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Sewage management challenges in mega cities in India: a case study of Mumbai

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ABSTRACT

This paper provides an overview of sewage management of Mumbai as a case study of a mega city in India. Mumbai generates 3,000 MLD sewage out of which 2,100 MLD gets treated. The trend of sewage generation, its treatment, the challenges faced by municipal authorities and initiatives taken along with policies and regulations has been discussed. The discharge of untreated sewage in open drains, unplanned development of the city and encroachment of squatter settlements were identified as some of the major challenges faced by Municipal Corporation. The initiatives like creating a better sewerage network through funded projects, up grading the existing sewage treatment plants (STPs) have been undertaken. The need of using advanced softwares like ArcGIS as a decision making tool for city planning has been highlighted. The role of the decentralized wastewater treatment technologies and reuse of treated sewage for non-potable purposes to overcome the challenges of sewage management has been explored.

Keywords: Sewage; STPs; Challenges; Mumbai; ArcGIS

1. Introduction

Freshwater is vital for living things on earth. It has numerous uses in household and industrial activities. It acts as a regulating factor for social and technological growth. The rate of increase in urban population has been almost 11 times since last century. It has risen from 26 million to 285 million. Due to this increase in population, the per capita freshwater availability is likely to go below 1000 cubic meters which will lead to a situation labeled as water scarcity by the end of 21st century [1]. With this increase in demand for freshwater, the quantity of sewage generated is also going to rise accordingly.

1.1. Sewage generation and treatment in world

As per The Organization for Economic Co-operation and Development's (OCED) database, in UK there is 100% sewerage network connection rate. Many of the European countries like Netherlands, Spain, Switzerland, Germany etc. have more than 90% population connected with the sewerage network. According to the available database, only 3 countries, Ireland, Slovenia and Slovak Republic have around 60–70% population covered under sewerage network connection [2].

In terms of sewage treatment also, UK treats all the collected sewage, 50% each by secondary and tertiary treatment. Amongst the countries listed in the database, almost

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all the countries fully treat the collected sewage by secondary and/or tertiary treatment, with some exceptions. The countries like Iceland, Turkey and Portugal treat 60–70% of the sewage collected [2].

1.2. Sewage generation and treatment in India

The quantity of water supply to Indian cities has gradually increased from 10,171 MLD in the year 1978 to 77,435 MLD in the year 2016. There has been corresponding increase in the quantity of the sewage being generated. Its quantity has shown seven fold increase from 8,233 MLD to 61,948 MLD in the year 1978 and 2016 respectively. Over the years, the quantity of sewage getting treated has shown similar progress. 34.3% of total sewage generated in India was getting treated in the year 1978 whereas currently 37.6% of it is getting treated [3,4]. There is a need for extensive sewerage network for collecting and transporting the sewage generated to the STP for the treatment.

1.3. Sewage generation and treatment in State

Amongst the different states in India, Maharashtra generates maximum quantity (8,143 MLD) of sewage, followed by Uttar Pradesh (7,124 MLD). The lowest quantity of sewage is generated in Lakshadweep (8 MLD). Despite having the maximum installed treatment capacity of 5160 MLD, high percentage (16%) of polluted river stretches are observed in Maharashtra [5]. This may be mainly due to non-operational (344.5 MLD capacity) and under construction (132 MLD) STPs in the state [6].

In this paper, we present an overview of current status of sewage generation and its treatment in Mumbai, the capital city of the state of Maharashtra, in terms of their capacity, treatment technologies etc., the challenges faced by municipal authorities with respect to the sewage management and the initiatives taken by them. It also gives an account of various policies and regulations devised at country, state and local level in order to avoid the possible adverse impacts due to the discharge of untreated sewage into the environment.

As per 2011 census, the population of Mumbai is 12.4 million [7]. Out of the total population, 52.5% of population lives in squatter settlements while the remaining 47.5% of it lives in legal settlements. The floating population from nearby areas like Thane and Navi Mumbai travel every day to Mumbai adding a lot of stress on the municipal services [8].

2. Methodology

Literature review was carried out to understand the population and types of toilet facilities used by people. The data on history of sewage generation and treatment in Mumbai was also obtained through literature review. The primary data was collected through actual site visits. The assessment of seven big STPs was done in terms of number of pumping stations, length of sewers (in km), installed and treatment capacity (in MLD) of each STP and its location of discharge into the receiving water body either through outfall or in the creek. The information regarding the source of waste water received (that is municipal, institutional, residential and commercial wastewater), the treatment technologies used in small STPs (260) in Mumbai was also collected. The information regarding the challenges Municipal Corporation of Greater Mumbai (MCGM) faces with respect to sewage management and the initiatives taken to overcome them was collected through different reports and actual discussions with the concerned officials. The policies formulated from time to time at country, state and municipal corporation level have been incorporated by referring different reports and documents. The stipulated sewage discharge standards were compiled by referring Ministry of Environment, Forest and Climate Change (MoEF) documents.

Geographical Information System (GIS) is a computer-based tool which collects, stores, manipulates, analyzes and displays spatially relevant information [9]. ArcGIS is one of the most commonly used GIS software. It acts as a contextual tool for mapping and spatial reasoning and gives useful insights about the data and helps in proper city planning [10]. 29 STPs were mapped in Mumbai city using ArcGIS version 10.1. The feature class was generated by using the data incorporated in excel and then exporting it in ArcGIS 10.1. The digitization of drainage network for Mumbai was done and classification of open drains and storm water drains was made. Further, the digitization of ward boundaries for Mumbai city was done and merging of census data in polygon feature class was also carried out. In addition, the division of STP vis–a-vis population structure was studied in order to locate the areas with new STP requirements. Depending on this analysis, the recommendations are given. Fig. 1 depicts the diagrammatic representation of the methodology adopted during the study.

