Overview sanitation technologies applicable in flood prone areas

SANTE Project

Author:
Jan Spit, WASTE

Comments to:
jspit@waste.nl

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WASTE advisers on urban environment and development

Nieuwehaven 201
2801 CW Gouda e-
the Netherlands

fax:+31 182 550313
mail: jspit@waste.nl
website: http://www.waste.nl

FOREWORD

This document is a document in progress. The content is based on a literature and Internet search and experiences of WASTE in East and West Africa, India and Indonesia. It is also based on the experiences of the author Jan Spit who has worked since a long time in the field of sanitation and the sanitation course he developed for UNICEF.

Comments on this document are more than welcome used for improving this document to make it available to a broader audience.

Please send your comments to:

Jan Spit
WASTE Sanitation Adviser
jspit@waste.nl

Or your contact person at WASTE

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1 INTRODUCTION

1.1 *What this overview about*

There is a wide variety of sanitation technologies available, see the background information in our wiki https://santebangladesh.wikispaces.com/Background+information+on+Technical+Options

Not all technologies are suitable for flood prone areas. This overview filtered out those technologies that are not suitable.

Besides the suitability criteria for flood prone areas we need a reference to determine what technology is suitable in general.

During the SANTE kick-off meeting the following conditions have been mentioned to determine whether a technology is suitable or not:

- Faeces can not be seen;
- Faeces can not be smelled;
- Flies cannot touch the faeces.

1.2 *What does 'applicable in flood prone areas' mean?*

The three conditions mentioned in § 1.1 are too general to be used for a system selection. Hence, we have elaborated them and use the following definition as a reference:

The technologies proposed in the framework of SANTE should be Appropriate, Acceptable and Applicable in flood prone areas', which means:

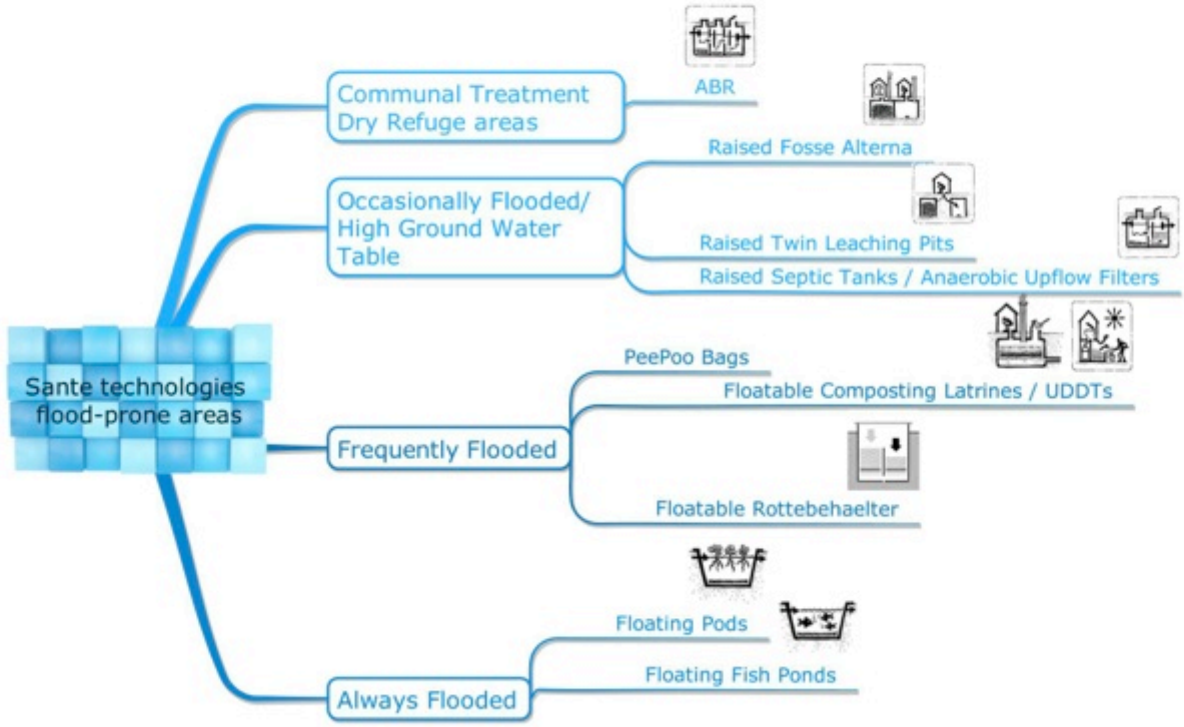
1. **Environmentally acceptable** safe from a public health point of view: the wastewater is handled in such a way that it cannot affect human beings. The wastewater is not accessible to flies, mosquitoes, rodents, etc. The handling of fresh excreta is avoided. In areas where the people depend on ground- or surface-water as a resource for drinking water, the ground- or surface-water should not be polluted;
2. **Convenient and safe**: there are limited odours and unsightly conditions. The facility is a short walking distance from the house and can be used safely by women, girls and elder people, also at night;
3. **Simple to operate**: the daily operation is minimal and only requires simple and safe routines;
4. **Long-lasting with minimal maintenance**: a long technical lifetime and only occasional maintenance, i.e. every 1 or 2 years;
5. **Upgradable**: in the future “step-by-step” (incremental) improvements and extensions are possible;
6. **Acceptable cost**: this does not mean necessarily that the system is cheap. The technology selected should be within the economic and financial reach of the household and government budgets;
7. **Resilient to floods**:
   - The system can be used for a minimum of 1 week during floods;

- The system can be brought into service after 1 month of floods without major repairs.

1.3 Overview

The following figure shows the technologies we filtered out. We distinguish between:

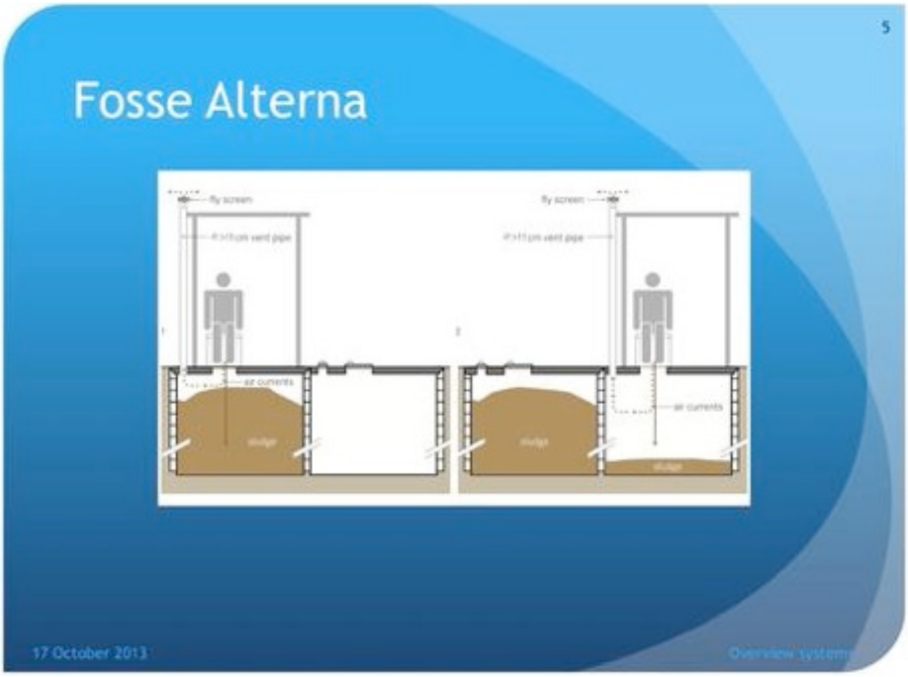
- Individual systems that are:
    - Occasionally flooded or that are in areas with a high groundwater table;
    - Frequently flooded;
    - Always flooded;
- Communal systems for dry refuge areas.



The systems are summarized here and elaborated in Chapter 2.

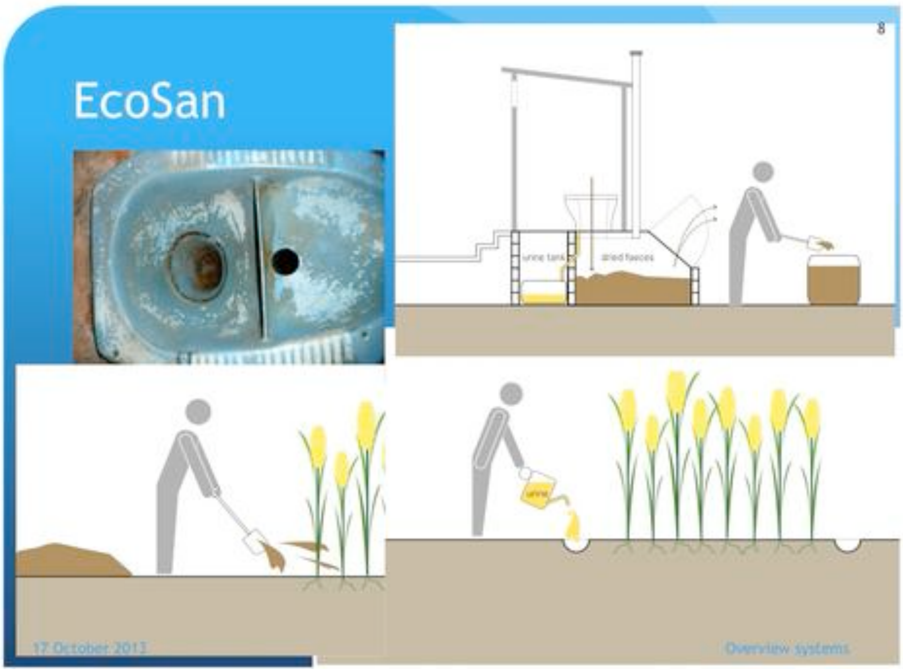
Peepoo. These are biodegradable plastic bags with urea. In contact with urine and faeces, the urea converts into ammonia and sanitises the contents of the bag. See: http://www.peepoople.com. For more info, read § 2.1.Appropriate for frequently flooded areas, but it requires change of current defecation habits during floods.

Raised Fosse Alterna: Pits are placed above the highest water level. Faeces are covered with earth, leaves etc. When one pit is full, it is sealed and the other one is used. For more info, go to § 2.2. Appropriate for occasionally flooded areas of areas with a high groundwater table, but not food frequently/ always flooded area.

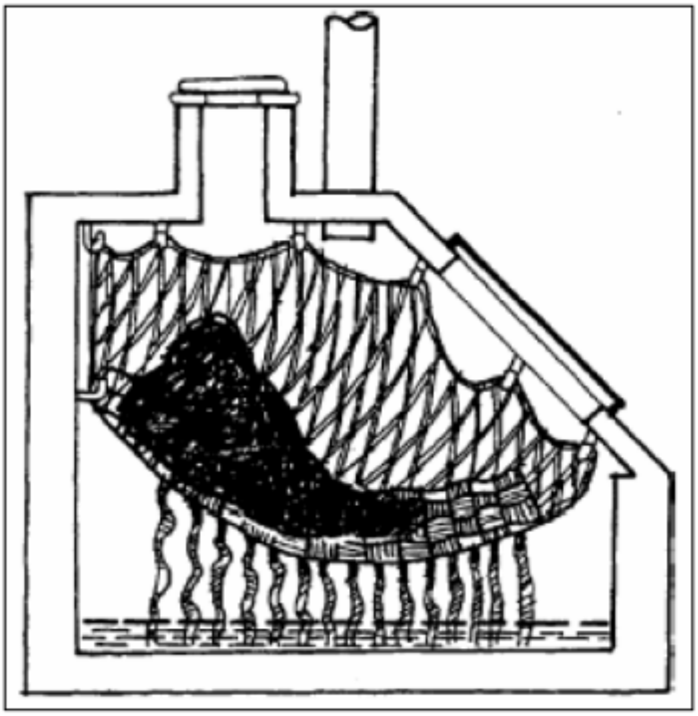


Floatable Composting Toilet: Continuous composting systems or Twin Composting chamber are placed above the highest water level. For more info, go to §2.3. Appropriate for areas that are frequently flooded.

Floatable EcoSan and UDDT toilets are placed above the highest groundwater level. Urine is separated and used in agriculture. Faeces are dried. For more info, go to § 2.4. Appropriate for areas that are frequently flooded.

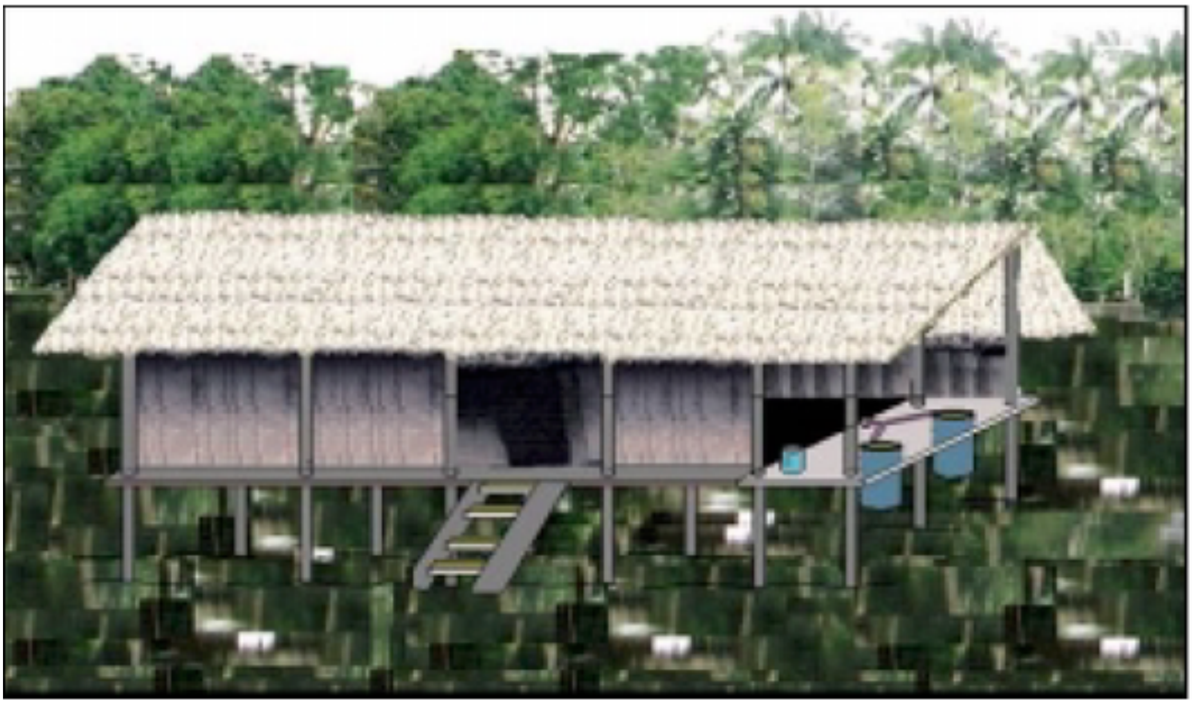


Floatable Rottebehaelter: Faeces, urine and anal cleansing water pass through a permeable bag and are dried by forced aeration. For more info, go to § 2.5. Appropriate for areas that are frequently flooded.



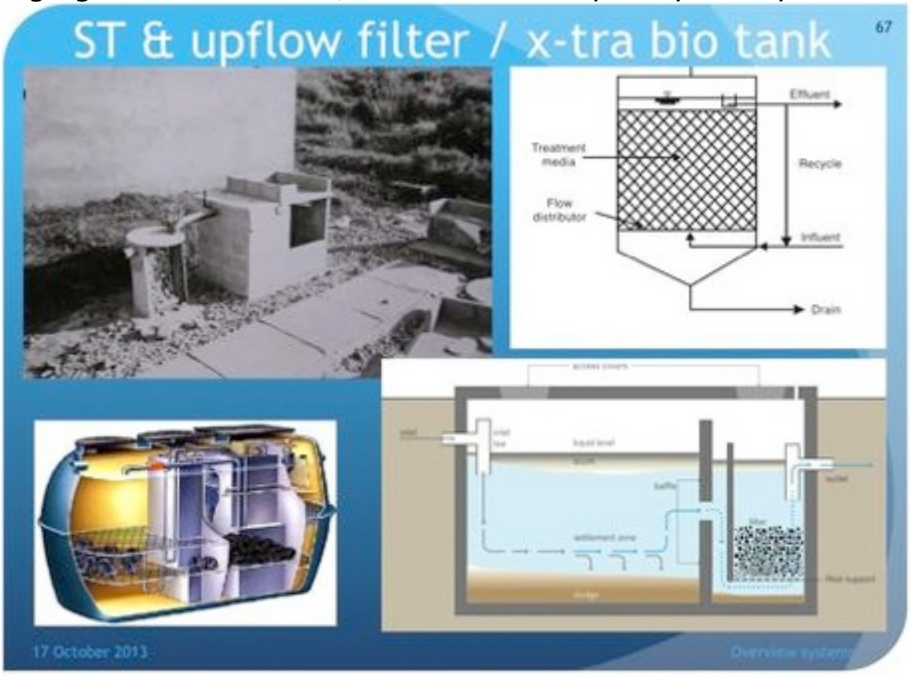
Fish ponds: Toilets hang above the water in floating ponds. For more info, go to § 2.6. Appropriate for areas that are always flooded.

Raised Twin Leaching Pits are placed above the highest water level. When one pit is full, it is sealed and the other one is used. For more info, go to § 2.7. Appropriate for occasionally flooded areas of areas with a high groundwater table, but not food frequently/ always flooded areas.



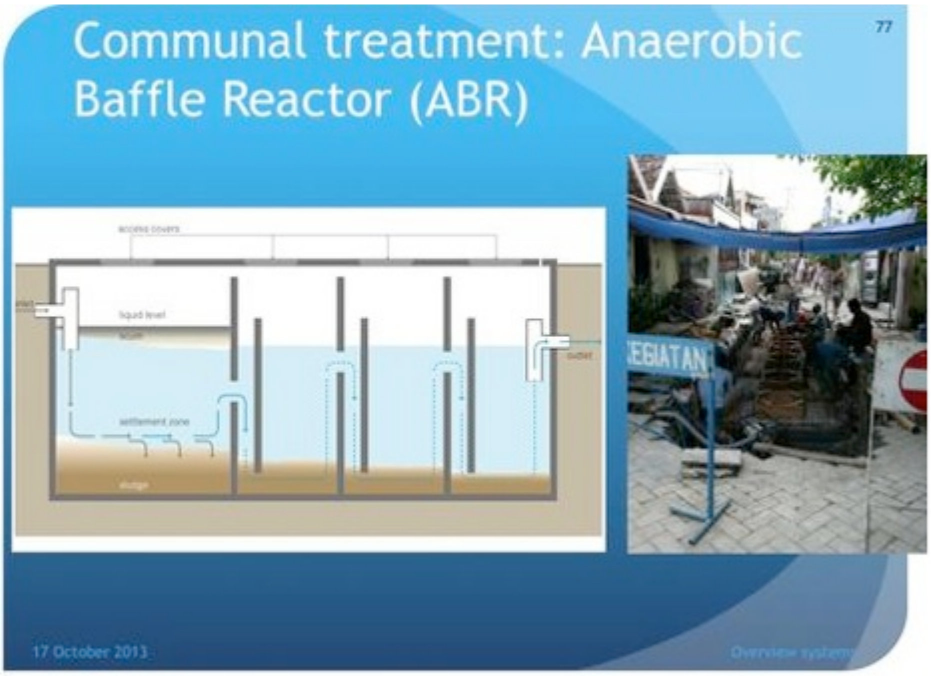
Raised Septic Tanks are placed on the ground level with the top above the highest water level to protect them from flooding. For more info, go to § 2.8. Appropriate for occasionally flooded areas of areas with a high groundwater table, but not food frequently/ always flooded areas.

The effluent from the Septic Tanks is treated in **Raised Anaerobic Upflow Filters**. For more info, see § 2.8. Appropriate for occasionally flooded areas of areas with a high groundwater table, but not food frequently/ always flooded areas.



Black water is treated in **Floating Pods**. For more info, see § 2.9. Appropriate for areas that are always flooded.

Communal Black Water is treated in **Anaerobic Baffle Reactors**. For more info, see § 2.10. Appropriate for treating communal wastewater during floods at refuge centres and other high areas such as dikes.



2 DESCRIPTION OF SANITATION TECHNOLOGIES

2.1 Peepoo

Peepoo is a personal self-sanitizing single-use biodegradable toilet. The bag is made of biodegradable plastics fulfilling EU-standard EN 13432 and contains urea that shortly after use inactivates all bacteria, viruses and parasites in the faeces. Peepoo is designed to provide maximum hygiene and convenience using minimum material. The slim elongated outer bag is thicker than the wide inner gauze that works as a funnel and protects the outer bag from contamination. Peepoo is sealed using a knot.

Dimensions of outer bag:

- Width: 150 mm
- Length: 380 mm
- Thickness: 25 microns

Dimensions of inner gauze:

- Circumference: 580 mm
- Length: 220 mm
- Thickness: 12 microns

Weight. 11 grams per Peepoo, of which 5 grams of biodegradable plastics and 6 grams of urea powder.

Volume. Each Peepoo can contain up to 800 ml of faeces and urine.

Materials:

- The outer bag and inner gauze is made of high performance fully biodegradable plastic that meets EU standard EN 13432. This means that the bag not only disintegrates but also that the molecules are broken down into carbon dioxide, water and biomass. The biodegradable plastic is made up of a mixture of aliphatic/aromatic co-polyesters (Ecoflex) and polylactic acid (PLA), with small additives of wax and lime. The base material Ecovi contains Ecoflex and PLA and is supplied by BASF. Information on Ecovio and Ecoflex can be found on www.ecovio.com;
- Urea (or carbamide) is a white crystalline substance with the chemical formula $(NH_2)_2CO$. It is highly water-soluble and contains 46 % nitrogen. Urea is considered an organic compound because it contains carbon. Urea is the most common artificial fertilizer in the world.

