

URBAN WATER SUPPLY AND WASTE WATER

POLICY WORKBOOK



Smart City
MISSION TRANSFORM-NATION



Ministry of Housing and Urban Affairs
Government of India



National Institute of Urban Affairs



Ministry of Housing and Urban Affairs
Government of India

ABOUT MINISTRY OF HOUSING AND URBAN AFFAIRS (MoHUA)

The Ministry of Housing and Urban Affairs is the apex authority of Government of India to formulate policies, coordinate the activities of various Central Ministries, State Governments and other nodal authorities and monitor programmes related to issues of housing and urban affairs in the country. The Smart Cities Mission was launched by the Ministry in 2015 to promote sustainable and inclusive cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of 'Smart' Solutions.



National Institute of Urban Affairs

ABOUT NATIONAL INSTITUTE OF URBAN AFFAIRS (NIUA)

National Institute of Urban Affairs (NIUA) is a premier institute for research, capacity building and dissemination of knowledge for the urban sector in India. It conducts research on urbanization, urban policy and planning, municipal finance and governance, land economics, transit oriented development, urban livelihoods, environment & climate change and smart cities.

The institute was set up to bridge the gap between research and practice, and to provide critical and objective analyses of trends and prospects for urban development. NIUA has assisted in policy formulation and programme appraisal and monitoring for the Ministry of Urban Development, state governments, multilateral agencies and other private organizations. It contributed to the National Commission on Urbanisation, participated in drafting the 74th Constitutional Amendment of 1992, prepared the Draft National Urban Policy and other documents for the roll out of the Jawaharlal Nehru National Urban Renewal Mission (JNNURM). It also guided the discourse on municipal finance by framing the Model Municipal Law.

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1. Executive Summary

The main objective of this workbook is to guide the city manager's to plan and implement actions aimed at improving urban water supply and sanitation service delivery. The workbook is designed to align with the vision for water and sanitation sector by managing the urban water demand and reducing the wastewater footprint. Some of the key areas critical for improving the sector performance revolve around infrastructure development in pace with urbanisation, management of water resources for its optimal utilisation ensuring safe, adequate and affordable water supply, integrated water and wastewater management planning, cost effective financing of urban water supply and sanitation operations, improving the governance framework for effective service delivery and preparedness in contingency situations like natural and man-made disasters.

2. Urban Water Supply

2.1. Project Planning - Stages

The stages of project planning and implementation are

- Project identification
- Pre-feasibility report
- Feasibility report
- Detailed Project Report
- Detailed engineering, technical specifications, tender documents
- Construction of project components
- Operations and maintenance

2.1.1. Project Identification

This stage is primarily a “desk study” based on existing information essentially meant for establishing project need. The report makes a case for sanctioning expenditure for carrying next stage of project preparation. The project report includes following information

- Description of project area and its physical environment
- Current population, physical distribution and socio-economic analysis
- Existing water supply system – identification of gaps in service delivery
- Population projection for the design period and accordingly assessment of water requirements
- Project need pointing adverse impacts of non-implementation of the project on a time scale
- Positioning of project to fit with national/regional/sectoral strategies
- Strategic plan for long term development of water supply services and its phasing
- Short term project components, its impact and design period
- Preliminary cost estimates – CAPEX, OPEX, funding source
- Indication on organisations involved in project preparation
- Timeline for future stages of project until its operationalisation

2.1.2. Project Pre-feasibility

Pre-feasibility study for a project may be a separate and discrete stage of project preparation or it may be first stage of comprehensive feasibility study. Pre-feasibility study is for screening and ranking of various project alternatives and selecting an appropriate alternative for next stage of detailed feasibility study. The pre-feasibility study helps in selecting a short-term project that fits into long term strategy for the sector.

Key components of the study

- Origin and concept of the project, how it was prepared, scope and status of the report

- Description of how the project fits into the regional development plan, long term sector plan, land use plan, water resources development etc.
- Agencies engaged in preparation of project report and their role in the study
- Description of project area and need of the project
 - Geographical description – topography, climate, culture, religion, migration etc.
 - Demography – current population, estimation of future population growth through various projection methods, factors likely to affect growth rates, migration patterns, implications on housing and other infrastructure
- Economic and social profiling
- Public health status – incidences of diseases related to water and sanitary conditions, maternal and infant mortality rates, life expectancy, health care programs, projects having bearing on improvements in environmental sanitation
- Institutions engaged in water supply and sanitation projects within the project area – roles, responsibilities and limitations
- Availability of water resources
 - Quantity and quality of surface/groundwater sources
 - Water use pattern across domestic, commercial, industry and irrigation
 - Pollution of water resources
 - Role of agencies/authorities responsible for managing water resources
- Existing water supply system and population served
 - Water sources, quantity and quality of water availability across seasons, components of the system – head works, transmission mains, pumping stations, treatment works, balancing/service reservoirs, distribution system
 - Areas covered, hours of supply, water pressures, bulk metering, metered/unmetered supplies, private water supply
 - Distribution of population as per the water supply source
 - House service connections
 - Unaccounted for water, reasons and efforts on reduction of same
- Existing sanitation systems
 - Existing sanitation and waste disposal systems, population served, impact of these systems on drinking water quality and environment
 - Drainages and solid waste management system
- Project Need – section highlights gaps in existing and desired service standards and consequences if the project is not taken up, priority of improvements needed in the existing system, expansion of the system or construction of new system, urgency of project preparation and implementation

Long term plan for Water Supply

- Any improvement in water supply services to be planned in a phased manner fitting into long term sector strategy consistent with future overall development plans for the project area. Long term plans are typically prepared for a period of 25 to 30 years. Sequential development actions to be identified to provide target service coverage at affordable costs. From this sequence, a priority project encompassing some or all actions to be implemented in the near-term can be selected which further becomes the subject of comprehensive feasibility study
- Service standards can be upgraded over a period of time, therefore various options can be considered for different areas. While setting the standards, the community preferences and affordability of the same should be of prime consideration. For the same the existing income levels of the project beneficiaries, tariff policies and practices and cost to the user should be carefully analysed.
- Assessment of water requirements based on the set service standards within the project area. These demand forms the basis for planning and provision of system requirements.
- The water demand in the project area should also consider the water requirements for upgrading sanitation facilities (proposals if any). Consistencies needs to be maintained for projects for both water supply and sanitation services.
- Planning for systems requirement – utilisation of existing infrastructure, reduction in water losses, alternative water sources (surface/ground), alternative transmission and treatment systems, distribution system including pumping stations
- Need assessment for supporting activities – health education, staff training and institutional improvements to be included as essential project components
- Project costing – CAPEX and OPEX

Proposed water supply project

The least cost development activity sequence for improvement in service standards is the proposed water supply project. As discussed earlier the section mainly consists of

- rehabilitation of existing facilities and construction of new infrastructure
- support activities – training, consumer education, equipment and other measures for O&M of the system
- consultancy services (if required) for conducting detailed feasibility study, detailed engineering/construction/supervision, studies for reducing water losses, tariff studies etc.
- Support documents for project submission – location maps, technical information of each physical component, preliminary engineering designs and drawings
- Implementation schedule for conducting feasibility studies, project appraisal, project sanction, fund mobilisation, implementation, trial runs and commissioning
- Cost estimates – annual requirement of funds (based on annual progress on each physical component) with due allowances for physical contingencies and inflation

- Environment and social impact – any major environmental or social impact likely to be caused by the project and its effect on project feasibility
- Institutional responsibilities – mapping of organisations/departments/agencies responsible for further planning and project preparation, approval, sanction, funding, implementation and O&M and indication of strength of personnel requirement.
- Project Finance – Capital costs (refer above), financing plan for the project identifying potential sources of funds and contribution from each one of them over the project period (possible sources of funds – cash reserves, grants from state/central government, loans from government and private financing institutions, open market borrowings, loans/grants from bilateral/international agencies)
- OPEX plan for the next 10 years
- Conclusions and recommendations

2.1.3. Project Feasibility

For small and medium size projects, the pre-feasibility report can be used for seeking financial approval if report is based on comprehensive and reliable data, adequately analysed, no major environmental/social impact envisaged due to project actions and importantly no major technical and engineering problems envisaged during construction and operations of the system.

However, in major projects, particularly those wherein bilateral/international funding agencies are involved, comprehensive feasibility studies to be taken up before investment decisions are made.

The difference between pre-feasibility and feasibility studies is that in later, the project is detailed to a greater extent to see if it is feasible technically, financially, economically, socially, legally, environmentally and institutionally. Additional data/information may be required to assess the mentioned aspects. However, the contents of the report are on similar lines to those as mentioned in the pre-feasibility report.

What are key design considerations for water supply system?

a. Design Considerations

The basic design considerations require specifying area to be covered and population to be served, design period for the water supply system, per capita water supply envisioned, assessment of water needs other than domestic use, sources of water supply and location of these facilities, utilization of existing treatment infrastructure, points of water intake and wastewater disposal.

b. Water Quality and Quantity

The quality of water from source may vary in terms of quality and quantity, therefore water projects should have measures to mitigate the variations in water availability by provision of storage that can be brought to use during peak demand periods. Variations in water quality may be handled at water treatment plants through suitable modifications.

c. Water Conservation

Increase in water demand owing to rapid urbanisation, growing commercial and industry is exerting enormous stress on easily extractable fresh water resources and also resulting in deteriorating quality. Ground water resources are being contaminated due to polluting industries and excessive abstraction. Same stands for surface water sources being subjected to domestic wastewater and industrial effluents. This necessitates application of advanced treatment processes that would impact the finances of the urban local body. An integrated approach for water management is need of the hour that should focus on following:

- increasing the water availability
 - augmentation of water resources by storing rainwater on surface (natural ponds, reservoirs, lakes, artificially created depressions, tanks) and subsurface storage (dykes, artificial recharge wells)
- water supply management
 - improvement in water supply by minimizing losses and wastage and unaccounted for water (UFW) mainly because of leakages in transmission mains and distribution systems. Wastage in water mains is due to corrosion, fractures, faulty joints, faulty connections, service pipes and fittings within the consumer's premises
 - another important source of wastage is by consumers – running water taps, replacing stored water by fresh water resulting in wastage of potable water, leakages in reservoirs and treatment plants usually not captured by normal metering systems
 - water transmission loss assessment in areas with intermittent supply can be done only for the water mains – 5-7% losses considered as satisfactory, 10-20% as unsatisfactory (actions advisable) and beyond 20% remedial measures are positively required.
 - Reduction in UFW could be achieved through detection and prevention of leakages, metering of water supplies, waste-not-taps and plan for repair and maintenance of distribution system
- Water demand management
 - Aims at reducing water demand through optimal utilisation for essential and desirable needs. It involves identification of practices/activities consuming water more than functional requirement.
 - Use of water saving fixtures like plumbing fixtures, low volume dual flushing cisterns, reuse of treated wastewater for non-potable purposes like flushing, irrigation, gardening, use in building construction, road cleaning etc. resulting in less pressure on fresh water sources

d. Design period for water supply schemes

The water supply projects are typically designed for 30 years. The gap between design period and completion of the scheme should not exceed 2-5 years. Land provisions should be made in the beginning for future expansions. The design period of key project components mentioned below:

Sl. No.	Items	Design period in years
1.	Storage by dams	50
2.	Infiltration works	30
3.	Pumping:	
	i. Pump house (civil works)	30
	ii. Electric motors and pumps	15
4.	Water treatment units	15
5.	Pipe connection to several treatment units and other small appurtenances	30
6.	Raw water and clear water conveying mains	30
7.	Clear water reservoirs at the head works, balancing tanks and service reservoirs (overhead or ground level)	15
8.	Distribution system	30

e. Design population for water supply scheme

The population forecast and accordingly the water demand is one of the most critical factor in designing of a water supply scheme. The project area and developments across industrial, commercial, education, social, administrative purposes and importantly daily migration and during festivals needs to be factored in the designing of scheme. In-depth understanding of the water users profile would help in adopting appropriate method to arrive at the population growth trends within the project area. There are various methods for population forecasting as follows:

Demographic method of population projection

The method takes into consideration the existing and anticipated birth and death rates of the region or city for the period under consideration. An estimate of emigration and immigration to the city, growth of city wise area, and net increase in population is calculated accordingly by arithmetical balancing

Arithmetical increase method

Method applicable to large and old cities. Involves calculating average population increase from last decade and adding to present population to estimate population for the next decade. Ideally suitable for well-settled and established communities

Incremental increase method

In this method increment in arithmetical increase in population is determined from past decades and average of that increment is added to average increase. Generally, this method gives higher numbers than arithmetical increase method

Geometrical increase method

In this method the rate of growth in population in past decades and average of percentage increase is used to estimate future increment in population. Gives much higher values and suitable for growing towns/cities and having scope for vast expansion.

Similarly, there are other methods like decreasing rate of growth method, graphical method, graphical method based on single city, graphical method based on cities with similar growth pattern, logistic method and method of density.

Generally, while forecasting population growth one or more methods are used however the figures are finalised based on judgements on relative probabilities of population expansion within the project area according to the nature of development and also on existing and contemplated town planning regulations.

f. Per capita water supply

The water supply scheme should provide adequate supplies for

- Domestic needs – drinking, cooking, bathing, washing, flushing of toilets, gardening and individual air conditioning
- Institutional needs
- Public purposes – street washing, flushing of sewers, watering of public parks and green areas
- Industrial and commercial users
- Firefighting
- Livestock requirements and
- Unaccounted for water (UFW)

The factors affecting consumption across above uses are size of the project area (larger the size, higher the consumption), characteristic of urban population and standard of living (cities with larger proportion of people living in slums will have lower consumption than cities with people living in flats and bungalows), industries and commerce (industries are generally high water consumers), local climatic conditions (water usage in hot weather would be more than cold weather), water metering (consumption high in areas with flat rate being charged than where meters are installed).

Recommended per capita water supply as per the Code of Basic Requirements of Water Supply, drainage and Sanitation (IS: 1172-1983) and National Building Code as well is a minimum of 135 lpcd for residences provided with full flushing system excreta disposal.

Recommended per capita water supply for designing water supply schemes

Domestic and non-domestic needs

Sl. No.	Classification of towns/cities	Recommended Maximum Water Supply Levels (lpcd)
1.	Towns provided with piped water supply but without sewerage system	70
2.	Cities provided with piped water supply where sewerage system is existing/contemplated	135
3.	Metropolitan and Mega cities provided with piped water supply where sewerage system is existing/ contemplated	150

- Towns with water supply through stand posts – 40 lpcd to be considered
- Unaccounted for Water (UFW) to be limited to 15% in addition to the per capita supply
- Bulk supply for commercial, institutional and minor industries to be separately assessed

Institutional needs

Sl.No.	Institutions	Litres per head per day
1.	Hospital (including laundry)	
	(a) No. of beds exceeding 100	450 (per bed)
	(b) No. of beds not exceeding 100	340 (per bed)
2.	Hotels	180(per bed)
3.	Hostels	135
4.	Nurses' homes and medical quarters	135
5.	Boarding schools / colleges	135
6.	Restaurants	70(per seat)
7.	Air ports and sea ports	70
8.	Junction Stations and intermediate stations where mail or express stoppage (both railways and bus stations) is provided	70
9.	Terminal stations	45
10.	Intermediate stations (excluding mail and express stops)	45 (could be reduced to 25 where bathing facilities are not provided)
11.	Day schools / colleges	45
12.	Offices	45
13.	Factories	45 (could be reduced to 30 where no bathrooms are provided)
14.	Cinema, concert halls and theatre	15

In addition, provisions for fire-fighting demand and industrial needs to be considered while designing water supply schemes.

g. Water Quality

The key objective of the water works management is to ensure supplying of water free from pathogenic organisms, clear, palatable and free from undesirable taste and odour, free from minerals which could produce undesirable physiological effects.

Recommended guidelines for physical and chemical quality parameters

Sl. No.	Characteristics	*Acceptable	**Cause for Rejection
✓1.	Turbidity (NTU)	1	10
✓2.	Colour (Units on Platinum Cobalt scale)	5	25
✓3.	Taste and Odour	Unobjectionable	Objectionable
✓4.	pH	7.0 to 8.5	<6.5 or > 9.2
5.	Total dissolved solids (mg/l)	500	2000
6.	Total hardness (as CaCO ₃) (mg/l)	200	600
7.	Chlorides (as Cl) (mg/l)	200	1000
8.	Sulphates (as SO ₄) (mg/l)	200	400
9.	Fluorides (as F) (mg/l)	1.0	1.5
10.	Nitrates (as NO ₃) (mg/l)	45	45
11.	Calcium (as Ca) (mg/l)	75	200
12.	Magnesium (as Mg) (mg/l)	≤ 30	150
If there are 250 mg/l of sulphates, Mg content can be increased to a maximum of 125 mg/l with the reduction of sulphates at the rate of 1 unit per every 2.5 units of sulphates			
13.	Iron (as Fe) (mg/l)	0.1	1.0
14.	Manganese (as Mn) (mg/l)	0.05	0.5
15.	Copper (as Cu) (mg/l)	0.05	1.5
16.	Aluminium (as Al) (mg/l)	0.03	0.2
17.	Alkalinity (mg/l)	200	600
18.	Residual Chlorine (mg/l)	0.2	>1.0
19.	Zinc (as Zn) (mg/l)	5.0	15.0
20.	Phenolic compounds (as Phenol) (mg/l)	0.001	0.002
21.	Anionic detergents (mg/l) (as MBAS)	0.2	1.0
22.	Mineral Oil (mg/l)	0.01	0.03
TOXIC MATERIALS			
23.	Arsenic (as As) (mg/l)	0.01	0.05
24.	Cadmium (as Cd) (mg/l)	0.01	0.01
25.	Chromium (as hexavalent Cr) (mg/l)	0.05	0.05
26.	Cyanides (as CN) (mg/l)	0.05	0.05
27.	Lead (as Pb) (mg/l)	0.05	0.05
28.	Selenium (as Se) (mg/l)	0.01	0.01
29.	Mercury (total as Hg) (mg/l)	0.001	0.001
30.	Polynuclear aromatic hydrocarbons (PAH) (µg/l)	0.2	0.2
31.	Pesticides (total, mg/l)	Absent	Refer to WHO guidelines for drinking water quality Vol 1. – 1993
RADIO ACTIVITY+			
32.	Gross Alpha activity (Bq/l)	0.1	0.1
33.	Gross Beta activity (Bq/l)	1.0	1.0

3. Urban Wastewater Management¹

This section serves as a guide for city managers to plan for appropriate sewage/septage collection, treatment and disposal system as per the service standards and discharge norms without causing any health or environmental concerns. The planning can be broadly divided into three-time phases: short term, mid-term and long-term planning.

The short-term planning can look at immediate provision of on-site system (non-sewered sanitation). This could be either aimed at safe containment of faecal matter or treatment at source. Examples of on-site system are pit latrines, aqua-privies, septic tank with soak pit etc. The on-site treatment could be through bio-digesters, twin-pit toilets, household level decentralised wastewater treatment system (DEWATS). Short term actions are usually designed for a period of 5 years from the base period and is an interim arrangement until the execution of long term plan.

The mid-term planning can look at provision of decentralised (non-conventional) approaches of collection, conveyance, treatment and reuse/disposal of wastewater to avoid sewage discharges into open environment, in areas where conventional sewerage systems are not possible to implement. Decentralised sanitation systems includes collection and conveyance of wastewater through simplified sewerage systems (settled sewer/small bore) and treatment through small scale decentralised wastewater treatment systems at household/community level. Medium term plans should have a target of 15 years from the base year.

The long-term plan looks at conventional approaches of wastewater management through centralised collection, transportation, treatment and disposal/reuse in environmentally safe manner. It encompasses the short and mid-term plan ultimately leading to 100% population coverage and formulated for a period of 30 years from the base year.

The section discusses framework for planning conventional wastewater management.

How to plan wastewater management system?

The City Sanitation Plan (CSP) as per the guidelines in National Urban Sanitation Policy (NUSP), 2008 forms the basis for planning of wastewater management projects in urban areas. The management could be a combination of approaches like conventional sewerage system, decentralised wastewater management systems or on-site sanitation (refer decision making matrix on next page).

The CSP should ideally have actions defined towards

- Elimination of Open Defecation
- Conversion of insanitary toilets to sanitary ones
- Retrofitting of on-site containment/treatment structures like septic tanks as per recommended specifications

¹ This section is extensively sourced from Manual on Sewerage and Sewage Treatment Systems – 2013, CPHEEO

- In areas where water supply is inadequate, provision for decentralised wastewater management system including treatment and non-conventional sewers (settled or simplified sewers/small bore sewers)
- Faecal sludge and septage management in areas dependent on on-site sanitation in the form of leach pits, twin pits, septic tanks with/without soak pits etc. – desludging of containment units, transportation, treatment and reuse/disposal
- Mechanisation of cleaning of sewers and emptying of septic tanks, safety gear for sanitation workers
- Planning for conventional sewerage system in areas with a minimum of 135 lpcd water supply or where contemplated
- Plan for recycling and reuse of treated wastewater and sludge
- Provision of public toilets with appropriate containment/treatment systems

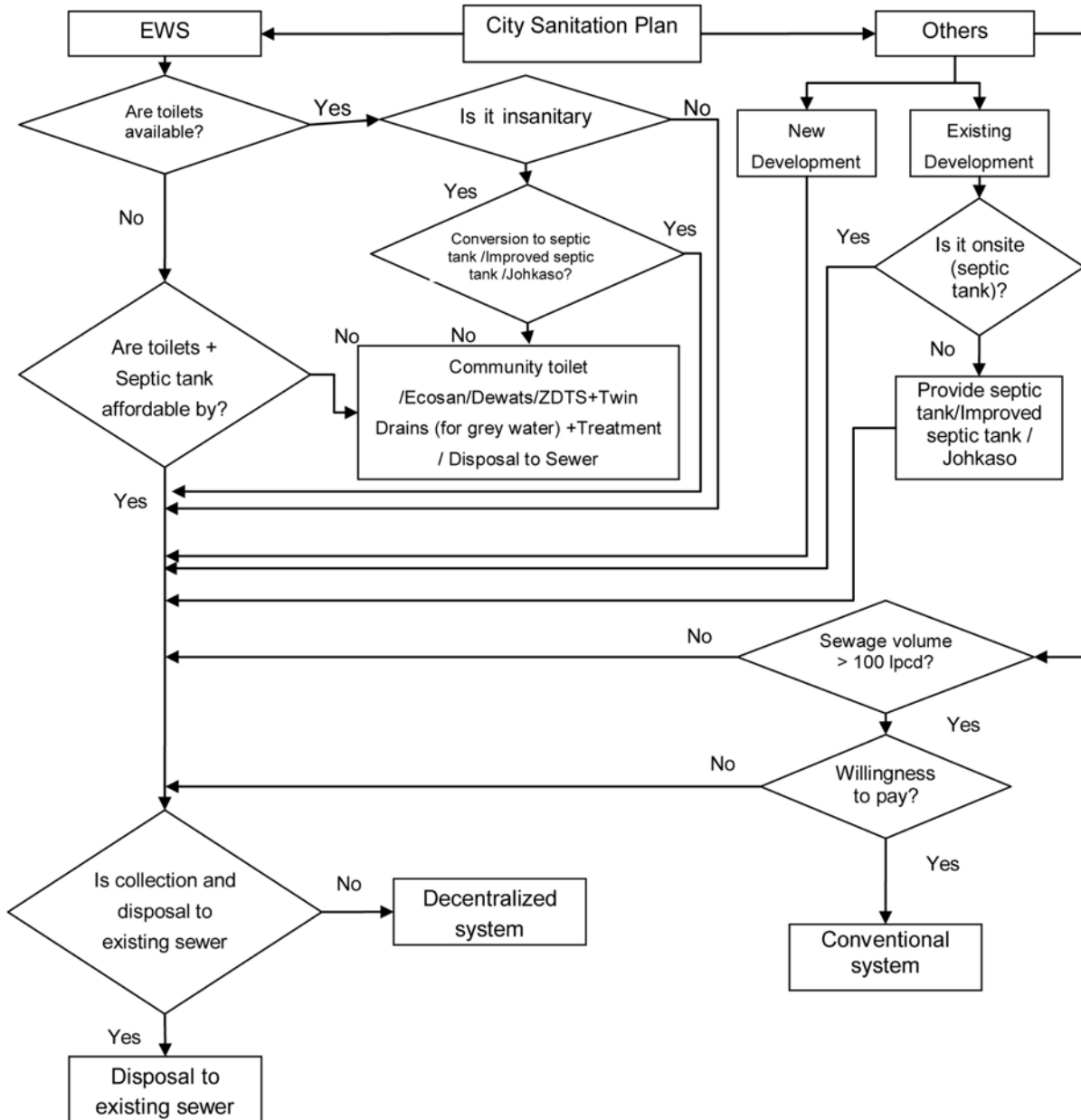
Planning for wastewater should also consider looking at sector plan for solid waste management and storm water drainage system as both would have influence on the performance of wastewater management systems envisaged within the project area.