3. Results and discussion

3.1. Sewage generation and treatment in Mumbai

MCGM is the government body responsible for sewage treatment and disposal in Mumbai city. Mumbai is divided in 24 wards for better management by MCGM. In 1880, sewerage treatment work with primary treatment was initiated by MCGM. In 1935, a treatment plant at Dadar with Activated Sludge Process was established for North of Worli area. In 1950, North Dadar area treatment plant at Dharavi was established, resulting in 98% of sewage collected and treated for old city limits of Mumbai (68.71 km^2) extended up to Mahim and Sion. In 1950, Suburban area of H, K, L, M and N wards (210.34 km^2) was added to sewerage treatment system. In 1957, Suburban area of P, R, S and T wards with an area of 158.66 km^2 were added to sewerage treatment system. In 1960, Primary treatment plants at Khar, Versova and Ghatkopar were constructed. In 1976, World Bank agreed to finance Integrated Water supply and Sewerage project. MCGM had reconstructed pumping stations in 1995 [11].

During 2000–2010, main sewer lines in Mumbai were rehabilitated by using GRP (Glass reinforced polyethylene) under a project initiated by World Bank. Also, for storm water drain, 7–8 big pumping stations were constructed. Overall, 60–70% sewage is collected for treatment. MCGM is planning strategies to collect remaining 30% sewage for

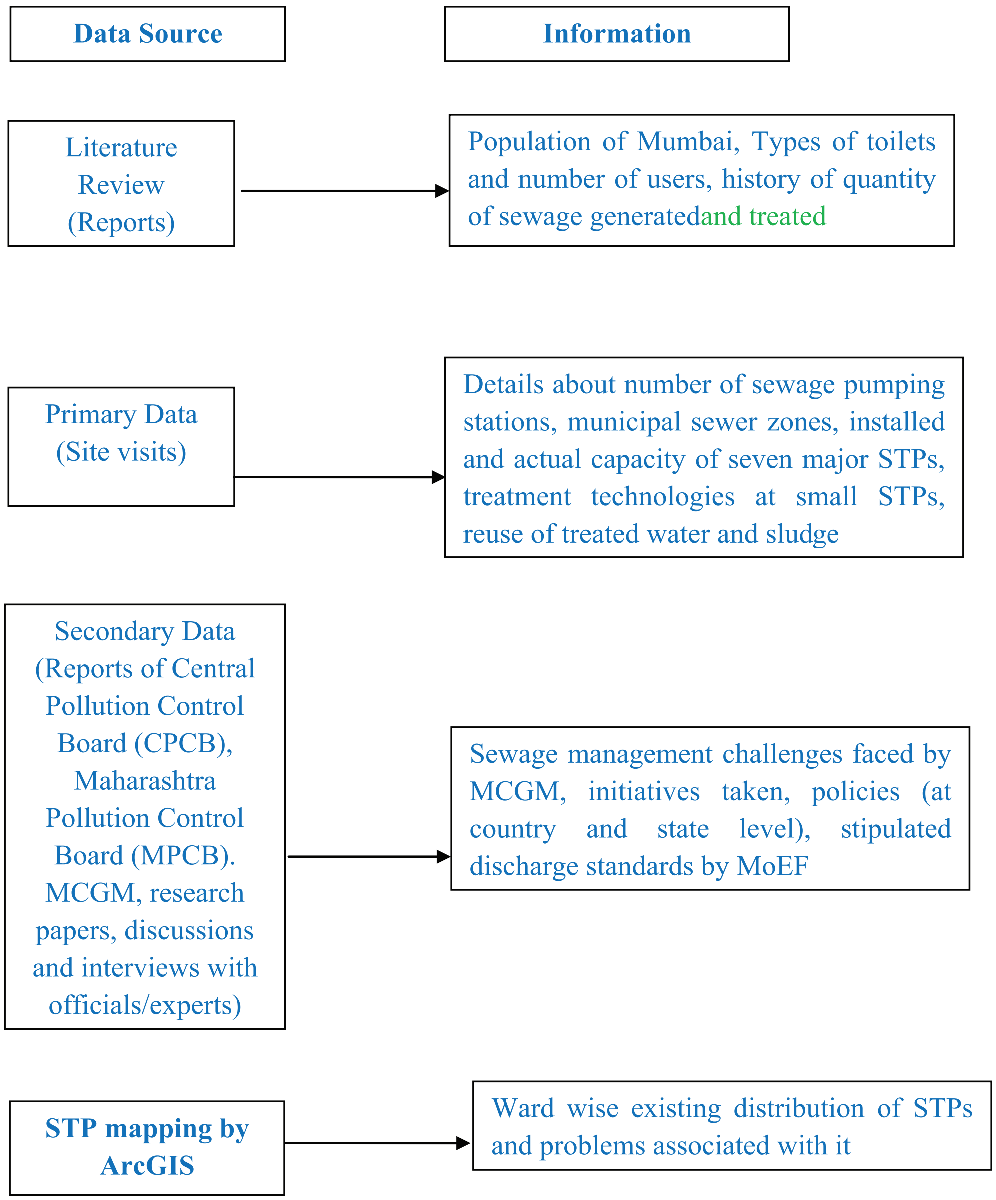

Fig. 1. Diagrammatic representation of methodology adopted.

treatment in near future. In Mumbai, some portion of the sewage is discharged into the sea through marine outfalls and some portion is discharged in to the creek after primary treatment. In 1900, entire sewage was brought to Worli outfall [11].

There are 3 departments for sewage management in MCGM –

1. Sewerage operations – takes care of operations and maintenance of STPs.
2. Sewerage projects – takes care of planning and laying new sewer lines and augmentation of existing lines.
3. MSDP - Mumbai Sewage Disposal Project in operation since 2001

3.2. Mumbai sewage disposal projects

3.2.1. Mumbai sewage disposal project (MSDP-I)

MCGM with the assistance of the World Bank implemented integrated water supply and sewerage projects in 1974. For the Mumbai Sewage Disposal Project, the Sewerage Master Plan Stage-I began in 1979 and got completed in 2004. Under this plan, MCGM implemented first Mumbai Sewage Disposal Project in 1991 which was completed in 2003. The main objectives of this project were - to strengthen the capacity of corporation in management of sewerage services like planning, designing, construction, quality management operation and maintenance, improving the health and environmental conditions predominantly in coastal marine environment [11]. The Sewerage Master Plan I has been executed and all the targets are mostly achieved, indicating need for Master Plan II to address sewerage needs for Mumbai.

