Sanitation is more than life …

Sustainable Sanitation Options for Sri Lanka

A composite document on behalf of
WORLD VISION Lanka Tsunami Response Team

VOLUME III: Guidelines and Technical Option Sheets

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Sustainable Sanitation Options for Sri Lanka Volume III

0. Introduction – how to use Volume III

Volume III of the COMPOSITE DOCUMENT on Sanitation provides practical tools for appropriate sanitation implementation.

Volume III is a stand-alone document, however, the application of the Guidelines and Technical Option Sheets provided in Volume III may be more clear to you, if you have read Volume I and worked through the section on appropriate sanitation selection in Volume II. Doing so is recommended, if you are not yet very experienced in the selection of appropriate sanitation options for different specific locations during reconstruction in Sri Lanka.

Volume III is divided into two sections:

- The first section provides guidelines for sanitation; it contains lists of criteria that toilet and treatment facilities must fulfil. Please work through these lists if you are not sure, if the facilities that you are constructing correspond with these guidelines. ►►**page 4**►
- In the second section, recommended sanitation options are explained in detail in technical option sheets. ►►**from page 12 onwards** ►

  In accordance with the results of your decision, flip to the corresponding technical option sheets in Volume 3 ►**refer to table of contents, page 2** ►

Each technical option sheet provides you with

- a brief introduction of the system
- state under which conditions the system is applicable
- list advantages and challenges
- give a typical example of such a system, with technical drawings and BOQ (if applicable); otherwise providing essential design information
- present design variations of the system
- provide information for up-scaling, if possible
- list operation and maintenance steps
- refer you to local expertise, if available in Sri Lanka
- highlight approaches and tools for successful implementation
- provide a cross-check to confirm that you have chosen the correct system for your site conditions

As the user of the document, you can focus only on information relevant to your specific situation and demands by following the arrows, leading you to relevant sections:

►►**Vol. …, page ….** ►

1. Guidelines for Sanitation

The following guidelines were developed by the authors, based on standards and policies of the Sri Lankan government, World Health Organization, World Bank, UNICEF, OXFAM and Sphere Project, combined with the international practical experience of WTO.

►►Vol. I►

►►Appendices 1 & 2►

a) Toilets, collection and treatment installations, disposal and re-use options shall be selected according to climatic conditions of the specific location.

b) Toilets, collection and treatment installations, disposal and re-use options shall be selected in order to prevent pollution of ground and surface water, and to reduce the consumption of valuable drinking water for sanitation purposes.

c) Toilets, collection and treatment installations, disposal and re-use options shall be selected according to the specific needs and cultural values of the intended users.

1.1. Guidelines for Toilets

1.1.1 General Guidelines

a) Toilets should be installed sufficiently close to the house or inside the house to allow rapid, safe and acceptable access at all times of the day and night.

b) The maximum number of calculated users per toilet should not exceed 20.

- Use of toilets is arranged by household(s) and/or segregated by sex.
- Toilets are no more than 50 m from dwellings, or no more than one minute's walk.
- Separate toilets for women and men are available in public places.
- Shared toilets are cleaned and maintained to fulfil the needs of all intended users.

c) Toilets are sited, designed, constructed and maintained in such a way as to be comfortable, hygienic and safe to use by all sections of the population, including children, older people, pregnant women, physically and mentally disabled persons:

- provide privacy in line with the habits of the users;
- allow for the disposal of women's sanitary protection, or provide women with the necessary privacy for washing and drying sanitary protection cloths;
- allow for the immediately and hygienically disposal of children faeces;
- do not present a health hazard;
- do not promote fly and mosquito breeding;
- allow easy cleaning of slab surface;
- naturally aerated preventing unpleasant smell and increasing the frequent use capacity;
- lit at night for security and convenience.

d) Toilet room: Technical Guidelines:

- If the toilet building is separated from the house,
  - The siting of the toilet building should be at least within 30 m distance to water supply sources, and the water sealed floor of the toilet room should be at least 0.3 m above the groundwater level avoiding groundwater contamination.
  - The siting of the toilet building should be in sufficient distance to trees avoiding roof destruction by falling branches and fruits.
  - In coastal areas the toilet construction should be secured by massive reinforced concrete piles in each corner.

►►**Appendix 5**►

  - The minimal internal dimension of a toilet room, whether inside the house or within, should have the width of 1.1m and the length of 1.4m (squatting type) and width of 1.1m and the length of 1.7m (sitting pedestal); larger dimensions are recommended as they will provide more comfort to the user.
- Toilet cabins should be larger dimensioned where children need to be helped by parents.
- If men's urinal is installed in the same toilet cabin, enough additional space should be foreseen to keep distance to the sitting / squatting device.
- The minimal internal height should be 2.23m (Sri Lanka Government Standard).
- If only one outside wall exists, a window opening of at least 0.20m² should be provided.
- If more than one outside wall exists, at least two walls should have a window area of at least 0.20m² each.
- The roof must be constructed with a minimal slope of 1:15 for rainwater run-off.
- Gutters shall be fixed at the roof, providing the possibility of rainwater harvesting for hand washing purposes and reducing problems with stagnant water around the toilet building during rain season. Alternatively, the gutter should drain the water to an infiltration field to avoid stagnant water and erosion.
- Vent pipes must be covered with a mosquito proof mesh.
- For security and privacy, the toilet room must have a door, which must be lockable from inside.
- The door width should be at least 0.75m
- The inside walls should be covered with ceramics, tiles or a smooth painting up to 1.0m above the floor to facilitate easy cleaning.
- The floor should be laid with ceramics or smoothly painted thus facilitating easy and hygienic cleaning.
- The facility itself should consist of either a squatting pan or a sitting pedestal; the surface should be made of material which is easy to clean even with little water and without chemical disinfectants.
- A hook for hanging up clothes should be provided inside.
- Water supply for personal cleansing shall be secured.

- Hand washing devices shall be provided in or near to the toilet room.
- If the toilet facility is elevated and more than two steps are necessary to provide access, handrails should be installed.
- If electricity is available, a connection for lighting the toilet room at night should be installed.

e) Social and Cultural Guidelines

- Design, construction and location of toilets must take into account the preferences of all intended users. Therefore future users have to be asked prior to designing and construction
  - about their preference for siting the toilet room;
  - on the most appropriate cleansing materials;
  - about their preferred toilet habit like squatting or sitting;
  - about sanitation related religious norms (for example: direction toilet is facing; separate buildings for men and women);
  - about norms and perceptions related to locally predominating toilet habits.

f) Operation & Maintenance Guidelines

- Provide material for washing hands with soap after using the toilet, and after cleaning a child or a sick person.
- Water must readily be available. Keep a container filled with water handy at the facility at all times.
- Always keep the interior as well as the immediate surroundings of the toilet clean.
- As a daily routine the squatting pan or sitting pedestal has to be cleaned thoroughly by using a toilet brush.
- As a daily routine the toilet floor should be cleaned.
- Refrain from using bio-toxic chemical disinfectants to clean the squatting pan or sitting pedestal. The biological process in septic tanks and any other biological treatment installation could be disturbed and consequently inactive organic sludge will clog the tank volume sooner as designed.
- After each use the squatting pan / the sitting pedestal must be covered by means of a lid.
- Keep the toilet door closed all the times, when in use and otherwise.
- Maintain the superstructure of the facility. Encourage an occasional lime wash to improve the external appearance of the facility. Keep wooden parts painted with either wood preservative or enamel paint.
- Mosquito proof mesh on top of the vent pipe must be inspected regularly and replaced if damaged.
- Ensure that there is adequate drainage around the facility.
- Where public / communal toilets are provided or toilets are shared, a proper cleaning and maintenance system must be established by the community or by sub-contractors.

1.1.2 User Oriented Guidelines

a) Toilet designs should meet the needs of children:

- Provide additional cover to reduce the diameter of the hole in the squatting pan / sitting pedestal.
- Install steps towards pedestal.
- Teach parents to train their children why and how to use toilets.
- Provide hand washing facilities accessible to children's height.
- Toilet cabins should be larger dimensioned as children need support by parents.

b) Toilet designs should meet the needs of disabled persons according to their disability:

- for persons with squatting difficulties:
  - Install a sitting toilet.
  - Make a simple hand support or a raised seat.
- for persons with difficulties of controlling the body:
  - Make supports for back, sides and legs.
  - Add a removable seat belt or bar in front.
- for blind persons:
  - Place the toilet within the house.
  - If the toilet is outside the house, install a rope or fence as guide from the house to the toilet.
- for persons with difficulties to undress:
  - Provide enough space which has to be maintained dry and clean within the toilet room to be used for undressing and dressing.
- for persons with difficulties to sit:
  - Install movable handrails.
  - Install steps towards pedestal.
- for persons who use a wheelchair:
  - Construct toilet room big enough so that a wheelchair can fit inside.
  - The dimension must be wide enough to enter with the wheelchair and turn around inside.
  - Level the path to the toilet room or install a ramp to allow wheels to roll easily in the toilet room.
  - Install an extra wide door for easy access – at least 1.5m.
  - Install a hand rail to make moving from wheelchair to toilet seat easy.
  - Install a comfortable toilet seat / sitting pedestal on the same level as the wheelchair seat.
  - Install arm or shoulder supports close to the pedestal.

c) Toilet designs should meet the needs of elder people:

- Install a sitting pedestal.
- Install a hand rail as support when squatting or standing up.
- Level the path to the toilet room avoiding obstacles on the way.
- If the toilet is outside the house, install a rope or fence as guide from the house to the toilet.
- Provide enough dry space in the toilet for comfortable undressing and dressing.

1.1.3 Setting Oriented Guidelines

a) Hospitals: Ill people need easy access to a toilet as they frequently suffer from reduced mobility.

- The path to the toilet should be straight and easy to find and well signposted.
- Any obstacles in the path to the toilet should be avoided.
- Toilet rooms must be separated for women and men.
- Number of women's toilet cubicles must be 3-fold the number of men's cubicles.
- Urinals are installed for men – 1 for 20 users.
- The number of men toilet cubicles in hospitals shall be calculated as for 20 users per toilet.
- The number of women toilet cubicles in hospitals shall be calculated as for 15 users per toilet.
- A closed container for the disposal of women sanitary napkins has to be provided within the cubicle.
- Cleanliness and continuous maintenance of hospital toilets is crucial for the recovering process of ill people.

b) Schools: when planning / designing school toilets the internal rules of the establishment have to be considered:

- Build separated toilet rooms for girls and boys.
- At Muslim Schools (as for Muslim homes): separated toilet buildings for girls and boys; siting and facing direction must respect the siting of local mosque and the direction to Mecca.
- At least 1 toilet room / 20 girls.
- A closed container for the disposal of sanitary napkins has to be provided within each cubicle for girls and women teachers.
- At least 1 toilet room / 30 boys.
- Urinals for boys should be installed: 1 urinal / 20 boys.
- If use of toilets is only allowed during break time, the number of toilet rooms must be increased up to 15 users per facility.

- Teach teachers to train their students why and how to use a toilet and to wash their hands.
- Hand washing facility must respect children's size.
- A toilet cleaning and maintenance service has to be activated within the school.

c) Public toilets (communal toilets):

- The ratio of women**:** men cubicles should be 3**:**1.
- Urinals should be provided for men (and at lower level at least one for boys).
- Means to wash the hands after defecation with soap should be provided and users should be trained to do so. At least one hand washing facility must respect children's size.
- A communal cleaning and maintenance system must be in place.

d) Emergency situation and camps:

- Defecation fields
    - Should only be accepted in the weeks following immediately after a disaster and not be in use for more than 2 week.
    - Must be installed separately for women and men.
    - Should be spaced according to distribution of people in the camp.
    - Should be located on sloping land, away from shelters and water resources.
    - Easy access must be ensured without too far to walk.
    - Soil should be easy to dig to cover faeces.
    - It must be ensured that no surface pollution happens.
    - Dimension should be as large as possible to be safely managed.
    - Screens made of plastic sheets and wooden frames should be installed providing basic privacy and sight protection.
    - Sanitary Assistants as supervisors for women's field and men's field should be named.
    - Hand washing facilities at the entrance/exit must be provided.
- Trench latrines:
    - A shallow trench latrine should not be used longer than 3 weeks.
    - A deep trench latrine should not be used longer than 6 weeks.
    - Trench latrines should be provided separately for women and men.
    - Easy access must be ensured without too far to walk
    - Cover slab with hole and foot rests, made of concrete or wooden blanks, must be installed.
    - Privacy should be provided by improved superstructure made of wood, corrugated iron sheets or prefabricated toilet cubicles.

- Sufficient number of latrines to cope with peak use in the morning and evening must be provided, applying a design for a maximum of 25 people/m length of trench per day.
- At least one separated compartment for disabled persons should be provided.
- Sufficient soil to cover the content of the trench must be provided.
- Sanitary Supervisors must be in charge for women's and men's toilets; they must several times a day clean the foot boards and surrounding areas and periodically cover the trench content with 5 to 10cm soil.
- Hand washing facilities has to be installed at the entrance/exit.

e) Transitional Shelter and Camps:

- Shared toilets:
  - Calculated utility time should be at minimum 1.5 years.
  - If not to be used after decommissioning of the camp, the toilet and treatment facilities must also be decommissionable.
  - Construction should be resistant to variation of weather conditions throughout the year.
  - There should be a maximum of calculated 20 users per toilet.
  - Toilet facilities should be separately designated to women and men or to up to two families.
  - If toilets are not under the responsibility of families, a community based service for cleaning and maintenance has to be implemented.
  - Water supply for personal cleansing has to be secured.
  - A closed container for the disposal of women sanitary napkins has to be provided within each cubicle.
  - Hand washing facilities have to be installed at the entrance/exit.
- Individual household toilet:
  - According to environmental conditions a pour flush or a dry / composting toilet with urine diversion device should be installed.
  - Toilet room dimensions and devices should be adapted to user needs.
  - In case of dry toilet, sufficient amount of ash / lime / soil / saw dust has to be available for covering faeces after toilet use.
  - In case of dry toilet: once a week additional amounts of ash / lime / dry soil / saw dust have to be added.

1.2. Guidelines for Treatment options

1.2.1 General Guidelines

a) For sanitation to be sustainable, affordable and environmental it is essential that the selected treatment technology and process are appropriate to the local conditions.

b) Technologies for the treatment of human excreta and urine should be considered as technologies recovering valuable nutrients and useful by-products for agriculture, forestry, gardening, and greenery, avoiding pollution of ground and surface water and contamination of soil.

c) The ecological and economical impact of treatment technologies should be calculated for 20 years of utility.

d) Final products from treatment installations (sludge) have to be hygienically safe without any hazardous impact on public health and environment. Therefore Open Defecation Fields, Trench latrines, conventional deep Pit latrines and Ventilated Improved deep Pit (VIP) latrines are not considered as components of sustainable and environmental sound sanitation systems.

e) Results of treatment technologies and processes (treated wastewater as effluent) must fulfil Sri Lankan *General Standards for Discharge of Effluents into Inland Surface Water & Tolerance Limits for Industrial and Domestic Effluents Discharged into Marine Coastal Areas*.

►►**Appendix 4b**►

f) An overall assessment of related criteria has to be carried out when planning the implementation of a sanitation system.

g) Operation instructions for any treatment technology have to be respected in order to ensure and maintain the successful implementation of the treatment processes.

h) Maintenance must be carried out for all treatment technologies referring to the specific requirements of each process in order to keep the systems well operating.

i) Neighbourhood or community based treatment options have to be explained to the concerned population in order to achieve their informed choice and ownership.

j) If neighbourhood or community based treatment options are selected, a responsible person or committee must be selected and trained.

k) Costs for operation and maintenance should be analysed and shared by users.

l) Operation and maintenance should be carried out that way that personal and environmental damages do not occur.

2. TECHNICAL OPTION SHEETS

Recommended sanitation options are explained in detail in the following technical option sheets. These are arranged according to the potential path of wastewater: beginning at the toilet, continuing with pre-treatment, transport / collection, and ending with secondary and tertiary treatment.

The technical options are categorized as follows:

Toilet	Pre-treatment	Collection	Secondary Treatment	Tertiary Treatment
Toilet house	Septic tank	Vacuum sewer	Anaerobic sanitary system	Horizontal flow gravel filter
		Small bore sewer	Baffled reactor	Vertical flow filter
		Gravity sewer		French drain filter
Special On-Site New Movable Improved Shallow Toilet (SON-MIST)				
Dry, urine diversion toilet				

Combinations of different technical options are possible.

Nr. 1 Toilet House

Keyword: sanitation, structure, toilet, pour flush, collection, wastewater



Description

Toilet houses provide privacy and security to the user during defecation; they should permit comfortable toilet use. Pour flush toilets are the most common toilet models in Sri Lanka, collecting the blackwater and transporting it to any of the possible collection and treatment systems.

The toilet house must fulfil requirements as stated in the guidelines ►►**page 4 onwards**►

The technical requirements are also highlighted in the plan below.

The same requirements must be fulfilled by toilet rooms located within houses.

System is applicable under the following conditions

Can be constructed at all locations because the height of the elevation of the toilet house can be adapted to the ground and groundwater conditions – and therefore the selected treatment option.

If a pour flush toilet is used, water supply for flushing must be secured.

Typical Example

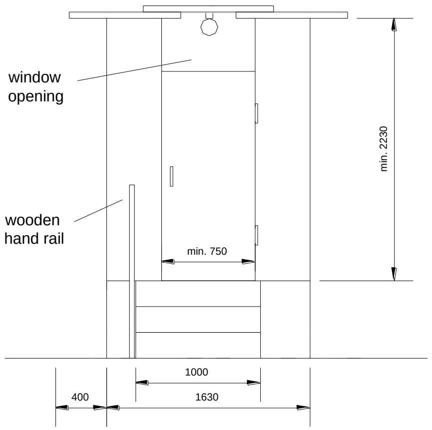
The following displays an example of a pour flush toilet.

The designed system has its complete substructure above the ground. This allows gravity flow from the toilet to the treatment facility.

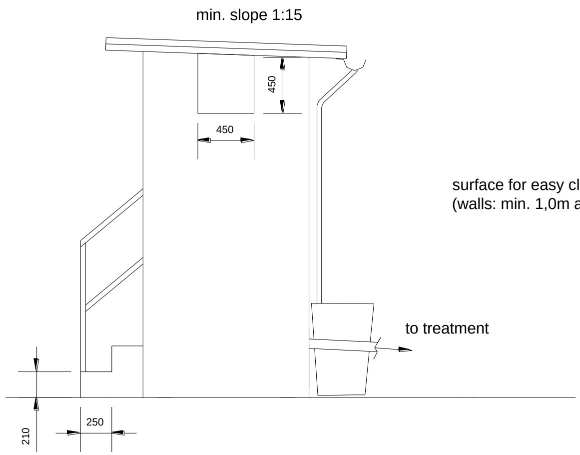
The super-structure, which is designed to fulfil the requirements of the guidelines, is constructed with 115mm width cement blocks and has a reinforced concrete slab roof. Alternatively, other locally available materials can be used (especially for transitional settings more low-cost materials may be appropriate).

The sub-structure is constructed to fulfil structural stability; water-proof construction is not necessary.

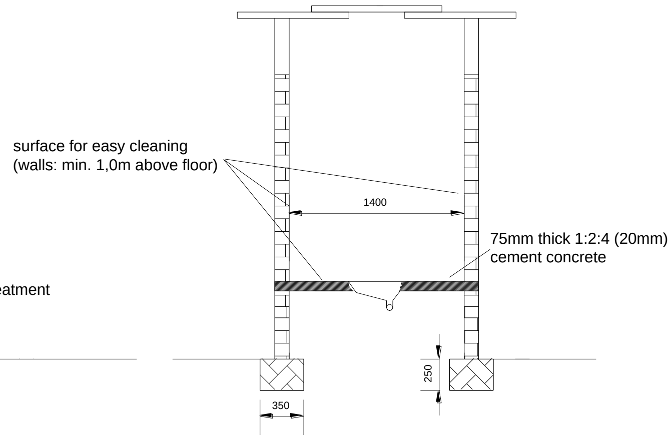
Front Elevation



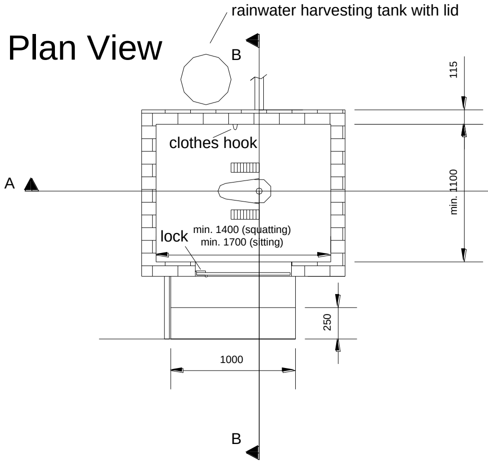
Side Elevation



Section A-A



Plan View



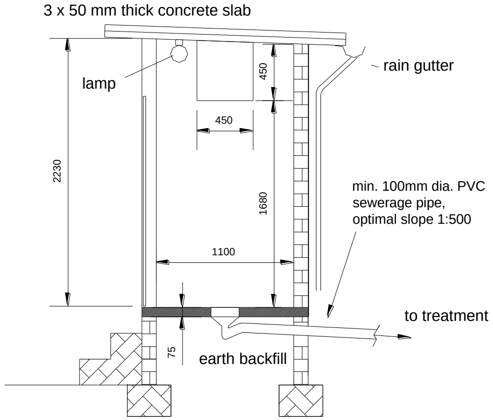
The entrance to the toilet house can also be moved to the shorter side, if space requirements or user preferences make this more appropriate.

