Technical guidance manual on household sanitation and wastewater reuse facilities

For WASH cluster partners for appropriate facilities in urban and rural communities in occupied Palestine territory

MANUAL - PART 2: DESIGN OF SYSTEMS

Jan Spit
JERUSALEM, 26 April 2012

7. DRY ON-SITE SANITATION SYSTEMS 7-1
7.1. Introduction 7-1
7.2. Squatting plate 7-4
7.3. Arbor (Sabar) Loo 7-8
7.4. Fossa Alterna 7-12
7.5. Dry Urine Diversion Toilets 7-16

8. WET ON-SITE SANITATION SYSTEMS 8-18
8.1. Introduction 8-18
8.2. Twin Leaching Pits 8-19
8.3. (Low cost) Septic Tank with infiltration system 8-26
8.4. Soakaway 8-32
8.5. Leach field 8-34
8.6. Anaerobic Upflow Filter 8-39

9. GREY WATER MANAGEMENT SYSTEMS 9-1
9.1. Introduction 9-1
9.2. Soakaway 9-1
9.3. Leaching Field 9-2
9.4. Evaporation Field 9-2
9.5. Grey water reuse 9-3
9.6. Vertical Flow Constructed Wetland 9-4
9.7. Anaerobic Upflow Filter and reuse 9-8

10. NEIGHBORHOOD BASED (URBAN VILLAGE) SEWERAGE AND SEWAGE MANAGEMENT 10-1
10.1. Introduction 10-1
10.2. Neighborhood sewerage 10-1
10.3. Neighborhood Sewage Treatment: Anaerobic Baffle Reactor 10-4

11. SEPTAGE MANAGEMENT: SLUDGE DRYING 11-1

REFERENCES .... A

APPENDICES (SEE SEPARATE DOCUMENTS) I

APPENDIX 1-1: TERMS OF REFERENCE I

APPENDIX 1-2: CAMBODIA CASE STUDIES I

APPENDIX 2-1: WASTE DECISION SUPPORT TOOL (DST) USER INTERFACE I

APPENDIX 2-2: WASTE DST COLLECTION STORAGE AND TREATMENT I

APPENDIX 2-3: WASTE DST CONVEYANCE I

APPENDIX 2-4: WASTE DST TREATMENT .... **I**

APPENDIX 2-5: WASTE DST REUSE AND DISPOSAL .... **I**

APPENDIX 3-1: SSWM ARBORLOO .... **I**

APPENDIX 3-2: SSWM FOSSA ALTERNA .... **I**

APPENDIX 3-3: SSWM UDDT .... **I**

APPENDIX 3-4: SSWM COMPOST FILTERS .... **I**

APPENDIX 3-5: SSWM TERRA PRETA SANITATION .... **I**

APPENDIX 3-6: SSWM TWIN LEACHING PITS .... **I**

APPENDIX 3-7: SSWM SEPTIC TANK .... **I**

APPENDIX 3-8: SSWM LEACH FIELD .... **I**

APPENDIX 3-9: SSWM ANAEROBIC FILTER .... **I**

APPENDIX 3-10: SSWM EVAPORATION FIELD .... **I**

APPENDIX 3-11: SSWM CONSTRUCTED WETLAND .... **I**

APPENDIX 3-12: SSWM SOLID FREE SEWERS .... **I**

APPENDIX 3-13: SSWM SIMPLIFIED SEWERAGE .... **I**

APPENDIX 3-14: SSWM ABR .... **I**

7. Dry on-site sanitation systems

7.1. Introduction

In section 4.2 we provided a technology selection menu. The menu of selected dry systems is presented in Figure 7-1.

Figure 7-1: Technology selection menu dry systems

User interface	Emptying conditions	Soil conditions	Collection Storage / Local Treatment	Transport/ Conveyance	Treatment	Reuse/ Disposal
Dry	No willingness to empty		Arbor Loo			
	Willingness to empty	Digging possible	Fossa Alterna			
		Hard rock	UDDT/ EcoSan			

Figure 7-2 shows a typical oPt area where dry on-site systems are more appropriate then wet on-site systems: low density areas where the population, nomadic Bedouin, have simply not enough water available to pour-flush the faeces and keep the water seal of the pour-flush toilet functioning properly. When constructed, operated and maintained properly, dry on-site systems provide the same convenience and health benefits as wet on-site systems. And, of course, the communities are familiar with these systems, because they construct them their selves, see Figure 7-3.

Figure 7-2: Typical area for dry systems (UNICEF/Spit, 2012)

Figure 7-3: Dry toilet Bedouin community (Spit, 2012)

Description[1][2][3]. A Dry Toilet is a toilet that operates without water. The Dry Toilet may be a raised pedestal that the user can sit on, or a squat pan that the user squats over. In both cases, excreta (both urine and faeces) fall through a drop hole. The Dry Toilet is usually placed over a pit; if two pits are used, the pedestal or slab should be designed in such a way that it can be lifted and moved from one pit to another. The slab or pedestal base should be well sized to the pit so that it is both safe for the user and can be slightly slopes towards the outer edges to prevents stormwater from infiltrating the pit (which may cause it to overflow).

