GUIDELINES FOR DECENTRALIZED WASTEWATER MANAGEMENT

Prepared by
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For
Ministry of Urban Development,
Government of India

December, 2012

Preface

The Ministry of Urban Development, Government of India, had funded the setting up of a Centre of Excellence in the area of Decentralized Wastewater Management, in the Department of Civil Engineering at IIT Madras in the year 2009 (No. N-11025/30/2008/UCD). The scope of the project included: (i) preparation of detailed implementation plan in identified cities in case of decentralized wastewater management, (ii) helping the ULBs in the implementation of the plan for decentralized wastewater management plan, and (iii) documentation and dissemination of the concepts and findings. The CoE in DWWM at IIT Madras has worked extensively with ULBs in Guntur in Andhra Pradesh and Tiruchirapalli in Tamil Nadu in this regard. One of the other major responsibilities of the center is to prepare a manual on decentralized wastewater management.

A manual on the Decentralized Wastewater Management system, dealing with all aspects, has been prepared. The purpose of this capsule guideline is to provide the decision makers with an essence on various aspects of decentralized wastewater management. The soft version of the capsule guideline has several links to the appropriate chapters / sections of the manual to provide detailed information to engineers / consultants who may be engaged in planning, design, operation and maintenance.

It is hoped that this manual and guideline will lead to a better management of wastewater and improve the hygiene and sanitation conditions in our country. Many dedicated persons have contributed to the preparation of the manual and capsule guideline directly or indirectly. A list of persons who have contributed directly and names of those who have taken lead in preparing this report is provided in the following page.

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1. Introduction

Availability of sufficient quantity of safe water is a basic requirement for survival of human beings. Water can be contaminated by several means. Most of the bacteriological contamination of water originates from the feces of human, animals and birds. Discharge of domestic sewage, rotten food materials and vegetation also can cause bacteriological contamination of water. Due to (a) the wide practice of septic tanks in habitations without collection systems, (b) absence of appropriate necessary further downstream treatment (c) non-availability of supportive sullage management and (d) absence of septage management, especially in relatively denser populations in peri-urban and land scarce areas, compounded by open defecation in rural settings in sandy soils, much of the shallow groundwater as well as surface water sources are contaminated by pathogens. Provision of facilities and services for the wastewater treatment is very essential because 80% of diseases are caused by improper sanitation / inadequate hygienic conditions. A 10% extra investment in wastewater treatment is expected to result in an 80% savings in providing basic health care. It is also estimated that 6.4 % of Indian GDP is lost due to improper sanitation. Economic loss in tourism industry alone in India is estimated to be $448 million/year. Improper wastewater management also has significant adverse effect on wild life and fisheries. Discharge of wastewater into water bodies also leads to loss of recreational facilities and quality of life. This capsule guideline provides an insight into ways and means of planning and executing decentralized wastewater management systems by Urban Local Bodies.

2. Wastewater Management

Wastewater management systems can be either conventional centralized systems or decentralized systems. Centralized systems are usually planned, designed and operated by government agencies which collect and treat large volumes of wastewater for the entire communities. On the other hand, decentralized wastewater management (DWWM) systems treat wastewater of individual houses, apartment blocks or small communities close to their origin. Typically, the decentralized system is a combination of many technologies within a given geographical boundary, namely, onsite systems, low cost collection systems and dispersed siting of treatment

facilities. Wastewater treatment systems such as pit latrines, septic tanks, DEWATS etc., which are used for partially treating wastewater in individual residences or a small cluster of houses, are termed as "On Site Wastewater Treatment (OSWT)" systems. OSWT need not have any wastewater collection system, while a DWWM may have a small sewerage system. It may also be noted that any city or town can have a combination of centralized, decentralized and on-site wastewater management systems, to meet the overall city sanitation.

A decision tree to select wastewater management system (on-site, decentralized, and centralized) is given in Figure 1.

Bahao toilets are the toilets directly connected to storm water drain (Source: From discussions on Sewerage Manual Revision in the Working Group Meetings and made available to IITM for use in this DWW Manual only for uniformity between the two upcoming manuals of MoUD)

3. Decentralized Wastewater Management Systems

Decentralized wastewater management (DWWM) may be defined as "*the collection, treatment, and disposal/reuse of wastewater from individual homes, clusters of homes, isolated communities, industries, or institutional facilities, as well as from portions of existing communities at or near the point of waste generation*" (Tchobanoglous, 1995). In case of decentralized systems, both solid and liquid fractions of the wastewater are utilized near their point of origin, except in some cases when a portion of liquid and residual solids may be transported to a centralized point for further treatment and reuse.

Typical examples where a decentralized system can be established is given in Figure 2.
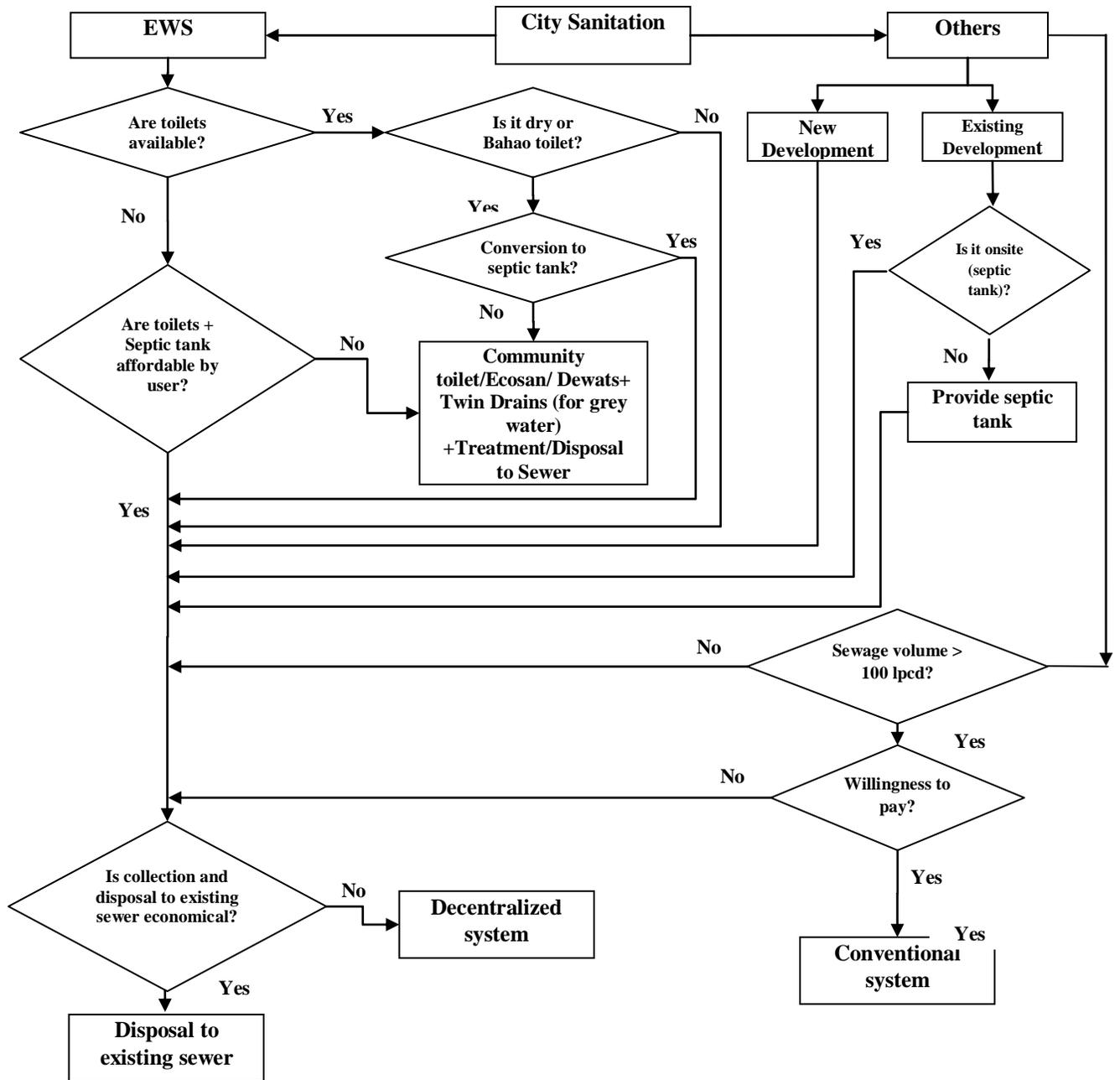
Figure 1 Decision Tree

City Sanitation → **EWS** (left) / **Others** (right)

EWS branch:
- Are toilets available?
  - Yes → Is it dry or Bahao toilet?
    - Yes → Conversion to septic tank?
      - No → Community toilet/Ecosan/ Dewats+ Twin Drains (for grey water) +Treatment/Disposal to Sewer
      - Yes →
    - No →
  - No → Are toilets + Septic tank affordable by user?
    - No → Community toilet/Ecosan/ Dewats+ Twin Drains (for grey water) +Treatment/Disposal to Sewer
    - Yes → Is collection and disposal to existing sewer economical?
      - No → Decentralized system
      - Yes → Disposal to existing sewer

Others branch:
- New Development
  - Yes →
- Existing Development
  - Is it onsite (septic tank)?
    - No → Provide septic tank
- Sewage volume > 100 lpcd?
  - No →
  - Yes → Willingness to pay?
    - No →
    - Yes → Conventional system

Figure 1. Decision Tree: Selecting the wastewater management system (Onsite, Decentralized or Conventional)