If only one outside wall exists, a window opening of at least 0.2m² should be provided. If more than one outside wall exists, at least 2 walls should have a window area of at least 0.2m² each.

The toilet house can also have a lower elevation, if adequate treatment can still be provided (lower groundwater table permits lower location of treatment; gained elevation results in added soil zone for treatment). Flooding during rain must be prevented.

The toilet house should have a lockable door (min. width 750mm), hook for hanging clothes, toilet brush and light, if possible.

Section B-B



Bill of Quantities

Materials	**Estimated amount**	**Unit**	**Comments**
Masonry, superstructure, 115mm thick brick work using 1:5 cement mortar	6.75	m^2	The design should be adapted to local conditions. • Different building materials may be more readily available and therefore more appropriate in certain locations. For construction material ►►**Appendix 3**► • Users may prefer different toilet models (sitting or squatting; concrete, plastic or porcelain); in case of sitting toilet minimal room dimensions are 1.7m x 0.8m • Disabled persons require larger room area for wheelchair access ►►**Vol.III, page 7**► • Dimensions may vary due to space constraint.
Masonry, substructure, 115mm thick brick work using 1:5 cement mortar	3.2	m^2	
Foundation & steps, 150mm-225mm R.R.masonry in 1:5 cement mortar	0.93	m^3	
concrete floor, toilet room & chamber, 75mm thick 1:2:4 (20mm)	1.55	m^2	
concrete roof slabs, 1:2:4 (20mm), form work	3	number	
floor rendering, 15 mm thick 1:3 cement sand, smooth with cement slurry, 100mm high red cement skirting	1.4	m^2	
15mm thick 1:1:3 cement lime sand semi-rough plaster, inside and outside, walls and roof	20	m^2	
one coat of approved quality water proofing, roof slab			
SUMMARY			
Cement	8.4	bag	
Sand	1.3	m3	
Aggregate 20mm	0.50	m3	
Rubble 150 x 225mm	1.1	m3	
115mm cement blocks	262	number	
Excavation	0.58	m3	
Earth backfill	0.8	m3	
Steel bars, 10mm dia	24	m	
Binding wire	0.25	kg	
PVC Pipe, 50mm dia	3.5	m	
PVC L-piece, 50mm dia	2	number	
PVC T-piece, 100mm dia	1	number	
PVC L-piece, 100mm dia	1	number	
PVC Pipe, 100mm dia	3	m	
Handrail, wooden	1	number	
Door, wooden, ledged and battened, 750mm x 1675mm	1	number	
Door frame			
Lock, hook & hinges	1	number	
Lamp	1	number	
Gutter	1.7	m	
Rain drain	1.8	m	
Rain collection barrel	1	number	
Red cement powder	0.5	kg	
Squatting pan	1	number	

Design Variations

Users can install a toilet bowl according to their liking or needs: sitting, squatting; made of plastic, concrete or porcelain.

The superstructure can be made from any materials. Structural stability, minimal dimensions and adequate protection against vision and rain must be ensured.

The required window area can either be one or two large window openings or scattered small openings by leaving out single blocks during block or brickwork of the walls.

The inside walls and floor must allow for easy cleaning. Surfaces can be covered with ceramics, tiles or a smooth painting.

The roof slabs in the example facilitate handling. Other roof constructions can be chosen. Structural stability (esp. up-lift during storm) and water-proofing against rain must be ensured.

Adaptations are required for disabled persons (see guideline).

Operation & Maintenance

Water must readily be available. Keep a container filled with water handy at the facility at all times.

Provide material for washing hands with soap after using the toilet, after cleaning a child or a sick person.

Always keep the interior as well as the immediate surroundings of the toilet clean. As a daily routine the squatting pan or sitting pedestal has to be cleaned thoroughly by using a toilet brush. The toilet floor should also be cleaned daily. Refrain from using chemical disinfectants to clean the squatting pans or sitting pedestals.

Keep the toilet door closed all the times, when in use and otherwise. Maintain the superstructure of the facility. Encourage an occasional lime wash to improve the external appearance of the facility. Keep wooden parts painted with either wood preservative or enamel paint.

Ensure that there is adequate drainage around the facility.

Where public / communal toilets are provided or toilets are shared, a proper cleaning and maintenance system must be established by the community.

Cross-Check – System not to be applied under the following conditions

Inadequate water supply for toilet flushing

→ in this case, water supply must first be secured or a dry sanitation system must be applied.

►►**Technical Option Sheet Nr. 3**►

Nr. 2 Special On-Site New Movable Improved Shallow Toilet (SON-MIST)

Keywords: pit, movable, tree planting, ecological, urine diversion, compost & fertilizer, water saving, transitional settlement, landscaping

Description



SON-MIST – movable toilet house structures, making way for fruit tree or compost production

Special **O**n-site **N**ew **M**ovable **I**mproved **S**hallow **T**oilets (SON-MIST) are low-cost, decommissionable toilet facilities **for transitional settlements**. Similar to conventional ventilated sealed pit latrines, SON-MIST reduce the risk of ground water pollution because the shallowness of the pit ensures that the faecal matter is contained within the biologically active upper soil zone. When the pit fills, the toilet house, including the concrete slab, are moved to a neighbouring location and a tree is planted on the site of the first pit. SON-MIST could be improved by installing a urine separation pan with a collection container in case of higher groundwater table and sand soil conditions to avoid infiltration of nitrogen. Decommissioning of the sludge is not necessary as this remains as fertilizer for the trees.

System is applicable under the following conditions:

Suitable **for transitional shelters** – particularly in regions with water scarcity (no flush water)

Suitable in areas with interest in landscaping and seeking to lower decommissioning costs

Not suitable in areas of rocky ground, extremely high groundwater or flooding

Advantages and Challenges

	Advantages	Challenges
Health	- excreta is contained within the pit, and tree protects excreta from accidental exposure - no handling of hygienically questionable material necessary - relatively free of odours and flies	
environment	- faecal matter is contained and decomposed in the biological active soil layers - water-saving - nutrient reuse through composting process and tree planting - urine could be separated and stored for 2 month for sanitization before used as nitrogen-fertilizer	- Promotes fruit-gardening and landscaping
economic	- very low investment cost - no maintenance cost – can be done by the user - micro loan program for banana/papaya/coconut or other fruit tree plant possible	- Should include hand washing facility near the toilet cabinet
social	- allows users to construct toilet house to their liking - maximum 8 users per toilet cabinet - include urinal for men and boys	- requires teaching users to place ash, soil or leaves into the pit every day - hand washing after applying covering material is required
technical	- requires only little space - can be constructed from local materials - no special skills required for construction	- requires availability of ash, leaves, sand or soil

Essential Design Information

SON-MIST is made up from 4 parts:

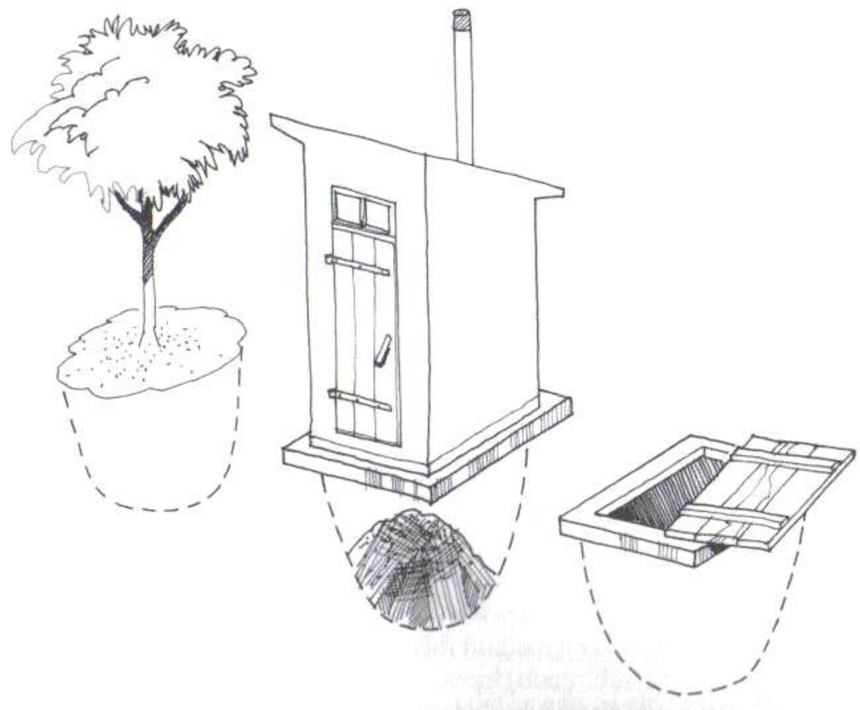
1. The shallow pit
2. The “ring beam” or concrete rings to protect the pit and to support the concrete slab
3. The concrete slab, which sits on the ring beam or concrete rings (could include a urine separation pan)
4. The toilet house constructed with any type of light material which surrounds the slab

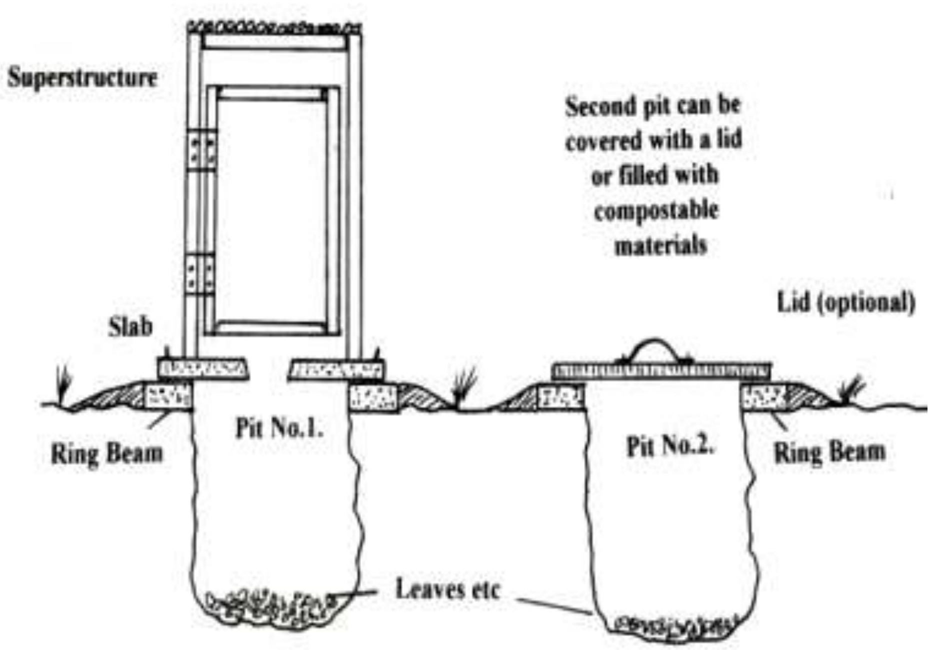
The implementing agency should complete the design, supervise the construction until completion and guarantee the proper function of the system for the time of one year.

Typical Example

The pictures below show a typical SON-MIST.

The slabs can be 1.2 metres in diameter and fit over larger ring beams constructed over pits 1 metre in diameter. The pit should be only between 0.5 m and 1.0 m in depth.





source: Stockholm Environment Institute, 2004

Design Variations

In areas with a very high groundwater table, the toilet house and slab can be slightly elevated with lined brickwork or a concrete ring, partially placing the pit above the ground to provide for additional groundwater protection.

►►**Appendix 4a**►

Although the toilet house should be structurally sound, a light structure is preferred, to allow easy disassembly and movement. Users can design and construct superstructure and cabinet to their liking themselves with local materials.

There are two variations of SON-MIST:

1) When the pit fills, a tree is planted at the location of the old pit and the toilet house is moved to a new location. This process is repeated every time. Smaller pits can be used, but more land is needed, as the toilet keeps moving to a new location.

2) When the pit fills, the toilet is moved to a second location and the first pit is filled-up with soil and covered. The pit should either be large enough to provide the users with one year of usage ($1m^3$) or three smaller pits ($o.5m^3$) should be constructed. After one year, the contents of the first pit will have composted and are hygienically safe. When the last pit is covered and closed, the finished compost can be removed from the first pit and used in the garden. The toilet moves back and forth between the same toilet locations.

SON-MIST could be improved by installing an urine separation pan with a collection container in case of higher groundwater table and sand soil conditions to avoid infiltration of nitrogen. Smell and flies are further efficiently reduced if urine diversion is practiced and if no other organic household waste is thrown into the pit during use as a toilet. Urine diversion toilet bowls or simple funnel constructions installed in the toilet hole can be used to collect the urine. It can be collected separately, stored in air-tight containers for two months and then applied to the garden as a high-quality fertiliser, or led to an infiltration bed together with wash water. ►►**Technical Option Sheet 3**►

Up-Scaling

In decommissioning the toilet, it is possible to improve on the original toilet using the same concrete slab.

Operation & Maintenance

Leaves or paper waste are put in the base of the pit before use.

Faeces should always be covered with a small cup of sand and ash or other dehydrating or degradable material.

Every day some soil, wood ash and dry leaves are added to the pit to control odours and flies, as well as assisting the composting process. No non organic garbage should be placed in the pit.

Filled pits used as composting pits before planting trees – should be protected with cover against playing children.

Keep the toilet clean.

When the pit is full, the toilet house and slab are moved to another place and a thick layer of soil and leaves (150mm) is placed over the pit contents. Depending on the model chosen, a tree can be planted or compost can be produced.

The ring beams or concrete rings can stay in place.

The toilet is used again in the same way at a new location and the process begins over again.

No decommission of the sludge is necessary as this stays as fertilizer for the trees.

Cross-Check – System not to be applied under the following conditions

Not to be used for permanent settlements without sufficient gardening space for rotating toilet cabinet, areas of extremely high groundwater tables, flooding or rocky underground.

Nr. 3 Dry Urine Diversion Toilet

Keywords: dry, urine diversion, compost & fertilizer, ecological, water saving

Description

Dry, urine diversion toilets in Sri Lanka, with pipe for urine and wash water infiltration

Dry, urine diversion toilets combine toilet house and treatment facility into one cost-efficient, space saving, above the ground structure. Urine and faeces are collected separately by special toilet models of various possible designs to create hygienically safe and valuable fertiliser end products from what is normally considered a waste. If accompanied by specific awareness raising campaigns and supervision in the initial phase of implementation, they provide ideal groundwater protection from faecal contamination and protect water resources by eliminating the need for flush water.

The toilet house must fulfil requirements as stated in the guidelines ►►**Vol. III, page 4 onwards**►

The technical requirements are also highlighted in the plan below.

The same requirements must be fulfilled by toilet rooms located within houses.

System is applicable under the following conditions:

Suitable for all geographical conditions – particularly in regions with water scarcity, high groundwater table, flooding area or rocky soil

Recommended for individual households with insecure water supply, esp. where residents did not have toilets or pit latrines before (requiring less behavioural adaptation)

Recommended for individual permanent households or temporary settlements (one toilet per household – user responsibility) where pour flush toilets have failed in the past or will fail because of lacking water supply.

Not recommended for public or communal toilets, due to high possibility of misuse.

As school toilet facilities dry urine diversion toilets are workable following a training of children and teachers.

Urine diversion sets and additional men's urinals could be used to improve existing pit latrines; due to separation of faeces and urine many vectors are controlled, smell is reduced and groundwater pollution protection is improved.

Advantages and Challenges

	Advantages	Challenges
Health	- excellent pathogen retention and treatment in the faeces storage chamber - no handling of hygienically questionable material necessary - no fly or insect breeding	- patience: never touch fresh faeces, even if fertilizer is needed
environment	- faecal matter is prevented from contaminating the groundwater - no smell - water-saving - provides soil conditioner & fertilizer if required	- no use of bleach for cleaning the toilet bowl - use of little water for cabin cleaning
economic	- low investment cost - low maintenance cost (no gully suckers required) - micro loan program for banana/papaya/coconut plant possible	- not only for poor communities - low-cost but durable and representative superstructure
social	- job creation for manufacturing of new toilet models - job creation for social workers - internationally proven to be appropriate to all cultures, gender and user situation	- requires trained social workers for intensive awareness raising to ensure proper use even by visitors
technical	- minimal space requirements - can be constructed from local materials	- requires availability of ash, saw dust, lime or sand - water tight chamber construction is essential; requires good / precise mason skills

Typical Example

The dry, urine diversion toilet presented in the plan and BOQ below can be used to collect and treat the toilet waste of up to 8 adults. The designed system is an example with two chambers for collecting faecal matter.

Urine and wash-hygiene water are diverted to an infiltration bed close to the structure, providing moisture and nutrients to a banana, papaya plant, other plant with large nutrient consumption.

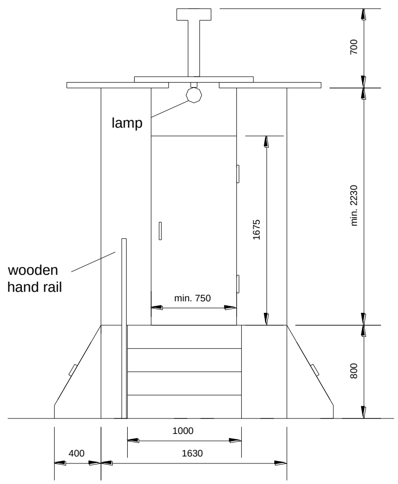
The super-structure, which is elevated to create sufficiently sized faeces chambers below it, is constructed with 115mm cement blocks and has a concrete slab roof. Alternative, other locally available materials can be used.

The sub-structure is water-proofed with plaster to ensure dry conditions, even in the case of heavy rain or flooding. Alternatively, other water-proof material can be used for construction, if they fulfil structural stability and weather resistance.

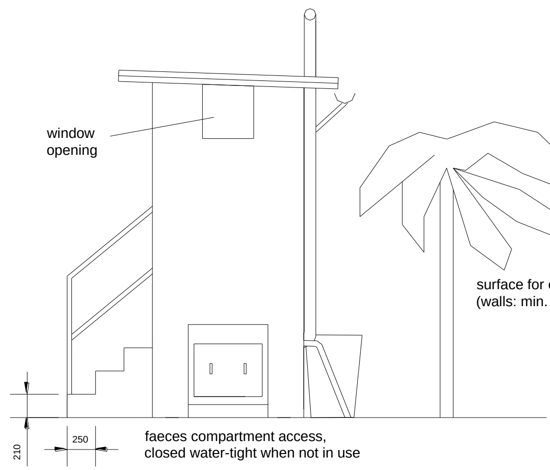
Concrete slabs allow access to the faeces chamber when required.

The implementing agency should complete the design, supervise the construction until completion and guarantee the proper function of the system for the time of one year.

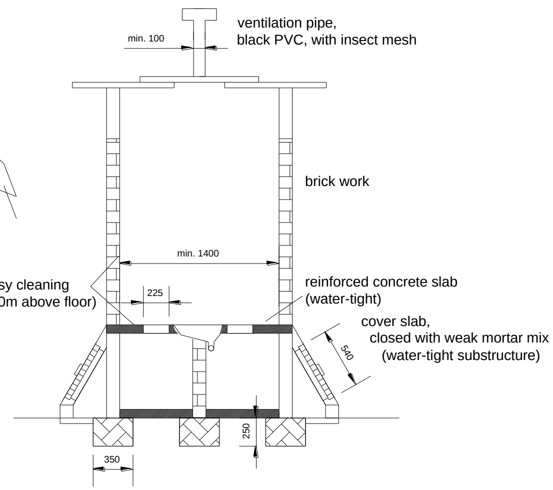
Front Elevation



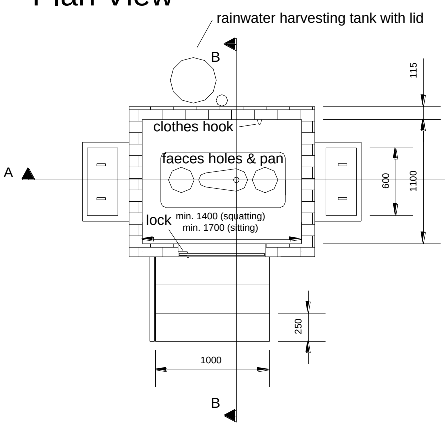
Side Elevation



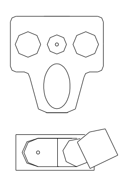
Section A-A



Plan View



alternative urine separation models



two faeces holes (left & right), plastic urine funnel (top middle), wash-hygiene bowl, plastered concrete (bottom)

plastic squatting pan, urine and hygiene-wash water drain (left), faeces hole with sliding foot-operated lid (right)

If storage containers (plastic bins or reed baskets) are placed directly beneath the faeces opening, another kind of urine separation toilet can be used (with only one faeces hole). Movement and replacement of full containers leads to elimination of the separation wall and of one of the compartment hatches, if placed and sized appropriately. It also facilitates handling.

