सत्यमेव जयते

स्वच्छ भारत
एक कदम स्वच्छता की ओर

Technological Options for Solid and Liquid Waste Management in Rural Areas

MINISTRY OF DRINKING WATER AND SANITATION
SWACHH BHARAT MISSION (GRAMIN)
GOVERNMENT OF INDIA
April 2015

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Ministry of Drinking Water and Sanitation
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Govt. of India

April 2015

बीरेन्द्र सिंह
Birender Singh

ग्रामीण विकास, पंचायती राज और
पेयजल एवं स्वच्छता मंत्री
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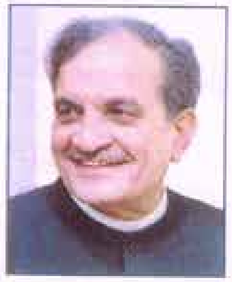
MINISTER OF RURAL DEVELOPMENT, PANCHAYATI RAJ
AND DRINKING WATER & SANITATION
GOVERNMENT OF INDIA



MESSAGE

The Ministry of Drinking Water and Sanitation is the nodal ministry for the overall policy, planning, funding and coordination of programmes of rural drinking water and sanitation in the country. To accelerate the efforts to achieving universal sanitation and to systematically address the implementation issues, the Prime Minister of India launched the Swachh Bharat Mission (SBM-G) on October 2, 2014.

The objective of the mission is to bring about improvement in the cleanliness, hygiene and the general quality of life in rural areas. Solid and liquid waste management (SLWM) is one of the key components of the programme. To create clean villages, it is essential that the IEC and capacity building interventions must focus on (SLWM) so as to create a felt need among the people. This must lead to the setting up of systems for the scientific disposal of waste in such a way that has a tangible impact on the population. The Community / Gram Panchayats have to be motivated to come forward and demand for such a system, which they have to subsequently operate and maintain.

All Gram Panchayats are to be targeted for coverage with a SLWM project under Swachh Bharat Mission activities. One of the objectives of this Ministry is to initiate SLWM projects in all Gram Panchayats without delay.

I am delighted to note that the book has been prepared by the Ministry of Drinking Water and Sanitation, Government of India detailing technical options on SLWM, which can be implemented in rural areas. This book has been reviewed and vetted by a high level technical committee headed by Padma Vibhushan Prof. R.A. Mashelkar.

I hope this technical manual will be a great help for implementers at the grass root level to make our nation clean.

(Birender Singh)

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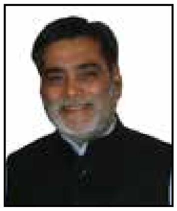
एक कदम स्वच्छता की ओर

राज्य मंत्री
पेयजल एवं स्वच्छता मंत्रालय
भारत सरकार

सत्यमेव जयते

MINISTER OF STATE
DRINKING WATER & SANITATION
GOVERNMENT OF INDIA

राम कृपाल यादव
Ram Kripal Yadav



MESSAGE

There exists a direct relationship between sanitation, health and human well being. To accelerate the efforts to achieve universal sanitation coverage and to put focus on sanitation, the Prime Minister of India launched the Swachh Bharat Mission that aims to achieve Swachh Bharat by 2nd October, 2019, which in rural areas shall mean improving the levels of cleanliness through Solid and Liquid Waste Management activities and making Gram Panchayats Open Defecation Free (ODF) and clean. Proper management of solid and liquid wastes in rural areas has been a major challenge for all the concerned stakeholders. To achieve the goal of Swachh Bharat Mission-Gramin (SBM-G), adequate efforts are required to improve environmental sanitation including management of solid and liquid wastes at household as well as community levels through sustainable methods. In rural areas, most of the solid and liquid wastes are of organic in nature. There is ample chance of safe recycling and reuse of such wastes for economical uses.

Improvement of sanitation is a socio-technical issue. Required impact of waste management can be achieved through social mobilizations supported by socio-culturally acceptable and economically affordable technologies. The book describes several technologies for solid and liquid waste management. There are several options for SLWM, suitable for different socio-economic groups of communities.

I am pleased to note that the book has been prepared by the Ministry of Drinking Water and Sanitation, Government of India with the efforts of Shri G. Balasubramanian, Deputy Adviser (Sanitation), MoDWS and Dr. Pawan Kumar Jha, Ex. Consultant (Sanitation & Waste Management), National Resource Centre, MoDWS based on the needs of many stakeholders of sanitation programmes in view. The inputs / suggestions received from Prof. A.A. Kazmi, IIT, Roorkee; Dr. Markus Starkl, Competence Centre for Decision Aid in Environmental Management, Vienna, Austria; Prof. Arunabha Majumder, Ex Director, AIIH&PH, Kolkata; Prof. S.R. Wate, Director, NEERI; Prof. A.B. Gupta, MNIT, Jaipur; ShriLokendraSingh, DRDO; and Water Aid India, are thankfully appreciated. This book is finally vetted by a high level Technical Committee constituted by the Ministry, under the Chairmanship of Padma Vibhushan Prof. R.A.Mashelkar, former Director General, CSIR. The book will prove useful for Public Health Engineers, Sanitarians, NGOs, CBOs and communities involved in the field of solid and liquid waste management in rural areas.

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Technological Options for
Solid and Liquid Waste Management in Rural Areas

Contents

CHAPTER- 1
INTRODUCTION

1.1 INTRODUCTION

Proper management of solid and liquid wastes is an important determinant of improved sanitation in any community. The goals of sanitation fail miserably when solid and liquid waste management aspect is not given proper attention to improve health and living environment of the community. In rural areas, this aspect is mostly neglected due to lack of proper infrastructure, unavailability of sustainable technology at household or community level and moreover lack of adequate O&M infrastructure and awareness of common people. In most of the rural areas it is not a felt-need problem.

Management of solid or liquid wastes in rural areas is much easier than in urban areas due to the fact that there are no highly contaminated industrial wastes. In rural areas, most of the wastes can be safely reused for beneficial purposes with limited resources. Further, in rural areas there are usually less space constraints allowing for the application of natural wastewater treatment systems therefore increasing to choice of options.

A number of waste prevention techniques for solid and liquid waste management are available, and they are commonly summarized as the so-called 4Rs: Reduction, Reuse, Recycling and Recovery. In India with its great diversity of climate, terrain, resource availability, livelihood, culture and habit, the quantity and quality of waste generated vary significantly. In general, typical indigenous systems prevail in different regions, whereby a chain of material use exists based on zero disposal and discharge. There are specific uses attributed to each part of the farm products. For example, rice is used for cooking, rice husk for fuel, rice straw as fodder, cattle dung for fuel and compost and ash as manure in rice fields etc., such that there is no waste generated beyond the assimilative capacity of the environment. However, due to increasing population, growing consumerism, changing food habit, increasing use of plastics, packaging and use and throw items etc, the management of waste is emerging as an issue needing urgent attention from the point of view of health and environment even in rural settings.

There are also increasing concerns on liquid waste, especially the grey water generated in households, institutions and common places and wash water from kitchen, bathroom, markets etc. The stagnant water provides conducive domain for breeding for disease vectors. The absence of storm water drains or dilapidated streamlets etc. enhances the water logging scenario, creating unhygienic and anaesthetic conditions. The liquid waste also poses serious problems by contaminating surface water as well as ground water, the later especially in high water table regimes. There are several technologies suitable for different socio-economic and geological conditions of rural areas. Some of the natural wastewater treatment technologies evaluated by Starkl et al. (2013), also been included in this handbook. This handbook aims to provide complete information on sustainable technologies for wastewater as well as solid wastes for rural areas. Selection of technology by community should be based on the availability of space requirement, onetime cost and operation and maintenance costs of the system. Their needs active involvement of community right from planning, designing, execution and operation and maintenance of the systems for solid and liquid waste management.

1.2 SOLID AND LIQUID WASTE MANAGEMENT UNDER THE SBM (G) GUIDELINES

To accelerate the efforts to achieve universal sanitation coverage and to put focus on sanitation, the Prime Minister of India launched the Swachh Bharat Mission on 2nd October, 2014. The Mission Coordinator shall be Secretary, Ministry of Drinking Water and Sanitation (MDWS) with two Sub-Missions, the Swachh Bharat Mission (Gramin) and the Swachh Bharat Mission (Urban), which aims to achieve Swachh Bharat by 2019, as a fitting tribute to the 150th Birth Anniversary of Mahatma Gandhi, which in rural areas shall mean improving the levels of cleanliness in rural areas through Solid and Liquid Waste Management activities and making Gram Panchayats Open Defecation Free (ODF), clean and sanitised. The Mission shall strive for this by removing the bottlenecks that were hindering the progress, including partial funding for Individual Household Latrines from MNREGS, and focusing on critical issues affecting outcomes.

The main objectives of the SBM (G) are as under:

a) Bring about an improvement in the general quality of life in the rural areas, by promoting cleanliness, hygiene and eliminating open defecation.

b) Accelerate sanitation coverage in rural areas to achieve the vision of Swachh Bharat by 2nd October 2019.

c) Motivate Communities and Panchayati Raj Institutions to adopt sustainable sanitation practices and facilities through awareness creation and health education.

d) Encourage cost effective and appropriate technologies for ecologically safe and sustainable Sanitation.

e) Develop where required, Community managed sanitation systems focusing on scientific Solid & Liquid Waste Management systems for overall cleanliness in the rural areas.

The objective of SBM (G) is to bring about improvement in the cleanliness, hygiene and the general quality of life in rural areas. Solid and Liquid Waste Management (SLWM) is one of the key components of the programme. To create clean villages, it is essential that the IEC interventions focus on Solid and Liquid Waste Management so as to create a felt need for these activities amongst the population. This must lead to the setting up of systems for the scientific disposal of waste in such a way that has a tangible impact on the population. The Community / Gram Panchayat have to be motivated to come forward and demand for such a system, which they have to subsequently operate and maintain.

Once the demand is created, to ensure that the resources are used efficiently, SLWM is to be taken up in project mode for each Gram Panchayat (GP) with financial assistance capped for a GP on number of household basis to enable all GPs to implement sustainable SLWM projects. The total assistance under SBM (G) for SLWM projects shall be worked out on the basis of total number of households in each GP, subject to a maximum of Rs.7 lakh for a GP having up to 150 households, Rs.12 lakh up to 300 households, Rs.15 lakh up to 500 households and Rs.20 lakh for GPs having more than 500 households. Funding for SLWM project under SBM (G) is provided by the Central and State Government in the ratio of 75:25. Any additional cost requirement is to be met with funds from the State / GP, and from other sources like Finance Commission funding, CSR, Swachh Bharat Khosh and through the PPP model.

Under Solid and Liquid Waste Management, the following activities inter-alia may be undertaken:

i. ***For Solid Waste Management:*** States are to decide the technologies suitable to their areas. Technologies identified by the Committee on Technologies may also be considered for implementation. Collection, segregation and safe disposal of household garbage, decentralized systems like household composting and biogas plants shall be permitted. Activities related to maximum reuse of organic solid wastes as manure should be adopted. Such technologies may include vermi-composting, NADEP composting, or any other composting method, individual and community biogas plants. Funds allocated for Solid and Liquid Waste Management may be used to implement safe disposal solutions for menstrual waste (used sanitary cloths and pads) and setting up incinerators in Schools, Women's Community Sanitary Complexes, Primary Health Centre, or in any other suitable place in village and collection mechanisms etc., can be taken up. Technologies may include appropriate options that are socially acceptable and environmentally safe.

ii. ***For Liquid Waste Management:*** States are to identify suitable technologies. Methods adopted for

Management of liquid wastes may focus on maximum reuse of such waste for agriculture purposes with least operation and maintenance costs. For collection of waste water, low cost drainage/ small bore system, soakage pit may be adopted.

For details of the technologies suitable for rural areas, this handbook and other publications under preparation to be issued by the Ministry of Drinking Water and Sanitation may be referred.

All GPs are to be targeted for coverage with a SLWM project. SLWM Projects for each GP should be part of the annual District Plan. The Annual District Plan should be approved by State level Scheme Sanctioning Committee (SLSSC). Each individual SLWM project may be approved at the DWSC level as per the technical and financial rules of the individual states. The objective is to initiate SLWM projects in all GPs without delay.

CHAPTER- 2

TECHNOLOGICAL OPTIONS FOR LIQUID WASTE MANAGEMENT

2.1 CRITERIA FOR SELECTION OF TECHNOLOGY

There is a range of technological options for Waste water and Solid Waste Management. Selection of technology should be made taking in account its sustainability in terms of social, economical and environmental aspects. Selected technology should be socially acceptable, economically affordable and environmental friendly. It further should be suitable for the expected capacity for operation and maintenance, in both technical and financial terms. This aspect is of particular importance as different types of technologies will require varying degree of technical and financial inputs during the life time of the technology to keep it in sustainable operation mode. The following points should be considered in selecting any technology:

- **Health**-differences in risk of infection between the options
- **Environment** - differences in emissions into air and water and the use of energy and natural resources.
- **Economy** - annual and recurring costs related to the options
- **Socio-cultural aspects** - the appropriateness to current or local cultural context, institutional viability.
- **Technical function** - robustness against extreme conditions, maintenance requirements, risk of failure, effect of failure, structural stability.
- **Capacity:** Local capacity for operation& maintenance in technical and financial terms

All stakeholders should be involved in the planning and decision making process based on their interest and experience. Different technical options should be compared against the above mentioned points and the preferred option selected. It should be justified why the preferred option is considered the most sustainable in the given context and ensured that it meets the minimum required standards.

2.2 WASTEWATER GENERATION & CHARACTERIZATION

The wastewater from various household activities can be classified into;

i. Grey water: Wastewater generated from bathing, kitchen and other household activities except toilet.

ii. Backwater: Wastewater generated from toilets.

iii. Combined wastewater: It can be either mix of grey water and effluent of septic tank treating black water or effluent of septic tank treating black and grey water.

iv. Sewage: Combined grey and black water generated from household in the absence or presence of septic tank.

The characteristics of the above mentioned types of wastewater are the function of level of water supply and per capita pollution load. The level of water supply plays a major role in deciding the concentration of pollutants. Other significant factors are settlement and decomposition in drains, sewers under warm weather conditions, partially treated sewage from septic tanks, lifestyle of the population. The best was to ascertain the characteristics is to conduct the sampling and analyse various water quality parameters of the outfall or drain. The samples should be analyzed for the parameters like BOD, COD, TSS, Total Coliforms and Faecal Coliforms.

In the absence of data, the following characteristics (Table 2.1) can be assumed for various kinds of Wastewaters: These values are obtained based on the analysis under the sponsored research project by the Ministry of Drinking Water & Sanitation to the Department of Civil Engineering, IIT Roorkee, Uttranchal.

Table 2.1: Typical values for parameter for various kinds of Wastewaters

Parameters	Grey water	Black water	Septic Tank Effluent*	Septic Tank Effluent**	Mixed Wastewater***	Sewage
BOD (mg/L	100-300	600-1000	300-600	80-160	150-400	250-400
COD (mg/L)	200-500	1000-2000	600-1000	200-400	300-600	500-800
TSS (mg/L)	100-300	800-1200	300-500	200-400	150-350	600-1000
Fecal Coliforms (MPN/100 ml)	10^2-10^3	10^6-10^7	10^5-10^6	10^3-10^5	10^4-10^5	10^5-10^7
Total Coliforms (MPN/100 ml)	10^2-10^3	10^7-10^8	10^6-10^7	10^4-10^6	10^5-10^6	10^5-10^7

*(Treating Black water only)

** (Treating Grey water + Black water)

***Septic Tank Effluent & Grey water

Note: *These concentrations are analysed on-site, the values could be 20-40 % lower at the STP site due to settling, biodegradation etc. process in the wastewater collection system depending on the climatic conditions, type and length of the collection system etc.,*

2.3 WASTEWATER COLLECTION & TREATMENT SYSTEM IN RURAL AREAS

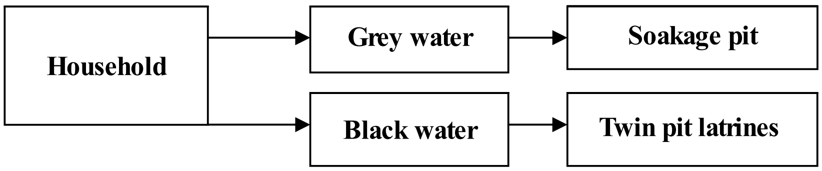
In India, as per 2011 census, rural areas sanitation coverage is 32.7% that constitutes 14.7 % septic tank, 8.2% pit toilets with slab, 2.3 % pit toilets without slab, 2.2 % piped sewer system, 1.9 % public toilets, 2.5 % other toilets, 0.3 % toilets cleaned by humans, and 0.2% others.

As per the prevailing rural conditions of the country, 8 different options are suggested for safe wastewater (Grey water, Black water, combined wastewater & sewage) collection, treatment and disposal/reuse as per the end user requirement. These options are either on-site solutions, or decentralised or mixed solutions. Which is most suitable should be elaborated in a thorough feasibility study that takes into account the above mentioned criteria for technology selection.

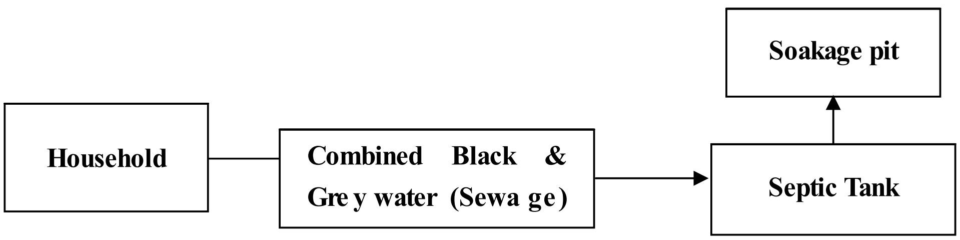
The configurations could be any one of the following options depending on the standard of living, water availability, fund constraints, soil and topographical conditions, density of population etc., of the village.