Table 7-1: Advantages and disadvantages Dry Toilets

Advantages	Disadvantages
• Does not require a constant source of water • Can be built and repaired with locally available materials • Low capital and operating costs • Suitable for all types of users (children, adults, elderly and physically impaired.)	• Odours are normally noticeable (even if the vault or pit used to collect excreta is equipped with a vent pipe). Can be reduced if a cup of ash is added after each use. • The excreta pile is visible, except where a deep pit is used. A cover should be placed on top to prevent ingress and egress of flies and other vectors • Does not prevent ground water contamination • Not suitable for high water table areas

There is a wide range of dry systems available. Three systems are discussed in detail:

- The Arbor/Sabar Loo (section 7.3);
- The Fossa Alterna (section 7.4);

[1] After Tilley (2008)
[2] See Appendix 2-1: WASTE Decision Support Tool (DST) User Interfaces
[3] See Smart Sanitation Solutions, NWP (2008)

- Urine Diversion Dehydration Toilets (section 7.5).

These systems use a squatting plate as user interface. Section 7.2 discusses the features of the squatting plate.

7.2. Squatting plate[4]

A suitable base or foundation for latrine or toilet fixtures is often included in the construction of the pit or other substructures. Alternatively, the base may be constructed separately of wood or integrally as part of the squatting plate. It is essential to determine whether the local preference is to sit or squat during defecation.

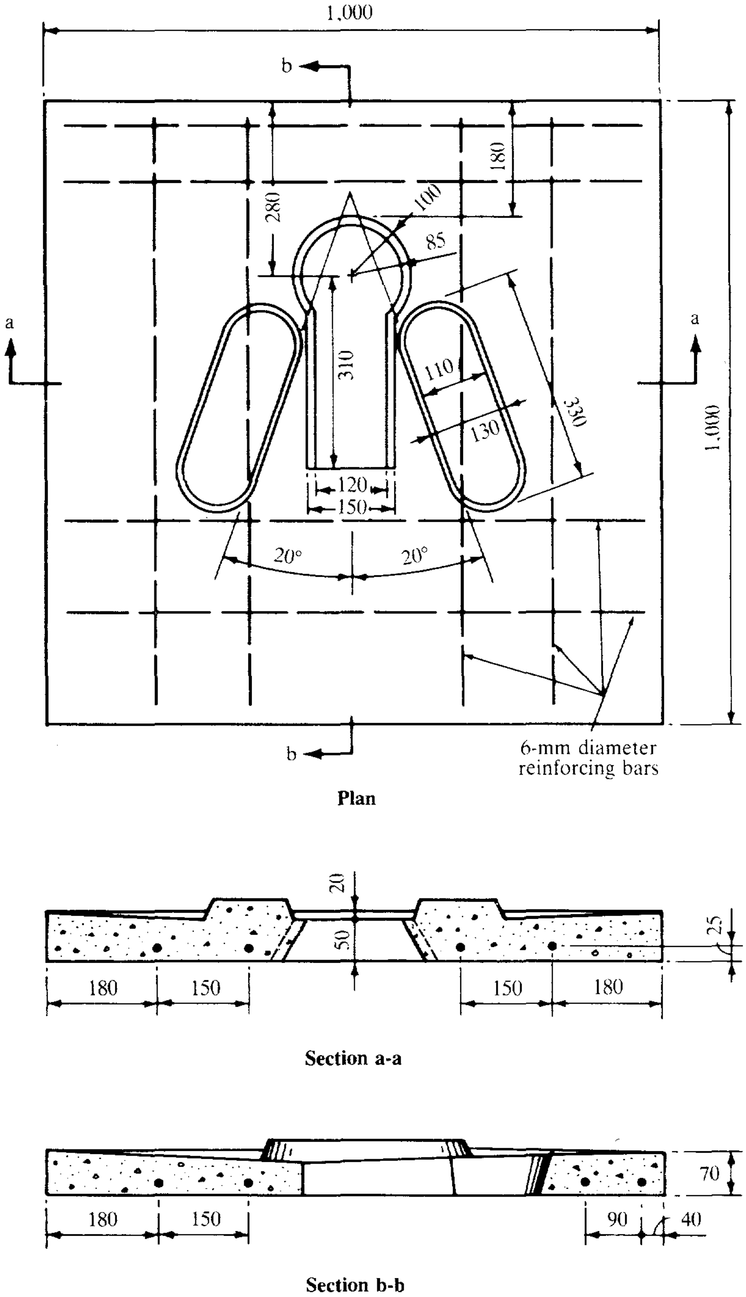
Design considerations squatting plates. There are several important design considerations:

- The opening should be about 400 mm long, to prevent soiling of the squatting plate and at most 200 mm wide, so that children could not fall into the pit. A 'keyhole' shape is suitable, see Figure 7-4;
- Footrests should be provided as an integral part of the squatting plate and properly located so that excreta fall into the pit and not onto the squatting plate itself;
- The free distance from the back wall of the superstructure to the opening in the squatting plate should be in the range of 100 to 200 mm; if it is less there is insufficient space and if it is more there is the danger that the rear part of the squatting plate will be soiled. In general, the preferred distance is 150 mm;
- The squatting plate should have no sharp edges or rough surfaces that would make its cleaning difficult and unpleasant.
- It should be slightly raised from the ground-level to ensure that excess water (during cleaning of the surrounding area or in areas of potential flooding) does not enter the pit.
- The opening should have a cover (removable see figure 7-5, or operated by a pulley system that also serves for additional hygienic measures) to ensure that flies do not enter the pit.

A variety of materials can be used to make the squatting plate: timber, reinforced concrete, ferrocement, and sulphur cement are usually the cheapest, but glass-reinforced plastic, high-density moulded rubber, or PVC (polyvinyl chloride) and ceramics can also be used. Cost and aesthetics are the important criteria, apart from strength and rigidity. A variety of finishes can be applied to concrete or ferrocement squatting plates (for example, alkali-resistant gloss paint and polished marble chippings) or the concrete itself can be coloured. Aesthetic considerations are often extremely important to the users and should never be ignored by engineers and planners; indeed planners should make a special effort to determine community preferences before the final design stage. Figure 7-4 shows a good design for a reinforced concrete squatting plate. Other factors should also be considered particularly if used by children, elderly or physically impaired such as handrails next to the squatting plate.

[4] After Kalbermatten, 1982

Figure 7-4: Squatting plate design (Kalbermatten, 1982)



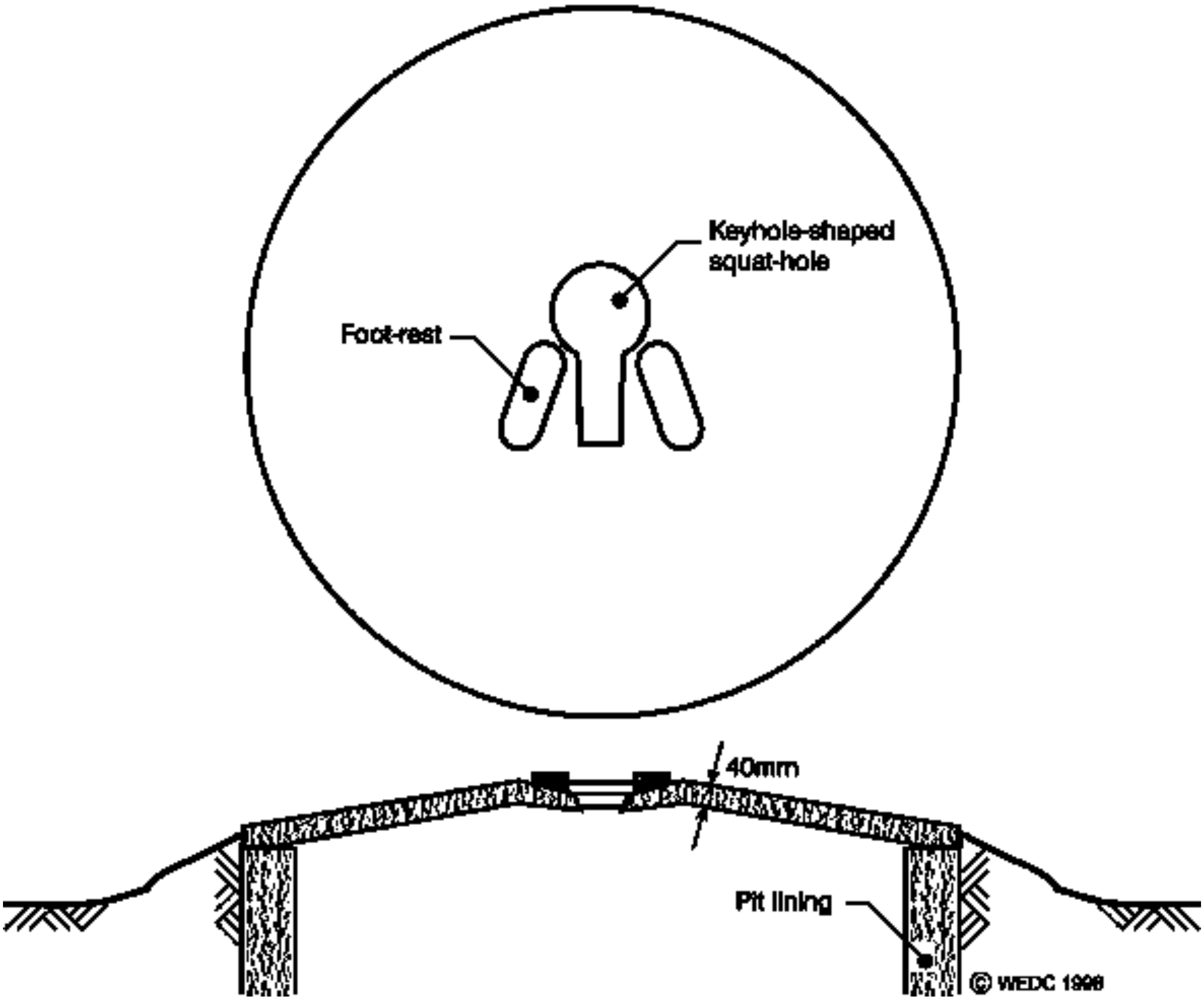
Source: Adapted from Wagner and Lanoix (1958).