Urine can alternatively be collected separately, stored air-tight for two months, diluted with 10x the amount of water, and used as a fertilizer.

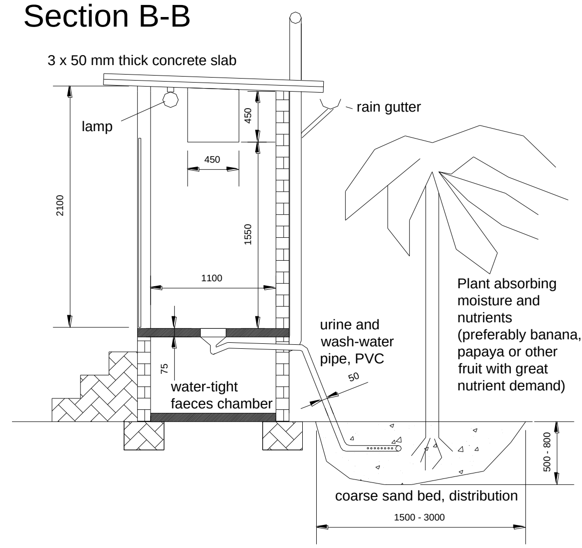
The entrance to the toilet house can also be moved to the shorter side, if space requirements or user preferences make this more appropriate. The openings to the storage chamber can also be from the back to either side of the ventilation pipe.

If only one outside wall exists, a window opening of at least 0.2m² should be provided. If more than one outside wall exists, at least 2 walls should have a window area of at least 0.2m² each.

A slightly elevated location should be chosen to prevent water standing against the sub-structure when it rains.

Section B-B

3 x 50 mm thick concrete slab



Bill of Quantities

Materials	Estimated amount	Unit	Comments
Masonry, superstructure, 115mm thick brick work using 1:5 cement mortar	8.75	m^2	The design should be adapted to local conditions. • Different building materials may be more readily available and therefore more appropriate in certain locations. For construction material ►►**Appendix 3**► • Users may prefer different toilet models (sitting or squatting; concrete, plastic or porcelain). • Users may prefer either the two chamber system or one chamber with storage devices. • Dimensions may vary due to space constraint.
Masonry, substructure, 115mm thick brick work using 1:5 cement mortar	3.2	m^2	
Foundation and steps, 150mm-225mm R.R.masonry in 1:5 cement mortar	0.93	m^3	
Concrete in floor, toilet room and chamber, 75mm thick 1:2:4 (20mm)	3.1	m^2	
concrete roof slabs, 1:2:4 (20mm), form work	3	number	
Floor rendering, 15 mm thick 1:3 cement sand, smooth with cement slurry, 100mm high red cement skirting	1.4	m^2	
Water-tight plaster, substructure	3.0	m^2	
15mm thick 1:1:3 cement lime sand semi-rough plaster, inside and outside, walls and roof	20	m^2	
One coat of approved quality water proofing, roof slab			
SUMMARY			
Cement	11	bag	
Sand	1.8	m^3	
Aggregate 20mm	0.90	m^3	
Rubble 150 x 225mm	1.2	m^3	
115mm cement blocks	340	number	
Excavation	0.58	m^3	
Steel bars, 10mm dia	36	m	
Binding wire	0.25	kg	
PVC Pipe, 50mm dia	3.5	m	
PVC L-piece, 50mm dia	2	number	
PVC T-piece, 100mm dia	1	number	
PVC L-piece, 100mm dia	1	number	
PVC Pipe, 100mm dia	3	m	
Mesh cloth, insect protection in vent pipe			
Handrail, wooden	1	number	
Door, wooden, ledged and battened, 750mm x 1675mm	1	number	
Door frame			
Lock, hook & hinges	1	number	
Lamp	1	number	
Red cement powder	0.5	kg	
Gutter	1.7	m	
Rain drain	1.8	m	
Rain collection barrel	1	number	
Faeces hole lids	2	number	
Banana or papaya, if not already existing	1	number	
Squatting pan	1	number	

Design Variations

Users can install a toilet bowl according to their liking or needs: sitting, squatting; made of plastic, concrete or porcelain. Some separation models are available in a range of colours (eco-solutions). Simple urinals can also be provided to facilitate urine separation and public acceptance.

The superstructure can be made from any materials. Structural stability, minimal dimensions and adequate protection against sight and rain must be ensured.

Urine can collected separately in jerry cans or other containers. If collected, it should be treated by air-tight storage for 3 to 6 month before being diluted 10 to 1 with water and used as a liquid fertilizer rich in phosphorous and nitrogen. Urine Storage: urine could be mixed with/in composted garden waste to get rid of it. It produces valuable compost.

Faecal storage and treatment can be practiced with two possible systems:

a) Two chamber system: the compartment below the toilet is divided into two chambers. When one chamber is full, it is closed and the second one is used. When the second is full, the first is emptied. The toilet room either has two faecal openings (one leading to each chamber), or the toilet bowl can removed and turned around to use the other chamber.

b) Storage receptacles: the compartment below the toilet contains several containers. Plastic bins or locally produced reed baskets can be used. When one of the containers fills, the chamber is accessed and the full container is replaced with an empty one. The full container remains in the compartment. When all storage capacity has been exhausted, the full container with the longest storage time is removed and emptied. Reed baskets are perfect if further composting is desired.

Access to the faeces chamber can be through a water-tight door, a concrete slab or a temporary hole (weak mortar brickwork) in the chamber wall.

The substructure can be created from any materials that provide water-tight conditions in the chamber and structural stability for the superstructure.

The roof slabs in the example facilitate handling. Other roof constructions can be chosen. Structural stability and water-proofing against rain must be ensured.

Up-Scaling

Dry, urine diversion toilets are limited to the use of 8 regular users. If more users are to be serviced, more toilets must be constructed.

Dissemination of the system requires awareness raising campaigns focused on conveying the problems with current sanitation systems (use of limited water resources and risks to health through groundwater and well contamination) and leading the users to the development of dry sanitation systems.

Social marketing requires awareness raising campaigns, introducing the system as a hygienic and advantageous form of sanitation – and not as a compromise. Site visits to existing systems pilot projects are necessary to convince users and decision makers about the practicability and lack of odour of the system.

Large scale dissemination is supported through the creation of a market value and market demand for organic fertilisers. Household gardening activities should be encouraged or contacts to local farmers and fertilizer companies for collection and marketing should be established.

Operation & Maintenance

Urine drains together with the wash-hygiene water and is infiltrated to a plant bed (in Sri Lanka: preferably banana, papaya plant, other plant with large nutrient consumption) outside the toilet house. If urine is collected individually, it should be stored air-tight for two month for treatment, diluted with 10x the amount of water and used as an effective fertiliser in the garden. Collected urine can also be used in post-composting with other organic waste (no meat).

Faeces drop into a water-tight chamber below a larger toilet opening. Instead of flushing with water, the faeces are covered with dry ash, saw dust, lime, dry soil or sand to absorb moisture, prevent insect breeding and to cover the faeces from the sight of the next user. A lid covers the faeces opening when it is not in use. A ventilation pipe ensures a constant draft of air into the faeces opening and up the pipe, ensuring fresh air within the toilet room while drying the faeces. As liquids and solids are separated and well ventilated, the toilet remains odourless and insect free.

The storage chamber must be kept dry at all times; special care to avoid water from splashing into the chamber must be taken during wash-hygiene and toilet cleaning.

Dry material (ash, saw dust, lime, dry soil or sand) should be available to cover faeces at all times.

Illustrated instructions for how to use the toilet should be provided and posted on the walls. Visitors must be instructed to prevent misuse.

Mosquito netting on the top of the vent pipe must be kept intact (monitored once a month).

The faeces opening of the toilet should be closed when not in use.

When the first faeces compartment fills, it is closed for storage treatment of the faecal matter and the second one is used. To prevent human contact with fresh excreta, the faeces are stored in the compartment for a minimum of 6 to 12 months – ensuring pathogen destruction before handling. The stored faeces turn into a hygienically safe soil conditioner. When the second chamber is full, the first one is emptied with a shovel. The non-odorous, soil-like matter in the chamber can either be composted with household solid waste or used as an effective soil conditioner. As a security measure, hand washing is recommended after emptying the chamber.

Local expertise in Sri Lanka

National Water Supply & Drainage Board (contact: D. Senevirathne, Chief Sociologist) - Colombo

Action Contre La Faim (contact: Kannan Pasupathiraj) – Jaffna

Practical Action (contact : Varuna Rathnabharathie, Ganga Kariyawasam) – Colombo, Ambalantota

Approach and Tools:

Community and user participation**:** Workshops with decision-makers in the community and user families, site visits to existing sites, accompaniment during first months

Cross-Check – System not to be applied under the following conditions

Monitoring and guidance cannot be provided in the first months of system operation.

→ experience shows that monitoring should be provided at least once every month for one year.

Nr. 4 Septic Tank

Keywords: pour flush toilets, on-site, wastewater, primary treatment, settling, partial digestion, sludge

Description

Plastic and concrete septic tanks in Sri Lanka

Septic tanks are water-tight containers, which provide primary treatment by separating, retaining and partially digesting settleable and floatable solids in wastewater. They can be used in combination with any type of water seal toilet (preferably pour- or low-flush). Septic tank effluent must receive proper secondary treatment before being discharged to the groundwater or surface water bodies. Directly ensuing soakage pits may not be applied, if the vertical distance from the bottom of the soakage pit to the highest seasonal groundwater is less than 1.5 meters. In these cases, septic tanks must be combined with French drain filters, constructed wetlands, baffled reactors or equivalent treatment. Septic tanks accumulate sludge, which must be emptied after approximately 5 years and treated separately.

Caution is advised: Many applied systems in Sri Lanka are labelled "septic tanks" although their designs are insufficient.

Septic tanks must be designed and constructed in accordance with ►►**Appendix 4a**►

Code of Practice for the Design and Construction of Septic Tanks and Associated Effluent Disposal Systems, Sri Lanka Standards Institution, 2003

System is applicable under the following conditions

Suitable if flush water is available, space requirements are met, and underground septic tank installation is feasible

Suitable in densely populated locations with high ground water table – if secondary treatment can be provided, gully sucker access is possible, and gully suckers and sludge treatment facility is available or can be anticipated

Required before small-bore sewer system ►►**Technical Option Sheet Nr. 5b**►

Not suitable in areas of great water scarcity (lack of flush water) or rocky underground

Advantages and Challenges

	Advantages	Challenges
Health	- no fly or insect breeding - immediate isolation of wastewater from humans	- requires service provision for sludge removal & treatment by community/municipality - tank location must be chosen to ensure access by truck
Environment	- high retention time, good pre-treatment - no surface or groundwater pollution (if constructed water-tight and with appropriate subsequent treatment) - no smell - possible nutrient recovery with appropriate subsequent system	- requires service provision for sludge removal and treatment (see above)
Economic		- relatively high cost per household for septic tank - high long-term maintenance costs (gully sucker)
Social	- water sealed, well-known toilet system - widely used pre-treatment of domestic wastewater	- users must refrain from using chemical cleaners
Technical	- can be constructed from local materials - pre-fabricated models are available - low everyday maintenance requirements	- in areas of high ground water table or rocky underground, toilet must be elevated to maintain the pipe slope towards the septic tank - installation of concrete tanks

Essential Design Information

Structural

Septic tanks must be water-tight and must provide sufficient structural strength and integrity to withstand external soil pressures, internal and external water pressures and any likely imposed loading. Septic tanks situated under driveways and parking areas shall be designed to carry the appropriate vehicle loads.

In areas of high groundwater table, the tank should be filled with water immediately after or during installation to prevent flotation.

Capacity

Septic tank should consist of two chambers (the first one should be twice the size of the second).

The preferred geometry of a septic tank is rectangular, with length between 2 to 4 times the width. Tanks of other shapes such as circular section (with axis either horizontal or vertical) may be used, provided the area of the water surface in the tank during normal operation is sufficient to ensure proper solids separation.

In the absence of detailed analysis, the minimum surface area requirement may be estimated empirically as follows:

Minimum surface area (m^2) = working capacity of tank (m^3) / 3.

The working capacity of a single tank shall always be greater than $1 m^3$ and less than $12 m^3$.

Where the required working capacity exceeds $12 m^3$, parallel sets of tanks shall be used such that the working capacity of each is less than $12 m^3$.

The minimum internal width of a tank shall be 750 mm.

The minimum depth below liquid level shall be 1 m.

The working capacity of a septic tank must be selected appropriately to allow for adequate separation and retention of settleable and floatable solids (see up-scaling section of this chapter for formulas and tables).

Inlet and outlet arrangements

In the case of elevated toilet rooms, exposed pipes should be secured against climbing children.

Tee fittings (allowing access through maintenance openings for cleaning shall be provided at the inlet and outlet.

The inlet fitting shall extend below the water level in the tank by at least 20 percent of the liquid depth. Ideally, it should extend down to 20 cm above the floor of the tank.

The outlet fitting shall extend a minimum of 300 mm below the liquid level of the tank.

The invert of the outlet pipe shall be at least 50 mm below the invert of the inlet pipe.

Access openings

One or more access openings shall be provided for inspection and desludging.

Openings may be circular, square or rectangular. Circular access openings shall be at least 500 mm in diameter. Square or rectangular openings shall have a minimum minor dimension of 500 mm. Septic tank maintenance lids should be secured with concrete slabs or a water tight weak mortar mix to prevent misuse or rainwater & groundwater infiltration.

Freeboard

A minimum of 200 mm freeboard shall be provided between the liquid level and the highest point of the tank ceiling.

The air space thus provided shall have a volume equivalent to at least 10 per cent of the total tank volume.

Chamber partitions

Septic tanks should have multiple compartment tanks. Chamber partitions shall have one or more openings of a total area greater than the area of the inlet to the tank, at a height between 30 – 70 per cent of liquid depth from the bottom of the tank. The minimum dimension of an opening shall be 100 mm.

Vent pipe

A vent pipe of minimum 25 mm diameter shall be provided extending outside the tank to above the toilet house roof.

A single vent pipe is sufficient, provided the air space in each chamber of the tank is interconnected with another through an opening of minimum 25 mm diameter. If not, each chamber must be vented separately.

The pipe shall be covered with a suitable mosquito proof mesh at the top.

Sludge Minimisation

Several simple measures can greatly reduce the amount of sludge accumulation within the septic tank:

- make sure the septic tank is air-tight (providing anaerobic conditions within the tank)
- extend the inflow pipe to 20cm below the floor of the first chamber (to ensure mixing of new with old sludge)
- provide a ventilation pipe, which extends above the roof of the toilet house

Important

Septic tanks only provide pre-treatment. If the distance from the bottom of the intended soakage pit to the highest seasonal groundwater is less than 1.5m, appropriate secondary treatment must be applied.

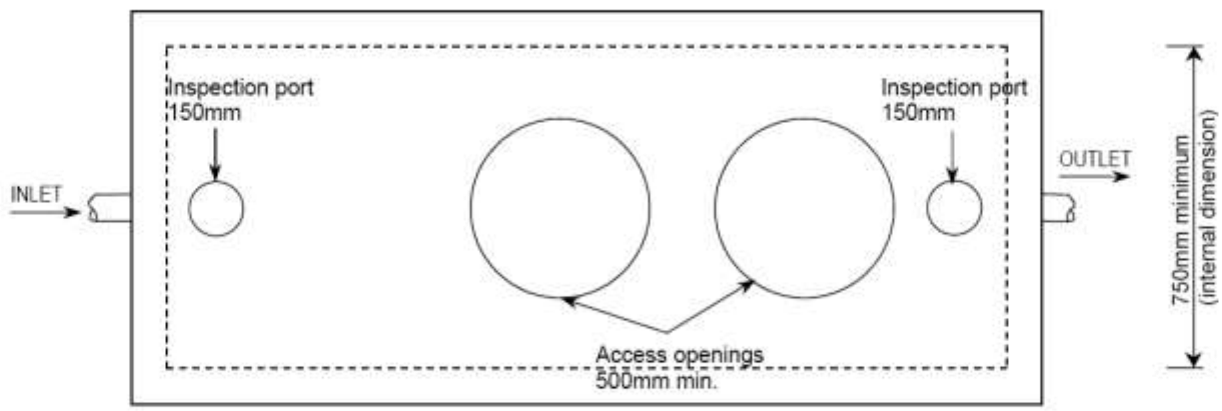
►►Technical Option Sheets Nr. 6, 7, 8 & 9►

The implementing agency should complete the design, supervise the construction until completion and guarantee the proper function of the system for the time of one year.

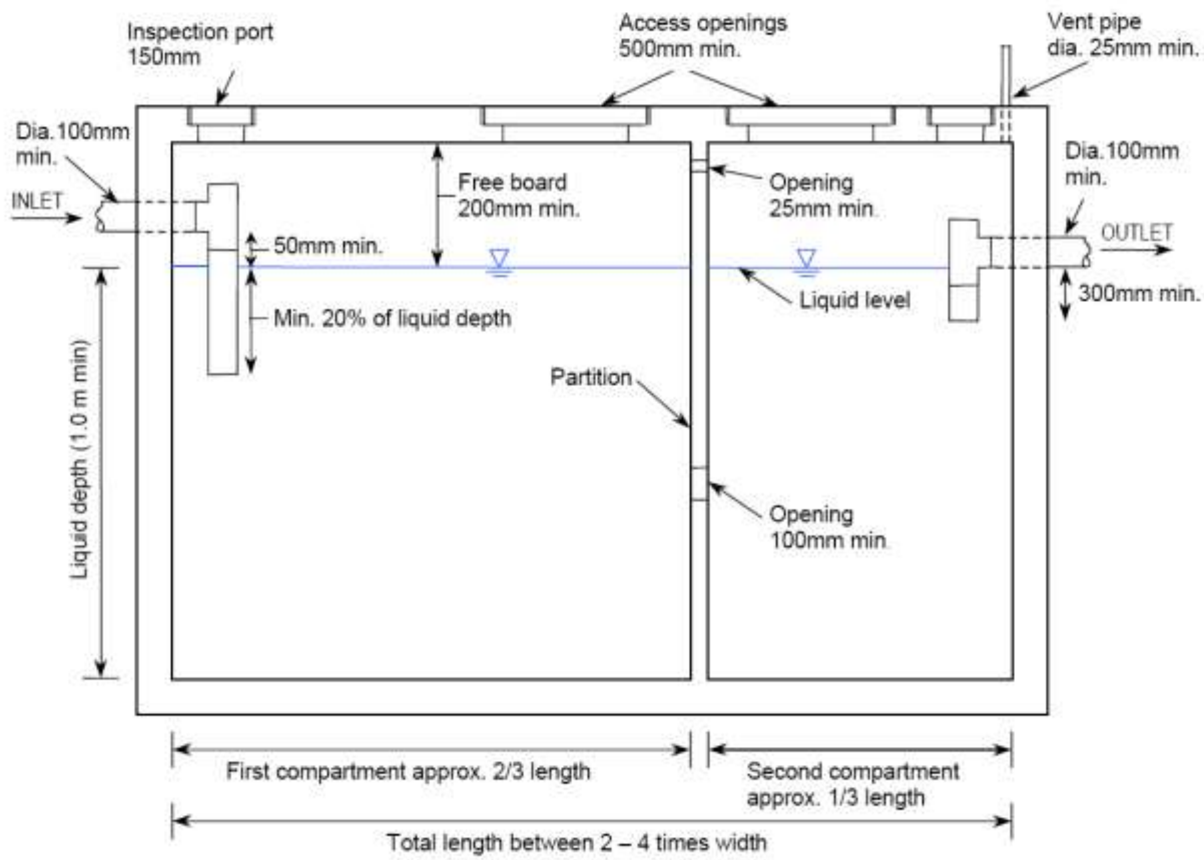
Typical Examples

Depending on site conditions and available materials, septic tanks can greatly vary in design.
The following drawings give an overview over possible septic tank designs.