Ammonia based self-sanitisation: Peepoo works as a micro-treatment plant. With the help of the enzyme urease present in the human faeces, the urea powder in Peepoo breaks down to carbon dioxide and ammonia. The ammonia acts as a microbicide and within 2-3 weeks all disease producing pathogens found in human faeces are inactivated, at temperatures of 20 degrees Celsius or above. If only the risk for epidemics diseases is taken into account, pathogenic bacteria such as salmonella and Vibrio cholera are inactivated in less than a week at 20 degrees

Celsius. There is no methane gas development from the faeces inside Peepoo since all bacteria are inactivated. The PhD thesis from the Swedish University of Agricultural Sciences on ammonia-based sanitisation of human excreta can be downloaded from: http://pub.epsilon.slu.se/2361/1/nordin_a_101005.pdf

Usage: To facilitate usage Peepoo is ideally fitted on a Peepoo Kiti, a Peepoo seat/holder for sitting or squatting. (Any small container/bucket with an upper outer diameter of 18.5-19.7 cm, equalling an outer circumference of 58-62 cm, and a minimum height of 15 cm can be used.) To ensure women's and girls' privacy Peepoo Yizi, a privacy tent for personal hygiene, is ideally offered as part of the supply.

No smell: Peepoos are odour free for 12-24 hours after use and can thus be stored in the immediate environment until disposed of.

Disposal: Used Peepoos should ideally be collected in a collection system. Peepoos are harmless to the environment as they are self-sanitising, prevent the faeces from developing methane gas and degrade into only carbon dioxide, water and biomass. It is therefore also safe to directly dispose of and burry used Peepoos in the ground. Used Peepoos can be reused as safe high-value fertiliser as all pathogens are inactivated shortly after use. The bag will not start to degrade before the content is properly sanitised.

Distribution unit: Peepoos are distributed in Peepoo Personal Packs, each containing 28 Peepoos and one Moyla (disposal bag) packaged in a protecting waterproof outer flow-pack.

Shelf life: Peepoo Personal Packs has a guaranteed shelf life of two (2) years. Storage conditions are ideally dark and dry in 15-30 degrees Celsius.

Packaging (subject to change): Twenty (20) Peepoo Personal Packs are packed in a cardboard box with dimensions 400x300x200 mm. The weight of each box is approximately 7 kg. One Euro-Pallet contains 80 boxes, i.e .1600 Peepoo Personal Packs. One standard 20-foot dry cargo container can contain up to 11 Euro-Pallets, amounting to 17,600 Peepoo Personal Packs.

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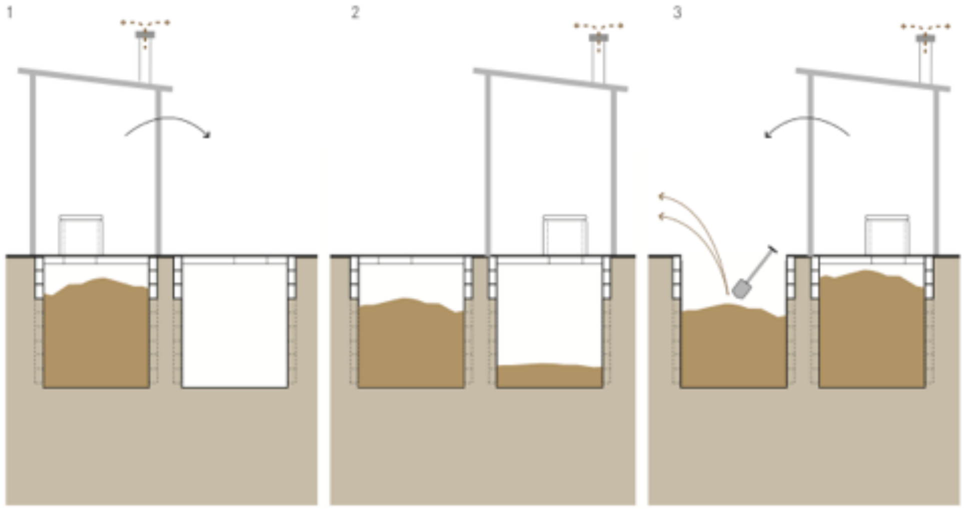
More info: www.peepoople.com

2.2 Raised Fosse Alterna

Useful alternative to raised pit latrines. The most common solution for excreta disposal in areas of high water table is to build raised pit latrines. When these latrines are full and can be emptied, they can be converted into a **Fossa Alterna**, which is an alternating, waterless (dry) double pit technology. Compared to the Double Ventilated Improved Pit Latrine, which is just designed to collect, store and partially treat excreta, the Fossa Alterna is designed to make "EcoHumus" or "humanure".

The Fossa Alterna is dug to a maximum depth of 1.5 m' and requires a constant input of soil. One of the Fossa Alterna pits should fill over a period of 12–24 months depending on the size of the pit and the number of users. The full pit should be sized to ensure that the contents of the first pit degrade during the time it takes for the second pit to fill up, which, ideally, should take one year. The material in the full pit will degrade into a dry, earth-like mixture that can be easily removed manually. "Bulking material" such as soil, ash, and/or leaves should be added to the pit after defecation (not urination). The soil and leaves introduce a variety of organisms like worms, fungi and bacteria, which help in the degradation process. Also, the pore space is increased, which allows for aerobic conditions. Additionally, the ash helps to control flies, reduce odours and make the mix slightly more alkaline. The Fossa Alterna should be used for urine, but water should not be added (small amounts of anal cleansing water can be tolerated). Water encourages the development of vectors and pathogens but it also fills the pore- spaces and deprives the aerobic bacteria of the oxygen that is required for degradation. The choice of User Interface will determine the material that enters the pit. Since bulking material is used to continuously cover the excreta, moisture is removed, which in turn removes any smell. This can be further reduced with the a **ventilation pipe**.



(Source: Tilley, 2008)

The Fossa Alterna pits are relatively shallow with a depth of 1.5 meters. Even though the pits are shallow, this should be more than enough space to accommodate a family of 8 for one year. To optimize the space, the material that mounds in the centre of the pit (underneath the toilet) should be pushed to the sides periodically. Unlike a simple or ventilated pit, which will be covered or emptied, the material in the Fossa Alterna is meant to be reused. Therefore, it is extremely important that no garbage is put into the pit as it will reduce the quality of the material recovered, and may even make it unusable. Emptying the Fossa Alterna is easier than emptying other pits: the pits are shallower and the addition of soil means that the material is less compact. The material that is removed is not offensive and presents a reduced threat of contamination.

Ventilation pipe. Pit ventilation has an important role in reducing flies and mosquito breeding. The draft discourages adult flies and mosquitoes from entering and laying eggs. Nevertheless, some eggs will be laid and eventually adults will emerge. Flies are attracted to light, therefore if a lid is placed on the defecation hole after each use, the only source of light will be from the top of the vent pipe. If the vent pipe is large enough to let light into the pit, and if the superstructure is sufficiently dark, the flies will try to escape up the vent pipe. The vent pipe, therefore should be covered by a gauze screen so that the flies are prevented from escaping and spreading disease, and eventually fall back to die in the pit. Both the vent pipe and the gauze screen must be made from corrosion-resistant materials (for example, fiberglass or PVC). It is recommended that the pipe diameter should be 75 to 200 mm and that it should extend 300 to 600 mm above the roof to allow any smell to dissipate away from the area.

Adequacy The Fossa Alterna is appropriate for areas that are liable to flood occasionally as long as the floor level is above the highest flood level. It is a useful solution for areas that have poor soil and could benefit from the composted humus material as a soil amendment. A constant source of soil, ash and/or leaves is required. The Fossa Alterna is not appropriate for grey water as the pit is shallow and the conditions must remain aerobic for degradation. Another grey water treatment system must be used in parallel. The material is manually emptied from the Fossa Alterna (it is dug out, not pumped out), so vacuum truck access to the pits is not necessary. The Fossa Alterna technology will only work properly if the two pits are used sequentially and not concurrently. Therefore, an adequate cover for the pit that is currently not in use is required. The Fossa Alterna is especially appropriate when water is scarce. It is not suited for rocky or compacted soils (that are difficult to dig) or for areas that flood frequently.

Health Aspects/Acceptance. By covering faeces with soil/ash, flies and odours are kept to a minimum. Public health engineers and promoters are encouraged to review the difference between the Fossa Alterna and a Double VIP, as the former offers a more environmentally sustainable solution that is also conducive to improved safe management of excreta. Demonstration units can be used to show how easily one can empty a Fossa Alterna in comparison to emptying a Double Pit. Keeping the contents sealed in the pit for the duration of at least one year makes the material safer and easy to handle. The same precautions that are taken when handling compost should be taken with the humus derived from the Fossa Alterna.

Maintenance. When the first pit is put into use, a layer of leaves should be put into the bottom of the pit.

Periodically, more leaves should be added to increase the porosity and oxygen availability. Following the addition of faeces to the pit, a small amount of soil or ash should be added. To lengthen the filling time of the pit soil is not added to the pit following urination. Occasionally, the mounded material beneath the toilet hole should be pushed to the sides of the pit for an even distribution of materials. Depending on the dimensions of the pits, materials should be emptied every year.

Fossa Altera at a glance (Source: sswm.info)

Working Principle	The fossa Alterna consists of two partially lined pits and is designed to make compost, which can be used in agriculture to improve soil quality. The fossa Alterna requires a constant input of soil. One of the pits is used at a time. When the first pit is filled up it is closed and the other pit is put in use
Capacity/Adequacy	The fossa Alterna is designed for rural and peri-urban areas. It is simple to build and can be constructed by the user itself with locally available material.
Performance	The decomposition of the faecal material is going well as long as dry material is added and water inlet is prevented
Costs	Low-cost
Self-help Compatibility	Can be built and repaired with locally available material. It must be maintained correctly (instruction by an expert).
O&M	The fossa Alterna requires the frequent addition of dry material (soil, leaves, ash).
Reliability	If well maintained and constructed, high.
Main strength	No water required; Produces humanure.
Main weakness	Requires large amount of dry material. Not suitable with a high groundwater table.

Advantages and disadvantages Fossa Alterna

Advantages	Disadvantages
▪ Can be built and repaired with locally available materials ▪ Because double pits are used alternately, their life is virtually unlimited ▪ Excavation of humus is easier than faecal sludge ▪ Potential for use of stored faecal material as soil conditioner ▪ Flies and odours are significantly reduced (compared to non-ventilated pits) ▪ Does not require a constant source of water ▪ Suitable for all types of users ▪ Low (but variable) capital costs depending on the superstructure materials; ▪ No or low operating costs if self-emptied ▪ Suitable for areas with limited space ▪ Suitable for areas where vacuum trucks cannot enter. ▪ Significant reduction in pathogens ▪ Requires constant maintenance ensuring deposits of regular material soil, ash, leaves, etc.)	• Placing of any garbage in the pit may ruin reuse opportunities to create Compost/EcoHumus • Only suitable for high groundwater table areas or those prone to flooding if the pit is lined and impermeable, or built above-ground.

Design. The approximate volume of the pit can be calculated as a function of the following equations:

- $V = N * S * T / 1000$;
- $F = N * q / i$.

Where:

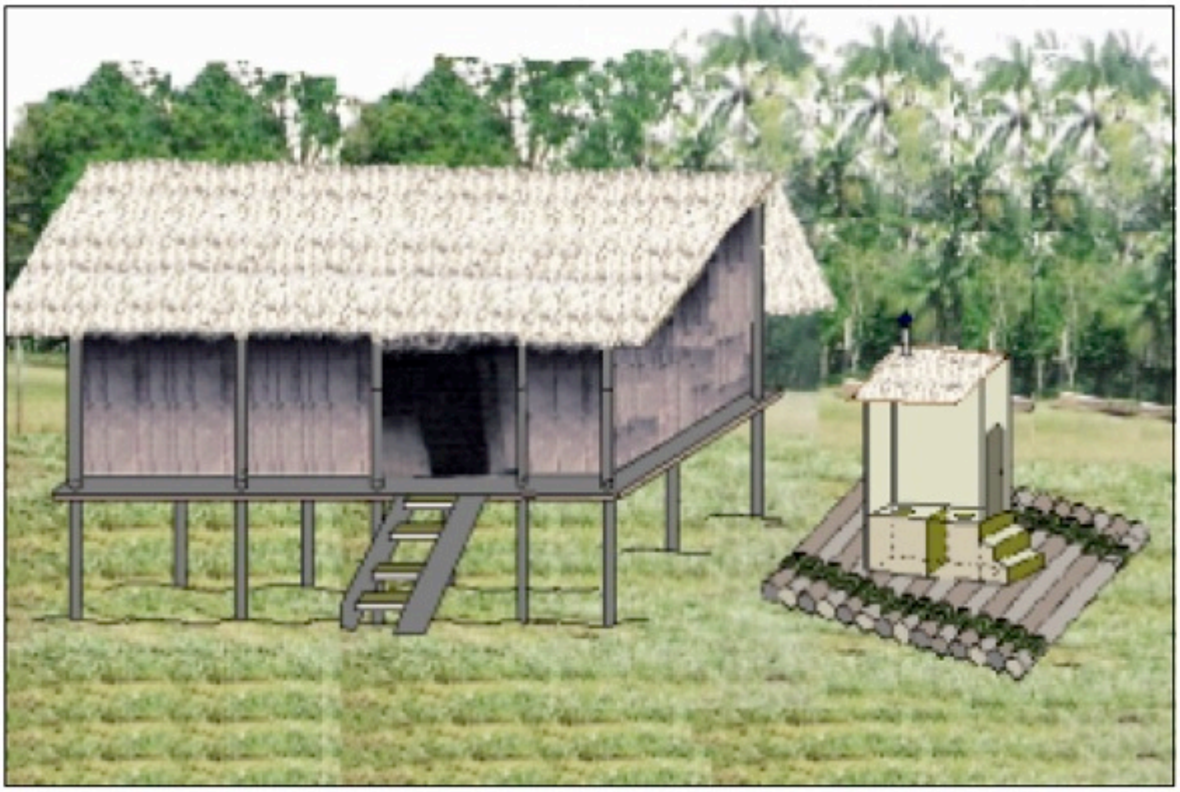
- V = Pit volume (m^3);
- N = Number of users (capita);
- S = Sludge accumulation rate (lcy, litres/cap/year), see sludge accumulation rate (annex 1);
- T = Lifetime pit
- F = Infiltration area (m^2);
- q = Amount of water used for anal cleansing and flushing (lcd);
- i = infiltration capacity soil ($l/m^2/day$), see infiltration capacity soil Annex 2.

A square shaped pit, for a family of 8 persons (N=8), a sludge accumulation rate of 60 lcy (S=60), a lifetime of 1 year (T=1), and a water use of 2 lcd (q = 2) and an infiltration rate of 20 l/m2/day (i=20), the Volume (V) and Infiltration area (F) are:

- V = 8 * 60 * 1 / 1000 = 0.48 m^3, say a pit 1 m' * 1 m', a sludge depth of 0.48 m';
- F = 8 * 2 / 20 = 0.8 m^2; hence a liquid depth of 0.8/4 = 0.2 m' at a pit circumference of 4 m^2 per 1 m' depth;
- Total pit depth with a freeboard of 30 cm: sludge depth + liquid depth + freeboard = 0.48 m' + 0.2 m' +0.3 m' = 0.98 m'.

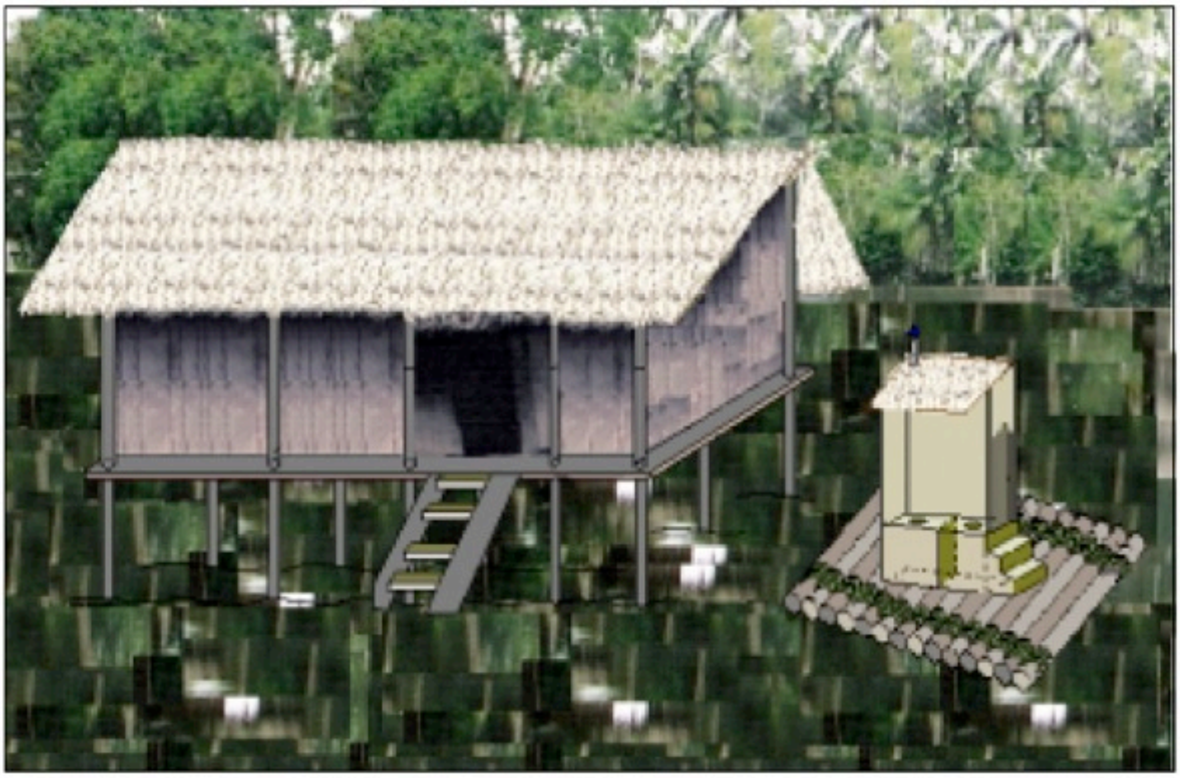
2.3 Floating composting toilets

Composting Toilet. In composting toilets, faeces or excreta fall into a composting chamber together with cleansing material. Dry organic material such as sawdust is added to adjust moisture content and C/N ratio in order to obtain optimum conditions for thermophilic composting. Organic household waste can also be added. Depending on the process, shorter or longer maturation periods and maybe also secondary treatment are required. Urine might be diverted to decrease humidity of the compost and to be reused separately. The final product is a humus-like soil (humanure), which is valuable as soil amendment improving its fertility, structure and water retention capacity.



Floating composting toilet dry season (Unatsabar, 2005)

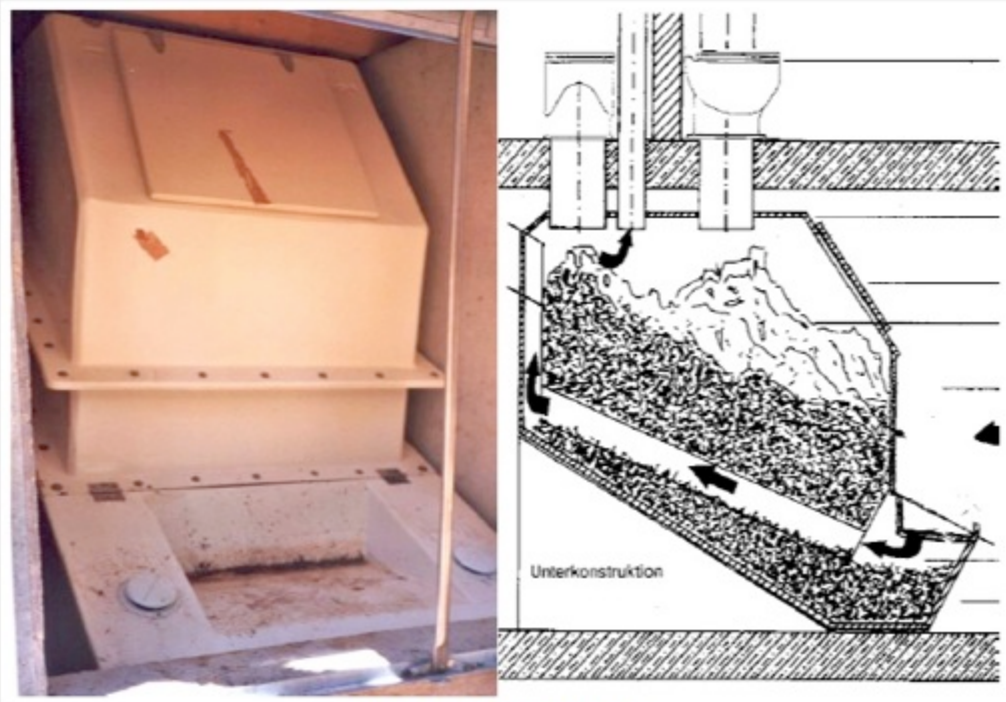
Composting toilets are toilets systems, which allow to minimise water use and to recycle nutrients contained in excreta and faeces. There are various different systems (i.e. pits or vaults; urine diversion or not; low-tech and high-tech; single-vault continuous or multiple vault batch). The functioning of the various different composting toilet systems is basically the same. Faecal matter and toilet paper or other dry cleansing material fall into a composting chamber. Organic household waste can also be added. Good ventilation serves to prevent excessive humidity and odour. To increase composting properties, dry material, which contains carbon (such as sawdust or ash) are added. This regulates the carbon to nitrogen ratio (C/N) and enhances the composting process. If ash and lime are used as adding material, this has the additional beneficial effect of raising pH, which leads to improved pathogen die-off. Often, composting toilets also have a drainage system to allow the drainage of liquids. This leachate has very high concentrations of nutrients, organics but also contain pathogens. They need to be collected, treated and if possible reused. Urine diversion usually reduces leachate production, see below. The end product of composting toilet is an odourless (and generally stabilised) material, called humanure, which is a valuable as soil conditioner (improving nutrient content, structure and water retention capacity of the soil). Depending on the local conditions, humanure can be harvested after some weeks or years. After this, it may be directly reused or requires a secondary treatment for complete pathogen removal



Floating Composting Toilet during flooding (Unatsabar, 2005)

Basic Design Principles. Composting toilets have a chamber in which all excreta and faeces are confined. The design of the chamber varies much but generally, they are watertight and well aerated (as composting is an aerobic process). Urine is either diverted or not, and there may be a drainage system or not. A grinder or mixer to homogenise the compost is included in some high-tech models but not necessarily required. The chambers are built as vaults above ground (like for the clivus multrum, the double vault Vietnamese composting toilet or the skyloo, see picture below) or underground pits. This factsheet focuses on above ground composting toilets (vault composting toilets). You can find information on typical pit composting toilets in the factsheets for the Arborloo and the Fossa Alterna.