3.1. Project Planning - Stages

The process of preparation of a sewerage project follows the same framework as mentioned for an Urban Water Supply project. Refer sections 2.1.1, 2.1.2 and 2.1.3 for the same.

Refer next page for decision tree for selection of appropriate technical option for wastewater management in urban areas.

Decision tree for selection of appropriate technical option



3.2. Design Considerations for Sewerage System

3.2.1. Estimation of Design Flows

Design Period

The time duration for which the capacity of the sewer will suffice is referred to as the design period. The design period should be fixed considering the life of structures and equipment deployed, and regular wear and tear. The sewage flow volumes are largely a function of the population served, population density and water consumption. The collection systems are usually designed for peak flows of the population at saturation density as mentioned in the master plan of the project area. Trunk sewers, interceptors, and outfalls are difficult and uneconomical to be extended and duplicated, hence designed for longer design periods. The right of way for future laying of trunk sewers should be acquired and reserved. The

recommended design period for various components of the collection system is mentioned below:

Sl. No	Component	Design Period, Years (from base year)
1	Land Acquisition	30 years or more
2	Conventional sewers (A)	30
3	Non-conventional sewers (B)	15
4	Pumping mains	30
5	Pumping Stations-Civil Work	30
6	Pumping Machinery	15
7	Sewage Treatment Plants	15
8	Effluent disposal	30
9	Effluent Utilization	15 or as the case may be
(A) Typical underground sewers with manholes laid in the roads (B) All types such as small bore, shallow sewers, pressure sewers, vacuum sewers		

Population forecast

Refer section on “Design population for water supply scheme” under water supply project (earlier in this document)

In cases wherein, a master plan containing land use pattern and zoning regulations is available for the town, the anticipated population can be based on the ultimate densities and permitted floor space index provided for in the master plan. In the absence of such information on population, the following densities are suggested for adoption:

Densities of Population vs. Populated areas

Size of town (Population)	Density of population per hectare
Up to 5,000	75-150
Above 5,001 to 20,000	150-250
Above 20,001 to 50,000	250-300
Above 50,001 to 1,00,000	300-350
Above 1,00,001	350-1,000

In cities where Floor Space Index (FSI) or Floor Area Ratio (FAR) limits are fixed by the local authority this approach may be used for working out the population density. The FSI or FAR is the ratio of total floor area (of all the floors) to the plot area.

Tributary Area

The natural topography, layout of buildings, political boundaries, economic factors etc., determine the tributary area. For larger drainage areas, though it is desirable that the sewer capacities be designed for the total tributary area, sometimes, political boundaries and legal

restrictions prevent the sewers to be constructed beyond the limits of the local authority. The need to finance projects within the available resources necessitates the design to be restricted to political boundaries.

Per capita sewage flow

The entire quantum of water consumed by the population within the project area should normally contribute to the total flow in a sanitary sewer. However, the wastewater flows are slightly less than the water consumption, since some water is lost in evaporation, seepage into ground, leakage etc. In arid regions, mean sewage flows may be as little as 40% of water consumption and in well developed areas; flows may be as high as 90%. However, the conventional sewers shall be designed for a minimum sewage flow of 100 litres per capita per day or higher as the case may be.

The industries and commercial buildings often use water other than the municipal supply and may discharge their liquid wastes into the sanitary sewers. Estimates of such flows have to be made as per table below.

No.	Institutions	Water Supply (litres)
1	Hospital including laundry and beds exceeding 100	450 per bed
2	Hospital including laundry and beds not exceeding 100	340 per bed
3	Lodging houses / hotels	180 per bed
4	Hostels	135 lpcd
5	Nurses homes and medical quarters	135 lpcd
6	Boarding schools/colleges	135 lpcd
7	Restaurants	70 per seat
8	Airports and Seaports, duty staff	70 lpcd
9	Airports and Seaports, alighting and boarding persons	15 lpcd
10	Train and Bus stations, duty staff	70 lpcd
11	Train and Bus stations, alighting and boarding persons	15 lpcd
12	Day schools/colleges	45 lpcd
13	Offices	45 lpcd
14	Factories, duty staff	45 lpcd
15	Cinema, concert halls and theatres	15 lpcd

The mixing of industrial effluents through discharge into public sewers is undesirable due to the possible detrimental effects of such effluent on the operation of biological sewage treatment process. This aspect has been well recognized in recent times and industrial areas having polluting industries are generally located such as to avoid mixing with sewage. However, in cities that have undergone unregulated growth in the past, polluting industries may exist in pockets of mixed land use. In such cases, those industries are required to implement zero liquid discharge (ZLD) by reusing the effluents after appropriate treatment in house. Of all the industries, this shall strictly apply to the automobile service stations and machine shops from where the spent metal plating baths and oil & grease shall be prevented from entering the sewers.

Storm runoff

The sanitary sewers are expected to carry only domestic wastewater. However, in most of the urban areas, storm water finds its way into sewers. Strict inspection, vigilance, and proper design and construction of sewers and manholes is required to eliminate this flow or bring it down to a very insignificant quantity. However, in small habitations where rainfall is almost a continuous affair, it may be necessary to include storm water in the design of sewers.

Estimation of Storm Runoff

The storm runoff is that portion of the precipitation, which drains over the ground. Estimation of such runoff reaching the storm sewers therefore is dependent on the intensity, duration of precipitation, characteristics of the tributary area, and the time required for such flow to reach the sewer. The design of storm water sewers begins with an estimate of the rate and volume of surface runoff.

A rational approach for estimating storm runoffs is to study the existing precipitation data of the area for doing a suitable forecast. Storm sewers are not designed for the peak flow of rare occurrence such as once in 10 years or more, but it is necessary to provide sufficient capacity to avoid too frequent flooding of the drainage area. The maximum runoff, which has to be carried in a sewer section should be computed for a condition when the entire basin draining at that point becomes contributory to the flow and the time needed for this is known as the time of concentration (with reference to the concerned section). Thus, for estimating the flow to be carried in the storm sewer, the intensity of rainfall which lasts for the period of time of concentration is the one to be considered contributing to the flow of storm water in the sewer.

3.2.2. Types of sewers

There are different types of collection system:

Separate Sewers

These sewers receive domestic sewage and such industrial wastes pre-treated to the discharge standards as per the Environment Protection Act 1986. The consent to discharge into sewers are given by the local pollution control administration.

Combined Sewers

These sewers receive storm water in addition to the domestic wastewater. This collection system has some advantages in areas with intermittent rainfall occurring throughout the year and with a terrain that permits collection of same by gravity. As otherwise, in regions of seasonal rainfall like in monsoons, the combined system will have serious problems in achieving self-cleansing velocities during dry seasons and necessitating complicated egg-shaped sewers etc. to sustain velocities at such times, plus the treatment plant to be designed to manage strong sewage in dry season and dilute sewage in monsoon season as also the hydraulics. These sewers are also ideally suited for resorts and private development.

Pressurized Sewers

Pressurized sewers are for collecting sewage from multiple sources to deliver to an existing collection sewer, and/or to the STP and are not dependent on gravity and thus topography is not a challenge. The principle advantages are the ability to sewer areas with undulating terrain, rocky soil conditions and high groundwater tables as pressurized sewers can be laid close to the ground. An important issue is for each plot to have a grinder pump set and each commercial plot to have its own grease interceptors to remove excessive fats, oils & grease before the grinder pump. A disadvantage is the need to ensure unfailing power supply to the grinder pump and hence this is perhaps limited to high profile condominiums and not the public sewer systems in India.

Vacuum Sewer System

The vacuum sewer collects sewage from multiple sources and conveys it to the STP. As the name suggests, a vacuum is maintained in the collection system and when a house sewer is opened to atmospheric pressure, sewage and air are pulled into the sewer, whereby the air forms a “plug” in the line, and air pressure pushes the sewage toward the vacuum station. This differential pressure comes from a central vacuum station. These sewers can take advantage of available slope in the terrain, but have a limited capacity to pull water uphill may be to some 9 m. A disadvantage is the need to ensure unfailing power supply to the vacuum pump and hence this is perhaps limited to high profile condominiums and not the public sewer systems in India.

3.2.3. Design of sewer networks

The designing of sewer networks requires accurate information regarding site conditions. This includes:

- Site plan - A plan of the site to scale with topographical levels, road formation levels, level of the outfall, location of wells, underground sumps and other drinking water sources
- The requirements of local bye-laws
- Subsoil conditions - Subsoil conditions govern the choice of design of the sewer and the method of excavation
- Location of other services (such as position, depth and size of all other pipes, mains, cables, or other services, in the vicinity of the proposed work)
- Topography

The designing of sewer system as part of the overall sewerage project starts with preliminary survey with the anticipation of future growth in any community in terms of population or commercial and industrial expansion. The anticipated population, its density and its wastewater generation is generally estimated for a specified planning period which usually recommended is 30 years. The prospective disposal sites are selected and their suitability is evaluated with regard to physical practicability for collection of sewage, effects of its disposal on surrounding environment and cost involved.

The preliminary survey is followed by detailed survey that looks into presence of rock or underground obstacles such as existing sewers, water lines, electrical or telephone wires,

tunnels, foundations, etc., have significant effect upon the cost of construction. Therefore, before selecting the final lines and grades for sewers necessary information regarding such constructions is collected from various central and state engineering departments. Besides the location of underground structure, a detailed survey regarding the paving characteristics of the streets, the location of all existing underground structures, the location and basement elevations of all buildings, profile of all streets through which the sewer will run, elevations of all streams, culverts and ditches, and maximum water elevations therein are also made. The above details are noted on the map. The scale of the map may vary depending upon the details desired. It is recommended to adopt the following scales for various plans and drawings depending upon the detailed information desired.

Index Plan - 1 : 100,000 or 1 : 200,000

Key Plan and general layout - 1 : 10,000 or 1 : 20,000

Zonal Plans - 1 : 2,500 or 1 : 5,000

Longitudinal sections of sewers - 1 : 500 or 1 : 2,250 or 1 : 2,500

Structural drawings - 1 : 20 or 1 : 50 or 1 : 100 or 1 : 200

3.2.4. Layout of System

The sewer system layout involves the following steps:

- a. Selection of an outlet or disposal point
- b. Prescribing limits to the drainage valley or Zonal Boundaries
- c. Location of Trunk and Main Sewers
- d. Location of Pumping Stations if found necessary

In general, the sewers will slope in the same direction as the street or ground surface and will be connected to trunk sewers. The discharge point may be a treatment plant or a pumping station or a water course, a trunk sewer or intercepting sewer. It is desirable to have discharge boundaries following the property limits. The boundaries of sub zones are based on topography, economy or other practical consideration. Trunk and main sewers are located in the valleys. The most common location of sanitary sewer is in the centre of the street. A single sewer serves both sides of the street with approximately same length for each house connection.

3.2.5. Designing of Sewage Treatment Plants

3.2.5.1. Sewage characteristics

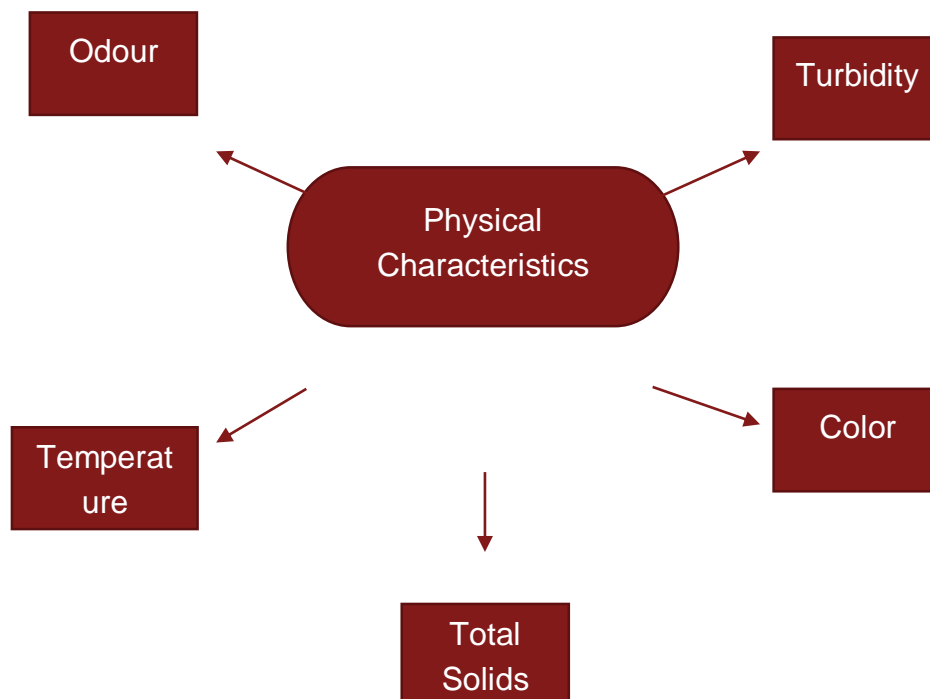
Sewage consists of various residential, public and industrial mixtures of wastewater, which contains organic and inorganic materials in dissolved or suspended or colloidal form as well as microorganisms useful and harmful to life.

Characterization and examination of sewage is a must before designing any sewage treatment plant to work efficiently.

The characteristics of sewage are classified as

- Physical characteristics
- Chemical characteristics
- Biological characteristics

Physical characteristics



Color

Color of the sewage is due to the suspended and other matter found in the wastewater. Fresh sewage has a soap solution color i.e. grey-brown color whereas the decomposed sewage has dark grey color.

Odour

Fresh sewage is of soapy-oily odour but stale sewage has offensive odour due to the release of hydrogen sulphide (H₂S) and methane (CH₄).

Temperature

The wastewater temperature is commonly higher than that of local water supplies. Temperature affects chemical reactions, reaction rates, aquatic life, and the suitability for beneficial uses. Furthermore, oxygen is less soluble in warm than in cold water. The wastewater temperature is commonly higher than that of local water supplies. Temperature affects chemical reactions, reaction rates, aquatic life, and the suitability for beneficial uses. Furthermore, oxygen is less soluble in warm than in cold water. (Temperature ~ 40 °C)

Turbidity

Sewage is generally more turbid than water due to the presence of suspended particles in it.

Solids

Solids can be classified into various categories depending upon the size of the particles.

- TS- Total Solids
- TSS-Total Suspended Solids

If the particle size is very small if it is completely dissolved in the solution we can call it as dissolved solids. If the particle size is in between 0.01 micrometre to 1 micrometre, they are colloidal solids. These colloidal solids are very stable that means they will not be settling down in the liquid or water so they will always be in that Brownian motion, so it is very difficult to remove them especially from water and wastewater.

Suspended solids are those solids that do not pass through a 0.2-um filter. About 70% of those solids are organic, and 30% are inorganic. The inorganic fraction is mostly sand and grit that settles to form an inorganic sludge layer. Total suspended solids comprise both settleable solids and colloidal solids. Settleable solids will settle in an Imhoff cone within one hour, while colloidal solids (which are not dissolved) will not settle in this period. Suspended solids are easily removed by settling and/or filtration. However, if untreated wastewater with a high suspended solids content is discharged into the environment, turbidity and the organic content of the solids can deplete oxygen from the receiving water body and prevent light from penetrating.

Chemical Characteristics

Sewage contains complex compounds derived from urine, faeces and inorganic compounds.

pH

The acidity or alkalinity of wastewater affects both treatment and the environment. Low pH indicates increasing acidity, while a high pH indicates increasing alkalinity (a pH of 7 is neutral). The pH of wastewater needs to remain between 6 and 9 to protect organisms. Acids and other substances that alter pH can inactivate treatment processes when they enter

wastewater from industrial or commercial sources. Wastewater with an extreme concentration of hydrogen ions is difficult to treat biologically. If the concentration is not altered before discharge, the wastewater effluent may alter the concentration in natural waters, which could have negative effects on the ecosystem.

Alkalinity in wastewater results from the presence of calcium, magnesium, sodium, potassium, carbonates and bicarbonates, and ammonia hydroxides. Alkalinity in wastewater buffers (controls) changes in pH caused by the addition of acids.

Wastewater usually is alkaline due to the presence of groundwater (which has high concentrations of naturally occurring minerals) and domestic chemicals. The alkalinity of wastewater is essential where chemical and biological treatment is practiced, in biological nutrient removal and where ammonia is removed by air stripping.

Dissolved oxygen (DO)

It is the amount of oxygen dissolved in the waste water. Presence of it indicates that the sewage is fresh or oxidation has been occurring after the treatment. It is necessary to ensure that at least 4 ppm of DO in stream in which treated wastewater is being disposed.

BOD

Biochemical oxygen demand is defined as the amount of oxygen required by the bacteria to oxidize the organic matter present in the sewage.

COD

Chemical oxygen demand is the total measurement of all chemicals in the water that can be oxidized.

Biological Characteristics

Many disease-causing viruses, parasites, and bacteria also are present in wastewater and enter from almost anywhere in the community. These pathogens often originate from people and animals who are infected with or are carriers of a disease.

For example, greywater and blackwater from typical homes contain enough pathogens to pose a risk to public health. Other likely sources in communities include hospitals, schools, farms, and food processing plants

- TC (MPN) Total coliforms, most probable number
- FC (MPN) Fecal coliforms, most probable number

Pathogenic organisms present in wastewater can transmit communicable diseases. The presence of specific monitoring organisms is tested to gauge plant operation and the potential for reuse. Coliform bacteria include genera that originate in feces (e.g. Escherichia) as well as the genre not of fecal origin (e.g. Enterobacter, Klebsiella, Citrobacter). The assay is intended to be an indicator of fecal contamination; more specifically of E. coli which is an indicator microorganism for other pathogens that may be present in feces. Presence of fecal coliforms in water may not be directly harmful and does not necessarily indicate the presence of feces.

Table 1 Constituents of domestic wastewater

Constituent (mg/L)	Strong	Medium	Weak
Total Solids	1200	700	350
Dissolved solids (TDS)	850	500	250
Suspended solids	350	200	100
Nitrogen (as N)	85	40	20
Phosphorous (as P)	20	10	6
Chloride	100	50	30
Alkanility (as CaCO ₃)	200	100	50
Grease	150	100	50
BOD ₅	300	200	100

Discharge norms

According to the CPCB report of 2017, the following are the discharge norms of wastewater

Table 2 Effluent discharge limits as per CPCB report 2017

Parameter	Standards			
	Inland Surface water	Public sewers	Land for irrigation	Marine coastal area
Temperature	Shall not exceed 5°C above the receiving water temperature	-	-	Shall not exceed 5°C above the receiving water temperature
Ammonical Nitrogen as N (mg/L)	50	50	-	50
Total Kjeldahl Nitrogen, as NH ₃ , (mg/L)	100	-	-	100
Free Ammonia, as NH ₃ , (mg/L)	5	-	-	5

Parameter	Standards			
	Inland Surface water	Public sewers	Land for irrigation	Marine coastal area
Biochemical Oxygen demand, 3 days at 27°C, (mg/L)	30	350	100	100
Chemical Oxygen demand (mg/L)	250	-	-	250

However, as per Ministry of Environment, Forest and Climate change notification, 13th October, 2017:

Parameters	Location	Concentration not to exceed (mg/L)
Bio-chemical Oxygen Demand (BOD)	Metro Cities*, all State Capitals except in the State of Arunachal Pradesh, Assam, Manipur, Meghalaya Mizoram, Nagaland, Tripura Sikkim, Himachal Pradesh, Uttarakhand, Jammu and Kashmir, and Union territory of Andaman and Nicobar Islands, Dadar and Nagar Haveli Daman and Diu and Lakshadweep.	20
	Areas/regions other than mentioned above	30
Total Suspended Solids (TSS)	Metro Cities*, all State Capitals except in the State of Arunachal Pradesh, Assam, Manipur, Meghalaya Mizoram, Nagaland, Tripura Sikkim, Himachal Pradesh, Uttarakhand, Jammu and Kashmir, and Union territory of Andaman and Nicobar Islands, Dadar and Nagar Haveli Daman and Diu and Lakshadweep.	<50
	Areas/regions other than mentioned above	<100

*Metro Cities are Mumbai, Delhi, Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad and Pune.

Notes:

(i) All values in mg/l except for pH and Fecal Coliform.

(ii) These standards shall be applicable for discharge into water bodies as well as for land disposal/applications.

(iii) The standards for Fecal Coliform shall not apply in respect of use of treated effluent for industrial purposes.

(iv) These Standards shall apply to all STPs to be commissioned on or after the 1st June, 2019 and the old/existing STPs shall achieve these standards within a period of five years from date of publication of this notification in the Official Gazette.

(v) In case of discharge of treated effluent into sea, it shall be through proper marine outfall and the existing shore discharge shall be converted to marine outfalls, and in cases where the marine outfall provides a minimum initial dilution of 150 times at the point of discharge and a minimum dilution of 1500 times at a point 100 meters away from discharge point, then, the existing norms shall apply as specified in the general discharge standards.

(vi) Reuse/Recycling of treated effluent shall be encouraged and in cases where part of the treated effluent is reused and recycled involving possibility of human contact, standards as specified above shall apply.

(vii) Central Pollution Control Board/State Pollution Control Boards/Pollution Control Committees may issue more stringent norms taking account to local condition under section 5 of the Environment (Protection) Act, 1986”.

3.3. Sewage treatment approach:

Why treatment is needed?

Sewage is wastewater from domestic activities such as cooking, cleaning, laundry or bathing. Exposure to sewage through ingestion or bodily contact can result in disease, severe illness, and in some instances death from the bacteria, viruses and parasites contained in the waste. Therefore, it is important for sewage to be properly treated.

Below are some technologies that can be used to treat the sewage. These technologies are classified under mechanized and non-mechanized treatment options.

3.4. Treatment technologies:

3.4.1. Mechanized treatment options

3.4.1.1. Upflow Anaerobic Sludge Blanket reactor (UASB)

The Upflow Anaerobic Sludge Blanket reactor (UASB) is a single tank process. Wastewater enters the reactor from the bottom and flows upward. Suspended sludge blanket filters and treats the wastewater as the wastewater flows through it. The sludge blanket comprises of microbial granules (1 to 3mm in diameter), i.e., small agglomerations of microorganisms that, because of their weight, resist being washed out in the upflow. The microorganism in the sludge blanket degrades organic compounds. As a result, gases like methane and carbon dioxide are released. The rising bubbles mix the sludge without the assistance of any

mechanical parts. Sloped walls deflect material that reaches the top of the tank downwards. The clarified effluent is extracted from the top of the tank in an area above the sloped walls.

After several weeks of use, larger granules of sludge form which, in turn, act as filters for smaller particles as the effluent rises through the cushion of sludge. Because of the upflow regime, granule-forming organisms are preferentially accumulated as the others are washed out. UASB is not appropriate for small or rural communities without constant water supply or electricity. The technology is relatively simple to design and build, but developing the granulated sludge may take several months. The UASB reactor has the potential to produce higher quality effluent than Septic Tanks and can do so in a smaller reactor volume. Although it is a well-established process for large-scale industrial wastewater treatment and high organic loading rates up to 10 kg BOD/m³/d, its application to domestic sewage is still relatively new.