3.2.2. Mumbai sewage disposal project (MSDP-II)

Mumbai Sewage Disposal Project (Stage II) Master Plan was prepared in 2001 and its work was initiated in 2007. It aims to provide 100% collection of wastewater, minimize impact of wastewater on environment by improving wastewater collection, treatment and disposal by the year 2025 [11]. The project involved laying of 60 km long new sewers, up sizing of 100 km of sewer lengths, construction of 18 new pumping stations, construction of 2 new waste water treatment plants with total investment of 4,495 Crore [12,13].

As per CPCB report 2009, about 2,671 MLD of sewage was generated in Mumbai in 2005–2006 of which 2,130 MLD (80%) of sewage was treated. In 2008, Mumbai generated 2,400 MLD sewage along with the maximum treatment capacity of 2,130 MLD, which comes out to be 88% of total quantity of sewage generated [14]. As per Revised City Development Plan, MCGM, 2012, Greater Mumbai generates around 2,680 MLD of sewage out of which only about 1,700 MLD or 63% is collected. This is because; a large percentage of population in Mumbai lives in slum area where providing sanitation services still remain a challenge. Currently, 60% of the Greater Mumbai area covering 42% of population (including 2% of the slum population) is connected with piped sewer lines [15]. Currently, Mumbai generates 3,000 MLD sewage out of which 2,100 MLD is treated and released into the Arabian Sea and the creeks [16].

There are 6000 Manholes and 1550 km sewer line in Mumbai to collect sewage from various parts of the city. There are 50 sewage pumping stations which collect sewage from surrounding areas and discharge it in the water bodies. Mumbai is divided into 7 municipal sewer zones viz. Malad, Versova, Bandra, Worli, Colaba, Ghatkopar and Bhandup with three main outfalls viz. Bandra outfall, Worli outfall and Colaba outfall. These 7 zones have seven terminal pumping stations, where planning and execution of secondary treatment facilities is in progress. At some places, there are 2 pumping stations known as Influent pumping station (IPS) and Effluent pumping station (EPS). At Bandra and Worli, there are 2 pumping stations whereas in Colaba, Malad, Bhandup, Ghatkopar and Versova there is only 1 pumping station. Fig. 2 shows the distribution of households depending on the usage of the type of the toilet facility in Mumbai city.

Out of 7 major plants of MCGM, Ghatkopar, Versova and Bhandup treatment facility have Aerated Lagoons and 4 plants discharge raw sewage. At Ghatkopar, Versova and Bhandup treatment facility, the treated sewage complies with prescribed standards of BOD and COD; whereas at Colaba, Worli and Bandra, the treatment facility is complying with SW II standards. SW II standards are water quality standards for coastal water (receiving the sewage through outfall) depending on their designated best use. The coastal waters complying with SW II standards can be used for bathing, contact water sports and commercial fishing [17]. Table 1 shows detailed information of 7 large STPs of Mumbai.

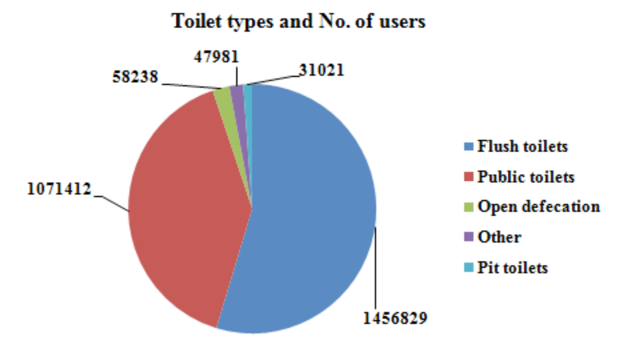

Fig. 2. Distribution of households by type of toilet facility in Mumbai city,Source: [9].

For disposal of sewage into the sea, MCGM had done a study on currents and internal streams and it was suggested that – 1. At Bandra and Worli outfall, sewage is to be disposed at 3.7 km away from the shore; 2. At Colaba outfall, sewage is to be disposed 1 km away from shore.

There are different sources of sewage generation like municipal, residential, institutional and commercial. To study sewage treatment from all these sources, in detail, we have divided STPs according to type of source of sewage generation. From our study, we found out that there are 195 commercial STPs, 50 municipal STPs, 10 residential STPs and 5 institutional STPs. These STPs rely on 18 different treatment technologies. Table 2 presents technology wise distribution of STPs along with type of STPs.

Table 3 shows capacity wise division of STPs, from 0 to 150 MLD, out of which maximum number (195) were in 0–5 MLD capacity.

After proper treatment, sewage could be used for different non-potable purposes like gardening, irrigation, toilet flushing etc. In Mumbai, out of 260 STPs, only 15 plants have mentioned reuse for water for irrigation purpose and for gardening and flushing, whereas only 1 plant has mentioned the reuse of sludge. 244 plants have not mentioned any reuse of treated water or sludge. Table 4 shows number of STPs reusing either the treated sewage and/or sludge.

3.3. Population and STP distribution mapping using ArcGIS

ArcGIS is now widely being recognized as a decision-making tool in the field of waste management. It helps in assessing the suitability of site for locating the sewage treatment plant, especially in an urban area, in order to avoid the various environmental hazards arising in case of improperly located waste management system [18]. Fig. 3 shows ward-wise population distribution and distribution of STPs in each ward based on its treatment capacity. It can be visualized that the concentration of STP's is higher in the eastern region with many small STPs and two large capacity municipal plants (at Bhandup and Ghatkopar each). Most of the sewage generated in South Mumbai is directed towards Worli STP which puts a tremendous load on the existing facility. Therefore, there is an urgent need to set up alternate plants so as to reduce the load on central STP at Worli. P/N ward (Malad West