Option-1: Sanitation System using Soak pits and Twin-Pit Latrines

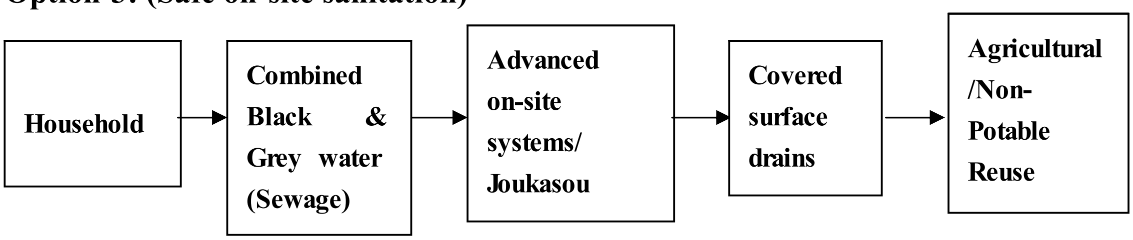
(Sandy soil and deep groundwater table, piped water supply, sparse population)



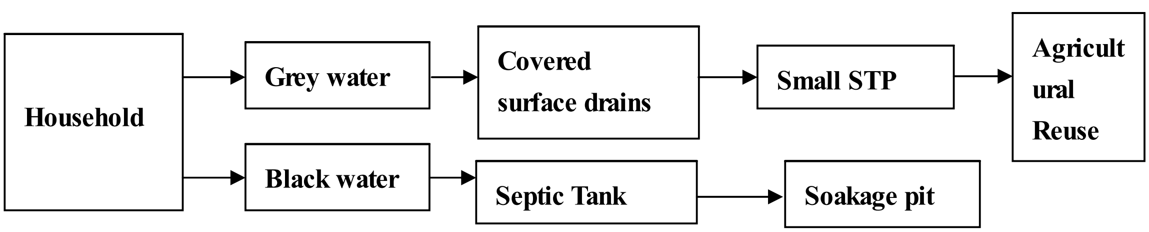
Option-2: Sanitation System using Soak pits (Sandy soil and deep groundwater table, piped water supply sparse population)



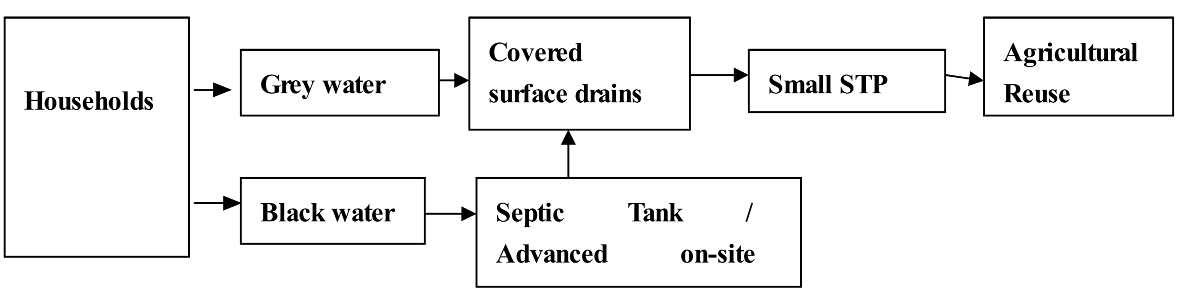
Option-3: (Safe on-site sanitation)



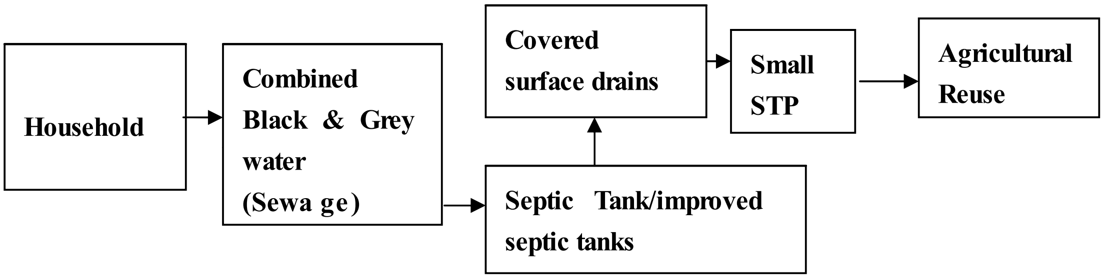
Option-4: Sanitation System using Soak pits and Covered surface drains (Sandy soil and deep groundwater table, piped water supply, sparse population)



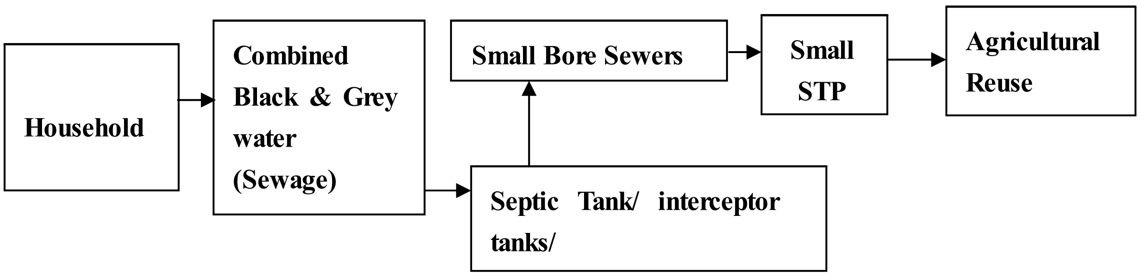
Option-5: (Sanitation system using covered surface drains)



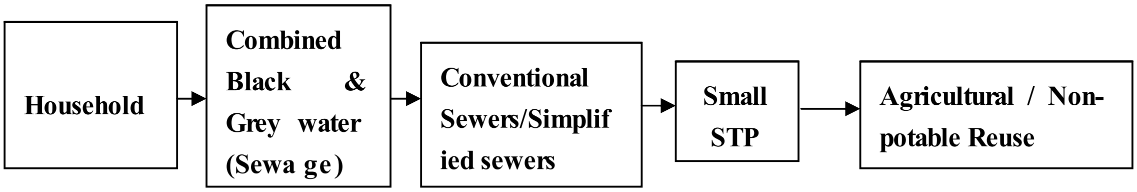
Option-6: (Sanitation system using covered surface drains)



Option-7: (Partly Sewered sanitation using small bore sewer)



Option-8 (Fully Sewered sanitation)



Note: It should be noted that the options using a soak pit may not be environmentally friendly depending on the soil type and groundwater table and should generally be avoided if financial resources allows. Table 2.2 below summarises the 8 options:

Table 2.2: Options for wastewater management in rural areas

Sl. No.	Type	Collection	Treatment/disposal*	Reuse options
1.	On-site	Not required	Soakage pit for grey water. Twin pit latrine for black water	No option for reuse
2	On-site	Not required	Septic tank + soakage pit	No option for reuse
3	On-site - advanced	Not required	Advanced on-site systems	On-site reuse for agriculture
4	Mixed	Covered surface drains for grey water only	Decentralised STP for grey water, septic tank+ soakage pit for black water	Reuse of treated grey water in agriculture
5	Decentralised non sewered	Covered surface drains	Septic tank for black water, treatment of grey water + effluent from Septic tank in decentralised STP	Reuse of treated combined waste water in agriculture

6	Decentralised –non sewered	Covered surface drains	Septic tank for combined sewage, treatment of effluent in decentralised STP	Reuse of treated combined waste water in agriculture
7	Decentralised - sewered	Small bore sewer	Treatment of effluent from septic tank / interceptor tank in decentralised STP	Reuse of treated combined waste water in agriculture
8	Decentralised - sewered	Conventional or simplified sewer	Decentralised STP for combined sewage	Reuse of treated combined waste water in agriculture. Non potable reuse options can be explored.

* It should be noted that septic and other tanks require regular desludging, see chapter (Septage and Sludge treatment)

2.4 WASTEWATER COLLECTION SYSTEM

Removing wastewater of any form i.e., grey water, combined grey water and septic tank effluent or sewage and storm water is an important environmental health intervention for reducing disease. Poorly drained wastewater and storm water forms stagnant pools that provide breeding sites for disease vectors. Hence, there should be proper systems for the collection of wastewater.

There are three common types of collection systems of wastewater;

i. Covered surface drains

ii. Small bore sewers

iii. Conventional sewers

2.4.1 Covered Surface drains

In rural areas of India, per capita water supply is very less. It ranges from 40 lpcd to 70 lpcd only. Consequently, generation of waste water is too low to make conventional sewer system effective. One of the cheapest and interim options for disposal of grey water, grey water + septic tank effluent is the covered surface drains. Further, open channels often exist in rural areas and hence can be upgraded to covered drains with little efforts.

The objective of covered surface / storm water drain is to remove waste water/ rain water from the households/ premises in a controlled and hygienic manner in order to minimize public health and environmental risks, inconvenience to residents and the deterioration of other infrastructure. This requires:

- Removal of grey water and/or septic tank effluent generated from various household activities
- Removal of storm water, that is, water which runs off the land and houses as a result of rainfall.

The recommended section of covered surface drain is shown in the figure (Fig 2.1).The half rounded central channel for the peak dry weather wastewater flow, while the outer channel

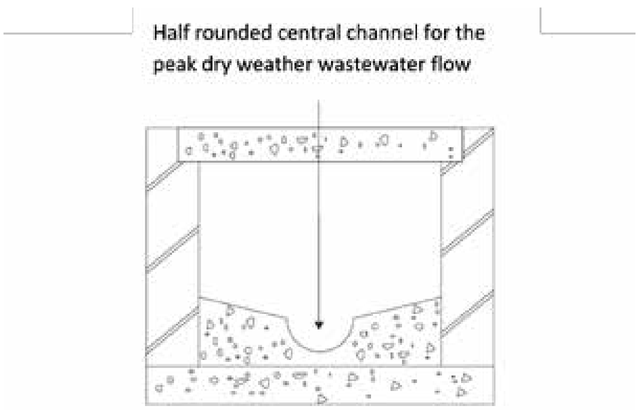


Figure 2.1. A Typical Channel section for carrying both dry weather wastewater flow and storm water.

facilitates storm water discharge. The outer channel floor should preferably gently down to the central channel.

Since, open drain/channel have a higher friction than a pipe. In relatively flat areas, pipe flow could be better, an alternative option would be laying the pipe into the open channel and cover it. The important design considerations are as follows:

- The raising of road surfaces above the plinth level of nearby houses should always be avoided.
- In the absence of rainfall data, drainage schemes should normally be designed for a return period of 1 year or less. Rainfall intensity in the range of 50-100 mm per house can be assumed.
- Both opened and covered drains give rise to maintenance problem and their total length should be minimized.
- Covered drains should not be smaller than about 500 mm in square cross section

Applicability:

It is an interim and fast solution of wastewater collection and can be applied in any village at reasonable cost. However, to prevent clogging, regular cleaning service for the removal of sludge is necessary. Further, if existing open channels (Nallas) are upgraded it has to be taken care of providing sufficient slope of the drains for dry weather flow as existing drains often lead to stagnant dry weather flow which causes unhygienic conditions and may infiltrate in the ground.

2.4.2 Small Bore Sewers

For grey water, surface drain is the cheapest option for collecting such waste water. For black water, mixed with grey water, small bore / swallow sewer is the appropriate and sustainable options for collecting waste water in rural areas. Small bore sewer systems are designed to receive only the liquid portion of household wastewater for off-site treatment and disposal. Grit, grease and floating materials are separated from the waste flow in interceptor tanks similar to septic tanks. Such interceptor tanks are installed after each household or group of households as per the site conditions. Depending upon the size of interceptor tanks and inflow of waste water, settled solids should be removed periodically from the interceptor tanks.

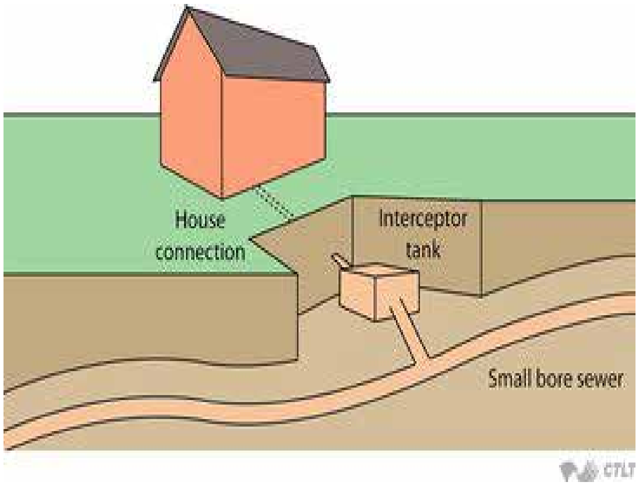


Figure 2.2: A schematic diagram of Small bore sewer (Source: Website Jhsphopen Courseware, 2013)

Small bore sewer systems consist of:

- **House connection:** The house connection is made at the inlet to the interceptor tank.
- **Interceptor tank:** It is designed to detain the liquid flow for 12 to 24 hours and to remove both floating and settleable solids from the liquid stream. Volume is also provided for storage of the solids, which are periodically removed through an access port. The design of interceptor tank is similar to conventional septic tanks
- **Sewer:** Sewers are small bore pipe

(minimum diameter of 100 mm) which are trenched into the ground at a depth sufficient to collect the settled wastewater from most connections by gravity. Unlike conventional sewers, small bore sewers are not necessarily laid on a uniform gradient with straight alignment between manholes or cleanouts.

- **Cleanout Manhole:** Cleanouts and manholes provide access to the sewers for inspection and maintenance. Also, they can be easily concealed to prevent tampering. They function as flushing points during sewer cleaning operations.
- **Vent:** The sewers must be ventilated to maintain free-flowing conditions.
- **Pumping Station:** Lift stations are necessary where elevation differences do not permit gravity flow. Either residential or major lift stations may be used

The Small bore system has the following advantages:

(a) **Reduced water requirements.** It is suitable where per capita waste water generation is very low. It is more suited in rural areas where per capita water supply is low, making conventional sewer system technically unfeasible.

(b) **Reduced excavation costs.** With the troublesome solids removed, the sewers can be designed with minimum depth, required to maintain self cleansing velocity when the slope is kept minimum, excavation costs are minimised.

(c) **Reduced materials costs.** Peak flows, for which the small bore sewers must be designed to handle, are lower than those experienced with conventional sewers because the interceptor tanks provide some surge storage. Expensive manholes are not required in case of small bore system.

(d) **Reduced treatment requirements.** Interceptor tanks arrest floating materials, oil and grease and most of the settleable solids from wastewater. Therefore, it reduces cost of the treatment, as it requires lesser hydraulic retention time for treatment of such waste water.

Thus, small bore sewer systems provide an economical way to upgrade existing sanitation facilities to a level of service comparable to conventional sewers. Because of the lower costs of construction and maintenance and the ability to function with little water, small bore sewers can be used where supply of water is low and consequently low volume of waste water is generated per household.

Disadvantages with small bore sewer system

The principal disadvantage of the small bore sewer system is the need for periodic evacuation and disposal of solids from each interceptor tank in the system. The interceptors must be cleaned regularly. Without regular desludging, the sludge will overflow into the sewer system and cause sewer blockages.Thus, concerned Panchayat / community should be able to exercise effective control over connections to the system and cleaning of interceptors. Public authority may not be not able to perform frequent sewer cleaning.

Applicability

- Small bore sewer is possible applied in area which has septic tanks facilities.
- It is an alternative to conventional sewerage where water supply is less.

2.4.3 Conventional/Simplified Sewers

In areas where sufficient water is available, the best and complete option for the wastewater collection is the conventional sewerage system. The sewerage systems are designed to collect both grey water and black water and transport them away from homes to the treatment plant or disposal point. The conventional sewerage system is a high-cost sanitation system; it is usually deep laid as per the topographical situation. The conventional sewerage system is discussed in detail in the CPHEEO Manual for sewage treatment.

As an alternative to a conventional sewer system a simplified sewer system may be constructed. A simplified sewer system is similar to a conventional one; however, it uses less conservative design criteria which mean that smaller diameters and slopes can be used. Further, a simplified sewer system is usually located on properties which are accessible but not used for heavy traffic (cars, etc.) which allows more shallow construction. Hence, a simplified sewer system can be considerably cheaper than a conventional one. Design guidelines can be found at:

http://www.efm.leeds.ac.uk/CIVE/Sewerage/manual/pdf/simplified_sewerage_manual_full.pd

Applicability:

The conventional/simplified sewerage system is the ultimate sanitation solution and can be applied in all rural areas with adequate piped water availability and funds are not a constraint. If a simplified sewerage system is constructed special care should be taken for cleaning access as a simplified sewer system may be more prone to blockages than a conventional one.

2.5 On-Site Wastewater Treatment Systems

On-site wastewater treatment systems are designed to treat and mostly dispose of effluent on the same property that produces the wastewater. A septic tank and soakage pit combination is the oldest and most common type of on-site system. However, due to the groundwater pollution related issues, newer advanced onsite system have came up in last 2-3 decades which represent scaled down versions of municipal sewage treatments.

In India about 14 % of rural population is covered by septic tank systems. The following sections deals with various technologies conventional (septic tank) to advanced on-site sanitation systems are discussed.