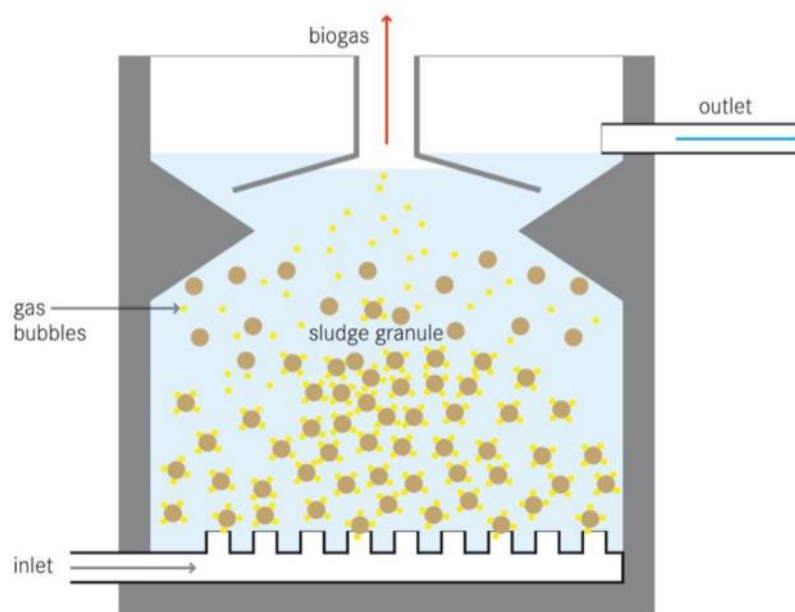


Figure 1 Schematic diagram of a UASB reactor.

Capacity/Adequacy	Centralized or decentralized at community level, for industrial wastewater or blackwater. The system requires a continuous and stable water flow and energy.
Performance	60 to 90 % BOD; 60 to 80 % COD and 60 to 85 % TSS; low pathogen reduction minimal removal of nutrient (N and P) HRT: minimal 2 hours, generally 4 to 20 hours
Costs	Investment is comparable to baffled reactors. For operation usually no costs arise beneath desludging costs and operation of feeding pump.

Self-help Compatibility	Can be constructed with locally available material but requires skilled staff for construction, maintenance and operation.
O&M	Desludging is not frequent but feeder pump and control of organic loads requires skilled staff for operation and maintenance.
Reliability	Not resistant to shock loading and sensitive to organic load fluctuations.
Main strength	High removal of organics and solids (BOD and TSS) with low production of sludge and the possibility to recover biogas; only little land required.
Main weakness	Requires skilled staff, electricity and is sensitive to variable flows.

3.4.1.2. Activated Sludge Process (ASP)

An activated sludge process refers to a multi-chamber reactor unit that makes use of highly concentrated microorganism to degrade organics and remove nutrients from the wastewater to produce high quality effluent. To maintain the aerobic conditions and keep the activated sludge suspended, a continuous and well-timed supply of oxygen is required.

Different configurations of the activated sludge process can be employed to ensure that the wastewater is mixed and aerated in an aeration tank. Aeration and mixing can be provided by pumping air or oxygen into the tank or by using surface aerators. The microorganisms oxidise the organic carbon in the wastewater to produce new cells, carbon dioxide and water. Although aerobic bacteria are the most common organisms, facultative bacteria along with higher organisms can be present. The exact composition depends on the reactor design, environment, and wastewater characteristics. An activated sludge process is only appropriate for a Centralized Treatment facility with a well-trained staff, constant electricity and a highly developed management system that ensures that the facility is correctly operated and maintained.

Because of economies of scale and less fluctuating influent characteristics, this technology is more effective for the treatment of large volumes of flows. An activated sludge process is appropriate in almost every climate. However, treatment capacity is reduced in colder environments.

The flocs (agglomerations of sludge particles), which form in the aerated tank, can be removed in the secondary clarifier by gravity settling. Some of this sludge is recycled from the clarifier back to the reactor. The effluent can be discharged into a river or treated in a tertiary treatment facility if necessary, for further use.

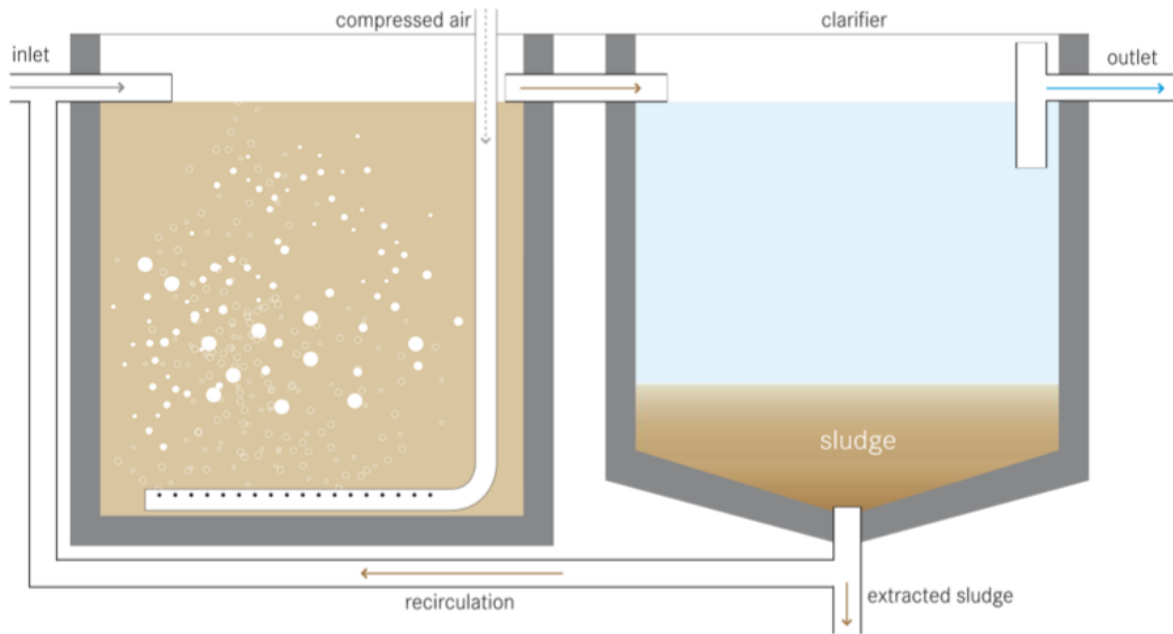


Figure 2 Schematic diagram of an activated sludge process. (Source: EAWAG, 2005)

Capacity/Adequacy	High-tech centralized system, not adapted for small communities. Almost every wastewater can be treated as long as it is biodegradable. Usually applied in densely populated areas for treatment of domestic wastewater.
Performance	80 to almost 100% BOD and TSS removal. High nitrogen removal. P accumulated in biomass and sludge. Low pathogen removal. HRT of some hours up to several days
Costs	Very high construction and maintenance costs; operation very expensive due to requirement of permanent professional operation, high electricity consumption and costly mechanical parts.
Self-help Compatibility	System parts not locally available; implementation only possible by experienced consultant firms.
O&M	Activated sludge units require professional operation and maintenance providers.
Reliability	Fails in case of power failure or fall-out of technical equipment.
Main strength	High removal efficiency for large range of wastewaters.

Main weakness	Highly mechanized system requiring expert design, operation and maintenance as well as mechanical spare parts. Large energy requirements (e.g. for aeration).
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3.4.1.3. Trickling filter

A trickling filter is a fixed-bed, biological reactor that operates under (mostly) aerobic conditions. Pre-settled wastewater is continuously 'trickled' or sprayed over the filter. As the water migrates through the pores of the filter, organics are [no- compendium] aerobically [no- compendium] degraded by the biofilm covering the filter material.

The trickling filter is filled with a high specific surface area material, such as rocks, gravel, shredded PVC bottles, or special pre-formed plastic filter media. A high specific surface provides a large area for biofilm formation. Organisms that grow in the thin biofilm over the surface of the media oxidize the organic load in the wastewater to carbon dioxide and water, while generating new biomass.

The incoming pre-treated wastewater is 'trickled' over the filter, e.g., with the use of a rotating sprinkler. In this way, the filter media goes through cycles of being dosed and exposed to air. However, oxygen is depleted within the biomass, and the inner layers may be anoxic or anaerobic.

This technology can only be used following primary clarification since high solids loading will cause the filter to clog. A low-energy (gravity) trickling system can be designed, but in general, a continuous supply of power and wastewater is required.

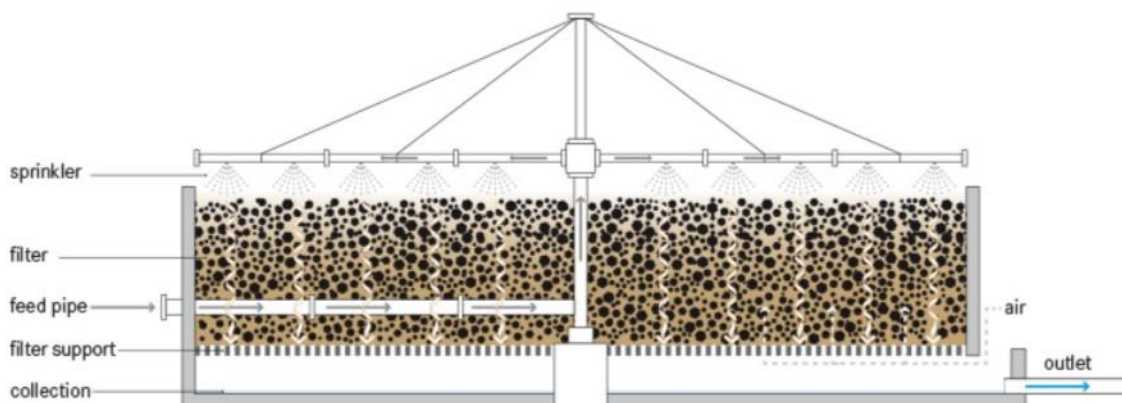


Figure 3 Schematic diagram of a trickling filter. (Source: EAWAG,2005)

Capacity/Adequacy	Semi-centralised to centralised. The system is usually applied in urban areas for treatment of domestic wastewater. It can be applied for bigger and smaller communities.
Performance	BOD: 65 to 90 %. Low TSS removal. Total Coliforms: 1 to 2 log units N: 0 to 35%. P: 10 to 15 %.
Costs	Medium; investment costs depend on type of filter materials and feeder pumps used; operational costs determined by electricity consumption of feeder pumps.
Self-help Compatibility	Low. Design, planning and implementation by expert consultants; no community labour contribution possible; feeder pumps required; permanent staff required for operation.
O&M	Civil engineer needed for construction, professional service providers required
Reliability	Resistant to shock loadings but the systems do not work during power failures.
Main strength	High treatment efficiency with lower area requirement compared to wetlands or ponds; resistant to shock loading.
Main weakness	Requires expert skills, pumps and continuous electrical power, as well as ample and continuous wastewater flow required

3.4.1.4. Sequential Batch Reactor (SBR)

The Sequencing Batch Reactor (SBR) is a different configuration of the conventional activated sludge systems, in which the process can be operated in batches, where the different conditions are all achieved in the same reactor but at different times. The treatment consists of a cycle of five stages: fill, react, settle, draw and idle. During the reaction type, oxygen is added by an aeration system. During this phase, bacteria oxidise the organic matter just as in activated sludge systems. Thereafter, aeration is stopped to allow the sludge to settle. In the next step, the water and the sludge are separated by decantation and the clear layer (supernatant) is discharged from the reaction chamber

At least two tanks are needed for the batch mode of operation as continuous influent needs to be stored during the operation phase. Small systems may apply only one tank. In this case, the influent must either be retained in a pond or continuously discharged to the bottom of the tank in order not to disturb the settling, draw and idle phases. SBRs are suited to lower flows, because the size of each tank is determined by the volume of wastewater produced during the treatment period in the other tank

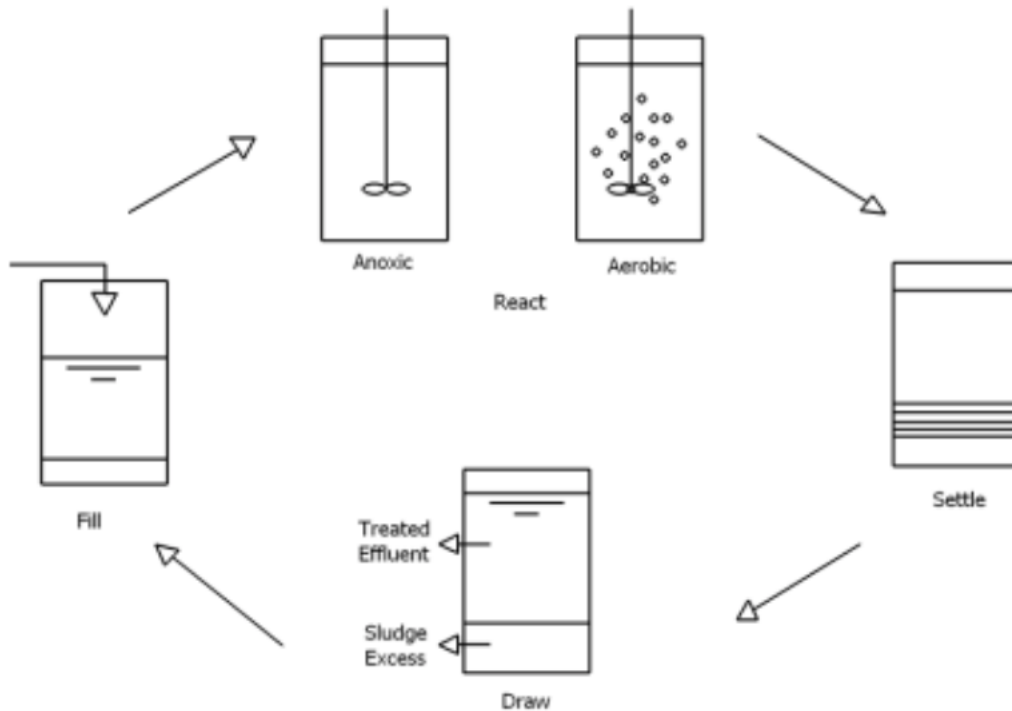


Figure 4 Schematic process diagram of SBR

3.4.1.5. Membrane Bio Reactor (MBR)

Membrane Bioreactors (MBR) are treatment processes, which integrate a perm-selective or semi-permeable membrane with a biological process (JUDD 2011). It is the combination of a membrane process like microfiltration or ultrafiltration with a suspended growth bioreactor, and is now widely used for municipal and industrial wastewater treatment with plant sizes up to 80'000 population equivalents. Due to it being a very technical solution; it needs expert design and skilled workers. Furthermore, it is a costly but efficient treatment possibility. With the MBR technology, it is possible to upgrade old wastewater plants.

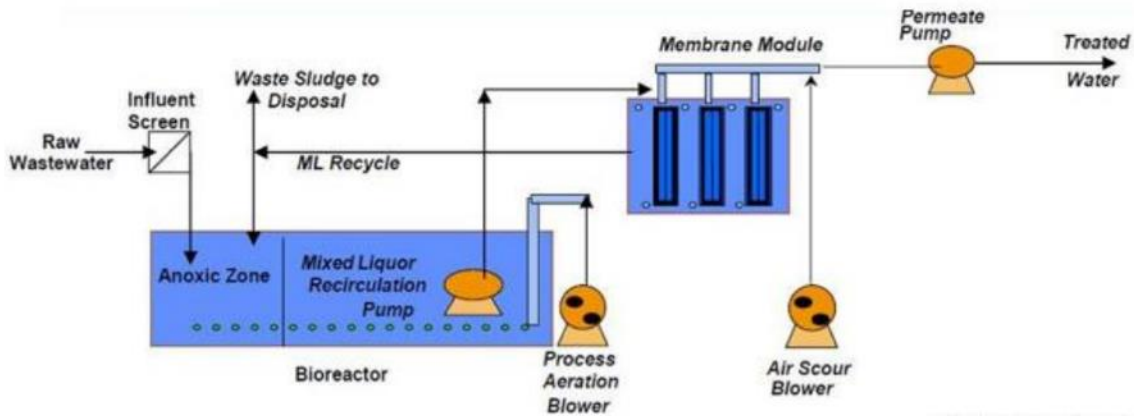


Figure 5 Schematic process diagram for MBR. (Source: Fitzgerald,2008)

Capacity/Adequacy	Applicable in conventional wastewater plants.
Performance	High
Costs	High capital and operational costs.
Self-help Compatibility	Low
O&M	Membranes need to be cleaned regularly.
Reliability	High if membranes are maintained correctly.
Main strength	Secondary clarifiers and tertiary filtration processes are eliminated, thereby reducing plant footprint.
Main weakness	High operation and capital costs (membranes).

3.4.2. Non-mechanized treatment options

3.4.2.1. Anaerobic Baffle Reactor (ABR)

An Anaerobic Baffle Reactor (ABR) is mainly a small septic tank (settling tank) followed by a series of anaerobic tanks (at least three). Most of the solids are removed in the first and the largest tank. Effluent from first tank then flows through the baffle and is forced to flow up through activated sludge in the subsequent tanks. Each chamber provides increased removal and digestion of organics.

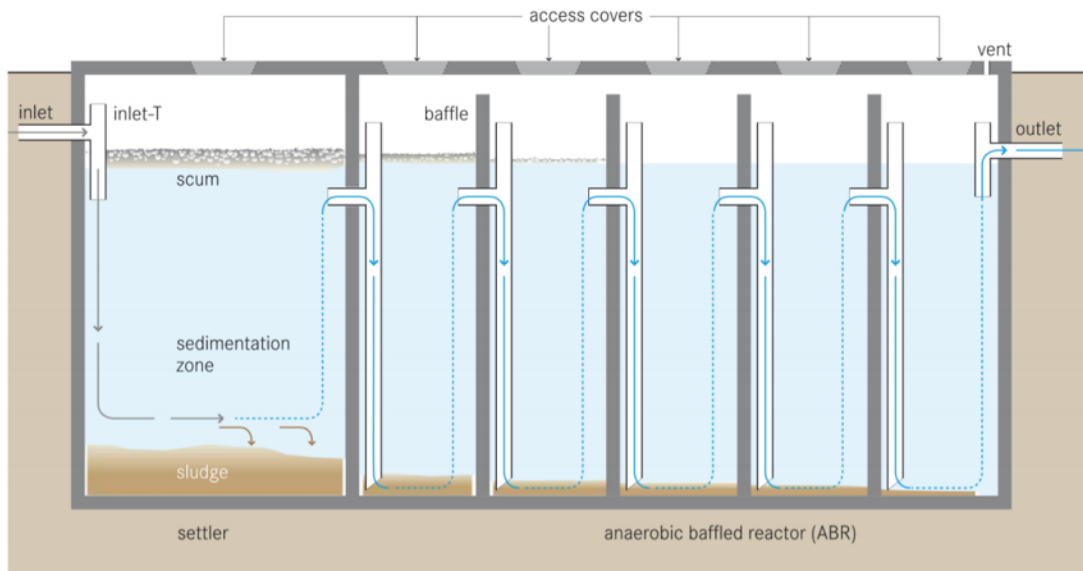


Figure 6 Schematic diagram of ABR (Source: EAWAG, 2005)

Capacity/Adequacy	Community (and household) level; For pre-settled domestic or (high-strength) industrial wastewater of narrow COD/BOD ration. Typically integrated in DEWATS systems; Not adapted for areas with high ground-water table or prone to flooding.
Performance	70- 95% BOD; 80% - 90% TSS; Low pathogen reduction. HRT: 1 to 3 days
Costs	Generally low-cost; depending on availability of materials and economy of scale.
Self-help Compatibility	Requires expert design, but can be constructed with locally available material.
O&M	Should be checked for water tightness, scum and sludge levels regularly; Sludge needs to be dug out and discharged properly (e.g. in composting or drying bed); needs to be vented.
Reliability	High resistance to shock loading and changing temperature, pH or chemical composition of the influent; requires no energy.
Main strengths	Strong resistance; built from local material; biogas can be recovered.

Main weakness	Long start-up phase.
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3.4.2.2. Anaerobic filter

An anaerobic up-flow filter is a fixed-bed biological reactor with one or more filtration chambers in series. As wastewater flows through the filter, particles are trapped, and organic matter is degraded by active biomass that is attached to the surface of the filter material.

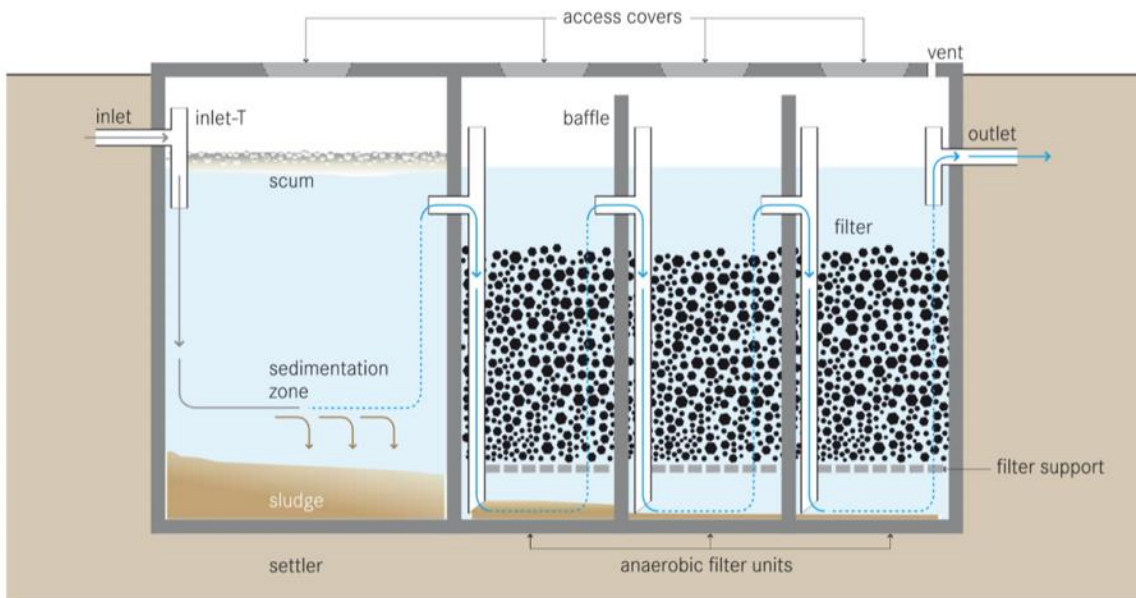


Figure 7 Schematic diagram of Anaerobic up flow filter (Source: EAWAG, 2005)

Capacity/Adequacy	Household and community level; as secondary treatment step after primary treatment in a septic tank or an anaerobic baffled reactor; effluents can be infiltrated into soil or reused for irrigation; not adapted if high ground-water table or in areas prone to flooding.
Performance	BOD: 50 to 90%; TSS: 50 to 80 %; Total Coliforms: 1 to 2 log units HRT: about 1 day
Costs	Generally low-cost; depending on availability of materials and frequency of back flushing and desludging.
Self-help Compatibility	Requires expert design, but can be constructed with locally available material.
O&M	Regularly backflush to prevent clogging (without washing out the biofilm); desludging of the primary settling chambers; needs to be vented if biogas not recovered.

Reliability	Reliable if construction is watertight and influent is primary settled; Generally good resistance to shock loading.
Main strength	Resistant to shock loading; High reduction of BOD and TSS.
Main weakness	Long start-up phase.

3.4.2.3. Constructed Wetlands (Horizontal flow)

A horizontal subsurface flow constructed wetland is a large gravel and sand-filled basin that is planted with wetland vegetation. As wastewater flows horizontally through the basin, the filter material filters out particles and microorganisms degrade the organics. The filter media acts as a filter for removing solids, a fixed surface upon which bacteria can attach, and a base for the vegetation. Although facultative and anaerobic bacteria degrade most organics, the vegetation transfers a small amount of oxygen to the root zone so that aerobic bacteria can colonize the area and degrade organics as well. The plant roots play an important role in maintaining the permeability of the filter.