A ferrocement version of this is possible and advantageous, since it need only be 18 to 25 mm thick, rather than 70 mm as shown, with consequent savings in materials and weight but with equal strength. Figures 7-5 and 7-6 show the SanPlat, see www.sanplat.se. Figure 7-7 shows the squatting plate as part of a dome-shaped pit cover.

Figure 7-5: SanPlat

Figure 7-6: SanPlats for Arbor Loos (Simpson, 2009)

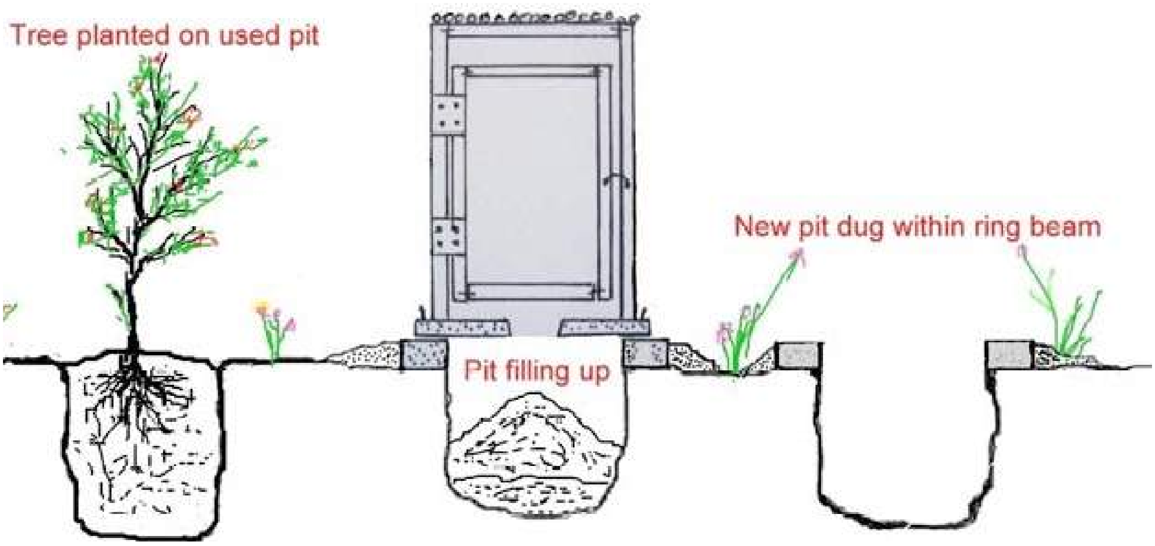
Figure 7-7: Squatting plate as part of dome shaped pit cover (WEDC, 1998)



7.3. Arbor (Sabar[5]) Loo[6]

Useful alternative to abandoned cesspits for nomadic Bedouin communities. When cesspits or the 250 litres of the 'temporary' toilets in Area 'C' are full and cannot be emptied, they can simply be filled with soil and covered. Although there is no benefit recovered, the full pit poses no immediate health risk, and with time, the contents will degrade naturally. Alternatively, the 'Arbor Loo' is a shallow pit that is filled with excreta and soil/ash and then covered with soil; a tree planted on top will grow vigorously in the nutrient-rich pit.