2.5.1 Septic Tanks

A septic tank is a combined sedimentation and digestion tank where the retention time of sewage is one to two days. During this period, settleable solids settle down to the bottom. This is accompanied by anaerobic digestion of settled solids (sludge) and liquid, resulting in reasonable reduction in the volume of sludge, reduction in biodegradable organic matter and release of gases like carbon dioxide, methane and hydrogen sulphide. The effluent although clarified to a large extent, will still contain appreciable amount of dissolved and suspended putrescible organic solids and pathogens, as the efficiency is only 30-50 % for BOD and 60-70 % TSS removal.

A typical two compartment septic tank is shown in figure 2.3.

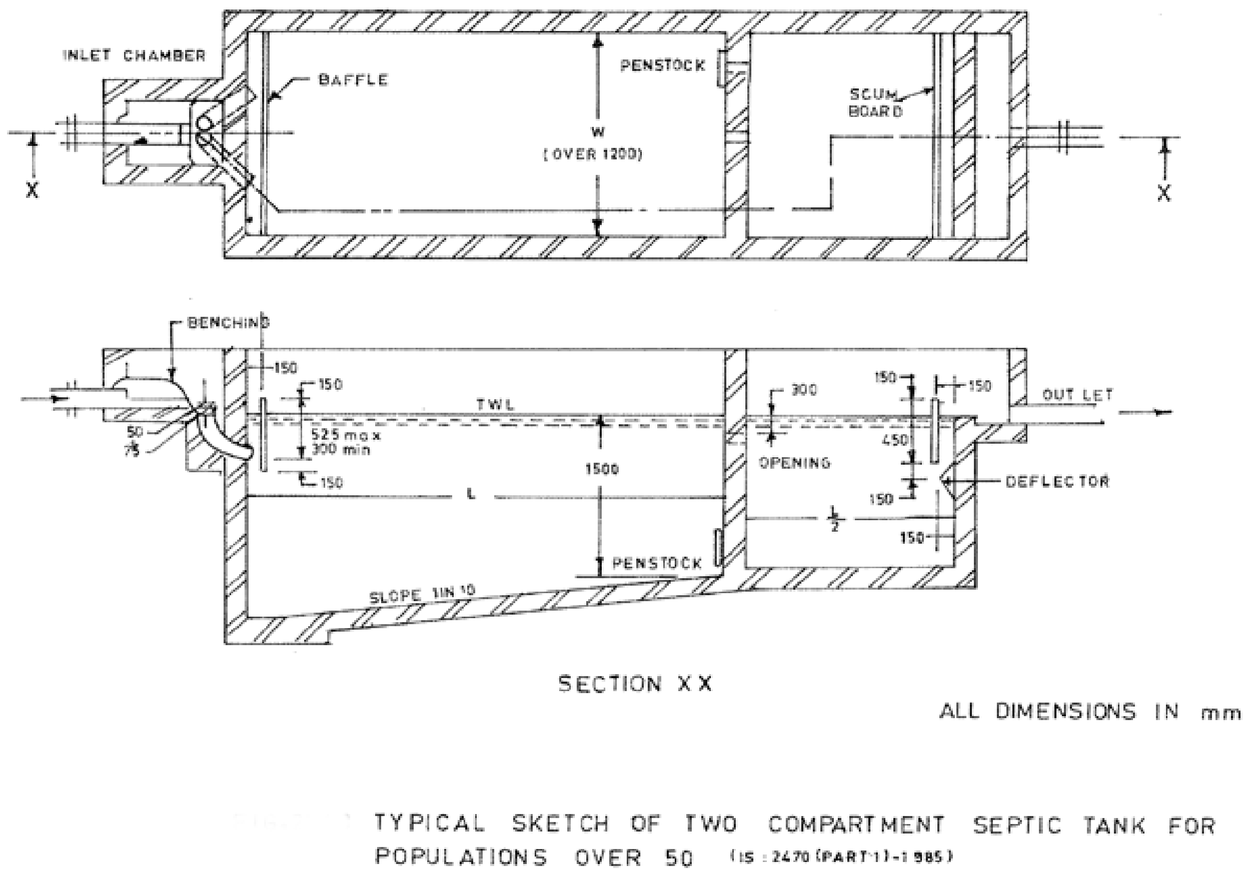


Figure 2.3. Structure of a septic tank, (**Source:** CPHEEO, 1993)

Hence, the effluent of septic tank should be discharged into the small bore sewer or covered surface drains. The outfall from such drains should be connected to a small sewage treatment plant. The second option of septic tank effluent discharge could be a soak pit. It should be noted that the option using a soak pit may not be environmentally friendly depending on the soil type, groundwater table, population density and should generally be avoided if financial resources allow.

In order to control the effluent quality and prevent the clogging of soakage pits, septic tank requires desludging. Though desludging frequencies vary, it is generally recommended to desludge tanks every two to three years, or when the tank become one-third full. The most satisfactory method of sludge removal is by vacuum tankers. Regular desludging activities require well-organized community and public/private service providers.

Applicability

The conventional septic tank system is particularly applicable for:

i. Primary treatment of wastewater from individual houses.

ii. It is suitable even for high water table areas where drainage facility for effluent discharge is available.

iii. Septage/Sludge collection and treatment facility is available nearby.

Disadvantages of septic tank

i. Safe removal of septage from septic tank is a problem. Due to lack of any such policy septage is disposed of in open space, low land areas or drains causing health and environmental pollution.

ii. Lower treatment efficiency (30-60 % BOD and SS Removal) and associated cost and space requirements for the construction of soakage pit is comparatively higher.

iii. Septic tank is incapability to handle hydraulic shock loads, as peak flow disturbs the settling zone and causes high suspended solids in the effluent.

2.5.2 Biotank System

The system is developed by DRDO for the treatment of toilet wastewater. It is made of FRP and consist of different chambers for the primary treatment of wastewater.

Fig. 2.4 DRDO Biotanks showing different chambers

Fig. 2.5 A completely covered DRDO Biotank

The effluent from the biotank, is released into reed bed. A reed bed system performs secondary treatment of the wastewater coming out of the biotank. The reed bed system comprises of bed of sand and pebbles along with reed plants capable of natural amelioration of the wastewater coming out of the bio tank. It eliminates smell, suspended particulates, pathogenic and other microorganisms more than 99%.

Natural reed plants-microbial consortium work efficiently at wide range of temperature and effluent is very safe to discharge into environment and may be used for irrigation purposes.

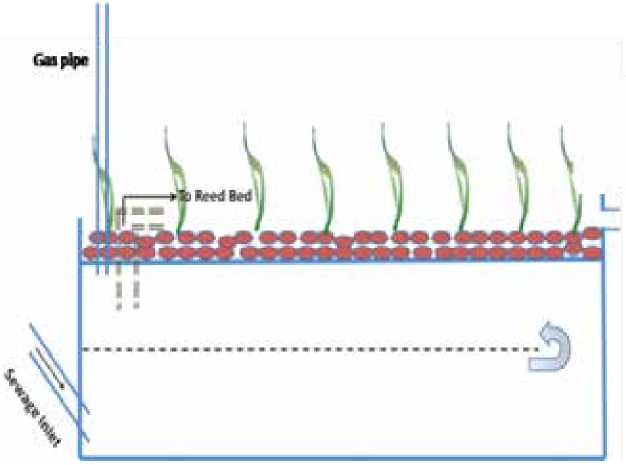


Fig. 2.6 Reed Bed system:

Fig. 2.7 BioTank cum Reed Bed systems at DRDO, Tezpur, Assam

The effluent from the reed bed may be stored to a tank for further use or may be released directly to the agro fields for irrigation when available or in a drain.

Applicability

i. The system can be implemented in any soil condition. It is more suitable for high ground water table areas as there is no chance for ground water pollution

ii. Due to requirement of lesser area it is suitable even for high population density areas where lack of space is a major concern for construction of toilets

iii. Recurring cost is almost nil

iv. Effluent is suitable for reuse in agriculture purpose.

Limitations:

i. Trained manpower is required to implement the system

ii. Reed bed system is useful to treat any domestic waste water. However, its cost and space requirement is the limiting factor for acceptance at household level.

2.5.3 Advanced On-Site Systems

To enhance the efficiency of septic tank system, one of the recommended solutions is the provision of anaerobic filter type and contact aeration system for the treatment of septic tank effluent. Such system can be used with system made of brick, cement or package type. The package type is based on well established Japanese technology Jouksou. The later type advanced on-site systems were developed with light weight materials such as plastics and fibreglass and used in many countries.

Three types of advanced on-site systems are discussed herewith in the following sections;

2.5.3.1 Package Type Anaerobic Filter System

This type of package on-site treatment system can be prefabricated of LLDPE (Low Linear Density Polyethylene) or FRP (Fiber Reinforced Plastic) and can be installed easily in a very short time. It consists of two chambers, i.e., settling and anaerobic filter. The first chamber works as a septic tank, where settleable solids are settled down and further degraded anaerobically at the bottom zone. The second chamber consists of upflow anaerobic filter where further removal of organic matter takes place. Anaerobic filters are made up of synthetic plastic media with high specific surface area (Figures 2.8 and 2.9). The high specific surface area not only prevents clogging but also provides intensive contact between the wastewater and the fixed film anaerobic bacteria for the fast degradation of organic matter. The treatment performance ranges 50-70 % for BOD and SS removal.

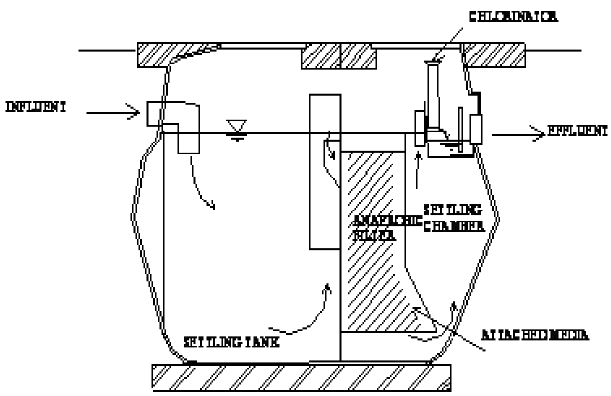


Figure 2.8. Typical cross-sectional drawings of prefabricated septic-tank anaerobic filter type systems
(Kazmi A. A. 2003)

Figure 2.10: A prefabricated Anaerobic Filter installed under Sponsored Project by MDWS
(Source Kazmi 2003)

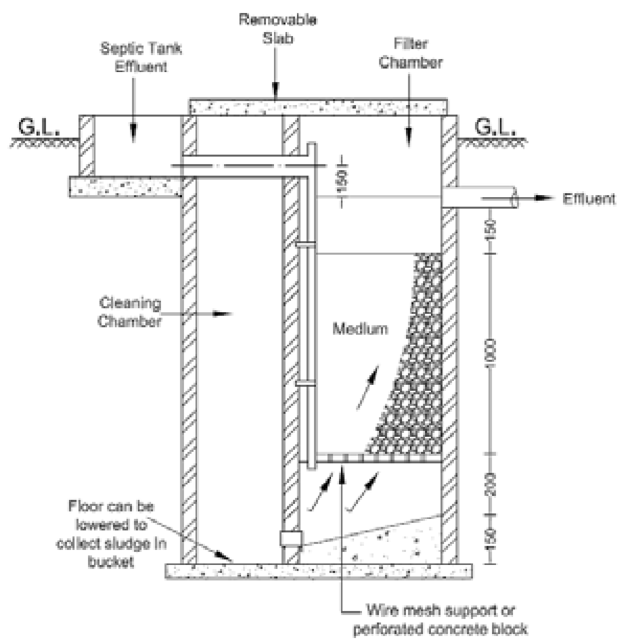


Figure 2.9. Typical cross-sectional drawings of conventional septic-tank anaerobic filter type systems
(IS 2470: Part 2: 1985)

A prefabricated package Anaerobic Filter Type advanced on-site system was installed for the treatment of black water at Navodaya Vidhyalala in Shikarpur Gram Panchayat, near Roorkee City. The project was sponsored by the Ministry of Drinking water supply & sanitation. The installation of the system is provided in Figure 2.10. The results of initial one month monitoring are provided herewith in Table 2.3

Table 2.3: Treatment performance of the system for black water

Parameter	Influent	Effluent	Avg Removal Efficiency
BOD (mg/L)	673-1380	310-870	58
COD (mg/L)	1005-2100	772-1140	61
TSS (mg/L)	642-1288	226-956	75

Although, at the initial start-up stage, packaged type septic tank- anaerobic filter system only removes BOD and TSS around 58 to 75 % respectively, but gradually, after formation of biofilm on the media, it improves upon the effluent quality in terms of BOD and SS without any requirement of power.

Applicability

The package type anaerobic filter system is particularly applicable for:

- As an alternative to conventional septic tank from individual houses where higher effluent quality is desired.
- Septage/Sludge collection and treatment facility is available nearby.

2.5.3.2 Package Contact Aeration System

It consists of two chambers, i.e., settling and contact aeration with synthetic plastic media. The first chamber works as a septic tank, where settleable solids are settled down and further degraded anaerobically at the bottom zone. Second stage is high specific surface area fixed film plastic media to retain high mass of aerobic micro-organism to degrade the organic matter in the wastewater. The high specific surface area not only prevents clogging but also provides intensive contact between the wastewater and the fixed film aerobic bacteria for the fast degradation of organic matter (Figure 2.7). The treatment performance ranges 80-95 % for BOD and SS removal. (Kazmi A.A, 2003).

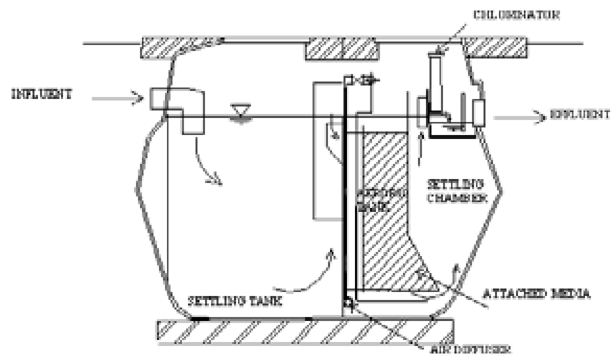


Figure 2.11: Typical cross-sectional drawings of package contact aeration system (Kazmi 2003)

Applicability

The package type contact aeration system is particularly applicable for :

- Wastewater treatment from individual houses where high effluent quality is desired for reuse or to discharge to sensitive water bodies.
- Rural areas having continuous power supply.
- Sensitive, tourist and un-approachable locations
- Sludge collection and treatment facility is available nearby.

2.5.3.3 Package Anaerobic Filter–Contact Aeration System.

It consists of anaerobic filter chamber, contact aeration chamber, sedimentation chamber and disinfection chamber in series. The anaerobic filter chamber separates, anaerobically decomposes and stores solid matter in the influent. The contact aeration tank is used for the aerobic treatment of effluent from the anaerobic filter chamber by the action of bio film grown on the surface of contact media (Figure 2.12). Tablets of chlorine disinfectant are stored in a cylinder and gradually dissolve to disinfect effluent. There is no sludge treatment in the system, and the sludge that produced in the treatment process is collected by a vacuum truck for further treatment and disposal. (Kazmi A.A, 2003).

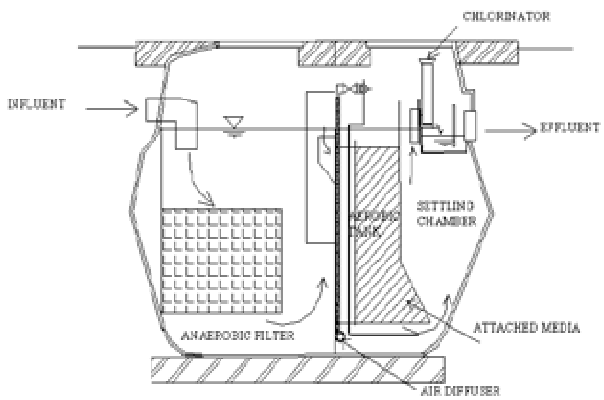


Figure 2.12. Typical cross-sectional drawings of package anaerobic filter-contact aeration system (Kazmi. 2003)

Applicability:

The system is particularly applicable for :

i. Wastewater treatment from individual houses where high effluent quality is desired for reuse or to discharge to sensitive water bodies.

ii. Rural areas having continuous power supply with availability of skilled manpower.

iii. Sensitive and un approachable locations

iv. Climatic variation is high from season to season.

v. Septage/Sludge collection and treatment facility is available nearby.

2.5.4 On-Site Wastewater Disposal System (Soakage Pit)

Soakage pit is a covered, porous-walled chamber that allows water to slowly soak into the ground They do not provide any direct treatment and are based on the principle that the effluent gets treated as it passes through the surrounding soil before entering the ground water table or other water body. It is only applicable for highly permeable sandy soil with deep groundwater table.. If the ground is not sandy and water logged during wet season the soakage pit may not work.

A diagram of a typical soakage pit is as follows (Figure 2.13). Soakage pits, although easy to construct, is usually an inadequate means of disposing the wastewater because it release the effluent over a small area which may clogged or

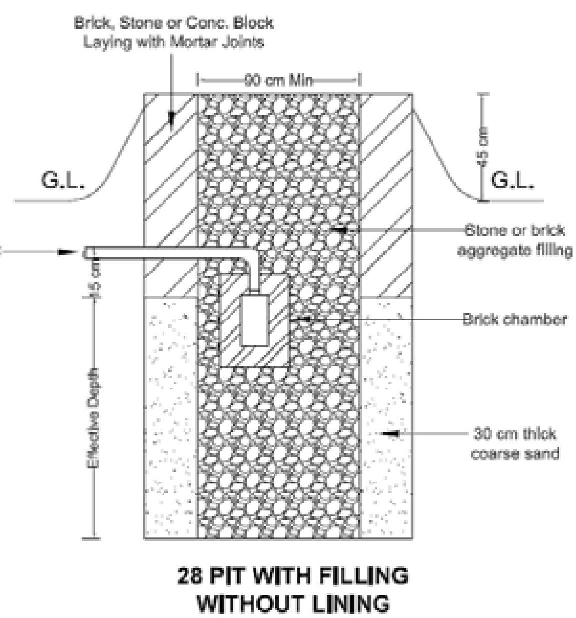


Figure 2.13 Typical illustrations of Soakage pit (IS 2470 : Part 2 : 1985)

lose its ability to treat the wastewater. Many cases of groundwater bacterial pollution are reported in shallow aquifer near the soakage pits. The problems are aggravated due to as septic tanks are not desludged regularly in the country. The soakage pits should generally be avoided if financial resources allow.