In continuous vault composting toilets, such as the clivus multrum, compost can continuously be harvested on one end, while faeces fall into the other. In batch systems, the composting chamber is changed once it is full and the next one is used during which the other one is closed and left aside for maturation. Batch systems, especially in low-tech models, are much safer as they prevent mixing of fresh and matured material. Typical batch systems are double vaults or movable containers.



Terra Nova Composting Toilet

Continous composting latrine (Amazonia Workshop, 2004)

Composting toilets rely on the aerobic degradation of organic matter, resulting in a hygienic product that can be used as soil fertiliser. Composting is possible at high temperatures (thermophilic composting) and at low temperatures (ambient or mesophilic composting). Thermophilic composting is faster and more efficient to inactivate pathogens. The optimal operational conditions for thermophilic composting are:

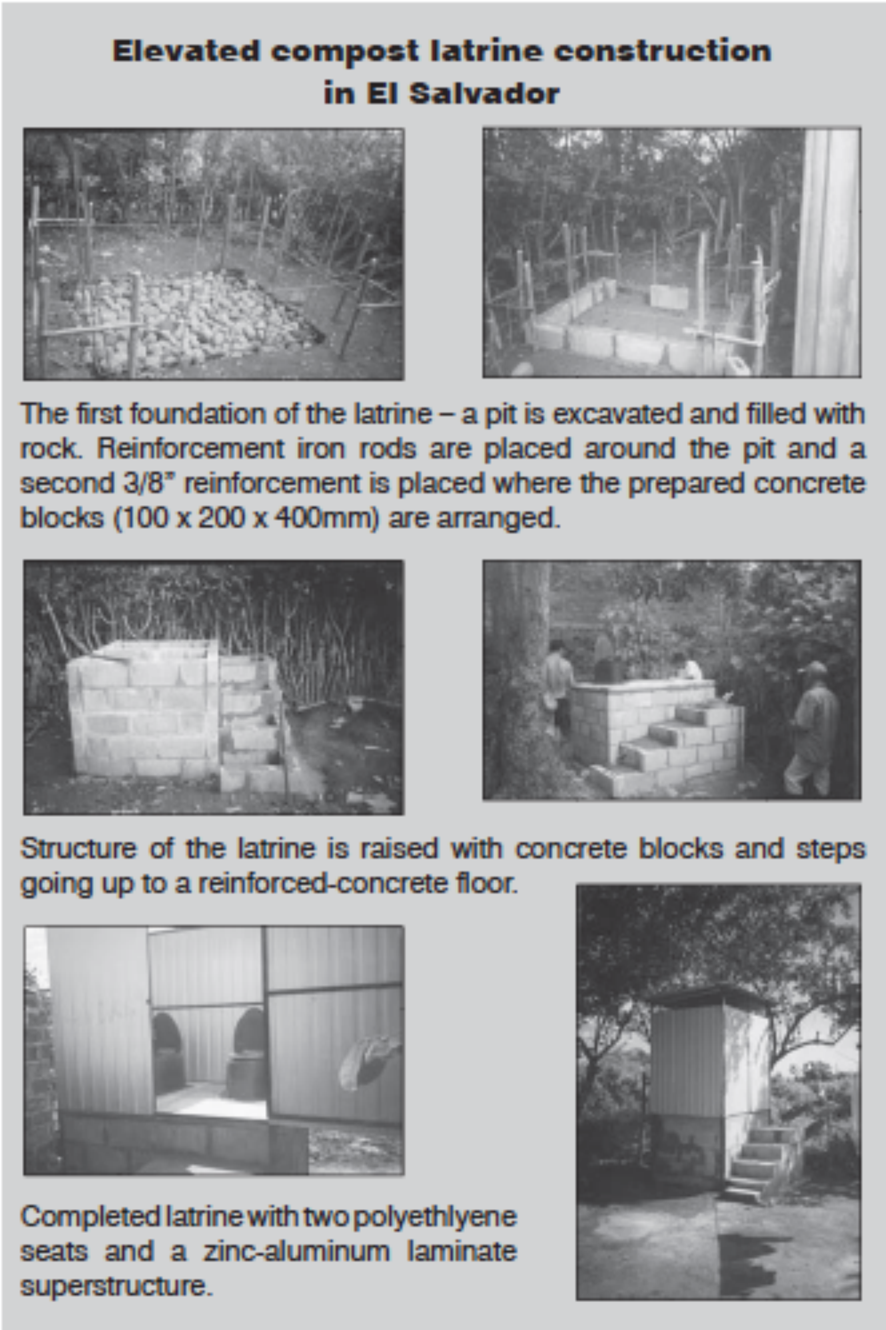
- Good aeration;
- A moisture content of 50 to 60 %;
- A C/N ration of 30 to 35.

The carbon to nitrogen ration (C/N) of excreta (including urine) is about 7 to 8, but for optimal thermophilic composting, it needs to be 20 to 35. The addition of paper, wood or bark chips, sawdust, ash or other similar substances will help to increase the C/N ratio. However, if the C/N ration becomes too high (> 30 to 35), then the composting is slowed down, impairing the attainment of required temperatures. Adding bulk material is also important to reduce humidity in the chamber and thus the potential of odour and fly breeding problems. The addition of organic household waste can also help to raise the C/N ratio. It can be added to a composting toilet through the toilet itself or through a separate chute.

The toilet can be designed either with or without urine diversion (see also urine diversion components). Urine adds more water and it has a very high nitrogen content. With urine diversion, less bulking agent is needed and the C/N ratio is naturally enhanced.

Ventilation of composting toilets is important in order to maintain low moisture content of the compost and to prevent odour. Best ventilation is designed similar as for urine diversion dehydration toilets. It can be done naturally or mechanically. Mechanical ventilation requires a fan or another mechanical device and power/solar energy. For natural ventilation, a difference of pressure (or temperature) is required inside and outside the vaults. This can be given by wind or a stack effect. The stack effect can be achieved by installing the ventilation pipe outside and expose it to the sun (it may also be painted in black). When the air in the pipe heats up, it rises upwards out of the vent; a downward draught of cooler air of higher density then flows in through the squat plate hole, replacing the vacuum space created after warm air rising (OKETCH 2005).

Due to its complexity, thermophilic composting can be difficult to manage and often, the operating range of composting toilets is varying within the thermophilic, mesophilic and ambient composting. Even though the pathogen content is considerably reduced in composting toilets, complete pathogen destruction can only be achieved if good process conditions can be guaranteed. This can be done by using an advanced toilet design with insulation for maintaining a high temperature within the whole composting chamber (GTZ 2006). If thermophilic composting cannot be guaranteed, longer maturation times or a secondary treatment may be required (see also co-composting at small and large scale or drying and storage of faeces). In practice, thermophilic composting of faeces at the domestic level is questionable, as only slight elevation of the temperature was recorded in some trial. Therefore low-cost composting toilets at the household level may only be adapted if a secondary treatment is provided to ensure safety of the system.



Elevated compost latrine construction in El Salvador (Unicef)

Health Aspects. If operation conditions for thermophilic composting are adequate (moisture content 50 to 60 %, carbon to nitrogen ratio 30 to 35 and mixing with bulking material), the temperature will rise to between 50 and 65 °C (WHO 2006). Such temperatures will effectively inactivate pathogens (WHO 2006). Otherwise, secondary treatment will be necessary (see above). After a secondary treatment step, humanure is a highly valuable soil conditioner.

Cost Considerations. There are many designs and models offered by manufacturers all over the world with a large range of prices (GTZ 2006). Low-tech composting toilets can also be self-constructed with locally available material.

Operation and Maintenance. In composting toilet sufficiently organic bulking material should be added after each use in order to enhance the drying process and control the C/N ratio. The immediate coverage of the fresh faeces with an additive material also lowers nuisances caused by odour or flies.

A squeeze test can be used to check the moisture level within the composting chamber. A squeeze test requires the user to squeeze a handful of compost: The compost should not crumble and feel dry, nor should it feel like a wet sponge. Rather, the compost should only leave a few drops of water in the user's hand.

With time, salt or other solids may build up in the tank or in the leachate collecting system, which can be dissolved with hot water and/or scraped out.

In multi-vault/container systems, filling is generally stopped when the vault is 2 to 3 qua. Then content is covered with soil and the vaults or containers are sealed. The maturation periods depends on temperature and the local climate. Under optimum thermophilic conditions, it may only take some weeks until the faeces or excreta are decomposed and hygienized. However, batch systems should be designed such as each filled vaults/containers can maturate for at least during two years. That means that each vault of a double-vault composting toilet should be large enough to hold at least two years' accumulation.

Emptying composting toilet constitutes a critical handling point. The emptying frequency depends on the size of the chambers, the feeding rate and the composting rate (volume reduction, pathogen removal). Generally, composting chambers should be emptied every 2 to 10 years. Proper protection measures, mainly personal protection, should be taken, especially if the material is not fully hygienized. In this case the material should be further treated or stored out of reach from people until proper maturation times have been reached. In addition to protective clothing (e.g. gloves and boots), normal hygiene and washing after the emptying operation are important.

At a Glance

- **Working Principle:** Faecal matter is collected in vaults or pits together with organic bulking agents. At optimum conditions, thermophilic composting takes place transforming the faeces or excreta into humus like toilet compost (humanure), which can be used as a soil amendment;
- **Capacity/Adequacy**: Composting toilets can be constructed everywhere. Pre-fabricated high-tech models are available. Simpler composting toilets can be constructed by the user itself with locally available material;
- **Performance.** Depends much on the local climatic conditions and operation and maintenance. At optimum conditions, resulting humanure is completely safe.
- **Costs.** Depends on technology level; from moderate to high-cost;
- **Self-help Compatibility.** Can be built and repaired with locally available material. Expert design maybe required;
- **O&M**. Composting toilets require the frequent addition of organic bulking material and control of moisture and temperature;
- Reliability. If well maintained and constructed, high;
- **Main strength**. No water required and no risk of soil water pollution; Produces humanure;
- **Main weakness.** Requires large amount of organic bulking material and thermophilic composting is not always achieved.

Applicability

- Composting toilets are suitable for both industrialised and developing countries, especially in arid regions and regions without piped water for sewers (GTZ 2006);
- Composting toilets can be constructed at the household level, or they can be built in cluster for institutions, schools, hostels and so on (CALVERT 1999). However, open access community compost toilets are not recommended other than in well-educated and highly motivated communities (CALVERT 1999);
- Composting toilets can be built beside or as part of a house in rural, urban or peri-urban areas and can even be established inside a house or apartment (CALVERT 1999). In several projects, composting toilets have also been successfully implemented in houses with several floors with the collecting chamber being situated in the basement (GTZ 2006);
- Composting toilets are generally sealed systems; therefore they are also adapted to areas prone to flooding or high water table (CALVERT 1999);
- Composting toilets are slightly more expensive than urine diversion dehydration toilets in terms of excreta management because of the need for the control of the C/N ration (GTZ 2006), but the nutrients contained in the compost from composting toilets are more readily available than those from dehydration toilets (GTZ 2006).

Advantages

- Operate reliably during dry (no water required) and wet seasons (in comparison to dehydration toilets);
- Can reduce the volume of the faecal matter considerably (up to 30 %, GTZ 2006);
- Can reduce the volume of solid waste, as organic waste can be added to the toilet;
- No need to dig pits (in the case of vault composting toilet);
- Urine can be collected separately;
- End product (humanure) is a valuable soil amendment;
- Low-cost and high-cost versions are available;
- Can be built and repaired with locally available material, If leachate is controlled, composting toilets can also be constructed where the groundwater table is high or on bedrocks.

Disadvantages

- Requires bulking material and careful operation;
- Moisture and temperature should be controlled;
- Leachate requires secondary treatment;
- More expensive than ordinary pit latrine.

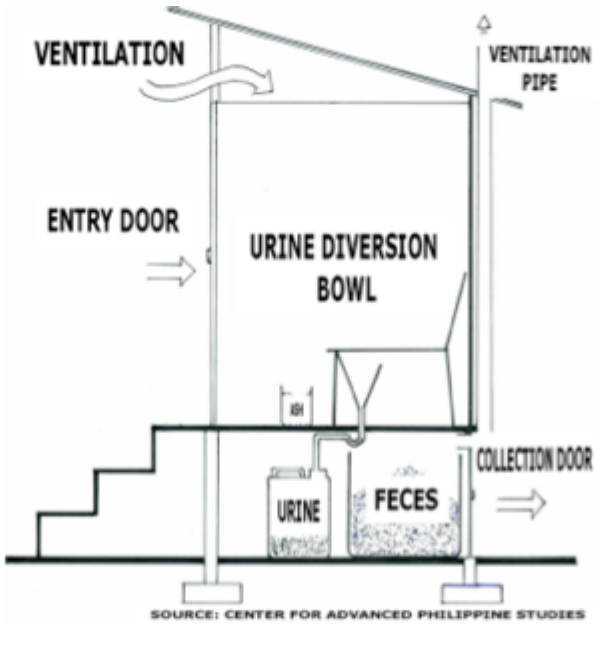
Applying conditions

- Dry urine diversion toilets, see § 2.4, are used in regions that are water scarce, or that have an impermeable soil or a high ground water table;
- They are suitable in rural and suburban areas, where urine and faeces can be used in agriculture;

- There needs to be sufficient public awareness about the risks of handling urine and faeces;
- Experiences in Bangladesh are mixed, so there needs to be a considerable effort to encourage behaviour change.

2.4 EcoSan / Urine Diversion Toilets

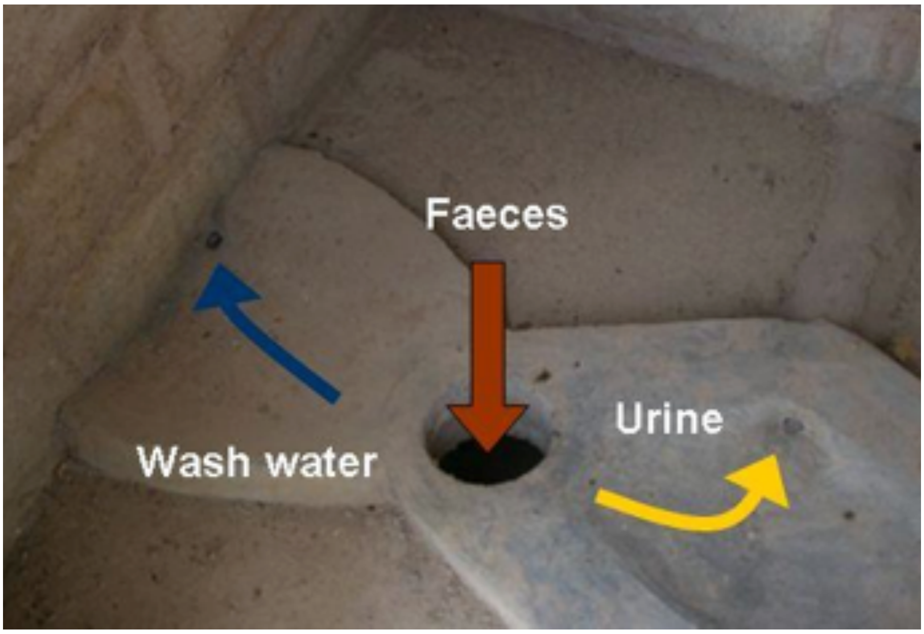
A Urine Diversion Toilet is a special form of composting toilet. The toilet has two compartments, keeping urine and faeces separate. Urine leaves the toilet through a pipe / tube. Faeces are stored directly beneath the toilet. After defecation, dry soil, ash or sawdust is spread over the faeces, controlling odour by absorbing moisture. Men, as well as women, need to sit while urinating to ensure that the urine is diverted into the correct channel. Water used for anal cleaning must be kept separate in order not to dilute faeces or pollute urine with pathogens. This requires a separate facility for anal cleansing. Small amounts of anal cleaning water can be infiltrated. Larger volumes need to be treated (together with grey water) to prevent ground water pollution. Dry urine diversion toilets can be made out of ceramic, ferrocement, fibre-enforced materials, or strong, durable, plastic and painted wood. It is important that the surface is smooth and hardened.



Some more info on the UDDT.
Engineers, architects, water specialists, pollution experts, farm research scientists, doctors, social scientists, and environmentalists etc. have joined hands to promote the Urine Diverting Dehydration Toilet (UDDT) as a new approach to manage human waste, namely, urine and faeces. While urine is a liquid fertilizer with tremendous potential for using in agriculture, faeces can contain pathogens that are harmful to human beings and contaminate water, soil etc. In UDDTs, faeces, urine and wash water are collected separately and thus urine and wash water are not allowed to mix with faeces. Urine collected (e.g., in a jerry can) can be used as liquid fertilizer in kitchen gardens or for other crops. Faeces is collected in a chamber and allowed to compost over a period of time (18 months). Wash water is let into a filter bed near the toilet to raise crops. Thus, UDDTs ‘close the sanitation loop’ by turning human waste into a nutrient for raising crops. UDDTs are most suitable in areas of water logging, water scarcity, dry, sandy and coastal areas.

USE AND MAINTENANCE USE

- Remove the lid;
- After putting a bit of ash into the drop hole, sit in such a way that the faecal matter drops directly into the drop hole;
- After defecating, sprinkle a handful of ash or saw dust or lime powder into the drop hole. Over the faecal matter;
- Close the drop hole with the lid;
- Move a few centimetres backwards and complete washing your body;
- Wash your hands thoroughly using soap or ash after using the UDD Toilet.



MAINTENANCE

Explain usage practices carefully and many times – till users follow them scrupulously!

- Ensure that the lid is closed after defecation;
- While washing after defecation, ensure that water does not enter the drop hole. But if a few drops of urine or wash water enter the drop hole, apply a little extra ash/saw dust or lime;
- Apply ash carefully over the faeces so that it does not fall inside the urine bowl or washbowl – since this may clog the flow of liquids;
- Remove any spillage on the rim of the drop hole during defecation, with a small piece of paper or wet cloth which, may then be dropped inside the drop hole into the chamber;
- Wipe the floor of the toilet outside the urine bowl and washbowl with a waste cloth or mop, (purchased from the market). · Keep ash in a small container inside the toilet;
- After one year of closing the chamber remove the cement mortar, take out the slab. The compost can then be taken by hands without any hesitation (it has been tried and tested!). This can be done by the house owners themselves – and there is no need to hire sanitary workers or a vehicle to remove the compost from the chamber;
- Replace the mosquito net in the vent pipe cowl once in 6 months;

- Educate the user about the dehydration of the faeces and the essence of the UDDT – and that the lesser the water used for washing after defecation the better it is! Inform them also that while they need only 2-3 litres for washing after defecating in a UDDT around 8 - 10 litres is needed to push the faeces out of sight in the conventional flush toilets.

DO'S

- Cover the floor with dry powdered ash/saw dust or lime powder (in order to absorb moisture from the floor), before using the chamber for the first time;
- Keep ash or saw dust in a bucket inside the toilet – Always;
- Sprinkle ash over the faeces and cover the drop hole with the lid, after use;
- Keep water in a small bucket and use a small mug;
- Keep a brush/small piece of cloth fixed to a stick for cleaning the pan at regular intervals. If need be use a damp cloth for cleaning the pan;
- Wash hands with soap after defecation & after handling the urine container or cleaning pan;
- Level the content of the first chamber when it is 75% full, and also apply ash or saw dust or lime at the top and seal the chamber for composting for nine months. Start using the second chamber;
- Wear gloves while emptying the vault and wash hands with soap afterwards.
- Make sure the vent pipe is straight and extends at least 15 cm above the roof;
- Ensure that the cowl at the top of the vent pipe is covered with mosquito netting;
- Instruct new users and children in the proper use of the toilet;
- Mark the chamber that is not in use or sealed for composting - so that it is not opened!;
- Place water in the toilet, in a small bucket with a mug, for anal washing.

DON'TS

- Do not use both the chambers at the same time;
- Do not allow urine or water to not enter the faeces chamber;
- Do not use chemicals, acids and water for cleaning the pan;
- Do not use partially digested or fresh excreta as fertilizer since it can be harmful;
- Do not empty the vault before nine months after sealing it for processing;
- Do not allow rain water to enter the pan from vent pipe or from ventilator or door;
- Do not leave urine container open and unprotected;
- Do not urinate standing, the urine will splash on the latrine floor causing foul odour;
- Do not make any provision for a water tap inside the toilet.