Figure 7-8: Arbor Loo (CAPS, 2012)



Arbor Loo. When a cesspit or 250 litre metal drum is full, and cannot be emptied, "Fill and Cover", i.e. filling the remainder of the pit and covering it is an option, albeit one with limited benefits to the environment or the user. With the Arborloo option, a tree is planted on top of the full pit while the superstructure; ring beam and slab are moved from the full pit to a new empty pit and thus repeated in an endless cycle (usually moved once every 6 to 12 months). A shallow pit is needed, about 1 meter deep. The pit should not be lined, as the lining would prevent the tree or plant from growing properly. Before the pit is used, a layer of leaves is put into the bottom. After each defecation, a cup of soil, ash or a mixture should be put into the pit to cover the excreta. If available, leaves can also be added occasionally to improve the porosity and air content of the pile. When the pit is full, the top 15cm of the pit is filled with soil and a tree is planted in the soil. Banana guava trees (among many) have all proven to be successful. A tree should <u>not</u> be planted directly in the raw excreta. The tree starts to grow in the soil and its roots penetrate the composting pits as it grows. It may be best to wait for the rainy season before planting if water is scarce. Other plants such as the highly appreciated cactus, the Sabar or Opuntia ficus-indica with the prickly pears can also be planted on top of the pit.

[5] Sabar (Arabic) means cactus and at the same time 'easy/slowly'
[6] After Tilley (2008)

Figure 7-9: Sabar (UNICEF/Spit, 2012)

Figure 7-10: Sabar Loo? (UNICEF/Spit, 2012)

Adequacy. Filling and covering pits is an adequate solution when emptying is not possible and when there is space to continuously re-dig and fill pits. The Arbor/Sabar Loo can be applied in nomadic Bedouin areas, but also in rural, peri-urban, and denser areas if space is available. Planting a tree or cactus in the abandoned pit is a good way to reforest an area, provide a sustainable source of fresh fruit and prevent people from falling into old pit sites.

Health Aspects/Acceptance. There is a minimal risk of infection if the pit is properly covered and clearly marked. It may be preferable to cover the pit and plant a tree rather than have the pit emptied, especially if there is no appropriate technology available for treating the faecal sludge. Users do not come in contact with the faecal material and thus there is a very low risk of pathogen transmission. Demonstration projects that allow community members to participate are useful ways of showing both the ease of the system; it's inoffensive nature, and the nutrient value of composted excreta.

Operation and maintenance. A cup of soil and/or ash should be added to the pit after each defecation and leaves should be added periodically. Also, the contents of the pit should be periodically levelled to prevent a cone- shape from forming in the middle of the pit. There is little maintenance associated with a closed pit other than taking care of the tree or plant. If a tree is planted in the abandoned pit, it should be watered regularly. A small-fence should be constructed with sticks and sacks around the sapling to protect it from animals (see Figure 7-10).

Table 7-2: Advantages and disadvantages Arbor (Sabar) Loo

Advantages	Disadvantages
• Simple technique for all users • Low cost • Low risk of pathogen transmission • May encourage income generation (cactus planting and fruit production) • Suitable for areas where vacuum trucks cannot enter • Does not require any human contact with the waste	• Labour intensive (a new pit needs to be dug every 6 to 12 month) • Does not prevent ground water contamination • Not suitable with a high groundwater table • Not suitable in loose soil conditions where the pit cannot be reinforced (unless with bio-degradable materials, woven baskets or with wooden slats leaving a gap between each slat) • Is only possible where there is enough space

See also:
- Appendix 2-5: WASTE DST Reuse and Disposal;
- Appendix 3-1: SSWM Arbor Loo.

Design Arbor Loo. The approximate volume of the pit can be calculated as a function of the following equations:
- $V = N * S * T / 1000$;
- $F = N * q / i$.

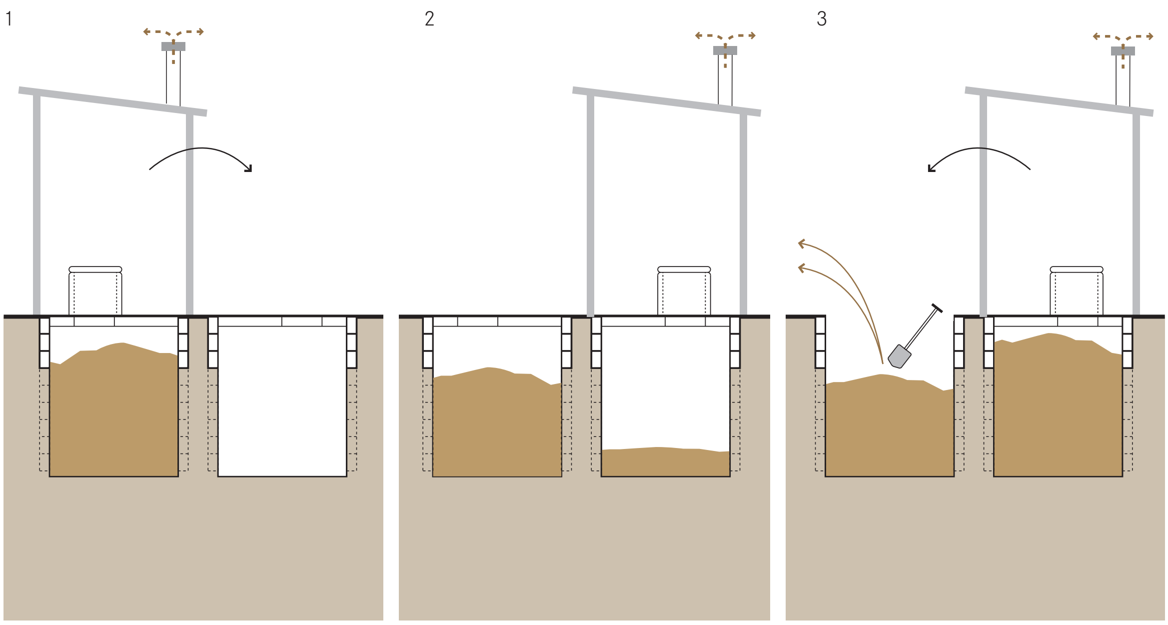
Where:
V = Pit volume (m^3);
N = Number of users (capita);
S = Sludge accumulation rate (lcy, litres/cap/year), see section 4.3;
T = Lifetime pit;
F = Infiltration area (m^2);
q = Amount of water used for anal cleansing and flushing (lcd);
i = infiltration capacity soil ($l/m^2/day$), see section 4.3.