TYPICAL SEPTIC TANK ARRANGEMENT



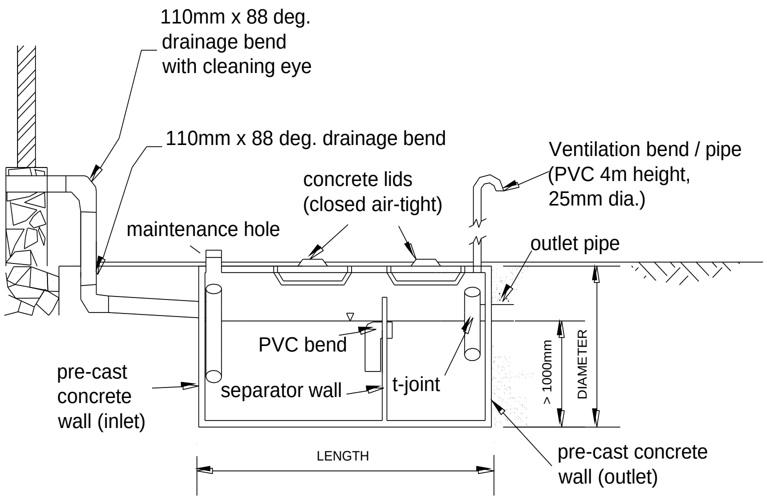
PLAN



SECTION

(Code of Practice for the Design and Construction of Septic Tanks and Associated Effluent Disposal Systems, Sri Lanka Standards Institution, 2003)

Pre-fabricated concrete septic tank



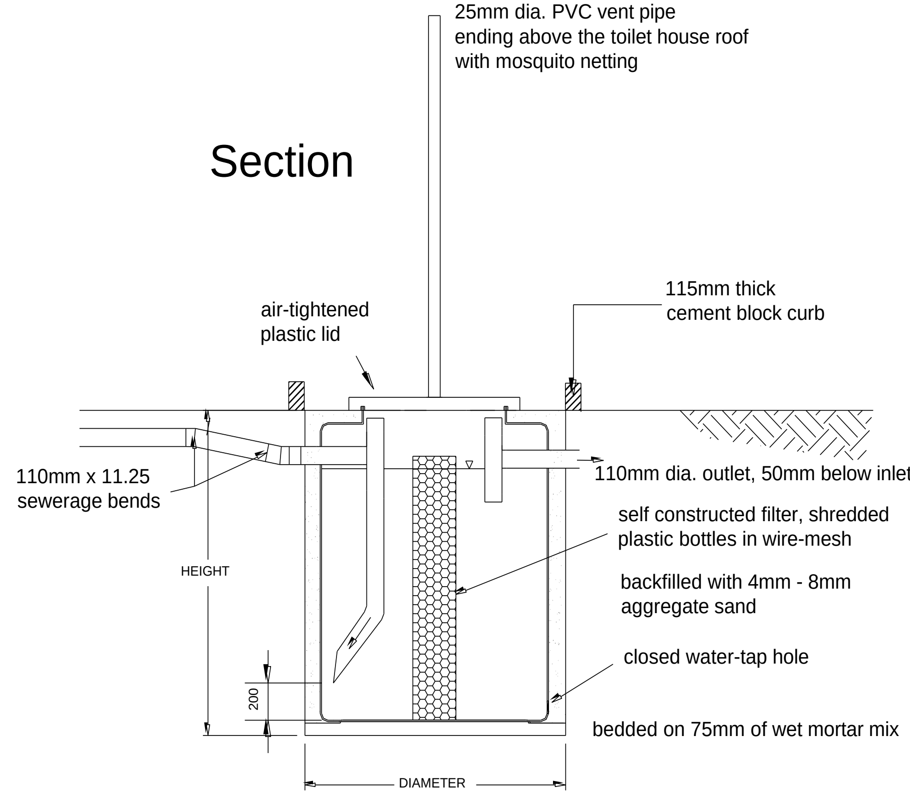
In-situ cast concrete tanks can also be used, but special care must be taken to ensure water-tightness of the tank (floor and walls should be finished with water-tight plaster).

Selected models should be checked to verify that they conform in design and capacity for the intended use.

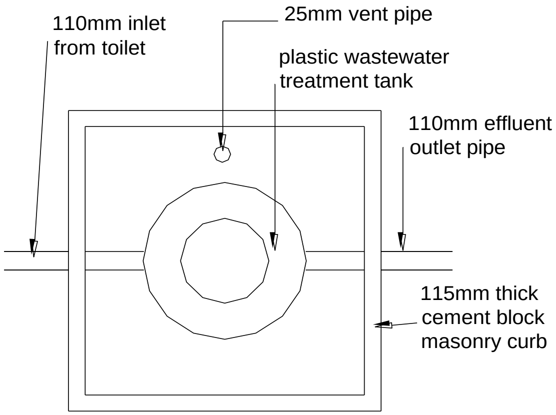
For volume calculations >>page 35>

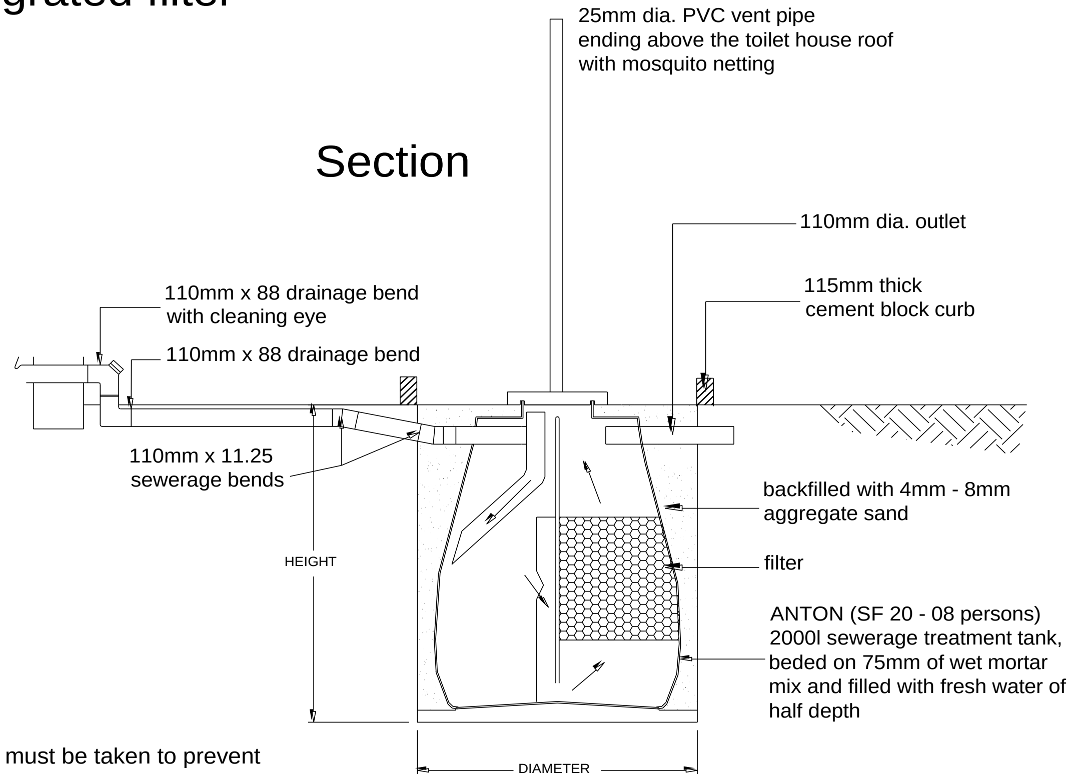
Drinking water tank -

improved to a plug-flow anaerobic septic tank to reduce desludging frequency



Plastic septic tank with integrated filter





Precaution must be taken to prevent overloading of the shell of the plastic tank by the soil/external pressure

ANTON Biocell plastic wastewater treatment tank, cylindrical, standing - including built in filter, recommendable

up to 5 users:	SF16, 1470mm diameter,	1560mm height
up to 6 users:	SF18, 1515mm diameter,	1750mm height
up to 8 users:	SF20, 1515mm diameter,	1900mm height

Plastic septic tanks are also available from GreenTec - without incorporated filter.

Selected models should be checked to verify that they conform in design and capacity for the intended use.

Design Variations

Septic tanks can be constructed in-situ in reinforced concrete, or are available in pre-cast reinforced concrete, glass fibre or polyethylene. Air- and water tightness has highest priority.

Masonry work should be avoided unless material availability permits nothing else and high-quality brick-laying with inside and outside water-tightening plastering on walls and floor can be ensured by quality masons. It should be totally avoided in areas where the tank would be either wholly or partly below the seasonal high groundwater table.

Septic tanks can be rectangular or cylindrical (standing or laying) – short circuiting must be prevented by baffles or separation walls.

In case of extreme space restrictions, pre-fabricated plastic septic tanks with integrated built-in filter are available (see example above), thus achieving a higher degree of treatment.

Septic tanks without integrated filter can be upgraded by placing a self-constructed filter into the tanks. These can be constructed as a wall of shredded plastic bottles, encased in chicken wire and placed vertically in the tank. When the filter clogs, the wastewater will flow over it, allowing continuous use of the system. It can also be easily removed and cleaned. Gloves, shoes and mouth protection should be worn during maintenance.

Septic tanks can also be manufactured by adapting water supply (see example above)

►►**Vol. III, page 32**►

This can reduce septic tank costs by over 50%.

Up-Scaling

Larger amounts of treated wastewater demand larger septic tank volumes.

First, the intended use of the building (including potential future uses), the maximum number of users (for single households, always assume a minimum of 5 residents) and amount of wastewater must be identified.

Then, the working capacity of a septic tank can be calculated as the sum of the volumes required for settling, digestion, as well as sludge and scum storage with the formulas stated below.

If the required volume is greater than $12m^3$, two parallel tanks are required or please refer to technical solutions for larger applications, like “sewer networks”, “biogas treatment” and “baffled reactor / anaerobic filter”.

DETERMINATION OF WORKING CAPACITY OF SEPTIC TANKS.

C.1 The working capacity of a septic tank shall be the sum of the volumes required for settling, sludge digestion and sludge and scum storage and shall be estimated as follows.

C.2 The volume required for settling, shall be calculated as follows.

$V_s = t_s .Q$

Where, V_s = volume required for settling (m^3)

Q = average daily flow of wastewater (m^3/d)

t_s = time required for settling (days)
= (1.5 – 0.3.logQ), (> 0.2) (days.)

C.3 The volume required for sludge digestion shall be calculated as follows.

$V_d = q_s .t_d.p$

Where, V_d = Volume required for sludge digestion (m^3)

q_s = volume of fresh sludge per person per day (m^3/person/day)
= 0.001 m^3/p/d for allwaste or grey water
and = 0.00055 m^3/p/d for blackwater only

t_d = time required for sludge digestion (days)
= 33 days (for an ambient temperature of 20^0C)

p = population equivalent.
= Q (m^3/d)/ 0.2 (m^3/p/d) for allwaste
= Q (m^3/d)/ 0.05 (m^3/p/d) for blackwater
= Q (m^3/d)/ 0.15 (m^3/p/d) for greywater

C.4 The volume required for sludge storage shall be calculated as follows.

$V_{st} = r.p.n$

Where, V_{st} = volume required for sludge storage (m^3)

n = desludging interval (> 1) (years)

r = Volume of digested sludge per person per year ($m^3/p/y$)
= 0.04 $m^3/p/y$ for allwaste or grey water
= 0.022 $m^3/p/y$ for black water only

C.5 The volume required for scum storage shall be taken as $0.5V_{st}$.

C.6 Then the design working capacity of the septic tank shall be

$$\text{Required volume, } V = V_s + V_d + 1.5V_{st} \quad (m^3)$$

Determination of working capacity of septic tanks – Exemplary calculation (spread sheet on accompanying CD)

assumed parameters		
number of people	5	number
amount of wastewater per person and day	0.04	m³/d
Volume of fresh sludge per person per day - q_s	0.00055	m³/(p*d)
Time required for sludge digestion (20°C) - t_d	33	days
desludging interval - n	5	years
Volume of digested sludge per person per year - r	0.022	m³/(p*year)
calculated parameters		
average daily flow of wastewater - Q	0.2	m³
population equivalent - p	4	number
time required for settling - t_s	1.7	days
Volume required for settling - V_s	0.34	m³
Volume required for sludge digestion - V_d	0.07	m³
Volume required for sludge storage - $V_{st, sl}$	0.44	m³
Volume required for scum storage - $V_{st, sc}$	0.22	m³
Working capacity of septic tank - V	**1.07**	**m³**

Required volumes for increased number of household members (under same conditions as stated above)

Number of household members	**V [m³]**
5	1.07
6	1.28
7	1.49
8	1.70
9	1.91
10	2.11
11	2.32
12	2.52

Operation & Maintenance

All systems shall be inspected for structural defects, defects in construction and conformity with the design specifications prior to commissioning. All such defects detected shall be repaired and rectified such that the original requirements have been satisfied prior to commissioning the system. Pre-commissioning tests to ensure water-tightness shall be performed .

Septic tanks must filled up to the liquid level with water prior to commissioning. Since the biological processes within the septic tank require up to six to eight weeks to reach full functioning capacity, the tank may be 'seeded' to accelerate the start-up process. Seeding shall be done by adding a small quantity (up to one fifth the working capacity of the tank) of digesting sludge from a functioning septic tank, or fresh cow dung slurry or pig slurry. The 'seed' shall be added to the first chamber of the tank.

Depending on the size of the septic tank, wastewater quality and the number of users, sludge must be removed from the system every 3 to 5 years. Every 6 months, users should monitor the sludge and scum levels within the septic tank using the 'white towel' test. When sludge accumulation has reached one third to half of the depth of the liquid tank volume, it should be removed. Adequate sludge removal and treatment services must be provided; access to the septic tank by the service must be guaranteed. Tanks should not be completely emptied during desludging. Between 100mm – 150 mm of sludge should be left in the bottom of the tank as 'seed' for the next cycle of operation.

The most common form of blockage is due to solids blocking the inlet device in a septic tank. This may be cleared by rodding the inlet device from above (through an access opening or inspection port) with a suitably flexible rod.

All access covers shall be properly replaced and sealed air-tight after each opening.

Broken and damaged access covers shall be promptly repaired or replaced.

The mosquito-proof mesh cover over vent pipes shall be inspected monthly and replaced as required.

Users should not apply chemical detergents for toilet bowl cleaning to ensure proper treatment and prevent fast sludge accumulation.

They should be trained in the required maintenance during construction.

Approach and Tools

Hygiene promotion programmes;

Training of users on water saving, toilet cleaning & the importance of proper septic tank sludge removal

Cross-Check – System not to be applied under the following conditions

No space for on-site septic tank installation

Great water scarcity (lack of flush water)

Rocky underground (difficult installation)

High groundwater table, appropriate secondary treatment cannot be provided

Site is not accessible by gully sucker

Gully suckers and sludge treatment facility is not available and cannot be anticipated in the near future

Nr. 5 Sewer Systems

This section introduces vacuum (A) and small-bore (B) sewer systems. In part (C) both systems are compared with each other and with conventional gravity sewer systems.

(A) Vacuum Sewer Systems

Keywords

Wastewater, collection, water saving, vacuum, suction pressure

HDPE Vacuum Pipe with individual connection (left), collection chamber (centre), wastewater collection, water supply and storm water drainage pipes in one trench (right)

Description

Vacuum sewer systems are low-maintenance wastewater collection systems, which save water by using air as the main transport medium within the pipelines, by creating a low pressure within the network. They can be combined with any type of (low-)flush toilet (including pour flush) and any form of subsequent treatment unit. They can be installed very close to the surface in all types of terrain and can even transport wastewater around obstacles and up-hill. They require a power supply at only one centralised location.

System is applicable under the following conditions

Most suitable in areas where a collection is needed but other options are too costly or not feasible.

- flat topography: gravity systems demand installation at great depths to maintain adequate flow (pump stations, lift stations)
- rock layers, running sand or a high groundwater table make deep excavation difficult
- areas short of water supply or poor communities that must pay for and cannot afford great amounts of water necessary for operation of gravity systems
- areas that are ecologically sensitive
- areas where flooding can occur
- areas with obstacles to a gravity sewer route
- installation of a new fresh water network, allowing sewerage pipe installation in the same trench
- where potable water is in short supply and/or people are poor, often flushing velocities in gravity sewers are difficult to attain and maintain. A vacuum system relies on the negative pressure to propel the liquid at scouring velocities and it is largely independent of the volumes of water used.

Advantages and Challenges

	Advantages	Challenges
health	- High hygienic safety (closed system) - No pathogen contamination of the groundwater - No rodents in the system - Wastewater is aerated in the pipe, no smell & toxic gases - No toilet backflow or manhole overflow, during flooding	
environment	- Optimal groundwater protection - Significant water savings; air does the flushing - Tool for energy recovery (biogas) from blackwater - Reduction of BOD within the system	- Energy supply required at the vacuum station
Economic	- Low excavation costs, no heavy equipment - Small diameter HDPE or U-PVC pipes (75 to 200mm) - Inexpensive to over-, under- or by-pass obstacles - Water saving and reuse possibilities - Highly concentrated wastewater, results in a smaller and more efficient treatment plant - Reuse possibilities increased	- Investment costs in land for (semi-)centralized treatment - Investment costs in collection chambers, vacuum station and energy stand-by units - Covering O&M costs
Social	- "High tech" appearance facilitates public acceptance - Users do not need to change toilet habits or sanitary devices - Job creation due to shallow trench excavation - Step by step upgrading of sanitation facilities possible without change or upgrading of vacuum sewer system	- Maintenance management is required
Technical	- No heavy equipment required for installation - Modular design possible, can be combined with small bore sewer or gravity sewer - No blockage, clogging or sedimentation – resulting in very low maintenance of the sewer network - No manholes required – no possibility to throw rubbish into the sewer - Water, Gas and Sewage pipes, Electricity and Communication cables can be installed in the same shallow trench - Up-scaling easier than with conventional systems - Technical equipment concentrated at central vacuum station	- Radius 2km - Space requirements for (semi-)centralized vacuum station - Requires an electrical connection at the vacuum station - Requires trained construction workers and operators

Essential Design Information

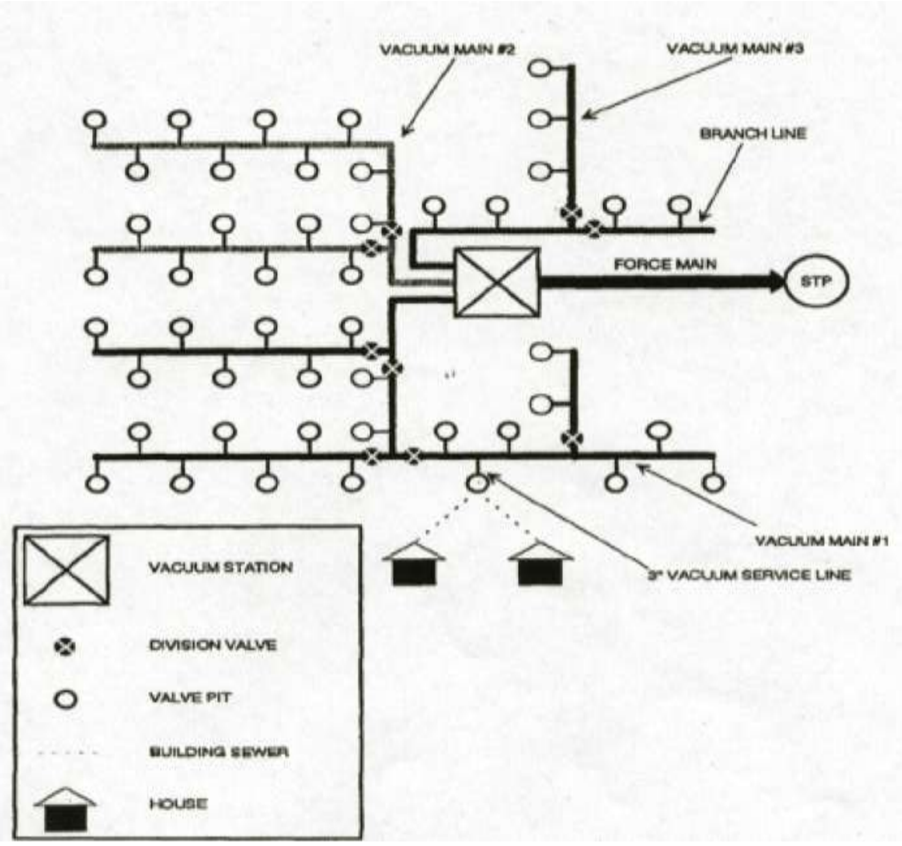
The system consists of three basic elements: collection chambers, sewer network and a vacuum station. The vacuum station creates a low pressure of 0.6 bar within the sewer network with vacuum pumps.

The wastewater drains from the household to a collection chamber by gravity. These chambers are not mechanised and can be located on or near the plot, and can receive wastewater streams from of several neighbouring households. When the wastewater in the collection chamber reaches a certain level, an interface valve is triggered and opens automatically without external power supply. This valve connects the collection chamber to the sewer network. Together with the wastewater, about 6 times more air will be sucked into the system. The air is used as transport medium for the water, reaching transport velocities of 4 to 6 m/s on the way to the vacuum vessel or pump sump in the vacuum station. When the collection chamber is emptied, the interface valve closes again. The pump sump is connected to a treatment facility.

A generator should be provided to act in a duty/standby mode. The vacuum pumps require a power supply of approximately 30 to 40 kWh per connected person per year. Pressure sensors regulate the running times of the vacuum pumps to maintain permanent low pressure in the system.