ADVANTAGES OF USING UDDTs

- Suitable in areas where pour flush may not be: UDDTs can be built in almost all geographical and demographic conditions, but are particularly useful in rocky terrain, areas with high water tables (e.g., coasts) and places where water is scarce (e.g., deserts) – where conventional flush toilets are difficult or expensive to construct, or have negative impacts on the environment (e.g., contamination of groundwater/depletion of ground water);

- Saves water: Pour-flush toilets use approximately 4-10 litres of water to flush the faeces depending on the flushing systems, while the UDDT requires water only for anal cleaning which will be a maximum of 1 litre of water per wash;
- Easier maintenance: They cause limited problems in disposal of black water due to smaller quantity, are easy to maintain;
- Recovers nutrients for agriculture: On an average, each person produces about 5 kg of elemental NPK in excreta per year (about 4 kg in urine and 1 kg in the faeces), all of which is available as fertilizer from the urine and compost produced by a UDDT;
- Reduced amount of waste to be treated: Compared to regular mixed systems, source separation of faeces and urine in toilets generates less material requiring treatment;
- Lower pollution: Apart from reduced odour and fewer flies, there is also lower risk of pathogens leaking from the system.

URINE AND FAECES AS FERTILIZER

Urine: Urine can be applied in a variety of ways

- Diluted application before or during sowing or planting, or on the young plant;
- Urine can be applied in one large dose or several smaller ones during the cropping season;
- Urine can be used as a liquid plant food mixed with water. Diluted urine can be added to the soil where vegetables (and plants like maize) are growing – once a week or even twice or thrice a week, provided that the plants are also watered frequently at other times. Undiluted application may be made to soil beds before planting;
- Urine can be used as an 'activator' for compost heaps. The transformed organic nitrogen will be available to plants when the compost has matured;
- Concentrated fermented urine can be applied to beds of dried leaf mould as a medium for growing vegetables and ornamental plants;
- A future possibility, when large amounts of diverted urine are available from urban areas, is to use human urine to produce a concentrated fertilizer in powder form.

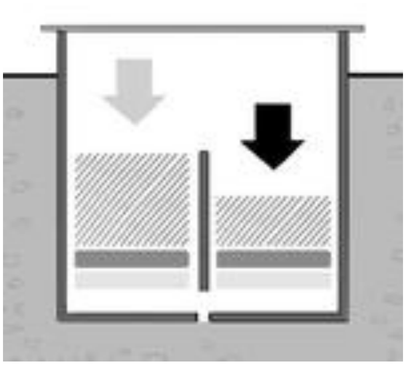
Faeces: Composting and vermicomposting is the best and most efficient method to produce organic fertilizer from human excreta. Faeces contain less nutrient than urine, the humus produced from faeces actually contains higher concentrations of phosphorous and potassium. Once the pathogens are destroyed through dehydration, the resulting inoffensive material can be applied to the soil to increase the amount of available nutrients, to increase the organic matter content and to improve the water-holding capacity. The simplest form of recycling is when the individual household use the product as fertilizer in his/her own garden or farmland.

- Remove the dehydrated but slightly moist compost from the UDDT chamber;
- Apply the compost in furrows or holes close to where the plants will later be growing.

Advantages of applying organic fertiliser:

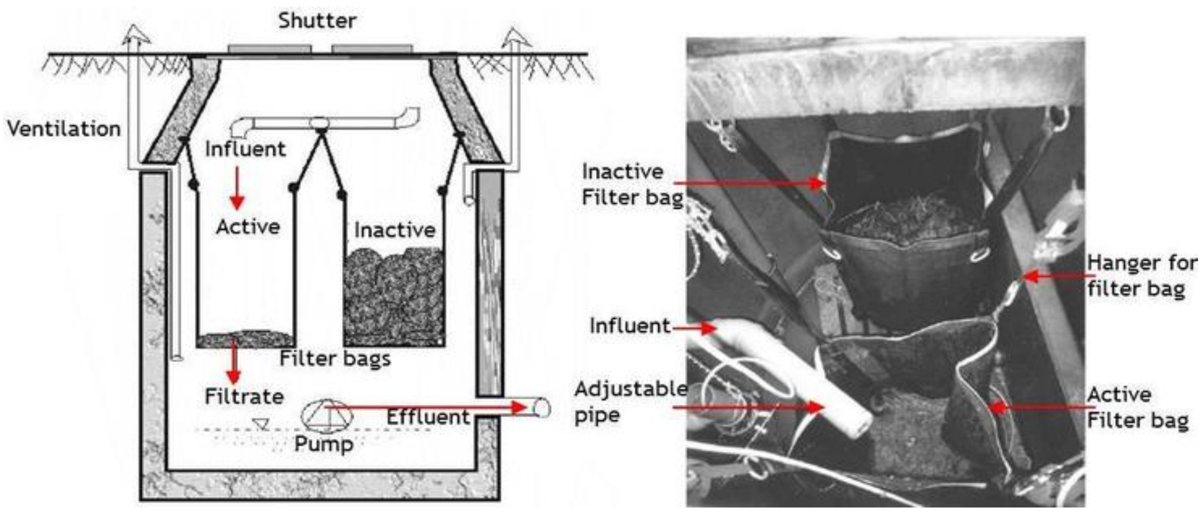
- Improves soil structure;
- Improves pore space;
- Increases water-holding capacity;
- Enhances water supply for crops;
- Increases the diversity of micro-organisms;
- Enhances a multitude of biochemical processes;
- Increases the capacity to buffer pH and pollutants;
- Improves storage and exchange capacity for (micro) nutrients;
- Steadily releases a reservoir of NPK by mineralization;
- Improves overall soil quality through the increase in soil organic matter (SOM) which in turn influences many soil functions. Soil organic matter (particularly >5µm), play an important decisive role in orientation of soil clay particles, soil compaction and hence regeneration of its structure.

2.5 Rottebehaelter



The rottebehaelter or compost filter is a fairly new method for pre-treating wastewater. There are two different methods: two chamber compost filters or compost filter bags. Grey-water or domestic wastewater flows directly into this filter. The solids stay in the filter and are decomposed and transformed into humus by aerobic digestion; the liquids are drained at the bottom and forwarded to the constructed wetland. As it is an aerobic process, there are neither biogas emissions nor bad odours. From time to time, the operator has to add bulking material like straw or wood chips, to enforce the dehydration and to avoid clogging of the filter.

The wastewater flows directly into the composting filter. It consists of two chambers; each chamber has a capacity of one year. As soon as the first chamber is full, the influent pipe can be switched to the second chamber for the following year. In the meantime, the faecal sludge in the first chamber is dewatered, and the rotting process (aerobic digestion) successively decomposes the material.



Rottebehaelter (Gujarel, 2005)

The raw black-water passes through a filter bag (made of jute or plastic material) into a chamber with a ventilation pipe. The liquid effluent from the compost filter is collected below the filter bags and normally needs to be treated in a constructed wetland, a fishpond oar a floating pod, as the hydraulic head loss in compost filters is about 1.5 m. The solid components of the black-water (i.e. faeces and cleansing material) are retained in the straw bed, which is contained in the filter bag.

Operation of rottebehaelter (Staufer, 2010)

The Final Product. The final product (after it has been fully aerated and left without addition of new material for 6 to 12 months) is black, compact material, which looks and smells like black soil or humus. Nevertheless, the material still needs secondary composting (see small and large scale composting) as it still contains pathogens such as Helminth eggs.

Cost Considerations. Compared to other water based systems, construction costs are relatively low. However, it is still more expensive than a dry toilet or composting toilet system. A compost filter needs expert design and constant input of straw or wood chips.

Operation and Maintenance. The compost filter bag needs regular maintenance. Once a week dry straw has to be added. Generally, 2 to 4 filter bags are used in alternating modes in two separate chambers (the dimensions of the chambers depend on the number of users); the retained solids are composted during the resting phase of 6 months, during which the second bag is used. Volume reduction during resting phase can be up to 75%.

An operator must maintain the active chamber of the two-chamber filter regularly: dry material such as straw or wood chips must be added weekly to monthly. This avoids clogging of the filter and advances the dehydration process. It is recommended, that the added material be arranged all over the compost filter surface. It should be slightly accumulated directly below the influent. If the filter is correctly maintained and operated, no unpleasant odour can develop.

Health Aspects. The chambers need to be covered in order to prevent people (especially children) from falling in. The active chamber contains fresh excreta. The material of the inactive chamber is less hazardous, but could still contain pathogens. Therefore, gloves are recommended for any maintenance or repair work of the filter. The decomposed material should be composted again, as a further hygienization (see small and large scale composting). It is also important to apply this material correctly if it is used for agriculture.

At a Glance

- **Working Principle:** The raw black water passes through a filter bag/chamber. The liquid effluent from the compost filter is collected below the filter and normally needs to be pumped to the constructed wetlands. The solid components of the black water (i.e. faeces and cleansing material) are retained in the compost filter;
- **Capacity/Adequacy.** Compost filters are used by small communities for primary treatment of grey- and black water;
- **Performance.** High;
- **Costs.** Compared to other water based systems, construction costs are relatively low;
- **Self-help Compatibility.** High, once it is constructed;
- **O&M.** Must be maintained regularly by unskilled labourers;
- **Reliability.** Reliable if designed and operated correctly, problems might occur with shock loads;
- **Main strength.** No bad odour, produces compost, no biogas emission;
- **Main weakness.** Risk of clogging and anaerobic conditions if not operated correctly.

Applicability. Compost filters are suitable for domestic waste- or greywater with high organic load. So far compost filters were constructed for single households and small communities. Further treatment (e.g. composting) of the filter material must be available.

Advantages

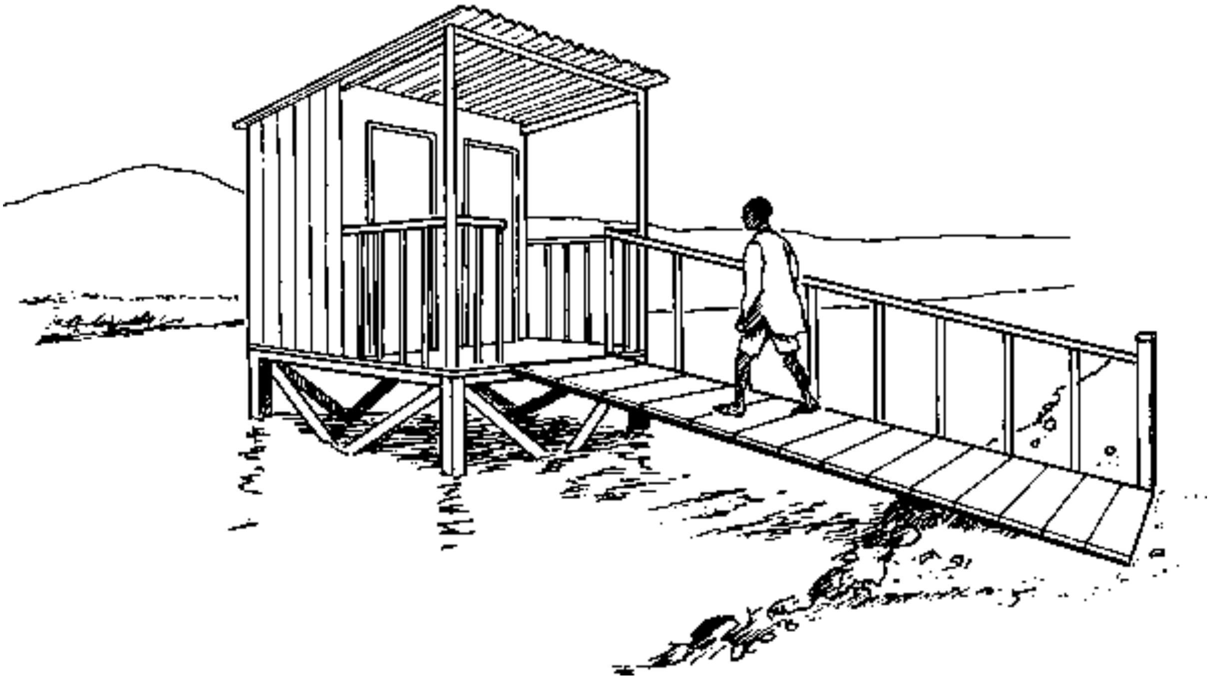
- The effluent (filtrate) from a compost filter has no unpleasant odour compared to anaerobic pre-treatment systems (e.g. septic tanks);
- There is no biogas production since it is an aerobic process;
- Produces compost that can be used for gardening or farming;
- Can be operated and maintained by everyone after a short training.

Disadvantages

- Needs more “hands-on” maintenance than other pre-treatment method;
- Use is limited to small units (decentralised wastewater treatment systems);
- Compost filter bags only work with highly concentrated black-water, because too many solids may be washed out of the filter bags otherwise;
- Clogging may occur, usually due to having selected the wrong filter bags or substrate or due to bad maintenance;
- The leachate (liquid effluent) requires further treatment.

2.6 Over-hung latrine / fish ponds

An over-hung latrine consists of a superstructure and floor built over water. A squat hole in the floor allows excreta to fall directly, or via a chute, into the water below. Over-hung latrines are widely used, but rarely appropriate and the usual advice is that they should only be considered if other options are not possible, such as in areas prone to continued flooding. In those cased, the receiving water must be sufficiently deep throughout the year, preferably should be saline to prevent human consumption, and should be flowing away from settlements. The main constraint is that they only can be used where the contamination of the watercourse will have no adverse effect downstream; cannot be used over still water or where water is used for recreation, washing etc.; and superstructure must be solidly constructed and safe for users.



Overhung latrine (http://helid.digicollection.org/en/d/Js2669e/7.6.5.html, Accessed 26 October 2013)

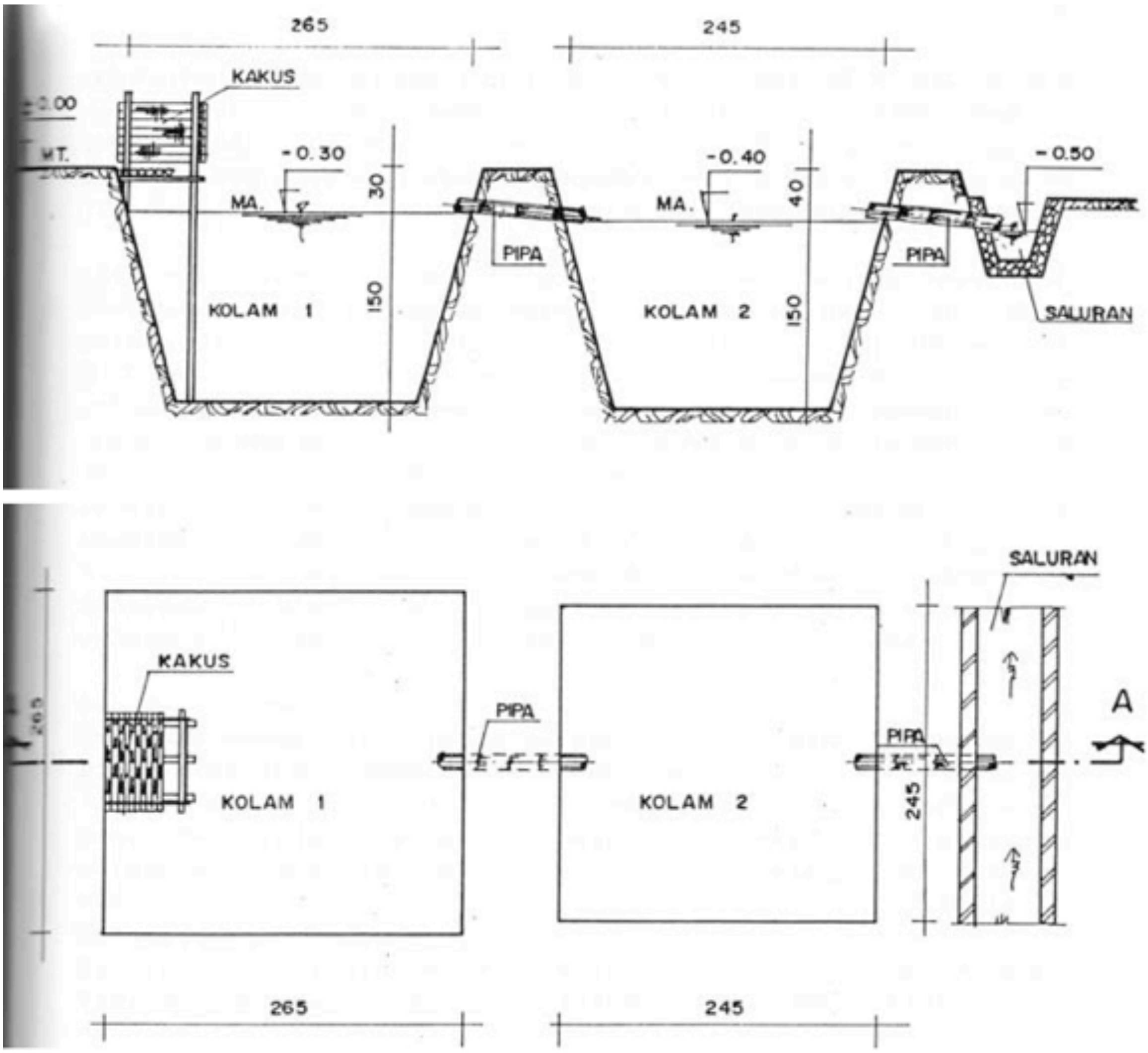
Overhung latrine Bangladesh (Source: http://helid.digicollection.org/en/d/Js2669e/7.6.5.html, accessed 26 October 2013)

These constraints can be overcome in a (Fish) Pond system: the overhung latrines are located to ponds where the faecal matter is sufficiently long retained to kill the pathogens. In practice, two ponds are to be provided in series to attain the objective:

- To prevent foul smell, the first pond should have a surface of at least 1.4 m^2/user;
- To prevent contamination of the environment by discharge of effluent which contains too many pathogens, the second pit should have a volume of at least 1.2 m^3/user.

Hence, for a family of 5:

- First pond: surface area 5 * 1.4 = 7 m^2, depth say 1.5 m', volume 10.5m^3;
- Second pond: volume: 5* 1.2 = 6 m^3.



Planning overhung latrines:

- Temperature: in areas with temperatures are higher than 25 degrees, ponds may be smaller than the guidelines above; in areas with temperatures lower, the ponds should be larger;
- Topography: the topography should allow discharge of the effluent;
- Geology: if the soil is unstable or permeable, the ponds should be lined;

- Hydrology: during the dry season, the losses of the water due to evaporation might be 10 litres/m2/day or for the ponds above: (7+6) * 10 = 130 litres/day and exceeding the inflow of 50 litres per day (assuming 10 litres/person/day);
- Local materials and skills: the overhung latrine can be constructed by the household itself at virtually no cost.

Fish. Bangladesh is a country with hundreds of rivers and ponds and is notable for being a fish-loving nation, acquiring the name "Machh-e Bhat-e Bangali" which means, "Bengali by fish and rice". Hence, in the ponds of the overhung latrine fish can be stocked. The wastes put into the ponds are nutrients for the plankton. Fish in the ponds graze on the plankton and keep the ponds in ecological balance and the following beneficial effects:

- Insect control by the consumption of insect larvae;
- Reduction of nitrogen and phosphorus concentration;
- Reduction of the number of suspended solids;
- Increase of pH due to lower CO2 consumption by the larvae.

Despite the reduction of pathogens, fish is still contaminated and it is necessary to stock fish in fresh clean water for 2-3 weeks prior to consumption.

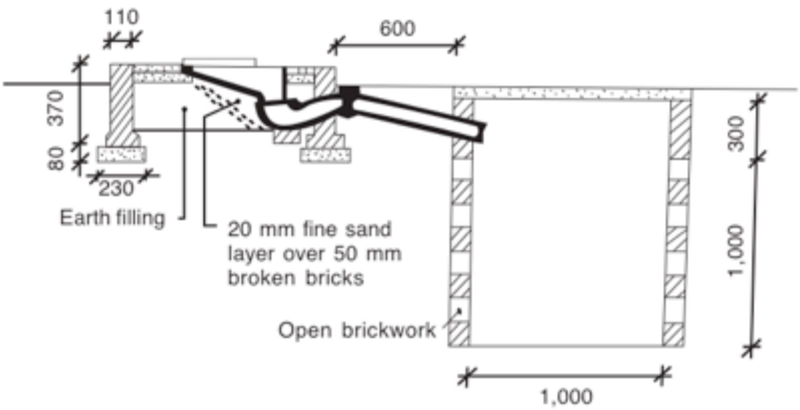
Design. When applying fish ponds:

- The oxygen concentration must be more than 3 g/m^3, if at nigh the oxygen concentration is less, ' surface breathers' should be introduced;
- To promote oxygenation by algae, ponds should be shallow;
- The wastewater should not contain any settle able, putrefying or toxic material;
- To utilize the extra natural food in wastewater, it is more efficient to maintain relatively large standing stocks of young fish such as fingerlings than small stocks of full-grown fish;
- By selecting the species adapted to environmental conditions of a wastewater pond, 98% survival rate for fish can be attained;
- A high pH, normally related to high phytoplankton productivity, is a possible cause of fish mortality. Increasing the waste water flow may improve survival conditions;
- Fish production is reported to be up to 0.86 kg/m^2/month, compared to 0.47 without wastewater;
- Reduction of pathogens might be up to 99.6%.

