habitants' daily needs, requirement of infrastructure facilities is steadfastly increasing, out-pacing the capacity of the concerned local government agencies to provide the services even at the minimum level of expectation. Water being the lifeline of any society, its need is always given the top priority. However, the aspect of management of the concomitant discharge (sewage) out of various water uses is not given due importance at all. In consequence, these indiscriminate wastewater discharges reach the riverine system, on which the city/town is fully dependent for drinking water, to pollute and contaminate. This in fact is the sole reason for frequent occurrences of water-borne diseases, sometimes even in the

form of epidemics. Emphasis should be given for collection, conveyance, treatment of sewage and appropriate disposal of treated wastewater.

5.4 There is a strong necessity for proper management of water and wastewater for securing protection of water resources. Even privatisation of this service sector may be thought of with all seriousness.

5.5 Municipal solid wastes need to be managed in a scientific manner by adopting cradle to grave approach to avoid contamination of water resources due to leachate.

5.6 Activities under all service sectors forming infrastructure of a planned city need to be co-ordinated at the highest level to make the city a healthy place to live in.