A square shaped pit, for a family of 8 persons (N=8), a sludge accumulation rate of 40 lcy (S=40), a lifetime of 1 year (T=1), and a water use of 2 lcd (q = 2) and an infiltration rate of 20 $l/m^2/day$ (i=20), the Volume (V) and Infiltration area (F) are:
- V = 8 * 40 * 1 / 1000 = 0.32 m^3, say a pit 1 m’ * 1 m’, a sludge depth of 0.32 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 = 0.32 m’ + 0.2 m’ +0.3 m’ = 0.82 m’.

7.4. Fossa Alterna[7]

Useful alternative to lined cesspits for static Bedouin communities. When a cesspit in the 'temporary' toilets in Area 'C' is full and can be emptied, it can be converted into a **Fossa Alterna** (see Figure 7-11), which is an alternating, waterless (dry) double pit technology. Compared to the Double Ventilated Improved Pit Latrine (see Appendix 2-2 WASTE DST Collection Storage Treatment), 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 anaerobic 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, and remove moisture which in turn removes any smell. This can be further reduced with the addition of a **ventilation pipe**.

Figure 7-11: Fossa Alterna (Tilley, 2008)



[7] After 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[8]. 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 static Bedouin communities without a reliable water supply as it is especially adapted to water-scarce environments. See Figure 7-12. 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.

[8] After Kalbermatten, 1982

Figure 7-12: Area suitable for Fossa Alterna (UNICEF/Spit, 2012)

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 different 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.

Table 7-3: Fossa Altera at a glance

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.

Table 7-4: Advantages and disadvantages Fossa Alterna

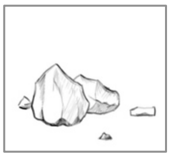
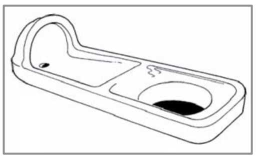
Advantages	**Disadvantages**
• Can be built and repaired with locally available materials • Because double pits are used alternately, their life is virtually unlimited • Excavation of humus is easier than faecal sludge • Potential for use of stored faecal material as soil conditioner • Flies and odours 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 • Not suitable for high groundwater table areas or those prone to flooding (unless pit is lined and impermeable, or built above-ground similar to design shown in figure 7-13).

See also:

- Appendix 2-5: WASTE DST Reuse and Disposal;
- Appendix 3-2: SSWM Fossa Alterna.

Design. The same procedure can be followed as for the Arbor Loo. See section 7.3.

7.5. Dry Urine Diversion Toilets[9]


A useful alternative for Bedouin communities in hard rock areas, who are used to work with manure. The toilet has two compartments, keeping urine and faeces separate. See Figure 7-13. 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 cleaning. 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.

Applying conditions

- Dry urine diversion toilets 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 on the West Bank are mixed, so there needs to be a considerable efforts to encourage behaviour change.

Further reading. The reader is invited to learn more on these systems by consulting:

- Appendix 2-5: WASTE DST Reuse and Disposal;
- Appendix 3-3: SSWM UDDT;
- Appendix 3-4: SSWM Compost Filters;
- Appendix 3-5: SSWM Terra Preta Sanitation.