Since, it is one of the cheapest alternative for disposal of septic tank effluent, it should be

- 20 m away from drinking water source
- 20m away from another soakage pit
- Adequate contact area with the surrounding soil to absorb the effluent in to the soil. In case of less permeable soils, larger pits will be needed.
- Adequate openings shall be left in the walls of the pit to have the contact with the surrounding soil

Applicability

i. Where ground is permeable.

ii. Population density is less & plot sizes are large

iii. Water is supplied through pipelines.

iv. Deep water table (at least 5 m below the bottom of soakage pit).

v. Septic tanks are well maintained and desludged regularly,

2.6 DECENTRALISED WASTEWATER TREATMENT SYSTEMS

There are several technologies available for rural wastewater treatment all over the world. A survey in India has shown that also in India a wide diversity of different decentralised wastewater treatment technologies is already available. These technologies can be classified into natural and built treatment systems. Built treatment systems further can be classified in aerobic and anaerobic treatment systems. Combinations of different types of technologies are often used. Which technology is most suitable depends on various factors such as available land, available capacity for operation, financial resources, energy supply, required effluent quality and so on (Table 2.4).

A. Natural treatment systems:

i. Waste Stabilization Ponds - Anaerobic-Facultative- Aerobic/maturation

ii. Duckweed Pond System

iii. Constructed wetlands

B. Built treatment systems:

a. **Anaerobic**

i. Anaerobic baffled reactor

ii. UASB

b. **Aerobic**

i. Package contact aeration systems

ii. Extended Aeration systems

iii. Sequencing Batch Reactor systems

Table 2.4 : Classification of Various Wastewater Treatment Technologies

Technology	Natural or built	Aerobic/ anaerobic/ mixed	Expected effluent quality (low, medium, high)*	Area Requirement (m^2/person)	Power Requirement kWh/ person. year	Existence in India
Waste stabilization pond system	natural	mixed	Medium to high	2.0-3.0	Nil	All over India
Duckweed pond system	natural	aerobic	Medium to high	2.5-6.0	Nil	Larger number in Punjab
Constructed wetlands	natural	aerobic	Medium	1.5-2.5	Nil	Less experience in India

UASB	built	anaerobic	low	0.1-0.2	Only for Pumping	All over India in urban areas, but very less experience in rural areas
Anaerobic baffled filters	built	anaerobic	low	0.2-0.4	Nil	All over India
Package aeration systems	built	Mixed	High	0.1-0.15	20-30	All over India
Extended aeration systems	built	Aerobic	High	0.1-0.2	15-25	All over India
Sequencing batch reactor systems	built	Aerobic	Very High	0.05-0.1	10-20	All over India

Low Effluent Quality:	BOD- 50-150 mg/L, TSS - 100-200 mg/L
Medium Effluent Quality:	BOD- 20-50 mg/L, TSS- 50-100 mg/L
High Effluent Quality:	BOD < 20 mg/L, TSS <30 mg/L
Very High Effluent Quality:	BOD <10 mg/L, TSS < 10 mg/L

In general each treatment system needs a pre-treatment and may require, depending on the aspired effluent quality, some post treatment. In particular, constructed wetlands require a good pre-treatment to remove settleable solids and avoid clogging in the CW, while Anaerobic Baffled Reactor and UASB requires good aerobic post treatment to achieve the desired quality.

Natural treatment systems such as wastewater ponds or constructed wetlands have a good potential for rural areas if space is no constraint (Starkl et al, 2013). The reason is that these systems have no or little energy requirement and are simple in operation and therefore suitable for the situation on the ground in rural areas.

Apart from wastewater stabilization ponds and duckweed ponds there are only little experiences so far in rural India with different types and combinations of natural treatment systems and such systems should be piloted under Indian conditions.

In the subsequent sections various proven wastewater treatment technologies options are suggested for Indian conditions. Based on the end user water quality requirement, there can be a combinations of these technologies.

Option-1 (This is the most common treatment system in India for rural areas)

→ Anaerobic Pond → Facultative Pond → Maturation Pond → Agriculture Reuse

Option-2 (Recommended as an alternative of option-1)

→ Anaerobic Pond → Facultative Pond → Duckweed and fish pond → Agriculture Reuse

Option-3 (Recommended as an alternative of option-1 & 2)

→ Anaerobic Pond → Facultative Pond → Constructed Wetland → Agriculture Reuse

Option-4 (Recommended as an effective option, if funds allows the construction of anaerobic baffled reactor along with provision of sludge/septage treatment)

→ Anaerobic Baffled Reactor /UASB → Facultative Pond → Maturation Pond → Agriculture Reuse

Option-5 (Recommended as an alternative of option 4)

→ Anaerobic Baffled Reactor/ UASB → Facultative Pond → Duckweed & Fish Pond → Agriculture Reuse

Option-6 (Recommended as an alternative of option 4 &5

→ Anaerobic Baffled Reactor/UASB → Constructed Wetland → Agriculture Reuse

Option-7 (Option of complete sanitation and can be a pplied under all climatic and topographical conditions if funds, power supply and sludge treatment facility is not a constraint, Can be fitted in a very less space, high effluent quality)

→ Packa ge Contact Aeration → Agriculture Reuse/Non Potable Reuse

Option-8 (Option of complete sanitation and can be a pplied under all climatic and topographical conditions, if funds & power supply are not a constraint. Can be fitted in a very less space, high effluent quality for agriculture and non potable reuse)

→ Extended Aeration Process → Agriculture Reuse/Non Potable Reuse

Option 9(Alternative robust option of complete sanita tion and can be applied under all climatic and topographical conditions if funds & power supply are not a constraints. Can be fitted in a very less space, nutrient removal possible, high effluent quality for agriculture and non potable reuse)

→ SBR Process → Non Potable Reuse/Discharge to sensitive Water Body

2.6.1 Site Selection Criteria For Rural Small Sewage Treatment Plants

Ideally, a new site for a rural sewage treatment plant is one that can be developed economically without unnecessarily stressing the environment. Although numerous considerations, such as social and environmental factors, are difficult to quantify, cost effectiveness and construction requirements can be quantified when choosing among potential sites.

Sewage treatment facilities are almost universally perceived by the general public to be unacceptable neighbours. Public opposition is strong; however, with early involvement of the Village Panchayat in the planning process and a sincere desire by designers to listen and mitigate the public's concerns; much of the opposition can be minimized. Public involvement, or participation, is one of the most important elements in selecting and evaluating alternative sites. Some other important considering factors are as follows;

i. The site should not be liable to flooding and the elevation of the site should permit the discharge the effluent by gravity to the receiving streams or the level of the irrigation area to be commanded in case of reuse for irrigation.

ii. If the selected site is surrounded by residences, adequate measures should be taken to control odor from STP. If deodorization system is not provided an aerial / peripheral distance of 100 m from the odour-producing units to the habitation is recommended (CPHEEO 2014). However, this distance can be reduced by conducting public consultation. In addition, fragrant plants are one of the effective ways to control odor nuisance around the sewage treatment plants.

iii. It is important that a wastewater treatment plant site be accessible to personal and delivery persons at all times. Access to fire and other emergency vehicles must be available.

iv. In general, sites with special natural features should be avoided. The development of areas designated as wild, scenic, or recreational under the Act may be prohibited.

v. A site should accommodate present and anticipated future requirements. As growth occurs in the service area and treatment requirements increase, the plant will likely require additional space. The potential for such demands should be considered when selecting a site.

2.6.2 Waste Stabilisation Ponds

Waste stabilization ponds (WSP) are shallow man-made basin into which wastewater flows and from which, after a retention time of few days a well-treated effluent is discharged. WSP systems comprise of a series of ponds- anaerobic, facultative and maturation ponds in series (Figure 2.14). All these ponds have different functions.

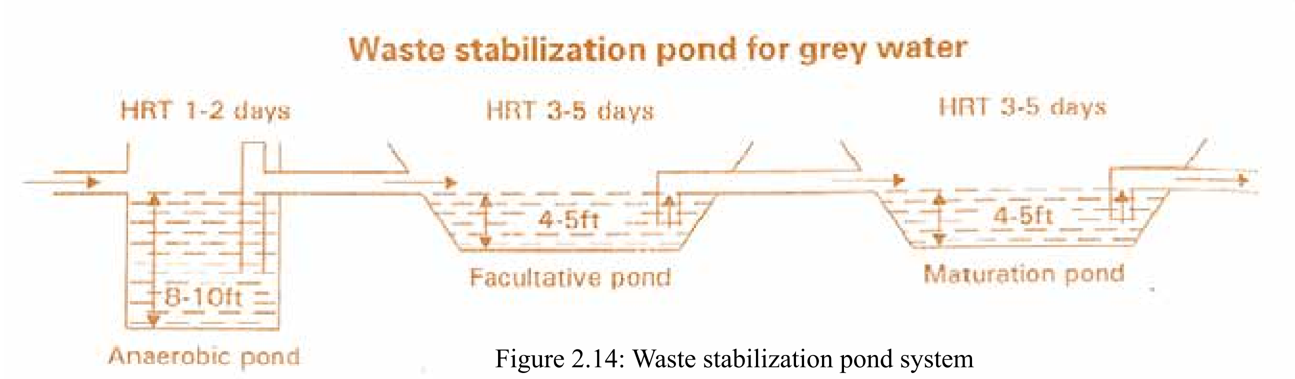


Figure 2.14: Waste stabilization pond system

Functions of different ponds under WSP system

Anaerobic and facultative ponds are designed for BOD removal and maturation ponds for pathogen removal, although some BOD removal also occurs in maturation ponds and some pathogen removal in anaerobic and facultative ponds. In case of waste water having low BOD level (< 150 mg/l), like grey water, maturation ponds may not be required. Moreover number of ponds for treatment depends on nature of reuse / disposal of effluent. In case of agriculture use of treated effluent such maturation pond is not required.

Anaerobic Pond: It is 2.5-5 m deep pond, settleable inorganic and organic solids in the wastewater are settled down as sludge. Inorganic solids such as grit and silt are conservative in nature and remain as bottom sludge, while organic solids are degraded anaerobically and converted to carbon dioxide, methane etc.. These ponds are designed for 1-2 days HRT (Hydraulic Retention Time) and 40-60 % BOD (Biochemical Oxygen Demand) removal can be expected. There must be two anaerobic ponds in parallel, so that the wastewater can be diverted to any of the pond during desludging. For proper functioning of anaerobic ponds desludging at every 1-2 years interval is necessary (Figure 2.11). As anaerobic pond is one of the source of H2S foul odour due to the reduction of sulphate to sulphide, options for covering and thereby recovering of biogas can also be explored (Figure 2.16).

Figure. 2.15 An anaerobic pond of a WSP

Figure 2.16 Desludging of anaerobic pond (Source: Kazmi 2003)

Fig.2.17 Covering of base of pond with plastic sheet Source- (Duncan Mara 1997)

Fig.2.18 A WSP pond with boulders at the base of embankment. Source- (Duncan Mara 1997)

In areas having high water table there is chance of ground water pollution through stabilisation pond system. It is equally true for any pond - based technology of wastewater treatment. To avoid such problem it is recommended that the base of the ponds should be made impervious by having brick lining or covering base of the pond with plastic sheet topped with soil (Fig-2.17). Use of plastic sheet is a cheaper option and will not affect the overall cost of the system much.

To check the embankments of the pond from soil erosion particularly during rainy season, there should be provision of putting boulders at the base of embankments up to the height of water level in the pond. It will help minimise the maintenance of embankment of ponds (Fig 2.18).

Facultative Pond. It is 1-1.5 m large shallow pond receives pre-settled wastewater from anaerobic pond. The functioning of the facultative pond is based on algal-bacterial symbiosis. In the top aerobic layer, where oxygen is supplied through algal photosynthesis is taken up by the bacteria for degrading non-settleable and dissolved organic matter. The algal and microbial biomass finally settled at the bottom and degraded anaerobically. A typical photograph of Stabilisation Pond System in Dewatwal village (Ludhiana District, Punjab) is shown in Figure 2.19.

Fig 2.19. A Stabilisation Pond System in Dewatwal village, Punjab

Maturation Pond

These are 1-1.5 m deep and essentially designed for pathogen removal. The HRT of these ponds can be kept between 3-5 days. In general maturation ponds will be required only when the treated wastewater is to be used for unrestricted irrigation and has to comply with the WHO guideline of <1000 faecal Coli forms per 100 ml, and when stronger wastewaters (BOD >150 mg/l) are to be treated prior to surface water discharge. Effluent from a well designed WSP can be safely used for agriculture purpose or surface discharge.

If properly maintained and by desludging anaerobic ponds regularly, the Waste stabilization ponds (WSPs) are a low-cost, low-energy, low-maintenance and, above all, the most sustainable method of wastewater treatment. It is the most appropriate method of wastewater treatment in India particularly in rural areas as the climate in India is very favourable for the efficient operation of WSP. The high temperatures that occur throughout the year in most of the country are especially favourable for anaerobic ponds.

Applicability

The Waste stabilization pond is particularly applicable for:

- Wastewater treatment in rural areas where large unused lands, away from homes and public spaces are available.
- Cheap labour is available for regular maintenance of pond system.

2.6.3 Duckweed Pond System

Duckweed based wastewater treatment is potentially suitable for small scale application at rural level and for medium-sized facilities at community, (peri-) urban level. Duckweed is a group name belonging to botanical family Lamnaceae that consists of four genera namely-

Spirodela, Lemna, Wolffia and Wolfiella; first 3 genera are commonly found in India. It is cosmopolitan and found everywhere in organic nutrients rich stagnant water. It has very high growth rate; at optimum nutrient environment it doubles within 2-3 days. It tolerates wide range of temperature- between 100-460C, depending upon the genera. Size of the plant is very small. Wolffiella is the smallest plant having pin head size, while Spirodella is the largest one, having its size of 2-3 cm only. The most important feature with this plant is that it contains up to 30 % edible protein, vitamins A and C. It is a complete feed for certain species of fish like Grass carp, Silver carp, Common carp, Rehu and Mrigal. High yield of fish has a direct linkage with economic return and thus, employment avenue with the system. The system is being adopted in several developing countries (Sascha Iqbal, 1999).

Since duckweed grow very fast in waste water, it uptakes nutrients from waste water very quickly and form green mat over water (Fig. 2.20). Thus, in addition to normal settling of waste water, there is bioaccumulation of nutrients in duckweed. Duckweed has the ability to bio accumulate up to 99% of the nutrients, dissolved solids and even heavy and toxic elements of wastewater up to certain extent. These are permanently removed from wastewater as plants are harvested. Hence, it reduces Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), suspended solids, bacterial and helminthic pathogens, some organic compounds, ions of potassium, nitrogen, phosphate and even heavy metals of wastewater to a level, quite safe for disposal.

Fig. 2.20: A duckweed pond with bamboo barriers
(Source: Iqbal Sascha, 1999)

Duckweed based pond system can be used to give further treatment to effluent from facultative pond to meet more stringent BOD and TSS regulation and can generate some financial returns from duckweed-fish cultivation. Some kind of pre-treatment such as anaerobic pond/anaerobic baffled reactor and facultative pond are required for duckweed pond.

Since duckweed is a free floating plant, it requires only bamboos or PVC cubicles (4m x5 m), to check drifting of duckweed to one end, along with wind. Bamboos are more preferred as there is chance of theft of PVC articles in villages. Duckweed can be found everywhere in stagnant water in villages. No other equipments are required for this treatment process.

Required size of the pond depends on quantity of waste water generated per day. For a half mld of waste water, one hectare of pond surface area (0.5 hac for duckweed and 0.5 for fish pond) is required. It is suitable for a village having population of 4000-5000. Size of the fish pond normally should be half of the treatment pond. However, additional larger size of the fish pond is more useful to have more economic return in terms of fish production. Duckweed forms a green mate over waste water, thus reduces the chance of mosquitoes to breed in waste water.

Since duckweed grows very fast, its regular harvesting is required. 25% of the area of duckweed pond should be harvested daily. It can be harvested manually through a simple net device attached with a bamoo (Fig 2.21). Freshly harvested duckweed is filled into a wickerwork basket, where it remains for some time to allow some water drainage and pathogen removal by sunlight irradiation (Fig 2.22).

Fig. 2.21 Harvesting of duckweed through net (source (Iqbal Sascha, 1999)

Fig. 2.22 Freshly harvested duckweed (source (Iqbal Sascha, 1999)

There should be four nos. of fish feeding stations made up of bamboos in a pond. Freshly harvested duckweed should be put at any fixed time daily (Figure 2.23) at the fish feeding stations. It fixes biological clocks in fish and the same accumulates at the fixed time at fixed locations.

2.23. A pond with fish feeding stations (Source: Iqbal Sascha, 1999)

Fig 2.24. Harvesting of various carp species fed exclusively on duckweed. The vigorously jumping fish indicate healthy fish and good pond water quality. (Photograph: PRISM).