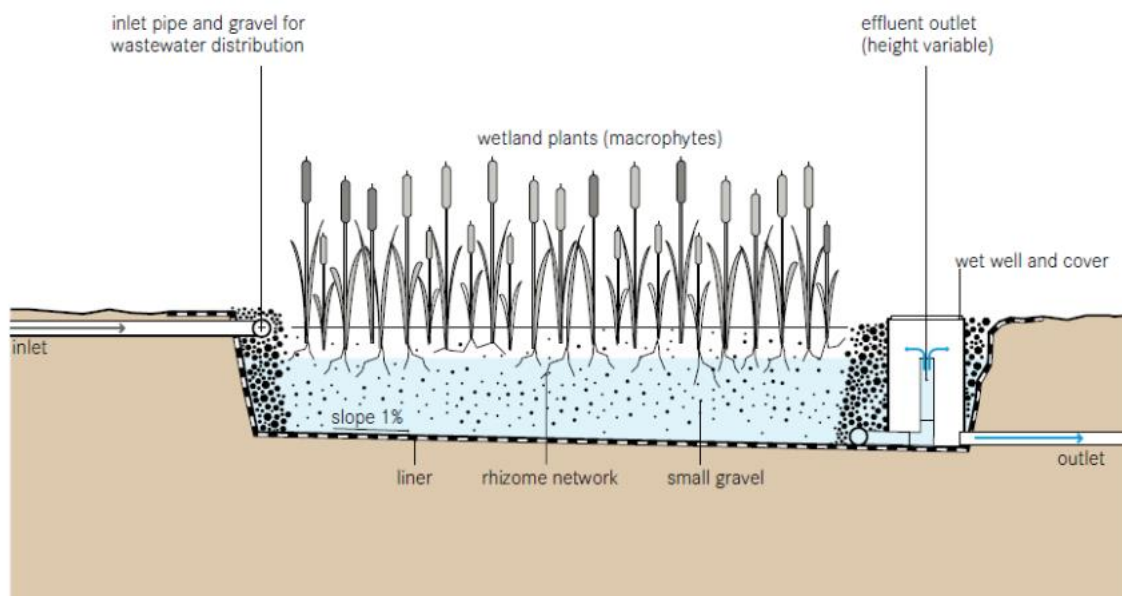


Figure 8 Schematic diagram of horizontal flow constructed wetlands (Source: Tilley et al., 2014)

Capacity/Adequacy	It can be applied for single households or small communities as a secondary or tertiary treatment facility of grey- or blackwater. Effluent can be reused for irrigation or is discharged into surface water (MOREL and DIENER 2006).
Performance	BOD=80 to 90 %; TSS=80 to 95 %; TN=15 to 40 %; TP=30 to 45 %; FC ≤ 2 to 3 log; LAS > 90 %
Costs	The capital costs of constructed wetlands are dependent on the costs of sand and gravel and also on the cost of land required for the CW. The operation and maintenance costs are very low (MOREL and DIENER 2006).
Self-help Compatibility	O&M by trained labourers, most of construction material locally available, except filter substrate could be a problem. Construction needs expert design.
O&M	Emptying of pre-settled sludge, removal of unwanted vegetation, cleaning of inlet/outlet systems.
Reliability	Clogging of the filter bed is the main risk of this system, but treatment performance is satisfactory.
Main strength	Efficient removal of suspended and dissolved organic matter, nutrients and pathogens; no wastewater above ground level and therefore no odour nuisance; plants have a landscaping and ornamental purpose (MOREL and DIENER 2006).
Main weakness	Permanent space required; risk of clogging if wastewater is not well pre-treated, high quality filter material is not always available and expensive; expertise required for design, construction and monitoring (MOREL and DIENER 2006).

3.4.2.4. Constructed Wetlands (vertical flow)

A vertical flow constructed wetland is a planted filter bed that is drained at the bottom. Wastewater is poured or dosed onto the surface from above using a mechanical dosing system. The water flows vertically down through the filter matrix to the bottom of the basin where it is collected in a drainage pipe. The important difference between a vertical and horizontal wetland is not simply the direction of the flow path, but rather the aerobic conditions. By intermittently dosing the wetland (4 to 10 times a day), the filter goes through stages of being saturated and unsaturated, and, accordingly, different phases of aerobic and anaerobic conditions. During a flush phase, the wastewater percolates down through the unsaturated bed. As the bed drains, air is drawn into it and the oxygen has time to diffuse through the porous media. The filter media acts as a filter for removing solids, a fixed surface

upon which bacteria can attach and a base for the vegetation. The top layer is planted and the vegetation is allowed to develop deep, wide roots, which permeate the filter media. The vegetation transfers a small amount of oxygen to the root zone so that aerobic bacteria can colonize the area and degrade organics. However, the primary role of vegetation is to maintain permeability in the filter and provide habitat for microorganisms. Nutrients and organic material are absorbed and degraded by the dense microbial populations. By forcing the organisms into a starvation phase between dosing phases, excessive biomass growth can be decreased and porosity increased.

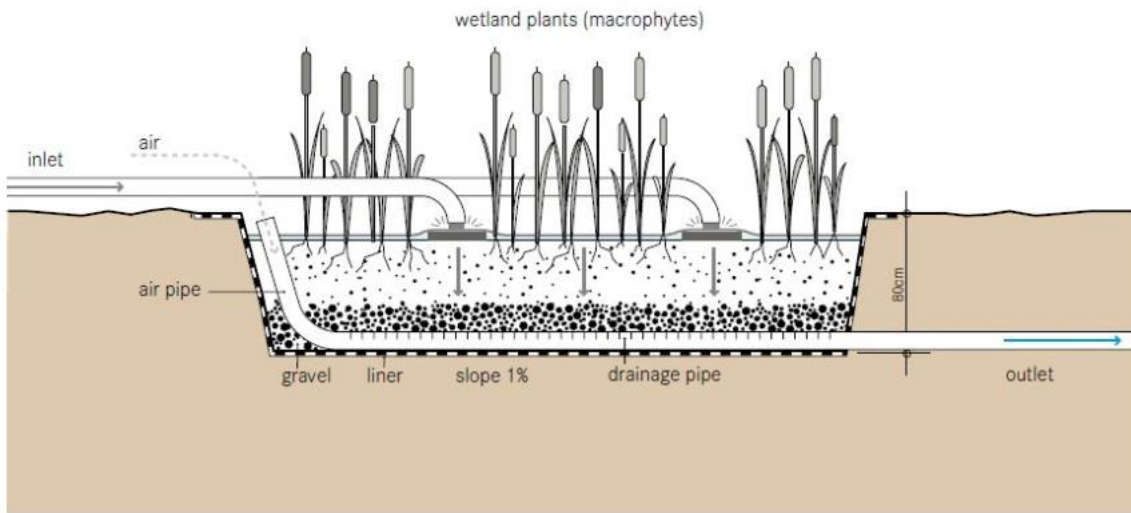


Figure 9 Schematic diagram of vertical flow constructed wetlands (Source: Tilley et al., 2014)

Capacity/Adequacy	It can be applied for single households or small communities as a secondary or tertiary treatment facility of grey- or blackwater. Effluent can be reused for irrigation or is discharged into surface water (MOREL and DIENER 2006).
Performance	BOD= 75 to 90%; TSS= 65 to 85%; TN < 60%; TP < 35%; FC ≤ 2 to 3log; MBAS ~ 90%; (adapted from: Morel and Diener 2006)
Costs	The capital costs of constructed wetlands are dependent on the costs of sand and gravel and also on the cost of land required for the CW. The operation and maintenance costs are very low (Morel and Diener 2006)
Self-help Compatibility	O&M by trained labours, most of construction material locally available, except filter substrate could be a problem. Construction need expert design. Electricity pumps maybe necessary.

O&M	Emptying of pre-settled sludge, removal of unwanted vegetation, cleaning of inlet/outlet systems.
Reliability	Clogging of the filter bed is the main risk of this system, but treatment performance is satisfactory.
Main strength	Efficient removal of suspended and dissolved organic matter, nutrients and pathogens; no wastewater above ground level and therefore no odour nuisance; plants have a landscaping and ornamental purpose (Morel and Diener 2006)
Main weakness	Even distribution on a filter bed requires a well-functioning pressure distribution with pump or siphon. Uneven distribution causes clogging zones and plug flows with reduced treatment performance; high quality filter material is not always available and expensive; expertise required for design, construction and monitoring (Morel and Diener 2006)

3.4.2.5. Waste Stabilization Pond (WSP)

Waste Stabilization Ponds (WSPs) are large, manmade water bodies. The ponds can be used individually or linked in a series for improved treatment. There are three types of ponds, (1) anaerobic, (2) facultative and (3) aerobic (maturation), each with different treatment and design characteristics. For the most effective treatment, WSPs should be linked in a series of three or more with effluent flowing from the anaerobic pond to the facultative pond and, finally, to the aerobic pond. The anaerobic pond is the primary treatment stage and reduces the organic load in the wastewater. The entire depth of this fairly deep pond is anaerobic. Solids and BOD removal occurs by sedimentation and through subsequent anaerobic digestion inside the sludge. Anaerobic bacteria convert organic carbon into methane and, through this process, remove up to 60% of the BOD. In a series of WSPs, the effluent from the anaerobic pond is transferred to the facultative pond, where further BOD is removed. The top layer of the pond receives oxygen from natural diffusion, wind mixing and algae-driven photosynthesis. The lower layer is deprived of oxygen and becomes anoxic or anaerobic. Settleable solids accumulate and are digested on the bottom of the pond. The aerobic and anaerobic organisms work together to achieve BOD reductions of up to 75%.

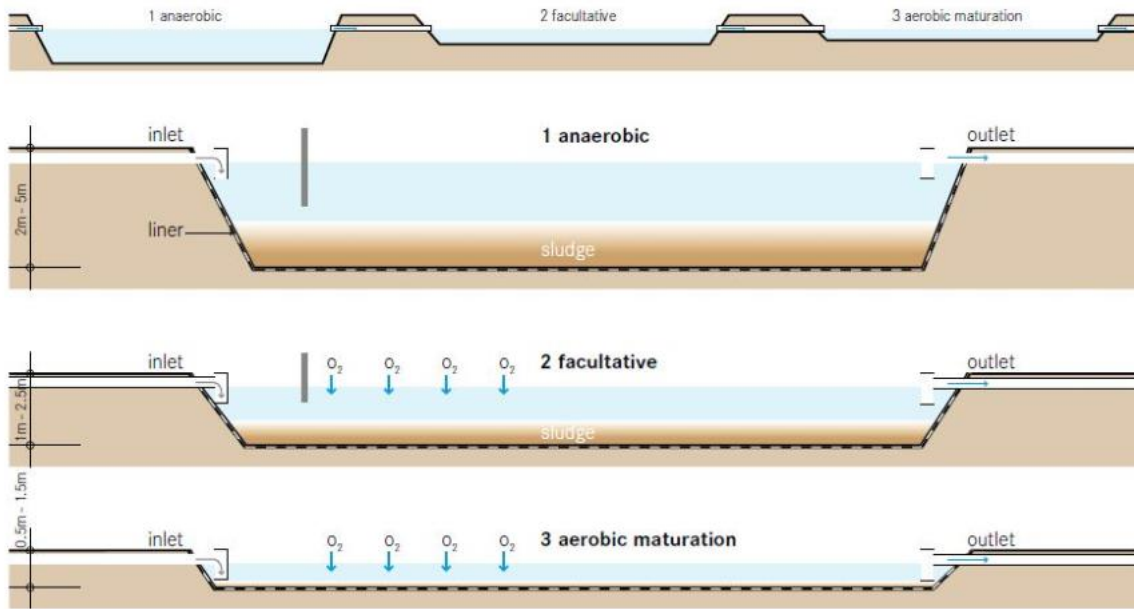


Figure 10 Schematic diagram of waste stabilization ponds (Source: Tilley et al., 2014)

Capacity/ Adequacy	Almost all wastewaters (including heavily loaded industrial wastewater) can be treated, but as higher the organic load, as higher the required surface. In the case of high salt content, the use of the water for irrigation is not recommended
Performance	90% BOD and TSS; high pathogen reduction and relatively high removal of ammonia and phosphorus; Total HRT: 20 to 60 days
Costs	Low capital costs where land prices are low; very low operation costs
Self-help Compatibility	Design must be carried out by expert. Construction can take place by semi- or unskilled labourers. High self-help compatibility concerning maintenance.
O&M	Very simple. Removing vegetation (to prevent BOD increase and mosquito breath) scum and floating vegetation from pond surfaces, keeping inlets and outlets clear, and repairing any embankment damage.
Reliability	Reliable if ponds are maintained well, and if temperatures are not too low.
Main strength	High efficiency while very simple operation and maintenance.

Main weakness	Large surface areas required and needs to be protected to prevent contact with human or animals
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3.5. Comparison of various treatment technologies

The following matrix shows different wastewater treatment technologies and their potential in terms of performance in terms of quality of treated sewage, potential of revenue generation from reuse of treated byproducts, environment impact, land requirement for setting up of STP, CAPEX and OPEX costs and requirement of skilled manpower for operations. The pointers can be a guide for city managers to choose a technology that suits their specific requirements.

Criteria	ASP	UASB+ASP	SBR	MBBR	MBR	WSP
Performance in Terms of Quality of Treated Sewage						
Potential of Meeting the RAPs TSS, BOD, and COD Discharge Standards	+++	+++	++++	++++	++++	++
Potential of Total / Faecal Coliform Removal	+++	+++	+++	++++	++++	++++
Potential of DO in Effluent	+++	+++	+++	+++	+++	+++
Potential for Low Initial/Immediate Oxygen Demand	++++	++++	++++	++++	++++	++++
Potential for Nitrogen Removal (Nitrification-Denitrification)	+	+	++++	++	++	+
Potential for Phosphorous Removal	+	+	++++	++	++	+
Performance Reliability	++++	++	++	+++	++++	++
Impact of Effluent Discharge						

Potential of No Adverse Impact on Land	++	++	+++	+++	++++	+++
Potential of No Adverse Impact on Surface Waters	+++	+++	+++	+++	++++	+++
Potential of no adverse impact on ground water	+++	+++	+++	+++	++++	++
Potential of economic viable resource generation						
Manure/soil conditioner	++	++	+ +	++	+	+
Fuel	++ +	++	+	+	+	+
Economically viable electricity generation/Energy recovery	++ ++	+++	+	+	+	+
Food	++	+	+	+	+	+
Impact of STP						
Potential of no adverse impact on health of STP staff	++	+	+ + +	++ +	++ +	++
Potential of no adverse impact on surrounding building /properties	++ +	++	+ + +	++ +	++ +	++ ++
Potential of low energy requirement	++	++	+ +	++	+	++ ++
Potential of low land requirement	++ +	++	+ + +	++ +	++ ++	+

The samples should be analyzed for the following parameters; pH, Temperature, Colour, Odour, Alkalinity, TSS, Volatile SS, BOD (Total & Filtered), COD (Total and Filtered), Nitrogen (NH₃, TKN, NO₃), Phosphorus (Ortho-P & T-P), Total Coliforms and Faecal Coliforms, TDS, Chloride, Sulphates, Heavy Metals (if there is a chance of industrial contamination).

3.6.3. Unit operation in Biological treatment

The physical activities used to implement the processes are called unit operations. For example, the physical processes of screening, grit (sand) and suspended solids being settled out are together referred to as primary treatment. The metabolic process is called secondary treatment. Unit operation means the physical activity. For example, simple settling of raw sewage is carried out in primary clarifiers. Pumping air into the sewage for supplying oxygen to the aerobic metabolism is called aeration. Settling of the microorganisms after aeration is carried out in secondary clarifiers. The concentration of settled out organics and microorganisms from primary settling or secondary settling or both together is carried out in sludge thickeners. The anaerobic metabolism of thickened sludge is carried out in sludge digesters.

3.6.4. Arrangement of treatment units in STP

The preferred arrangement will have the following guidelines:

- The civil construction of units can be integrated by common walls especially sewage holding structures
- This can be either rectangular or square tanks touching each other or circular tanks inscribed concentrically.
- This will economize on costs of piping because sewage can be conveyed by channels through all such units.
- Stop gates operated by hand wheels on a rack and pinion method can replace costly buried valves and avoid the difficulty of O&M of such buried valves.

3.6.5. Buffer zone around STP

Adequate measures may be taken for de-odourization in the STP. The units in the STP which need deodorization system are screen chambers, grit chamber, primary clarifier, sludge thickening and dewatering units. However, the odor emissions are negligible for sludge treatment facilities of extended aeration systems due to in-situ aerobic digestion of sludge. Wherever the STPs are provided with de-odourization system, specific buffer zones are not required.

In case of STP's where de-odorization system cannot be provided, an aerial / peripheral distance of 100 m from the odour-producing units to the habitation is recommended. However, this distance can be reduced by conducting public consultation

3.6.6. Required Engineering data

The mandatory data shall include:

- a. Contour map and elevations connected to the nearest Survey of India permanent bench mark.
- b. Soil tests till it attains hard stratum and test bores at a grid of 500 m squares
- c. Rainfall of nearest observatory for at least 50 years
- d. Highest intensity of rainfall
- e. Earthquake records of the region
- f. Maximum flood level at the site and in the identified receiving water
- g. Wind rose.

4. Faecal Sludge and Septage Management (FSSM)

4.1. Introduction to FSSM

The term “Sanitation” is defined as safe management of human excreta with an objective to protect and promote public health by providing a clean environment and breaking the cycle of disease.

Sanitation System - Also referred to as sanitation chain or sanitation service chain. A collection of technologies and services that deals with human excreta from the time it is generated until it is used or disposed of safely. A sanitation system includes five components:

1. user interface
2. excreta storage
3. emptying and transporting faecal sludge
4. faecal sludge treatment and
5. faecal sludge use or disposal

A sanitation system also includes the management, operation and maintenance required to ensure that the system functions safely and sustainably.

On-site sanitation - A large part of urban India still relies on on-site sanitation. It is defined as a sanitation system in which excreta and used water are collected and stored on the location where it is produced. It is also referred to as on-plot sanitation or non-sewered sanitation.

On-site sanitation technology - An on-site sanitation technology, also known as latrine is made up of the part included in the first two components of a sanitation system: user interface and excreta storage. Excreta is collected and stored where it is produced (for example, pit latrine, septic tank, aqua privy, and non-sewered public toilets). Often, the faecal sludge has to be transported off-site for treatment, use or disposal.

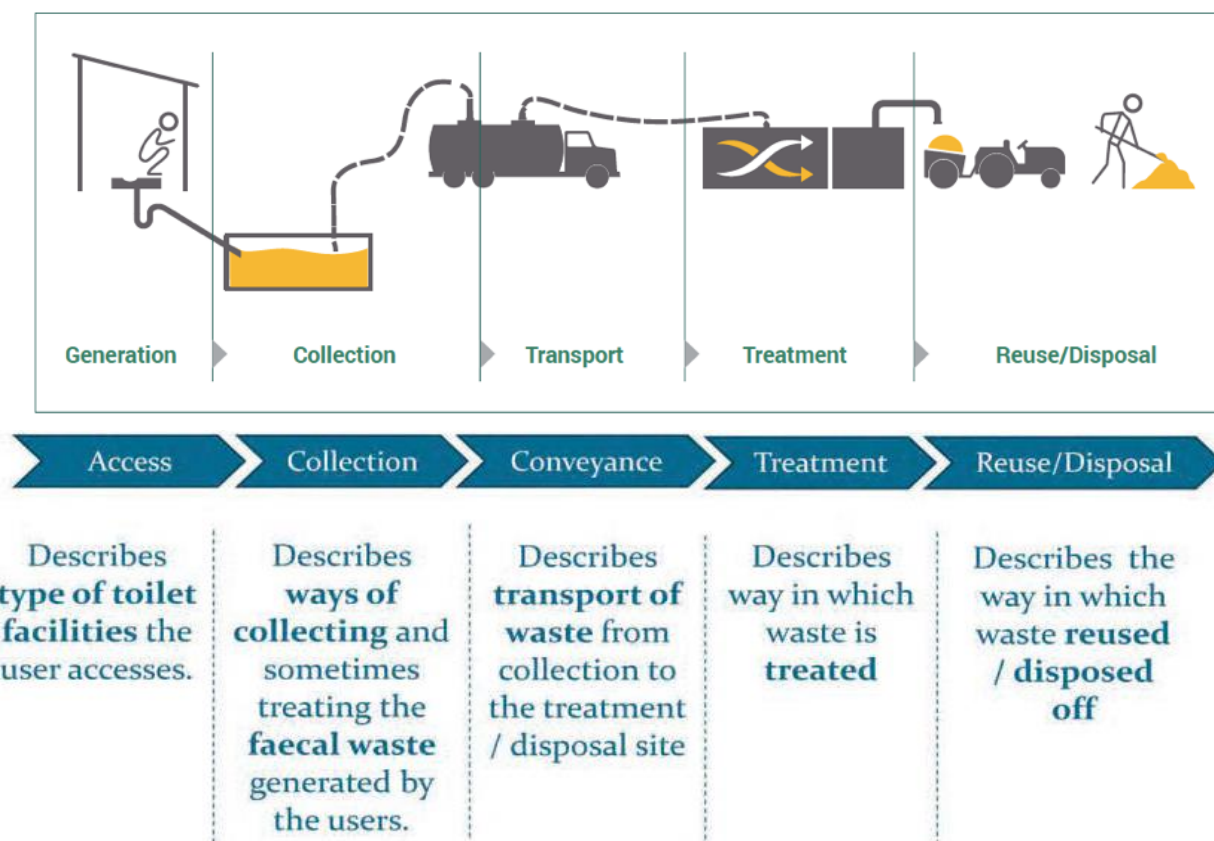
Faecal sludge – ‘Faecal Sludge’ is raw or partially digested in slurry or semisolid form, the collection, storage or treatment of combinations of excreta and black water, with or without grey water. It is the solid or settled contents of pit latrines and septic tanks. The duration of storage, temperature, soil condition, and intrusion of groundwater or surface water in septic tanks or pits, performance of septic tanks, and tank emptying technology and pattern (Ministry of Housing and Urban Affairs, 2017).

Septage – The liquid and solid material that is pumped from a septic tank, cesspool, or such on-site treatment facility after it has accumulated over a period of time. Septage is the combination of scum, sludge, and liquid that accumulates in septic tanks.

Faecal Sludge and Septage Management (FSSM) – A sanitation system that deals with human excreta from the time it is generated until it is used or disposed of safely. FSM includes emptying, transportation, treatment and use or disposal of faecal sludge from on-site

sanitation technology. (like pit latrine or septic tank) FSSM mainly addresses the last three components of a sanitation system i.e. emptying and transport of faecal sludge/septage, its treatment and its use or disposal.

Sanitation service chain



4.2. Need for FSSM

India under its flagship program of Swachh Bharat Mission (SBM) Urban has made significant progress in percentage of urban population having an access to a toilet (individual, shared, community, public). The toilets are usually provided with various kind of on-site sanitation system like pit latrines, toilets having twin pits, septic tanks with or without a soak pit to contain/partially treat the excreta. Septage needs to be removed periodically from these on-site systems since they are designed for containment of faecal sludge for limited period.

However, the issue starts when these systems are full and there are no management measures in place for its safe confinement or transport to either a treatment facility or open disposal. The emptying of on-site sanitation technologies and effective management of faecal sludge is an essential service that is often neglected. Ideally, on-site sanitation technologies should be emptied in a safe and hygienic manner by well-equipped and protected workers who transport the sludge for treatment, use or disposal. However, in reality, most technologies are either abandoned or emptied using unsafe and unhygienic methods. The faecal sludge is simply dumped by the home, in the street, or in nearby water sources. This has negative impacts on the urban environment and public health. It is estimated that 1 truck of faecal sludge and septage carelessly dumped equals to 5,000 people defecating in open.

1 gram of feces may contain one hundred parasites eggs, one thousand protozoa, 10 lakh bacteria and 1 crore virus.

Considering the fact that the urban population in coming years will still be relying on on-site sanitation systems, the need for proper management of faecal sludge/septage is now being recognized and measures are being taken by central government and state governments in this direction.

- Ministry of Housing and Urban Affairs (MoHUA), Government of India released the National Policy on FSSM in 2017.
- FSM included as one of the major thrust areas under the AMRUT scheme
- Septage Management Advisory of Government of India provides references to CPHEEO guidelines, BIS standards, and other resources for preparing Sanitation Master Plan / FSSM plan.
- States are coming up with their FSM policy – 7 states have this policy in place.

4.2.1. Challenges in implementation of FSSM

Faecal sludge management is an urgent issue in many parts of the world. Unfortunately, it is not that simple and implementers have many challenges. These result from the complexity of the process. There are various stakeholders to involve including the household users, informal and formal private sector, government, non-governmental organizations (NGOs) and community-based organizations (CBOs). Some of the key challenges include:

Accessibility: On-site sanitation technologies are not always accessible to emptying services. They can also be located too far from a service provider. It is not worth the cost of transportation or the service provider's time. The roads can also be too narrow and poorly constructed for emptying vehicles. Furthermore, people constructing on-site sanitation technologies often do not take into account the emptying component. It can be difficult to have direct access to the latrine pit or septic tank.

Affordability: Many households cannot afford emptying services. They rely on informal private services to manually empty their on-site sanitation technology. Many manual transport services also cannot afford to take sludge to a treatment site that is located far away. Instead, they choose to dump the untreated sludge close to the on-site sanitation technology and directly into the environment.