Table 1
Seven large STPs in Mumbai managed by MCGM

Zone	Area	Pumping stations (No)	Length of sewer (km)	Installed STP capacity (MLD)	Treatment (MLD)	Capture %	Existing treatment stage [8]	Proposed treatment technology [8]	Outfall
1	Colaba	6	40	41	37	90	Preliminary	Activated sludge process	S. East coast/ Harbour, 1.2 km marine outfall
2	Worli	16	355	757	605	90	Preliminary	Activated sludge process	West coast / Arabian sea, 3.4 km marine outfall
3	Bandra	16	350	797	716	60	Preliminary	Chemically enhanced primary treatment	West coast / Arabian sea
4	Versova	2	160	131	115	80	Preliminary	Three stage lagoon	Malad creek
5	Malad	6	320	240	190	50	Preliminary	Activated sludge process	Malad creek
6	Bhandup	3	120	180	73	40	Preliminary	Activated sludge process	Thane creek
7	Ghatkopar	1	155	138	100	30	Preliminary	Activated sludge process	West coast / Arabian sea
	Total	50	1483	2284	1296				

Table 2
Treatment technology wise distribution of small STPs in Mumbai

Sr. No.	Treatment technology	Total plants	Municipal	Residential	Institutional	Commercial
1	Activated sludge process	7	5	1	0	1
2	Anaerobic baffle reactor	3	2	1	0	0
3	Lagoons	10	10	0	0	0
4	Concrete chamber septic tank (CCST)	16	1	0	0	15
5	Constructed soil filter (CSF)	3	1	0	0	2
6	Cyclic aerator sludge	4	4	0	0	0
7	DEWATS	2	1	0	1	0
8	Fluidized media reactor	4	0	3	0	1
9	Moving bed bio reactor	18	0	0	0	18
10	Neo bio-film	1	0	0	0	1
11	Package sewage treatment plant	22	0	0	0	22
12	Primary treatment	1	0	1	0	0
13	Rotating biological contactor	4	3	0	1	0
14	Sequence batch reactor	17	14	1	0	2
15	Soil biotech (SBT)	9	4	1	2	2
16	Solid immobilized biofilter	2	0	0	1	1
17	Up flow anaerobic sludge blanket (UASB)	1	1	0	0	0
18	Electrolysis	2	2	0	0	0
19	Unknown	134	2	2	0	130
	Total	260	50	10	5	195

area in Mumbai) is densely populated but doesn't have any STP. Although a good number of STPs are installed in Mumbai, it is important to consider sewage treatment options and study space availability at town planning level to ensure proper distribution of plants as per the population requirement.

3.4. Challenges faced by MCGM

Even though MSDP project which aimed to upgrade existing STPs to provide secondary and tertiary sewage treatment was planned 10 years ago,it still has not been initiated successfully. This has not only affected the plan of

Table 3
Distribution of small STPs in Mumbai depending on capacity

Sr. No.	Capacity	No. of STPs
1	0–5 MLD	195
2	5.1–10 MLD	2
3	10.1–50 MLD	17
4	50.1–100 MLD	9
5	100.1–150	0
6	150.1 MLD Above	1
7	Unknown	36
Total		260

Table 4
Number of small STPs in Mumbai reusing treated sewage and /or sludge

Sr. No.	Type of reused resource	No. of plants
1	Reuse of treated water	15
2	Reuse of treated Sludge	1
3	No reuse mentioned	244
Total		260

distribution of treated water but has also resulted in escalating the project's initial cost of Rs. 2,300 Crore in the year 2006 to Rs. 14,368 Crore in the year 2018. The causes for this delay and other challenges faced by MCGM in the sewage management of Mumbai city are discussed in the following section [19].

3.4.1. Sewage discharged in open drains

Malad is the largest zone amongst the 7 zones with a population of 2.85 million and covering an area of 115 km^2 in the western suburbs in Mumbai. The area is characterized by squatter settlements. There are six pumping stations in this zone and currently approximately 320 km of sewers are connected by a major interceptor sewer. This interceptor sewer from Shimpoli to Malad cannot cope with all the sewage flow at some locations due to blockage, collapse and insufficient size. The interceptor from Goregaon is clogged and the rising main is not of sufficient size. As a result, 3 pumping stations pump part of their flows directly into the open drains [11].

3.4.2. Land availability for expansion of STPs

This issue was highlighted in case of expansion of STP at Bandra. MCGM had acquired the land but part of it was later on given to Maharashtra State Road Development Corporation (MSRDC) for Bandra-Worli Sea Link's construction. Approximately 5.5 ha land was given for water transport project related activities (like construction, and modernization of existing jetty along the Bandra-Worli Sea Link) to the Mumbai Maritime Board (MMB). As per the agreement, MSRDC and MMB were supposed to pay land cost and rental fee to MCGM. However, neither any payment has been made, nor has any land made available. Due to the unavailability of land, MCGM has not been able to treat the sewage generated in Bandra and Dharavi. This would result in MCGM being penalized for not being able to achieve SW II class standards as per MPCB's directive [20].

3.4.3. Encroachment by squatter settlements/ Interconnects in sewer lines and storm drainage system

In a city like Mumbai, due to the problem of informal settlements on the banks of the storm water drains has resulted in their width narrowing. Some of the natural drainage channels which were intended to carry the storm water drains now have residential buildings built on their flood plains. Raw sewage from these residents is directly discharged into storm water drains. Therefore, in addition to storm water, the drains also carry sewage overflow from septic tank [16]. 40–45% population of Mumbai is in slums and these are without sewer connections as these are illegal settlements. Also the solid waste from these slums comes into storm water drains clogging and choking the same.

3.4.4. Other environmental concerns

Most of the development works for pumping, treatment and disposal of sewage are located in the coastal areas, which fall under Coastal Regulation Zone (CRZ) I or II. Environmental Impact Assessment (EIA) is carried out for any of the above-mentioned work [16]. MoEF has already denied permission for a proposed waste water treatment plant that was to be built near Malad Creek based on the regulation that construction of a sewage treatment plant is not permissible under the CRZ Notification, 2011 [21]. Sewer lines in many places are more than 100 years old and dilapidated; therefore, there is risk of environmental pollution due to leaking sewers [15].