Up to 10 tonnes of fish can easily be harvested per year per hectare of fish pond (Fig 2.24). Little specific information is available on the health risks associated with bioaccumulation of heavy metals and toxins in fish and other animals fed on duckweed grown in wastewater. However, there is no chance of such effects when duckweed is grown in domestic sewage in rural areas as there is no chance of heavy metals in sewage. Krishnan and Smith (1987) reported acceptable levels of heavy metals and pesticides in fish grown in sewage stabilisation ponds. Adhikari et.al (2009) also reported that concentration of different heavy metals tested in fish were below the permissible level of WHO. The reason could be growth rate of fish being much higher than the bioaccumulation of heavy metals, resulting in acceptable level of such metals in fish.

Advantages of duckweed based treatment of waste water

- Duckweed grows rapidly and is capable of nutrient uptake under a wide range of environmental conditions. Compared to most other aquatic plants, it is less sensitive to low temperatures, high nutrient levels, pH fluctuations, pest, and diseases (Dinges1982).
- Duckweed and its associated microorganisms are capable of absorbing and disintegrating a number of toxic compounds (Landolt and Kandeler 1987).
- Duckweed has been observed to efficiently absorb heavy metals (Landolt and Kandeler 1987). This characteristic may be detrimental if duckweed is used as feed.
- When grown on nutrient-rich waters, duckweed has a high protein and a relatively low fibre content and is, thereby, suitable for use as high-quality feed supplement.
- Harvesting of duckweed plants from the water surface is easy.
- A complete duckweed cover on the wastewater may efficiently prevent the growth of algae in the water body and result in a clear effluent of low TSS content.
- The presence of a dense duckweed mat has been reported to decrease and control the development of mosquito and odour in a wastewater body.
- There is economic return and employment avenue in term of pisciculture when duckweed is used as fish feed grown on domestic sewage.

Applicability

The Duckweed pond is particularly applicable for:

- Large land area is available after facultative pond system.
- Cheap labour is available for the maintenance of the pond system.

2.6.4 Constructed Wetlands

A horizontal flow constructed wetland (horizontal flow CW) is a planted filter bed for secondary or tertiary treatment of wastewater (e.g. grey water or black water). After primary treatment for solids removal in a UASB or Anaerobic baffled reactor, the wastewater is fed at the inlet zone and flows horizontally through the porous filter medium (sand or gravel) until it reaches the outlet zone (Fig.2.25). The water is treated by a combination of biological and physical processes. The effluent of a well-functioning constructed wetland can be used for irrigation and aquaculture or safely been discharged to receiving water bodies. Horizontal flow CW are relatively inexpensive to build where land is affordable and can be maintained by the local community as no high-tech spare parts, electrical energy or chemicals are required.

A horizontal subsurface flow constructed wetland is a large gravel and sand-filled channel that is planted with aquatic vegetation. As wastewater flows horizontally through the channel, the filter material filters out particles and microorganisms degrade organics. The water level in a Horizontal Subsurface Flow Constructed Wetland is maintained at 5 to 15 cm below the surface to ensure subsurface flow (Tilley, et al 2008). To avoid clogging of the wetland, pre-treatment is necessary. It has been established that a horizontal filter bed area of about 2 m2 /PE is sufficient for the complete secondary and tertiary treatment of wastewater including the removal of pathogenic germs (Sonavane et.al 2008), (CPCB, 2008).

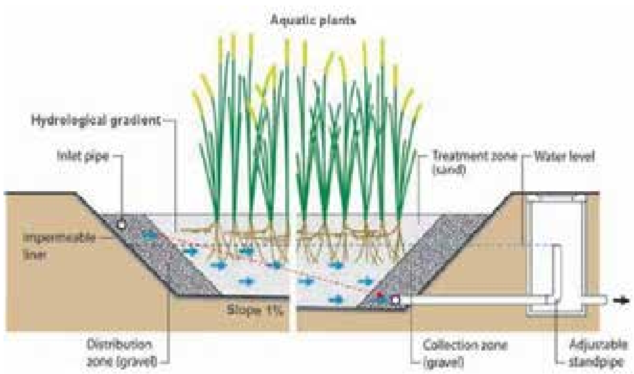


Figure 2.25. Horizontal flow constructed wet land: Tilley et al. (2008)

Pre-treated wastewater flows slowly through the porous medium under the surface of the bed in a horizontal path until it reaches the outlet zone. At the outlet, the water level is controlled with an adjustable standpipe. A common design suggests a water level of about 60 cm which is maintained at ca. 5 to 15 cm below the surface of the CW to avoid anaerobic conditions in the bed.

An important role of treatment efficiency is the oxygen supply. Horizontal filter beds have a very small external oxygen transfer and a smaller inlet compared to a vertical flow constructed wetland. Therefore, they require a larger area. If topography allows for gravity flow, horizontal flow filters are not dependent on energy and can be operated by gravity. The treatment process of constructed wetlands is based on a number of biological and physical processes (adsorption, precipitation, filtration, nitrification, predation, decomposition, etc.) (Hoffmann et al. 2010).

Maintenance of all wetlands can include dredging, sediment build-up, mowing of impoundment structures to control trees, and pest control of insects, muskrats, and beavers. The water level should be maintained 5cm below the wetlands gravel surface to control/ eliminate odors. The gravel at the inlet end of some systems if clogged, require the first 30 to 60cm of gravel to be replaced. Dosing with small doses may prevent this. Another management technique used to be prevent clogging is draining the wetland two to three times a year during the growing season. Simply unplug the wetland, allow it to completely drain, and immediately re-plug. This also encourages root penetration to the bottom of the wetland, particularly in the few years of operation.

Selection of species for Constructed wetland

With the available experience the following list of species can be given:

i. *Phragmites australis (reed)*

ii. *Phragmites karka (reed)*

iii. *Arundo donax (mediteranean reed)*

iv. *Typha latifolia (cattail)*

v. *Typha angustifolia (cattail)*

vi. *Juncus (bulrush)*

The vegetation is a critical component for the successful operation of wetlands. For horizontal CW, in principle, all helophytes can be used, which are deep rooted and oxygenate the Rhizosphere through the roots.The most common maintenance activities are pulling out undesirable plant species such as willow tree saplings, removing dead vegetation and cleaning pipes. Other maintenance activities include replanting, fertilizing, cleaning / brushing screens and pipes, and installation of barriers to exclude deer.

Planting Techniques

Planting of reeds can be done in the following ways:

- Reeds can be planted as rhizomes, seedlings or planted clumps.
- Clumps can be planted during all seasons. (2 / m2)

- Rhizomes grow best when planted in Pre-Monsoon. (4 - 6/ m2)
- Seedlings should be planted in Pre-Monsoon (3 - 5/ m2)

Vegetation Management

The vegetation is a critical component wetlands and successful performance depends on a relatively dense stand of healthy plants. Disease and insect infestation can cause problems, but this has not been experienced to date at operational constructed wetlands. The oxygen transfer capability of the plant can be overwhelmed by very-high-strength wastes, and affected plants may die. A major threat to some of the emergent vegetation used in constructed wetlands is damage from muskrat and nutria. These animals use both Typhalatifolia and scirpus as a food source and for nesting material. The most common maintenance activities are pulling out undesirable plant species such as willow tree saplings, removing dead vegetation and cleaning pipes. Other maintenance activities include replanting, fertilizing, cleaning / brushing screens and pipes, and installation of barriers to exclude deer. The need to control turtles and burrowing animals has also been reported (Taylor, 1998). Several techniques that may be used to harvest wetland plants include thinning or weeding vegetation using modified farm equipment or floating harvesters, controlled burning on as area basis to maintain the system's hydraulic profile, and complete removal of the excessive accumulations of litter and the upper sediment or soil layer using construction equipment (Robert, 1991).

Cost Benefit

The cost of installing a constructed wetland varies depending on quantity of water to be treated, pollution load, site location, availability of Gravel media etc. However these systems are quite cheaper than the conventional treatment systems. In addition to low capital, operational and maintenance cost, treatment of domestic waste through constructed wetland technology in localized areas affects sufficient savings in:-

- Laying long distance sewage pipelines for collecting and transporting it to long distances for centralized treatment.
- Expenditure on energy and maintenance of conventional treatment system cost of technical manpower.

Recycling and reuse of root zone treated water in irrigation and washing of vehicles etc. will reduce pressure on drinking water and also will save high cost involved in treating water for drinking standards which is generally used for above purposes (Vipat, 2003)

Applicability

- For all kind of pre-treated wastewaters.
- Availability of large land areas
- Availability of cheap labour for the operation and maintenance of the system

2.6.5 Phytorid Technology for Sewage Treatment

Phytorid technology is developed by NEERI for sewage treatment NEERI is a government research institute under Council of Scientific and Industrial Research. This is one of the most reputed laboratories for environmental research and consultancy. This technology has world patent to its credit. The national environmental policy recommends use of constructed wetland systems for efficient sewage treatment.

Simple Solution for sewage treatment: The main objective of the proposed project is to provide a simple, feasible, practically sound, eco-friendly, maintenance free and cost-effective technology, which can handle the sewage waste water treatment leading to reuse of treated water for purposes like gardening. Phytorid is a scientifically developed systematic treatment methodology for waste water.

- Phytorid combines Physical, Biological and Chemical processes
- Works on gravity
- No electric power requirement
- Scalable technology
- Easy to maintain
- Adds to aesthetics
- Cost effective

Typical Design features: The sub-surface flow type, Phytorid system is proposed for the treatment of sewage or domestic wastewater which will consists of a basin or a channel with a barrier to prevent seepage, but the systems / cells / beds contain a suitable depth of porous media. A primary treatment facility would also be constructed along with basic for effective removal of solids and thus reduces the marginal BOD.

The porous media also supports the root structure of emergent vegetation. The design of the Phytorid system assumes that the water level in the cells will remain below the top of the filter media.

The vegetation to be utilized for the said Phytorid system is very important. Various species of aquatic plants have been utilized to attain maximum efficiency in the treatment of domestic wastes. These include species like Phramites australis, Phalaris arundinacea, Glyceria maxima, Typha spp., other common grasses etc.

Advantage of Phytorid technology: Treatment efficiencies of the removal of fecal coliforms, BOD, COD, nutrients are up to 80%, which is greater than the traditional chemical methods

- It is a very cost effective technology when compared with the traditional wastewater treatment methods.
- Since it utilizes natural vegetation and rhizosphere microorganisms, it is eco-friendly method of treating sewage.
- An important factor to be considered is the aesthetic improvement that is provided by this methodology.
- No mosquitoes and odor nuisance
- The treated water can be used for enhancement of environmental architecture such as roadside fountains.
- The quality of treated water is comparable to irrigation standards.

Methodology: The treatment process consists of primary treatment plant followed by Phytorid treatment system. The hydraulic loading shall be started with 40% capacity in the beginning till the time of acclimatization of the plants to the hydraulic load and shall be later increased to 100%. The further loading and efficiency shall be monitored to establish how much more of either hydraulic or BOD load can be effectively used. This would entirely depend upon the variation in the sewage characteristics used for treatment.

Land area requirements: The total areas required for sewage treatment plant for a capacity of 25m3/ day is approximately 30 m2. The area includes area requirements settler tank, Phytorid bed and treated water collection tank.

Treatment efficiencies: Phytorid system being natural method, the final efficiencies as indicated in Table 2.5, will be achieved after the system is stabilized which may require a period of 6 months after commission.

Table 2.5. Performance of Phytorid Technology

Pollutant	Performance (% removal)
Total suspended solids	75-95
Biochemical oxygen demand	70-80
Chemical oxygen demand	60-75
Total nitrogen	60-70
Phosphate	50-60
Fecal coliform	85-95

Operation and Maintenance: This technology is natural system; as a result operation is mostly passive and requires little operator intervention. Requirement for area can change on various factors such as load (kg BOD / day), ambient temperature, topography of the region, flow characteristics, etc. Maintaining uniform flow across the Phytorid system through inlet and outlet adjustment is extremely important to achieve the expected treatment performance. Sampling of inlet and outlet will be carried out for a period of 3 months every fortnight after stabilization of the treatment systems of first one year.

2.6.6 Soil Bio Technology (SBT) for Sewage Treatment

This technology has been developed by IIT, Mumbai. SBT engages three fundamental process of Nature – Photosynthesis, respiration and mineral weathering. This is achieved by soil micro-organisms which are regulated by soil micro –organisms (geophagus earthworms). Primary and Secondary treatments are achieved in the SBT. The organic & inorganics in waste water is consumed and converted into useful by-products and simultaneously water of desirable quality is produced. SBT thus removes BOD, COD, Ammonia, Nitrogen, Nitrate nitrogen suspended solids bacteria, colour, odour. The SBT is ideal for treating waste water less than 5 MLD.

Soil Bio Technology (SBT) is an efficient process of synthesis to completely utilize solids and liquids. It is economical in capital and recurring costs. It has a simple looking construction, free from conventional electro-mechanical systems which are prone to breakdowns. It efficiently integrates the physical,chemical and biological processes into a single aerobic system based on natural biophysical and bio-chemical principles. A specified additive is added in a predefined proportion. SBT is a synthesis process which harnesses the energy, carbon and other elements of the waste and converts them to precious " Bio-energy" products like vegetation, energy rich soil, complete Bio-fertilizer and water. It offers a bacterial removal of approx. 99.99 % thus ensuring a healthier environment in a sustained manner without any side effects.

Some of the salient features of SBT:

- Rejuvenation/creationof soil.
- Can be utilizable for all sorts of organic and inorganic molecules present in the effluents.
- No req. of electricity and chemical (Electricity requirement only for pumping).
- Generate Bio-energy
- Little space area as per requirement per person (100 litre per day) is 0.021 m2

Fig 2.26 Application of SBT

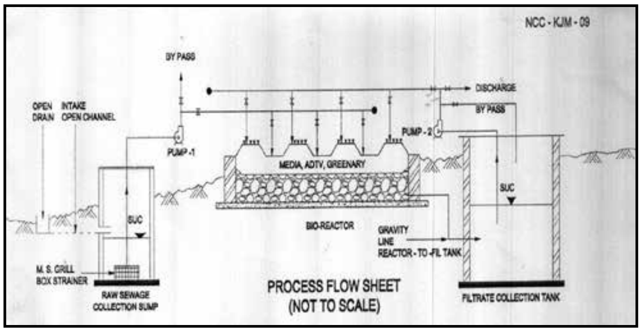


Fig 2.27 Design of a typical SBT

Fig. 2.29: An ABR under construction

2.6.7 Anaerobic Baffled Reactor (ABR)

An anaerobic baffled reactor (ABR) is an improved septic tank, which, after a primary settling chamber, uses a series of baffles to force all kind of wastewater to flow under and over the baffles as it passes from the inlet to the outlet (Figures 2.28, 2.29 & 2.30). The wastewater is introduced into the chamber at the bottom, leading to an enhanced contact with the active biomass which results in an increased retention and anaerobic degradation of suspended and dissolved organic pollutants. ABRs are robust and can treat a wide range of wastewater, but both remaining sludge and effluents still need further treatment in order to be reused or discharged properly (Tilley et al., 2008).

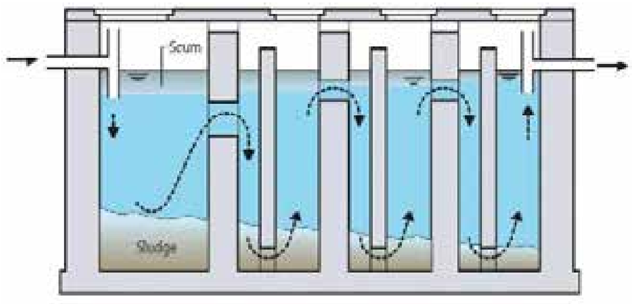


Fig. 2.28. Anaerobic Baffled Reactor;
(Source: Morel & Diener 2006)

Fig. 2.30.   An ABR after completion
(http://cseindia.org/content/wastewater-recycling)

ABRs are suitable for a wide range of wastewater, but its efficiency increases with higher organic load. The system must be followed by polishing aerobic treatment such as facultative pond, constructed wetland etc., ABRs take advantage of the easy construction, low cost and strong resistance of septic tanks but allow for much higher treatment efficiency. The BOD removal efficiency is reported between 60-80 %, much higher than conventional septic tank. The most important design parameter is the upflow velocity which should not exceeds 2 m/h. The organic loading should also be less than 3 kg COD/m3/d.

Applicability

- Wastewater treatment in rural areas where land is limited.
- Septage/Sludge collection and treatment facility is available nearby.

2.6.8. Upflow Anaerobic Sludge Blanket (UASB) Reactor

The UASB is a high rate suspended growth type of reactor in which a pre-treated raw influent is introduced into the reactor from the bottom and distributed evenly. “Flocs” of anaerobic bacteria will tend to settle against moderate flow velocities. The influent passes upward through, and helps to suspend, a blanket of anaerobic sludge. Particulate matter is trapped as it passes upward through the sludge blanket, where it is retained and digested. Digestion of the particulate matter retained in the sludge blanket and breakdown of soluble organic material generates gas and relatively small amounts of new sludge. The rising gas bubbles help to mix the substrate with the anaerobic biomass (Figure 2.31).