Collection chambers must be watertight and structurally designed to withstand the forces exerted on them without excessive deflection. They should be sited so that flooding back into homes is prevented. They must be sized to take 25% of the average daily flow before overflowing and should be made of smooth, corrosion resistant material. As the chambers are watertight and could be sealed, they could be placed directly in the groundwater table or in flooded area levels; in this case small diameter venting is required; ventilation pipes should extend above the roof top.

The pipe network is made of PE-HD or polyvinyl chloride (PVC); both can be electro welded or solvent welded (cemented). Only the short gravity sewer from the house to the collection chamber must have a minimum diameter of 100mm and be laid at 1:60 or steeper. The minimum size of the vacuum sewer grid should be 90mm diameter. Pipelines should be designed to withstand the suction internal pressure and temperature. The minimum pressure rating of selected pipes should be 9 bar. Where pipelines are exposed they should be protected from extremes of temperature and ultra-violet radiation. The minimum cover to the vacuum main pipeline should be only 1m and 1.2m under roads. The minimum cover to the vacuum service connection should be 900mm. The vacuum sewer mains and branch connections should have isolation valves ever 500m and 200m respectively.



Source: AIRVAC

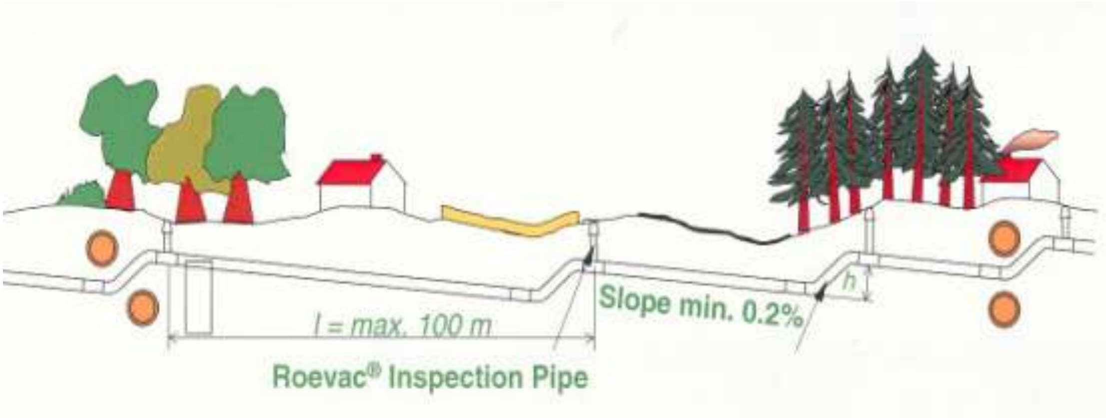
Since the flushing velocity is provided by the suction pressure, the pipelines do not require a downward slope, although they should have a minimum gradient of 1 in 500; however the pipes can even be laid uphill. Lifts – or short upward sections of pipe – can be used to ensure that the pipes do not have to be laid at excessive depths or to avoid objects. It is recommended that the pipe should be laid with a saw tooth profile. All bends should have a radius of 300 mm or more.

There is no need for special sewer drawings as all piping equipment is internationally standardized and available piping equipment and special parts as the collection chamber are provided by the supplier.

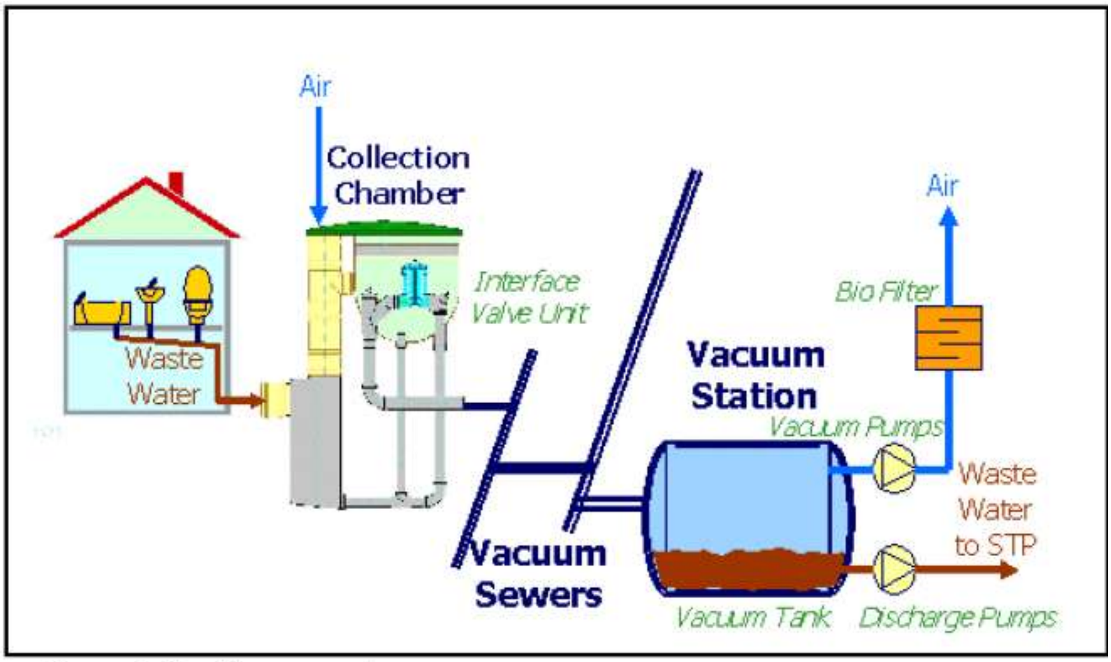
No pump capacities to meet the peak wet weather flow are required for vacuum sewer, compared to gravity sewer and small bore sewer where the wet weather peak flow should be used as design criteria.

In contrary to the Sri Lankan Guidelines 2005, where Water and Waste Water pipes are not allowed in the same trench and where fresh water pipes must always be installed at a higher elevation than sewage pipes, water supply and vacuum sewage pipes can be placed in the same trench. There is no infiltration, no exfiltration and no groundwater contamination (see German Water Association Standard: ATV-DVWK-A116, Part 1; April 2004, page 9).

The implementing agency should complete the design, supervise the construction until completion and guarantee the proper function of the system for the time of one year.



Design of vacuum sewer layout (saw tooth profile), Source: ROEVAC Manual



Source of picture: Roevac manual

Design Variations

The collection chamber can be prefabricated: concrete, fibrous cement, polyethylene high density (PE-HD) or glass reinforced plastics (GRP).

The pipes can be made of PE-HD or polyvinyl chloride (PVC).

The constructional design of the vacuum station can vary, e.g. as monolithic or stonewalled.

Vacuum vessel can be installed in a building or be buried in vacuum chambers made of steel.

The vacuum and sewage pumps (if necessary) are usually rotary vane, centrifugal or rotary piston pumps.

Up-Scaling

As in most developing societies, experience dictates that as living standards are raised, water use increases. This greatly impacts flows and velocities in conventional sewer systems. Vacuum systems however can handle both the initial and final situation, as the system depends on a different principle of liquid transport.

Since the flow can be distributed over time by different sized collection chambers, additional households can be added.

The design of vacuum sewer systems demands engineering expertise and technical understanding. Since specific equipment is required, design features depend on the manufacturer of the vacuum station.

Construction workers must undergo training before installing such a system.

Capacity building training for the design and construction of small is outlined in

►►Vol. I, Chapter 8►

Operation & Maintenance

Technical supervision and pressure test of all piping segments should be done before refilling the trenches.

Ideally maintenance is conducted by the same service provider, who is responsible for the wastewater treatment facility.

The sewer system itself is nearly maintenance-free. Due to the under-pressure in the reticulation pipe system, an extended pump run time, will indicate damage of pipes. Thus periodical control and maintenance of the valves and the piping is not necessary.

Access to pipes can be gained at each collection chamber. Division valves are installed on major branch connections and on the mains to allow for isolation of particular sections for troubleshooting or repairing. Inspection pipes, installed at distances of approx. 100 m permit insertion of inflatable balls and precise location of the problem. Operation & Maintenance personnel should be trained.

The vacuum station should be inspected weekly, collection chambers and vacuum vessel yearly and the valve diaphragm in the collection chamber needs to be changed every 5 years.

User fees or communal payment models should cover maintenance costs. Additional benefits (use of irrigation water or biogas) from the treatment system can be awarded to the personnel.

Cross-Check – System not to be applied under the following conditions

Not to be applied if experts to design and construct the system are not available and training cannot be provided.

Not to be applied if economic comparison favours another type of sewer system.

Not to be applied if storm and household wastewater are to be combined into one collection system.

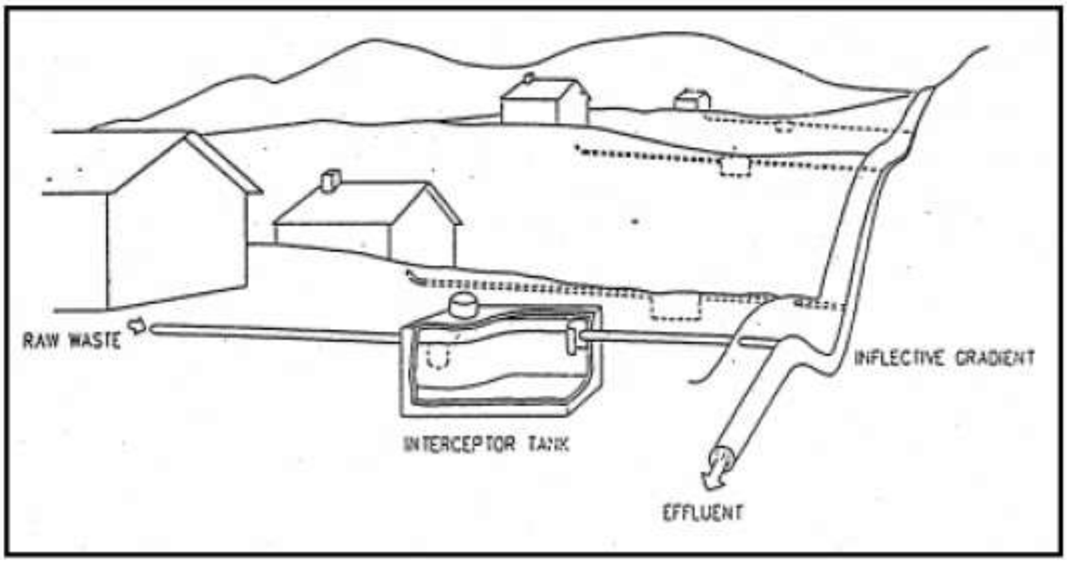
Not to be applied if due to a limitation to maximum design flow, a gravity sewer should be preferred.

(B) Small-bore sewer systems

Keywords

Wastewater, collection, gravity, solid free, common effluent drain

Description



Small-bore systems are wastewater collection systems with smaller diameters than conventional gravity sewer systems. This is made possible by installing interceptor tanks close to the wastewater source, thereby removing most solids from the wastewater before it passes into the collection system. Small-bore sewers can be combined with any type of (low-)flush toilet (including pour flush) and any form of subsequent treatment unit. They function as a result of the elevation difference between inlet and outlet, can be installed very close to the surface in all types of terrain and even allow inflective gradients.

A small-bore sewer is also known by the term "solid free sewer" or "common effluent drain". In this technical option sheet the term "small-bore sewer" is used.

System is applicable under the following conditions

Most suitable in areas where a collection is needed but other options are too costly or not feasible.

- relatively flat topography
- rock layers, running sand or a high groundwater table make deep excavation difficult
- areas short of water supply or poor communities that must pay for and cannot afford great amounts of water necessary for operation
- In high density areas, where the population is relatively poor
- Low density areas, allowing inexpensive sewer construction (due to minimal excavation depths)
- Can be in conjunction with both gravity and vacuum sewers with each system serving a different area

Advantages and Challenges

	Advantages	Challenges
health	- wastewater is lead away from the households	- foul smelling pre-fermented wastewater effluent
environment	- controlled wastewater collection and decentralised treatment	- effluent of system can be odorous and corrosive (careful design required)
Economic	- water saving - small pipe diameters - shallow trench excavation, no heavy equipment required - treatment facility can be smaller due to pre-treatment in household septic or settlement tanks (COD reduction of approximately 50%, nitrogen and phosphorus load is unchanged)	- cost of septic or settlement tanks - maintenance of septic or settlement tanks required, as defined in the Sri Lanka Standard SLS 745 (gully suckers and sludge treatment)
Social	- job creation through hand dug excavation of trenches - users do not need to change toilet habits or sanitary devices	- importance of septic tank maintenance must be understood
Technical	- sewer pipes can be laid at flat gradients and with inflective gradients (good for relatively flat areas) - no heavy equipment required - curves and dips are possible to avoid obstacles	- lacking septic or settlement tank emptying leads to operational problems

Essential Design Information

The small-bore system requires interceptor tanks at the head of the sewer to prevent gross solids entering the sewer. A household that already has a septic tank can therefore readily be connected to a small-bore system. Households that do not have a septic tank will first have to construct a settlement tank. Due to the removal of solids, small bore systems allow flow with small amounts of wastewater. Thereby, poor households with low water consumption can be provided with waterborne sewer connections. The system may or may not include a pumping station. The essential components of the system are described below.

Connection pipe: allows the effluent to gravitate from the house to the interceptor tank. A 100mm diameter pipe at a slope of at least 1:60 is required.

Interceptor tank: is used to settle the solids that are carried in the effluent from the house. It is designed to remove both floating and settleable solids from the liquid stream. The tank is basically a septic tank or to a combined grease trap and settler. Technically, it would be acceptable to provide a tank to be shared by adjoining plots. The level of the tank should be not deeper than necessary so that the maximum potential energy (arising from its elevation) is available to conduct the flow in the main sewer.

Sewers: It is recommended that at least the first two metres of the connecting pipe from the interceptor tank to the plot boundary should have a diameter slightly smaller (50mm diameter) than the sewer main. This would reduce the risks of blockage in the main sewer. Possible misuse of the tank would then result in the plot owner being inconvenienced rather than the neighbourhood. The small-bore sewer mains should consist of plastic pipe with a minimum diameter of 100 mm as this is economical, smooth and resistant to corrosion. They are laid at a sufficient depth to collect the settled wastewater from the tanks by gravity. Unlike gravity sewers, small-bore sewers are not necessarily laid to uniform grades. The sewer may have low points or dips which may remain full under static conditions. The horizontal alignment can also curve to avoid objects. The design of the sewer makes maximum use of the energy resulting from the difference in elevation between the upstream and downstream ends of the sewer. The sewer is not intended to carry solids so is designed on hydraulic considerations only.

Clean-outs and manholes: provide access points to the sewer for the purpose of maintenance and inspection. Manholes are not favoured because they allow the ingress of grit and other solids and they also cost more. Clean-out points are used as a flushing point during sewer cleaning.

Vents: The sewers have to be vented to prevent air-locks. Especially high points of the sewer should be ventilated either by placing a house connection at this point or by installing a clean-out with a ventilation cap.

Pumping stations: are required where elevation differences do not permit gravity flow.

The design procedure for a small-bore system is much the same as a gravity sewer design with the following aspects being calculated in the design of a small-bore system:

Sewer flows: Unlike a gravity sewer, the small-bore sewer can operate on the effluent from a toilet with low water usage. This means that households served by a standpipe or yard tap can also contribute to sewer flows and must be included when sizing the sewers.

Peak flows: The flows that reach the small-bore sewer are attenuated markedly in the interceptor tanks. The attenuation is a function of the liquid surface area in the tank and the length of time over which the wastewater is discharged into the tank. A conservative peak flow factor of 2 is recommended for domestic users. In addition, an allowance must be made for infiltration. The amount of infiltration will depend on the quality of workmanship, the type of pipe used and the dryness of the ground. A conservative allowance of 20 $m^3/ha\cdot$should be allowed if clay pipes are used and 10 m^3/ha for U-PVC pipes. The peak flow from institutional, commercial and industrial contributors must be assessed individually. Pumping stations capacities should be equal to the calculated peak inflow rate to the pumping station.

Hydraulic design: Unlike conventional gravity sewers, which are designed for open flow channel conditions, small-bore sewers can be installed with sections below the hydraulic grade line. Thus flow in a small-bore sewer may alternate between open channel and pressure flow. Separate design calculations or analysis must be made for each sewer section in which:

- the type of flow does not vary, and
- the slope of the pipeline is reasonably uniform. A minimum pipe diameter of 100 mm is recommended in sewer mains. The design must ensure that an overall fall exists across the system and that the hydraulic grade line during peak flow does not rise above the invert of the interceptor tank outlets.

The critical points are:

- the high points where the flow changes from pressure flow to open channel, and
- points at the end of long flat sections

Care with these points must be taken during construction to ensure that the pipe is not laid above the designed elevation. Between these critical points, the sewer can be laid with any profile as long as the hydraulic gradient remains below all interceptor tank outlet inverts and no additional high points are created. The hydraulic design of the pipeline shall be checked to ensure that it can be flushed between successive cleanouts at 0.5m/sec without backing up into adjacent septic tanks. Pipelines should be kept at depths which provide at least the following:

- 300 mm cover on plots
- 1 m cover on public land such as in road reserves
- 1.2 m cover when crossing roads.

Clean-outs should be located as follows:

- at the upstream ends of the system
- at the intersection of sewer lines
- major changes of direction
- at high points, and
- at intervals of 150 to 200 m in long flat sections.

Major pumping stations to serve large drainage basins are conventional in design except that the pumps do not have to have such large capacities because the peak flows are attenuated significantly in the system. It is recommended that pumps that can pump 100mm diameter solids be installed, although the pumps theoretically should not have to pump solids. Corrosion and odours are major problems because of the septic nature of the effluent in small bore sewers. All equipment exposed to the atmosphere in the wet well should be made from non-ferrous materials. All concrete surfaces above the low water mark should be coated with a chemically resistant material. A fresh air vent should be provided at all pumping stations to ventilate the wet well. This should be at least 150mm in diameter and extend at least 9m above ground level so that odours are not a nuisance to the neighbours. Self-priming pumps, with suitable corrosion resistance, situated above the wet well would be ideally suited to this application.

The implementing agency should complete the design, supervise the construction until completion and guarantee the proper function of the system for the time of one year.

Operation & Maintenance

Maintenance of the pipe leading to the on-site septic tank is the responsibility of the plot owner. Maintenance responsibility must be clearly defined if septic tanks are shared by several households. Septic and settlement tanks must be desludged regularly to prevent solids from entering the sewer.

Ideally maintenance is conducted by the same service provider, who is responsible for the wastewater treatment facility. Compared to gravity sewers, maintenance is reduced by the on-site pre-treatment.

User fees or communal payment models should cover maintenance costs. Additional benefits (use of irrigation water or biogas) from the treatment system can be awarded to the personnel.

Cross-Check – System not to be applied under the following conditions

Users do not have water availability for flush toilets → dry system should be considered

Adequately sloping topography allows cost-efficient conventional gravity sewer.

An economic comparison on investment and operation & maintenance costs over lifetime shows that vacuum sewers are preferable.

Experts to design and construct a small-bore sewer network are not available and training cannot be provided

(C) Comparison between gravity, small bore sewer and vacuum system

Comparison between Gravity, Vacuum and Small Bore Sewer Systems

The basic calculation is made upon the assumption that about 50% of the houses have in-house water supply and 50% have backyard taps.

1) Gravity system

Using gravity sewer criteria for a village in Sri Lanka, where a slow connection rate is expected, it can be shown that a sewer serving an area, where 2000 people live at a density of 25 people per hectare requires an elevation drop of approximately 9m. Note that only 50% of the 2000 people can be served because they have house connections and hence enough water to flush the pipes. If the ground surface falls at 1 in 400 the end of the sewer will be about 8m deep. This is impractical to excavate, especially as rock is usually encountered before this depth. To avoid excessively deep sewers it is necessary to either use a flushing tank or construct a pumping station. Both have obvious disadvantages. It is estimated that about 6000m of main sewer would be needed (5400m of 150mm diameter, and 300m each of 200 and 250mm diameter) and one pumping station. The maintenance of the reticulation system plus the operation and maintenance of the pumping station and treatment works make up the operating costs.

2) Vacuum sewer

For the assumed situation, a vacuum sewer may require slightly less than 6000m of pipe because it does not need to follow the contours. In addition, even people with yard taps can connect so all 2000 people have the benefit of a waterborne collection system. All the pipes would have a minimum diameter of 90mm and they lie between 1 and 2m below ground level. About 80 collection chambers are required. In addition, a vacuum station and pumping station (usually combined) are needed. The maintenance of the reticulation system plus the operation and maintenance of the vacuum and pumping station and treatment works make up the operating costs.