3.4.5. Changing standards

As per the consent granted by MPCB, the effluent of STPs is also required to make sure that treated effluents meet the prescribed standards. MPCB through their consent in the year 2015, allowed up-gradation of STPs with the condition of achieving the norms of 100/100 mg/l BOD/SS for disposal through Marine Outfall and 20/30 mg/l BOD/SS for disposal into the creek. It also allowed additional time to upgrade STPs at Bhandup, Ghatkopar, Versova and Malad till 2019 to achieve further stringent standards 20/30 mg/l BOD/SS. On the other hand, CPCB in their letter dated 9th October 2015 under section 5 of EP Act 1986 has directed MCGM to ensure that STPs of adequate capacity are provided for complete treatment of the sewage generated and also to ensure that the treated effluents shall meet the standards of BOD/TSS of 10/10 mg/l within a period of 5 years from the date of notification [16].

3.4.6. Unplanned development of city

In the city of Mumbai, the people live in squatter settlements built in hilly or congested areas. These are unplanned

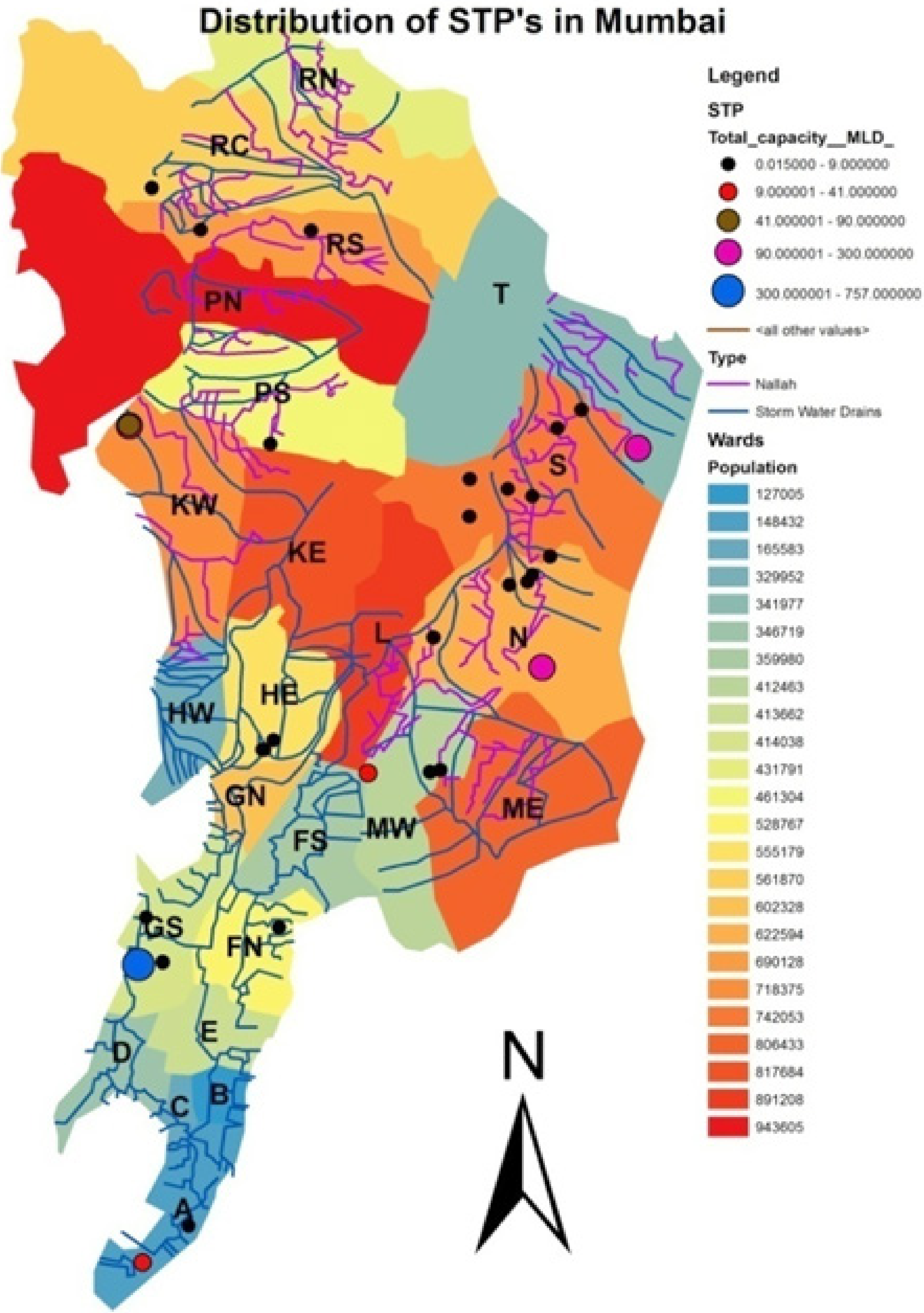

Fig. 3. Distribution of STPs in Mumbai.

residential colonies where sewerage lines cannot be built. 30–40% of the total sewage is generated from these squatter settlements and the sewage from this area flows directly through the open drains which are not connected to MCGM sewer line. MCGM is considering diverting this sewage to nearby sewer line or construct STP to treat it and add in sewer line for further treatment and disposal. Also, at such places, there is not enough space even to build toilets and therefore people often resort to open defecation adding to the pollution problem. The other problem Mumbai faces is due to the development of unauthorized settlements without basic urban services [22].

3.4.7. Contamination

In the city of Mumbai, the drinking water from the service reservoirs is intermittent. Because of this non-continuous supply, during non-supply hours, sewage can cause contamination by entering the water supply pipelines through joints, disconnected connections, tampered mains, faulty fittings, etc. Even though sufficient care is being taken by monitoring the water quality at different points through the supply, reports of contamination are observed [16]. There are growing concerns about releasing polluted water into the sea.

3.5. Initiatives by MCGM [16]

3.5.1. Recycle and reuse

MCGM has made recycle and reuse of waste water compulsory for the high-rise buildings and construction of STP is mandatory for such buildings. In Mumbai, there are few private industries taking initiatives to treat sewage. Currently MCGM is charging them 3–4 Rs per kiloliter for treatment. Also, to promote recycle and reuse program preparation of "Grey Water Recycle Bylaws" is in progress with help of All India Institute of Local Self-Government (AIILSG).