The biogas, the liquid fraction and the sludge are separated in the gas/liquid/solids (GLS) phase separator, consisting of the gas collector dome and

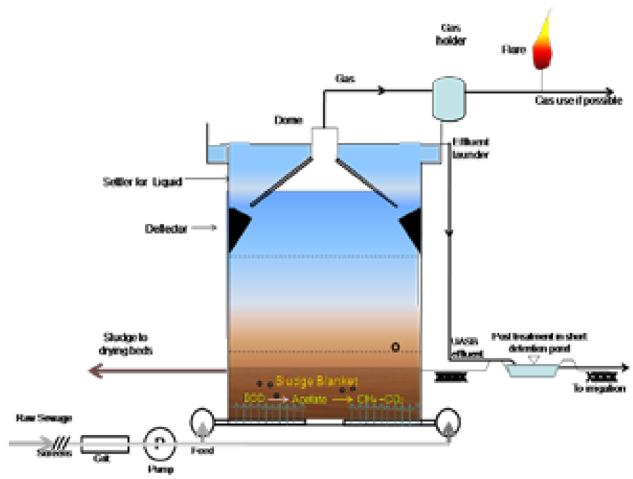


Figure 2.31. Schematic Diagram of UASB based plant (Source Kazmi A. A.2003)

a separate settler. The settling zone is relatively free of the mixing effect of the gas, allowing the solid particles to fall back into the reactor. The clarified effluent is collected in gutters at the top of the reactor and removed. The biogas has methane content typically around 75 percent and may be collected and used as a fuel or flared.

A properly designed UASB reactor eliminates the need for mechanical mixing and has few moving parts. If gravity distribution of the influent is possible, the treatment plant may need pumps only to remove excess sludge from the reactor periodically for transfer to drying beds.

In India, many UASB plants are working satisfactorily for sewage treatment in urban areas of India. The BOD and TSS removal efficiency generally varies from 60 to 70 %. In some areas corrosion and odor issues were noted for systems treating high incoming sulphates in the sewage.

However, the main problem in achieving high quality effluent was due to non-suitable post treatment method. Generally, The 1-day HRT pond is used for the post treatment of UASB effluent., it requires very large area and able to remove additional 20-40 % BOD & TSS. The final effluent BOD of UASB & pond system varies between 20-50 mg/L.

Apart from wastewater stabilization ponds and duckweed ponds there are only little experiences so far in rural India with different types and combinations of natural treatment systems and such systems should be piloted under Indian conditions.

In rural areas, the treated wastewater is generally used for irrigation, if medium to low quality effluent is needed, then the system is very promising. In addition, very limited experience is available on the application of UASB in rural areas; there is a need of piloting the system for rural conditions.

Applicability

1. In rural areas where electricity is available for pumping the wastewater.
2. Where land cost is high and limited area is available.
3. Influent sulphates in the wastewater is low
4. Strength of wastewater is high.

2.6.9 Settling-Contact Aeration System

It can be a concrete, steel, LLDPE or FRP tank which can be used anywhere for aerobic treatment of sewage. It is ideal for schools, hospitals and other complexes in rural areas. The system consists of three zones, Solid Separation Zone, Aeration Zone and Final Sedimentation Zone respectively.

A. **A settling –contact aeration system – steel tank.** Solid Separation Zone transforms the influent solids to settled solids while allowing scum to float on the surface. It is a primary sedimentation zone in which settled sludge is stabilized by anaerobic digestion. The treatment efficiency of the chamber is in the range of 30 % BOD removal. Second stage is the aerobic zone along with plastic media installed inside the tank which in turn increases the surface area and retain micro-organism long enough to digest the organic substance remained. Final stage involves the sedimentation where organic wastes are settled in the Sedimentation zone. The settled waste in the bottom of the tank is pumped back to the primary sedimentation zone as a return sludge having active biomass (MLSS) to increase the efficiency of the system and ensure the effluent quality meets the stipulated standards (Fig. 2.32).

Fig. 2.32: A Typical Package Contact Aeration System (Source: Nishihara Env. Technology, Japan)

The system is compact tubular tank easy to transport. Sludge removal is once in 3 years. It works from no load to peak load. Can take weight up to 30 tones, hence may be installed underground and may be relocated or upgraded easily. Many Package Contact Aeration systems were installed for various residential housing colonies, institutions, offices and hotels all over India.

B. **A settling–contact aeration system–LDDPE type.** A simplified method for settling - contact aeration system has been developed and tested. The system is connected with a toilet block having 3 nos. of WCs and one bath used by over 20 persons per day. The system has two Linear Low Density Polyethylene (LLDPE) tanks of different sizes. They are connected in series with inlet chamber of waste water. Smaller tank (1st tank) has retention time of 12 hrs where as larger (2nd tank) has of two days. 1st tank works as anaerobic settling chamber and 2nd as aerobic & treatment chamber (Fig 2.33). In the 2nd chamber, air is provided through air pump having flow of 60-80 lpm. It is desirable to provide air for 24 hrs. However, due to limited elecric supply it is not feasible always.At reduced air supply level of BOD and other parameters of waste water will increase.

Figure. 2.33 LDDPE made settling–contact aeration system

Fig. 2.34 Coirs used as growth medium

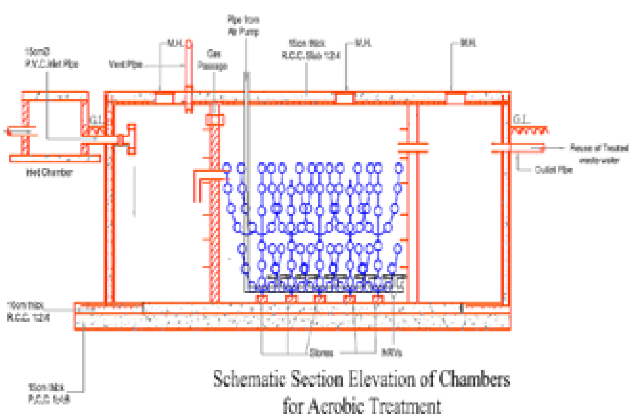


Fig 2.35 Schematic diagram of settling –contact aeration system

Table 2.6

Parameters	Value (mg/l) except pH, of effluent	
	Aerobic condition	Anaerobic condition
BOD	7	65
COD	19	125
TKN	3.4	35
Phosphorus	2.2	10
TSS	25	52
pH	7.5	7.4

Air pump operates on 50 watt electricity. Air diffuser is provided at the bottom of the tank through non- return valves fitted in ½”- ¼” inter connecting G.I. pipes at multiple points. For the bacteria growth media, coir rope which is having huge rough surface area can be used (Jha, P.K, 2010). Such growth medium is easily available in most of rural areas and much cheaper than other plastic media. Required length of 5-10 coir ropes can be tied at one end and with a brick/ stone and put in aeration chamber. In this way coirs remain submerged and float in waste water (Figs. 2.34) Removal of coir is much easier as they are tied and pulled out of chamber easily. A schematic diagram of the system is depicted (Fig 2.35). Treated waste water is stored in a storage tank from where it is reused for agriculture purposes. Results of different parameters of effluent under aerobic and under anaerobic conditions from different plants using same design and methods are presented in Table-2.6. Effluent is chlorinated to make bacteria free, whenever required. Such effluent, under aerobic condition, is free from any odour and colour making suitable for use in agriculture and other non- potable purposes. Effluent from anaerobic condition can be used for agriculture purpose.

Applicability

The Package Contact Aeration System is particularly applicable for:

- Wastewater treatment in rural areas connected to small bore sewers or conventional sewerage or on-site where high effluent quality is desired for reuse or to discharge to sensitive water bodies.
- Rural areas having continuous power supply for much better quality of effluent
- Sensitive and unapproachable locations
- Where land cost is high and limited area is available

2.6.10 Extended Aeration

The extended aeration process is a modified activated sludge process which provides biological treatment for the removal of BOD and TSS under aerobic conditions. Air may be supplied by surface or diffused aeration to provide the oxygen required to sustain the aerobic biological process As depicted in Figure 2.36, wastewater enters the treatment system and is typically screened and degritted immediately to remove large suspended, settleable, or floating solids that could interfere with or damage equipment downstream in the process. If the plant requires the flow to be regulated, the effluent will then flow into equalization basins which regulate peak wastewater flow rates. Wastewater then enters the aeration tank, where it is mixed and oxygen is provided to the microorganisms. The mixed liquor then flows to a sedimentation tank where most microorganisms settle to the bottom of the sedimentation tank and a portion is pumped back to the incoming

wastewater at the beginning of the plant. This returned material is the return activated sludge (RAS) (US EPA, 2000). The material that is not returned, the waste activated sludge (WAS), is removed for treatment and disposal. The clarified wastewater then flows over a weir and into a

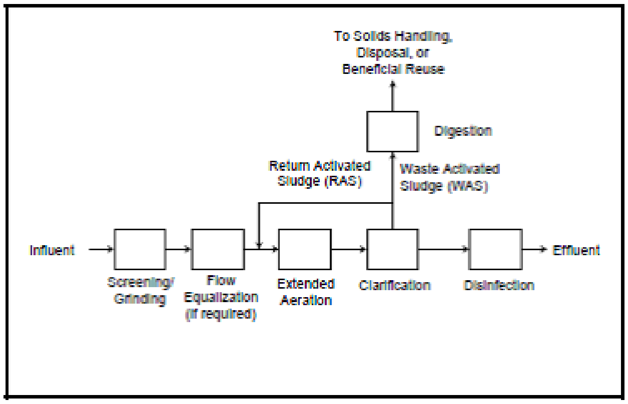


Figure 2.36 A typical flow sheet of Extended Aeration system (Source: USEPA 2000)

collection channel before being diverted to the disinfection system.

Thousands of extended aeration plants and its variants such as oxidation ditches, sequencing batch reactor are installed all over the globe for the treatment of rural area wastewater and working very efficiently. The extended aeration process has a special ability to handle extremely high organic and hydraulic shock loads, no washout of biomass, reliable performance. More than 95 % BOD removal is reported in many plants.

Applicability

The Extended Aeration System is particularly applicable for:

- Wastewater treatment in rural areas connected to small bore sewers or conventional sewerage where high effluent quality is desired for reuse or to discharge to sensitive water bodies.
- Large villages with wastewater discharge > 500 m^3/d
- Rural areas having continuous power supply.

2.6.11 Sequencing Batch Reactor Process

A sequencing batch reactor (SBR) is another type of extended aeration activated sludge system in which equalization, aeration and clarification all occur in a single reactor, by cycling through a series of steps: fill with anoxic mixing, aeration, settling, and decanting. Typically, sludge is wasted during the decant phase of the cycle (Figure 2.37). Typically two or more batch reactors are used to optimize system performance. SBR systems are typically used for flow rates starting from 0.1 MLD onwards and have the advantages of operational flexibility and minimal footprint. Plants are fully automatic and require least manpower for maintenance.

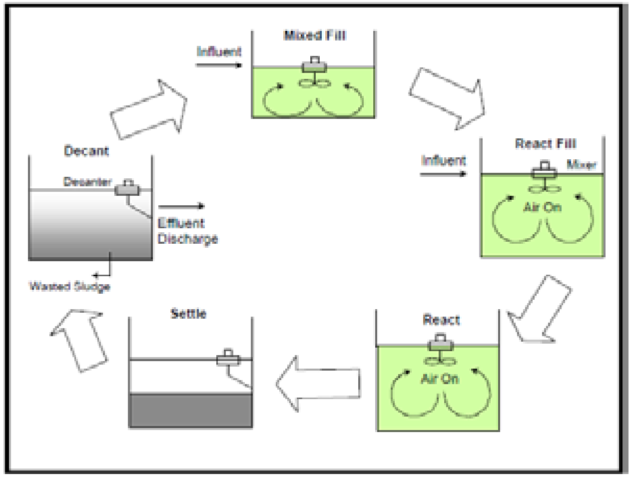


Figure 2.37. A Typical Cycle of Sequencing Batch Reactor (USEPA 2000)

a. The SBR is a time-oriented, periodic process that can be designed and operated to simulate virtually all conventional continuous-flow activated sludge systems, from contact stabilization to extended aeration.

b. Improved effluent quality: extended aeration mode, a special ability to handle extremely high organic and hydraulic shock loads, no washout of biomass, reliable performance. More than 95 % BOD removal advantages same as extended aeration processes.

c. No primary & secondary settling tanks, no return sludge pumping, hence lesser operation & maintenance.

d. Low volume of sludge production. Lower Annual Operating Costs due to low volume sludge pumping, low waste sludge production, savings in precipitating chemicals (optimized biological phosphorous removal) and savings for cost of operating personnel and equipment.

e. Because of the flexibility of working in time rather than space, the operating policy can be modified to meet new effluent limits, handle changes in wastewater characteristics, and accommodate the fluctuations in seasonal flow rate, all without increasing the sizes of the physical plant.

f. Proven effluent quality below 10 mg/l BOD_5, TSS and COD < 50 ppm, T-N to 10 mg/L and T-P to 2 mg/L.

Applicability

The SBR technology based system is particularly applicable for :

- Wastewater treatment in rural areas connected to small bore sewers or conventional sewerage where high effluent quality is desired for reuse or to discharge to sensitive water bodies.
- Rural areas having continuous power supply with availability of skilled manpower.
- Large villages with wastewater discharge > 500 m3/d
- Sensitive and un approachable locations
- Where land cost is high
- Nutrient removal is required for discharging the treated effluent in lakes and oceans
- Climatic variation is high from season to season.

2.7 SEPTAGE AND SLUDGE TRATMENT

Septage is the sludge generated from septic tanks, advanced-on-site systems, package plants, which is a fluid mixture of untreated and partially treated sewage solids, liquids and sludge of human or domestic origin. It has an offensive odour, appearance and contains significant levels of oil, grit, hair, debris and pathogenic microorganisms. Proper management of septage from rural areas is the need of hour.

2.7.1 Desludging of Septic Tanks and Advanced On-Site Systems

In most of the cases the septic tanks are desludged manually. This is considered as an unpleasant and repulsive job since the sludge (including fresh excreta) generally gets spilled around the tank during emptying, and poses a risk of transmission of diseases of faecal origin. The most satisfactory method of sludge removal is by vacuum tankers. Though desludging frequencies vary, it is generally recommended to desludge tanks once every three to five years, or when the tank becomes one third full. Frequent desludging also helps reduce the pollution levels in the liquid effluent, which normally enters waterways untreated.

2.7.2 Treatment of Septage

Co-treatment of septage along with domestic sewage at a sewage treatment plant (STP) of a nearby city is a feasible and acceptable alternative for septage treatment. Though septage is much concentrated in its strength than the domestic sewage, its constituents are similar to municipal wastewater. Sewage treatment plant should have an adequate capacity in order to accept the septage without hampering the normal functioning of other processes. The nearby city municipality should check the incoming load to the STP, if it is lower than the design capacity, then the difference in BOD and SS load can be accepted as septage. It is perhaps the best option as most of the sewage treatment plants in the country are working under capacity.

When the distance or the capacity of the plant becomes a limiting factor, it is not a feasible option to transport and treat the septage to the sewage treatment facilities. In this case treatment plants specially meant for septage treatment becomes an attractive option. Independent septage treatment plants are designed specifically for septage treatment and usually have separate unit processes to handle both the liquid and solid portions of septage. These facilities range from mechanical dewatering, sludge drying beds, Waste stabilization ponds etc., The benefit of using these treatment plants is that they provide a regional solution to septage management. Many septage treatment plants use lime to provide both conditioning and stabilization before the septage is de-watered. Dewatered sludge can be used as organic fertilizer after frying and composting. The remaining effluent/filtrate/supernatant can be released to another treatment process such as WSP, Anaerobic baffled reactor, constructed wetland or combination of these of extended aeration activated sludge where it can undergo further treatment and then finally can be safely discharged.

For the treatment of septage from rural areas the following option is suggested;

Septage Pretreatment ----- lime stabilization (optional)-------- Pumping------- Sludge Drying beds (FRP covered in regions of high rainfall) ------------Dewatered & Dried Sludge---- Composting----- Reuse as Organic Fertilizer;

Filtrate of Sludge Drying Bed------ Pumping ------ Anaerobic Baffled Reactor/Covered Anaerobic Ponds ------- Facultative ----- Aerobic/Maturation Ponds----- chlorination ----- discharge

2.8 KARNAL TECHNOLOGY

The Karnal Technology involves growing trees on ridges 1m wide and 50cm high and disposing of the untreated sewage in furrows (**Reference source not found.**). The amount of the sewage/effluents to be disposed off depends upon the age, type of plants, climatic conditions, soil texture and quality of effluents. The total discharge of effluent is regulated in such a way that it is consumed within 12-18 hours and there is no standing water left in the trenches. Through this technique, it is possible to dispose off 0.3 to 1.0 ML of effluent per day per hectare. This technique utilizes the entire biomass as living filter for supplying nutrients to soil and plant; irrigation renovates the effluent for atmospheric re-charge and ground storage. Further, as forest plants are to be used for fuel wood, timber or pulp, there is no chance of pathogens, heavy metals and organic compounds to enter into the human food chain system, a point that is a limiting factor when vegetables or other crops are grown with sewage.

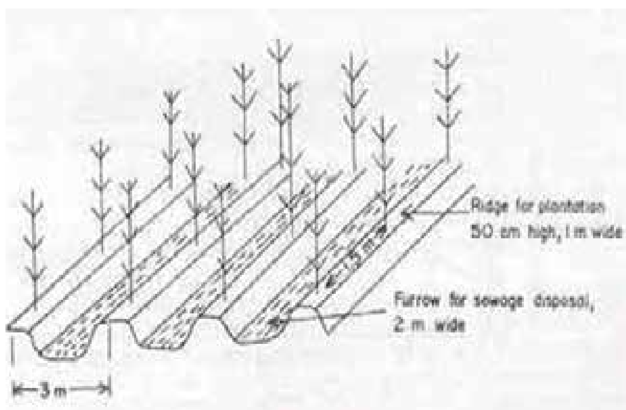


Figure 2.38. Outline of Karnal technology and a STP based on Karnal Technology
(punenvis.nic.in/water/technologies3.htm)

Though most of the plants are suitable for utilizing the effluents, yet, those tree species which are fast growing can transpire high amounts of water and are able to withstand high moisture content in the root environment, are most suitable for such purposes. Eucalyptus is one such species, which has the capacity to transpire large amounts of water, and remains active throughout the year.