Investment: There is a lack of faecal sludge management services because there is a need for investment in construction, operation, and maintenance. Many faecal sludge technologies stop functioning because there is little to no funding available for long-term operation and maintenance.

Policy: Policy makers still focus on sewerage systems rather than on-site sanitation, which is often considered a temporary solution. Therefore, not many countries have a policy on faecal sludge management. As a result, faecal sludge management is often unplanned, unreliable, and operated by informal private services.

Legal Frameworks: Laws on faecal sludge management are non-existent or weak. This leads to illegal dumping of untreated sludge into the environment. In countries where there are laws, there have been challenges with enforcing them.

4.3. FSSM Planning

The key objectives of preparing a FSSM plan is to ensure safe containment of human excreta (by converting insanitary toilets into sanitary ones, refurbishment of on-site sanitation systems to avoid leakages and designing of new systems as per standards), safe emptying and transport of faecal sludge to avoid environmental and health hazard and proper treatment and reuse of faecal sludge and septage.

The FSSM plan maps out the process to be followed by city managers and provides guidance on various aspects like technology, finance, enabling framework, stakeholder engagement, institutional arrangements including private sector participation and citywide implementation framework.



4.3.1. Assessment of existing situation

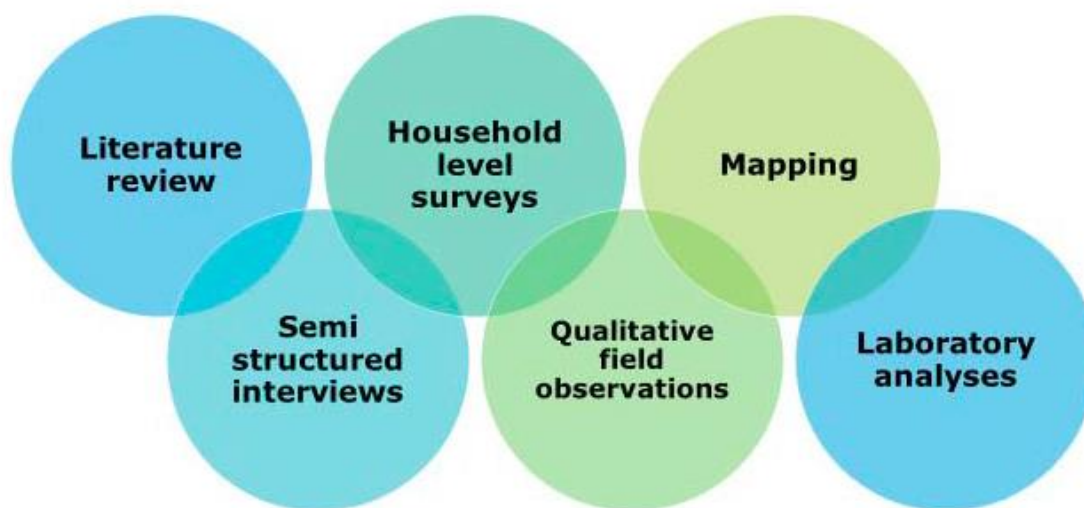
This step mainly involves understanding of current situation with regards to service performance across the service chain through a city level assessment. It is an important step, which provides an initial sense of the state of FSM in the city, help in understanding the context and identifying gaps in key services.

- Septage Generation – type of containment system at household level
- Service performance - all sanitation services at ULB level
- Conveyance and transportation options for faecal sludge and septage
- Technology Options for treatment and disposal, in order to design the most appropriate option for treatment

- Financing options; sources of financing for FSTPs, tariffs, different models for CAPEX and OPEX
- Institutions (ULBs and state level) and capacity to implement FSM
- Regulatory environment and Norms for FSM
- Private sector engaged in FSM

There are various tools and methods that can be adopted for data collection. Refer below

Tools and method of data collection



Based on the baseline assessment as discussed above, the city can initiate planning for FSSM. The planning needs to be done mainly for the following:

- a. Planning for technology options for containment
- b. Planning for desludging and conveyance
- c. Planning for technology options of treatment and reuse

4.3.2. Planning for technology option for containment

Considering the type of on-site containment systems in the city, it is important to understand the deciding factors for selecting a suitable and appropriate containment system. The criteria for selection of appropriate containment system are mentioned below:

- Availability of space
- Soil and groundwater characteristics
- Type and quantity of input
- Desired output
- Availability of technologies for subsequent transport
- Financial resources
- Management considerations

4.3.3. Planning for desludging and conveyance

Desludging can be done in broadly two ways – either on demand based or by a scheduled based system. In a ‘demand based desludging system’, households raise a service request for desludging services by the ULB or private contractors. The ULB could then decide to undertake desludging itself or through its empanelled panel of operators. The ULB levies emptying charges on the HHs. This is currently being practiced in predominantly all of the ULBs across India. Whereas, in a scheduled desludging system, the ULB prescribes a scheduled regime and provides services either itself or through its empanelled operators at a fixed time interval. For e.g. The ULB will send alert and scheduled desludging of OSS systems in 3 years. Here, the charges are built into the annual property tax levied on the households.

There can be two models for provision of desludging services in a city. Model 1 – ULB manages the desludging on its own and Model 2 – ULB outsources the desludging to private agencies

The technology options for emptying and conveyance of septage mainly includes vehicles required for desludging of on-site sanitation systems from every household within a city. The criteria for selection of vehicles should be based on the following:

- Road widths/ condition/ terrain
- Quantity of faecal sludge and septage generated
- Financial resources available
- Availability of skilled human resources to operate and maintain the vehicles
- After sale service/ skill for repair of the vehicle
- Method of desludging – (will affect the number of vehicles)

4.3.4. Planning for technology options of treatment and reuse

The most important aspect in determining the technology option for faecal sludge treatment is assessment of quantity of septage generation in the city. Based on an ‘Advisory Note on Septage Management in Urban India, MoHUA’ and United States Environmental Protection Agency (USEPA) 1984, per capita septage generation can be assumed at 230 litres per year. This means, by multiplying the current year’s population of the ULB with 230 litres/year, the ULB can estimate the quantity of total septage generation in the city in a year. For more precise estimation of septage generation, the ULB could conduct a sample survey of different types of properties connected with OSS. From the survey, the ULB could then derive the total septage volume generated across the city.

4.3.5. Planning for treatment and disposal site

For planning treatment infrastructure for faecal sludge, the ULB has to first assess the existing infrastructure available in the city before planning to establish a new Faecal Sludge Treatment Plant (FSTP). If the ULB is partially covered with sewerage network and has a functional STP, then the septage can be disposed in the sewer line. However before that, the ULB

needs to ensure that there is spare capacity at the existing STP to take the septage load and more importantly the treatment technology at STP is capable to treat the pollution load in septage. The characteristics of domestic wastewater and faecal sludge/septage varies significantly.

If the ULB currently has no sewerage network but has plans to establish the same with functional STP in next 2-3 years (in case these have been approved as part of service level improvement plan (SLIP) under the AMRUT or any other state government supported schemes or self-financed), it is advisable to construct sludge drying beds and dispose the septage in sludge drying beds till the STP become functional. This is an interim solution to manage faecal sludge and septage safely. If the ULB is currently not covered with sewerage network or a STP, and it has no plans to establish the same; the ULB can decide to construct a dedicated FSTP for safe reuse and disposal of faecal sludge.

The key parameters for selection of site for setting up of FSTP are mentioned below:

Land availability: Availability of government land for establishing a treatment plant. Private land will cost more to acquire it for setting up a treatment plant.

Distance of treatment site: Long distance of treatment site will lead to higher fuel cost and might result in lesser trips.

Neighborhood: the treatment plant needs to be appropriately distanced from a residential area. The site's immediate environs need to be assessed.

Uninterrupted electricity: The treatment plant will require a reliable power supply for its efficient functioning, if the treatment technology has mechanical parts for its operation.

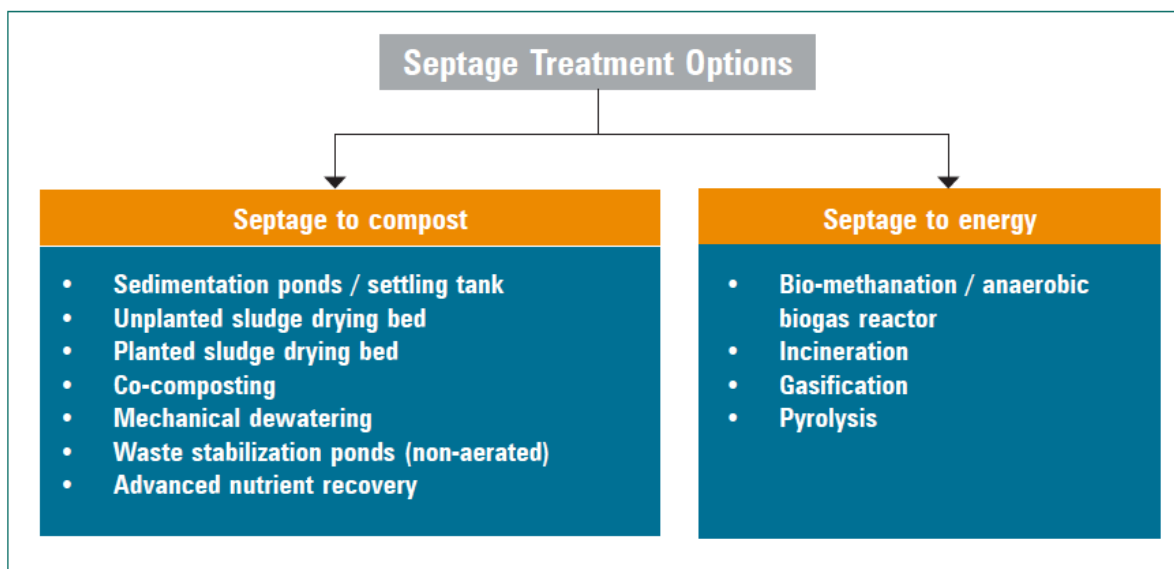
Geological parameters: Geological parameters such as depth of groundwater table at the selected location and type of soil should be considered. Also, it will be an advantage if the selected site is not prone to flooding.

The key factors for selection of treatment technology are mentioned below:

Various treatment technologies are available and the ULB should carefully assess based on the selection criteria and then decide a suitable technology. ULBs need to know the advantages and disadvantages of the treatment technology and should assess how much mechanization is required to run the treatment plant. ULBs should also assess the geological condition of the site and requirement of capex and opex for the treatment technology. A full life cycle cost of the plant should be worked out for the technology and it should be viable for the city to comfortably operate and maintain the same.

Some of the treatment technologies will also require before and after treatment of the septage, which also needs to be considered.

The septage treatment options can be selected based on the requirement of reuse of end products. The septage can be converted into compost or energy after its treatment. Some of the options available for treatment are mentioned below:



4.3.6. Financing for citywide implementation of FSSM

After understanding all the components of the FSSM value chain, it is essential to identify the possible financial sources to implement the FSSM plan in the city. Currently, SBM, Smart Cities Mission and AMRUT are the missions which have fund allocation for implementing FSSM in the city. Funds can be availed from the SBM for construction of toilets and OSS systems, whereas fund for procuring vehicles and equipment for conveyance of septage, establishing FSTP can be availed from Smart Cities Mission and AMRUT mission.

The ULB needs to assess the requirement of CAPEX and OPEX across the value chain for better planning of FSSM. To ensure financial sustainability of FSSM services, it is important to assess capacity for financing for both CAPEX and OPEX over the planning period.

4.3.7. Tools for Citywide FSSM Planning

There are various tools available to guide the city managers through the process of preparation of citywide FSSM plan. These tools are discussed in detail below:

SANIPLAN tool for FSSM

SANIPLAN is a decision support tool that provides a structured approach to planning for urban sanitation. It focuses on integrated service performance with a detailed assessment of finances. It is a planning tool which can support more informed stakeholder participation. Based on local priorities, users can identify key actions for service improvement. Its dashboards also support more informed interaction with decisions makers.

SANIPLAN has three modules: 1) performance assessment, 2) planning and 3) financial planning. A key feature of SANIPLAN is to develop a feasible financing plan for both capital and operating expenditures in context of local finances. SANIPLAN can be used for various sectors – water, sanitation, solid waste, and can be customized for a specific context.

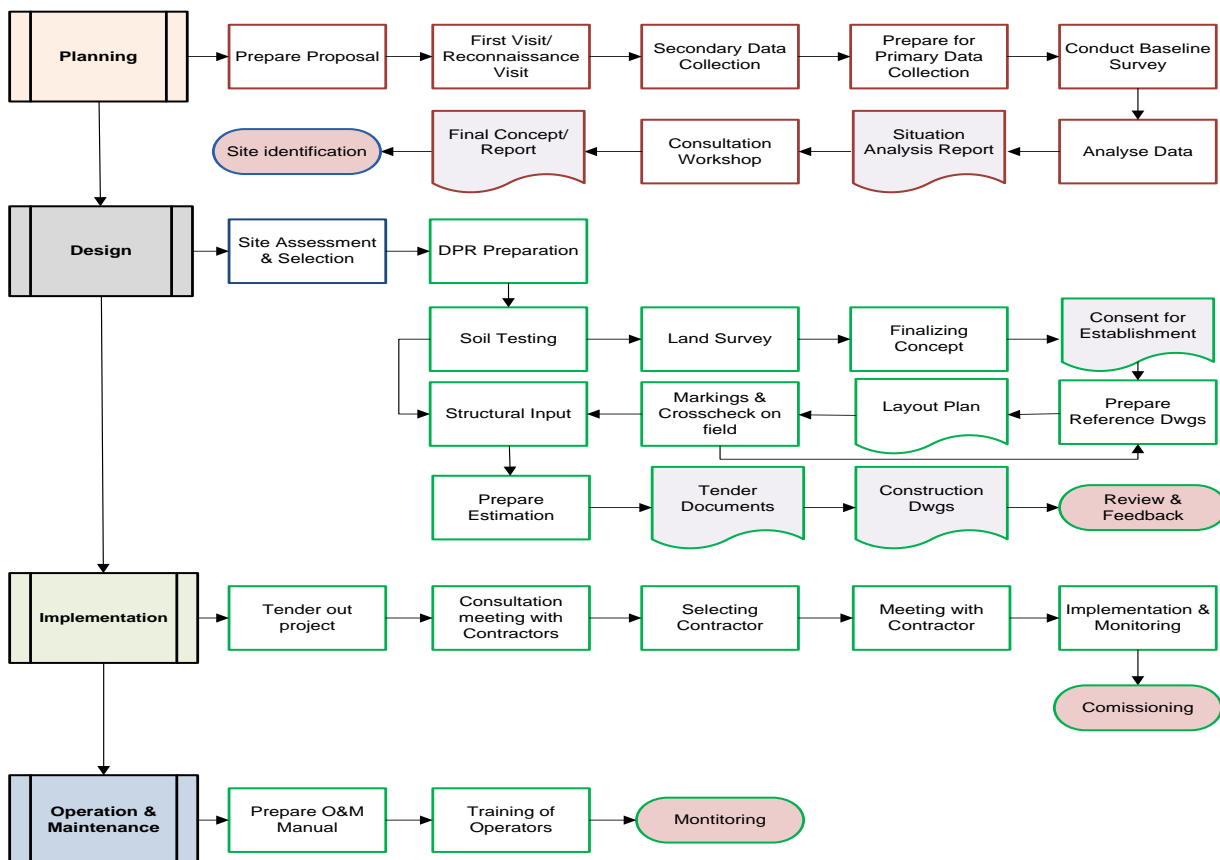
SaniTab

SaniTab is an easy to use app (android based only) for conducting sanitation surveys. It can be used to generate baseline information and to create a database for properties connected with OSS systems. It can be used for planning and monitoring ODF and faecal sludge management activities in cities, or for impact assessment. It is easy to administer and allows quick analyses. Key features of SaniTab are

- Citywide digital data collection tool
- Providing enabling environment for spatial analysis
- Quick and ease in survey, minimizing human error
- Real time monitoring of survey activity

4.3.8. Detailed Project Report for Faecal Sludge Treatment Plant (FSTP)

The steps towards preparation of detailed project report for implementation of FSTP in any city/town is explained in diagram below:



5. Improvements in Urban Water Supply & Wastewater Management

5.1. Improving Water Access

Definition

World Health Organization defines “Access to safe drinking water is measured by the percentage of the population using improved drinking-water sources”.

Rationale and Need

Universal access of safe drinking water is a fundamental need and human right. One of the most important recent milestones has been the recognition in July 2010 by the United Nations General Assembly of the human right to water and sanitation.²

As per United Nations, “The right to water entitles everyone to have access to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic use”.³

As a Global Plan of action, the sustainable Goal 6 “Ensure availability and sustainable management of water and sanitation for all” for the access of water.

No city receives in India 24x7 piped water supply.

According to CPHEEO 2011 and Census 2011, 70% of Urban Households have the access of piped water supply. ⁴ According to 2012 United Nations Educational, India is the World Biggest consumer of the ground water extracting on the rate of 251 cubic kilometer (cu km) annually. 80 % of Drinking Water and two-third of irrigation needs of India are conveyed by Ground Water. Furthermore, 60% of districts face groundwater over-exploitation and/or serious quality issues.⁵

The biggest concern is that most cities do not provide the quantum of water according to existing per capita norms. While Indian cities are supposed to conform to the standards laid down in the Manual on Water Supply and Treatment (CPHEEO, 1999), the cities are rarely able to meet these standards as cities clearly receive only 69 lpcd, as opposed to the norm of 135 lpcd.⁶

² <http://www.un.org/en/sections/issues-depth/water/>

³ <http://www.unwater.org/water-facts/human-rights/>

⁴ http://wateraidindia.in/wp-content/uploads/2018/06/State-of-Urban-water-supply_2018_WEB.pdf

⁵ <http://wateraidindia.in/faq/drinking-water-problems-india/>

⁶ http://iihs.co.in/knowledge-gateway/wp-content/uploads/2015/08/RF-WATSAN_reduced_sized.pdf

5.1.1. Planning and Implementation

Sources of Water Supply can be Primary (River, Lake, Rainwater, Ground water, Wells) and Secondary (Canals, Dams, Tankers, Tap water).

Water Policy and Action Plan for India 2020⁷

Information System and Water Resources Assessment

A national information system that builds itself on micro-watershed level databases and integrates with the state and national levels is required. This database should contain information on rainfall, ground water, surface water availability and also water use for different purposes along with its quality.

- Uniform standards for coding, classification, processing
- Demand Management, Conservation and Efficiency of Utilisation
- Integrated Planning for Maximising Water Usability
- Water Allocation for Various Uses
- River Life, Pollution and Environment

A minimum good quality water flow should be ensured at all times as required for the life of the river and for sustaining livelihoods. This should include the allocation of water for various purposes including conserving the environment, preventing groundwater salinity and sea water intrusion, supporting livelihood based on aquatic life and other uses of water, recreation, and cultural activities like bathing and festivities.

- Watershed Areas Management
- Irrigation and Hydropower

Irrigation planning either in an individual project or in a basin, as a whole should take into account the irrigability of land, cost effective irrigation options possible from all available sources

- Groundwater Management, Flood Management and Drainage
- Action Programme and Implementation Schedule
- Implementation of Watershed Projects, Financing Projects and Water Service Charges, Maintenance and Modernization, Action Programme and Important Implementation Aspects

5.1.2. Monitoring/KPIs

As per WHO Access to safe drinking water is measured against the proxy indicator: the proportion of people using improved drinking water sources:

- a. Household connection
- b. Public standpipe
- c. Borehole
- d. Protected dug well

⁷ http://planningcommission.nic.in/reports/genrep/bkpap2020/10_bg2020.pdf

- e. Protected spring
- f. Rainwater collection

Minimum set of standard performance parameters as per Ministry of Housing and Urban affairs (MoHUA), Govt. of India

WATER SUPPLY		
S. No.	Indicator	Benchmark
1.	Coverage of Water Supply connections	100%
2.	Per Capita Supply of Water	135 lpcd
3.	Extent of Non-revenue Water	15%
4.	Extent of Metering	100%
5.	Continuity of Water supplied	24 Hours
6.	Efficiency in redressal of customer complaints	80%
7.	Quality of Water Supplied	100%
8.	Cost Recovery	100%
9.	Efficiency in Collection of Water Charges	90% ⁸

5.1.3. Best Practices

Performance Benchmarking of Urban Water Supply and Sanitation in Gujarat: Data Book (2008-09)⁹ - The Performance Assessment System (PAS) Project developed by the Centre for Environmental Planning and Technology (CEPT) University proposes an assessment system with a set of key performance indicators for urban water and sanitation and links the planning and fund allocation process to performance. Initiated in early 2009, the PAS Project includes three major components of performance measurement, performance monitoring and performance improvement. It covers all the 400+ urban local governments in Gujarat and Maharashtra.

5.2. Water Quality

Definition

Water is defined as safe if it is free from biological contamination (guinea worm, cholera, typhoid etc.) and within permissible limits of chemical contamination (excess fluoride, brackishness, iron, arsenic, nitrates, etc.) as per IS-10500 standard of Bureau of Indian Standards (BIS).

Rationale and Need

⁸ <http://mohua.gov.in/upload/uploadfiles/files/Indicators%26Benchmarks.pdf>

⁹ <https://www.pas.org.in/Portal/document/ResourcesFiles/pdfs/Performance%20Benchmarking%20of%20UWSS%20in%20Gujarat%20Part%20I%20&%20Part%20II.pdf>

India is facing the problem of water scarcity due to the unavailability of safe drinking water. Major causes of polluted surface and ground water is over exploitation of water ground water, mismanagement, discharge of untreated municipal and industrial waste in the water bodies.

5.2.1. Planning and Implementations

In India, The Water Quality is monitored by Central Pollution Control Board (CPCB)¹⁰ under National Water Quality Monitoring Programme. Different states in India, depending upon their state of devolution to Panchayati Raj Institutions (PRIs) in rural and municipalities in urban areas, have further devolved the powers to regulate water supply. At the state level, normally the water supply agency or parastatal institutions such as Public Health Engineering Departments (PHED) or Water Boards (e.g. Delhi), or Water Corporations (e.g. UP, Maharashtra) are responsible for planning, designing, implementation and operation and maintenance of the water supply schemes.¹¹

5.2.2. Monitoring/KPI's

The BIS drinking water specification (IS 10500:1991) was drawn up in 1983 and its most recent revision dates back to July 2010 (Amendment No. 3) with the objective of assessing the quality of water resources and checking the effectiveness of water treatment and supply by the concerned authorities.^{12 13} The qualitative testing of water supply is tested in labs for the presence of contamination is carried out twice a year – Pre Monsoon and Post Monsoon recommended by Uniform Drinking Water quality Monitoring Protocol, 2013.

5.3. Rain Water Harvesting

Definition

RWH is simply the act of capturing rainwater and either storing it for use or recharging it into the ground reducing the dependency on other supplies and flooding of the city in rainy season. RWH can be broadly harvested in two ways – Rooftop RWH with direct storage and Groundwater Recharge.

In terms of Safe drinking water, Rainwater is the purest form of water and if a layout is free of contamination sources and periodically cleaned, and then the water will be safe potable when run through household filtration system. Nevertheless, It is highly recommended that prior to consuming water from an RWH system, the owner first test their water for potability by sending a sample to one of the city's several testing labs. For groundwater aquifer through recharge wells, than the earth's soil is itself filtration system If residents ensure to maintain the cleanliness of their storm drains from solid and liquid waste, then the water recharged will be perfectly safe to consume. RWH can be done on Household Level and Community Level by the means of Recharge wells and Storm water Recharge wells.