3.5.2. Improvement program for reducing contamination of water

For reducing the risk of leakage and subsequent contamination, MCGM is replacing/rehabilitating tertiary network at locations wherever required. During 2015–2016, old Distributor Water Mains of 40 km length was replaced by laying new water mains. In addition to this, 28 km of distributor water mains was rehabilitated by internal cement mortar lining. This has successfully resulted in contamination reduction. Road department of MCGM has also undertaken major initiative in the form of Road Improvement Programme. Under this programme, the department aims to renew the water service connections at the time of road improvement. In squatter settlements, MCGM has taken initiatives like replacing existing old and corroded GI pipelines and laying suitable size of water mains on passages of squatter settlements.

3.5.3. Projects proposed in financial year 2016–2017

Under Mumbai Sewage Disposal Project, for the financial year 2016–2017, the budget provisions of Rs. 198.33 Cr is proposed for laying new sewer lines in unsewered area and up sizing of existing sewer lines in City, Eastern and Western suburbs whenever required.

3.5.4. Action plan for up-gradation of STPs

As per CPCB's directive, the stricter standards to be achieved within 5 years for discharge of treated sewage from STPs have to be taken into account while planning for all the future projects. MCGM has already initiated action for up-gradation of the STPs to meet the above-mentioned norms. MCGM is planning to increase the treatment capacity of STPs except for that in Colaba and Worli Zone. They also propose to improve the treatment starting from preliminary to tertiary treatment along with recycle and reuse facilities.

3.5.5. MSDP Phase II

The major goal of the MSDP master plan to be implemented by MCGM is to provide a healthier and improved environment for people living in the city, while minimizing the impact of wastewater on the natural environment. MCGM aims to achieve this by increasing the quality and reliability of wastewater collection, treatment and disposal using affordable and sustainable technologies over the duration of the planning period up to year 2031 through initiatives like Slum Sanitation Programme (SSP). The programs like these will help to cause behavioral change in people's mindset against open defecation.

3.5.6. Identifying commercial and residential locations discharging domestic wastewater

MPCB is planning to direct residential complexes generating more than 20,000 L of sewage every day, to install their own STPs. As per MPCB's member secretary, the work to mark commercial and residential locations generating significant quantity of sewage and treating it at the source has been initiated. The process of issuing notices not abiding by the policy of not treating the generated sewage at source has begun from February 2018 [23].

3.6. Public opinion

As a part of Government of India's Swachh Bharat Mission, a survey ranking exercise called "Swachh Survekshan" is carried out in the urban as well as rural areas to evaluate their cleanliness and ability to implement Swachhata mission initiatives. The "citizen's feedback" constitutes an integral part of the survey methodology. The questionnaire for feedback collection has three questions related to sanitation facilities. As per the available data of Swachh Survekshan 2017, Greater Mumbai secured 22nd rank among 500 cities in India. 50% the people residing in Mumbai agreed to the fact that public toilets are available within each 500 m area of the city. Only 21% of the population of the total participating in giving the feedback accepted that the basic infrastructure is available at Public/Community Toilet. Out of the total feedback giving citizens, 68% had individual household toilet [24].

By virtue of effective implementation of sanitation programme aided by public awareness campaign of Malaria Control Department of MCGM, there is significant decrease in number of malaria cases. As per the survey conducted with fishermen, there is a decline in fish catch, mainly due to coastal water pollution caused due to the discharge of untreated sewage. In case of tourism, the reduction of 11–22% has been predicted owing to sewage discharge led aesthetic degradation of coasts and beaches in Mumbai [8].

3.7. Policies and discharge standards for sewage treatment and disposal

3.7.1. Policies

At present, in India, there are no policies dealing exclusively with the important issues of sewage management with respect to its safe handling, transport and disposal. Currently, the development of sewerage infrastructure for the disposal of sewage is the responsibility of the respective state governments and urban local bodies (ULB) with their work being supported by different environmental laws and central government funded scheme [25]. Table 5 outlines various policies which addresses the key issues pertaining to sewage management in India.

The following section discusses the implications of implementing the above mentioned policies for the purpose of sewage management and the different challenges still being faced by the concerned authorities in improving the existing scenario.

According to a report of Centre for Science and Environment published in 2010, installed treatment capacity for STPs was only 19% of total sewage generation as compared to an installed capacity of 30% [26]. This is due to inability to raise the required revenue and inadequate managerial capabilities [27]. Later on, it was increased to 29% of wastewater generation in Class I and II types of cities with the various river action plan developed and other awareness programs [1]. There is a need of significant investments for installing sewage treatment systems at minimum of 500 different locations within India. As per the "Inventorization of Sewage Treatment Plants" report, in India, out of total 816 STPs, 522 STPS are operational, 79 STPs are Non-operational, 145 STPs are under construction and 70 STPs are proposed for construction. Out of different states and Union Territories (UT), Himachal Pradesh had maximum percentage (45%) of non-operational STPs [7].

In terms of consent status, in Maharashtra, out of the total 76 STPs, all the 60 operational STPs have applied for consent. In the states like Punjab, although it has maximum number of STPs (86), none of the operational STPs has obtained consent from its state pollution control board. Even, Uttar Pradesh, the biggest state with high population density, has not applied for the consent for 62 operational STPs. In Jharkhand, the consent has already expired but has not applied for renewal and STPs are still operational. This shows that the mandatory provision of obtaining consent under Water (Prevention and Control of Pollution) Act, 1974 is being violated in these states. There is an urgent need for State Pollution Control Boards to use their statutory power to take action against defaulting STPs.