EWS: Economically Weaker Section

Bahao toilets are the toilets directly connected to storm water drain (source: From discussions on sewerage Manual Revision in the Working Group Meetings and made available to IITM for use in this DWWW Manual only for uniformity between the two upcoming manuals of MoUD)
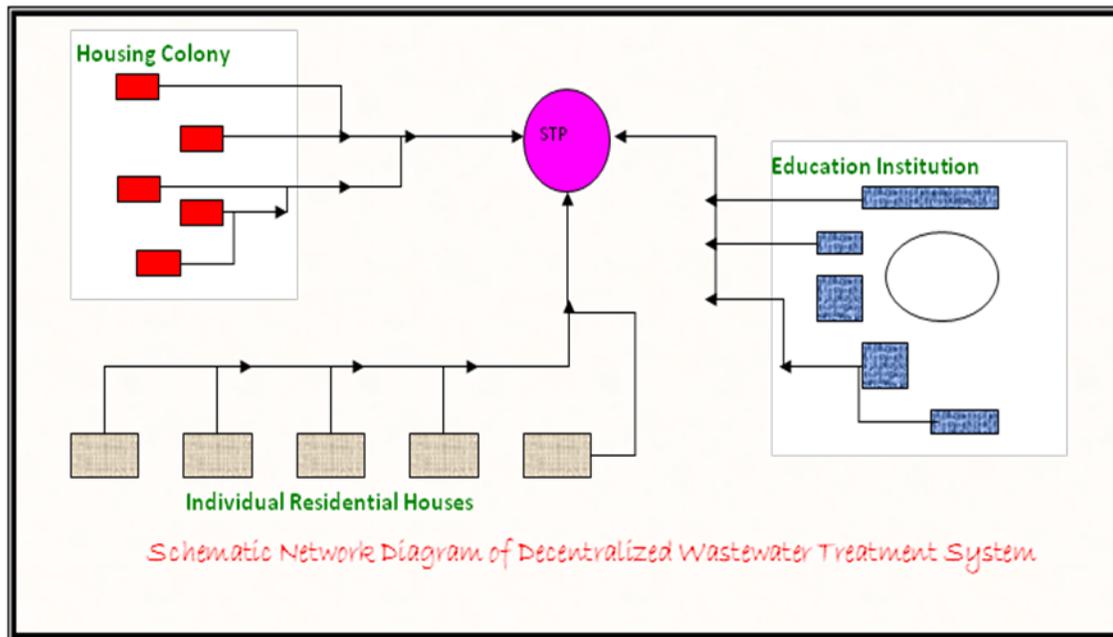
Figure 2: Typical situation ideal for decentralized wastewater management

3.1. Advantages of Decentralized Wastewater Management Systems (DWWMs)

1. Flows at any point in the system would remain small, implying less environmental damage from any mishap.

2. System construction results in less environmental disturbances as smaller pipes would be installed at shallow depths and could be more flexibly routed.

3. The system expansion is easier, new treatment centers can be added without routing ever more flows to existing centers.

4. Entry of industrial waste could be more easily monitored.

5. Sector wise treatment is permits sewage transmission over shorter distances.

6. Treatment units are close knit and are free from odours and insects.

7. Lesser investment is required for the sewer pipelines.

8. Community participation is essential; hence people can participate in the monitoring of the system performance. This instills confidence among the people.

9. Quality of treatment is more efficient than traditional system due to accurate estimation of wastewater generation and lower quantity of wastewater;

10. Treated sewage can be effectively used within the sector for applications like toilet flushing, landscape irrigation and cooling tower make ups.

11. Maintenance of the sewerage system is easier.

12. Ecology of rivers, streams ponds can be effectively managed by letting better treated waters incrementally along their length.

13. Groundwater recharge options can be related to appropriate sites the carrying all sewage back and forth before and after treatment.

3.2 Disadvantages of DWWMs

1. Policies regarding installation, operation and maintenance are not yet well established in many of the developing countries.

2. Standardization of the systems is difficult as significant variation exists with regard to technical design to suit the local geography and climatic conditions.

3. Local people will have to bear all by themselves the O&M of the treatment plant.

4. Getting a site for the STP may be difficult amidst built up sections and eventually, only the graveyards or cemeteries have to be the site.

3.3 Advantages of On-Site Wastewater Treatment systems

1. System construction would result in less environmental disturbances as almost no collection system is required.

2. This can be used as a preliminary stage in the wastewater management system in an expanding urban area;

3. Treatment units are closely packed systems, mostly free from awful odours and insects;

4. Almost no investment is required for the sewer pipelines;

5. Planned, constructed and maintained by individual households / establishments

6. Power requirement is zero

7. Maintenance of the treatment system is very easy;

3.4. Disadvantage of On Site Wastewater Treatment Systems:

1. Policies regarding installation, operation and maintenance are not well established in many of the developing countries;

2. Standardization of the systems is difficult as significant variation exists with regard to technical design to suit the local geography and climatic conditions;

3. Individual households / establishments will have to bear the operation and maintenance cost of the treatment systems;

4. Improper maintenance of the treatment plant will have significant environmental consequences;

5. Commonly used onsite systems such as pit latrines, septic tanks and anaerobic baffle wall reactors will not be able to meet the discharge standards. Effluents from such systems will have high COD and pathogen content.

4. Situations Suitable for DWWM

Following situations are suitable for implementation of DWWM:
- where clusters of on-site systems are existing and there is no control on the fate of the pollutants
- improper maintenance of on-site treatment systems and exorbitant cost of conventional remediation by implementation of centralized systems
- community / institutional facility is far away from the existing centralized system
- localities where there is scarcity of freshwater
- localities where there is a possibility for localized reuse of treated wastewater
- localities where discharge of partially treated wastewater is prohibited due to various environmental reasons
- localities where extension of existing centralized system is impossible
- newly developed or existing clusters of residences, industrial parks, public facilities, commercial establishments and institutional facilities

As mentioned earlier, a combination of centralized, decentralized and onsite treatment systems also can be planned to achieve over all city sanitation. This situation is demonstrated in Fig 3

TIRUCHIRAPPALLI CITY CORPORATION
Ward Details

AREA : 146.9 SQ.Km
SCALE 1:5000

REFERENCE:
UNDER GROUND DRAINAGE
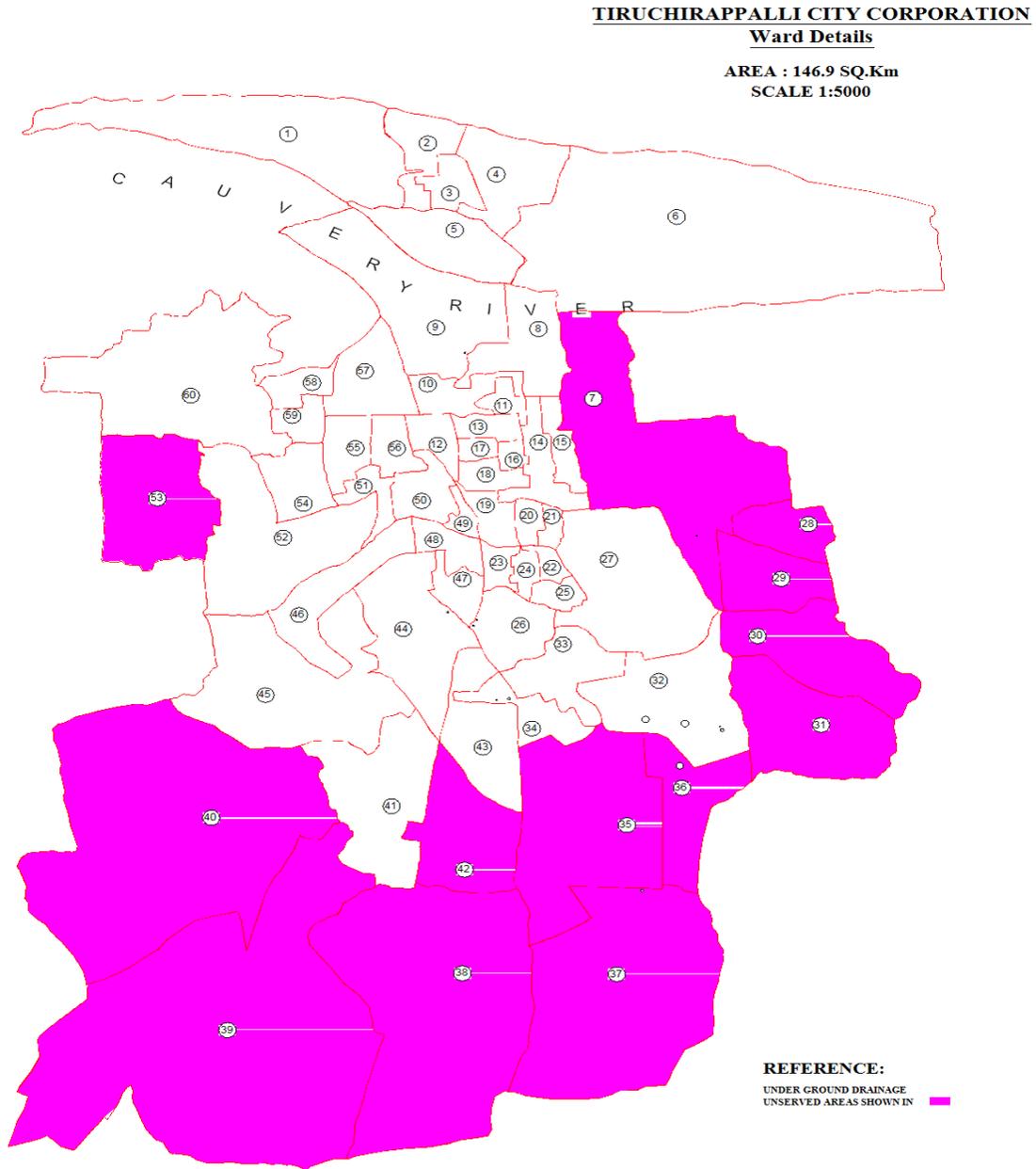UNSERVED AREAS SHOWN IN

Figure 3. Planned areas for underground sewerage system and un-sewered areas (Shown in pink colour) of Trichy municipality

Much of the sewage generated in the city is transported to the extreme south end of the city to the existing treatment system. Wherever the underground drainage system (UGD) is not existing presently, it may be advisable to come up with decentralized or onsite wastewater management systems rather than extending the UGDs. The UGDs are not planned in these areas may be due to many reasons such as i) low elevations of the localities, ii) obstructions like railway track , iii) highly scattered population etc.

5. Planning for DWWM

The first step in the planning for DWWMS is the site selection. The potential sites are identified based on

i) Population density, land availability,

ii) Topography,

iii) Reuse potential,

iv) Existing streams for discharge of treated wastewater if required**.**

A reconnaissance survey should be conducted for possible locations for DWWM. These possible locations should confirm to the overall sanitation plan for the city / town, and should not overlap with those areas where a centralized system already exists or in the offing. Ranking of sites from the preliminary list, for implementing the DWWM, is based on assigning weightages to certain criteria. Following criteria, along with the corresponding ranks, can be used.