3) Small-bore sewer

For the assumed situation a small-bore sewer requires a pipe length of slightly less than 6000 m because it is not forced to follow contours. All people can connect to the waterborne wastewater system. Nearly all the pipe work would require a minimum diameter of 100mm, but about 300m will require a diameter of 160mm. The depth of the trenches would be in the range of 1 to 2.5m and 330 interceptor tanks would need to be constructed. The treatment works would only need to treat half the COD load. The peak hydraulic load would be calculated on a factor of 2 (and not 6). The maintenance of the reticulation system plus the operation and maintenance of the treatment works plus the emptying of the interceptor tanks make up the operating costs.

Conclusion

The conventional gravity sewerage system is well known and is often exclusively associated with waterborne sewer facilities. This often restricts the extent of provision of these services because of either practical restraints or lack of capital. With appropriate design standards the service reliability and functionality of both vacuum and small-bore systems can be ensured, thus allowing waterborne sanitation to be brought to the wider public. In countries like Sri Lanka, these systems also promote water saving as they can operate with low water consumption.

Design comparison	Gravity System	Vacuum System
Pipe Diameters	Large (> 200)	Small (80 – 200)
Pipe Material	PE or stoneware or concrete	HDPE or U-PVC
Trenches	Deep (up to 8 m and more) Wide	Shallow (1 – 1.2 m) Narrow
Excavation	Complicated and long term	Simple and fast
Machinery required	Heavy machinery	Simple or even no machinery
Lifting Stations	Required to avoid deep trenches	Not required
Leakage / Exfiltration	Possible (statistically 30-50%)	Impossible, closed system with under pressure
Infiltration	Possible: storm water, ground water etc.	Not possible, closed system
Traffic (construction)	High impact on local traffic	Low impact on local traffic
Pipelines for fresh water and waste water in the same trench	Not allowed	Possible and allowed
System	Open	Closed
Manholes	Required	No manholes, inspection pipes only
Fouling of waste water	Possible, often when septic tank effluent connected	Not possible, due to aeration
Flushing of pipelines	Required to avoid blockages	Not required

Nr. 6 Anaerobic Sanitary Systems

Keywords

Waste water treatment, black water treatment, brown water treatment, fertilizer, anaerobic, digester, renewable energy, effluent reuse, biogas

Description

Sanitary biogas systems are efficient, hygienic and ecologically sound wastewater treatment units with the additional benefits of energy production and an effluent of high nutrient content. They can be combined with any type of (low-)flush toilet (including pour flush) and their effluent can be used directly for fertiliser application and irrigation. Alternatively, they can be followed by constructed wetlands or other aerobic tertiary treatment to allow other forms of reuse of the effluent for car-washing, toilet flushing or outdoor cleaning purposes. The treatment of organic solid kitchen and garden wastes can also be integrated into the concept to increase biogas production and reduce household waste. Unlike septic tank systems, sanitary biogas units do not require frequent sludge removal.

System is applicable under the following conditions

Suitable under most conditions – floating of the facility during construction must be prevented in areas of high groundwater. Not suitable in areas of great water scarcity or rocky underground.

Public buildings incl. schools with secured – even if limited – water supply, allowing reuse.

Newly constructed residential areas with individual toilets attached via a small bore sewer, gravity sewer or vacuum network: ►►**Technical Options Sheets 5A, 5B, 5C**►

Sanitary biogas systems should compete with costs for septic tanks.

Community sanitation centres in permanent settlements, where residents cannot construct private toilets, due to financial, topographic or limited space conditions.

Depending on local conditions different designs may be appropriate and could be adapted with design support from biogas technology experts.

Advantages and Challenges

	Advantages	Challenges
health	- no fly or insect breeding - hand washing facilities could be installed in the same toilet room, to use water for toilet flushing	- requires post-treatment of effluent if no agricultural, gardening or landscaping use is considered
environment	- high retention time (treatment) of the wastewater - no smell - treatment of all domestic wastewater, including solid organic waste; no stagnant wastewater in the community - no surface or groundwater pollution - no greenhouse gas emissions produced from organic waste and wastewater when treated in sanitary biogas systems and biogas is used	- requires post-treatment of effluent if no agricultural, gardening or landscaping use is considered - Clean Development Mechanism strategies could be added as financing source for dissemination programmes with cluster implementation (www.unfcccc.org)
economic	- comparatively low investment cost, due to material savings of multi-household treatment - recovering costs by water saving and fertilizer use - recovering costs by biogas energy use	- investment costs in land - covering O&M costs
social	- all kinds of toilets could be connected - understanding of link between sanitation and community development	- users / cleaning personnel must be taught to refrain from applying bio-toxic chemical cleaners
technical	- can be constructed from local materials - qualified work for responsible and dedicated masons and plumbers	- space requirements for facility, decision over land use - biogas facility requires training of construction and plumbing workers

Essential Design Information

A sanitary biogas unit must be constructed air-tight to guarantee the intended anaerobic microbiological processes. These processes minimize sludge accumulation (only 10% removable sludge compared with aerobic treatment systems) through acidification, liquefaction, and fermentation of the settled solids and the production of biogas. 80% of the organic matter is converted into biogas, while a residue of organic matter is pushed out in dissolved form as effluent. Subsequently, the rate of degradation equals that of formation – eliminating the need for sludge removal. Since biological activity demands average soil temperatures above 15 degrees Celsius, the system can be operated optimally in Sri Lanka.

If biogas is to be utilised, it can be assumed that the toilet blackwater of approximately 5 households (maximum about 40 litres of biogas/(person x day) are produced without adding other organic waste) are needed to cover the basic cooking needs of one family (1m³ biogas per day). Lighting (heating) with biogas lamps is feasible, but recommendable only as a secondary solution, due to increased maintenance issues and low energy use – only 3-5% of the energy content is used for light, the rest is emitted as heat. Try to attach multiple wastewater producers, as the cost per capita decreases with the size of the treatment facility. Incurring costs are offset by the benefits from use of the gas for cooking or lighting. For volume consideration it must be considered, that it takes at least twenty days to eliminate 90% of UOD (ultimate oxygen demand) from blackwater. And pre-sanitization of blackwater takes at least 50 days at temperatures around 30 degrees Celsius.

The implementing agency should complete the design, supervise the construction until completion and guarantee the proper function of the system for the time of one year.

Typical Example

The following biogas digester can be used to treat domestic toilet wastewater of 50 users.
The designed system is a fixed dome reactor with a flat bottom slab.
The dome is constructed of brickwork (l = 23cm, w = 13cm, h = 7cm, tensile strength = 330kN/m^2).
Other locally available water- and gas-tight materials with a similar tensile strength can also be applied.
The digester receives a water-tightening plaster of 2cm thickness on the inside and outside.
The bottom slab is constructed of 7cm thick concrete with a reinforced foundation ring.

The biogas digester has the following technical parameters:

• retention time	50 days
• digester volume	28.25 m^3 net
• gas production	3.02 m^3/day
• gasholder size	3.02 m^3
• digester / gasholder ratio	9.3 : 1
• inner radius of hemisphere	2.46m
• lower slurry level	1.62m
• upper slurry level	1.97m

A cylindrical displacement tank was chosen:

• cylindrical unit volume	3.02m^3
• radius of the tank	1.33m
• height of the overflow	0.54m
• wall and bottom slab thickness	7cm
• maximum gas pressure	0.88 m WC

Assumptions made in design:

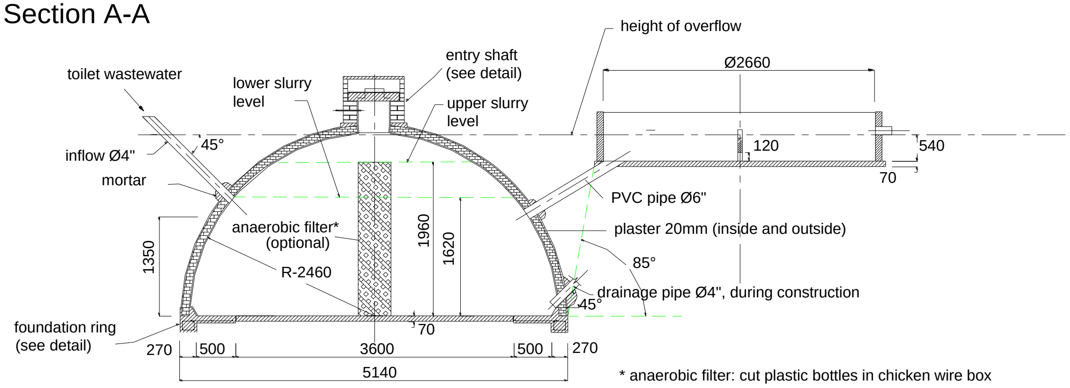
• Average feed load per person & day	1.3 kg, 20% total solids content, 15% volatile solids
• flush water per day/person	10 litres
• average digester temperature	26°C

Assumptions result in wastewater of the following characteristics:

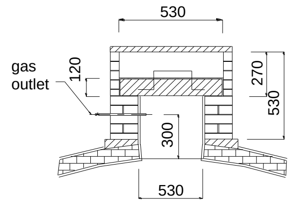
• total solids content of wastewater	2.3%
• volatile solids content	1.73%

Biogas digester

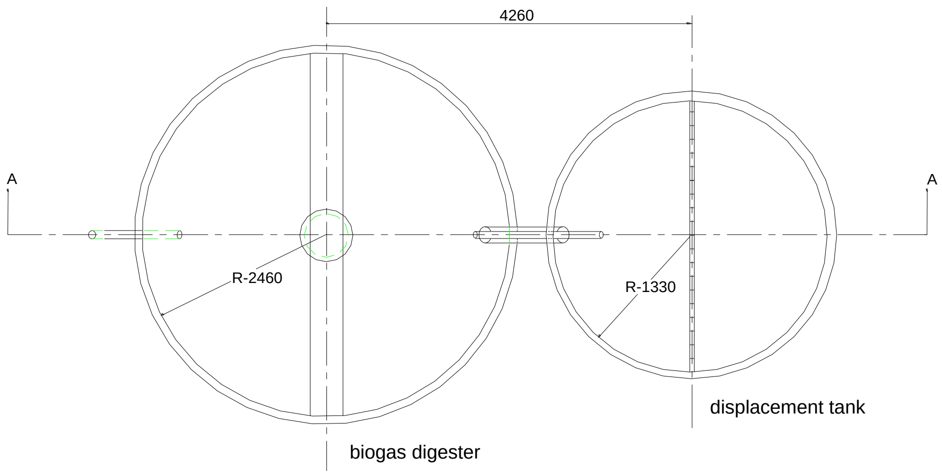
Section A-A



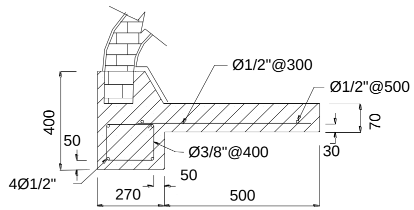
Detail: entry shaft



Plan View



Detail: Foundation



treatment of blackwater from 50 people:
digester volume - 28.25 m3
volume of displacement tank - 3.02 m3

Bill of Quantities

Materials	estimated amount	Unit	Comments
Masonry, entry shaft	0.17	m^3	The design should be adapted to local conditions. • Different building materials may be more readily available and therefore more appropriate in certain locations. • Dimensions may vary due to space constraints. • Different physical conditions (soil, temperature, wastewater composition) will influence the design. • Construction and maintenance labour knowledge and capacity influence appropriate design option (prefabricated or locally constructed)
Masonry, hemisphere	2.71	m^3	
Masonry, displacement tanks	0.39	m^3	
Mortar for masonry	0.26	m^3	
Concrete, foundation	2.27	m^3	
Concrete, entry hatch	0.06	m^3	
Concrete, bottom slab, displacement tanks	0.43	m^3	
Gas-tight plaster, gasholder	0.26	m^3	
Gas-tight plaster, inner surface	43.63	m^2	
Gas-tight plaster, outer surface	47.07	m^2	
SUMMARY			
Bricks	1562	pieces	
Concrete	1218	kg	
Lime	92	kg	
Gravel	1.58	m^3	
Sand	2.15	m^3	
Inner plaster	0.87	m^3	
Outer plaster	0.94	m^3	
Ground excavation	65.25	m^3	
Inlet PVC pipe 4 inches	1.72	m	
Outlet PVC pipe 6 inches	1.68	m	
Reinforcement bars ½”	25.75	m	
Reinforcement bars $^3/_8$”	24.50	m	

Note:

Bill of Quantities (BOQ) for gas pipes and equipment depends on distance from biogas digester to location of gas utilisation.

Material specifications

	Cement	Lime	Sand	Gravel
Concrete	1	0	2	4
Plaster	1	0.25	4	0
Soft mortar	1	3	15	0
Gas-tight plaster	1	0.25	2.5	0

For more detailed information on material specifications for water and air-tight structures

►►**Appendix 3**►

Up-Scaling

The design of biogas digesters demands engineering expertise. The factors decisive for design are too complex to be expressed in simple up-scaling tables.

Construction must be carried out by qualified masons.

Capacity building, i.e. training for design and construction of biogas digesters is outlined in

►►Vol. I, Chapter 8►

Operation & Maintenance

Toilet users must be advised not to apply chemical detergents for toilet bowl cleaning, as their application kills the active bacteria in the digester – disabling the treatment process and resulting in fast sludge accumulation, which must be removed from the digester and can plug following treatment units.

Maintenance must be carried out by trained personnel, which should be trained during the construction process.

The trained personnel should check all control openings weekly and remove any obstructions to the regular flow.

If biogas is utilised, storage, pipelines and appliances must be monitored regularly by trained personnel.

User fees or communal payment models should cover maintenance costs. Additional benefits (use of irrigation water or biogas) can be awarded to the personnel.

Local expertise in Sri Lanka

Practical Action, Colombo is part of the Sri Lankan biogas network.

Approach and Tools

Hygiene & Health promotion campaign; if shared toilets: education for ownership and responsible use of toilet facilities; decision-making process over communal / private land use for treatment facilities.

Cross-Check – System not to be applied under the following conditions

Users do not have water availability for flush toilets

→ Dry system should be considered ►►**Technical Option Sheet Nr. 3**►

Rocky underground

Knowledge of the system is not available and training is not possible

Nr. 7 Baffled Reactor

Keywords

Pour-flush toilets, low-flush toilets, natural treatment, DEWATS, effluent reuse, community ownership, biogas

Description

inspection opening, baffled anaerobic filter, constructed wetland with effluent reuse (irrigation & car washing), Kandy, Sri Lanka

Baffled reactors, also sometimes called baffled septic tanks, are efficient, hygienic and ecologically sound anaerobic treatment units for collected organic wastewater. They can be combined with any type of (low-)flush toilet (including pour flush). Constructed out of local materials, the system provides easy maintenance, easily available spare parts and low operational costs; it does not have treatment process relevant movable parts and is not dependant on external energy inputs, like electricity. If the landscape is slightly sloped, water flow is caused by natural gravity, therefore no pumps are required. Effluent can be used for fertiliser irrigation or other forms of reuse for car-washing, toilet flushing or outdoor cleaning purposes, if followed by constructed wetlands or other aerobic tertiary treatment. If baffled reactors are constructed gas-tight, biogas can be collected and used

►►**Technical Option Sheet Nr. 6** ►

System is applicable under the following conditions

Suitable under most conditions – floating of the facility during construction must be prevented in areas of high groundwater. Not suitable in extremely water scare areas without secured water supply (lack of flush water) or rocky underground.

Public buildings incl. schools with secured – even if limited – water supply, allowing reuse.

Newly constructed residential areas with individual toilets attached via a small bore sewer, gravity sewer or vacuum network (see appropriate chapters). Baffled reactor should compete with costs for septic tanks.

Community sanitation centres in permanent settlements, where residents cannot construct private toilets, due to financial, topographic or limited space conditions.

Advantages and Challenges

	Advantages	Challenges
Health	- no fly or insect breeding - hand washing facilities can be installed in the same toilet room, as this used water can be used to flush the toilet pipe	- requires service provision for primary settled sludge removal and treatment – location should ensure access by truck (not necessary if biogas tank or plug-flow anaerobic septic tank)
Environment	- high retention time (treatment) of the wastewater - no smell - treatment of all domestic wastewater, therefore no stagnant wastewater in the community - no surface or groundwater pollution	- requires service provision for sludge removal and treatment (see above)
Economic	- recovering of costs by water saving, reuse and perhaps biogas collection and use	- covering O&M costs - investment costs in land
Social	- all known water flush toilet systems - understanding of link between sanitation and community development	- users / cleaning personnel must be taught to refrain from applying bio-toxic chemical cleaners
Technical	- can be constructed from local materials - qualified work for responsible and dedicated masons and plumbers - no movable parts or energy requirements - easy operation, minimal maintenance - if construction is gas-tight, biogas should be recovered and used/burnt	- space requirements for facility, decision over land use - requires training of construction (and plumbing) workers

Typical Example

The following plans exemplify a decentralised wastewater treatment system (DEWATS) with a combination of septic tank, baffled reactor and anaerobic baffled filter at a hospital with 50 beds.

A sewer network collects the organic wastewater from all parts of the hospital and feeds it into the treatment inlet (A). From there the wastewater is led into a sedimentation chamber or septic tank (B), where it undergoes primary treatment. It continues into a baffled reactor (C), where the wastewater is forced to flow through collected sludge beneath the baffles and then several anaerobic filters (D). With the help of anaerobic bacteria these treatment units are able to reduce BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand) by 80-90%. Finally the wastewater is lead to a constructed wetland (E) – the details of which are discussed in the appropriate technical option sheet – and final treated and/or stored in a polishing ponds (F).

The space requirements for the construction of the anaerobic treatment units (A) through (D) amounts to approximately 60 m^2 and is a closed underground construction. The area above the treatment unit can either be used as construction space for the hospital or other purposes (parking lot, recreation area, etc.) as long as structural demands are met and maintenance access to the chambers can be assured.

The time of completion of the construction is estimated at a period of 6 months. Construction Design sketches and a BOQ can be found on the following pages.

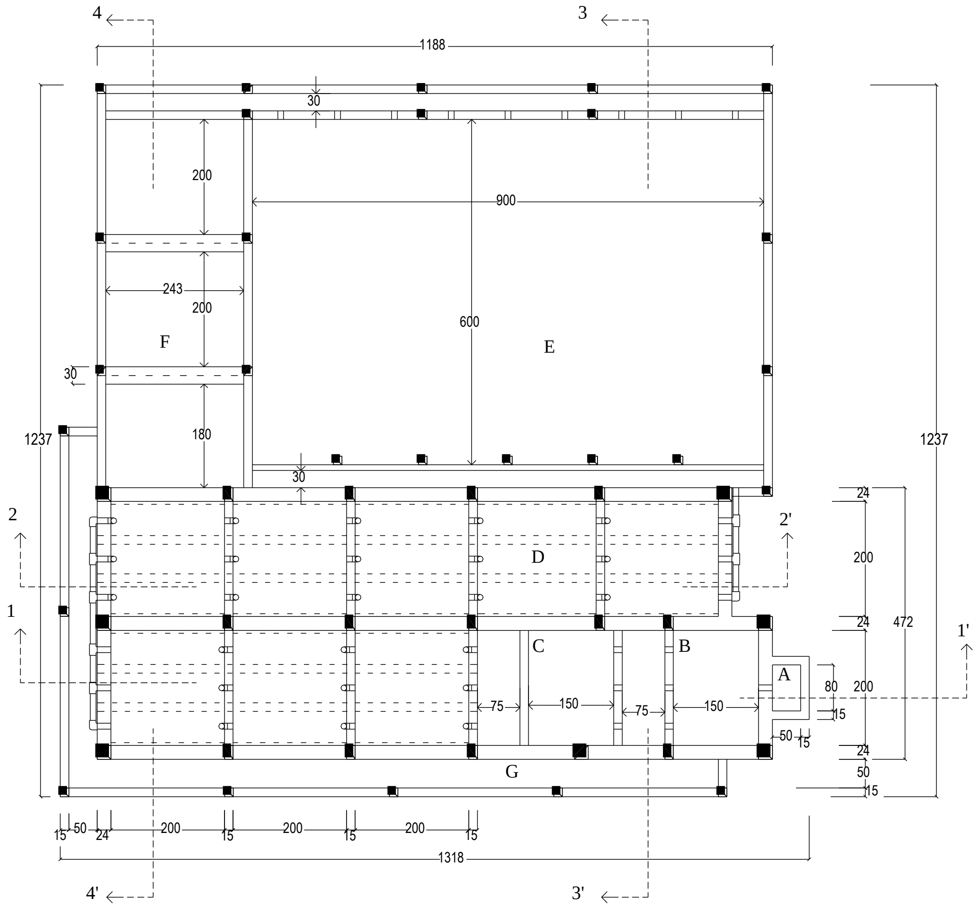
The implementing agency should complete the design, supervise the construction until completion and guarantee the proper function of the system for the time of one year.