¹⁰ <http://cpcb.nic.in/water-pollution/>

¹¹ https://en.wikipedia.org/wiki/Water_supply_and_sanitation_in_India

¹² <http://www.indiawaterportal.org/articles/indian-standard-drinking-water-bis-specifications-10500-1991>

¹³ <http://cgwb.gov.in/Documents/WQ-standards.pdf>

Rationale and Need

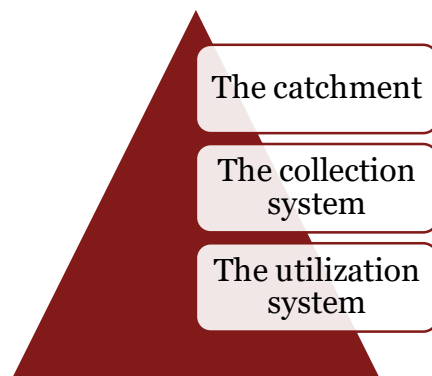
With depleting aquifers and fluctuating climate conditions, RWH can go a long way to help mitigate these effects. Capturing the rainwater can help recharge local aquifers, reduce urban flooding and most importantly ensure water availability in water-scarce zones.¹⁴

5.3.1. Planning and Implementation

Since 2002, many municipal corporations and states in India have passed legislations mandating the construction of rainwater recharge structures in all new buildings. Central Ground Water Board (CGWB) and MINISTRY OF DRINKING WATER AND SANITATION has prepared a document for Rainwater Harvesting, which envisages construction Rainwater Harvesting structures in the Country.^{15 16} Kerala, New Delhi, Indore, Hyderabad, Tamil Nadu, Rajasthan, Gujrat etc. has already mandated and implemented the RWH in the Byelaws.¹⁷

Components of Rainwater Harvesting

RWH system has three components:



Catchment: Catchment refers to the prepared surface area the runoff from which is collected. Catchment can be the rooftop area of households, buildings or designated ground area. If the surface is impervious and smooth, the runoff occurs immediately. If the surface is pervious, the run-off occurs only after the surface is saturated.

Several factors affect runoff, which include:

- Intensity of rainfall- the more the intensity, the more and
- Sooner the runoff
- Duration (the length of time) of rainfall - the longer the duration, the more will be the water available for harvesting
- Timing of rainfall- during the first rainfall, more water is used up in wetting or percolating the catchment, and the runoff will be more if a second rainfall occurs soon after the first

¹⁴ <http://www.indiawaterportal.org/topics/rainwater-harvesting>

¹⁵ http://cgwb.gov.in/documents/RWH_GUIDE.pdf

¹⁶ <https://mdws.gov.in/documents/rain-water-harvesting>

¹⁷ <https://www.cseindia.org/legislation-on-rainwater-harvesting--1111>

• The surface characteristics - in harder catchment area with smooth surface the runoff will be more.

Collection system: It is the arrangement made for collecting and storing the rainfall with minimal quantitative loss.

Utilization system: It is required to make use of the collected rainwater for gainful purposes. It generally includes a distribution system that directs water to the point of use. This may be a hose, a channel, pipes, perforated pipes or drip irrigation system. This may be a hose, a channel, pipes, perforated pipes or drip irrigation system. If gravity flow is not possible, an electric pump may also be the part of distribution system.¹⁸

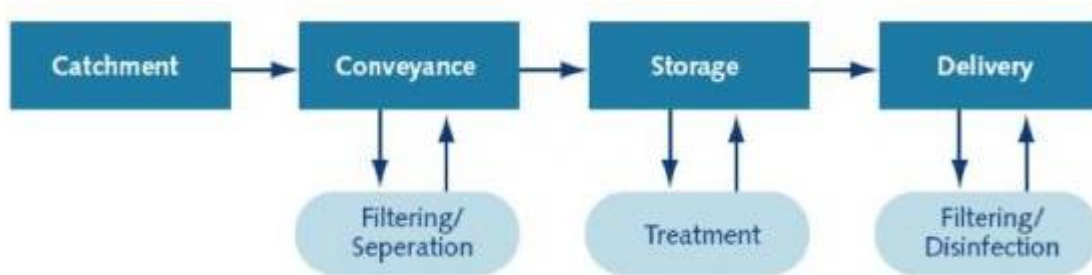


Figure 11 Process diagram of a drinking water RWH system. Source: THOMAS & MARTINSON (2007)

5.3.2. Best Practices

5.3.2.1. Tamil Nadu- Case of Chennai¹⁹²⁰

The Rain Water Harvesting movement launched in 2001 in for the state of Tamil Nadu by the Honourable Chief Minister. It has had a tremendous impact in recharging the groundwater table all over Tamil Nadu.

Amendments made to Section 215 (a) of the Tamil Nadu District Municipalities Act, 1920 and Building Rules 1973, have made it mandatory to provide RWH structures in all new buildings.

To consolidate the gains, various measures have been taken up for rejuvenation of RWH structures created already in both public and private buildings, besides creating new ones.

IEC activities will be continued in the Town Panchayats to sensitize all the stake holders to sustain the momentum. During 2011-12, in order to give a fillip to this laudable programme, the Town Panchayats have undertaken the construction of new RWH structures and renovation of old RWH structures. IEC activities are being carried out in Town Panchayat areas to sustain the momentum of the programme.

There are 1821 water bodies maintained by Town Panchayats with an extent of 6286.84 acres. In order to restore the 243 water bodies Rs. 55.52 crore has been allocated for the years 2011-12 and 2012-2013 under IUDM and NABARD. Similarly, during 2013-2014, 561

¹⁸<http://cpcbenvi.nic.in/scanned%20reports/Concepts%20and%20Practices%20for%20Rainwater%20Harvesting.pdf>

¹⁹ <http://www.chennaietrowater.tn.nic.in/whatwhy.html>

²⁰ <http://www.tn.gov.in/dtp/rainwater.htm>

improvement works such as desilting and strengthening of bund and sluice works have been taken up at a cost of Rs.18.40 crore under General fund. Proposed to taken up 88 water body improvement works in 68 Town Panchayats at an estimated cost of Rs.28.15 crore.

Chennai situation:

Chennai City receives rainfall during North-East Monsoon (Oct - Dec) and South-West Monsoon (June - September). A major portion of the rainfall is during North-East Monsoon. Sometimes the city also receives rainfall during January and February, but that is quite rare.

The annual rainfall in Chennai is in the range of 1200 - 1300 mm. This is higher compared to the India's average rainfall of 800 mm.

How much water can be harvested?

The total amount of water that is received in the form of rainfall over an area is called the rain water catchment/endowment of that area. Out of this, the amount that can be effectively harvested is called the water harvesting potential. The collection efficiency accounts for the fact that all the rain water falling over an area cannot be effectively harvested.

Illustration 1

Consider a building with a flat terrace area of 100 sq.m. The average annual rainfall in Chennai is approximately 1300mm. In simple terms, this means that if all the rain that falls on the terrace is retained, then in one year there will be rain water on the terrace floor to a height of 1300mm.

Area of Terrace	100 sq.m.
Height of rainfall	1.30m (1300 mm)
Volume of rainfall over the Terrace	Area x Height of Rainfall 100 sq.m. x 1.30 m : 130 cu.m. (1,30,000 litres)

Assuming that 60% of the total rainfall is effectively harvested. Volume of water harvested = $1,30,000 \times 0.6 = 78,000$ litres

That means ($78,000 / 365 \sim$) 213 litres of water per day will be available for the household. That much quantity of water is enough to meet the drinking and cooking needs of a household having around 8 to 10 members.

Illustration 2

Take example of a multi-storied building with a terrace area of 500 sq.m.

For the annual rainfall of 1300 mm, assuming that 60% of the rain water is harvested, the total rainwater harvesting potential for this building will be:	500 x 1.3 x 0.6 cu.m.= 390 cu.m.= 3,90,000 litres
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If there are 16 flats in the building the per day water availability per flat will be 67 litres/day.

Illustration 3

Name of the building	School campus/building
Terrace area	3,500 sq.m
Annual rainfall	1300 mm
Quantity of rain water harvesting potential assuming that 60% of the rainfall can be harvested	3,500 x 1.3 x 0.6=2730 cu.m.=27,30,000 litres
Water availability per student per day	365 x No.of students

From the above illustration it is quite clear that the rain water harvesting has a vast potential to meet the water needs of individual house holds and institutions.

If we take the Chennai Metropolitan area for knowing the rain water harvesting potential

$$\text{Area} = 173 \text{ sq.km} = 173 \times 10^6 \text{ m}^2$$

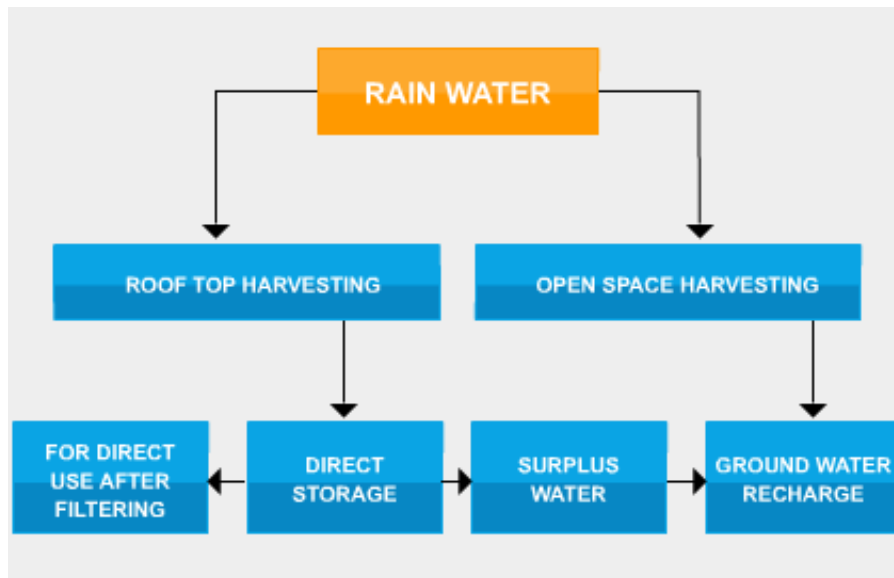
$$\text{Rainfall} = 1.30 \text{ m}$$

$$\text{Quantity of water which can be harvested (assuming 60\% rain fall can be harvested)} = 173 \times 10^6 \times 1.30 \times 0.6 = 135 \times 10^6 \text{ m}^3 = 135000 \text{ ML} = 370 \text{ MLD}$$

How to Harvest Rainwater

Harvesting rain water is very simple. When it rains we have to collect this water and not to allow it to run away. There are various techniques to do it. Broadly, rain water can be harvested for two purposes.

- Stored for ready use in containers above ground or below ground.
- Charged into the ground for withdrawal later (ground water recharging).



Rain Water Harvesting in Different type of Buildings

- a. Sloping Roofs – Thatched and Tiled Roof
- b. FOR COMMON HOUSES WITH RCC ROOF

For step by step approaches please go to link - <http://www.chennaietrowater.tn.nic.in/methods.html>

CMWSSB Initiatives in RWH

As a water conservation measure, Government has given an exceptional thought to proposals such as RainWater Harvesting. CMWSSB has decided to embark upon popularising the RWH techniques among the residents of Chennai city, as also in the neighbouring areas.

Considering the importance of Rainwater harvesting in conserving the precious ground water resource, the Board has taken initiative to constitute a fully dedicated "Rain Water Harvesting Cell".

The main objective of the Cell is

- to create awareness and to offer technical assistance free of cost to the residents
- to provide to the citizens 'cost effective solutions'.

CMWSSB has created several models, detailed designs etc., which are available in the form of brochures, booklets and are being distributed to the public. CMWSSB have also tried to disseminate related information through electronic and print media quite vigorously. An Information Centre on RWH was opened from 10.8.2001 onwards at the CMWSS Board Head Office.

Efforts were taken to convert the Rain Water Harvesting campaign launched by the Government as people's movement. A number of seminars/ workshops and exhibitions were organised involving various Government agencies, NGOs and private individuals. As a result

of this intensive campaign the Rain Water Harvesting has become popular in Chennai city and the people are adopting it on their own.

Realizing the importance on regulatory mechanism for providing rainwater harvesting CMWSSB has made the installation of Rain Water Harvesting structures as a compulsory pre-requisite for providing water and sewer connections for all the new buildings.

Regular training programme are being conducted at the Metrowater Resources Centre for the benefit of public, private engineers and building workers. A list of Resource Persons has been prepared and made available. Details on RWH have also been put up on the Metrowater website.

The initiatives taken by CMWSSB can be categorised into macro level and micro level initiatives.

- At macro level the Board has constructed a number of check dams to recharge ground water in wellfield area and also have constructed injection wells to arrest saline water intrusion in one of its wellfield close to coast.

Groundwater Regulation Act

On the basis of clear evidence of sea water intrusion into the Minjur aquifer, the Tamilnadu Government realised the necessity of saving the coastal aquifers and other ground water potential zones in and around the city and enacted legislation to regulate and control the extraction, use or transportation of ground water.

The Act which came into force with effect from 15.2.88 has been named as "The Chennai Metropolitan Area Groundwater (Regulation) Act, 27 of 1987". A total number of 243 revenue villages of the neighbouring two districts and the city of Chennai are included in the scheduled areas of the Act.

The Act envisages

- Registration of existing wells
- Regulation of sinking new wells
- Issue of licences to extract ground water for non-domestic purpose and
- Issue of licences for transportation through goods vehicles. Licences were issued by the Revenue officials on payment of prescribed fees after getting technical clearance from CMWSSB.

At micro level, this Board have taken a no. of steps to popularise RWH at individual house hold level in Chennai city. This Board has also implemented RWH in the public buildings such as Raj Bhavan, Children's Park, Egmore Museum, Presidency College, Stanley Hospital, Nochikuppam slum and Lady Willingdon Higher Secondary School to create models for demonstration. In Chennai city, a total no.of 38,218 RWH structures have been constructed by individuals and in Government Buildings.

Some major initiatives at Micro Level are as follows:

- To create public awareness on the importance of RWH among the public.

- To popularise simple and cost effective RWH methods in order to attract larger participation of the public.
- To offer technical guidance/assistance about the methods to be adopted based on the local geological formations and site conditions.
- To monitor water level and water level quality in the Rainwater Harvested areas and wells (both existing and proposed areas/wells).
- To assure proper maintenance of the RWH structures after installation.
- To do and undertake anything which would promote RWH (both in individual houses and public places).

Impact of Initiatives

After the implementation measures such as construction of check dams across Koratalaiyar river, there has been phenomenal increase/rise in the ground water table.

As a matter of fact, during the year 2000-2001, Metrowater Board has been able to increase the drawl from 55 mld to the present 100 mld of water (50% of city supply) from these Wellfields only due to the measures undertaken by the CMWSS during the last 5 to 6 years.

Rain Water Harvesting and Flood Mitigation-Road side RWH Structures

Metrowater identified some 45 water stagnating areas in Besant Nagar in the stretch of Alcot Kuppam to Odai kuppam, 14 locations on Kamarajar Salai and 4 locations in Chintadripet for implementing RWH structures. In the rainwater stagnated at the rains.

As the stagnant rainwater can be recharged into the ground, suitable RWH structures were installed to these locations as a measure of flood mitigation.

The newly constructed storm water drains provided with percolation pits for recharging the underground aquifers.

Storm water drains can be connected to nearby open wells/recharge pits and in nearby parks.



Monitoring the quality of water

Water stored from the house roof top is presumed to be pure and potable as it will not flow on the ground and come into contact with any liquid or solid materials which can alter its quality. Therefore the monitoring is done by Analysis of Water Samples as per the standards.

Disinfecting water

Disinfecting is the process of killing the disease causing micro-organism present in the water. This can be done either by boiling the water in a vessel before consuming or by dissolving bleaching powder in required quantity to the water stored in the tank.

For disinfecting using bleaching powder, the general dosage recommended is 10 milligrams of bleaching powder containing 25% of free chlorine per litre of water. this meets the required standard of 2.5 milligrams of chlorine per litre of water.

After adding the bleaching powder, the water shall be stirred thoroughly for even distribution of the disinfectant agent. The water should be kept without use for about 30 minutes after adding bleaching powder.

Recommended dosage of bleaching powder for Disinfecting water

Storage	Dosage of bleaching powder (in grams)			
	Full tank	Tank three fourth (3/4) full	Tank half (1/2) full	Tank one fourth (1/4) full
Capacity of Tank (litre)				
5,000	50	37.5	25	12.5
6,000	60	45.0	30	15.0
7,000	70	52.5	35	17.5
8,000	80	60.0	40	20.0
9,000	90	67.5	45	22.5
10,000	100	75.0	50	20.0

For more Best Practices Rain water harvesting in urban areas – <http://www.rainwaterclub.org/docs/R.W.H.industries.urban.pdf>

5.4. Storm Water Drainages

Definition

Storm water drainages consist of open channels, are more common in urban or densely built-up areas, and they normally serve to take the drainage from highways as well as from buildings.²¹

Rationale and need

The soft Landscape in Urban India is inundated by the development shrinking the Nature's absorbent for Rainwater. The substitute Man-Made Storm water Drainages along roads are insufficient or Polluted, Clogged by the discharge of Industrial, Municipal waste in Urban Locations.

The Roads are flooded at the time of Rainy season. The city managers face serious challenges in big cities and industries, where most of the open area is covered by roads or some concrete structures without proper drainage. There major issues addressed from storm water drainage are Urban Flooding, Disaster Management, Ground Water Recharge, Water access.

A survey of 23 states in 2010-11 covering a total of 1,383 urban local bodies (ULBs), found 56 of the 104 large cities had storm water drainage coverage below 50% (a level termed by the ministry as needing "immediate action for improvement") and 93 had coverage below 75% ("caution for improvement").²²

The National Green Tribunal (NGT) has recently directed the municipal bodies of Delhi and other authorities responsible for maintenance of stormwater drains to protect them from encroachment and pollution.²³

5.4.1. Urban Floods

Urban floods are the floods occurring in urban areas, and are primarily caused by heavy rainfall overwhelming the drainage capacity.

Urban flooding is different as compared to the flooding of rural areas in following major aspects:

- High Impervious surface cover
 - Increase in runoff volume and flow velocity
 - Reduces the time of concentration
 - Large flows reaching discharge outlets in short time span.
- Sub-surface Drainage Network

²¹ https://www.who.int/water_sanitation_health/hygiene/plumbing16.pdf

²² <http://spaenvis.nic.in/index1.aspx?lid=2439&mid=1&langid=1&linkid=565>

²³ <https://www.downtoearth.org.in/news/what-drains-mean-to-cities-44069>

- capacity of drainage network is limited by its design
- involves complex open channel hydraulics; design & maintenance of drains influence capacity.
- Higher concentration of population and assets
 - greater risk to human lives and high cost of damages to assets.

Urban Flooding in Major Indian Cities

Cities	Flooding Years
Ahmedabad	2001
Bangalore	2005, 2009, and 2013
Chennai	2004 and 2015
Delhi	2002, 2003, 2009, 2010, 2013, 2016
Guwahati	2010 and 2011
Hyderabad	2000, 2001, 2002, 2006 and 2008
Jamshedpur	2008
Kolkata	2007 and 2013
Mumbai	2005, 2007, and 2015
Srinagar	1992, 2014 and 2015
Surat	2006 and 2013

(NIUA 2016)

Space Applications Centre ISRO

5.4.2. Planning and Implementation

5.4.2.1. Guidelines for Management of Storm Water

*National Disaster Management Authority (NDMA, 2010) of Government of India has published guidelines*²⁴

The same has been discussed below:

- a. Catchment as basis for Design: States and cities have political and administrative boundaries. However, rainfall and runoff processes are independent of these boundaries, and depend on the watershed delineation. The outline of the drainage divide must follow the actual watershed boundary rather than the administrative boundaries. Each urban area may consist of a number of watersheds. A watershed is the geographic region within which water drains into a stream, river, lake or sea. The watershed may be composed of several sub watersheds and catchments. The catchment is the area draining surface water to a particular location or outlet point. Catchment will be the basis for planning and designing the storm water drainage systems in all Urban Local Bodies (ULBs).
- b. Contour Data: Accurate contours are necessary for determining the boundaries of a watershed/catchment and for computing directions of flow. Detailed contour maps at required resolution should be prepared for proper delineation of drainage catchments. Contour mapping of urban areas will be prepared at 0.2 to 0.5 m contour interval for detailed delineation of the watershed/catchment for planning drainage systems.

²⁴ https://ndma.gov.in/images/guidelines/management_urban_flooding.pdf

- c. **Rainfall Variations:** The conventional practice for designing of a drainage system is to choose an appropriate, statistically relevant design storm to establish the storm water flows to be conveyed, based on existing national and international practices. Design storms can be estimated from rainfall data records where available. Rainfall is the main driver of runoff processes. The frequency and intensity of rainfall in India, not only shows a great variation but the intensity of rainfall also is generally much higher than in many other countries. There is wide variation of rainfall amongst the cities and, even within the city, rainfall shows large spatial and temporal variation; Due to the high variability of rainfall in space and time, rainfall measurements are required at high temporal and spatial resolution from dense Rain Gauge networks for the adequate design of new systems and/or renovation of existing drainage systems. Up to date Intensity Duration frequency (IDF) relationships need to be used to maintain design standards for new systems and retrofitting/replacement of old urban drainage systems.
- d. **Thunderstorm Rainfall Intensity:** Special consideration should be given to rainfall caused due to thunderstorms, which result in high intensity rainfall in short durations (e.g. 15 mm rainfall in 15 minutes i.e. 60 mm/h). Delhi and many other cities faced severe disruption due to flooding in 2009 and 2010, caused by thunderstorms embedded in monsoon systems which overwhelmed the drainage systems, designed for much lesser values of the rainfall intensity. By the very nature of formation, it is observed that severe thunderstorms result in rainfall intensities of the order of 50-70 mm/h which cause flash flooding. Hence, the frequency of thunderstorms becomes an additional consideration for planning future urban drainage systems.
- IDF curves should be developed for each city, based on extraction of data from the raw data charts at 15 minutes resolution and from Automatic Weather Stations (AWS) at 5minutes resolution, and
 - IDF relationships will be adjusted taking into account climate change impacts and urban heat island effects. At the very least, a trend analysis of short duration rainfall intensities will be carried out and if an increasing trend in the recent years is shown, higher intensities than those provided by IDF relationships will be used for resizing existing systems and design of new systems, especially for critical infrastructure like airports, major roads and railway tracks.
- e. **Design Flow:** To protect residential, commercial, industrial and institutional buildings in urban areas, safe management and passage of water, resulting from frequent storm events (hydrologic design aspects) and adequate capacity (hydraulic design aspects) must be considered. In the context of urban drainage, the main objectives of hydrologic analysis and design are to estimate peak flow rates and/or flow hydrographs for the adequate sizing and design of conveyance and quantity control facilities. To estimate peak flow rates, knowledge of the rainfall intensity, its duration and frequency is required for preparing satisfactory urban drainage and storm water management projects. Due to limited data, statistics and probability concepts are used in hydrologic analysis. Current international practice involves frequency analysis of rainfall intensities, based on extreme value distributions with adjustments for climate change effects. Intensity-Duration-Frequency (IDF) curves are required to be developed for systematic analysis. However,

the return period concept has an element of subjectivity. Increasing rainfall intensities induced by climate change, urban heat islands and other factors will possibly result in varying return periods for a given intensity of rainfall. The rainfall intensity to be used for design will also depend on the time of concentration. Higher the catchment area, higher will be the time of concentration and lower will be the design rainfall intensity, other factors remaining the same.

Peak flow rates can be estimated using the Rational Method. However, for computation of water level profiles in the drainage systems or channels/rivers, suitable software for flood routing should be used. The available public domain software are the HEC-HMS for hydrologic modelling of the watershed, HEC-RAS for river modelling, both developed by the US Army Corps of Engineers and SWMM (Storm water Management Model) for sewer/ drainage design, developed by the US Environmental Protection Agency. These software's are available on web.

- f. Runoff Coefficient for Long Term Planning: Keeping in view the projected rate of urbanization, it is imperative to consider a 50-year planning horizon. Due to development that is bound to take place during this period, it will be difficult to upgrade the underground drains once they are laid. Therefore, it is recommended that all future drainage plans for urban areas should be carried out, taking these factors into consideration. All future storm water drainage systems will be designed taking into consideration a runoff coefficient of up to $C = 0.95$ estimating peak discharge using the rational method, taking into consideration the approved land use pattern of the city.

Other major guidelines to be referred are-

- Central Public Health Engineering Organisation recommends rational method for design of storm water drainage infrastructure in India (CPHEEO 1993).²⁵
- Manual on sewerage and Sewage Treatment (MoHUA)²⁶

5.4.2.2. Drainage Network Design in India is based on Event Models.

Inventory of the existing storm-water drainage system will be prepared on GIS platform

Future Storm-water Drainage Systems will be designed with a Runoff Coefficient of up to 0.95 in using Rational Method taking into account the Approved Land-use Pattern;²⁷

It is common practice to assume the rainfall intensity corresponding to 2 years return period for general residential areas, and 5 years return period for important establishments and commercial areas.