Selection of specific sites from the preliminary list, suitable for the implementation of DWWM, is based upon the overall ranking for the site. Environmental sensitivity should also be considered while selecting the sites. Stakeholders participation is very essential for selecting the sites. For the chosen sites, detailed investigations should be carried out with respect to

 (i) Population,

(ii) Topography,

(iii) Wastewater quantity and quality,

(iv) Details of existing on-site treatment systems, (v) reuse potential, and

(vi) Presence of any drainage channel

Table 1 Ranking of sites

Sl. No.	Criteria	Rank
1	Number of High raise buildings /apartments /townships in the particular site	1.0
2	Educational institutions, commercial buildings, government buildings in the site	1.0
3	Problematic areas for UGD system / un-sewered areas and current wastewater disposal facilities	2.0
4	Availability of land	3.0
5	Topography – layout of land at lower elevation, higher elevations, slopes and isolated areas etc	4.0
6	Reuse potential of treated wastewater	5.0
7	Possibility of urban expansion in the coming decades eg: satellite town	6.0
8	People's awareness and cooperation	6.0

Based on the information collected, collection, treatment and reuse/disposal systems can be selected and designed.

6. Design Period for Decentralized Wastewater Treatment systems

Usually centralized sewage treatment systems are designed for 30 years. This design period is not suitable for decentralized wastewater treatment systems. Such a large design period will lead to over design of the treatment system and under performance. Hence, it is advisable to have a design period of 15 years. If this is not possible, other way to design a DWWM is to estimate the present day capacity and plan the system for an additional 20% capacity

7. Components of DWWM

Like the centralized wastewater management systems, DWWMs also have

(i) Wastewater collection system,

(ii) Treatment system, and

(iii) Reuse / disposal systems.

8. Wastewater Collection System

Wastewater collection system for the DWWMs can be designed as

(i) Micro scale conventional centralized system,

(ii) settled sewage system,

(iii) Small bore sewer system,

(iv) Shallow sewer system,

(iv) Twin drain system and

(v) Incremental sewerage system

- Micro scale conventional sewerage system may be adopted in locations where there is no underground drainage (UGD) system and either an on-site system is nonexistent or improperly designed / functioning and the ability of the user population to financially sustain the O&M costs. During the design, enough provisions should be given for reducing the operation and maintenance problems. For example, provision of flushing systems, proper trash screens etc are essential. Design example for a typical micro-scale conventional Sewerage system is given in Appendix

- The other systems may be adopted where ability of the user population to financially sustain the O&M costs of a centralized system is not possible.

- The settled sewerage system, shallow sewer system, small bore sewers, twin drain system can be adopted in already developed localities where UGD system is not there, but properly functioning on-site treatment systems like septic tanks are widely existent. The small bore sewer can be designed as a pressurized system or a vacuum system but this will require a 24 * 7 unfailing electrical power supply and as such may be suitable only for high style resorts at faraway places.

- Incremental sewerage system can be adopted for a newly developing locality.

Small bore sewers and shallow sewers can be adopted where per capita water supply is very low (< 50 lpcd). Conventional sewerage system cannot work in such areas due to low flow and the

violation of constraint on minimum velocity. Moreover, clogging will be perennial problem due to settlement of solids. Hence settled sewage is transported in small diameter pipelines, where minimum velocity constraint is not an issue. Here, the sewage is collected in a tank similar to septic tank where the solids are settled and undergo anaerobic degradation. The effluent, which is free from solids are transported through small diameter pipe lines to nearby decentralised/centralised treatment facility for further treatment.

The incremental sewerage system comprises of an integral twin drain on both sides of the road, the drain nearer to the property carrying the septic tank effluent and the grey water and the drain on the road side for storm water and the sewer drains are interconnected to flow out to treatment. The advantage of the twin drain system is that even if the per capita sewage falls to low quantities as say, 28 lpcd as in still there in some cases where water is scarce like in coastal fishermen communities where bathing is almost off site in a centralized well water source and the so called sewage is only from their septic tanks, cooking, floor washing etc, the design of the drain with removable cover slabs permits the daily scraping forward of the sediments progressively to the destination treatment site and something which the other options cannot provide. Eventually, these can be upgraded to be merged with a UGD when the community or the layout gets into as reasonable appreciable level of occupancy. Towards this, the town and country planning bye-laws may have to be amended to make it mandatory to provide twin drains in new layouts which are coming up without any underground drainage system. This will not increase the cost significantly it does not need any public consultation process for implementation. The concept of Centralised Vs Decentralised sewerage Layouts is given in Fig. 3.

The peak factor for decentralized wastewater treatment systems can be as low as 2 especially when small bore sewers or settled sewer systems are used. These systems provide an equalization effect in the settling chamber. For micro-conventional sewer systems, a peak factor similar to conventional systems can be employed (as per CPHEEO Guidelines).
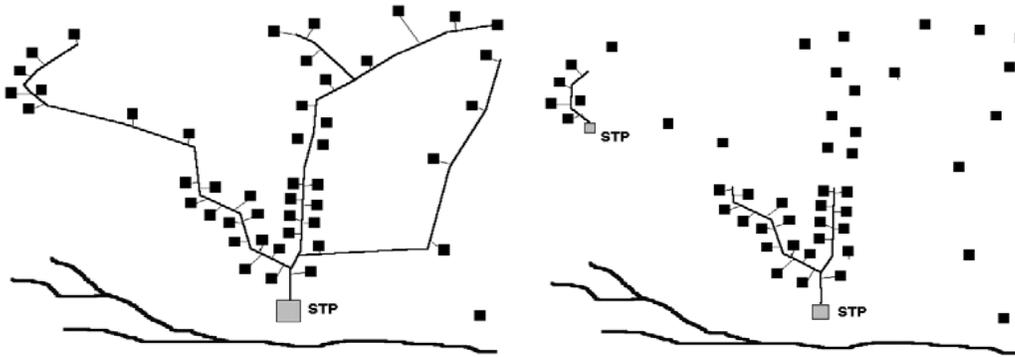
Figure 3. Concept of Centralized vs Decentralized Sewerage Layouts

9. Wastewater Characteristics

The wastewater characteristics in a DWWM system may be very different from the wastewater characteristics in a centralized system. The per capita water consumption could vary significantly from one locality to another. The per capita water supply in many peri urban and water scarce cities could be much lower than the standard value of 135 lpcd. On the other hand, the per capita water consumption in some of the institutional facilities and posh residential localities may be much more than the standard value. This has a bearing on the wastewater characteristics. Averaging of extreme conditions, as in centralized systems, may not be possible at all in DWWMs. Most of the time, the sewage in DWWMs has high BOD, if no settling facilities are provided prior to collection. In certain cases like institutions and office buildings, the carbon/nitrogen ratio may be significantly different from that of a conventional domestic wastewater. Hence, it is essential to determine / forecast the characteristics of wastewater in the DWWM, before selection of technology and design of treatment plant.

10. Wastewater Treatment

Wastewater treatment system involves primary treatment, secondary treatment and tertiary treatment. Primary treatment system consists of screens, grit chambers and primary sedimentation tank. Secondary treatment system mainly consists of biological treatment systems. Tertiary treatment is given to polish the treated wastewater coming out of secondary treatment

unit to meet the reuse / recycle requirement. A typical flow diagram of a wastewater treatment system is given in Fig 4.
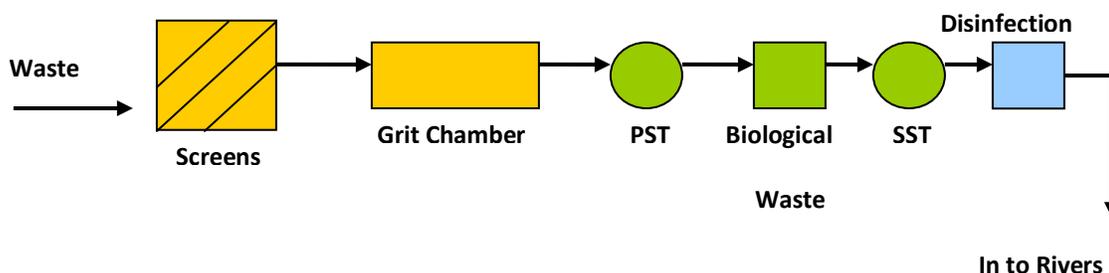

Fig 4. Flow diagram of a typical wastewater treatment system

11. Technology Selection

Appropriate wastewater treatment technology should be selected based on following considerations and goals.

Table 2. Factors to be considered while selecting Technologies for DWWM

Consideration	Goal
Treated Sewage quality standards	The technology must consistently meet the standards as required.
Power requirement	The process choice should consider minimizing power requirements
Land required	Minimize land requirement
Capital Cost of Plant	Process should allow optimum utilization of capital
Operation & Maintenance costs	Process design should be conducive to attaining lower running cost
Maintenance requirement	Simplicity and reliability
Operator attention	Easy to understand procedures
Reliability	Deliver the desired quality on a consistent basis
Resource Recovery	Ability to minimize operational costs.
Load Fluctuations:	Plant can able to withstand organic and hydraulic load fluctuations

12. Available Technologies

Presently, several treatment options are available and one can choose from these options to find the most appropriate technology for the locality under consideration. The treatment systems include

i) waste stabilization ponds

ii) Constructed wetlands

iii) USAB (anaerobic digesters) followed by constructed wet lands

iv) Moving bed bio-film reactor

v) Activated sludge process

vi) Extended aeration process

vii) Sequential batch reactors

viii) Membrane bioreactors

ix) bio-towers

x) Anaerobic baffled wall reactor

xi) Packaged treatment plants or

x) Any other technology able to meet the required treatment efficiency

Details of the treatment technologies, advantages and disadvantages, and achievable efficiencies are provided in the DWWM manual. Design steps and design examples for various treatment systems are provided in the appendix

A matrix of the technologies has been brought out in the Ganga River Basin Environmental Management Plan (GRBEMP) for the towns under Ganga basin and is extracted and presented in Table 3. With regard to the matrix, the following points are emphasized to put the issue of technology selection in perspective. The technologies shall be compatible to the volume of wastewater to be treated Vs the other aspects in section 11 above. The technologies can be any or combination of ponds, ASP, extended aeration, SBR, MBBR and MBR. In all cases, the use of treated sewage in constructed wetlands for growing locally needed fodder grass for cattle in rural

settings and even advanced further treatment for industrial cooling can be the options. The more direct reuse can be in farm forestry for coconut trees, poplar, eucalyptus etc., which have commercial value.