DEWATS: overview layout plan

Scale :

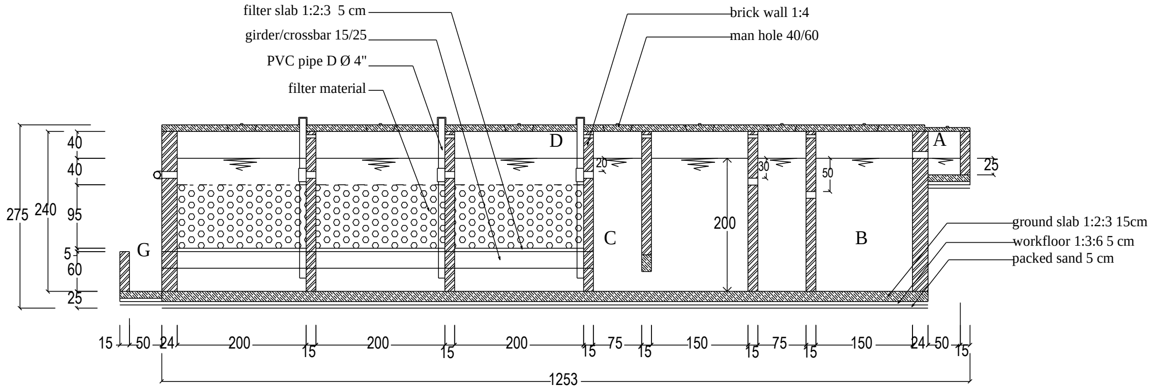
0 75 150 225 300

A - Treatment Inlet
B - Sedimentation Tank / Septic Tank
C - Baffled Reactor
D - Anaerobic Filters
E - Constructed Wetland
F - Polishing Ponds



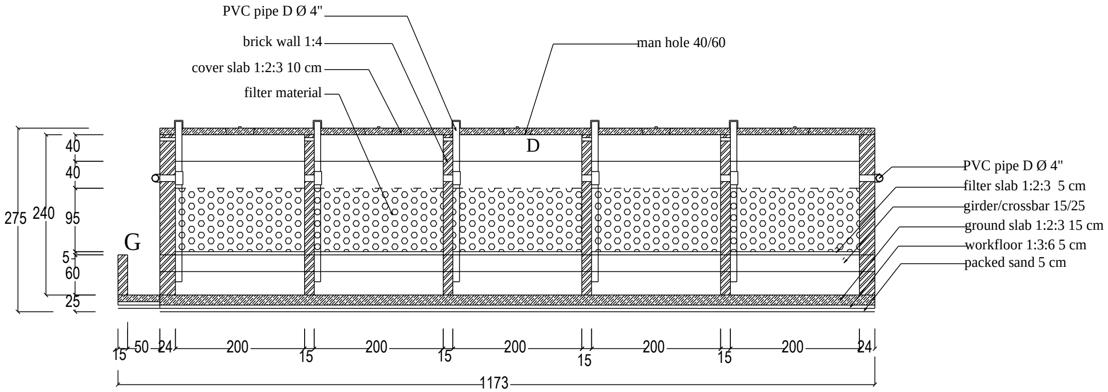
Cross Section 1 -1'

- A - Treatment Inlet
- B - Sedimentation Tank / Septic Tank
- C - Baffled Reactor
- D - Anaerobic Filters
- G - Effluent Chamber



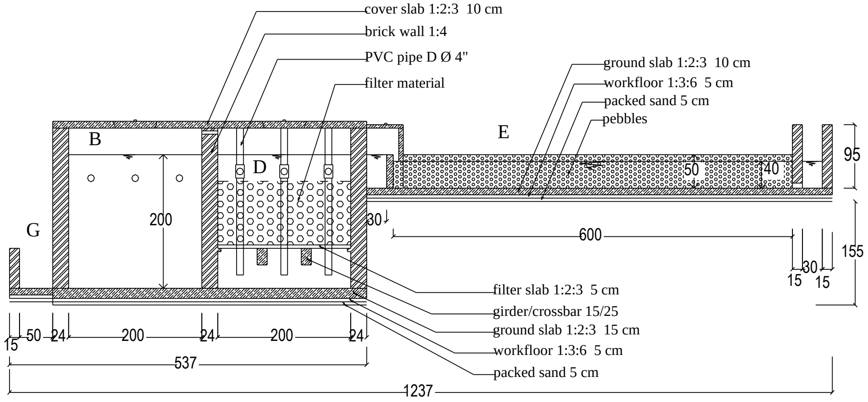
Cross Section 2 -2'

Scale: 0 75 150 225 300



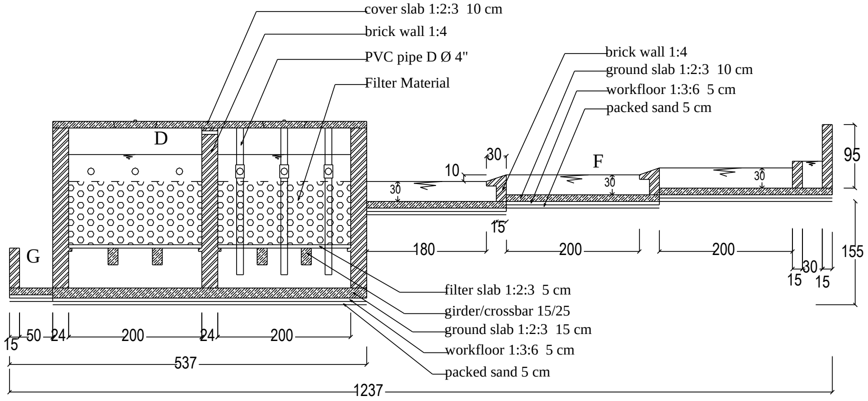
Cross Section 3 -3'

B - Sedimentation Tank / Septic Tank
D - Anaerobic Filters
E - Constructed Wetland
F - Polishing Ponds
G - Effluent Chamber



Cross Section 4 -4'

Scale:



Bill of Quantities

Materials	estimated amount	Unit	Comments
Excavation			The design should be adapted to local conditions. • Different building materials may be more readily available and therefore more appropriate in certain locations. • Dimensions may vary due to space constraints. • Different physical conditions (soil, temperature, wastewater composition) will influence the design. • Construction & maintenance labour capacity influences appropriate design choice
Soil removal	213.00	m^3	
Packing of sand	7.17	m^3	
Packing of soil	30.00	m^3	
Bricklaying and plaster work			
Bricklaying 1 : 4	42.71	m^3	
Reinforced concrete 1 : 2 : 3	31.95	m^3	
Work floor 1 : 3 : 6	9.14	m^3	
Plaster work 1 : 4	286.96	m^2	
Plaster work 1 : 4	178.67	m^2	
Filter & Fittings			
Filter Material anaer. Filter	30.50	m^3	
Filter Material constr. wetland	27.00	m^3	
PVC Pipes 4"	15.00	pc.	
T-connecting/knee joint 4"	30.00	pc.	
Grass planting	54.00	m^2	

Material specifications

	Cement	Lime	Sand	Gravel
Concrete	1	0	2	4
Plaster	1	0.25	4	0
Soft mortar	1	3	15	0
Gas-tight plaster	1	0.25	2.5	0

For more detailed information on material specifications for water and air-tight structures,

►►**Appendix 3**►

Design Variations

The effectiveness of a baffled reactor or an anaerobic filter is greater if pre-acidification and liquefaction of organic matter has taken place in a primary treatment step. This can be achieved by pre-treatment:

1) in a septic tank (two chambers), directly prior to the secondary treatment unit (as in the example)

2) in a biogas settler (one chamber),

3) with grease trap, settlers, sand trap and/or grid removal of solids at the household (esp. in the case of small bore sewer networks) and treatment of the organic material in a separate biogas reactor or composting unit.

The effectiveness of the baffled reactor can be improved by adding filter material within the chambers, turning the system into an anaerobic baffled filter (also shown in the typical example). Bacteria grow on the surface of the filter material (inert natural or synthetic material with a large surface area) thereby increasing the intensive contact of bacteria and wastewater. It should be noted however that bacterial growth on the filter material can cause clogging of the filter, making removal and cleaning of the filter material necessary. If space requirements permit, a larger baffled reactor without filter material is to be preferred.

Baffled reactors can be used to treat wastewater collected by a sewer system from individual households, or to treat wastewater directly at a communal sanitation centre. Furthermore, treatment can be done with or without the collection and use of biogas. The following design comparisons and cost estimates were calculated for up to 10 families – about 50 persons – connected to the treatment system. Five persons share one toilet. Estimates are based on comparison with international experience (Philippines, India, Indonesia and China).

Design comparisons	Comments
Individual household toilets vs. communal toilet centre	Community sanitation centres of this size are approx. 30% lower in cost per toilet unit, due to material and labour savings for common walls, foundations, and roof, stairs and pipe networks.
In-house-toilets connected to small sewer network leading to neighbourhood based wastewater treatment system with biogas use vs. without biogas use	At this scale, design with biogas will be approx. 45% more expensive for investment than without biogas use, due to 1) extra material costs for gas-tightness, gas collection, pipelines, appliances and 2) additional labour costs of qualified personnel (plumber) for installation and maintenance training for the users. But some of this investment costs could be recovered by the household energetic use of the biogas. This relative cost difference decreases with size of the treatment facility. Incurring costs are offset by the benefits from use of the gas for cooking or lighting and the nutrient rich effluent.

Up-Scaling

The facility can treat any amount of wastewater greater than 1 m^3/day.

Wastewater with a higher contamination (black water or brown water) requires more chambers.

The factors decisive for design are too complex and interrelated (peak flow, pollution load, up-flow velocity, retention time, temperature) to be expressed in simple up-scaling tables. The design of baffled reactors demands engineering expertise.

Construction must be carried out by qualified masons.

Capacity building training for design and construction of baffled anaerobic reactors is outlined in

►►**Vol. I, Chapter 8**►

Operation & Maintenance

Toilet users must be advised not to apply chemical detergents for toilet bowl cleaning, as their application kills the active bacteria in the baffled reactor – disabling the treatment process and resulting in fast sludge accumulation, which must be removed from the digester and can plug following treatment units.

Maintenance must be carried out by trained personnel, which should be trained during the construction process.

The trained personnel should check all control openings weekly and remove any obstructions to the regular flow.

If biogas is utilised, storage, pipelines and appliances must be monitored regularly by trained personnel.

User fees or communal payment models should cover maintenance costs. Additional benefits (use of irrigation water or biogas) can be awarded to the personnel.

Local expertise in Sri Lanka

Tropical Wastewater Engineering (contact: Dr. Harin Corea) – local experience with natural wastewater treatment processes.

Approach and Tools

Hygiene & Health promotion campaign; if shared toilets: education for ownership and responsible use of toilet facilities; decision-making process over communal / private land use for treatment facilities.

Cross-Check – System not to be applied under the following conditions

Users do not have water availability for flush toilets

→ Dry system should be considered ►►**Technical Option Sheet Nr. 3**►

Rocky underground

Experts to design and construct a baffled reactor are not available and training cannot be provided.

Nr. 8 Constructed Wetlands / Gravel Filters

This section introduces horizontal flow (A) and vertical flow (B) filter systems.

(A) Horizontal Flow Gravel Filter

The design of horizontal flow wetlands must be in correspondence with ►►Appendix 4a►

Code of Practice for the Design and Construction of Septic Tanks and Associated Effluent Disposal Systems, Sri Lanka Standards Institution, 2003.

Keywords

Pour-flush toilets, natural treatment, tertiary treatment, DEWATS, effluent reuse, community ownership

Description

Horizontal gravel filters, also referred to as constructed wetlands, subsurface flow wetlands or root zone treatment plants, provide natural treatment for pre-settled wastewater of a maximum COD content of 500 mg/l. They are therefore ideal as tertiary treatment for wastewater, which has already undergone secondary treatment in units, like baffled reactors, anaerobic filters or biogas digesters. Horizontal gravel filters have no movable parts, do not require operational control and deliver an effluent, which is suitable for irrigation, toilet flushing, car washing, etc.

System is applicable under the following conditions

Suitable if adequate space requirements can be met.

Public buildings incl. schools with secured – even if limited – water supply, allowing reuse.

Newly constructed residential areas with individual toilets attached via a small bore sewer, gravity sewer or vacuum network (see appropriate chapters).

Community sanitation centres in permanent settlements, where residents cannot construct private toilets, due to financial, topographic or limited space conditions.

Advantages and Challenges

	Advantages	Challenges
health	- Sub-surface flow prevents fly and insect breeding	
environment	- high retention time (treatment) of the wastewater - no smell - treatment of all domestic wastewater, therefore no stagnant wastewater in the community - no surface or groundwater pollution	
econom ic	- recovering of costs by water saving	- investment costs in land - covering O&M costs
social	- water sealed toilet system, well know in Sri Lanka - understanding of link between sanitation and community development	- users / cleaning personnel must be taught to refrain from applying chemical cleaners
technical	- can be constructed from local materials - can be constructed above ground - no movable parts - no permanent operational control - no maintenance, if well designed and constructed	- space requirements for facility, decision over land use

Essential Design Information

The distribution chamber must be wide enough to ensure homogeneous flow across the full width of the filter. Trenches filled with rocks of 50 to 100 mm diameter are provided at both ends of the filter to ensure equally distributed supply of water at the inlet and equally distributed reception at the outlet side. A perforated pipe that is connected to the outlet pipe lies below the strip of rocks for effluent collection.

The filter must have water-tight sides and base. The bed should be large and shallow (30 to 60 cm), filled with preferably uniform, round gravel. Fine soil should be removed from the gravel filter material by washing before installation. The size of the gravel depends on the quality of the wastewater. While large grain size with a high percentage of voids prevents clogging, it also reduces treatment performance. Round, uniform gravel of 6 - 12 mm or 8 - 16 mm is recommended. If only mixed grain sizes are available, it might be advisable to screen the gravel with the help of a coarse sieve to use the larger grains in the front and the smaller grains to the rear of the filter, as additional precaution against clogging. Care is to be taken when changing from a larger grain size to the smaller, because blockage happens predominantly at the point of change. A rather flat slope ($\alpha < 45°$) should join sections of one-grain size to another in order to obtain a larger connecting area. If grain diameters differ considerably, an intermediate zone consisting of intermediate size should be considered.

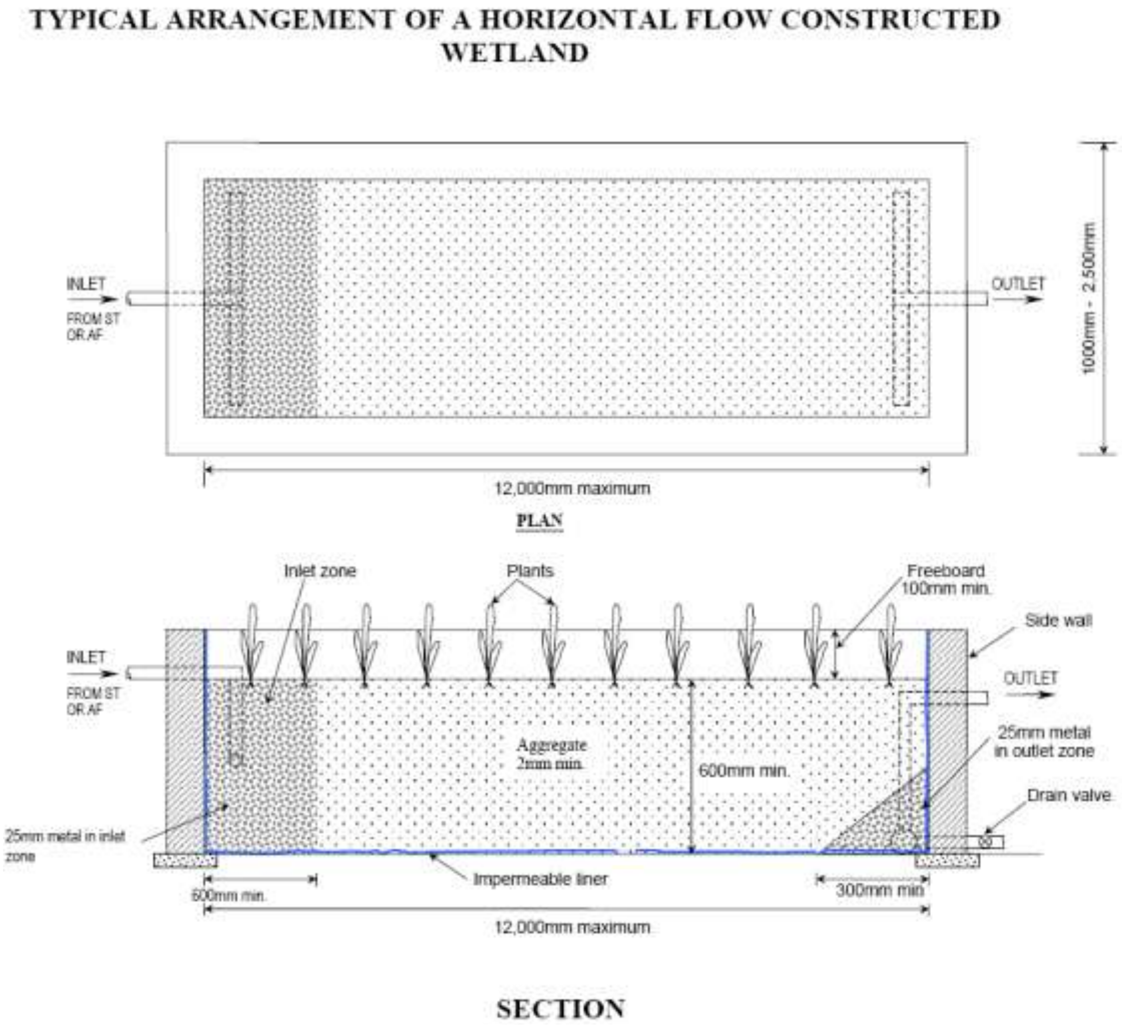
Hydro-botanical plants, with deep reaching and widely spreading roots, are planted on top of the gravel bed. Although the principle of the system appears quite simple, the processes involved are a complex combination of aerobic, anoxic and anaerobic bio-chemical reactions, combined with nutrient adsorption and evapo-transpiration processes of the plants on the filter.

The horizontal filter functions continuously with a permanent water level in the filter.

The implementing agency should complete the design, supervise the construction until completion and guarantee the proper function of the system for the time of one year.

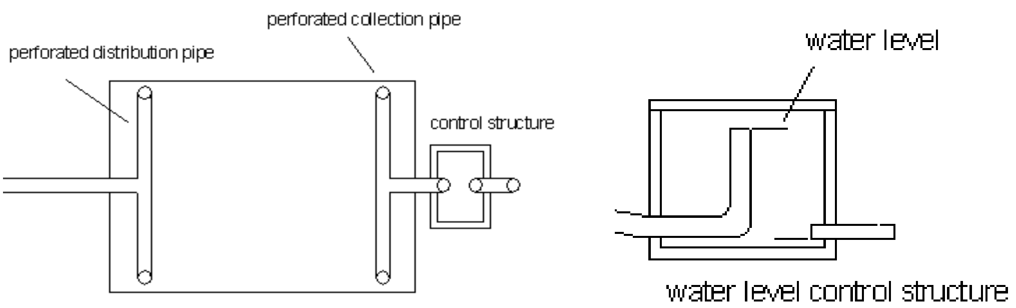
Typical Example

The following typical example is listed in *Code of Practice for the Design and Construction of Septic Tanks and Associated Effluent Disposal Systems, Sri Lanka Standards Institution, 2003* **►►Appendix 4a►**



Possibility for water level regulation:

water level control structure, which can be fitted with bendable elbow if elevation of facility is sufficient.



Design Variations

Filter basins can be constructed with masonry or concrete structures, using foils or clay packing for sealing.

Sloped side walls are less costly, but plants will not grow near the rim.

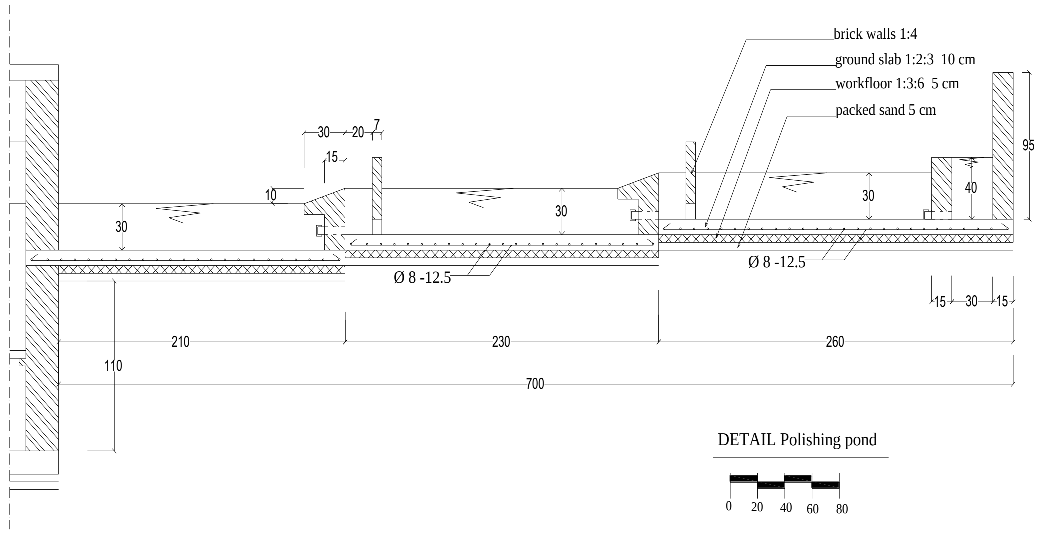
In case the length of the filter bed is more than 10m, an intermediate channel for re-distribution of cross-flow should be provided.