Module on Urban Storm Water and flood management-
<https://nptel.ac.in/courses/105101010/downloads/Lecture32.pdf>

²⁵ http://cpheeo.gov.in/upload/uploadfiles/files/engineering_chapter3.pdf

²⁶ <http://mohua.gov.in/publication/manual-on-sewerage-and-sewage-treatment-cpheeo-1993.php>

²⁷ https://vedas.sac.gov.in/vedas/downloads/ertd/Hydrology_8_11%20August%202017/L_7_Urban%20Storm%20Water%20Management_GauravJain.pdf

PLANNING AND DESIGN OF SURFACE DRAINS- Functional Plan on Drainage for NCR

http://ncpcb.nic.in/pdf_files/FP%20on%20Drainage/Chapter%205%20%20PLANNING%20AND%20DESIGN%20OF%20SURFACE%20DRAINS.pdf

5.4.3. Monitoring/KPI's

Storm Water Drainage: Extent of the network and effectiveness of the network are emphasized to assess storm water drainage systems performance. As this service does not yield any direct revenues, financial sustainability is not considered. Indicators selected are:

Coverage of Storm water drainage network - This indicator provides an estimation of the extent of coverage of the storm water drainage network in the city.

Incidence of water logging / flooding- This indicator provides a picture of the extent to which water logging and flooding is reported in the ULB within a year, which has impacted significant number of persons impacting normal life and mobility. This indicator provides an assessment of the impact or outcome of storm water drainage systems.²⁸

Indicator	Unit	Definition	Data Required	Benchmark Value
Coverage of storm water drainage network	%	Coverage is defined in terms of - % of road length covered by storm water drainage network	Total length of road network in the ULB Total length of primary, secondary and tertiary drains	100%
Aggregate number of incidents of water logging reported in a year	Nos. per year	Number of times water logging is reported in a year, at flood prone points within the city	Identification of flood prone points within the ULB limits. The points may be named as A1, A2, A3, An. b) Number of occasions of flooding / water logging in a year	Zero

²⁸ <http://www.asci.org.in/ssl/SLB%20toolkit.pdf>

5.4.4. Best Practices

5.4.4.1. Integrated Storm Water Management – An Approach for Urban Flooding In Hyderabad, India

Storm water management is a complex phenomenon especially in urban scenario where land costs are high. Especially in cities like Hyderabad, India unplanned settlements are more common in low laying areas which are water bodies once upon time. Since flooding is not a frequent process, people are ready to live in this areas as the chances of flooding is once in five or ten years. This is resulting into further worsening of the problem and frequency flooding is increasing. This is multiplying with changes in climate due to which intensity of rain is increasing year by year. A long-term vision is necessary to focus on urban stormwater management.

This vision provides a context for all planning, data collection, sensitivity analyses, capital expenditures and regulatory changes. In Integrated Stormwater management by prioritizing goals and actions (ideally through consensus) provides a road map for moving towards a target condition by identifying the interconnected nature of goals, values and expectations, risks and opportunities, what needs to be done to manage the risks and achieve the opportunities, who should be responsible, a general timeline for implementation. This framework addresses the goal of identifying options to change the way that land is developed and re-developed, so that people, property and natural systems can be better protected and over time, infrastructure can be managed more efficiently and watersheds can become healthier.

INTEGRATED STORMWATER MANAGEMENT PLANNING AND DESIGN

The objectives of an Integrated Stormwater Management plan (ISMP) will be watershed-specific, with following components:

- Drainage Objectives - Alleviate existing and/or potential drainage, erosion, and flooding concerns.
- Stream Protection Objectives - Protect and/or restore stream health, including riparian and aquatic habitat.
- Water Quality Objectives - Remediate existing and/or potential water quality problems. The ISMP should focus on the integration of stormwater management and land use planning.

An ISMP is an integral component of a local government's land development and growth management strategy because upstream activities (land use change) have downstream consequences (flood risk and environmental risk). A Layered approach may be useful to develop ISMP. Layered approach may involve

- First Layer – Identify the stormwater-related objectives for a watershed (e.g. protection of aquatic resources, protection of life and property, protection of water quality). These objectives define what the ISMP is striving to achieve.

- Second Layer – Develop strategies to achieve the watershed objectives. This includes setting performance targets to guide selection of site design solutions.
- Third Layer – Implement appropriate site design solutions (e.g. source controls) for achieving performance targets that suit local objectives and conditions.

To select appropriate storm water management strategies and site design solutions, it is first necessary to identify the resources to be protected, the threats to those resources, and the alternative management strategies for resource protection.

Table 3 Planning and Implementation of Integrated Storm Water Management Plan²⁹

S. No	ISMP DELIVERABLE	SCOPE OF DELIVERABLE
1	An inventory of the physical and biological systems	Streams, rivers, and drainage systems, wetlands, ponds and lakes, infiltration areas and aquifers, land use information flooding and erosion problem areas, water quality problems
2	Component plans to protect key resources, resolve identified problems, and accommodate development	Plan for integrating appropriate source controls with land development, including a description of any required regulatory changes, plan for improvements to drainage systems and stream reaches, plan for ongoing data collection and monitoring, cost estimates for all planned actions
3	An implementation program	Administration, projects, phasing and budgets, financing mechanisms, community education, maintenance activities, standards and schedules, performance monitoring

After defining the deliverables, seven step process may be used for development and implementing ISMP.

Table 4 Step process for development and impementing ISMP

Step	Scope	Description
1	<ul style="list-style-type: none"> • Secure Political Interest and Support • Inter-departmental & inter-agency steering committee Political and public support 	An ISMP process starts with a high-level political commitment to protecting property, water quality and aquatic habitat. This is required to convert high-level policy statements into concrete action so that there will be a flow of funding for the ISMP process. Without political support for funding, there will be no ISMP process. Once funding is assured, however, a key to a

²⁹ [http://www.ajer.org/papers/v5\(10\)/P05010101110.pdf](http://www.ajer.org/papers/v5(10)/P05010101110.pdf)

	<ul style="list-style-type: none"> Stakeholder focus groups 	successful outcome is that there be a commitment by all stakeholders to make the ISMP process work.
2	<p>Frame the Watershed Problems and Opportunities</p> <ul style="list-style-type: none"> Assemble existing information Identify and prioritize problems <p>(knowledge-based approach)</p>	This involves application of an interdisciplinary roundtable process. To identify and rank the problems and opportunities in a watershed. Sufficient time must be invested at this stage to ensure that there is a clear understanding of the problems to be solved. This understanding will then guide the rest of the ISMP process.
3	<p>Develop Objectives and Alternative Scenarios</p> <ul style="list-style-type: none"> Establish desired levels of environmental protection and other objectives Set appropriate performance targets Model alternative scenarios for achieving targets 	<p>It involves further application of the interdisciplinary roundtable process to:</p> <ul style="list-style-type: none"> determine which problems and/or opportunities are priorities for action establish objectives for dealing with these priority problems/opportunities develop alternative scenarios for achieving the objectives. Developing a common understanding among participants in the ISMP process is key to developing a shared vision of what is desirable, practical and achievable.
4	<p>Collect Meaningful Data and Refine Scenarios</p> <p>Collect data needed to:</p> <ul style="list-style-type: none"> refine scenario models evaluate effectiveness and affordability.g. hydrometric data, soils data 	Collect the additional data that may be needed to evaluate the effectiveness, feasibility and affordability of implementing the scenarios identified in Step #3 for meeting watershed objectives. This step may involve collecting site-specific data to refine the assumptions of the scenario models generated in Step #3
5	<ul style="list-style-type: none"> Evaluate Alternatives & Develop ISMP Component Plans Land Development Action Plan 	Once watershed objectives have been established, alternative scenarios for achieving those objectives have been generated, and the data needed to evaluate the effectiveness of these scenarios has been collected, the next step is to evaluate the alternatives and make decisions.

	<ul style="list-style-type: none"> Habitat Enhancement Plan Flood Risk Mitigation Plan 	<p>These decisions will provide the basis for developing plans for habitat enhancement, flood risk mitigation and relevant land development actions. These are all related components of an ISMP.</p> <p>The fourth component is a financial and implementation program (see Step #6), which is essential for moving from planning to action.</p>
6	Develop an Implementation Program Finance and implement ISMP actions	<p>The Financial Plan and Implementation Program should therefore outline how the land acquisition and capital financing of the elements can be achieved. Tools might include negotiations during zoning changes, land exchange, density bonuses. Strategies will be specific to the properties in question.</p> <p>In addition to capital financing, the regulatory framework is another component of implementation to be used in balance with public awareness and capital works programs.</p>
7	<p>Refine Through Adaptive Management Define adaptive management rules, roles and responsibilities</p> <p>Constantly improve integrated solutions</p>	<p>This is key to resolving stakeholder uncertainty associated with changes in standard practice. Monitoring and evaluating the performance of demonstration projects will provide confidence in new approaches. It will also provide the basis for optimizing stormwater system design to reduce costs while still achieving defined goals for protecting downstream property, aquatic habitat and receiving water quality</p>

Best Practices to be referred-

- Storm Water Drainage Design (Case Study Vijayawada)
https://www.researchgate.net/publication/312028043_Storm_Water_Drainage_Design_Case_Study_Vijayawada
- The drainage systems of India's cities
<https://www.ircwash.org/sites/default/files/Gupta-2005-Drainage.pdf>
- Storm water modeling in part of surat city
https://vedas.sac.gov.in/vedas/downloads/ertd/Hydrology_8_11%20August%202017/L_7_Urban%20Storm%20Water%20Management_GauravJain.pdf

4. Lagos state adaptation strategy on stormwater drainage management and flood control

http://resilientcities.iclei.org/fileadmin/sites/resilientcities/files/Resilient_Cities_2011/Presentations/C/C5_and_D5_Ogunbambi.pdf

5. Storm Water Drainage master plan of hapur (Asian Development Bank)

<https://www.adb.org/sites/default/files/project-document/78825/41598-012-tacr-ind-mp04.pdf>

5.5. Flood Resilience

Definition

Floods are any high stream flow, which overlap natural or artificial banks of a river or a stream and are markedly higher than the usual as well as inundation of low land. Sometimes copious monsoon rains combine with massive flows from the rivers, then the floods indeed become calamitous.

The term Resilience originates from ecology and can be defined, as the ability of a system to resist the perturbation or it is the speed the system recovers after being disturbed. Resilient Flood Risk Management focuses on the ability of a system to resist the flood, taking into account the consequences of floods. Applying the resilience strategies, decision maker does³⁰ not try to "fight against floods" but to find the way to "live with floods" by minimizing their impact.

Rationale and need

Building resilience to flooding is an important need to sustain the liveability and economic competitiveness of cities worldwide.³¹

According to the United Nations Global Assessment Report on Disaster Risk Reduction 2015, India's average annual economic loss due to disasters is estimated to be US \$9.8 billion. This includes more than US\$7 billion loss on account of floods.

According to the report of Climate Resilient Development Planning for Flood and Cyclone Risk Mitigation in Changing Environment 4-6 July 2017, NIDM "In India, 22 states and one Union territory (Andaman & Nicobar) are vulnerable to floods. However, the most vulnerable states of India are Uttar Pradesh, Bihar, Assam, West Bengal, Gujarat, Orissa, Andhra Pradesh, Madhya Pradesh, Maharashtra, Punjab and Jammu & Kashmir. On an average, an area of about 7 million hectares (17.50 mha maximum in 1978) was flooded, of which, on average crop area affected was of the order of 3.302 million hectares (10.15 m ha in 1988). The floods claimed on an average 1464 human life and 86288 heads of cattle dead 2 every year.

³⁰<http://daad.wb.tuharburg.de/fileadmin/BackUsersResources/Resilience/Introduction/IntroductionToFloodResilience.pdf>

³¹ <https://www.un-ihe.org/planning-and-delivery-flood-resilience-0>

The National Commission on Floods (Rashtriya Barh Ayog) Government of India (1980) laid a great stress on proper flood management for the specific problems of the Ganga and the Brahmaputra".³²

5.5.1. Planning and Implementation

Development Goals, 2030 Agenda (SDGs) & Paris Climate Agreement, 2015 have made the global community realize and recognize that DRR, CCA & sustainable development are linked to each other. Efforts are continuously increasing to adapt to climate change & reduce the disaster risks but at the same time the economic & social cost of these disasters are increasing year by year.

Sendai Framework for Disaster Risk Reduction

The theme of Sendai Framework i.e. "Build Back Better" may be helpful to create new pathways & approaches for integration of CCA & DRR to combat the perennial problems of flood & cyclone and their resultant destruction has been at the forefront of concern for disaster managers and policy makers.

National Policy on Disaster Management³³- To build a safe and disaster resilient India by developing a holistic, proactive, multi-disaster oriented and technology driven strategy through a culture of prevention, mitigation, preparedness and response.

The Disaster Management Act 2005³⁴ -

The **Disaster Management Act, 2005**, (23 December 2005) No. 53 of 2005, was passed by the Rajya Sabha, the upper house of the Parliament of India on 28 November, and by the Lok Sabha, the lower house of the Parliament, on 12 December 2005. It received the assent of The President of India on 9 January 2006. The Disaster Management Act, 2005 has 11 chapters and 79 sections. The Act extends to the whole of India. The Act provides for "the effective management of disasters and for matters connected there with or incidental thereto."

Establishment of National Disaster Management Authority³⁵

With effect from such date as the Central Government may, by notification in the Official Gazette appoint in this behalf, there shall be established for the purposes of this Act, an authority to be known as the National Disaster Management Authority.

National Disaster Management Guidelines, Management of Floods³⁶ - Recognising the gravity of the risk and vulnerability of India to floods, the NDMA, soon after its constitution initiated a series of consultations with the various stakeholders to develop Guidelines for strengthening the existing arrangements for flood preparedness, mitigation, and post-flood emergency response, relief, rehabilitation and reconstruction. The NDMA has prepared these

³² http://nidm.gov.in/PDF/trgreports/2017/July/4-6_vijayawada.pdf

³³ <https://ndma.gov.in/images/guidelines/national-dm-policy2009.pdf>

³⁴ https://ndma.gov.in/images/ndma-pdf/DM_act2005.pdf

³⁵ <https://ndma.gov.in/en/>

³⁶ <https://ndma.gov.in/images/guidelines/flood.pdf>

Guidelines for Flood Management (FM), to assist the ministries and departments of the GOI, the state governments and other agencies in preparing Flood Management plans (FMPs)

Guidelines Improving Flood Resistance of Housing 2010³⁷

Ever since the Kosi floods of 2008 inflicted damages and loss of lives in a colossal way, BMTPC thought of publishing the guidelines on improving flood resistance of housing which not only dwells upon the planning aspects of houses in flood prone areas but also on construction technologies to be adopted to make them safe in the event of inundation.

FMP During XII Plan³⁸

Flood Management Programme (FMP) during XII Plan for providing central assistance to States to the extent of Rs. 10,000 crore for taking up works related to river management, flood control, anti-erosion, drainage development, flood proofing works, restoration of damaged flood management works, anti-sea erosion and catchment area treatment.

Flood Forecasting³⁹

Flood forecasting has been recognized as one of the most important, reliable and cost-effective non-structural measures for flood management. Recognizing the crucial role it can play, Central Water Commission, Ministry of Water Resources has set up a network of forecasting stations covering all important flood prone interstate rivers. The forecasts issued by these stations are used to alert the Public and to enable the administrative and engineering agencies of the States/UT's to take appropriate measures.

This is a website for Central Water Commission's Flood Monitoring and Forecast dissemination. This can be explored using map-based exploration or list based exploration or Hydrograph View

For more information on planning and implementation on Flood management in India http://www.indiawris.nrsc.gov.in/wrpinfo/index.php?title=Flood_Management

5.5.2. Best Practices

Flood Resilience in Delta Cities- An explorative research on monitoring flood resilience in Delta Cities

<http://edepot.wur.nl/390189>

5.6. District Metering Areas (DMA)

Definition

DMAs are often used as a tool to control and cut down leakage in networks that have received little or no leak location work other than dealing with reported occurrences. Initially the DMAs will be used as a tool to determine which parts of the network are experiencing the highest

³⁷ <http://www.bmtpc.org/DataFiles/CMS/file/flood-guidelines.pdf>

³⁸ <http://mowr.gov.in/sites/default/files/Guidelines-FMP-XII%20Plan%20-Oct-2013.pdf>

³⁹ <http://india-water.gov.in/ffs/>

level of leakage and to discount areas where there is limited leakage, so that resources can be targeted to the greatest effect.

Rationale and Need

The need for District metering area is for Reducing Non-Revenue Water, Pressure management by water pressure readings and metering data daily, to facilitate leak detection, Monitoring and metering. As per CPHEEO, District Metered Areas (DMAs) are considered the fundamental building block for conversion from intermittent to 24-7 supply. The DMA operation as a continuously pressurized network, managed through a system, has a number of operational advantages.⁴⁰

- Water flows through the system at a lower rate than for intermittent supply. Therefore the lower the pressure, the lower the rate of leakage.
- System pressure can be measured and routinely controlled.
- Most significantly, as the distribution system is always full and under pressure, leaks can be detected using traditional or modern sounding techniques, accurately located and repaired
- Unauthorized connections can, in some cases, be considered as “leaks” and therefore detected.

5.6.1. Planning and Implementation

As per World Bank Report,⁴¹ the District Metered Area approach is a solution for an intricate problem affecting a large (unmanageable) area by dividing it into smaller (more manageable) ones. That is breaking down a big network into more numerous but smaller areas, the District Metered Areas.

Then, for each area the total net inflows and the volume of water billed are measured and the NRW is calculated as the difference between the two figures. Once this is done, areas where NRW levels are higher than desired are analyzed to determine the appropriate solutions and implement them according to a prioritized program.

District Metered Areas are discrete hydraulic areas created within the supply zones or service stations of the city or town with a defined and permanent boundary that typically cover about 500 to 3,500 connections. The establishment of District Metered Areas includes preliminary design, detailed site survey and data collection and an understanding of the feeder mains, networks valves and meters in the area, and the supply pattern. Depending on its supply scheme, each District Metered Area is installed with one or more district meters, which should be read and recorded regularly (ideally it would either have a data logger or it would be linked to a central control station for continuous data recording).

⁴⁰<http://cpheeo.gov.in/upload/uploadfiles/files/Guidance%20Note%20for%20Continuous%20Water%20Supply.pdf>

⁴¹<http://documents.worldbank.org/curated/en/479201468316169165/pdf/441260WSP0BOX31e0reduction01PUBLIC1.pdf>

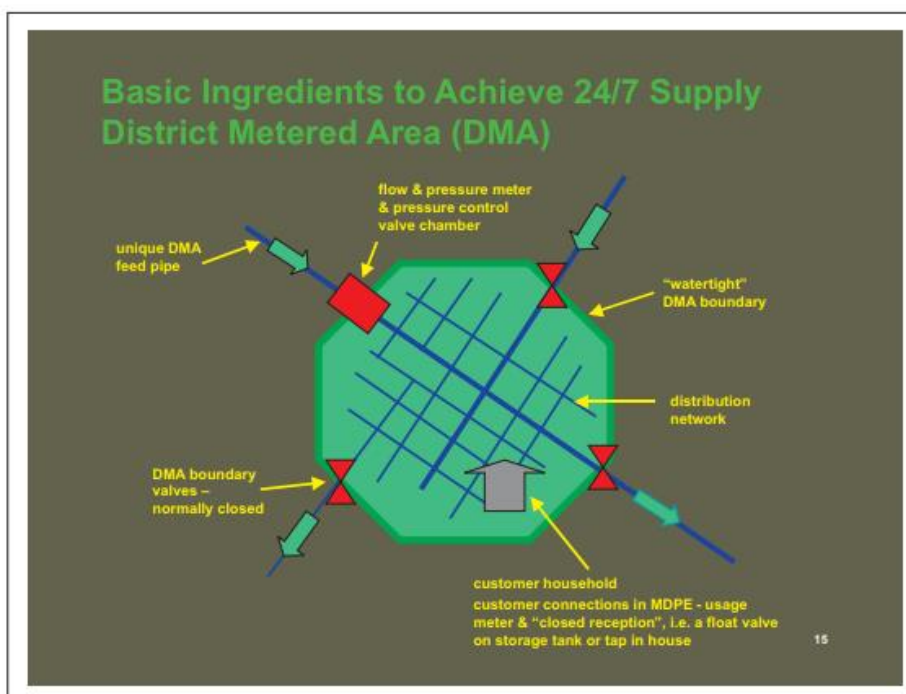


Figure 12 Basic Ingredients to Achieve 24-7 Supply in a DMA (CPHEEO)⁴⁰

5.6.2. Best Practices

Using a Pilot District Metered Area to Control Leakages (Bangalore)⁴¹

Project	Nonrevenue water reduction and control program
Agency	Bangalore Water Supply and Sewerage Board
Year	May 2003
Funded By	Japanese Bank for International Cooperation
Area	32,000 connections and 270 km of pipeline (of diameter 50–600 mm and age five to 70 years) in central Bangalore
Cost	US\$12 million
Implementing Agency	consortium -Larsen & Toubro (ground-level pipeline rehabilitation work) -Thames Water provided technical inputs

The project was implemented in two phases, with Phase I focusing on NRW reduction, establishment and maintenance of target NRW levels in each District Metered Area and staff training, and Phase II focusing on maintaining pressure and NRW levels at target levels as determined in Phase I.¹⁰ Phase I involved the formation of 21 District Metered Areas within five service stations in the pilot area.¹¹ The District Metered Areas covered about 1,000 to 3,500 consumer connections, with the exact number of consumers based on established boundaries and a network analysis.

Once District Metered Areas were created, levels of NRW were regularly monitored. Leakage detection was undertaken through noise logging, leak noise correlators, and ground microphones, especially during the night hours. Repair work including rehabilitation and replacement of pipes using medium density polyethylene pipes was undertaken. The

project controlled for apparent losses through a robust check of meters for accuracy in terms of functionality, water tightness and security and their subsequent replacement.

12 Physical losses were measured using the net night flow method and were monitored on a monthly basis. These calculations also took into consideration the impact of pressure as monitored in a few identified locations through data loggers.

Phase II involved constant monitoring, leak detection surveys, repair of leaks and rehabilitation of pipelines, and retesting of leakage levels in the District Metered Area till water loss levels were reduced and maintained at target levels. The pilot project has improved water service standards and quality. It is proposed that this pilot will be extended to all areas of the city. The Japanese Bank for International Cooperation has extended its loan component to US\$100 million. The project is designed to cover the balance 0.36 million-consumer connections that were outside the pilot zones.

5.7. SCADA (Supervisory Control and Data Acquisition)

Definition

According to National Programme on Technology Enhanced Learning, SCADA is an acronym that stands for Supervisory Control and Data Acquisition. SCADA refers to a system that collects data from various sensors at a factory, plant or in other remote locations and then sends this data to a central computer which then manages and controls the data.

It is an industrial computer-based control system which gathers and analyse the real-time data to track, monitor and control industrial equipment's across various industries such as electrical power, water & wastewater, oil & gas, transportation, telecommunication etc.

SCADA system in water & waste water

SCADA system have applications in both distribution plants and waste water treatment. In these plants PC based workstation are located in a control room which allow operators to view and perform control actions.

Rationale and Need

Gain Full Visibility of Remote SCADA System Sites⁴²

- Monitor and control critical system equipment with full visibility from a central location via reliable, always-on connectivity.
- Connect remote, orphan sites, where connectivity is otherwise unavailable, unreliable or cost-prohibitive.
- Enhance production by enabling more efficient and cost-effective collection of critical operations data.

⁴² SCADA System for Monitoring Water Supply Networks (Faculty of Electromechanical, Environmental and Industrial Informatics Engineering University of Craiova)

a. Reduce Maintenance Costs and Equipment Downtime

- Lower operations costs by enabling preventative maintenance with regular equipment monitoring.
- Reduce downtime and production losses with early fault detection and quick response time.
- Extend connectivity to sites without the cost of upgrading legacy SCADA system equipment.

b. Increase Efficiency and Reduce Site Visits

- Reduce labor, vehicle and fuel costs with process automation requiring fewer routine and emergency visits to remote sites.
- Deliver alarms and event notifications based on user-defined thresholds and criteria.
- Evolve from the use of auto dialers to a more comprehensive way of managing remote SCADA sites.

c. Connect to Remote PLCs and RTUs

- Provide connectivity between remote SCADA PLCs and the Human Machine Interface (HMI) system using edge analytics to send only relevant information.
- Streamline operations by using edge analytics to collect and analyze field data locally.
- Bridge the communications gap between RTUs and IP-based SCADA control systems.
- Support industry-standard protocols such as Modbus and OPC

Furthermore, In current scenario SCADA/EMS system needs to support a wide variety of user requirements starting from system operators to different market participants, regulators, data analyzers, and sharing of data to support the various MIS requirement. Further, legacy systems can present a number of problems that ranges from higher maintenance cost, low scalability, degraded performance, non-availability of support services etc. compared to facilities available in modern SCADA systems.