Table 3. Decision Matrix for Secondary Treatment Processes

Process	Effluent Quality	Coliforms removal	Nitrification-Denitrification	Phosphorous removal	Process Reliability	Land Use	Ease of Operation	Ease of Maintenance	Energy Recovery	Electrical Demand	Capital Cost	Track Record	Typical Capacity Range, MLD
ASP	G	G	P	P	VG	G	G	G	VG	A	A	VG	AF
EA	VG	G	P	P	VG	A	VG	VG	P	P	G	G	SF
MBR	VG	VG	P	P	G	VG	P	P	P	P	P	P	SF
MBBR	VG	VG	P	P	G	VG	P	A	P	A	G	P	SF
SBR	VG	VG	VG	VG	G	VG	G	G	P	A	A	G	AF
UASB + ASP	G	G	P	P	G	G	A	VG	G	A	A	G	AF
WSP	A	P	P	P	P	P	A	VG	P	VG	G	A	AF
CW	P	P	P	P	P	P	A	P	P	VG	G	P	AF

Abbreviations-
ASP-Activated Sludge; EA-Extended Aeration; MBR-Membrane Bio Reactor; MBBR-Moving Bed Biofilm Reactor; SBR-Sequencing Batch Reactor; UASB-Up flow Anaerobic Sludge Blanket; WSP-Waste Stabilization Pond; CW-Constructed Wetlands; VG-Very Good; G-Good; A-Average; P-Poor.

(Adopted from Gangapedia 003_GBP_IIT_EQP_S&R_02_Ver 1_Dec 2010)

It should be noted that the ranking of these technologies given in Table 3 is of general nature. However, the suitability of technology should be assessed for each situation depending on its specific conditions. For example, if adequate land area is available, obviously, ponds may be the best choice and if land is very scarce, the best choice may be MBR. This emphasizes that each situation has to be addressed on its inherent locational and public acceptance issues.

The cost of various treatment systems will vary based on market forces. Hence, it may not be wise to give a particular cost for a technology. As mentioned in the CPHEEO Manual "Whatever land is available should be used judiciously for various purposes and reserved for future. Minimum foot print will also be an important factor in evaluating the technology. The energy cost, operating cost and capital cost will be the determining factors in detailed project reports (DPRs) while looking into the technologies". The issue of bio-methanation and electrical energy generation, income generated by treated water selling and reuse etc. may also be considered in the net cost benefit analyses.

13. Tertiary Treatment

Though primary and secondary treatment units in conventional treatment process are capable of removing 90- 99% of enteric microbial load, organic matter and total phosphorus, the effluent from the secondary treatment unit may not always meet the requirements of water re-use or wastewater discharge. Most of the time, the effluent contains large number of enteric microbes, residual phosphorus and organic matter. Moreover, any upset in the secondary treatment unit can further reduce the quality of the effluent and increase the pollutant load on the discharge stream. Hence, it is important to polish the secondary effluent to improve its hygienic quality and meet the requirements set for wastewater discharge or reuse.

Typically, tertiary treatment units are provided to polish the secondary effluent and remove residual contaminants. A tertiary treatment process normally consists **of coagulation, solid/liquid separation and disinfection** units for the removal of residual suspended solids (SS),

colour, organic matter, offensive odour and microorganisms. Solid/liquid separation is normally achieved by filtration, floatation and adsorption. Disinfection of the pathogenic organisms is achieved by chlorination or Ozonation or UV disinfection or combination thereof.

14. On-Site Treatment Systems

On-site treatment systems can be adopted when the individual houses are scattered over a large area, and where centralized systems do not exist. This can also be preliminary option in newly developing localities. However, it is emphasized here that the option of on-site treatment system should be considered only as an interim solution, and not a permanent wastewater management option. Left unattended / improperly designed and maintained, on-site treatment systems can result in severe environmental hazard. Various on-site wastewater treatment systems are available. Selecting the most appropriate option requires a thorough analysis of all factors including cost, cultural acceptability, simplicity of design and construction, operation and maintenance, hydrogeological conditions and local availability of materials and skills.

The various on-site wastewater treatment systems are:

 i) Pit latrine (double pit latrine)

 ii) Septic tank,

 iii) Constructed wetland,

 iv) Anaerobic baffled reactor,

 v) Green toilets with separation of urine and feces

Guidelines for Septage management for on-site treatment systems are already available

15. Sludge Management

Collection, treatment and safe disposal of sludge are important stages in municipal sewage treatment practice. Primary sedimentation tank and secondary clarifiers are the main sources of sludge in conventional wastewater treatment. Depending upon the treatment process employed, sludge may also come from screens and grit chamber. Usually, the amount of sludge / solids

generated in screens and grit chambers in DWWM is not significant. These solids can be either used for land filling or disposed in the nearby municipal solid waste dump sites.

Disposal of sludge from municipal wastewater treatment plants has been a great concern for environmental engineers due to its bulk characteristic and offensive nature. However, the amount of sludge generated in decentralized wastewater management systems is not significant. If conventional treatment systems, which generate significant quantity of active sludge (which needs further treatment) are employed in DWWM, it is advisable to transport the sludge from the DWWT site to the nearby centralized wastewater treatment plant and treat the sludge there. Many of the processes such as extended aeration, MBBR, SBR, MBR etc. usually employed in DWWM generate very little quantity of stabilized sludge, which does not require any further treatment. This sludge can be used as manure, following the guide lines of CPHEEO. Following methods can be adopted for dewatering and volume reduction of the sludge:

    i) Centrifugation
    ii) Filter press and
    iii) Sludge drying beds

16. Operation and Maintenance

Operation and maintenance guidelines should be strictly adhered to for proper functioning of wastewater treatment plants.

17. Reuse Options for Treated Wastewater

The increasing demand for water in combination with frequent drought periods, even in areas traditionally rich in water resources, puts at risk the sustainability of current living standards. In industrialized countries, widespread shortage of water is caused due to contamination of ground and surface water by industrial effluents, and agricultural chemicals. In many developing countries, industrial pollution is less common, though they are severe near large urban centers. However, untreated or partially-treated sewage poses an acute water pollution problem that

causes low water availability. Global trends such as urbanization and migration have increased the demand for water, food and energy. Development of human societies is heavily dependent upon availability of water with suitable quality and in adequate quantities, for a variety of uses ranging from domestic to industrial supplies. Moreover, the forecasts for water availability are quite dire and water scarcity is endemic in most parts of the world. This emphasizes the need for water scarcity solutions and water quality protection from pollution. It is in this context, the Agenda 21 adopted by the United Nations Conference on Environment and Development, popularly known as the "Earth Summit" of Rio de Janeiro, 1992, identified protection and management of freshwater resources from contamination as one of the priority issue, that has to be urgently dealt with to achieve global environmentally sustainable development.

The need for increased water requirement for the growing population in the new century is generally assumed, without considering whether available water resources could meet these needs in a sustainable manner. The question about from where the extra water is to come, has led to a scrutiny of present water use strategies. A second look at strategies has thrown a picture of making rational use of already available water, which if used sensibly, could provide enough water for all. The new look invariably points out at recycle and reuse of wastewater that is being increasingly generated due to rapid growth of population and related developmental activities, including agriculture and industrial productions. Hence, wastewater reuse is perceived as a measure towards fulfilling following three fundamental objectives within a perspective of integrated water resources management.

- Environmental sustainability – reduction of pollutants load and their discharge into receiving water bodies, and the improvement of the quantitative and qualitative status of those water bodies (surface water, groundwater and coastal waters) and the soils.
- Economic efficiency – alleviating scarcity by promoting water efficiency, improving conservation, reducing wastage and balancing long term water demand and water supply.
- For some countries, contribution to food security – growing more food and reducing the need for chemical fertilizers through treated wastewater reuse.

Treated wastewater can be reused for any purpose such as landscaping, irrigation, recreation, industrial purposes and toilet flushing, depending upon the treated water quality. The planning of wastewater reuse project should consider the following important issues.

- Assessment of wastewater treatment and reuse / recycle need
- Assessment of water supply and demand
- Assessment of water supply benefits based on water reuse potential
- Analysis of reclaimed water market
- Environmental and economic analysis
- Implementation plan and financial analysis
- Public information and acceptance program

18. Regulations

Selection of Decentralized/onsite wastewater treatment system: Guidelines based on

- Hydrogeology
- Demography
- Population Density

Strict monitoring and quality assurance of design/construction/operation and maintenance of DWWMs is very essential to protect the environment and water sources. The performance of the systems should be monitored with respect to BOD5, COD, Suspended Solids, Total Kjedhal Nitrogen (TKN), Total P, and Fecal coliforms. The effluent should meet the regulations specified by the concerned regulatory board.

19 Operation and Maintenance of DWWMs

19.1. Screens

- Screens should be cleaned at regular intervals
- The rakes should be made of stainless steel to prevent rusting and associated injuries

- Before manual inspection of the screen chamber, stop the flow and then inspect
- Always use hand gloves and boots during the cleaning.