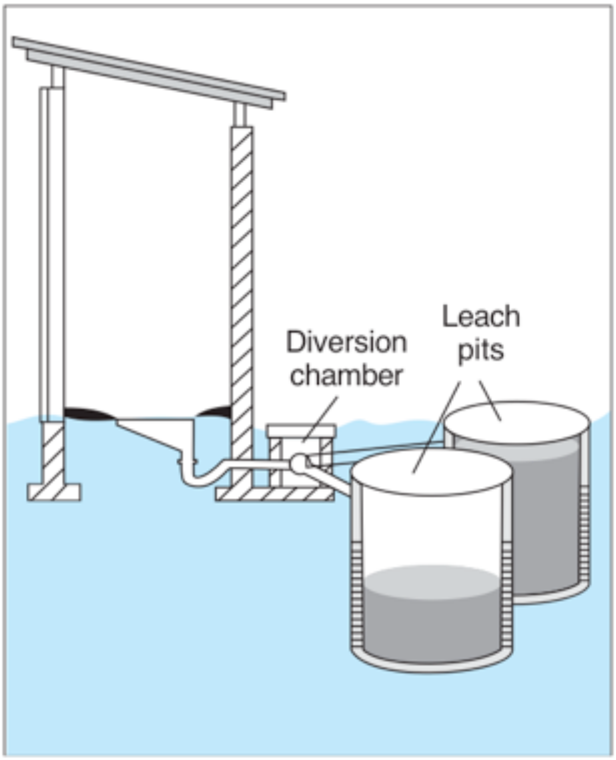
Revenue. With a per kilogram fish price for fish of 1750 taka, the revenue of the fish pond as designed above could be 13 m^2 * 0.86 * 1750 = 20,000 taka per month.

2.7 Twin Leaching Pits

Twin Leaching Pits for pour-flush toilets are two underground leaching pits linked to one single pour-flush toilet by a Y-junction or control box. The two pits are used alternately with both urine and faeces entering one pit at a time. Black water (i.e. excreta, flushing water and anal cleansing water) is directed into one of the pits. The pits are lined either with a porous material or holes in the walls allowing the liquid to infiltrate into the surrounding soil. During soil infiltration, most of the pathogens are filtered or die-off with time and distance - but in high groundwater table and/or densely populated areas, it can still lead to the pollution of ground water. Solids accumulate on the bottom of the pit and start to decompose by a combination of composting (aerobic digestion) and anaerobic digestion processes. When one pit is full, it is sealed and left aside for complete decomposition of solids, while the other is brought in use. When the decomposition of solids is completed (in general after 1-2 years), the end product is sanitised but still contains good organic matter and nutrients that can be reused on-site, much like compost, to improve soil fertility and fertilize crops.



Twin Leaching Pit Cross Section (Kalbermatten)



Twin Leaching Pits (WSP, 2008)

Honey comb brick work (WASTE, 2012)

As the effluent leaches from the pit and migrates through the dry soil, faecal organisms are removed. The degree of faecal organism removal varies with soil type, distance travelled, moisture and other environmental factors. There is a risk of groundwater pollution whenever there is a high or variable water table, fissures and/or cracks in the bed- rock. It is important to know the groundwater table depth and soil type as viruses and bacteria can travel hundreds of metres in saturated conditions. As soil and groundwater properties are often unknown, it is difficult to estimate the necessary distance between a pit and a water source. The table below provides some guidance and remedial actions, modifications of the pits if this is the case: an envelope of fine sand to retain the infiltration. It is recommended that the Twin Pits be constructed 1meter apart from each other to minimize cross-contamination between the maturing pit and the one in use. Water within the pit can impact the structural stability of the pit. Therefore, all walls should be lined up to the full depth of the pit to prevent collapse and the top 30cm should be fully mortared to prevent direct infiltration and ensure that the superstructure is supported.

Distance between bottom of the pit and the maximum groundwater table	Effective size of the formation soil	Minimum horizontal distance from drinking water source	Modification needed
> 2 m	< 0.2 mm (fine sand, clay and silt)	3 m	None
> 2 m	> 0.2 mm (coarse sand)	3 m	Provide envelope of sand and impermeable pit bottom
< 2 m	> 0.2 mm (coarse sand)	10 m	Provide envelope of sand and impermeable pit bottom
< 2 m	< 0.2 mm (fine sand, clay and silt)	10 m	None

Distance leaching pits from drinking water and modifications (Roy et al, 1984)

Y-Box (WASTE, 2012)

Adequacy. The Twin Leaching Pits with Pour Flush is a water-based technology and is only feasible where there is a constant supply of water for flushing (e.g. recycled grey water or rainwater). In areas with a high groundwater table the bottom of the pit needs to be placed at least one meter above the highest groundwater table. They are not suitable for areas that are frequently flooded. In order for the pits to drain properly, the soil must have a good absorptive capacity; clay, tightly packed or rocky soils are not appropriate. As long as water is available, the Twin Leaching Pits with Pour Flush technology is appropriate for almost every type of housing density. However, too many wet pits in a small area is not recommended as there may not be sufficient capacity to absorb the liquid into the soil matrix from all of the pits and the ground may become water-logged (oversaturated). The material is manually emptied from the Twin Pits (it is dug out, not pumped out), so vacuum truck access to the pits is not necessary. The Twin Pits will only work properly if the two pits are used sequentially and not concurrently. Therefore, an adequate cover for the out of service pit is required.

Health Aspects/Acceptance. The water seal (siphon) provides a high level of comfort and cleanliness, with few odours. It is a commonly accepted sanitation option, however some health concerns exist (pit leachate can contaminate groundwater, stagnant water in pits may promote insect breeding and pits are susceptible to failure/overflowing during floods).

Operation and maintenance. The pits must be emptied regularly and care must be taken to raise or appropriately seal the maintenance hatch particularly in areas prone to flooding during rainy seasons. After a 1-2 years resting time, the pits should be emptied manually using long handled shovels and proper personal protective equipment (masks, gloves and rubber boots at a minimum). If the pits are self-emptied there are no operational costs except for any replacements to the structure or slab in the event of damage.

Potential for upgrading. The manual pour flush toilet can be upgraded to have an integrated cistern for flushing instead of the manual pour flush system. In doing so, it can be easily upgraded to a low-cost sewerage system that also accepts grey water. The necessary design modifications are discussed below.

Design of the leaching pit. To size the leaching pits, it is important to determine the rate at which sludge (including faeces, urine and anal cleansing material) will accumulate, and the rate at which effluent will infiltrate in the surrounding ground. Only the depth below the invert level of the pipe from the division box can be taken into consideration to prevent filling up of the pipe to the division box.

The approximate volume of the pit can be calculated as a function of the following equations:

- $V = N * S * T / 1000$;
- $F = N * q / i$

Where:

- V = Pit volume (m^3);
- N = Number of users (capita);
- S = Sludge accumulation rate (lcy, litres/cap/year), see Annex 1;

- T = Desludging Period;
- F = Infiltration area (m^2);
- q = Amount of water used for anal cleansing and flushing (lcd);
- I = infiltration capacity soil ($l/m^2/day$), see Annex 2.

For a circular leaching pit, for a family of 8 persons (N=8), a sludge accumulation rate of 40 lcy (S=40) and a desludging period of 2 years (T = 2), a water use of 5 lcd (q = 5), and infiltration rate of 25 $l/m^2/day$, the Volume (V) and Infiltration area (F) are:

- V = 8 * 40 * 2 / 1000 = 0.64 m^3, say a pit with a diameter of 1 m' (surface area {(3.14)/4} * d^2 = 0.78 m^2 for d=1 m') a sludge depth of 0.64 m^3 /0.78 m^2 = 0.8 m';
- F = 8 * 5 / 25 = 1.6 m^2; hence a liquid depth of 0.5 m' at a pit diameter of 1 m' (circumference 'A' = 3.14*d=3.14), so 1.6 m^2/3.14 m^2/m'= 0.5 m';
- Total pit depth below invert level pipe: sludge depth + liquid depth = 0.8 m' + 0.5 m' = 1.3 m'.

DO'S AND DON'TS WITH LEACH PITS

DO'S

- Do use the pits alternately
- Do keep water in a bucket in the toilet for flushing.
- Do use minimum quantity of water.
- Do pour a little quantity of water on pan before it is used. It helps excreta slide more easily down the water seal and into pit.
- Do clean the toilet regularly with water or mild soap.
- Do remove manure from the pit preferably in summer/dry months.
- Do use the manure from the pit in agriculture as it contains good quantity of plant nutrients.
- Do handle such manure with care, minimizing hand contact as far as possible.

DON'TS

- Don't install a water tap inside the toilet, as it results in use of more water for flushing, decreasing the efficiency of the pit and increasing hydraulic load and possibly ground water pollution
- Don't use both the pits simultaneously.
- Don't use any chemicals and detergent (phenol) to clean the pan. It kills microbes resulting in reduced degradation of wastes.
- Don't allow kitchen water or bathing water to enter the toilet.
- Don't put solid material like sanitary napkins, paper, plastic etc. into the pan, as they may block the water seal, making the toilet non-functional. In case of blockage due to such objects, they should be taken out manually as they may cause more problems if stuck in the water seal.
- Don't remove the manure from the pit before a minimum of 18 months after it is filled and sealed.

COMMON CONSTRUCTION MISTAKES

PIT CONSTRUCTION

- Building only one pit: In most places only a single leach pit is being constructed and, that too, without a junction box. This causes the pit to become unusable once it is full – and since there is no alternative, the toilet will not be used any longer once the pit is full;
- Incorrect height: If the pit is at or below ground level, there is a possibility of rain water entering the pit, reducing the efficiency and life of the pit, and incur high repair costs;
- Pit is too deep: If it is too deep, there is a possibility that ground water will get contaminated. There could also be poor biological reaction rates causing poor level of composting of the solid waste in the leach pit. Both these impacts could have high costs.

HONEYCOMB MASONRY

- Too much honeycombing: If honey comb brickwork is done at all layers, it could make the pit structurally weak and could also increase the cost of construction;
- Holes too large: If the holes in the honeycomb are too large, there is a possibility of rodents entering the pit and eventually causing damage!;
- Honey combs given in top and bottom layers: This could lead to poor initial sedimentation (bottom layer) and loose soil entering the pit (top layer) reducing its capacity and thus its life.

COVER SLAB

- Cover slabs not sealed with cement mortar: This could lead to a foul smell. There is also the possibility of rain water entering the pit, reducing the efficiency and life of the pit;
- Poor quality of cover slab: This could cause cracks, foul smell, and rain water to enter the pit, reducing the efficiency and life of the pit.

JUNCTION CHAMBER

- Missing! If a junction chamber is not constructed, even if two pits are available, the second pit cannot be used once the first one is full – and hence he toilet will be dysfunctional once the first pit is full!;
- No manhole cover: This will make it difficult to divert the flow to either of pits.

VENT PIPE

- Provided!: This is a waste of money since the technology does not need vent pipes! Moreover, it is likely to result in a foul smell and a breeding ground for mosquitoes and flies (vectors).

Easy latrine. The Easy latrine is an interesting example on how a Leaching Pit Technology can become an interesting business opportunity.

2.8 Raised septic tanks

Septic tanks (and aqua-privies) can be used where the water table is high. These minimize groundwater contamination by reducing pathogens in the waste, especially if the final effluent is discharged on the ground surface of agricultural land. Such systems are most appropriate where water is available in reasonably large quantities and where water is used for anal-cleansing.

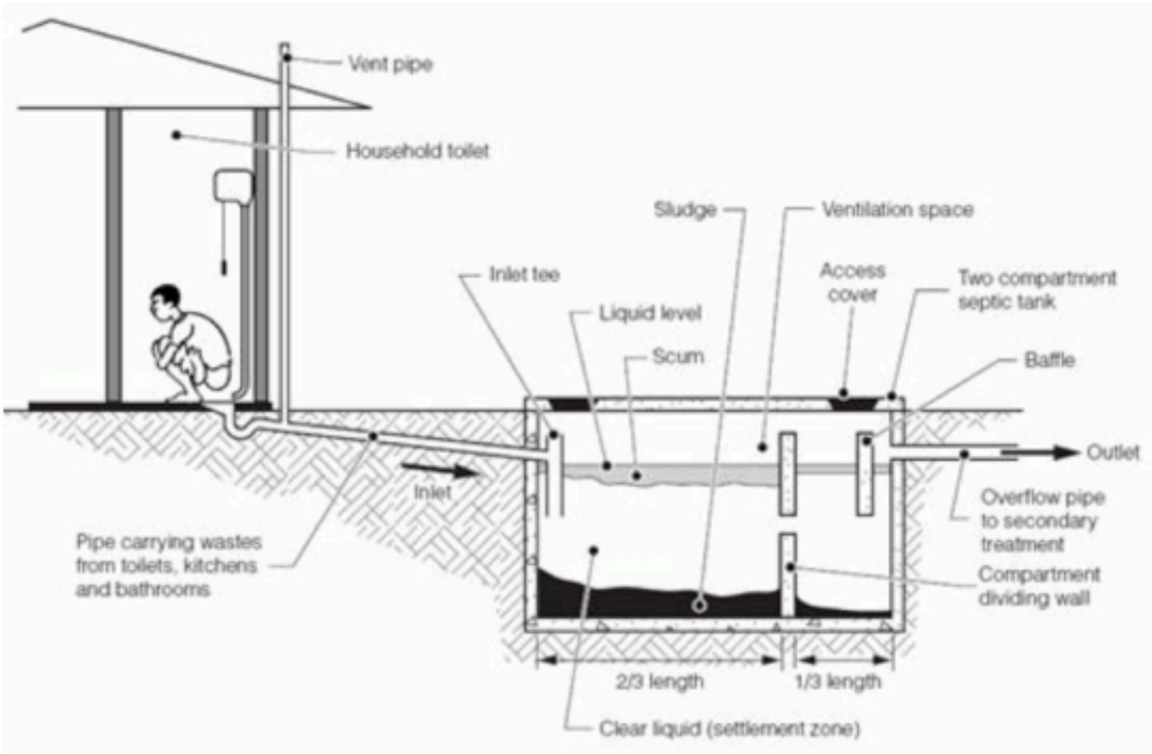
Attention! Prevent flotation! Septic tanks can be constructed above or below ground but, if below ground, the weight of the tank must be sufficient to prevent flotation due to high groundwater. Sufficient weight is most easily achieved by constructing a thick concrete base to the tank.

A simple relationship to calculate the depth of concrete required for the base is:

- Depth of concrete base (D) = Height of tank (H) / 2.4
- (Where the density of concrete is taken as 2.4kg/m^3.)

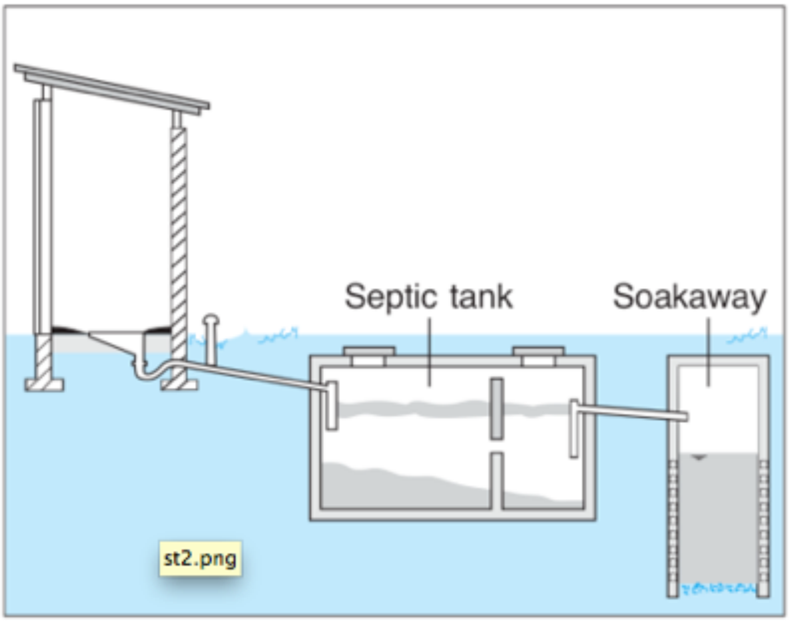
An alternative approach to prevent flotation as a result of uplift is to create a width toe by extending the base of the tank on all sides so that it is wider than the walls. For example, for a tank of width 1.0m and length 3.0m, the dimensions of the base might be 1.6m by 3.6m, creating a 300mm lip around the tank walls. The 300mm space around the tank is then filled with soil so that the weight of soil above the edges of the base assists in overcoming uplift. However, this design is more difficult to construct.

What is a septic tank? A Septic Tank is a watertight chamber made of concrete, fibreglass, PVC or PE, for the storage and treatment of black water only or a combination of black and grey water. Settling and anaerobic processes reduce solids and organics, but the treatment is only moderate. A Septic Tank should typically have at least two chambers. Liquid flows into the tank and heavy particles sink to the bottom, while scum (oil and fat) floats to the top. The first chamber should be at least 50% of the total length and when there are only two chambers, and it should be two-thirds of the total length. The first chamber is used to settle the solids. Wastewater enters the first chamber of the tank, allowing solids to settle and scum to float. The settled solids are anaerobically digested, reducing the volume of solids. The liquid component flows through the dividing wall into the second chamber, where further settlement takes place, with the excess liquid then draining in a relatively clear condition from the outlet into the leach field, also referred to as a drain field or seepage field. The inlet pipe from the toilet itself to the septic tank should also have a slope of between 1/4 -1/2 inch per foot angling towards the tank to reduce the rate of entry of the effluent into the tank. A lesser gradient could create blockages, whilst a sharper gradient could have too forceful entry of effluent into the tank. A “T-shaped” inlet will further dissipate the rate of the incoming effluent that prevents the settling solids below from being disturbed. The baffle, or the separation between the chambers, is to prevent scum and solids from escaping with the effluent. A “T-shaped” outlet pipe will further reduce the scum and solids that are dis-charged. With time, the solids that settle to the bottom are degraded anaerobically. As the system relies on bacteriological action for decomposition, therefore placing any chemicals or inorganic materials (such as pesticides, herbicides, paints or solvents) and detergents with high concentrations of bleach or caustic soda should not enter the system as they will prevent the bacteria and system from functioning. Excess water, oils and grease may also prevent the decomposition rate and render the system ineffective (noticed by increase in bad smell which relates to poor decomposition) and could also block the inlet pipe. The septic tank works under anaerobic conditions, which means bacteria operating in a non-oxygen environment. Oxygen should not be allowed to enter as it will destroy the bacteria used for decomposition and result in the septic tank working less efficiently. However, during the decomposition dangerous gases are created such as carbon dioxide and methane therefore a ventilation pipe with a screen (to prevent vectors entering and existing the tank) needs to be fitted either on entry point of the inlet tank or on the second chamber of the septic tank.



Septic tank with vent pipe (Practical Action, see: http://practicalaction.org/sanitation-technologies-answers)

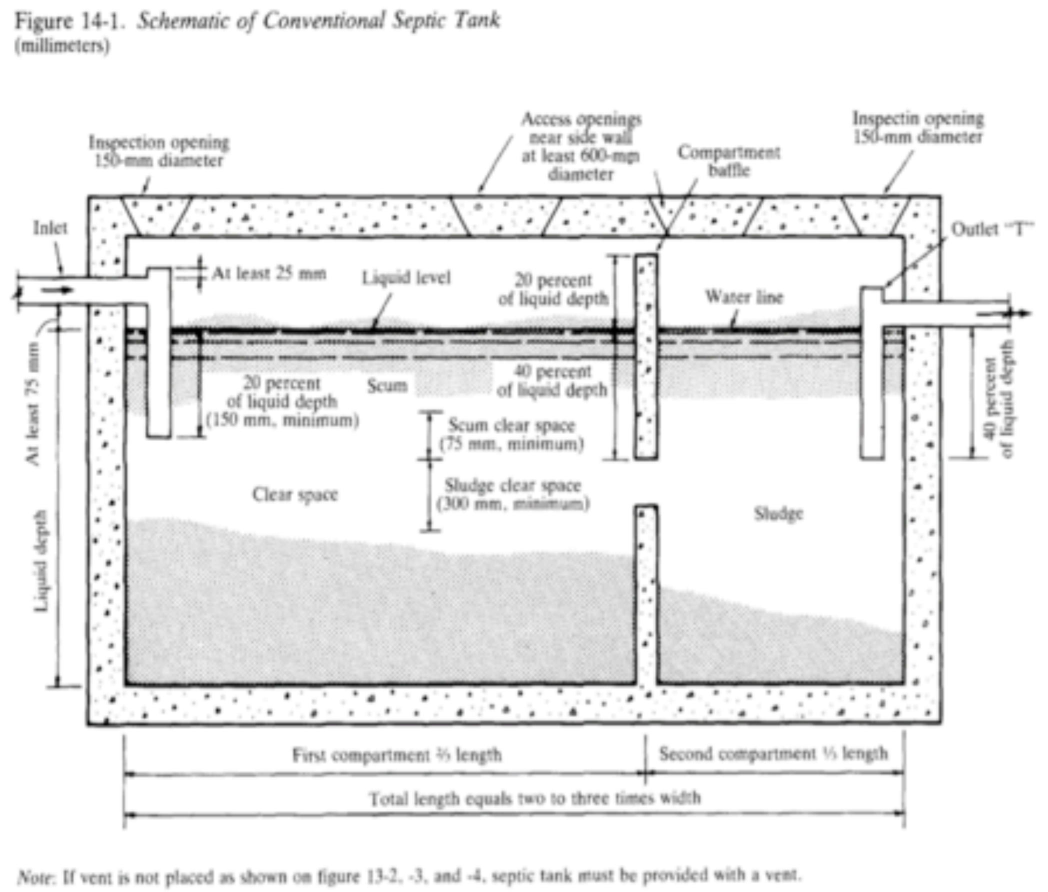
Generally, Septic Tanks should be emptied every 2 to 5 years, although they should be checked yearly to ensure proper functioning. Placing any non-biodegradable products into the system will just fill the tank and require it is be emptied more frequently. The design of a Septic Tank depends on the number of users, the amount of water used per capita, the average annual temperature, the pumping frequency and the characteristics of the wastewater. The retention time should be designed for 48 hours to achieve moderate treatment. The liquid effluent must be dispersed by using a Soak Pit or Leach Field or by transporting the effluent to another treatment technology via a Shallow sewer or Small Bore sewers.