This technology for sewage water use is relatively cheap and no major capital is involved. The expenditure of adopting this technology involves cost of making ridges, cost of plantation and their care.

This system generates gross returns from the sale of fuel wood. The sludge accumulating in the furrows along with the decaying forest litter can be exploited as an additional source of revenue.

As the sewage water itself provides nutrients and irrigation ameliorates the sodic soil by lowering the pH, relatively unfertile wastelands can be used for this purpose. This technology is economically viable as it involves only the cost of water conveyance from source to fields for irrigation and does not require highly skilled personnel as well. This technology seems to be most appropriate and economical viable proposition for the rural areas as this technology is used to raise forestry, which would aid in re-storing environment and to generate biomass. Five systems have been setup in Madhya Pradesh, 1 in Uttar Pradesh and 1 in Uttarakhand

2.9 WORKERS SAFETY ISSUES

Workers who come in contact with wastewater or sludge run into the danger of contracting infection or disease. The workers should be aware of this. The workers should wash themselves thoroughly after being around wastewater or practising first aid if when an injury occurs in the treatment or sewer systems. These are the biggest steps in avoiding problems with sickness and infection from the work.

The following preventive measures should be taken to prevent any kind of diseases;

2.9.1 Personal Hygiene Against Pathogen

The worker should take precautions because a large number of coliform 835 groups, various kinds of micro-organisms, and egg parasites exist in sewage. The workers should strive to maintain good health by taking care of the following points:

- Wear clean uniform, work boots, etc.
- After work and before having a meal, always wash hands and disinfect them.
- After work, take a shower if possible.
- Do not enter the offices and lounges wearing dirty clothes.
- If necessary, take vaccinations against tetanus, leptospirosis fever, and so on.

2.9.2 Health Check

Workers should have health check once a year so as to maintain their health, and prevent illnesses or detect them at an early stage. The results of the health check should be maintained as records.

CHAPTER - 3

TECHNOLOGICAL OPTIONS FOR SOLID WASTE MANAGEMENT

3.1 SOLID WASTE MANAGEMENT IN RURAL AREAS

Solid waste management in rural areas is perhaps the most neglected aspect of environmental sanitation. However, it is comparatively much easier to maintain solid wastes in rural areas than in urban areas. A number of waste prevention techniques are available, and they are commonly summarized as popularly known as 4Rs: reduction, reuse, recycling and recovery. To overcome the problem of solid wastes, following steps need to be taken:

i. Wherever possible, waste reduction should be preferred.

ii. Every effort should be made to reuse produced wastes

iii. Recycling should be the third option for the wastes.

iv. There are several options for recycling. Such options should be selected taking in view social and economical acceptability.

v. Attempts should be made to recover materials or energy from waste which cannot be reduced, reused or recycled.

In rural areas most of the household contains organic wastes, with little quantity of inorganic wastes and it is completely free from toxic wastes. Due to organic nature of wastes, composting is the most suitable, sustainable and environment friendly method of recycling and reuse of solid wastes in rural areas. Composting of household wastes in rural areas is an age old practice. As per the information available in literatures, these are based on the practices adopted in field conditions. In recent years there has been improvement of composting by using systematic and scientific methods.

Principle of composting

Decomposition and stabilisation of organic waste matter is a natural phenomenon. Composting is an organised method of producing compost manure. Compost is particularly useful for organic matters. In rural areas there is higher percentage of organic matters making more applicability of composting technology.

Composting can be carried out in two ways i.e., aerobically and anaerobically. During aerobic composting aerobic micro-organisms oxidize organic compounds to Carbon dioxide, Nitrite and Nitrate. Due to exothermic reaction, temperature of the mass rises up to 650 C. At such temperature mesophilic bacteria present in the heap die off and condition inside heap becomes anaerobic. To maintain aerobic condition with environmental temperature inside heap, it is churned up side down at regular intervals. The process is comparatively faster than anaerobic condition. During anaerobic process, the anaerobic micro organisms, while metabolising the nutrients, break down the organic compounds through a process of reduction. In this case temperature inside the heap does not raise much. The gases evolved are mainly Methane and Carbon dioxide. This process does not require churning. It takes longer time than aerobic composting.

3.1.1 Advantages of composting

i. Large amounts of vegetation, such as crop remains, garden weeds, kitchen and household wastes, hedge cuttings, garbage, etc, are put to use.

ii. When properly made, compost becomes immediately available as plant food without the need to be first broken down by soil microorganisms.

iii. Compost does not cause excessive weed growth, as is the case with ordinary farm manure.

iv. Good crops can be obtained without the need for extra chemical inputs.

v. All farmers, regardless of their financial abilities, can make and use compost.

3.1.2 Limitations for composting

i. Compost requires a lot of labour to prepare and spread it over the farm.

ii. The nutrient composition of the compost varies a great deal. It depends on the materials used and the preparation methods.

3.2. TECHNOLOGY OPTIONS FOR COMPOSTING OF ORGANIC WASTES

There are following options of composting of wastes

1. **NADEP Method**
2. **Bangalore method**
3. **Indore method**
4. **Vermi composting**
5. **Rotary drum composting**
6. **Biogas Technology**

3.2.1. NADEP Method

The NADEP method of organic composting was developed by a Gandhian follower namely Narayan Deotao Pandharipande of Maharastra (Pusad) (N.D. Pandharipande 2008). Compost can be prepared from a wide range of organic materials including dead plant material such as crop residues, weeds, forest litter, cattle dung and kitchen wastes. Compost making is an efficient way of converting all kinds of biomass into high value fertilizer that serves as good alternative to farmyard manure, especially for crop-growing households without livestock. In this method composting materials are put in layers (Fig 3.1)

Description

This method of making compost involves the construction of a simple, rectangular brick tank with enough spaces maintained between the bricks for necessary aeration (Figs. 3.2, 3.3). The size of the tank is 3m x 1.8 m or 3.6 m x 1.5 internally with 25 cm thick perforated brick wall all around in mud or cement mortar to a height of 0.9 m above ground. The above ground-perforated structure facilitates passage of air for aerobic decomposition. The floor of the tank is laid with bricks.

The tank is covered on top with a thatched roof. The ingredients for making compost are agro-wastes, animal dung and soil in the ratio of 45:5:50 by weight. The ingredients are added in layers starting with vegetable matter, followed by

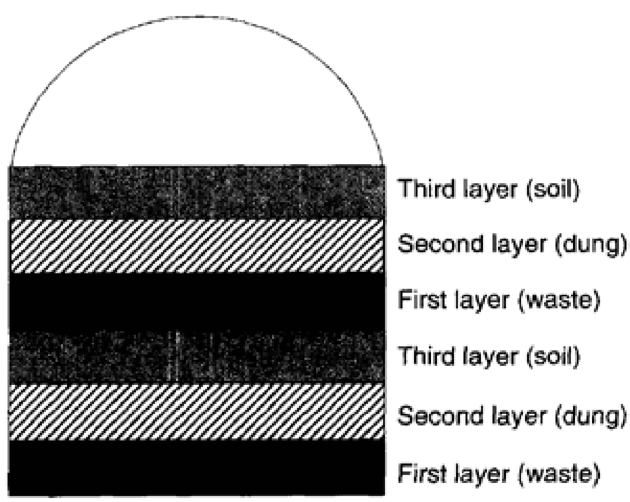


Fig. 3.1 Source: Pandhariponde, 2008

dung and soil in that order. Each layer can be of about 45 kg vegetable matters, 5 kg of dung mixed in 70 lts of water and 50 kg of soil so that 30 layers will fill the tank. For Convenience, the number of layers could be reduced to half, this number the quantities of ingredients in each layer. After 15-30 days of filling the organic biomass in the tank gets automatically pressed down to 2 ft. The tank is refilled by giving 2-3 layers over it and is 9 resealed. After this filling, the tank is not disturbed for about 3 months, when organic matters are almost completely degraded by the help of different groups of micro organisms. About 22-50 lts of water is to be sprinkled twice a week after the tank is fully loaded. After degradation, nutrients produced in the compost tank are absorbed by the soil layers thus preventing their loss. In some compost methods such nutrients especially nitrogen is lost in soil.

Fig. 3.2 A NADEP Composting in a shade
(Source: Pandharipond e, 2008)

Fig. 3.3 A NADEP composting showing aeration
(Source: Pandharipond e, 2008)

One tank can be used three times in a year. With production of 3 tons to 3.5 tons of compost produced per cycle, about 9 to 10 tons of compost can be made annually from one tank. The compost can be stored for future use. It is advisable to sprinkle cultures like Trichoderma, Azatobacter, whenever available to enhance the composting process. It enhances nitrogen contents of manure. It is necessary that a farmer should have at least 2 tanks so that when one is filled up the other one is available for loading the material generated in the farm.

Advantages of NADEP

In addition to have organic manure for its economical use and improvement of sanitation in villages, the NADEP method of composting has the following advantages:

i. It is very simple to construct and easier to operate.

ii. In this method, compost can be prepared with small quantity of cow dung (5Kg) and hence, it can be considered as appropriate rural model.

iii. Labour is required only for the construction and one time filling of the tank and excavation of manure. No labour is required during composting period for churning of wastes.

iv. There is no loss of plant nutrients in compost. Therefore, percentage of nutrients in manure is high in comparison to other composting methods.

Limitations with NADEP method

i. Filling of tank is cumbersome during the raining season,

ii. Expenditure on transport of soil is high when the unit is away from the field. However, if the tanks are installed in the same field, where agro-wastes are generated and manure to be used, this is not a limiting factor.

3.2.2. Bangalore Method

Acharya (1939) had initiated the work of composting the town refuse and night soil. This process is also called *Hot Fermentation Mechanism* of composting or the **Bangalore method.** The raw materials used are mixed plant residues, animal dung and urine, earth, wood ash and water. All organic material wastes available on a farm such as weeds, stalks, stems, fallen leaves, prunings, chaff, fodder leftovers and so on, are collected and stacked in a pile. Hard woody material like cotton or pigeon pea stalks and stubble are first spread on the farm road and crushed under vehicles such as tractors or bullock carts before being piled. Such hard materials should in any case not exceed ten percent of the total plant residues. Green materials, which are soft and succulent, are allowed to wilt for two to three days to remove excess moisture before stacking; they tend to pack closely if they are stacked in the fresh state. The mixture of different kinds of organic material residues ensures a more efficient decomposition. While stacking, each type of material is spread in layers about 15 centimeters thick until the heap is about one and a half meters high.

This is a pit method of composting where anaerobic condition is conventionally carried out in pits. Initially the waste is anaerobically stabilized in pits where alternate layers of organic wastes and animal dung are laid (CPHEEO 2000). The pit method of making compost conserves moisture, so it is useful in areas with low rainfall and a long dry season. It should not be used in wet areas, as the compost may become waterlogged.

The pit is completely filled and a final soil layer is laid, to prevent fly breeding, entry of rain water into the pit. The material is allowed to decompose for 4 to 6 months after which the stabilised material is taken out and used as compost. The Bangalore method requires longer time for stabilisation of the material & hence needs larger land space. The gases generated in this anaerobic process also pose smell & odour problems.

3.2.3 Indore Method

This process was developed by Howard and Wad in 1931 at Indore, Madhya Pradesh. In this method, waste materials such as plant residues, animal wastes, weeds, street refuse and other organic wastes can be composted. The waste materials are cut into small pieces and spread in layers of 10-15 cm thickness either in pits or in heaps of 1 m wide, I m deep and of convenient length. It is properly moistened with cow dung using earth. To ensure 50 % moisture sufficient water should be sprinkled for making the composting materials moist. Periodically, three to four turnings are given. This method of composting in pits involves filling of alternate layers of similar thickness as in Bangalore method. For starting the turning operation, the first turn is manually given using long handled rakes, 4 to 7 days after filling. The second turn is given after 5 to 10 more days. Third turn is also given after 5-10 days. Further turning is normally not required and the compost is ready in 4-5 weeks. The Indore method stabilizes the material in shorter time and needs lesser land space. As no odourous gases are generated in this process, it is environment friendly & hence commonly preferred. The composted material obtained by this method will contain 1.5 % nitrogen, 1.0 % phosphorus and 1.5 % potassium. Advantages and Limitations

The Indore process requires relatively high labour requirement and inadequate protection from rain, sun and wind. Loss of nutrients is rapid. Upper portion of heap gradually dries as a result of poor decomposition. However, this method can be applied by a farmer easily. No much technical inputs are required to complete the process.

3.2.4. Vermi composting

Vermi compost is a natural compost of organic wastes through Earthworms,(Fig. 3.4) who take up organic wastes and after degradation and digestion, convert such wastes in the form of granules, rich in nitrogen content. Such vermin cast or vermin compost has good plant nutrients and therefore compost. This is a natural composting method being used in India and other countries for centuries. However, in recent years there has been systematic methods developed to enhance such composting by using improved methods and strains of earthworms in rural as well as urban areas in India also.

Advantages of vermicompost:

a. Vermi compost is rich in all essential plant nutrients.

b. Vermi compost is easy to apply, handle and store and does not have bad odour.

c. It improves soil structure, texture, aeration, and water holding capacity. Vermi compost contains earthworm cocoon and increases the population and activity of earthworm in the soil.

a) Vermi compost is free from pathogens, toxic elements, weed seeds etc.

b) Vermi compost minimizes the incidence of pest and diseases.

Fig 3.4

c) It enhances the decomposition of organic matter in soil.

d) It contains valuable vitamins, enzymes and hormones like auxins, gibberellins etc.

Nutrient content of vermin compost

Depending upon the types of substrate, contents of plant nutrients vary with vermin compost. However, a typical vermicompost has the following percentage of plant nutrients:

Nitrogen- 1.5 – 2.5 % Calcium- 0.5 – 1.0 %, Phosphorus- 0.9 – 1.7 % Magnesium- 0.2 – 0.3 % Potash- 1.5 – 2.4 % Sulphur- 0.4 - 0.5 %, and other micronutrients with enzymes and hormones.

Materials for preparation of Vermicompost:

Any type of biodegradable waste is suitable for vermicompost. Kitchen wastes, animal/ cow dung and leafy biomass are more suitable for vermicompost.

Efficient earthworm species:

The following species of earth worm commonly found in India are used for vermicomposting:

i. *Eisenia foetida*

ii. *Amyanthes diffrigens*

iii. *Eudrillus engineac*

Methods of preparation of pit for vermicompost

i. The vermicompost can be prepared in concrete tank (Fig 3.5) or in soil pit lined with plastic sheet.

ii. Inn household a cement ring can be used as pit for vermin composting.

iii. The available bio-wastes should be collected and are to be heaped for pretreatment for 4-5 days

iv. Sprinkling of cow dung slurry to the heap may be done.

v. A thin layer of half decomposed cow dung (1-2 inches) should be placed at the bottom of the pit.

vi. Place the chopped weed biomass and partially decomposed cow dung layer wise (10-20 cm) in the tank / pot up to the depth of 2 ½ ft. The bio waste and cow dung ratio should be 60: 40 on dry wt. basis.

Fig. 3.5 vermicomposting in concrete ring (Source: Nagavallemma et.al 2004)

Fig 3.6. Concrete ring cover with gunny bag (Source: Nagavallemma et.al 2004)

Fig. 3.7 Processed vermin compost (Source: Nagavallemma et.al 2004)

i) Release about 2 kg earthworms per tonne of biomass or 100 nos. earthworms per one sq. ft. area.

ii) Place gunny bag on top of the cement ring to maintain moisture content of compost material.

iii) Sprinkling of water should be done to maintain 70-80 % moisture content..

iv) Sprinkling of water should be stopped when 90 % bio-wastes are decomposed. Maturity could be judged visually by observing the formation of granular structure of the compost at the surface of the tank.

v) Harvest the vermicompost by scrapping layer wise from the top of the tank and heap under shed. This will help in separation of earthworms from the compost. Sieving may also be done to separate the earthworms and cocoons.

Advantages of using Bio-fertilizer

i. Can replace 20 to 50 % of chemical fertilizer 'N' and 15 – 25 % of phosphatic fertilizers.

ii. Bio-fertilizers being cheap, provide highly cost effective supplement of chemical fertilizers.

iii. Increase farm productivity, generally 10-40 % in grain yield and 15 – 30 % in vegetable growth.

iv. Activates soil biologically thereby increasing natural fertility of soil, which causes sustainable agriculture.

v. Help in stimulating plant growth in general and roots in particular as they serve various growth promoting hormones like auxin, gibberellins etc. They help in better nutrient uptake and increase tolerance towards drought and moisture stress.

3.2.5 Rotary drum composting

A. For single household

A batch Rotary drum of 250 L capacity is used for batch composting of household organic waste (Kalamdhad and Kazmi, 2008). The inner side of the drum is covered with anti-corrosive coating. The drum is mounted on four rubber rollers, attached to metal stand and the drum is rotated manually. In order to provide the appropriate mixing of wastes, 40mm long angles are welded longitudinally inside the drum. In addition, two adjacent holes are made on top of the drum to drain excess water (Fig 3.8).

Once a day clockwise turning was carried out manually by handle, which ensures proper mixing and aeration. Thereafter, aerobic condition was maintained by opening half side doors. Two to three rotations at a time were made to ensure that the material on the top portion moved to the central portion, where it was subjected to higher temperature (Kalamdhad et al., 2008).