19.2 Grit Chamber

- Check the corrosion of the various parts of the grit chamber regularly.
- Spray mild insecticide weekly on the walking platform and joints of guide rail/ tubing
- Check oil in the gearbox connected to the scraper as per manufacturer's time schedule
- Before repairing any electrical/mechanical parts, switch of the power supply.
- Ensure all labourers wear oxygen support equipments and cylinders while on the detritus tank
- Once a day, close and open the inlet and outlet control gates of the detritus tanks
- Once in six months, isolate a detritus tank, drain it fully and inspect the scraper blades and other parts

19.3. Primary Sedimentation

- Make sure that all the weirs are at the same elevation
- Clean the sides and bottom of effluent launder once a day with a long handle wire brush
- Bleed the sludge whenever the sludge height exceeds the top of hopper
- If floating sludge is noticed, bleed more of settled sludge and check if all scrapers are alright
- If black and foul odour sludge is noticed, try to send all the flows to other tanks
- If scum is noticed in the settled sewage, increase the depth of the scum baffle plates
- If there is oil slick in the water surface, check oil guards of gearboxes or chain sprockets
- If sludge is escaping over the weir, evacuate bottom sludge almost completely
- If the problem continues, drain the tank and investigate the problem

19.4 Aerators

- Check the machinery for corrosions, cracks, crevices, loose bolts, alignment etc

- If eccentricity is detected, stop the aerator and call the service engineer of the company

- Check for oil / grease leaks from the assembly of motor and gearbox

- Check the temperature of the motor casing and compare with the rating by the manufacturer

- Make sure the connecting cable is securely fastened and has not become loose

- Observe the vertical shaft of the aerator for any wobbling or oscillation

- If anything unusual is observed, stop the aerator and inform plant superintendent

19.5 Biological Treatment systems

- Ensure the required biomass in the system by measuring the biomass concentration in the system and adjusting the recycling rate

- Avoid clogging of pipe lines, nozzles and other appurtenances. Follow the maintenance schedule provided by the manufacturer

- Avoid flushing out of biomass from the system by appropriate controlling of the flow

19.6 Pumps

- Check for unusual pump noise while running

- Make sure that while the pump is running, it is actually pumping out the sludge

- Carry out the oiling of gearbox and gland packing etc as per manufacturer's terms

- Check for ammeter reading against manufacturer guidelines while running

- If the pump is drawing more current, report to plant superintendent;

- Ensure that the working pump is rotated in every shift and the pumps are identified

20. Other Important Aspects

20.1. Technical Aspects

Decentralization dictates that the overall system would be composed of many small treatment units. The technical component can act to promote a comprehensive, integrated and sustainable wastewater collection, treatment and disposal/reuse. Such system can also facilitate reuse of

treated wastewater within or near the generating locality for horticulture and other non-domestic uses.

20.2. Financial Aspects

Economic consideration of a decentralized wastewater, one of the most important aspects, requires a detailed analysis of Cost-Benefit or Cost-Effectiveness, keeping in view the following points. The major fiscal advantage of a decentralized system is the elimination of a great deal of the collection system which costs about 80% of the sewage treatment system. The sewers in decentralized system like small bore sewer systems and settled sewer systems do not carry solids. Hence, the maintenance of such sewers is comparatively easy.

20.3. Social Aspect

Public acceptance of DWWM is vital to the overall future of wastewater reuse and the consequences of poor public perception could jeopardize future wastewater reuse projects. The selection of any DWW treatment technology must be accompanied in advance by a detailed examination of the self-sufficiency and technological capacity of the community. The treatment alternatives must be manageable by the local community. Regular and uninterrupted O&M of DWWS is essential to attain satisfactory performance for which the community must have skilled personnel for O&M in order to tackle any type of problems under contingencies.

20.4. Legal Aspects

As per the Constitution of India (Item No. 5 & 6 of the 12th Schedule of Article 243 W), Water Supply and Sanitation is a State Subject. It is the responsibility of the State Government and Urban Local Bodies to implement operate and maintain water supply and sanitation systems and also arrange finances for the same. Further, the 74th Constitution Amendment Act, 1992 provides a frame work and devolves upon the Urban Local Bodies the responsibilities of providing water supply and sanitation facilities in urban areas in the country. It is mandatory on the part of the concerned agency responsible for approval of DWMS, to incorporate adequate legal provisions in the Municipal Bye-Laws to accommodate and encourage implementation of decentralized in

their jurisdiction. While formulating City Development Plans, adequate land shall be earmarked in different places in the city for implementation of decentralized sewerage system. It is also advisable to have a proper inspection procedure before providing operational consent to DWWMS. Moreover, provisions should be provided to renew or stop the consent, based on the operation, maintenance and performance of the DWWMs.

APPENDIX

Appendix 1

Design steps for Pond System
The procedure for the design of the oxidation pond to treat wastewater is as follows:
1. Determine the organic load based on BOD
Total organic load   = average flow * BOD after primary treatment
Total organic load, OL   = Q_{avg} x BOD
2. Determine the total surface area
Total surface area, SA_T =   OL /OLR
Where OLR is the organic loading rate
3. Calculation of permissible OLR based on temperature correlation

Assuming the temperature at the coldest month as 18°C,
    OLR   =   20T − 120
4. Calculation of permissible OLR based on altitude and latitude

Assume elevation of pond above mean sea level = 10 m
OLR   =   OLRa = OLR at that altitude / (1 + 0.003 * 10)
Pond area, PA   =   OL/OLRa
5. Determine volume of pond

Volume of the pond, Vp   = D_{av}xPA
where D_{av} is the average depth of the pond preferably taken as 1.5m
Pond detention time, θ   =   Vp / Q_{avg}

6. Check for detention time based on bacterial reduction

    Detention time based on plug flow condition

In general, the efficiency of the BOD removal for the system is expressed in terms of

$$\frac{S_e}{S_i} = e^{-k(2\theta/n + \theta/n)}$$

Where S_e / S_i is the fraction of soluble BOD remaining
k is the reaction rate coefficient
n is the number of reactors and θ is the hydraulic detention time
Detention time based on completely mixed flow condition

$$\frac{S_e}{S_i} = \frac{1}{(1 + 2k\theta/n)((1 + k\theta/n)}$$

In actual pond system both mixed and plug flow condition prevails hence an average detention time of 17 days is acceptable

Area of the pond, Ap $=$ $\theta \dfrac{Q_{avg}}{D_{av}}$

Provide

Three ponds (two primary ponds in parallel and one secondary pond in series) of equal area and depth

7. Sludge accumulation

Depth required for sludge accumulation, D_S =   0.75 m (Assumption)

Volume of sludge V_s $=$ (2/3) (Ds) (Ap)

                                     Where D_s is the depth required for sludge accumulation

Desludging frequency $=$ $V_s/\{(0.07\ m^3/\text{person year})(4000)\}$

Recommended desludging frequency $=$ 8 years (because of non uniform deposition of sludge)

     Two maturation ponds are provided in series after the secondary pond

The Design example of an Oxidation pond is shown below:

Design Example for an Oxidation Pond

Design an oxidation pond to treat a wastewater flow of 600 m³/d

Design conditions:

Influent Biochemical oxygen demand, BOD = 165 mg/L

Total population   = 4,000

Sludge accumulation rate   = 0.07 m³/person year

Table 12.1 Recommended OLR for geographic location of oxidation pond

Latitude (°N)	BOD Loading Rate (Kg per day per hectare)
8	**325**
12	**300**
16	**275**
20	**250**
24	**225**
28	**200**
32	**175**
36	**150**

The latitude of Chennai City is 16°

Recommended OLR from Table 1 is 275 kg/d hectare

1. Determine the organic load based on BOD

Total organic load   = average flow * BOD after primary treatment

Total organic load, OL $=$ Q_{avg} x BOD

                                 $=$ $(600\ m^3/d)\ (165\ mg/L)\ (10^{-6}\ kg/mg)\ (10^3\ L/m^3)$

                                 $=$ 99 kg/d

2. Determine the total surface area

Total surface area, SA_T $=$ OL /OLR

$$= \quad (99 \text{ kg/d})/\{275(\text{ kg/hectare d}) (10^{-4} \text{ m}^2 \text{ /hectare})\}$$
$$= \quad 3600 \text{ m}^2$$

3. Calculation of permissible OLR based on temperature correlation

Assuming the temperature at the coldest month as 18°C,

$$\text{OLR} \quad = \quad 20T - 120 = (20 \times 18) - 120$$
$$= \quad 240 \text{ kg/d hectare}$$

4. Calculation of permissible OLR based on altitude and latitude

Assume elevation of pond above mean sea level   = 10 m

$$\text{OLR} \quad = \quad \text{OLRa} = \text{OLR at that altitude} / (1 + 0.003 * 10)$$
$$= \quad (240 \text{ kg/d hectare}) (10^4 \text{ hectare/m}^2)/(1 + 0.003 \times 10 \text{ m})$$
$$= \quad 233.1 \text{ kg/hectare d}$$

$$\text{Pond area, PA} \quad = \quad \text{OL/OLRa}$$
$$= \quad (99 \text{ kg/d})/\{233(\text{ kg/hectare d}) (10^{-4} \text{ m}^2 \text{ /hectare})\}$$
$$= \quad 4249 \text{ m2}$$

5. Determine volume of pond

Assume average depth of pond, Dav =   1.5 m

$$\text{Volume of the pond, Vp} \quad = \quad (1.5 \text{ m}) (4249 \text{ m}^2) = 6373.5 \text{ m}^3$$
$$\text{Pond detention time, } \theta \quad = \quad \text{Vp} / \text{Q}_{avg}$$
$$= \quad (6373.5 \text{ m}^3)/(600 \text{ m}^3/\text{d}) = 10.6 \text{ d}$$

6. Check for detention time based on bacterial reduction

Detention time based on plug flow condition

In general, the efficiency of the BOD removal for the system is expressed in terms of

$$\frac{S_e}{S_i} = e^{-k(2\theta/n + \theta/n)} =$$

$$\theta = -\frac{1}{k} \ln \frac{S_e}{S_i} \qquad (k = 0.2 \text{ /d})$$

$$\theta = -\frac{1}{0.2} \ln 0.1$$

(For 90% BOD removal)

$$\theta = \quad 11.5 \text{ d} \text{ (Based on plug flow condition)}$$

Detention time based on completely mixed flow condition

$$\frac{S_e}{S_i} = \frac{1}{(1 + 2k\theta/n)((1 + k\theta/n)}$$

$$0.1 = \frac{1}{(1+0.2 x 2\theta/3)((1+0.2 x\theta/3)}$$

$$\frac{S_e}{S_i} = \frac{1}{(1+0.2 x 2\theta/n)((1+0.2 x\theta/n)}$$

$$= 22.5 \text{ d}$$

In actual pond system diffusion conditions prevails and an average detention time of 17 days is acceptable

Area of the pond, Ap $\qquad = \qquad \theta\dfrac{Q_{avg}}{D}$ = (17 d) (600 m³/d/1.5 m)

$\qquad\qquad\qquad\qquad\qquad = \qquad 6800 \text{ m}^2$

Provide three ponds (two primary ponds in parallel and one secondary pond in series) of equal area and depth

> 7. Sludge accumulation

Depth required for sludge accumulation, D_S =   0.75 m (Assumption)

Volume of sludge	=	(2/3) (Ds) (Ap)
	=	(2/3) (0.75 m) (6800 m²)
	=	3400 m³
Desludging frequency	=	(3400 m³)/ {(0.07 m³/person year) (4000}
	=	12 years
Recommended desludging frequency of sludge)	=	8 years (because of non uniform deposition

Two maturation ponds are provided in series after the secondary pond

Appendix 2

Design Steps for a UASB Reactor

The procedures for the design of the USAB system to treat wastewater are the following

1. Determine the total organic load

Total organic load COD, OL   = Q_{avg} x COD

Where Q_{avg} is the average flow to the treatment unit and COD is the influent COD.