Source: WHO 2003. Reproduced with permission from the World Health Organization, Geneva.

HDPE Septic Tank

Because the Septic Tank must be desludged regularly, a vacuum truck should be able to access the location. Often Septic Tanks are installed in the home, under the kitchen or bathroom, which makes emptying difficult. If Septic Tanks are used in densely populated areas, onsite infiltration/leach fields for the liquid effluent should not be used otherwise the ground will become oversaturated and excreta may rise up to the surface posing a serious health risk. Instead, the Septic Tank should be connected to a sewer and the liquid effluent should be transported to a subsequent treatment or disposal site. Larger, multi-chamber Septic Tanks can be designed for groups of houses and/or public buildings (i.e. schools). Generally, the removal of 50 % of solids, 30 to 40 % of biochemical oxygen demand (BOD) and a 1-log removal of E-coli can be expected in a well-designed Septic Tank although, efficiencies vary greatly depending on operation and maintenance and climactic conditions. Even though the Septic Tank is watertight, care should be taken if constructed in areas with high groundwater tables or where there is frequent flooding.



Specification conventional septic tank (Kalbermatten, 1982)

Although the system does not provide total pathogen removal, as the entire tank is below ground, users therefore do not come in contact with any of the wastewater. Users should be careful when opening the tank because noxious and flammable gases may be released. A vacuum truck should be used to empty the sludge from the Septic Tank.

Low cost septic tank for black water only (Yayasan Dian Desa/WASTE, 2012)

Design & Maintenance. Septic Tanks should be checked to ensure that they are watertight using 25mm of cement plaster so as not allow any leakage. Because of the bacteriological content, care should be taken not to discharge harsh chemicals such as disinfectant into the Septic Tank. The digestion of waste creates bad smell and dangerous gases so a vent pipe should always be installed. 300mm should be kept between the top of the scum layer (on top of the liquid) and the bottom of the septic tank lid to allow for gases and a vent pipe should installed be made of galvanised steel and screened with mosquito mesh on top to prevent vectors entering. The outlet pipe should also have T-section and be 75mm lower than inlet. For discharge of the liquid effluent, the "Two Meter Rule" can be applied where, if there is 2 metres of fine sand or loam separating the drainfield and the ground water then virtually all pathogens will be removed This must be true all year round. Water is safe after travelling for ten days. So water can be extracted at least 15m away from a soakaway if the soil is fine. Limestone or fissured rock allows pathogens to travel much further. The first compartment is usually twice the size of the second. The liquid depth is 1 to 2 meters and the overall length-to-width ratio is 2 or 3 to 1. Experience has shown that, if sufficiently quiescent conditions for effective sedimentation of the sewage solids are to be provided, the liquid retention time should be at least twenty-four hours, preferably 48 hours. To size the septic tank, it is important to determine the rate at which sludge (including faeces, urine and anal cleansing material) will accumulate, and volume of wastewater

The approximate volume of the septic tank can be calculated as a function of the following equations:

- V = N/1000 * (S * T + q * HRT)

Where:

- V = Tank volume (m^3);
- N = Number of users (capita);
- S = Sludge accumulation rate (lcy, litres/cap/year), See annex 1;
- T = Desludging Period (years);
- q = Amount of wastewater (lcd);
- HRT = Hydraulic Retention Time (days).

For a rectangular tank for a family of 8 persons (N=8), a sludge accumulation rate of 25 lcy (S=25) and a desludging period of 2 years (T = 2), a combined black and grey water disposal of 90 lcd (q = 90) and a Hydraulic Retention Time of 2 days (HRT=2):

- V = 8/1000 * (25 * 4 + 90 * 2) = 2.24 m^3, say tank depth 1 m', tank width 1m', length first compartment 1.5 m', length second compartment 0.75m'
- Total tank depth: 1 m' + 30 cm freeboard = 1 + 0.3 = 1.3 m'.

Advantages and disadvantages Septic Tank

Advantages:

- Can be built and repaired with locally available materials
- Long service life

- No real problems with flies or odours if used correctly
- Low capital costs, moderate operating costs depending on water and emptying
- Small land area required
- No electrical energy required

Disadvantages:

- Low reduction in pathogens, solids and organics
- Effluent and sludge require secondary treatment and/or appropriate discharge
- Requires constant source of water

Septic tank at a glance

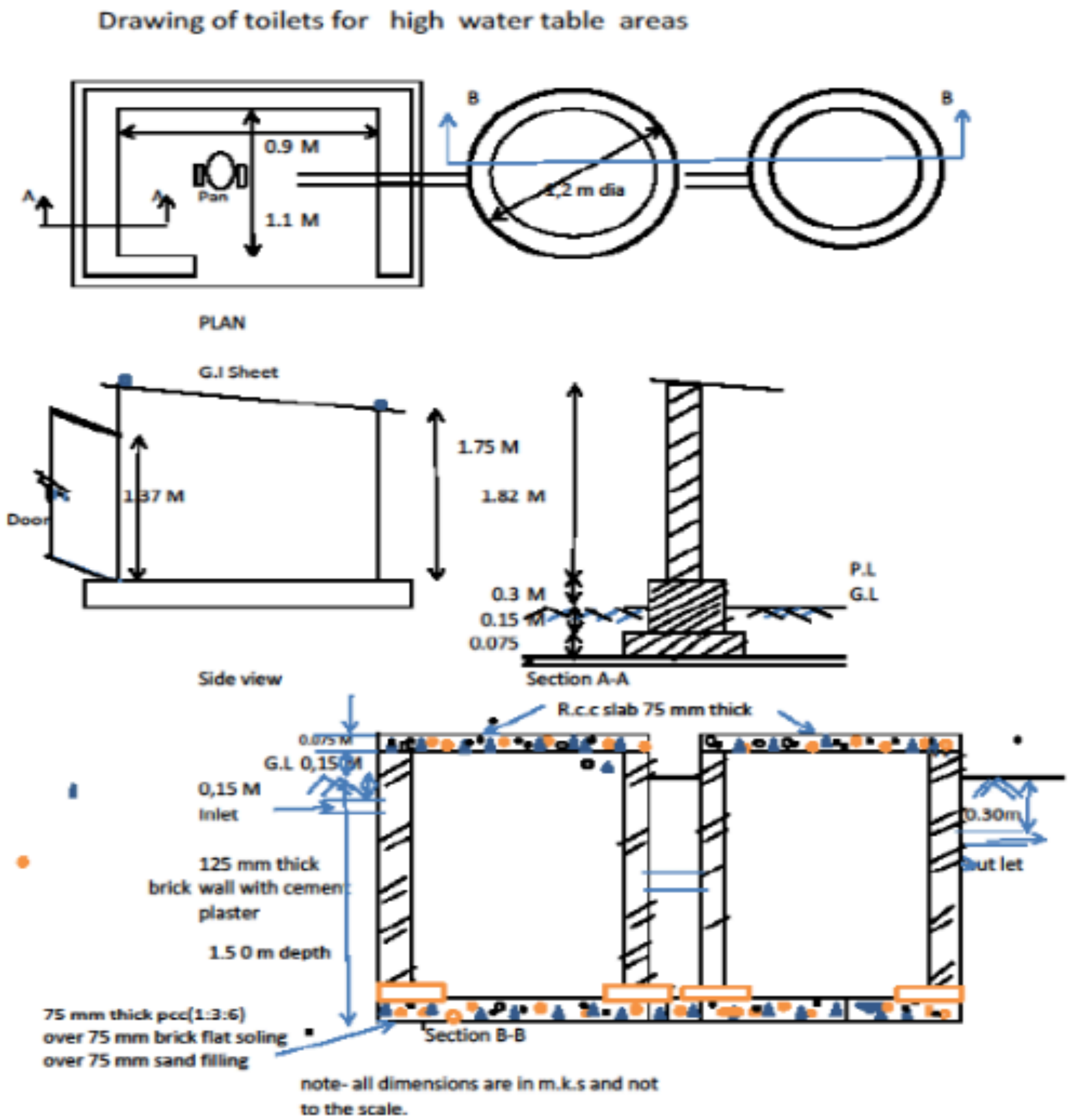
Working Principle	Basically a sedimentation tank (physical treatment) in which settled sludge is stabilised by anaerobic digestion (biological treatment). Dissolved and suspended matter leaves the tank more or less untreated.
Capacity/Adequacy	Household and community level; Primary treatment for domestic grey- and blackwater. Depending on the following treatment, septic tanks can also be used for industrial wastewater. Not adapted for areas with high groundwater table or prone to flooding.
Performance	BOD: 30 to 50%; TSS: 40 to 60 %; E. coli: 1 log units HRT: about 1 day
Costs	Low-cost, depending on availability of materials and frequency of de-sludging.
Self-help Compatibility	Requires expert design, but can be constructed with locally available material.
O&M	Should be checked for water tightness, scum and sludge levels regularly. Sludge needs to be dug out every 1 to 5 years and discharged properly (e.g. in composting or drying bed). Needs to be vented.
Reliability	When not regularly emptied, wastewater flows through without being treated. Generally good resistance to shock loading.
Main strength	Simple to construct and to operate.
Main weakness	Effluent and sludge require further treatment. Long start-up phase.

Effluent quality

As explained, the BOD and pathogen removal of a septic tank is limited:

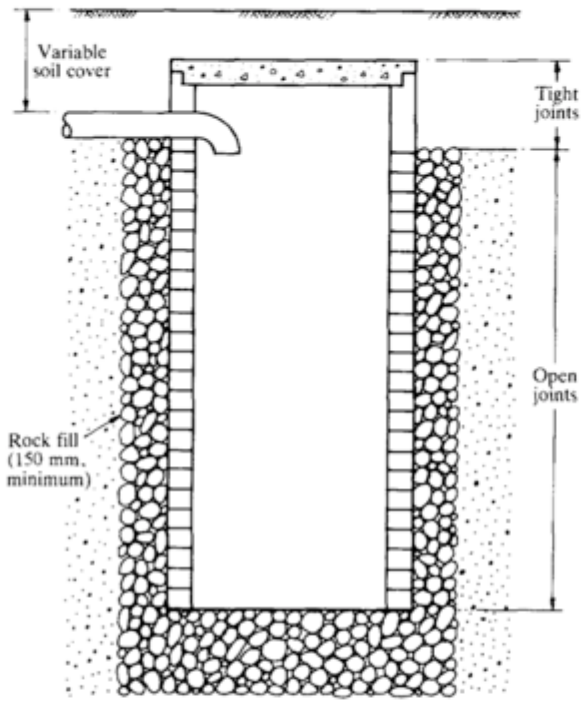
- BOD removal efficiency 30%-50%. At a removal efficiency of 40%, the effluent of a Septic Tank that holds black and grey water is (100%-40%) * 520 mgBOD/l = 320 mgBOD/l
- E-coli removal: log 1 units. At an influent quality of a Septic Tank that holds black and grey water at 105 E-coli/100 ml, the bacteriologic quality of the effluent is 10(5-1)= 104 E-coli/100ml.

Septic tank for flooded areas: the Balram Model. In rocky areas or areas where water can not be absorbed in the ground a low cost version of a septic tank, is the Balram Model. It consists of two separate masonry or concrete chambers connected by a pipe. Its advantage is the low cost, its obvious disadvantage is the fact that the effluent is not safe.



Balram toilet (Source: Handbook on Technical Options for on-site Sanitation, Ministry of Drinking Water and Sanitation, India, February 2012)

Soakaway. When the soil is sufficiently permeable, the septic tank effluent can be discharged in a soakaway / soak pit. A soakaway is a covered, porous-walled that allows water to slowly soak into the ground. Pre-settled effluent from the septic tank is discharged to the underground chamber from where it infiltrates into the surrounding soil. The soakaway can be left empty and lined with a porous material (to provide support and prevent collapse), or left unlined and filled with coarse rocks and gravel. The rocks and gravel will prevent the walls from collapsing, but will still provide adequate space for the wastewater. In both cases, a layer of sand and fine gravel should be spread across the bottom to help disperse the flow. The soakaway should be between 1.5 and 4 meters deep, but never less than 1.5 meters above the ground water table. As wastewater (pre-treated grey water or black water) percolates through the soil from the soakaway, the soil matrix filters out small particles and microorganisms digest organics. Thus, soakaways are best suited to soils with good absorptive properties; clay, hard packed or rocky soils are not appropriate.



Soakaway (Kalbermatten, 1982)

Adequacy. A Soakaway does not provide adequate treatment for raw wastewater and the pit will clog quickly. A soakaway should be used for discharging pre-settled black water or grey water. Soakaways are appropriate for rural and peri-urban settlements. They depend on soil with a sufficient absorptive capacity. They are not appropriate for areas that are prone to flooding or have high groundwater tables.

Health Aspects/Acceptance. As long as the soakaway is not used for raw sewage, and as long as the septic tank is functioning well, health concerns are minimal. The technology is located underground and humans and animals should have no contact with the effluent. It is important however, that the soakaway is located a safe distance from a drinking water source (ideally 30 meters). Since the soakaway odourless and not visible, even the most sensitive communities should accept it.

Maintenance. A well-sized soakaway should last between 3 and 5 years without maintenance. To extend the life of a soakaway, care should be taken to ensure that the effluent has been clarified and/or filtered well to prevent excessive build up of solids. The soakaway should be kept away from high-traffic areas so that the soil above and around it is not compacted. When the performance of the soakaway deteriorates, the material inside the soak pit can be excavated and refilled. To allow for future access, a removable (preferably concrete) lid should be used to seal the pit until it needs to be maintained. Particles and biomass will eventually clog the pit and it will need to be cleaned or moved.

Advantages and disadvantages Soakaway

Advantages

- Can be built and maintained with locally available materials;
- Small land area required;
- Low capital cost; low operating cost;
- Simple technique for all users.

Disadvantages

- Pre-treatment is required to prevent clogging, although eventual clogging is inevitable;
- May negatively affect soil and groundwater properties.

Design

The approximate dimension of the soakaway can be calculated as a function of the following equations:

- $F = N * q / i$

Where:

- F = Infiltration area (m^2)
- N = Number of users (capita)
- q = Amount of water used for anal cleansing and flushing (lcd)
- i = infiltration capacity soil ($l/m^2/day$), see annex 2.

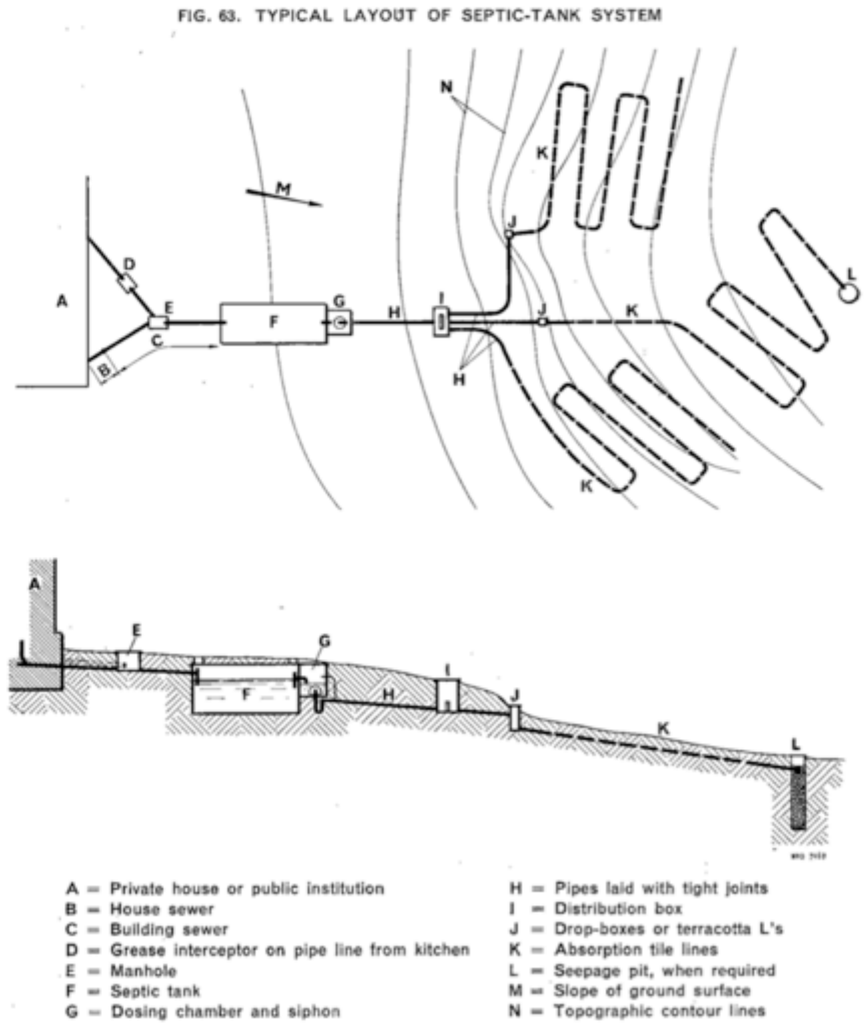
For a square soakaway, for a family of 8 persons (N=8), a per capita effluent of 30 lcd (black water) (q = 30), and infiltration rate of 25 l/m2/day (I = 25), Infiltration area (F) is:

- $F = 8 * 30 / 25 = 9.6$ m^2, hence a liquid depth of 1.6 m' in a square soakaway of 1.5 m' wide and 1.5 m' long: 9.6/(4*1.5) = 1.6 m'.

Leach field. A Leach Field, or drainage field, is a network of perforated pipes that are laid in underground gravel-filled trenches to dissipate the effluent from a septic tank. Effluent is fed into a distribution box, which directs the flow into several parallel channels. A small dosing system releases the pressurised effluent into the Leach Field on a timer (usually 3 to 4 times a day). This ensures that the whole length of the Leach Field is utilised and that aerobic conditions are allowed to recover between dosings. Each trench is 0.3 to 1.5meters deep and 0.3 to 1 meters wide. The bottom of each trench is filled with about 15 cm of clean rock and a perforated distribution pipe is laid overtop. More rock covers the pipe so that it is completely surrounded. The layer of rock is covered with a layer of geotextile fabric to prevent small particles from plugging the pipe. A final layer of sand and/or topsoil covers the fabric and fills the trench to the ground level. The pipe should be placed 15 cm from the surface to prevent effluent from surfacing. The trenches should be dug no longer than 20 meters in length at least 1 to 2 meters apart. Adequacy. Leach Fields require a large area and soil with good absorptive capacity to effectively dissipate the effluent. To prevent contamination, a Leach Field should be located 30 meters away from a drinking water supply. Leach fields are not appropriate for dense urban areas. Homeowners who have a Leach Field must be aware of how it works and what their maintenance responsibilities are.

Trees and deep-rooted plants should be kept away from the Leach Field as they can crack and disturb the tile bed.

Health Aspects/Acceptance. Since the technology is underground and it requires little attention, users will rarely come in contact with the effluent and so it should pose no health risk. The Leach Field must be kept as far away as possible from (> 30 meters) any potential potable water sources to avoid contamination.



Typical lay out septic tank system (Kalbermatten, 1982)

Maintenance. A Leach Field will become clogged over time, although with a well-functioning pre-treatment technology, this should take many years. Effectively, a Leach Field should require minimal maintenance, however if the system stops working efficiently, the pipes should be cleaned and/or removed and replaced. To maintain the Leach Field, there should be no plants or trees above it and no heavy traffic, which may crush the pipes or compact the soil.

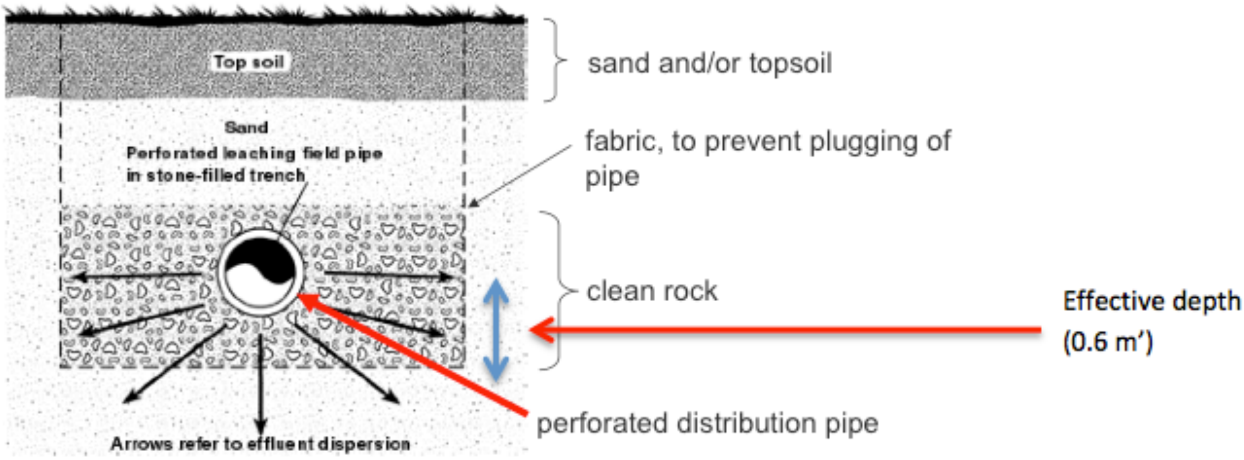
Design. The trench length required is calculated from the equation:

- L = N * q / (2* D* i)

Where:

- L = trench length in m'
- N = Number of users (capita)
- q = Amount of wastewater (lcd, litres / cap / day)
- D = effective depth
- I = infiltration capacity soil (l/m^2/day), see annex 2.