If the filter is drained during resting time, alternate charging could increase treatment performance of horizontal filters. To allow such alternate feeding, it is advisable to divide the total filter area into several compartments or beds.

Plant species with spreading root structure are suitable – Ornamentals, like Cannas spp. and Coleus spp., are commonly applied. The indigenous vegetable Kohila (Sinhala vernacular) is particularly suited for greywater wetlands.

To achieve further improvement of the final effluent, polishing ponds (as shown in the exemplary design) can follow constructed wetlands. Polishing ponds are shallow, water-tight reservoirs, which treat the water under aerobic conditions (oxygen exchange at the pond surface) and by pathogen destruction through the sun's UV radiation.

Drawing of polishing pond:



Up-Scaling

As a rule of thumb, 2m² of filter should be provided per cubic meter of domestic wastewater per day, allowing for a hydraulic loading rate of approximately 30 litres/m² and an organic loading rate of 8g BOD/m²×d.

Although gravel filters are simple in principle, successful design and construction requires a solid understanding of the treatment process, boundary conditions and good knowledge of the filter medium that is to be used. The dimensions of the filter depend on temperature, grain size of the filter medium, as well as hydraulic and organic loading. The relation between organic load and oxygen supply reduces with length. It is therefore most likely that anaerobic conditions prevail in the front part, while aerobic conditions reach to a greater depth in the rear part. Successful design requires training and/or experience.

Construction must be carried out by qualified construction personnel.

Capacity building training for design and construction of horizontal gravel filters is outlined in

►►Vol. I, Chapter 8►

Operation & Maintenance

Maintenance must be carried out by trained personnel, which should be trained during the construction process.

Since clogging is the biggest problem of constructed wetlands, one of the most important maintenance steps is to guarantee the proper operation of prior treatment steps to effectively remove suspended solids. Verification of adequate inflow quality can be tested with an Imhoff cone; the sediment after 60 minutes should not be more than 1 ml/l.

Toilet users must be advised not to apply chemical disinfectants for toilet bowl cleaning.

Weekly inspection of inflow and outflow structures ensures even distribution across the filter.

Flow should be regulated so that the water level in the filter remains below the filter surface.

Clogged gravel filter, indicated by surface flow, can become useful again after resting periods of several months, due to bacteria being left without feed.

Fallen leaves should be removed from the filter to prevent sealing of the filter surface. Plants are normally not harvested.

User fees or communal payment models should cover maintenance costs. Additional benefits (use of irrigation water or biogas) can be awarded to the personnel.

Local expertise in Sri Lanka

Tropical Wastewater Engineering (contact: Dr. Harin Corea) – local experience with natural wastewater treatment processes.

Approach and Tools

Education for ownership and responsibility for toilet facilities; community committee development; clarification of maintenance responsibility; decision-making process over communal / private land use for treatment facilities.

Cross-Check – System not to be applied under the following conditions

Space requirements cannot be met

Users do not have water availability for flush toilets

→ Dry system should be considered ►►**Technical Option Sheet Nr. 3**►

Experts to design and construct wetland are not available and training cannot be provided.

(B) Vertical Flow Filter

The design of vertical flow wetlands must be in correspondence with ►►Appendix 4a►

Code of Practice for the Design and Construction of Septic Tanks and Associated Effluent Disposal Systems, Sri Lanka Standards Institution, 2003.

Keywords

Pour-flush toilets, natural treatment, tertiary treatment, DEWATS, effluent reuse, community ownership

Description

Vertical filter under construction (left and middle), planted filter in operation (right) – Thotagamuwa, Sri Lanka

Vertical gravel filters provide natural treatment for pre-settled wastewater, which has ideally already undergone secondary treatment in units, like baffled reactors, anaerobic filters or biogas digesters. The system has no movable parts, does not require operational control and delivers an effluent, which is suitable for irrigation, toilet flushing, car washing, etc.

However, due to the vertical filters' intricate and difficult to install inflow distribution system, horizontal flow gravel filters are to be preferred for larger applications. ►►Technical Option Sheet Nr. 8(A)►

For single house applications, the French drain filter is more economical if the required space is available.

►►Technical Option Sheet Nr. 9►

System is applicable under the following conditions

Suitable if construction of functioning distribution system can be guaranteed.

Suitable if adequate space requirements can be met.

Public buildings incl. schools with secured – even if limited – water supply, allowing reuse.

Newly constructed residential areas with individual toilets and treatment systems or attached via a small bore sewer, gravity sewer or vacuum network (see appropriate chapters).

Community sanitation centres in permanent settlements, where residents cannot construct private toilets, due to financial, topographic or limited space conditions.

Not suitable in areas of extremely high groundwater table, due to insufficient filter depth.

Advantages and Challenges

	Advantages	Challenges
health	- Sub-surface flow prevents fly and insect breeding	
environment	- high retention time (treatment) of the wastewater - no smell - treatment of all domestic wastewater, therefore no stagnant wastewater in the community - no surface or groundwater pollution	
economic	- recovering of costs by water saving	- investment costs in land - covering O&M costs
social	- water sealed toilet system, well know in Sri Lanka - understanding of link between sanitation and community development	- users / cleaning personnel must be taught to refrain from applying chemical cleaners
technical	- can be constructed from local materials - can be constructed above ground - no movable parts - no permanent operational control - little maintenance, if well designed and constructed	- exact levelling and hydraulic calculation of distribution system required - required filter length above groundwater level can demand high elevation of toilet facility - space requirements for facility, decision over land use

Essential Design Information

The filter must have water-tight sides and base.

The filter bed consists of preferably uniform aggregate greater than 2mm in size. Fine soil should be removed from the gravel filter material by washing before installation. The ideal size of the aggregate depends on the quality of the wastewater. The bed should have a minimal depth of 600mm, although depths of at least 1500mm are recommended. Depending on the groundwater level and rockiness of the soil, a higher elevation of the toilet structure and previous treatment modules might be necessary to achieve this.

The inflow system (above the filter bed) must ensure homogeneous distribution across the full filter surface. Perforated PVC distribution pipes or hoses are placed in the middle of a 20 to 30cm high bed of 25mm aggregate. Exact levelling of the distribution pipes and a basic hydraulic understanding is required. Geo-textiles should be placed above and below the distribution layer to prevent clogging of the filter.

The distribution layer should be covered with soil and planted with hydro-botanical plants, with deep reaching and widely spreading roots, to prevent odours.

The collection layer (below the filter bed, separated by geo-textile) also consists of a 20cm high bed of 25mm aggregate. A 100mm diameter perforated collector pipe at the bottom of the layer is connected to the outlet of the filter.

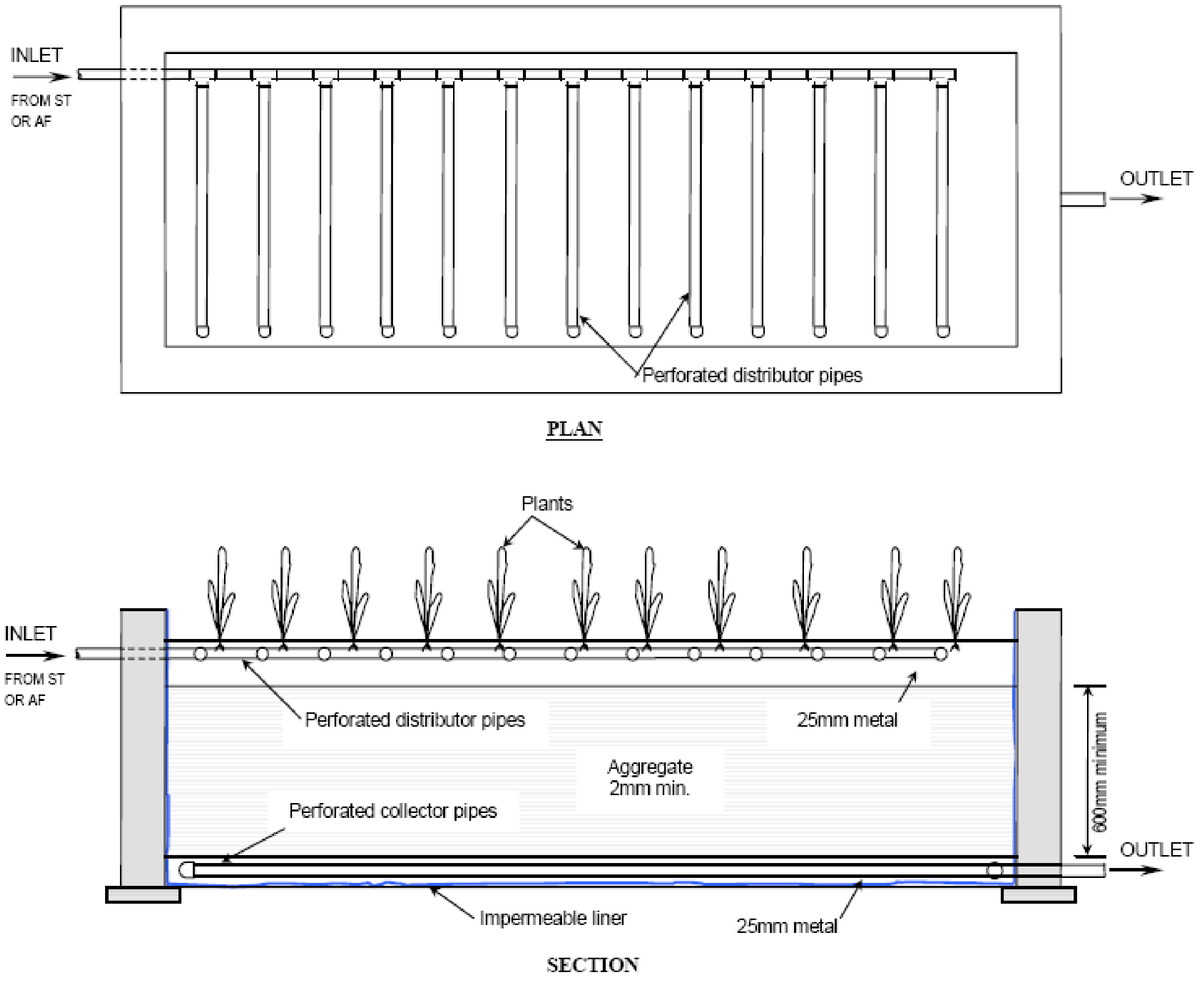
An effluent collection chamber is required to collect the water for reuse.

The implementing agency should complete the design, supervise the construction until completion and guarantee the proper function of the system for the time of one year.

Typical Example

The following typical example is listed in *Code of Practice for the Design and Construction of Septic Tanks and Associated Effluent Disposal Systems, Sri Lanka Standards Institution, 2003* ►►**Appendix 4a**►

TYPICAL ARRANGEMENT OF A VERTICAL FLOW CONSTRUCTED WETLAND



Design Variations

Filter basins can be constructed as masonry or concrete structures, using foils, plaster or clay packing for sealing.

The plan area of vertical flow filter must not necessarily be rectangular. It can be round or adapted to local space availability, as long as homogeneous flow distribution can be guaranteed.

Plant species with spreading root structure are suitable – Ornamentals, like Cannas spp. and Coleus spp., are commonly applied. The indigenous vegetable Kohila (Sinhala vernacular) is particularly suited for greywater wetlands.

To achieve further improvement of the final effluent, polishing ponds (as shown in option sheet 8A) can follow vertical filters.

Up-Scaling

As a rule of thumb, 2.5 to 3m² of filter area should be provided per cubic meter of domestic wastewater per day.

Homogenous distribution becomes increasingly difficult with larger vertical flow wetlands. Horizontal flow gravel filters are to be preferred. ►►**Technical Option Sheet Nr. 8(A)►**

Although gravel filters are simple in principle, successful design and construction requires a solid understanding of the treatment process, boundary conditions and good knowledge of the filter medium that is to be used. The dimensions of the filter depend on the wastewater quality, temperature, grain size of the filter medium, as well as hydraulic and organic loading. Successful design requires training and/or experience.

Construction must be carried out by qualified construction personnel.

Capacity building training for design and construction of vertical flow constructed wetlands is outlined in

►►**Vol. I, Chapter 8►**

Operation & Maintenance

Maintenance must be carried out by trained personnel, which should be trained during the construction process.

Since clogging is the biggest problem of constructed wetlands, one of the most important maintenance steps is to guarantee the proper operation of prior treatment steps to effectively remove suspended solids.

Toilet users must be advised not to apply chemical disinfectants for toilet bowl cleaning.

A clogged filter, indicated by reduced flow, can become useful again after resting periods of several months, due to bacteria being left without feed. The only alternative is removal, cleaning and replacement of the filter media.

User fees or communal payment models should cover maintenance costs. Additional benefits (use of irrigation water and biogas) can be awarded to the personnel.

Local expertise in Sri Lanka

Tropical Wastewater Engineering (contact: Dr. Harin Corea) – local experience with natural wastewater treatment processes.

Approach and Tools

Education for ownership and responsibility for toilet facilities; community committee development; clarification of maintenance responsibility; decision-making process over communal / private land use for treatment facilities.

Cross-Check – System not to be applied under the following conditions

High groundwater table, preventing adequate filter depth

Space requirements cannot be met

Users do not have water availability for flush toilets

→ Dry system should be considered ►►**Technical Option Sheet Nr. 3**►

Experts to design and construct wetland are not available and training cannot be provided.

Nr. 9 French Drain Filter

Keywords

Pour-flush toilets, low-flush toilet, grey water treatment, natural treatment, limited space, high groundwater table

Description

(plastic) septic tank with French drain filter during construction, effluent used for irrigation in a plant seepage-bed

French drain filters are simplified horizontal gravel filters for on-site sanitation with space constraints and high groundwater table. They provide simple filtration and anaerobic treatment, where high groundwater tables prevent direct septic tank effluent infiltration. They can be used with any water flush toilet (preferably low-flush or pour flush to reduce space requirements) and after pre-treatment (for example: septic tank). At the end of the French drain filter, water is infiltrated to the soil though a plant bed.

System is applicable under the following conditions

Recommended as on-site single household treatment for greywater;

Suitable as on-site secondary black or brown water treatment for single households where attachment of pre-treated effluents to a small bore sewer system for a more efficient form of wastewater treatment is not possible.

Suitable under great space constraints due to flexibility of layout (length of French drain can go around corners).

Suitable for areas with rocky underground;

Suitable for areas with high groundwater table, if a better solution cannot be applied

Advantages and Challenges

	Advantages	Challenges
Health	- Sub-surface flow prevents fly and insect breeding - No contact with waste water for playing children	
Environment	- higher retention time (treatment) of the wastewater than direct infiltration - no smell - treatment of all domestic wastewater possible, therefore no stagnant wastewater in the community	
Economic	- low cost - possible recovering of costs by plant cultivation - up-gradable to plant filter bed systems - neighbourhood systems possible to reduce costs	- organizational management if neighbourhood involved
Social	- water flush toilet system, well known in Sri Lanka - understanding of link between sanitation and community development	- users must be taught to refrain from applying bio-toxic chemical cleaners
Technical	- can be constructed from local materials - can be constructed close to or above the ground - area above the filter can still be used as a walkway - no movable parts, no permanent control - flexible layout - no maintenance, if well designed and constructed	- can clog after several years

Essential Design Information

The filter bed must be water and air-tight on all sides (including around the influent pipe) to prevent odour pollution and the infiltration of untreated wastewater to the soil.

The effluent from the filter is percolated into the active soil zone by subsequent infiltration beds or trenches. Requirements for "seepage beds" and "seepage trenches" must be fulfilled, as stated in ►►**Appendix 4a**►

Code of Practice for the Design and Construction of Septic Tanks and Associated Effluent Disposal Systems, Sri Lanka Standards Institution, 2003

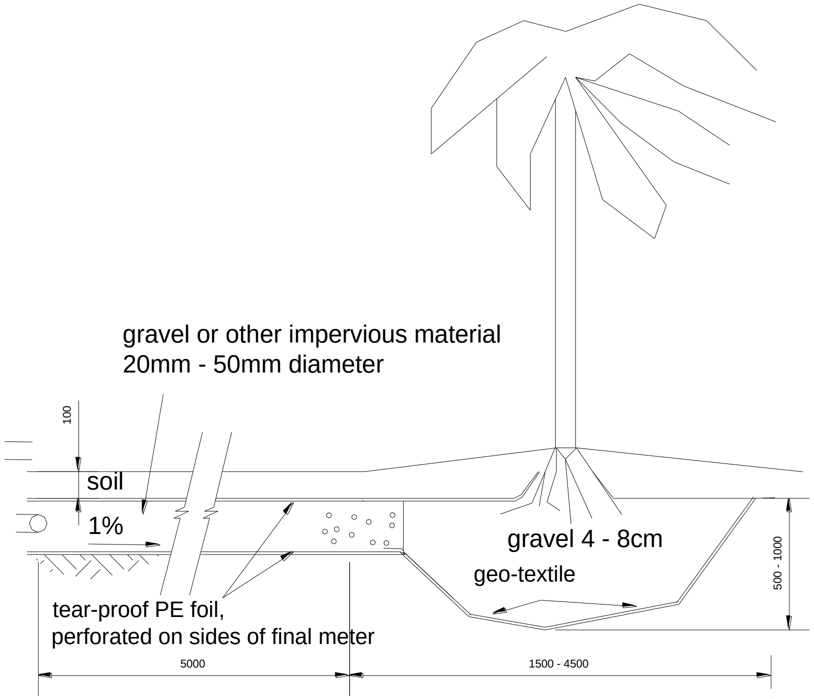
It is recommended to situated infiltration beds or trenches around existing coconut trees, banana or papaya plants and other (productive) vegetation on the property. If these are not available, provision of such plants to a family is advised, providing additional groundwater protection and obvious additional benefits.

The implementing agency should complete the design, supervise the construction until completion and guarantee the proper function of the system for the time of one year.

Typical Example

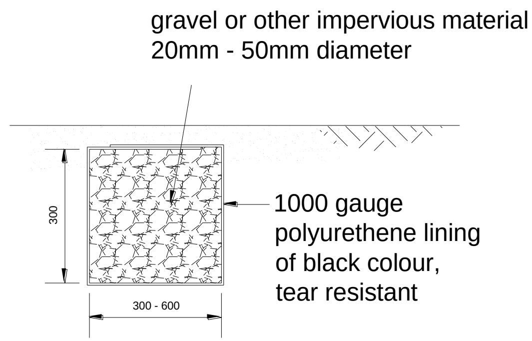
The following typical example (also shown in the pictures above) has been constructed in 2005 by the World Toilet Organization in collaboration with Habitat for Humanity in the Galle region.

French drain filter with infiltration bed



for infiltration pit / trench:
larger dimensions required for impervious soil,
in accordance with
Code of Practice for the Design and Construction of Septic Tanks and Associated Effluent Disposal Systems

Detail



Bill of Quantities – horizontal filter

Materials	estimated amount	Unit	Comments
Gravel 20mm - 50mm	0.5	m^3	Dimensions of the infiltration bed depend on amount of treated wastewater and permeability of the soil. Greater amounts of wastewater and decreasing soil permeability demand a larger infiltration surface area ►►**Appendix 4a►**
Gravel 40mm – 80mm	0.5 - 1.6	m^3	
1000 gauge polyurethene lining	8	m^2	
Geo-textile	1.5 - 4.8	m^2	

Design Variations

French drain filters can be adapted in their layout according to the layout of the plot (around the corners of buildings, around other obstacles).

Instead of gravel other inert materials can be used (for example: hole-drilled or shredded plastic bottles)

In areas of flooding, the infiltration zone should be covered with a geo-textile and covered with a 10 cm thick layer of soil to prevent flooding of the filter system.

Up-Scaling

Larger amounts of treated wastewater demand a greater infiltration zone; this must be designed according to Sri Lanka Standards ►►**Appendix 4a ►**

For larger applications ►►**Technical Option Sheet Nr. 8►**

Operation & Maintenance

The system is almost maintenance free.

Since clogging is caused by inefficient pre-treatment (removal of settleable solids), users must be taught to monitor sludge levels of their septic tanks to ensure timely sludge removal.

In the unlikely case of clogging, the filter can easily be opened and the filter material cleaned and replaced. Gloves, shoes and mouth protection should be worn during maintenance work.

Local expertise in Sri Lanka

Habitat for Humanity (contact: M.L.A. Lakshman Perera)

Cross-Check – System not to be applied under the following conditions

Space requirements cannot be met

Users do not have water availability for flush toilets

→ Dry system should be considered ►►**Technical Option Sheet Nr. 3►**