2. Determine the volume of the reactor

Volume of the reactor, VR   =   OL/OLR

Where OLR is the overflow loading rate

Water height   h   =   upflow velocity of flow x HRT

Check for Volume of reactor based on HRT

Volume of the UASB reactor, V   = Q_{avg} * HRT

3. Determine the surface area of reactor based on HRT

Surface area of the reactor, SA   =   V/h

Surface area/ units   =   SA/2

Diameter of each unit based on surface area is, $D = \{(4 \text{ x } SA/unit/\pi\}^{1/2}$

4. Determine the total height of the reactor

Total height of the reactor, H_T

Note: height of free board = 0.75 m

5. Determine the number of inlets

Provide one inlet /m^2 area of the reactor

Number of inlets   = (Surface area/ units) /SA_u where SA_u is the flow area/unit

6. Determine area of the settling tank

Area of the settling tank, A_s = Qavg /(No of units x Velocity in settling zone)

The Design example of an Up flow Anaerobic Sludge Blanket is shown below:

<u>Design a UASB system to treat a wastewater flow of 600 m^3/d</u>

Design conditions:

Average flow (Qavg)	=	600 m^3/d
Chemical oxygen demand, COD	=	320 mg/L

Assumptions

Hydraulic retention time	=	6 h
Upflow velocity, v	=	0.75 m/h
Organic Loading Rate, OLR	=	1.5 kg of COD/ m^{3}d
Freeboard, FB	=	0.75 m

Velocity in the settling zone, v_s =   1.2 m/h
Number of units, N   =   2
Flow area/ unit, SA_u =   2 m^2
1. Determine the total organic load

Total organic load COD, OL   = Q_{avg} x COD
                                                =   (600 m^3/d) x (320 mg/L) (10^{-6} kg/mg)
                                                (10^3 L/m^3)
                                                =   192 kg /d
2. Determine the volume of the reactor

Volume of the reactor, VR   =   OL/OLR
                                                =   (192 kg/d)/ (1.5 kg/ m^{3}d)
                                                =   128 m^3
Water height   h   =   upflow velocity of flow x HRT
                                                =   (0.75 m/h)x (6 h) = 4.5 m
3. Check for Volume of reactor based on HRT

Volume of the UASB reactor, V   = Q_{avg} * HRT
                                                =   (600 m^3/d) x (6 h) (1/24 d/h)
                                                =   150 m^3
4. Determine the surface area of reactor based on HRT

Surface area of the reactor, SA   =   (150 m^3)/ (4.5 m)
                                                =   33.33 m^2
Surface area/ units   =   33.33 m^2/2   =16.67 m^2
Diameter of each unit based on surface area is, D = {(4 x (12.5 m^2)/π}$^{1/2}$
                                                =   4.6 m
5. Determine the total height of the reactor

Total height of the reactor, H_T = 5.25 m
Note: height of free board = 0.75 m
6. Determine the number of inlets

Provide one inlet /m^2 area of the reactor
Number of inlets   = (Surface area/ units) /SA_u = 16.66 m^2/2 m^2 = provide 9 inlets
Provide 9 numbers of openings
(g) Determine area of the settling tank
Area of the settling tank, A_s = Qavg /(No of units x Velocity in settling zone)
                        = (600 m^3/d) (2)(1.2 m/h) (1/24 h/d)
                        = 10.41 m^2

Appendix 3

Design steps for a Moving Bed Biological Reactor

The procedure for the design of the MBBR is the following

1. BOD to be removed: $BOD = S_o - S$

where S_o is the influent substrate concentration, BOD_5

2. Food $F = Q_a BOD_r$ where Q_a is the average flow rate

3. Microorganisms $M = \dfrac{F}{FM}$

where F is the food and FM is the food to microorganism ratio.

Volume for which the carrier is filled = $V_c = 30\%$

Volume of film = $V_f = A_m t$ where A_m is the media surface and t is the thickness of biofilm

4. Aeration tank volume = $V_a = \dfrac{M}{X_t}$ where X_t is the biomass content in the wastewater

MBBR volume required = $V_{mbbr} = \dfrac{V_a}{V_f}$

MBBR reactor volume required = $V_r = \dfrac{V_{mbbr}}{V_c}$

5. Hydraulic detention time $\theta_c = \dfrac{V.X_t}{Y_{t.}Q_a.(S_o - S) - k_d.X_t.V}$

Where S = Concentration of limiting food in solution BOD in mg/L

k_d = endogenous decay rate constant t^{-1}

X_t = Biomass concentration in kg/m^3

Y_t = kinetic constants

6. Organic Loading Rate $OL = \dfrac{Q_a.S_o}{V}$

7. Dimensions of the aeration tank

Total Depth $H = \dfrac{4V_r}{3.14d^2}$

8. Excess Sludge $W_s = \dfrac{V.X_t}{\theta_c}$

Total height = H + 0.5

9. Air Requirement

Oxygen Transfer Capacity (OTC)

Actual oxygen transfer rate under field conditions = N

$N = [Q_a.(S_o - S)] - (1.42.W_s)$

DO concentration to be maintained in the aeration tank $\quad C1 = 2$

DO concentration at 25°C   Cs = 8.24

Oxygen transfer capacity under standard conditions, kgO$_2$/hr = Ns

$$N_s = \frac{9.17 \times N}{(C_s - C_1) \times 1.024^{(T-20)}}$$ Ns= 168.334 kg/day

Source:

http://nptel.iitm.ac.in/courses/Webcoursecontents/IITKANPUR/wasteWater/Lecture%2042.htm

Under theory of aeration

  10. Air Flow Rate into the aeration tank

Density $\rho = \dfrac{P \times M}{R \times (T + 273 \times 15K)}$

where Molecular weight of air   M = 28.97 $\dfrac{kg}{kg.mole}$

Universal gas constant   R = 8314 $\dfrac{Nm}{kg.moleK}$

Atmospheric pressure   P = 1.01325.10^5 $\dfrac{N}{m^2}$

Temperature   T = 25 K

Kg of O$_2$ per m^3 of air   O = 0.2318.ρ

E = 0.35

Air Flow Rate $A_f = \dfrac{N_s}{E \times O}$

The Design example of a Moving Bed Biological Reactor is shown below

Design Example for Moving Bed Biological Reactor

Design a MBBR for a flow of 490 m^3/d

Aeration Tank

μ_m= 6.day^{-1} k_d= 0.06day^{-1} k_s= 20 $\dfrac{gm}{m^3}$ f_d= 0.15 Y_t= 0.5

Assume

FM= 0.15day^{-1} X_t =4500 $\dfrac{gm}{m^3}$ S = 130 $\dfrac{gm}{m^3}$

BOD to be removed   BOD = S$_o$ − S   BOD$_r$ = 520$\dfrac{gm}{m^3}$

Food F = Qa.BODr = 254.8$\dfrac{kg}{day}$

Microorganism $M = \dfrac{F}{FM} = 1.699 \times 10^3 \text{kg}$

Assuming media surface Am = 500m^2/m^3 (**This value will vary depending on the media one select**)

Volume for which the carrier is filled = V_c = 30%

Thickness of biofilm = 25mm

      Volume of film = V_f = $A_m t$ = 12.5

    4. Aeration tank volume = $V_a = \dfrac{M}{X_t}$ = 377.48 m^3

    MBBR volume required = $V_{mbbr} = \dfrac{V_a}{V_f}$ = 30.199 m^3

    MBBR reactor volume required = $V_r = \dfrac{V_{mbbr}}{V_c}$ = 100.662m^3

$$\theta_c = \dfrac{V \times X_t}{Y_t . Q_a . (S_o - S) - k_d . X_t . V} \qquad\qquad \theta_c = 31.82 days$$

d = 5m

Dimensions of the aeration tank

    Total Depth $H = \dfrac{4V_r}{3.14 d^2}$ = 5.13m

    Excess Sludge $W_s = \dfrac{V . X_t}{\theta_c}$ = 38.54 $\dfrac{kg}{day}$

    Total height = H + 0.5 = 5.63m

Air Requirement

Oxygen Transfer Capacity (OTC)

Actual oxygen transfer rate under field conditions = N

N = [Q_a.(So − S)] − (1.42xW_s)   N = 2.001 x 10^{5}g/day

DO concentration to be maintained in the aeration tank   C1 = 2

DO concentration at 25°C   Cs = 8.24

Oxygen transfer capacity under standard conditions, kgO$_2$/hr = Ns

$$N_s = \dfrac{9.17 \times N}{(C_s - C_1) \times 1.024^{(T-20)}} \qquad\qquad \text{Ns= 261.146 kg/day}$$

Air Flow Rate into the aeration tank

Molecular weight of air   M = 28.97 $\dfrac{kg}{kg.mole}$

Universal gas constant   R = 8314 $\dfrac{Nm}{kg.moleK}$

Atmospheric pressure $P = 1.01325.10^5 \ \dfrac{N}{m^2}$

Temperature $T = 25 \ K$

Density $\rho = \dfrac{P \times M}{R \times (T + 273 \times 15K)}$ $\rho = 1.184 \ \dfrac{Kg}{m^3}$

Kg of O_2 per m^3 of air $O = 0.2318.\rho$

$O = 0.274 \ \dfrac{Kg}{m^3}$ $E = 0.35$

Air Flow Rate

$A_f = \dfrac{N_s}{E \times O}$ $Af = 113.258 \ \dfrac{m^3}{hr}$

Dimensions of the MBBR tank = 5.2m ht and 5 m dia

Appendix -4

Design Steps for Activated Sludge Process

The procedures for the design of an ASP are the following

1. BOD to be removed $BOD = S_o - S$ where S_o is the influent substrate concentration, BOD_5

2. Food $F = Q_a BOD_r$ where Q_a is the average flow rate

3. Microorganisms $M = \dfrac{F}{FM}$ where F is the food and FM is the food to microorganism ratio.

4. Volume of tank $V = \dfrac{M}{X_t}$ where X_t is the BOD content in the wastewater

5. Hydraulic detention time $\theta_c = \dfrac{V.X_t}{Y_t.Q_a.(S_o - S) - k_d.X_t.V}$

Where   S = Concentration of limiting food in solution BOD in mg/L
k_d = endogenous decay rate constant t^{-1}
X_t = Biomass concentration in kg/m^3
Y_t = kinetic constants