For a trench with an effective depth of 0.6 m' (D = 0.6 m', see figure below), for a family of 8 persons (N=8), a per capita effluent of 90 lcd (black water) (q = 90), and infiltration rate of 20 l/m^2/day (i=20), the trench Length (L): · L = 8 * 90 / (2 * 0.6 * 20) = 30 m', say 4 trenches of 7.5 m' each.



Advantages and disadvantages Leach Field

Advantages:

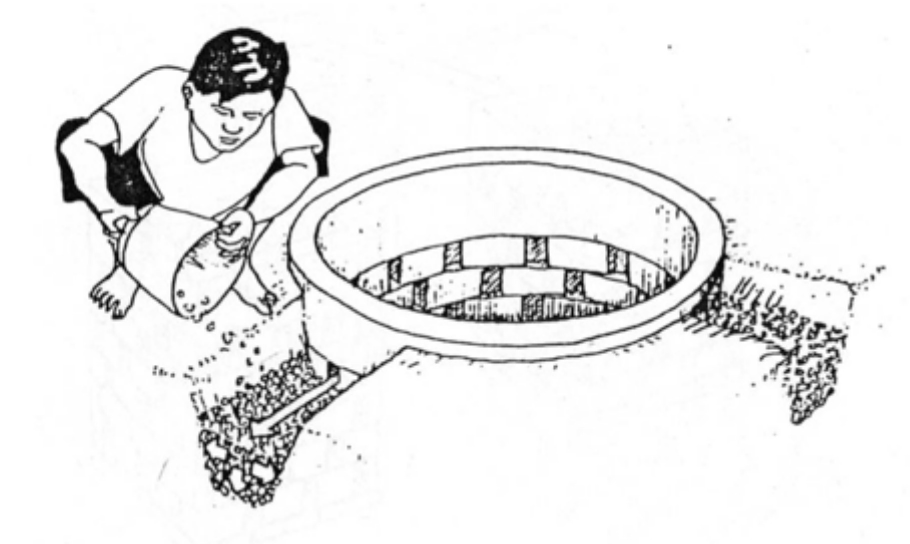
- Can be used for the combined treatment of black water and grey water;
- Has a lifespan of 20 or more years (depending on conditions);
- Low to moderate capital cost, low operating cost.

Disadvantages:

- Requires expert design and construction;
- Requires a large area (on a per person basis);
- Not all parts and materials may be available locally;
- Pre treatment is required to prevent clogging;
- May negatively affect soil and groundwater properties.

Combination Septic Tank / Infiltration In areas with high water table, the Septic Tank need to be raised in such a way that the bottom of the leaching pit is 1 meter above the highest groundwater table. A low solution is to apply a 'collar' around the septic tank.

Single chamber septic tank with 'collar' around the tank (YDD/WASTE)

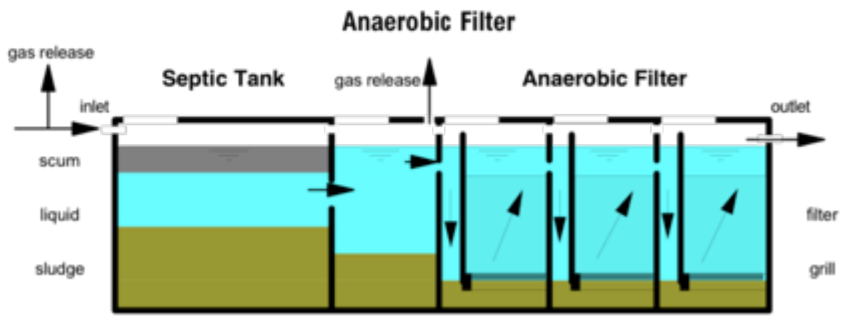


Gravel collar around pit in areas with high water table

2.9 Anaerobic Upflow Filter

In flood-prone areas, safe disposal of septic tank effluent is a challenge, as, by definition, it cannot infiltrate during floods. The combination with an Anaerobic Upflow Filter (AUF) improves the effluent quality.

An Anaerobic Upflow Filter is a fixed-bed biological reactor. As wastewater flows through the filter material, particles are trapped and organic matter is degraded by the biomass that is attached to the filter material. This technology consists of a sedimentation tank (or septic tank) followed by one or more filter chambers. Filter material commonly used includes gravel, crushed rocks, cinder, or specially formed plastic pieces. Sometimes crushed rocks may be used although these rocks may be subject to decomposition due to the low pH of the wastewater.

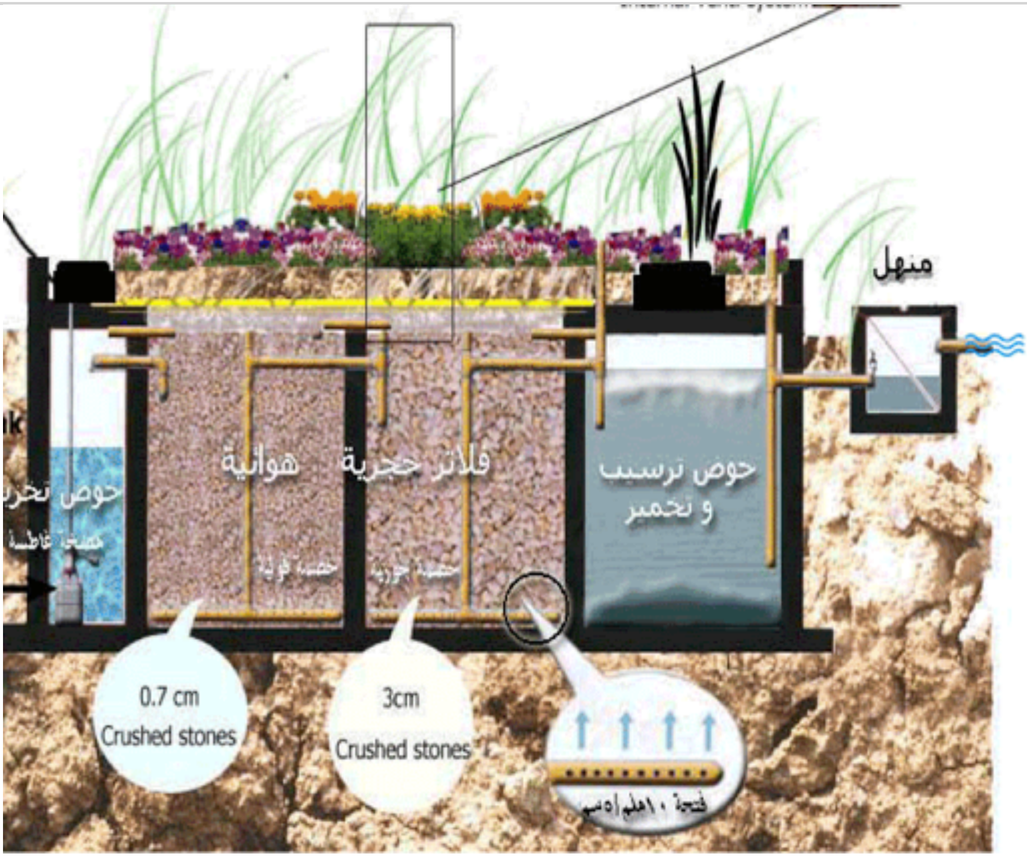


Principles Anaerobic Upflow Filter (Sasse, 1998)

Typical filter material sizes range from 12 to 55 mm in diameter. Ideally, the material will provide between 90 to 300 m2 of surface area per 1 m3 of reactor volume. By providing a large surface area for the bacterial mass, there is increased contact between the organic matter and the active biomass that effectively degrades it. The Anaerobic Filter can be operated in either upflow or downflow mode. The upflow mode is recommended because there is less risk that the fixed biomass will be washed out. The water level should cover the filter media by at least 0.3 m' to guarantee an even flow regime. Studies have shown that the HRT is the most important design parameter influencing filter performance. An Hydraulic Retention Time (HRT) of 0.5 to 1.5 days is a typical and recommended. A maximum surface-loading (i.e. flow per area) rate of 2.8 m/d has proven to be suitable. Suspended solids and BOD removal can be as high as 85% to 90% but is typically between 50 % and 80 %. Nitrogen removal is limited and normally does not exceed 15% in terms of total nitrogen (TN).

Plastic media (Sasse, 1998)

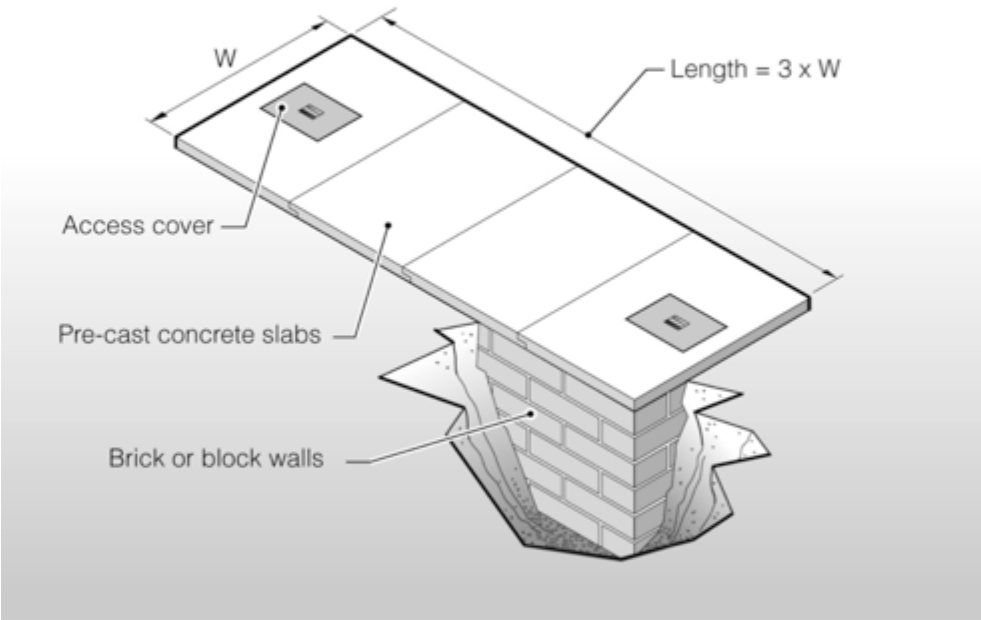
Adequacy. This technology is easily adaptable and can be applied at the household level or a small neighbourhood. An Anaerobic Filter can be designed for a single house or a group of houses that are using a lot of water for clothes washing, showering, and toilet flushing. It is only appropriate if water use is high, ensuring that the supply of wastewater is constant. The Anaerobic Filter will not operate at full capacity for six to nine months after installation because of the long start up time required for the anaerobic biomass to stabilize. Therefore, the Anaerobic Filter technology should not be used when the need for a treatment technology is immediate. Once working at full capacity it is a stable technology that requires little attention. The Anaerobic Filter should be watertight but care should be taken for construction in areas with high groundwater tables or where there is frequent flooding.



Two stages AUF filled with crushed stones (Burnat, 2010)

Health Aspects/Acceptance. Because the Anaerobic Filter unit is underground, users do not come in contact with the influent or effluent. Infectious organisms are not sufficiently removed, so the effluent should be further treated or discharged properly. The effluent, despite treatment, will still have a strong odour and care should be taken to design and locate the facility such that odours do not bother community members. As with septic tanks, to prevent the release of potentially harmful gases, the Anaerobic Filters should be vented. The desludging of the filter is hazardous and appropriate safety precautions should be taken.

Maintenance. Active bacteria must be added to start up the Anaerobic Filter. The active bacteria can come from sludge from a septic tank that has been sprayed onto the filter material. The flow should be gradually increased over time, and the filter should be working at maximum capacity within six to nine months. With time, the solids will clog the pores of the filter. As well, the growing bacterial mass will become too thick and will break off and clog pores. A sedimentation tank before the filter is required to prevent the majority of settleable solids from entering the unit. Some clogging increases the ability of the filter to retain solids. When the efficiency of the filter decreases, it must be cleaned. Running the system in reverse mode to dislodge accumulated biomass and particles cleans the filters. Alternatively, the filter material can be removed and cleaned. For ease of removal, it is recommended to use reinforce concrete slabs to cover the Filter in future to ensure easy operation and maintenance.



Precast concrete covers (WEDC, 2012)

AUF at a glance

Working Principle	Dissolved and non-settleable solids are removed by anaerobic digestion through close contact with bacteria attached to the filter media
Capacity/Adequacy	Household and community level; as secondary treatment step after primary treatment in a septic tank or an anaerobic baffled reactor; effluents can be infiltrated into soil or reused for irrigation; not adapted if high ground-water table or in areas prone to flooding.
Performance	BOD: 50 to 90%; TSS: 50 to 80 %; Total Coliforms: 1 to 2 log units HRT: about 1 day
Costs	Generally low-cost; depending on availability of materials and frequency of back flushing and desludging.
Self-help Compatibility	Requires expert design, but can be constructed with locally available material.
O&M	Regularly backflush to prevent clogging (without washing out the biofilm); desludging of the primary settling chambers; needs to be vented if biogas not recovered.
Reliability	Reliable if construction is watertight and influent is primary settled; Generally good resistance to shock loading.
Main strength	Resistant to shock load; High reduction of BOD and TSS.
Main weakness	Long start-up phase.

Design UAF. The approximate volume of the AUF can be calculated as a function of the following equations:

- V = N * q * HRT /1000 / p

Where:

- V = Tank volume (m^3);
- N = Number of users (capita);
- q = Amount of wastewater (lcd);
- HRT = Hydraulic Retention Time (days);
- p = pore space (%);

The volume of a filter for a family of 8 persons (N = 8), a combined black and grey water disposal of 90 lcd (q = 90), a Hydraulic Retention Time of 0.7 days (HRT = 0.7) and a pore space of 35% (p=0.35):

- V = 8 * 90 * 0.7 / 1000 / 0.35 = 1.44 m^3

Effluent quality. The BOD removal is significant but the pathogen removal of an AUF is limited:

- At a removal efficiency of 75%, the effluent of an AUF that receives Septic Tank effluent is (100%-75%) * 320 mgBOD/l = 80 mgBOD/l
- E-coli removal: log 2 units. At an influent quality 104 E-coli/100 ml, the bacteriologic quality of the effluent is 10(4-2)= 100 E-coli/100ml
- The figure below provides the sections and dimensions of a 25 m^3/day AUF. This shows concrete cover slabs that ensure easy access for operation and maintenance.

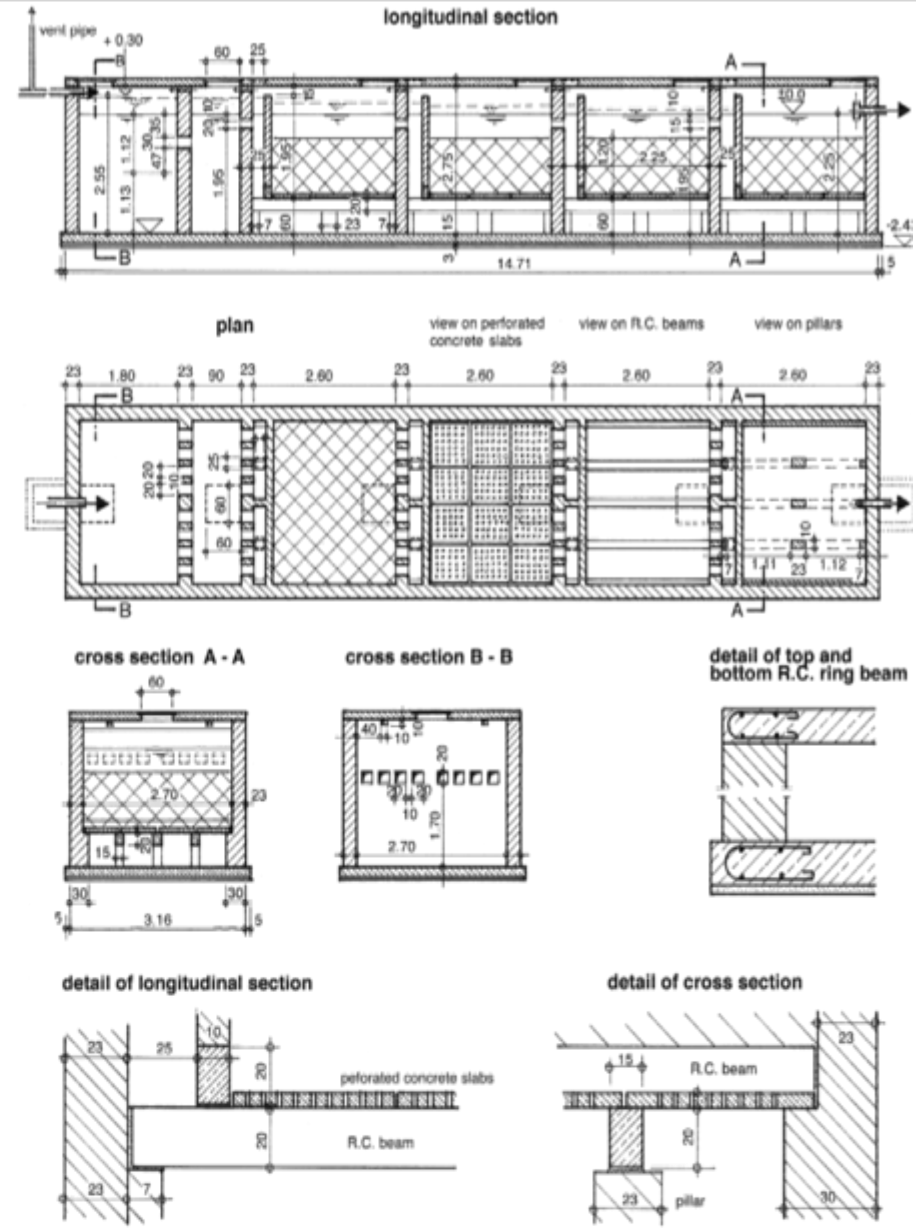


Fig. 23.
Anaerobic filter. Dimensions have been calculated for 25 m³ domestic wastewater per day.

25 m³/day AUF (Sasse, 1998)

Advantages and disadvantages AUF

Advantages

- Resistant to organic and hydraulic shock loads;
- No electrical energy required;
- Can be built and repaired with locally available materials;
- Long service life;
- Moderate capital costs, moderate operating costs depending on emptying;
- can be lowered depending on the number of users;
- High reduction of BOD and solids;

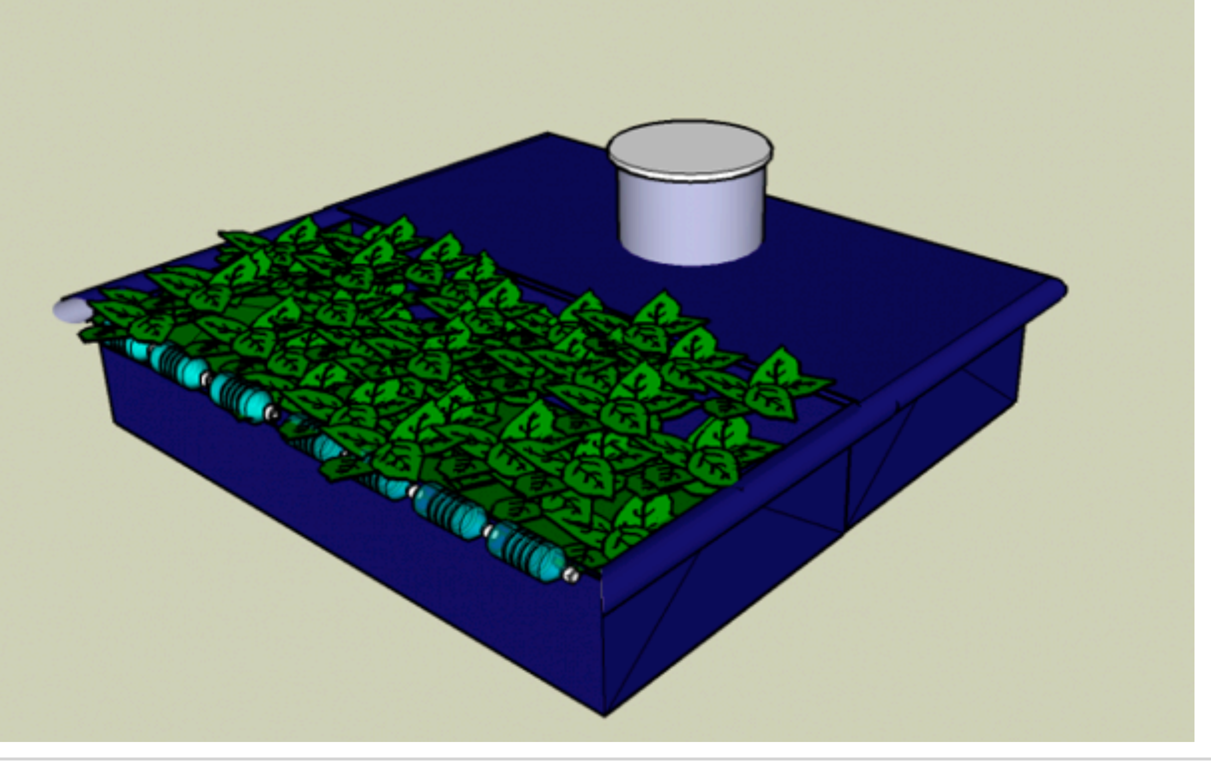
Disadvantages:

- Requires constant source of water;
- Effluent requires secondary treatment and/or appropriate discharge;
- Low reduction of pathogens and nutrients;
- Requires expert design and construction;
- Long start up time.

2.10 Floating pods

A Floating Pod is a floating an individual household wastewater treatment system that is similar in appearance to children's wading pools and that is positioned directly under the toilets. Similar to aquatic mesocosms, the Pods are filled with floating plants, and the bacteria that reside on the plant roots are capable of breaking down contaminants and making the water significantly cleaner.