5.7.1. Planning and Implementation

A SCADA monitoring system contains a few components that, when joined, allow staff to monitor their network. A SCADA system used to monitor a network includes alarm sensors, rtus, SCADA master units, and the communication network.

These parts unit to allow staff to monitor the system. By using advanced rtus, staff can monitor vital processes through both discrete and analog alarms.

As of January 2017, 47 SCADA control centres have been commissioned. SCADA is now fully functional in five towns (three in Tamil Nadu and two in Maharashtra) and by March 2017, it is expected to be completed in another 17 towns.⁴³

For the complete status of implementation in India please visit the link <https://powerline.net.in/2017/02/25/scada-implementation/>

5.7.2. Best Practices

Case Study: SCADA-Smart Water Project (Ahmedabad Municipal Corporation)⁴⁴

Project Category	Smart Water Project
Sub Category	Water management & treatment Project
Implementing Organization	AHMEDABAD MUNICIPAL CORPORATION
Name of Project	SUPPLY,INSTALLATION, T E S T I N G & COMMISSIONING OF ELECTRICAL, MECHANICAL AND INSTRUMENTATION WORKS FOR WATER OPERATION (E & M) DEPARTMENT OF AHMEDABAD MUNICIPAL CORPORATION.
Implementing Agency	Chetas Control Systems Private Limited Pune
Project Cost	33.36 Cr (Including 5 years O & M)
Funding Pattern	35% from Central Government from JNNURAM scheme 15 % from State Government and 50% AMC
Project Key Agenda	Acquisition of Real time Energy, hydraulic & Water Quantity and Quality parameter data from 145 nos. Water distribution station, 4 nos WTP, 5 Nos. French well at centralized location at a glance & generating inputs & implementing act for increasing efficiency of water distribution system.
Project Period	Oct 2014 to Apr 2021

After one-year monitoring on the system, AMC found the saving of Rs 6 crore as electricity bill and also utilized 23 MLD water, which was being wasted.⁴⁵

⁴³ <https://powerline.net.in/2017/02/25/scada-implementation/>

⁴⁴ https://smartnet.niua.org/sites/default/files/resources/scada_water_management_and_treatment_project_.pdf

⁴⁵ <https://india.smartcitiescouncil.com/article/see-how-scada-system-helps-ahmedabad-water-dept-save-rs-6-cr-electricity-bill>

5.8. Non-Revenue Water (NRW)

Definition

As per CPHEEO, NRW is made up of real losses and apparent losses. Real losses include leaks and bursts from the network.⁴⁶

Apparent losses include:

- Metering inaccuracies
- Theft (arising from illegal connections), meter tampering and fraud
- Losses arising from use of deemed consumption (for instance, where there is no meter, or the meter is broken)
- Errors and omissions in the billing database; and Legitimate unbilled water uses (for instance, pipe flushing)
- Legitimate unbilled water uses (for instance, pipe flushing).

As per world Bank, Non-revenue water is the difference between the volume of water put into a water distribution system and the volume that is billed to customers. NRW comprises three components: physical (or real) losses, commercial (or apparent) losses, and unbilled authorized consumption.

- Physical losses comprise leakage from all parts of the system and overflows at the utility's storage tanks. They are caused by poor operations and maintenance, the lack of active leakage control, and poor quality of underground assets.
- Commercial losses are caused by customer meter under registration, data-handling errors, and theft of water in various forms.
- Unbilled authorized consumption includes water used by the utility for operational purposes, water used for firefighting, and water provided for free to certain consumer groups.

Rationale and need

A World Bank study puts the global estimate of physical water losses at 32 billion cubic meters each year, half of which occurs in developing countries. Water utilities suffer from the huge financial costs of treating and pumping water only to see it leak back into the ground, and the lost revenues from water that could have otherwise been sold. If the water losses in developing countries could be halved, the saved water would be enough to supply around 90 million people.

Reducing NRW by half is generally a very realistic target within one to two years. Such a reduction can generate a boost in annual income from increased revenues and reduced costs, while at the same time servicing more people without new investment.

- The World Bank: Recommends NRW should be less than 25%

⁴⁶<http://cpheeo.gov.in/upload/uploadfiles/files/Guidance%20Note%20for%20Continuous%20Water%20Supply.pdf>

- United Kingdom: Recommendation for NRW stands at 19%
- Chile Water Regulator Authority has determined NRW level of 15%
- American Water Works Association's (AWWA) recommends NRW about 10%
- MoHUA, Govt of India recommends NRW should be less than 15%

“Reducing Non-Revenue Water is a matter of working smart rather than working hard. The key to success is information. Better the information about the distribution system, better the management systems, easier it is to prioritise actions in to manage NRW reduction programme successfully”.

The benefits of reducing NRW include⁴⁷

- Need for less water to be produced, treated, and pumped, translating into the delay of the expansion of capacity
- Reduction in apparent losses, which will result in more water being billed and more revenue for utilities
- Adequate understanding of consumption patterns, which will allow utilities to optimize distribution systems
- Better knowledge of real consumption, which will improve demand projections
- Reduced sewage flows and pollution

5.8.1. Smart NRW Management

The ‘Smart NRW Management’ concept works based on the principle of breaking the distribution system down into smaller more manageable units – District Metering Areas (DMA).

A hydraulic model is used to calculate the optimal number and design of these areas. Data produced from the DMAs enables the authority to focus on conducting the most economically advantageous activities. Once fully functional, the system can be further developed by building in a more advanced online system of monitoring and real-time control for the whole distribution system.

5.8.1.1. How to plan for NRW Reduction?

The most expensive element in water loss reduction is the repair or replacement of damaged pipes, which involves street excavations and inevitable disruption to traffic and businesses. In most situations replacing pipes based on pipe age or material will not give an equivalent water loss reduction. To prioritise investment and achieve the fastest possible return, it is necessary to have information about the condition of the water distribution system and a holistic plan for how to best rehabilitate and develop it.

⁴⁷https://sswm.info/sites/default/files/reference_attachments/MCINTOSH%202003%20Asian%20Water%20Supply%20Chap%209%20Non%20Revenue%20Water.pdf

5.8.1.2. Steps to achieve NRW Reduction

To optimise the work and make the best decisions, a master plan for NRW reduction is needed. This plan will analyse the water distribution network based on available data. Supplementary data collection will be necessary to provide as complete a level of information in the overview as possible.

Once completed, the master plan will provide:

1. An established baseline for the NRW reduction programme
2. A breakdown of the water balance, consisting of relations between the NRW elements (real losses, apparent losses, unbilled authorized consumption, etc.)
3. A strategy for establishing management systems, databases, SCADA, GIS and modelling tools
4. Activities developed on the basis of cost-benefit calculations (pressure management, district metering, intelligent pumping operation, leak detection, etc.)
5. A proposal for District Metering Areas (DMA) and Pressure Management Areas (PMA) based on hydraulic modelling and data analysis
6. A prioritised and completed work and activity plan
7. Budgets for the NRW reduction activities and specific Return on Investment (ROI)

5.8.2. Planning and Implementation

For reducing the NRW City Manager should approach by considering the following

- Accountability must be high at all levels.
- Water services must be adequately priced.
- Reducing commercial losses is very important, because it helps improve the revenue stream almost immediately.
- Reliable information on production and consumption is necessary.
- NRW is the result of a combination of factors, not of a single one.
- NRW programs must be institutionalized and not be the result of sporadic exercises associated with the availability of grants or loan financing.
- An enabling environment must be created to address NRW. This means that
 - Utilities must have autonomy in terms of management, and they need competent and motivated employees;
 - Tariffs must be adequate, which will result in cost and benefit incentives to reduce NRW; and
 - Good governance must be practiced.
- Programs for controlling NRW should plan for the three main causes of loss:
 - metering inaccuracies,

- unauthorized consumption, and
- Leakage.

Methods of controlling leakage passive control, regular sounding, district metering, waste metering, combined district and waste metering, and pressure control.

Selecting the most appropriate method would depend on the level of leakage, the cost of leakage, and the cost-effectiveness of each method.

5.8.3. Monitoring/KPI's

Performance Indicator ⁴⁸		
Indicator	Unit	Definition
Extent of Non-Revenue Water	%	This indicator highlights the extent of water produced which does not earn the utility any revenue. This is computed as - Difference between total water produced (ex-treatment plant) and total water sold expressed as a percentage of total water produced. NRW comprises - a) Consumption which is authorized but not billed, such as public stand posts; b) Apparent losses such as illegal water connections, water theft and metering inaccuracies; c) Real losses which are leakages in the transmission and distribution networks.
Data Requirements		
Data required for calculating the indicator	Unit	Remarks
a) Total water produced and put into the transmission and distribution system	million litres per day (or) month	Daily quantities to be measured through metering, and records should be maintained. Total supply for the month should be based on aggregate of daily quantum. Only treated water input into the distribution system should be measured. If water is distributed from multiple points, aggregate of that quantity should be considered. This quantum should include water purchased directly from any other sources and put into the distribution system, if any. Water may have been purchased from neighbouring ULBs, Cantonment Boards, etc.

⁴⁸ <http://www.asci.org.in/sslb/water4.htm>

b) Total water sold	million litres per day (or) month	Actual volume of water supplied to customers who are billed for the water provided. Ideally, this should be the aggregate volume of water consumed as per which consumers have been billed. However, in the absence of a complete and functionally effective metering regimen, alternate methods of measurement need to be evolved, with lower but acceptable levels of reliability.
Non-Revenue Water	%	Non-Revenue Water = $[(a - b) / a] * 100$

Source: Ministry of Urban development, Govt. of India.

5.8.4. Best Practices

BEST PRACTICES IN NON-REVENUE WATER MANAGEMENT IN SELECTED MEDITERRANEAN COUNTRIES ALGERIA, ISRAEL, JORDAN & MOROCCO February 2013

<http://www.swim-sm.eu/files/Best Practices in non-revenue water EN Final.pdf>

5.9. Water Supply Metering

Given the complex interplay of variables in large urban water supply systems, there is clearly a need for shifting to remote monitoring through building a comprehensive system that enables data capture at various locations and relying of information through appropriate networking and software applications.

There is virtually no metering of bulk water produced and distributed within the operational areas; neither is it metered at any point in its transmission to operational areas for distribution to customers. Without metering, the main operational parameter of a water service provider, it is impossible to effectively manage the system

The introduction of metering and levying water charges could help to maintain the supply-demand balance and will contribute to the sustainability of the utility. Importantly also, it sends the message to users that water is a scarce and valuable resource.

Water meters can be classified according to the technology used for their functioning. The choice depends on the flow measurement method, the type of end use, the range of flow rates and accuracy requirements in measurements.

5.9.1. Types of water meters⁴⁹

5.9.1.1. Mechanical metering:

These meters are positive displacement flow meters. They operate by isolating and counting known volumes of a fluid, while feeding it through the meter. By counting the number of passed isolated volumes, a flow measurement is obtained. These meters are suited for measurement of clear water with little turbidity and generally less expensive than non-mechanical types. Hence these are commonly used in urban water supply systems. However, they have a higher maintenance requirement and require full water flow in the pipeline during measurement.

In this metering system, an impellor is rotated by water passing through the meter which then further translated into a volumetric reading. This mechanism is calibrated by an adjustable device that is preset and security sealed.

- Advantages:
 - These are reliable and provide reasonably accurate means of measurement provided meter is correctly installed.
 - The initial cost is relatively low.
 - The in-line maintenance is simple.
- Disadvantages:
 - Mechanical parts can be damaged, making frequent accuracy testing necessary.
 - Prone to wear in silty water, resulting in loss of accuracy and frequent need for replacement.
 - Some head loss possible.
 - Short service life

5.9.1.2. Electromagnetic metering:

Electromagnetic meter is a non-mechanical meter mainly used in urban or wastewater and industrial systems. This is also known as mag flow meter. Technologically these are velocity-type water meter, except that they use electromagnetic system for determining the water flow velocity. Since Mag meters have no mechanical measuring element, they normally have the advantage of being able to measure flow in both direction, and use electronics for measuring and totalizing the flow. These meters do not have any moving part and are minimally affected by flow disturbances related to viscosity and density.

- Advantages:

⁴⁹ Guidelines on water meters, 2015

- Electromagnetic flow meters does not have moving parts, so it does not cause any additional pressure loss when the fluid passes.
- Besides the volume flow measuring, it can also measure temperature of the medium, viscosity, density and electrical conductivity.
- It measures only the average velocity. It is not affected by state of flow (laminar or turbulent)
- Disadvantages:
 - Require water supply.
 - Electric components are more vulnerable to damage.
 - Repair require skilled technician and specialized equipment.

5.9.1.3. Ultrasonic water metering:

Ultrasonic water meter uses an ultrasonic transducer to send ultrasonic sound waves through the fluid to determine the velocity and translate the velocity into measurement of the water volume. The ultrasonic meter has a sensor that can be either inserted inside, or attached outside of the pipe. The sensor measures the water velocity in the pipe, and then converts this into flow rate.

- Advantages:
 - Long term stability and accuracy over a wide range of conditions.
 - High reliability and minimum maintenance requirement.
 - Maintenance-free meter where no external power sources are available.
 - Communication port permits transfer of data from remote stations to central system via GSM - GPRS Modem.
 - Self-adjusting transducer continually adapts to changing pipe diameters due to scaling or corrosion
- Disadvantages:
 - Cost is higher in comparison to other type of flow meter.
 - Pipe wall needs to be fairly clean and free of rust and irregularities for getting better result.

5.9.2. Case Study: Bangalore: Bulk flow metering with intelligent operating systems⁵⁰

Bangalore, the capital city of Karnataka is among India's fastest growing cities with the population growing from 57 lakhs to 84 lakhs during 2001-11. Water supply and sewerage in Banagalore is managed under the Bangalore Water Supply and Sewerage Board (BWSSB). Bangalore city has a service area of 800 sq. km. with a population of 9.5 million. The present

⁵⁰ Urban water supply and sanitation in Indian cities, PEARL, NIUA

demand of water supply is 1283 MLD to which BWSSB is bale to supply 900 MLD of water which shows a deficit of 383 MLD. The city has 90-100 MLD od per capita water supply with 106 numbers of service stations setup. Number of water supply connection is 6.23 lakh (BWSSB) and total length of water supply line is 8,746 km.

The initiative includes:

- Implementation of two related initiatives namely installation of bulk meters and development and implementation of a software application to capture and track information from these bulk meters and to monitor and regulate the water supply system.
- Installation of flow meters at critical locations including inlet & outlet of all Ground Level Reservoirs (GLRs) and Elevated Service Reservoirs and on feeder mains which feed water directly to distribution network.
- All inlet and outlet meters were given an ID, based on location and were geo referenced, from this system the rate of flow and consumption till that particular hour can be obtained by looking at any selected flow meter at any specific location.

Intelligent Operations for water (IOW) developed by IBM, which will capture data from the bulk meters and transmit it to the users for analysis. IOW helps to manage water balance and provide equitable water distribution across the city.

Bulk flow metering helps the water operations in assessing the overall water balance along with identification of illegal connections. It provides indicators for leakages reduction programme and helps inefficient water distribution management. A water information hub that us part of IOW provides predictive and historical analysis, which helps in tracking leakages and other types of transmission and distribution losses. The software has been customized to BWSSB's bulk flow on State Data Centre and the water management system is based on IBM's Intelligent Operation Centre and Integrate Information Core platforms.

5.9.3. System Automatic Meter Reading System (Walk-by) Solution for Water Metering⁵¹

The Ranipet Common Effluent Treatment Plant (RANITEC), Ranipet district, Taminadu Province

Ranipet district chose this system for use in its entire network of 3-4 sq. km. which caters the need of 76 tanneries. The effluent from the tanneries was collected and transported to the treatment plant through a system of pumping stations, pressure and gravity mains. The total length of the pipe work is about 10 km. This system was opted because of its stable performance, as well as its general technical performance i.e. ease of maintenance, high hydraulic capacity, accuracy, durability, etc. Some of the benefits of this metering system are:

- It enhances data acquisition speed & correctness of reading.

⁵¹ http://projects.bizarresoftware.in/technomatics/new_website/pdf/case-study/CASE_STUDY_AMR_METERING.pdf

- Peak flow detection, Leakage detection and Backflow detection which reduces the percentage of NRW.
- Be warned in case of fraud attempts, internal failure or battery end of life which reduces cases of illegal connections.
- For the future upgradation, it allows walk-by remote reading and migration to automatic meter reading (AMR) without having to replace the radio modules in future.
- This patented principle allows using the relay mode in an intelligent and self-adapting way for that all the meters in a building could be read from one central point.

5.10. 24x7 Water Supply

Definition

“24x7 supply is achieved when water is delivered continuously to every customer of the service 24 hours a day, every day of the year, through a transmission and distribution system that is continuously full and under positive pressure throughout all of its pipelines and networks.”

Importance of continuous water supply

Reliability: 24x7 water supply reduces the time and money spent by citizens to store water. Without it, citizens have to install expensive water tanks, wait for public tankers to supply them, or buy water from private sellers. The poor are the hardest hit; they have to carry water over long distances, queue for hours at municipal stand posts to collect it or wake up late at night to fill their buckets and pots. Adults lose time that could be better spent in productive work, while children often miss school to collect water for their families. Continuous 24x7 water supply frees citizens from the burdens of unreliability.

Clean: Continuous water supply is critical for the people's health. When the pipes remain full, the water remains clean. Under intermittent service, when pumping stops and the pressure in the pipes drops, groundwater from the surrounding areas can be sucked in, bringing with it wastewater from homes, and drains. If the pipes are continuously filled with and supplying, the water there is less chance of such contamination. Continuous water supply thus helps keep water clean and safe for consumers.

Efficient: Throughout the world, municipal authorities have found that continuous water supply is the most efficient and cost-effective way of supplying water. This is because leaking pipes must be fixed before a 24x7 water supply system can be put in place. This, in turn, reduces the amount of water lost in distribution and makes more of it available for supply. In the long-term, these improvements reduce operating costs, unlike intermittent supply where pumping costs are high, the durability of pipes is reduced, and it is difficult for providers to ascertain how the network is operating.

Scenario in India

Three cities in water-stressed parts of Karnataka – Hubli- Dharwad, Belgaum, and Gulbarga - have shown that it is indeed possible to supply citizens with clean water on a continuous basis. About 200,000 people in five demonstration zones in these cities now receive 24x7 water under the World Bank-supported Karnataka Urban Water Sector Improvement Project, implemented in 2005.

A number of other such initiatives are now underway in India's states. These include Madhya Pradesh (Khandwa and Shivpuri), Karnataka (Mysore, Ilkal and Bijapur), Maharashtra (Nagpur, Aurangabad, Ichalkaranji and Lonavla), Andhra Pradesh (Vishakhapatnam), Bihar (Patna), Himachal Pradesh (Shimla), Chattisgarh (Raipur), Jharkhand (Ranchi), Gujarat (Vadodara), Tamil Nadu (Coimbatore), West Bengal (Chandernagore and Garulia), and Punjab (Chandigarh).⁵²

The Government of India recognizes the importance of 24x7 supply. Accordingly, the Ministry of Urban Development has made 24x7 water supply a Service Level Benchmark for

⁵² <http://www.worldbank.org/en/country/india/brief/faqs-24x7-water-supply>

water providers. The ministry has also issued a Guidance Note on Continuous Water Supply (24x7)⁵³.

5.10.1. Planning and Implementation

The System has to manage efficiently. Once leaking pipes are fixed and infrastructure maintained properly, more water is available to actually reach people's taps at a lower cost. And, when all connections are metered and water bills paid regularly, the financial situation of the provider improves and it can invest in maintenance needed to keep the system running efficiently, thus helping keep tariffs down.

Moreover, when people are charged according to the amount of water they consume -- volumetric charging – they tend to conserve this resource, reduce waste, and manage their consumption in keeping with their budgets.

There are three major stages in the implementation process:

- a. Planning and design
- b. 24-7 conversion
- c. Long-term operational stage.

The principal questions to be addressed with respect to each of these stages are:

- Does the water service provider have the necessary expertise, experience and resources in-house?
- If not, what are the perceived deficiencies and how may these be remedied?

The main options lie between:

- In-house implementation
- Outsourced implementation
- Mixed in-house and outsourced implementation.

The details for each option are addressed later in this Guidance Note. https://smartnet.niua.org/sites/default/files/resources/MoUD%20Guidance%20Notes%20for%20Continuous%20Water%20Supply%20%2824-7%20supply%29_0.pdf

5.10.2. Best Practices

5.10.2.1. 24X7 Water Supply in Malkapur (Maharashtra)

In India, the first complete town to get this fate in India was Malkapur in Maharashtra, a small town of 35000 people near Karad. Here the 4500 connections are all metered with Automatic Meter Reading (AMR) type of meters, which can be remotely read using Radio Frequency devices by just driving along the streets. This avoids the human element in reading the meters. The readings against each of the meter number received in the handheld device is downloaded to a computer which in turn prepares the bills to be sent to the consumers every

⁵³https://smartnet.niua.org/sites/default/files/resources/MoUD%20Guidance%20Notes%20for%20Continuous%20Water%20Supply%20%2824-7%20supply%29_0.pdf

month. There is continuous 24x7 water supply since March 2009. The elements of this success are:

- a. Well-designed distribution system, and well laid consumer connections, both of them with least joints;
- b. Leak proof material for both system and connections;
- c. Achieving equal distribution through control by ferrules;
- d. A completely informed and aware consumer who knows the value of water and saves every drop;
- e. The best quality AMR consumer and bulk water meters which allow calculation of water balance on day to day basis;
- f. The pressure sensors fitted in the network to understand the health of the system at any time against the simulated hydraulic model; and most important
- g. The telescopic tariff structure which has made consumers use of water judicious. Those who use less than 55 LPCD are given a discount of 15% in the bill and those who pay before due date are given a discount of 10%. 60% consumers have reduced their water bills than what they used to pay in the flat rate regime. The poor who used less water were immediately benefitted, those who used more water started reducing consumption. These demand management measures in the form of awareness and tariff have led to a sustainable 24x7 at 110 LPCD supply to the town with Non-Revenue Water of 9 to 12%, comparable to the World's best of 5% in Singapore.

This initiative has received "Prime Minister's Award for Excellence in Public Administration" and the "National Urban Water Award".⁵⁴

5.10.2.2. 24X7 Urban Water Supply- A PPP Attempt in Karnataka

In line with the GoK's 'Urban Drinking Water and Sanitation Policy Statement' (2003), the state cabinet and officials in the Karnataka Urban Infrastructure Development and Finance Corporation (KUIDFC) and Karnataka Water Supply and Sewerage Board (KWSSB) confirmed their commitment to be the first in India to demonstrate that 24x7 water supply is achievable.

The focus for this demonstration project—the Karnataka Urban Water Sector Improvement Project (KUWASIP)—were the three cities (all of which are municipal corporations) of Hubli-Dharwad, Belgaum, and Gulbarga in northern Karnataka, with a total population of around 2 million people.

The main objective was to undertake capital maintenance on the distribution network to prove (to the public and to the institutions in the water sector) that it is possible to deliver 24x7

⁵⁴ <http://www.h2opune.com/24X7-water-supply>

continuous, clean water in India. And also to prove that such a supply is affordable, that it can be sustained over time, that it does not require additional water resources to keep the pipes full, and that households, even poor households, are willing to pay a fair tariff for a consistently acceptable service.

For more information, please refer

<http://www.siudmysore.gov.in/pdf/bestpractices/24X7water.pdf>

https://www.wsp.org/sites/wsp/files/publications/WSP_Karnataka-water-supply.pdf

For more practices

https://niti.gov.in/writereaddata/files/document_publication/BestPractices-in-Water-Management.pdf

https://pearl.niua.org/sites/default/files/books/GP-IN2_WATSAN.pdf