[9] Smart Sanitation Solutions, WASTE (2006)

Figure 7-13 (below): UDD Toilet (CAPS, 2012)

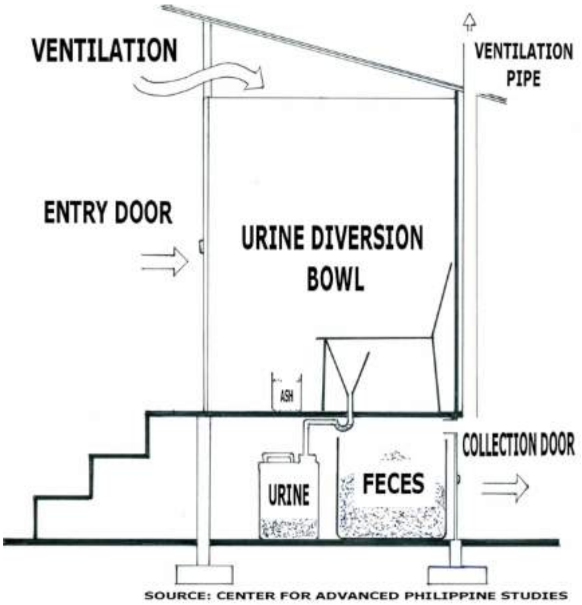


Figure 7-14 (below): Urine Diversion Toilet with washing facility (CAPS, 2012)

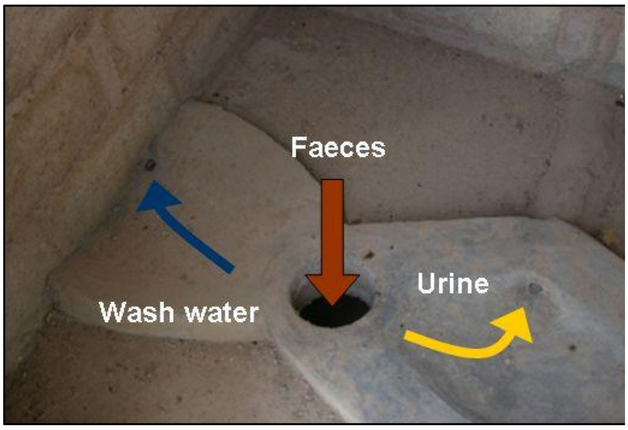


Figure 7-15 (right): Compost toilet in Bethlehem (UNICEF/Spit, 2012)

8. Wet on-site sanitation systems

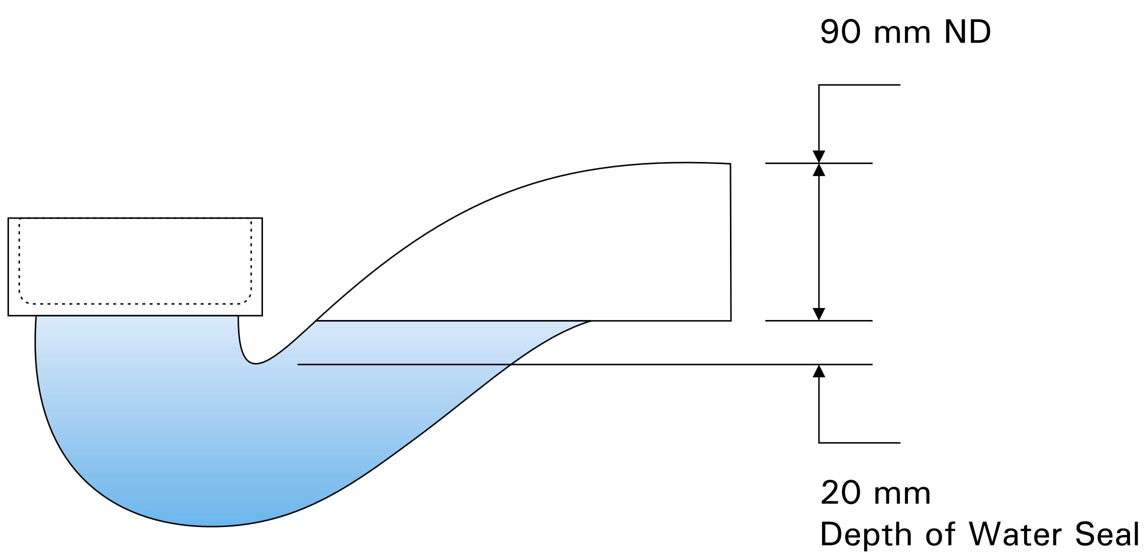
8.1. Introduction

In section 4.2 we provided a menu of various technologies that could be selected. The menu of potential wet systems is presented in Figure 8-1. Wet systems are suitable in areas where enough water is available to assure that the water seal of the toilet is filled with water. See Figure 8-2.