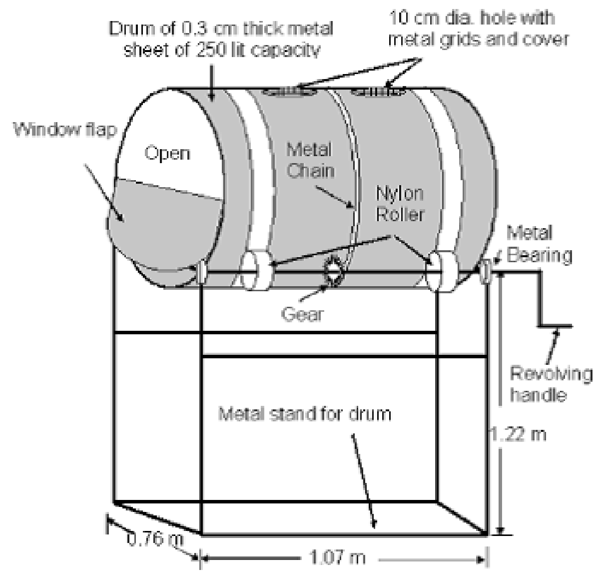


Figure 3.8. Single Household Rotary Drum Composter installed in IIT Roorkee (Source: Kalamdhad & Kazmi 2009)

Methodology

The drum is operated for the following waste combination:

Uncooked vegetables waste, cow dung, tree leaves and sawdust were collected from various places and the mixture is shredded to 1 cm in order to provide better aeration and moisture control.

Applicability

The drum is applicable for rapid composting of kitchen and other organic waste generating from a single household in all seasons without causing any odour, vector, leachate in all seasons. Primary stabilized compost was achieved within 15-20 days.

B. For Community purpose

Community scale continuous rotary drum composter of 3.5 m3 capacity is used for high rate composting of 150-200 kg organic waste per day (Figure 3.9). The drum has 3.5 m3 capacity and 3.7 m in length and 1.1 m in diameter, made up of a 4 mm thick metal sheet was operated. 7.5 kW motor with gear reducer is used to turn the drum in clockwise direction at a speed of 2 rpm.

Fig.3.9 A community rotary drum
(source Kalamdhad & Kazmi 2009)

In order to provide the appropriate mixing and agitation, 400 mm long angles with 4 mm width and 150 mm height were welded longitudinally. A 2.5 kW air blower fixed at the inlet end was used to suck the air from outlet end for aeration. It also promoted the escape of water vapours and foul gases generated during composting. Two ports are provided at the middle and outlet zone of drum to drain possible excess water and to collect compost samples.

Applicability

i. The rotary drum can be successfully applied in a small land area for rapid composting of all kind of organic waste (kitchen, cow dung, dry leaves etc.,) generated from household, institutions, and dairies in rural areas.

ii. The composting can be conducted in all seasons without causing any nuisance such as odor, vectors, leachate etc.,

3.2.6 Biogas Technology

Quantum of energy utilised is regarded as socio-economic status of any society. Due to lack of fuel, people in villages spend most of their valuable time to collect fire woods for cooking. In villages, most of the people use animal dung-cakes for cooking purpose. Such animal dung along with human wastes can be effectively used for biogas generation through on-site biogas plant linked with toilet. Biogas plant is important in providing sustainable energy sources in rural communities. Generation and utilization of bioenergy has multiple advantages. It helps improve sanitation, provide bioenergy at almost nil recurring expenditure and finally slurry / effluent of biogas plant has plant nutrient value to be used for agriculture purposes. Thus toilet linked biogas plant has additional benefits in terms of improving sanitation. In villages where household wastes contain mainly organics, they are also suitable for biogas generation. Such wastes can also be mixed in the same biogas plant to generate biogas production. In case of community toilets, biogas generation from human waste is sustainable option (Jha, 2005).

Biogas is a mixture of gas produced by methanogenic bacteria while acting upon biodegradable materials in an anaerobic condition. Biogas is mainly composed of 50 to 70 percent methane, 30 to 40 percent carbon dioxide (CO2) and low amount of other gases. Biogas is an odourless and colourless gas that burns with clear blue flame similar to that of LPG gas.

Quantity of biogas production from different feed materials

i. From animal dung- per animal, per day, around 10 kg dung is produced. Gas production rate from dung is about 1.4 cft per kg, i.e., per animal per day, 14 cft biogas is produced.

ii. From per person per day 0.3 kg of waste is generated that produces 1 cft of biogas.

iii. A total amount of biogas of one cum can be produced per day from a family having 4 members and 2 cattle heads.

Utilizations of biogas

One cum of biogas per day can be utilized in a family as follows:

a. Cooking of 3-4 family members for two times a day

b. Mantle lamps (2nos.) can be used for 6 hours per 24hrs. Such mantle lamps gives illumination equivalent to 4o watt bulb at 220 volt of electricity.

Manure value of sludge from biogas plant

Besides biogas, the manure of the biogas plant has much plant nutrient value. It is directly used for agriculture purpose. The following is the comparative value of plant nutrients (N,P,K, value) from biogas manure and other compost (Table 3.1).

Table 3.1

Sl. No.	Name of constituent	Compost Manure (%)	Biogas slurry (%)
1.	Nitrogen	0.50-0.75	1.30-1.50
2.	Phosphorus	0.70-0.80	0.85-0.92
3.	Potash	1.20-1.50	1.50-1.65

Design of biogas plant

For family size biogas plant there are basically two designs (1) Floating drum type popularly known as KVIC model and (2) Fixed dome type, popularly known as Deenbandhu Model.

In the KVIC model gas holder is made up of iron sheet (mild steel). During winter season when temperature fall down to 10 degree Celsius or so, this model ceases to function as the iron sheet gas holder acts as good conductor of heat and inner temperature of the digester also attains the same temperature. Secondly, this gas holder requires regular care and maintenance to prevent from getting worn out because of corrosion. It has short working life. Manufacturing of gas holder requires sophisticated workshop facility that is rarely found in rural areas. Therefore, in rural or in urban areas the success rate of this model of biogas plant is far below the level of satisfaction.

Night Soil Digesters

The night soil can be anaerobically digested either alone or in combination with cattle dung. It is rich in nitrogen and phosphorus in comparison to cow dung. The characteristics of night soil are different from the cow dung and are mentioned in table below:

Characteristics of night-soil and cow-dung
Table -3.2

No.	Characteristics	Night soil	Cow dung
1	Moisture content,%	85-90	74-82
2	Volatile solids as % of total solid	80-88%	70-80
3	Total Nitrogen as N,% on dry basis	3-5	1.4-1.8
4	Total Phosphorus as P2O5, % on dry basis	2.5-4.4	1.1-2.0
5	Potassium as K2O,% on dry basis	0.7-1.9	0.8-1.2

Source: CPHEEO, 1993

Design Criteria

The design criteria for night soil digester are listed in table below:

Table 3.3

No	Items	Magnitude
1	Volumetric organic loading, Kg VS/m^3 d	1.6
2	Hydraulic residence time , d	25-30
3	Solid concentration of slurry fed to digester , %	5
4	Volatile solids destroyed during digestion,%	45-55
5	Gas yield, m^3 kg of VS added in m3 / capita/d	0.5
6	m^3 / capita/d	0.034

Source: CPHEEO, 1993

Deenbandhu model - This model is predominately found in India. It is an underground fixed dome digester made up of complete brick or RCC structure (Fig. 3.10). It is a permanent structure having almost nil operation and maintenance costs. There is no separate gas holder, biogas is stored inside plant through liquid displacement chamber. This design is suitable also for generation of biogas from human wastes along with cow dung and kitchen wastes. There is almost no effect of atmospheric variation of temperature on biogas generation during winter season. It has several advantages over the KVIC design. The following section describes different aspects of Deenbandhu biogas plant.

Toilet linked biogas plants fed with cow dung- Cow dung biogas plant linked with toilet has additional advantages. There is additive effect on biogas production rate when cow dung based biogas plant is linked with toilet. For one cum of biogas production 25 kg of cow dung is required. Whereas, when plant is linked with toilet, only 17-20 kg of cow dung is required for the same quantity of biogas, depending on number of users of toilets in a family. Further percentage of methane in toilet linked biogas plant is higher (63.8%) over without toilet linked (60.4%). Such toilet linked biogas plants have been implemented in many families in Navsari District (Gujarat). Families having such plants do not use LPG or any other fuel except. Produced biogas is sufficient to meet their cooking requirement.

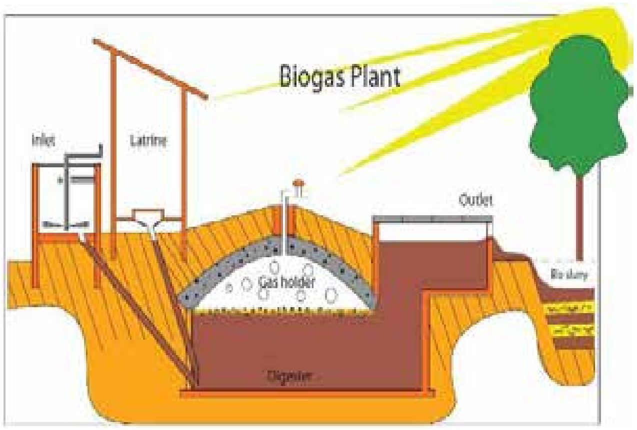


Fig. 3.10 A section of family size biogas plant of Deenbandhu Model (Source: Grassrootindia.com2013)

Fig 3.11. A cow dung based biogas plant linked with toilet

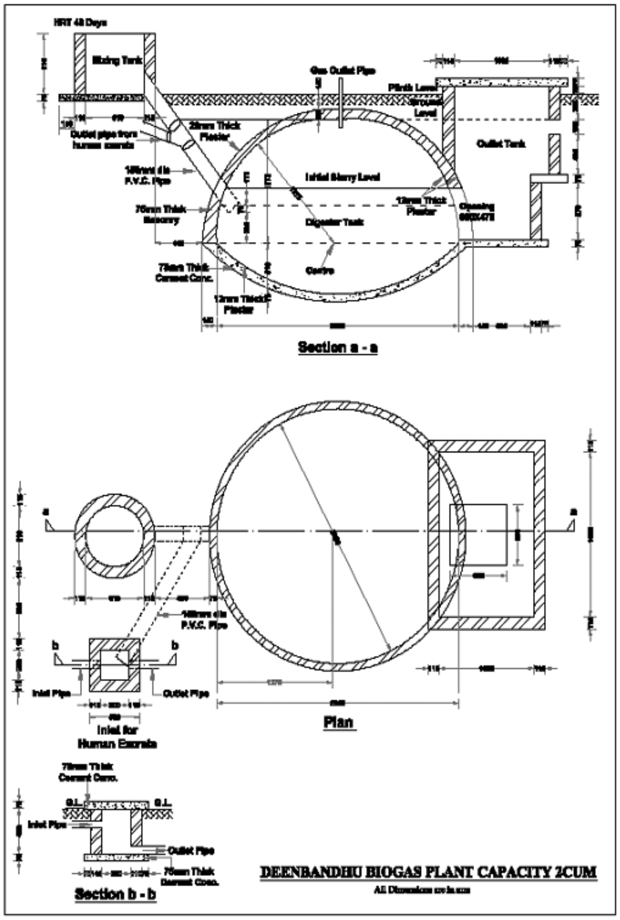


Fig 3.12 Drawing of a 4 cum biogas plant – Deenbandhu Model

Selection of site

Site of biogas plant should be selected properly, it should not be water logged and soil should be hard (high bearing capacity). It should not be constructed in a shaded area. Sunlight helps increase digester temperature therefore, production of biogas. Biogas plant should be as near to its use points- cooking and mantle lamps lighting. Longer the distance between biogas plant and its use will reduce gas pressure in gas pipe and hence will create problem.

Selecting a biogas plant size:

A biogas plant of specific capacity can be selected based on the daily availability of cattle dung, users of toilet (in case of toilet linked) and water requirements.

Materials required for biogas plant

The biogas plant can be set up with Bricks, Cement, Stone chips of 1/2" Coarse Sand, G.I. pipe 3/4" dia. sockets, 30 cm,, A.C./ PVC pipe 6" dia, Iron bars (6mm dia) for outlet tank cover, Paint (gas leak proof dibhapoxy), labour for digging pit, labour for construction, skilled masons, BG Stove, 10 m pipe line, lamp, accessories.

Components of a biogas plant:

Foundation

The foundation of the plant is bowl shaped with a collar around the circumference. The construction of the digester dome is based on this collar. Dome is divided in 2 parts, Digester & Gas storage. Digester: The bottom part is called the digester, where the mixture of dung and water passes through inlet chamber and anaerobic digestion by the help of different bacterial groups takes place producing biogas. Retention time of digester is kept normally as 40 days.

Gas storage: gas produced by the bacterial activity is stored in the upper part of the digester dome called gas storage. Capacity of the gas storage is designed for 50 % of the daily gas production capacity of the plant. However, as per requirement, gas storage capacity can be increased, depending on use of biogas.

Gas outlet pipe:

A nipple is fitted on the top of the dome, which is connected to a GI pipe of ½ inch. The gas reaches the kitchen through this pipe.

Inlet chamber:

Inlet is the point where cow dung is mixed with water before it passes to biogas plant through inlet pipe connected with chamber.

Outlet chamber

Outlet chamber or liquid displacement chamber has two functions- it allows passage of effluent from the biogas plant and it determines the storage capacity of biogas plant.

Factors affecting biogas generation

Temperature

For optimum biogas production, a temperature of 35- 370C is optimum. At lower temperatures gas production rate decreases. In winter season when temperature falls to 100 C or so, gas production almost ceases. However, in case of underground fixed dome digester like that of Deenbandhu model, there is least affect on biogas production due to atmospheric temperature difference. This is due to the fact that digester dome is covered with soil that acts as insulator. It has least impact on inside temperature.

pH

The pH range suitable for biogas production is rather narrow i.e. between 6.6 to 7.5. A pH value below 6.2 (acidic slurry) and above 8.0 (alkaline slurry) becomes toxic to the bacteria.

Total solid concentration in feed material

Total solid in feed material is an important aspect. Around 8% TS is optimum for biogas production. In case of cow dung, this concentration is achieved after mixing cow dung with water in the ratio of 1:1, i.e., 10 kg of cow dung is mixed with 10 lit. of water.

Testing the digester;

The digester of the Deenbandhu plant on completion is tested before commissioning through smoke test for detecting gas leakages. Smoke producing material is burnt inside the digester and thereafter all vents of the digester are closed and checked for leakage. Any section of the dome emitting smoke is identified and can be sealed.

Hydraulic testing for water leakages is done by filling half of the digester with water and marking the level. Thereafter, after a period of 6 to 7 days, the water level is rechecked. In case of leakages the water level will go down.

Starting a digester with feed material;

Initial digestion process with cattle dung feed should start within few weeks depending upon the temperature. If available, effluent (5-10%) from a running biogas plant should be added to new biogas plant once at the start as an inoculums. Cow dung itself contains a lot of mathanogenic bacteria, therefore, in case of unavailability of working biogas plant and its effluent, biogas production will continue.

Uses of biogas for cooking

Common uses of biogas are for cooking and lighting through mantle lamps. Biogas cooking

Fig 3.13, Use of biogas for cooking purpose in a rural family fitted with gas flow meters.

burners are available in markets (Fig. 3.13). A cooking burner consumes 8-24 cft of biogas per hour depending on its size. Biogas burns in blue flame without any shoot or odour like LPG. It contains around 1 % hydrogen sulphide that has pungent odour, but for cooking during burning there is no such odour at all such odour is useful to detect any leakage of biogas due to loose connection of pipe etc. In rural areas where people are mostly dependant on fire wood or dung cake for cooking purpose, biogas is a boon in improving health, environment and is economical.

Use of biogas for lighting

Lighting through mantle lamp is another common use of biogas (Fig 3.14). Such mantle lamps are available in markets. A Mantle lamp consumes 2-3 cft of biogas per hour. It gives illumination equivalent to 40 watt bulb at 220 volt of electricity. In rural areas in most of the families student can't study in night due to unavailability of electric supply and high cost of kerosene oil, biogas is a sustainable option and boon for such communities

Fig. 3.14 Biogas being used as lighting through mantle lamp

Do's and Don'ts while operating a biogas plant

Do's

i. Select the size of the biogas plant depending on the quantity of dung available with the beneficiaries.

ii. Install the biogas plant at a place near the kitchen as well as the cattle shed as far as possible.

iii. Ensure that the outer side of the plant is firmly compacted with soil.

iv. Ensure that the plant is installed in an open space, and gets plenty of sunlight for the whole day, all round the year.

v. Feed the biogas plant with cattle dung and water mixture in the right proportion-add 1 part of cattle dung to 1 part of water by weight to make a homogeneous mixture.

vi. Ensure that the slurry (mixture of dung and water) is free from soil, straw, etc.

vii. For efficient cooking, use good quality and approved burners and gas lamps.

viii. Open the gas regulator cock only at the time of its actual use.

ix. Adjust the flame by turning the air regulator till a blue flame is obtained, this will give maximum heat.

x. Light the match first before opening the gas cock.

xi. Cover the top of the inlet and outlet tank opening with wooden, stone or RCC cover, to avoid accidental falling of cattle and children.

Don't do

i. Don't install a bigger size of biogas plant if sufficient cattle dung or any other feed-stock to be used for biogas production is not available.

ii. Don't install the gas plant at a long distance from the point of gas utilisation to save the cost of pipeline and loss of biogas.

iii. Don't install the plant under a tree, inside the house or under shade.

iv. Don't add more than required quantity of either dung or water-doing so might affect the efficient production of gas.

v. Don't leave the gas regulator (valve) open when the gas is not in use.

vi. Don't inhale the biogas as it may be hazardous.

vii. Don't allow soil or sand to enter into the digester.

viii. Don't use the gas if the flame is yellow. Adjust the flame by the air regulator till it is blue in colour.

ix. Don't use the gas after initial loading of slurry, as it may take 15- 25 days for gas production in freshly loaded plants. No foreign material should be added.

x. Don't let any water accumulate in the gas pipeline; otherwise the required pressure of gas will not be maintained and the flame will not be proper.

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