The performances of STPs in terms of complying with the stipulated discharge standards were checked by CPCB in 2005. The study found that out of the total plants studied, 86% were operational and nearly 40% of them did not

Table 5
Policies related to sewage management in India

Issue	Policy/policies addressing the issue	Policy specifications
Sewerage network / STP construction	National Lake Conservation Plan (NLCP)[a]	The lake water pollution from point sources is to be prevented by providing sewerage and sewage treatment for the entire lake catchment area
	National River Conservation Plan (NRCP)[b]	NRCP provides funds (on Central and State Government sharing basis) for collection, transportation and treatment of municipal sewage
Consent status of STP	Water (Prevention and Control of Pollution) Act, 1974	Under this Act, it is mandatory to obtain a "consent to establish (CTE)" before starting STP work and "consent to operate (CTO)" after completing the construction and before starting the actual operation from the State Pollution Control Board (SPCB)
Treatment technologies implemented	None	–
Operation and Maintenance (O & M)	None	–
Compliance with the discharge standards	Environment (Protection) Act, 1986	
Reuse of treated sewage	Water (Prevention and Control of Pollution) Act, 1974	Reuse of treated sewage for irrigation
	MPCB's notice issued in 2014	It is mandatory for residential buildings and industries with more than 20,000 m^2 built up area to install their own STP

comply with the general discharge standards (described in subsequent section) [28]. The performance evaluation in 2007 noted that only 10% of STPs are "good" and the treatment performance of 54% of the STPs was in "poor" and "very poor" categories [29]. A study was conducted by CPCB for evaluating the treatment performance of 152 STPs funded under NRCP. Out of these, 49 and 7 STPs were not meeting the General Standards for Discharge of Environmental Pollutants into inland surface, public Sewers, land for irrigation, marine coastal areas under Schedule-VI of The Environment (Protection) Rules, 1986, for BOD and COD respectively. In Maharashtra, out of the evaluated 6 STPs, only 1 STP exceeded the prescribed standard for BOD and all of them had outlet COD concentration within the limits [27]. The reasons for this non-compliance are frequent electricity break downs, lack of technically sound personnel and irregular operation and maintenance due to high cost [25,30].

As far as the selection of treatment technology is concerned, activated sludge (AS) process was one of the most commonly used and significantly used conventional treatment technologies in STPs funded under NRCP. Other efficient treatment processes were identified to be oxidation pond (OP) and waste stabilization pond (WSP). These are termed as "natural technologies" and should be preferred over the conventional technologies as they have low energy consumption and do not require high number of skilled manpower. For efficient operation of STP, O&M of various components of STPs is essential. It is the duty of State Pollution Control Board to perform regular inspection of the plant and also to provide the required guidance to the concerned authorities and field staff in maintaining the optimum operation and maintenance of STPs [27].

MPCB vide notice (issued February 2014) has made it mandatory for residential buildings and industries with more than 20,000 m^2 built up area to install their own STP. In industries, reuse and recycling of water is being promoted. For residential buildings, according to revised environmental consent norms, nearly 80% of the treated waste should be recycled. In addition to this, it has been proposed that all STPs in industries and also building projects, STPs of local bodies discharging treated sewage in inland water bodies should meet the "inland freshwater" discharge standards schedule – VI- (See rule 3A), also called "General standards for discharge of environmental" for pollutants part-a : effluents (annexure-a) [31].

Currently, there are no specific regulations addressing the O&M aspects of STP. There is an urgent need to draft policies for promoting the application of low-cost decentralized treatment technologies to address the issue of the lack of sewerage network ultimately resulting in the pollution of receiving water bodies. Also, an action plan should be in place, delineating the methodology for the application of treated sewage for the irrigation purpose.

3.7.2. Stipulated discharge standards

3.7.2.1. Ministry of environment and forest's (MoEF) discharge standards for treated sewage

MoEF has laid down sewage discharge standards for various physico chemical parameters. The limits for treated sewage vary slightly based on the discharge location viz. inland surface water, public sewers, land for irrigation and marine coastal areas except BOD standard which shows significant variation depending on the discharge location [32].

National River Conservation Directorate (NRCD) has formulated guideline for Faecal Coliform (in MPN/100 ml) in 2 categories, i.e. desirable and maximum allowed depending on whether the treated sewage is going to be discharged on to the land or any water body.

3.7.2.2. General standards for discharge of heavy metals in public sewer

CPCB has provided general discharge standards for sewage disposal in public sewer with respect to heavy metals [33].

3.7.2.3. Notification on standards for STPs along with the time frame for implementation [34]

MoEF under the Environment (Protection) Act, 1986 (29 of 1986) has issued a notification dated 24th November 2015 for Standards for Sewage Treatment Plants along with the Time Frame for Implementation. The said notification proposes that

1. The standards will be applicable for discharge in water resources as well as for land disposal.
2. The standard for Fecal Coliform may not be applied for use of treated sewage in industrial purposes.
3. The existing STPs should achieve the standards within 5 years from date of notification.

MoEF had specified discharge standards for treated sewage differing with the categories for receiving water bodies such as inland surface water, public sewers and marine coastal areas. In contrast, the new notification on standards for STPs just mentions "water resources". Also, the earlier notification has designated standards for land disposal mentioned with its specific intended use for irrigation which is not mentioned in the notification issues in the year 2015. In terms of concentrations of various pollutants allowed for discharge, the new standards for STPs are much stricter in order to protect the water bodies. For example, MoEF's notification has allowed the discharge even when total suspended solids (TSS) concentration in the treated sewage was in the range of 100–600 mg/L, biochemical oxygen demand (BOD) was in the range of 30–350 mg/L, chemical oxygen demand (COD) concentration of 250 mg/L, ammonical nitrogen and total nitrogen with the concentration of 50 and 100 mg/L respectively. In contrast, the new STP standards allow the discharge of treated sewage only if the concentration is 20 mg/L for TSS. The discharge limits for BOD and COD has been brought down to 10 mg/L and 50 mg/L respectively. Similarly, the concentration of ammonical nitrogen and total nitrogen has to be brought down to 5 and 10 mg/L before discharging it into water bodies or on land.

NRCD has stipulated standard of 1,000 CFU/100 ml for faecal coliforms if the treated sewage is to be disposed into water or on land. As per the new notification, the limit has been reduced to less than 100 faecal coliforms per 100 ml of treated sewage.