Floating Pods contain common water hyacinth (Eichhornia crassipes) and associated mesocosm biota are constructed from tarpaulin and other locally available materials. The volume of a single Pod is ~236 litres (1 x 1.5 x 0.4 m). Two connected Pods are used per household. The first, which is positioned directly under the toilet, covered and predominantly anaerobic, is linked through a small opening to a second Pod, predominantly aerobic and containing plants. This set-up eliminates odour and increases treatment capacity.

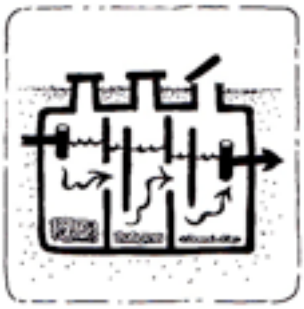


Design Floating Pod

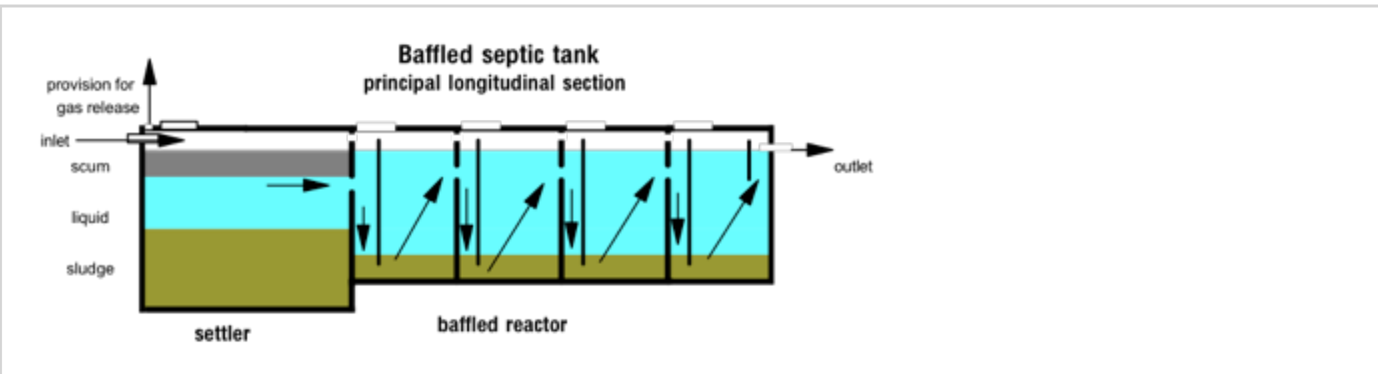
(Source: http://m.forum.susana.org/forum/categories/

105-processing-technologies-for-excreta-or-faecal-sludge/
4057-floating-treatment-pods-for-lake-communities
-in-asia-wetland-works-ltd-phnom-penh-cambodia)

2.11 Anaerobic Baffle Reactor



An Anaerobic Baffle Reactor (ABR) is an improved septic tank because of the series of baffles under which the wastewater is forced to flow. The increased contact time with the active biomass (sludge) results in improved treatment. The majority of settleable solids are removed in the sedimentation chamber at the beginning of the ABR, which typically represents 50% of the total volume. The upflow chambers provide additional removal and digestion of organic matter: BOD may be reduced by up to 90 %, which is far superior to that of a conventional septic tank. As sludge is accumulating, desludging is required every 2 to 3 years. Critical design parameters include a hydraulic retention time (HRT) between 48 to 72 hours, up-flow velocity of the wastewater less than 0.6 m’/h and the number of up-flow chambers (2 to 3).



ABR (Sasse, 1998)

ABR under construction in Surabaya (WASTE, 2012)

Adequacy. This technology is easily adaptable and can be applied at the household level or for a small neighbourhood. This technology is also appropriate for areas where land may be limited since the tank is installed underground and requires a small area. If installed in areas with a high groundwater table is should be watertight as infiltration could affect the treatment efficiency and contaminate the groundwater. Typical inflows range from 2,000 to 200,000L/day. The ABR will not operate at full capacity for several months after installation because of the long start up time required for the anaerobic digestion of the sludge. Therefore, the ABR technology should not be used when the need for a treatment system is immediate. To help the ABR to start working more quickly, it can be 'seeded', i.e. active sludge can be introduced so that active bacteria can begin working and multiplying immediately. Because the ABR must be emptied regularly, a vacuum truck should be able to access the location.

Health Aspects/Acceptance. Although the removal of pathogens is not high, the ABR is contained so users do not come in contact with any of the waste- water or disease causing pathogens. Effluent and sludge must be handled with care as they contain high levels of pathogenic organisms. To prevent the release of potentially harmful gases, the tank should be vented.

Maintenance. ABR tanks should be checked to ensure that they are watertight and the levels of the scum and sludge should be monitored to ensure that the tank is functioning well. Because of the delicate ecology, care should be taken not to discharge harsh chemicals into the ABR. The sludge should be removed using a vacuum truck to ensure proper functioning of the ABR.

ABR at a glance

Working Principle	Dissolved and non-settleable solids are removed by anaerobic digestion through close contact with bacteria attached to the filter media
Capacity/Adequacy	Household and community level; as secondary treatment step after primary treatment in a septic tank or an anaerobic baffled reactor; effluents can be infiltrated into soil or reused for irrigation; not adapted if high ground-water table or in areas prone to flooding.
Performance	BOD: 50 to 90%; TSS: 50 to 80 %; Total Coliforms: 1 to 2 log units HRT: about 1 day
Costs	Generally low-cost; depending on availability of materials and frequency of back flushing and desludging.
Self-help Compatibility	Requires expert design, but can be constructed with locally available material.
O&M	Regularly backflush to prevent clogging (without washing out the biofilm); desludging of the primary settling chambers; needs to be vented if biogas not recovered.
Reliability	Reliable if construction is watertight and influent is primary settled; Generally good resistance to shock loading.
Main strength	Resistant to shock load; High reduction of BOD and TSS.
Main weakness	Long start-up phase.

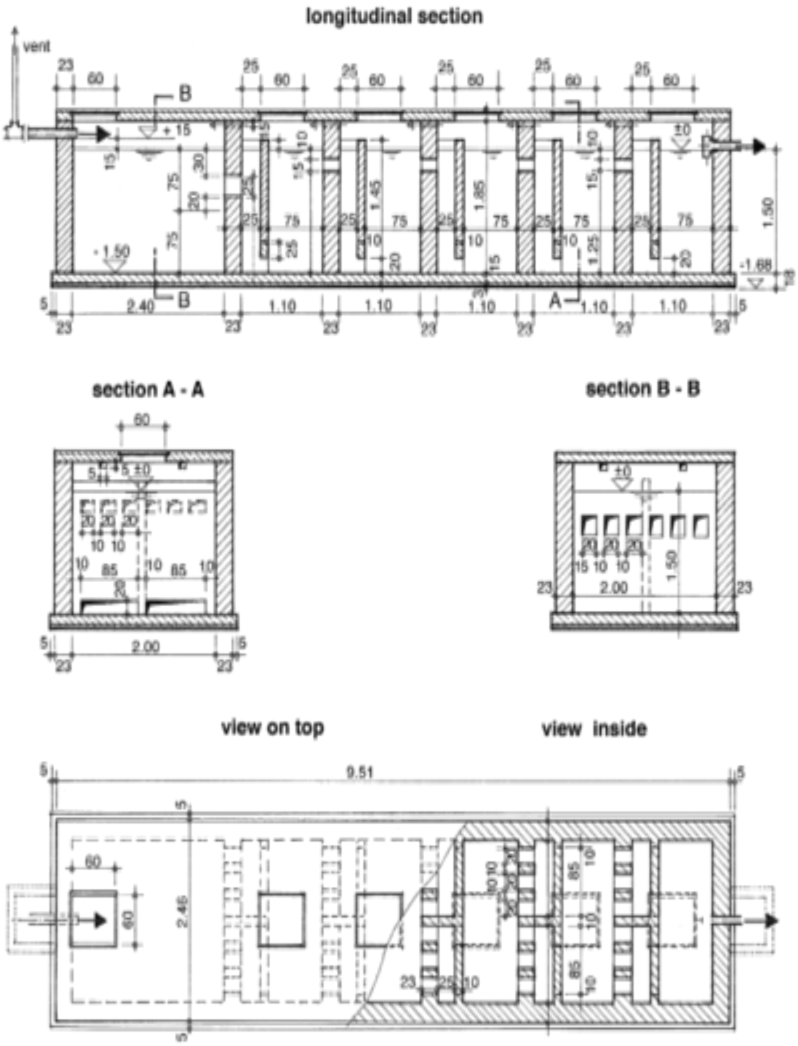
Advantages and disadvantages ABR

Advantages

- Extremely stable to hydraulic shock loads
- High treatment performance (for all, grey-, black- and industrial wastewater)
- Simple to construct and operate
- No electrical requirements (only physical mixing)
- Construction material locally available
- Low capital and operating costs, depending on economy of scale
- Ability to partially separate between the various phases of anaerobic catabolism
- Low sludge generation
- Reduced clogging
- Biogas can be recovered
- Low HRT, long biomass retention time

Disadvantages

- Needs expert design Long start-up phase
- Needs strategy for faecal sludge management (effluent quality rapidly deteriorates if sludge is not removed regularly)
- Effluent requires secondary treatment and/or appropriate discharge
- Needs water to flush
- Clear design guidelines are not available yet
- Low reduction of pathogens
- Requires expert design and construction



Dimensions 25m3 ABR (Sasse, 1998)

	A	B	C	D	E	F	G	H	I	J	K	L
1	**General spread scheet for anaerobic filter (AF) with integrated septic tank (ST)**											
2	daily waste water flow	time of most waste water flow	max. peak flow per hour	COD inflow	BOD_5 inflow	$SS_{settl.}$ / COD ratio	lowest digester temper.	HRT in septic tank	de-sludging interval	COD removal septic tank	BOD_5 removal septic tank	BOD / COD remov. factor
3	given	given	calcul.	given	given	given	given	**chosen**	**chosen**	calcul.	calcul.	calc.
4	m³/day	h	m³/h	mg/l	mg/l	mg/l / mg/l	°C	h	months	%	%	ratio
5	**25,00**	**12**	2,08	**633**	**333**	**0,42**	**25**	**2**	**36**	25%	26%	1,06
6			*COD/BOD_5 ->*	1,90		*0,35-0,45 (domestic)*		*2h*				
7	**treatment data**											
8	COD inflow in AF	BOD_5 inflow into AF	specific surface of filter medium	voids in filter mass	HRT inside AF reactor	factors to calculate COD removal rate of anaerobic filter				COD removal rate (AF only)	COD outflow of AF	COD rem rate of total system
9	calcul.	calcul.	given	given	**chosen**	calculated according to graphs				calcul.	calcul.	calcul.
10	mg/l	mg/l	m²/m³	%	h	f-temp	f -strenght	f-surface	f-HRT	%	mg/l	%
11	478	247	**100**	**35%**	**30**	1,00	0,91	1,00	69%	70%	142	78%
12			*80 -120*	*30-45*	*24 - 48 h*							
13				**dimensions of septic tank**								
14	BOD / COD rem. factor	BOD_5 rem rate of total system	BOD_5 outflow of AF	inner width of septic tank	minimum water depth at inlet point	inner length of first chamber		length of second chamber		sludge accum.	Volume incl. sludge	actual volume of septic tank
15	calc.	calcul.	calcul.	**chosen**	**chosen**	calcul.	**chosen**	calcul.	**chosen**	calc.	**requir.**	calcul.
16	ratio	%	mg/l	m	m	m	m	m	m	l/kg BOD	m³	m³
17	1,10	85%	49	**1,75**	**2,25**	1,69	**1,70**	0,85	**0,85**	0,00	10,00	10,04
18											*sludge l/g BODrem.*	
19	**dimension of anaerobic filter**							**biogas production**			**check !**	
20	volume of filter tanks	depth of filter tanks	length of each tank	number of filter tanks	width of filter tanks	space below perforated slabs	filter height (top 40 cm below water level)	out of septic tank	out of anaerobic filter	total	org.load on filter volume COD	maximum up-flow velocity inside filter voids
21	calcul.	**chosen**	calcul.	**chosen**	**requir.**	**chosen**	calcul.	assump: 70% CH_4; 50% dissolved			calcul.	calcul.
22	m³	m	m	No.	m	m	m	m³/d	m³/d	m³/d	kg/m³*d	m/h
23	31,25	**2,25**	2,25	**3**	2,69	**0,60**	1,20	0,97	2,10	3,07	1,57	0,98
24			**max!!**								*<4.5*	*< 2.0*

Calculation 25 m3 ABR (Sasse, 1998)

ANNIX 1: SLUDGE ACCUMULATION RATES

Sludge production – accumulation rate, 'S', litres/capita/year (lcy)

The sludge production or sludge accumulation rate is the volume of sludge that remains after anaerobic or aerobic decomposition. It depends on the type of decomposition and the type of material used for anal cleansing. Based on experiences in Indonesia (Spit, 2011) and Kalbermatten (1982) the following values can be used as a 'rule of the thumb:

In a wet environment (anaerobic conditions):

- Water for cleansing: 25 lcy;
- Degradable cleansing material: 40 lcy;
- Non-degradable cleansing material: 60 lcy;

In a dry environment (aerobic conditions):

- Water for cleansing: 40 lcy;
- Degradable cleansing material: 60 lcy;
- Non-degradable cleansing material: 90 lcy.

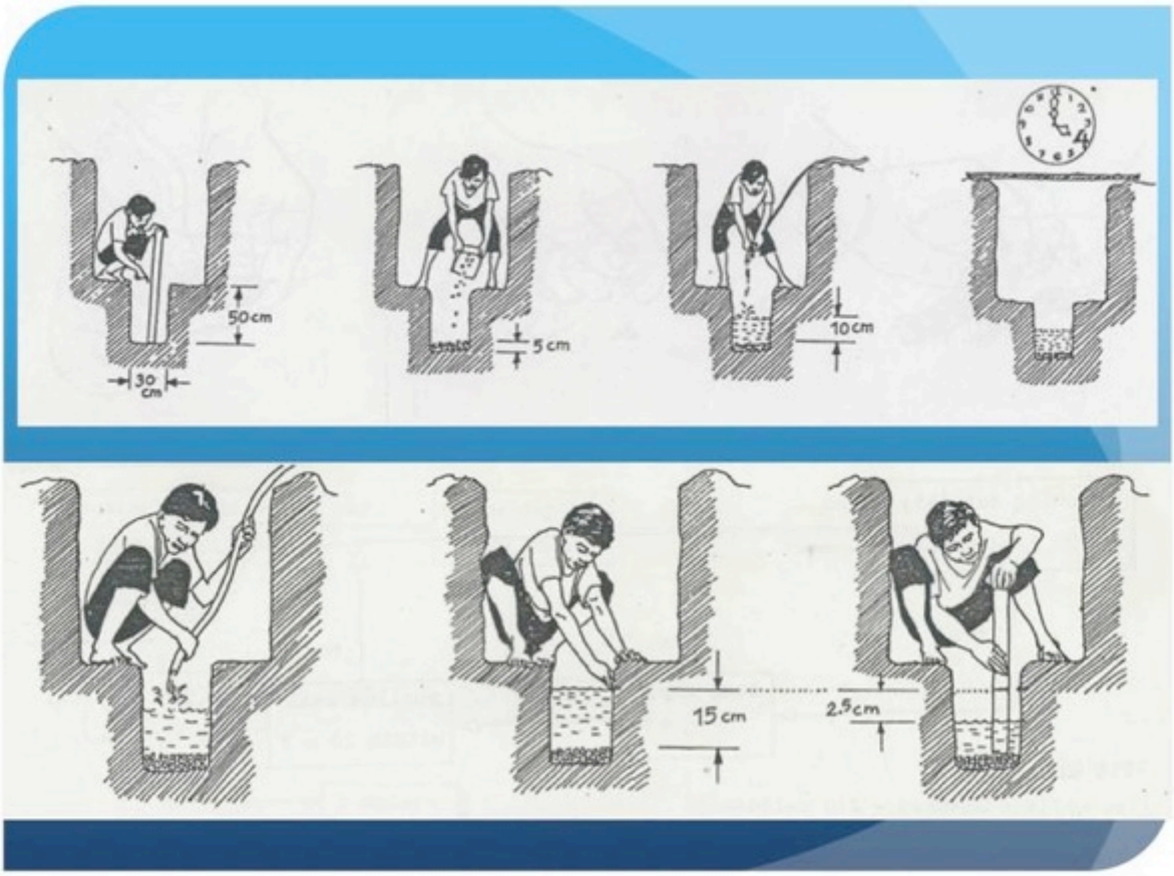
ANNEX 2: INFILTRATION RATE

Determining infiltration capacity soil (source: Twin Leaching Pit Toilets, Design and Construction Manual)

A percolation test is the most commonly used indicator to measure the ability of soils to absorb water. A simple percolation test to perform in the field is the falling head test. The procedure is as follows:

- Dig or bore at one meter deep a test hole 50 cm deep and with a diameter of 30 cm. I you expect different conditions in the two pits, dig test holes at both locations;
- Scratch the sides of the bottom of the hole with a sharp stick to get a natural soil surface and remove any loose material;
- Place crushed gravel (dia 10-20 mm) to a depth of about 5 cm in the hole to protect the bottom from scouring when the water is added;
- Fill the holes slowly wit at least 15 cm of clean water. Do this slowly to prevent the water washing away the sides of the hole. You may use a funnel with a hose attached;
- Cover the hole and leave it for 4 hours so the soil becomes saturated. This is very important. Immediately after the 4 hours soakage period begin measuring the percolation.

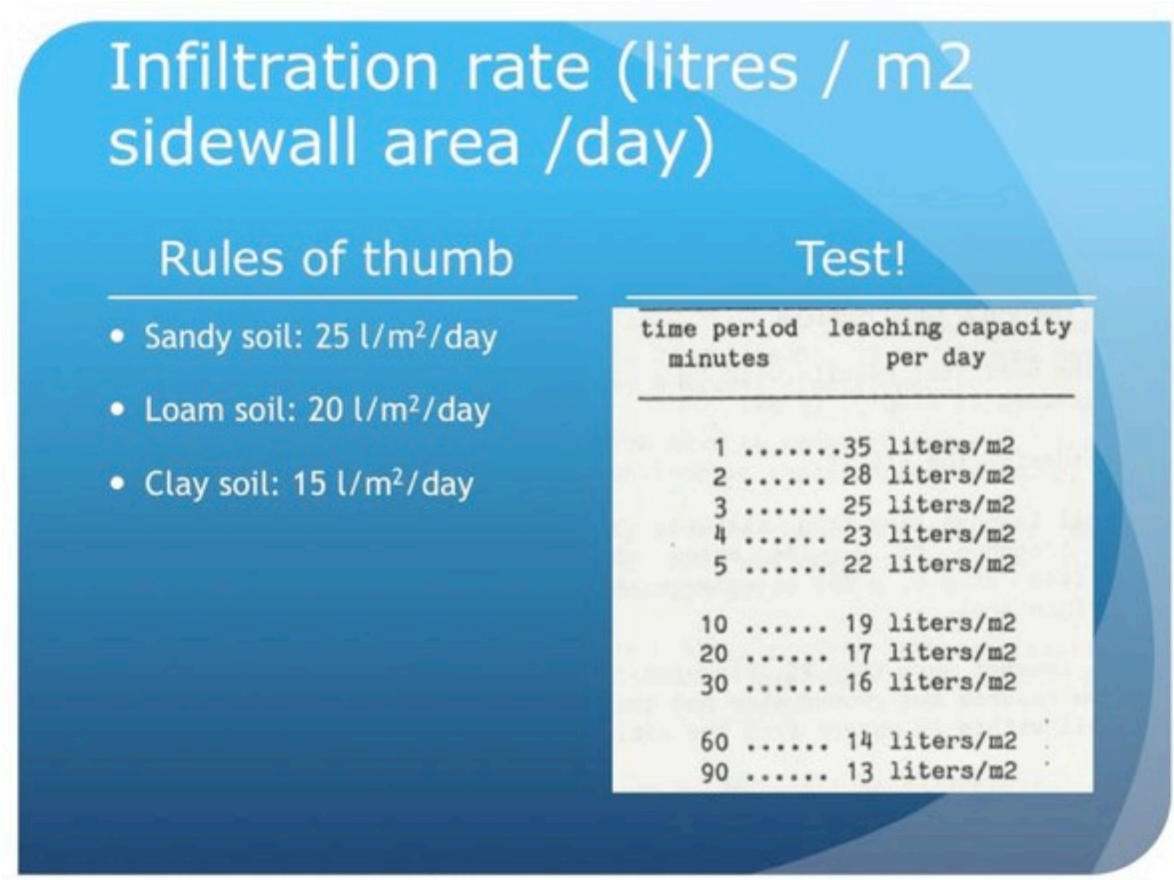
If the water seeps away completely in less than ten minutes after filling the hole twice, you may begin with the measurement immediately.



Measuring the percolation rate

- Fill the hole with water to a depth of 15 cm of gravel;
- Record the period of time it takes for the water level to drop 2.5 cm, beginning immediately after the hole has been filled;
- As soon as the level has dropped 2.5 cm, repeat (1) and (2) until two successive measurements differ by less than 2 minutes. You must repeat the test al least 3 times even if the first two measurements differ by less than 2 minutes.

Take the last time period recorded and mark the leaching capacity of the soil on the table below.



time period minutes	leaching capacity per day
1	35 liters/m2
2	28 liters/m2
3	25 liters/m2
4	23 liters/m2
5	22 liters/m2
10	19 liters/m2
20	17 liters/m2
30	16 liters/m2
60	14 liters/m2
90	13 liters/m2