6. Organic Loading Rate $OL = \dfrac{Q_a.S_o}{V}$

7. **Dimensions of the aeration tank**

Area $A = \dfrac{V}{H}$ Length $L = \dfrac{A}{W}$

Total Depth $H = H + FB$ $H = 5$ m
Actual dimensions $V = H.L.W$

8. Excess Sludge $W_s = \dfrac{V.X_t}{\theta_c}$

If $X_s = 10000 \dfrac{gm}{m^3}$

Return Sludge Ratio $R = \dfrac{.X_t}{X_s - X_t}$

9. Air Requirement
Oxygen Transfer Capacity (OTC)
Actual oxygen transfer rate under field conditions = N
$N = [Q_a.(So - S)] - (1.42.W_s)$

10. Air Flow Rate into the aeration tank

Density $$\rho = \frac{P \times M}{R \times (T + 273 \times 15K)}$$

where Molecular weight of air $$M = 28.97 \ \frac{kg}{kg.mole}$$

Universal gas constant $$R = 8314 \ \frac{Nm}{kg.moleK}$$

Atmospheric pressure $$P = 1.01325.10^5 \ \frac{N}{m^2}$$

Temperature $$T = 25 \ K$$

Kg of O_2 per m^3 of air $$O = 0.2318.\rho \quad\quad E = 0.35$$

Air Flow Rate $$A_f = \frac{N_s}{E \times O}$$

No of diffusers needed $\quad Number = ceil\left(\dfrac{A_f}{0.75 \times q}\right) \quad$ where q is the design discharge of each diffuser

The Design Example of Activated Sludge Process are cited below

Design an ASP for a flow of 498 m³/d

Aeration Tank

$\mu_m = 6.day^{-1} \quad\quad k_d = 0.06day^{-1} \quad\quad k_s = 20 \ \frac{gm}{m^3} \quad\quad\quad\quad f_d = 0.15 \quad\quad\quad\quad\quad\quad Y_t = 0.5$

Assume

$FM = 0.18day^{-1} \quad\quad\quad\quad X_t = 3500 \ \frac{gm}{m^3} \quad\quad\quad\quad\quad\quad S = 20 \ \frac{gm}{m^3}$

BOD to be removed $\quad\quad\quad BOD = S_o - 20 \quad\quad\quad\quad BOD_r = 430 \frac{gm}{m^3}$

Food $F = Qa.BODr \ = 129 \ \dfrac{kg}{day}$

Microorganism $M = \dfrac{F}{FM} = 716.7kg$

Volume of tank $V = \dfrac{M}{X_t} \ = 204.9m^3$

Hydraulic retention time $\quad HRT = 16.4$

$$\theta_c = \frac{V \times X_t}{Y_t.Q_a.(S_o - S) - k_d.X_t.V} \qquad \theta_c = 33 days$$

Organic Loading Rate $\quad OL = \frac{Q_a \times S_o}{V}$

$$OL = 0.659. \ \frac{kg}{m^3.day}$$

Dimensions of the aeration tank

Assume $\quad H = 4.5$ m $\quad W = 4$ m

Area $\quad A = \frac{V}{H} \qquad A = 45.53$ m^2

Length $\quad L = \frac{A}{W} \qquad L = 11.4$ m

FB $= 0.5$ m

Total Depth $\quad H = H + FB \quad H = 5$ m

Actual dimensions

$V = H.L.W \qquad V = 228$ m^3

Excess Sludge

$$W_s = \frac{V.X_t}{\theta_c} \qquad W_s = 21.5 \ \frac{kg}{day}$$

$X_s = 10000 \ \frac{gm}{m^3}$

Return Sludge Ratio

$$R = \frac{.X_t}{X_s - X_t} \qquad R = 0.538$$

Air Requirement

Oxygen Transfer Capacity (OTC)

Actual oxygen transfer rate under field conditions $= N$

$N = [Q_a.(So - S)] - (1.42 x W_s) \qquad N = 128.969$ kg/day

DO concentration to be maintained in the aeration tank $\quad C1 = 2$

DO concentration at 25°C $\quad Cs = 8.24$

Oxygen transfer capacity under standard conditions, kgO$_2$/hr $= Ns$

$$N_s = \frac{9.17 \times N}{(C_s - C_1) \times 1.024^{(T-20)}} \qquad Ns = 168.334 \ kg/day$$

Air Flow Rate into the aeration tank

Molecular weight of air　M = 28.97 $\dfrac{kg}{kg.mole}$

Universal gas constant　R = 8314 $\dfrac{Nm}{kg.moleK}$

Atmospheric pressure　P = 1.01325.10^5 $\dfrac{N}{m^2}$

Temperature　　　　　T = 25 K

Density　　　　$\rho = \dfrac{P \times M}{R \times (T + 273 \times 15K)}$　　$\rho = 1.184$ $\dfrac{Kg}{m^3}$

Kg of O$_2$ per m^3 of air　　　　　O = 0.2318.ρ

O = 0.274 $\dfrac{Kg}{m^3}$　　　E = 0.35

Air Flow Rate

$A_f = \dfrac{N_s}{E \times O}$　　　　　Af = 73.00 $\dfrac{m^3}{hr}$

Design discharge of each diffuser = 4.2 $\dfrac{m^3}{hr}$

No of diffusers needed　$Number = ceil\left(\dfrac{A_f}{0.75 \times q}\right)$　　No= 23

Provide 23nos of diffusers for Aeration Tank.

Dimensions of the Aeration tank = 11.4 m × 4m ×5m

Appendix-5

Design steps for Bio-tower

$$S_a = \frac{S_o + R_e S_e}{1 + R_e}$$

Where S_a is the BOD$_5$ of the mixture of raw and recycled mixture applied to the medium

S_e is the effluent substrate concentration, BOD$_5$

S_o is the influent substrate concentration, BOD$_5$

R_e is ratio of the recycled flow to the influent flow

Treatability constant at 25°C

$k = k.(1.035)^{T-20}$

Hydraulic loading Rate

Coefficient for plastic media $n = 0.5$

$$Q_1 = \left(\frac{k \times d}{-\ln\left(\frac{[S_e(1+R_e)]}{S_a + R_e Se}\right)} \right)^{\frac{1}{n}}$$

where d is the depth of medium and k is the treatability constant relating to wastewater and medium characteristic, min^{-1}

1. Surface area of the bio tower $SA = \dfrac{Q_a}{Q_1}$ where Q_a is the average flow rate

2. Diameter of tower $D = \left(\dfrac{4.5A}{\Pi}\right)^{0.5}$

3. Depth H=d+FB+2.25m

4. Volume $V = \dfrac{\Pi \times D^2 \times H}{4}$

5. Distributor Arrangement

   Arm length $L_a = \dfrac{D}{2}$

6. Orifices

$$A_o = \frac{\Pi \times d_o{}^2}{4}$$ Where d_o is the diameter of the orifice

Discharge through each orifice $q_o = C_d \times A_o \times (2gh)^{0.5}$ C_d is the coefficient of discharge

No of orifices needed $ONo = \left(\dfrac{q}{q_o} \right)$

The design example for a bio tower with recirculation is given below
<u>Design Example for a Bio Tower with Recirculation</u>

Design a bio tower with recirculation for a flow of 495 m³/d

Effluent BOD $Se := 195 \dfrac{gm}{m^3}$

Assume $Re := 4$

$$S_a = \frac{S_o + R_e S_e}{1 + R_e}$$ $Sa = 286. \dfrac{gm}{m^3}$

Treatability constant at 25°C
$K = 0.06 \text{day}^{-1}$ T=25 °C
$K = k.(1.035)^{T-20}$ $k = 0.071.\text{day}^{-1}$
Hydraulic loading Rate
Coefficient for plastic media $n = 0.5$
$d = 5$ $k = 0.071$

$$Q_1 = \left(\frac{k \times d}{-\ln\left(\dfrac{[S_e (1 + R_e)]}{S_a + R_e Se} \right)} \right)^{\frac{1}{n}}$$

$Q1 = 0.086 \ \dfrac{m^3}{m^2 \ \min}$

Surface area of the biotower

$$SA = \frac{Q_a}{Q_1}$$ $SA = 3.771 m^2$

Diameter of tower $D = \left(\dfrac{4.5A}{\Pi}\right)^{0.5}$ $D = 2.191\text{m}$

Free Board FB :=0.75m   d:=5m

Depth H:=d+FB+2.25m H= 8m

Volume $V = \dfrac{\Pi \times D^2 \times H}{4}$ $V = 30.168.\text{m}^3$

Distributor Arrangement

Flow Qa = 5.405 x 10^{-3} $\dfrac{m^3}{s}$

Arm length $L_a = \dfrac{D}{2}$ La = 1.096m

Assuming arm pipe diameter as 0.05m

Orifices

Assuming a diameter of 10 mm do = 0.01m

Head causing flow h = 0.75m

Cd:=0.6 $A_o = \dfrac{\Pi \times d_o^{\,2}}{4}$ Ao = 7.854 x 10^{-5} m^2

Discharge through each orifice $q_o = C_d \times A_o \times (2gh)^{0.5}$ qo = 1.807 x 10^{-4} $\dfrac{m^3}{s}$

No of orifices needed $ONo = \left(\dfrac{q}{q_o}\right)$ Orifice no = 7.476 ~ 8

Appendix 6

Design Example for Micro-Scale Conventional Sewerage System

Calculations for the design of a sewerage system are usually carried out in a tabular format. An example is provided in Appendix 1 to illustrate this.

Hydraulic properties of circular sections for Manning's formula

	Constant(n)			**Variable(n)**	
d/D	v/V	q/Q	n/n_0	v/V	q/Q
1.0	1.000	1.000	1.00	1.000	1.000
0.9	1.124	1.066	1.07	1.056	1.020
0.8	1.140	0.968	1.14	1.003	0.890
0.7	1.120	0.838	1.18	0.952	0.712
0.6	1.072	0.671	1.21	0.890	0557
0.5	1.000	0.500	1.24	0.810	0.405
0.4	0.902	0.337	1.27	0.713	0.266
0.3	0.776	0.196	1.28	0605	0.153
0.2	0.615	0.088	1.27	0.486	0.070
0.1	0.401	0.021	1.22	0.329	0.017

In Table 5.3,

v = velocity of flow when the depth of flow is d,

V = velocity of flow when the sewer is flowing full,

q = flow rate when the depth of flow is d,

Q = flow rate when the sewer is flowing full,

n = Manning roughness coefficient when the depth of flow is d,

n_0 = Manning roughness coefficient when the sewer is running full.