The toxic heavy metals like arsenic (As), mercury (Hg), lead (Pb), chromium (Cr), cadmium (Cd) etc., had specified limits for discharge of the treated sewage in public sewers. These standards have not been mentioned in the new notification. The standards for heavy metals are very essential in order to avoid the possible adverse impacts, especially if the treated sewage is intended to be used for irrigation of edible crops.

3.8. Reuse of sewage

Growing population in India is increasing demand of water in urban and rural areas leading to reduction in per capita availability of water. Therefore, wastewater reuse can be considered as one of the potential solution [35]. Water reuse has been practiced all the over the world since last hundreds of years. Some of the urban and outskirts areas, under drought conditions, have used wastewater (with or without treatment) from different sources like agriculture, sewage (both grey and black water) and industries for agricultural production [36].

The non-acceptance of wastewater for reuse and agriculture as an income source in urban areas proves to be a major barrier for waste water reuse. Unfortunately, policy makers don't consider wastewater as a priority issue. Further, the integrated solutions for wastewater are not taken into consideration due to lack of coordination amongst various stakeholders at various levels [36].

The precarious balance between growing demands and supplies brings forth the importance of recycling and reuse of water so that same water can be used for multiple purposes, one after the other, thereby reducing the demand for fresh supplies [37]. Recycling and reusing treated wastewater in industry as well as other domestic purposes can balance the demand for water. Wastewater irrigation can supply almost all nutrients and micro nutrients required by crops and are considered as a major resource in many parts of the world. Reuse of wastewater is emerging as an integral part of water demand management which preserves high quality fresh water, reduces pollutants as well as reduces overall supply costs. It would be possible to reuse 40–50% of secondary sewage for industrial and other uses [38–40].

In a study conducted by group of authors, through literature survey, some gaps like identification of opportunities and constraints to recycling, drivers for market availability for wastewater reuse, practicality for wastewater treatment and recycling, need for a uniform international approach to assess the feasibility of recycling and stakeholder objectives and priorities for wastewater recycling were identified [41]. This study also highlights that both developed and developing countries can share their data, technologies and experiences to reduce stress on water resources. In another study, it was observed that the treated sewage water can be reused for agricultural irrigation.

Wastewater is emerging as potential source for agricultural irrigation. Though wastewater- irrigated fields generate great employment opportunity, there are higher risks associated to human health and the environment on use of wastewater as wastewater is rarely treated and large volumes of untreated wastewater are being used in agriculture [25].

Ministry of Urban Development's (MoUD) "Handbook on Service Level Benchmarking" has defined recycling and reuse of sewage as "the percentage of sewage recycled or reused after appropriate treatment in gardens and parks, irrigation, etc. and, is to be at least 20% to begin with." In India, at various places and in the other parts of the world, treated sewage is currently being used for a wide range of applications like irrigating farms, forests and gardens, in flushing toilets, in cooling towers in industries, aquaculture and others [42].

The National Policy on Faecal Sludge and Septage Management (FSSM), developed by Ministry of Urban Development, Govt. of India, aims to promote recycling and reuse of treated sewage for all the possible non-potable applications [43].

3.9. Reuse of sewage in Mumbai

In the city of Mumbai, some of the prominent case studies of sewage reuse are:

a. Reuse Plant at Mumbai International Airport Limited (MIAL): Circular SBR tank followed by hypo chlorination, pressure sand filtration and ultra filtration has been installed to generate colour, organics and odour free sewage. Treated sewage is being reused partly for toilet flushing and the remaining portion is treated again using RO membranes to recover make up grade water for HVAC [44].
b. Sewage Reuse Plant at M/S Rashtriya Chemicals and Fertilizers, Mumbai: 23 MLD capacity STP was commissioned in the year 2000 to treat sewage contaminated with different industrial wastes. Originally it consisted of chemical and biological treatment but later on treatments like Ultra Filtration was added in order to improve the quality of the water prior to RO system (for maintaining the silt density index less than 3.0) as the influent was highly polluted. The treated water was reused for cooling grade makeup water [44].

3.10. Decentralized wastewater treatment as an option

The commonly followed methodologies of sewage collection and treatment are not only putting stress on natural resources like use of fresh water for flushing and carrying it to STP but also need investment of high capital cost and have high energy requirements. The possible solution to this problem could be adoption of decentralized wastewater treatment (DWWT) approach. It can prove to be a cost effective solution with an added advantage of possible reuse of treated sewage by the community. The success stories of DWWT demonstrate its applicability of DWWT technology as a sustainable sewage treatment option in an urban area like Mumbai [45].

3.11. Other future scope of work

MCGM has already undertaken the work of deepening of Mithi River. They claim that 95% of the work has been completed. This has resulted in three times increase in the carrying capacity of the river. This will help in preventing flooding during monsoon season and ultimately protecting the health of people [46]. Navi Mumbai Municipal Corporation (NMMC) is planning to provide extensive sewerage network so as to enable collection of all the sewage generated from their residential areas. This can serve as a case study for MCGM officials [47].

4. Conclusions

Mumbai, the capital city of Maharashtra, is one of the most populous cities in India. 70% of the total sewage generated in Mumbai gets treated. From the study, it was found that, in total, there are 260 STPs in Mumbai receiving the sewage from commercial, municipal, residential and institutional sources. There are eighteen treatment technologies being used at different STPs. The squatter settlements are responsible for the discharge of 30% untreated sewage due to lack of the sewerage network. In addition to this, the lack of space to build the toilets results in people resorting to open defecation which further aggravates the pollution problem. Due to lack of space and stricter discharge standards to be achieved, municipal authorities should look for cutting edge sewage treatment technologies. The programmes like SSP can cause behaviour change in people and prevent them from open defecation. ArcGIS software has played an important role in identifying the densely inhabited wards in the city of Mumbai and its requirement of connecting it to existing sewerage network or installing a new sewage treatment facility. The stricter implementation of policies, especially related to developing extensive sewerage network where ever possible, regular O&M of existing STPs, promoting decentralized treatment plants and reuse of treated sewage for non-potable purposes like flushing, gardening etc. would surely help the municipal authorities to achieve better sewage management in an urban city like Mumbai.

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