It may be noted here that flow rate Q may be determined using the following formula:

$$Q = \frac{0.3117}{n_0}(D)^{\frac{8}{3}}\sqrt{S_f}$$

Nalanda Nagar

All houses in Nalanda Nagar have their own septic tank. The sewer design is been done for main sewer pipes which can follow the route of road network connecting the maximum possible houses. The maximum elevation differences in this region are less than 1.2m , so the

Nalanda Nagar has almost flat gradients, but the area is a compact with dense population which is a plus for obtaining required velocities in sewer pipes.

Input:

Design parameters (Input)

Table A1 Design Parameters for Nalanda Nagar

Location	Design population Safety factor	LPCD	R.F	P.F
Nalanda Nagar	1.2	140	0.8	3

Survey Data (Input)

Table A2 Survey details for Nalanda Nagar

Pipe No. (n)	upstream_node No.	downstream_node No.	Order of pipe	GL at Respective nodes		Pipeslope (choosen)	Population	Length (m)	D_chosen (m) (Choosen)
				upstream (m)	downstream (m)				
1.00	1.00	2	1	101.15	100.37000	0.03120	450	25	0.1
2.00	2.00	3	2	100.37	100.01000	0.00700	554.4	74	0.1
3.00	3.00	4	3	100.01	99.72000	0.00600	283.2	100	0.15
4.00	5.00	6	1	99.84	99.78000	0.02000	222	62	0.1
5.00	6.00	7	2	99.78	99.72500	0.02000	18	60	0.1
6.00	4.00	7	4	99.72	99.72500	0.00350	54	88	0.2
7.00	8.00	10	1	99.3	99.36000	0.01700	276	36	0.1
8.00	9.00	10	1	99.3	99.36000	0.01300	372	36	0.1
9.00	10.00	11	2	99.36	99.62000	0.00600	36	30	0.15
10.00	11.00	4	3	99.62	99.72000	0.00600	12	35	0.15
11.00	12.00	10	1	99.41	99.36000	0.00900	656.4	88	0.1
12.00	12.00	7	1	99.41	99.72500	0.03000	26.4	48	0.1

Discharges from all the nodes are collected at the Final node 7. Location of sump for the treatment plant can be located beside it.
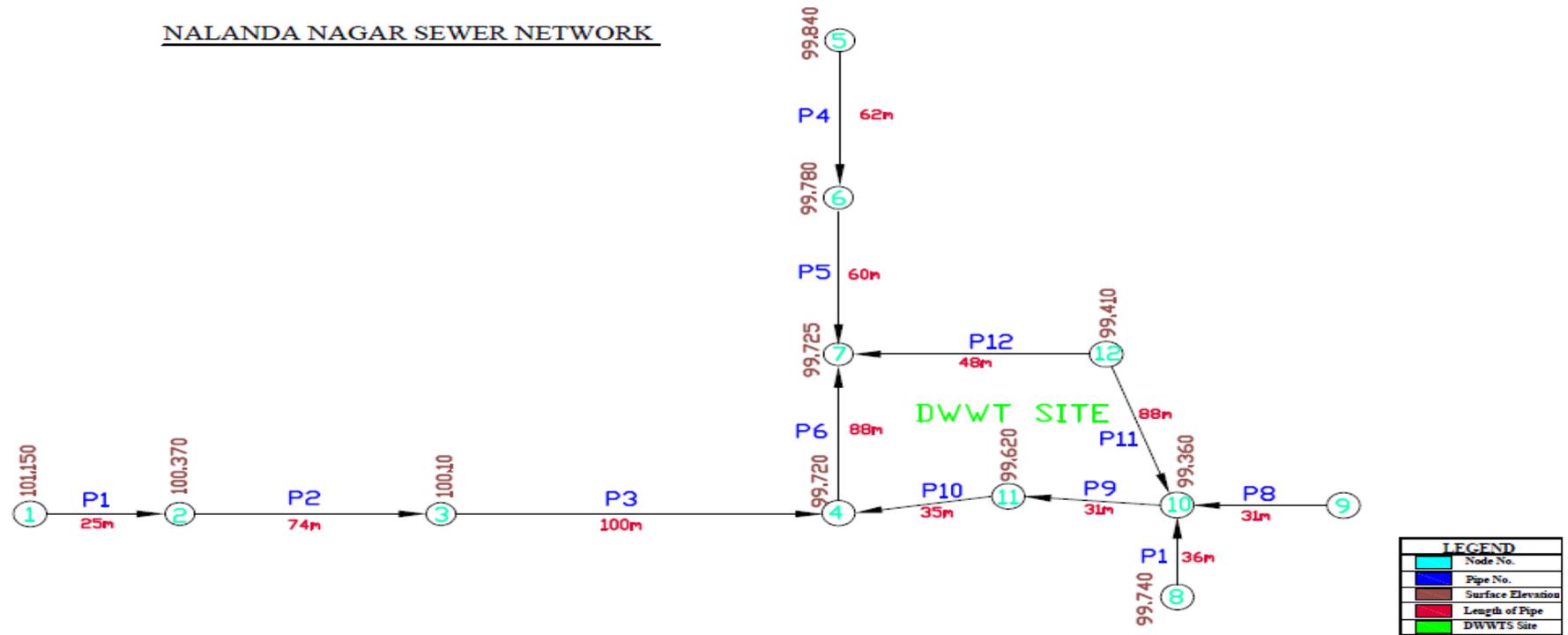
Figure A.1 Nalanda nagar Sewer Network

Table A3 Calculations for Sewer System Design

col (1)	col (2)	col (3)	col (4)	col (9)	col (10)	col (11)	col (12)	Col (13)	col (14)	col (15)	col (16)	col (17)	col (18)	col (19)	col (20)	col (21)	col (22)	col (23)
Pipe No. (n) (Input)	upstream_node No. (Input)	downstream_node No. (Input)	Order of pipe(Input)	pipeslope choosen (Input)	ground slope (- indicates pipe has to go against gravity) (given)	population (Input)	length (m) (Input)	indvPipe_discharge (m³/sec) (Calculated))	Discharge (m3/sec) (Calculated)	D_chosen (m) (Chosen)	Depth of Wastewater (m) (Calculated)	velocity (m²/sec) (Calculated)	burial depth upstream (m) (Calculated)	burial depth downstream (m) (Calculated)	Angle (Degrees) (Checking)	Wetted area (m2) (Checking)	Wetted perimeter (m) (Checking)	discharge_cal (m3/sec) (Checking)
1.00	1.00	2	1	0.0312	0.03120	450	25	0.00156	0.00156	0.1	0.02797	0.86737	1.00000	1.0	127.72107	0.00180	0.11146	0.00156
2.00	2.00	3	2	0.0070	0.00486	554.4	74	0.00192	0.00348	0.1	0.06799	0.61206	1.10000	1.25800	222.16837	0.00569	0.19388	0.00348
3.00	3.00	4	3	0.0060	0.00290	283.2	100	0.00098	0.00446	0.15	0.06394	0.62112	1.35800	1.66800	163.04260	0.00718	0.21342	0.00446
4.00	5.00	6	1	0.0200	0.00097	222	62	0.00077	0.00077	0.1	0.02191	0.60379	1.00000	2.18000	111.65026	0.00127	0.09743	0.00077
5.00	6.00	7	2	0.0200	0.00092	18	60	0.00001	0.00078	0.1	0.02208	0.60640	2.28000	3.42500	112.09808	0.00129	0.09782	0.00078
6.00	4.00	7	4	0.0035	-0.00006	54	88	0.00019	0.00933	0.2	0.09776	0.61168	2.79200	3.10500	177.43717	0.01526	0.30969	0.00933
7.00	8.00	10	1	0.0170	-0.00167	276	36	0.00096	0.00096	0.1	0.02546	0.60710	1.00000	1.67200	121.20921	0.00158	0.10577	0.00096
8.00	9.00	10	1	0.0130	-0.00167	372	36	0.00129	0.00129	0.1	0.03178	0.60056	1.00000	1.52800	137.26221	0.00215	0.11978	0.00129
9.00	10.00	11	2	0.0060	-0.00867	36	30	0.00012	0.00464	0.15	0.06539	0.62775	1.84200	2.28200	165.28032	0.00740	0.21635	0.00464
10.00	11.00	4	3	0.0060	-0.00286	12	35	0.00004	0.00469	0.15	0.06572	0.62923	2.38200	2.69200	165.78429	0.00745	0.21701	0.00469
11.00	12.00	10	1	0.0090	0.00057	656.4	88	0.00227	0.00227	0.1	0.04787	0.61231	1.00000	1.74200	175.12549	0.00371	0.15283	0.00227
12.00	12.00	7	1	0.0300	-0.00656	26.4	48	0.00009	0.00009	0.1	0.00713	0.36824	1.00000	2.75500	61.95471	0.00025	0.05407	0.00009

Cloumn (9)   = Population density x cumulative area served (8)

Column (10) = Water supply in Lpd per head x population (9) x % of water supplied returning as waste

Column (11) = rate of infiltration in Lpd per haectare x cumulative area served (8)

Column (12) = (Average sewage flow (10) + Average Groundwater infiltration (11)) x (peak flow factor)

Column (13): Chose a diameter (D) for the sewer line (minimum size is 150 mm)

Column (14): Chose a slope (based on prevailing ground slope)

Column (15): Calculate Q_{full} (flow rate when the sewer is flowing full) using Manning's equation

Column (16): Calculate Q_{actual} (this is same as given in column 12)

Column (17): Calculate $V_{full} = Q_{full} / (\pi D^2/4)$

Column (18): Calculate V_{actual} (refer to Table 4.12)

Column (19): Calculate d/D (refer to Table 4.12)

Column (20): Determine total fall (slope x length of sewer)

Column (21): Determine invert elevation at upper end (Minimum depth below ground level = 1.0 m)

Column (22): Determine invert elevation at lower end (using total fall)