Figure 8-1: Technology selection menu wet systems

User interface	Emptying conditions	Soil conditions	Collection Storage / Local Treatment	Transport/ Conveyance	Treatment	Reuse/ Disposal
Wet	No desludging services	Ground water table > 3 m' deep	Twin Leaching Pit			
	Desludging services	Infiltration possible	Septic Tank & Soakaway			
		No infiltration Possible	Septic Tank & AUF			

Figure 8-2: Water seal



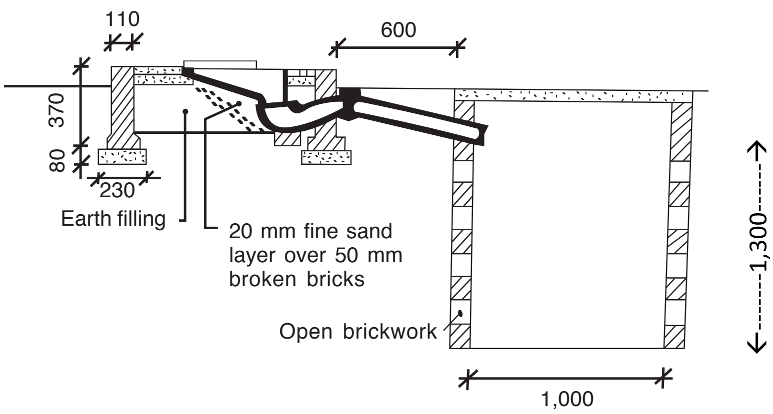
8.2. Twin Leaching Pits

The Twin Leaching Pit technology is an excellent way to upgrade an existing 250 litre cesspit in static communities where there is adequate water available for flushing. See Figure 8-3.

Figure 8-3: Future Twin Leaching Pit? (UNICEF/Spit, 2012)

Twin Leaching Pits[10] for pour-flush toilets are two underground leaching pits linked to one single pour-flush toilet by a Y-junction or control box. See Figure 8-4, Figure 8-5 and Figure 8-7. The two pits are used alternately with both urine and feaces 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. See Figure 8-6. 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 sanitized (see section 4.3) but still contains good organic matter and nutrients that can be reused on-site, much like compost, to improve soil fertility and fertilize crops.

Figure 8-4: Twin Leaching pit cross-section (measurements in mm) (Kalbermatten, 2012)



[10] After Tilley (2008) and Tilley/Sandec (2008)

Figure 8-5: Twin Leaching Pit (WSP, 2008)

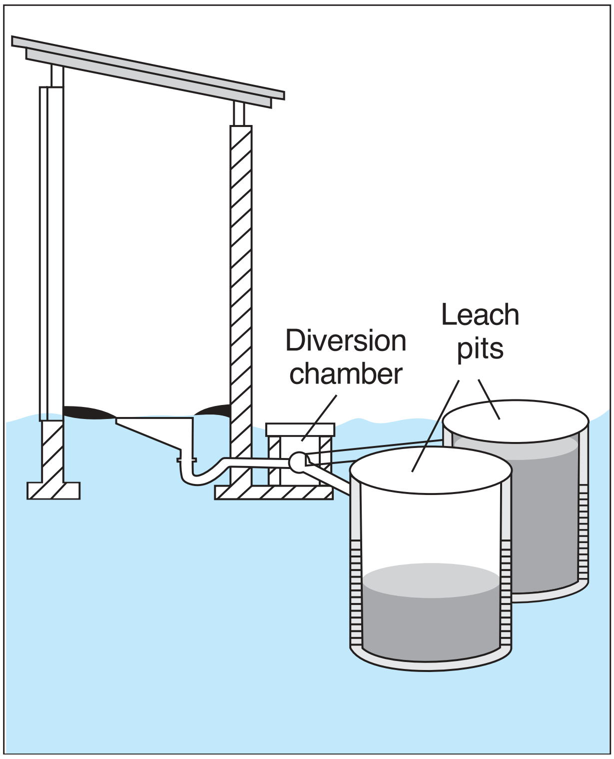


Figure 8-6: Detail pit (SHAW/Spit, Indonesia 2012)

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 (see Part 1 of The Manual for how to conduct leaching capacity of soil). As soil and groundwater properties are often unknown, it is difficult to estimate the necessary distance between a pit and a water source. Table 8-1 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.

Table 8-1: Distance leaching pits from drinking water and modifications

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

Minimal distance of leach pits from drinking water sources in different soil conditions. Source: ROY et al. (1984)

Figure 8-7: Control box or 'Y'-junction (SHAW/Spit, 2012)

Adequacy: The Twin Leaching Pits with Pour Flush is a permanent technology that is appropriate for areas where it is not possible to continuously move a pit latrine. It 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). This technology is not adequate for areas with a high groundwater table or 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 (see section 10.2). 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 section 4.3;
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 section 4.3.

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 $\frac{\pi}{4}$ * 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 $A = \pi * d = 3.14\ m2/m'depth$, 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' (see Figure 8-4).

Further reading. The reader is invited to learn more on these systems by consulting:

- Appendix 2-2: WASTE DST Collection Storage and Treatment;
- Appendix 3-6: SSWM Twin Leaching Pits.

Table 8-2: Twin Leaching pits at a glance

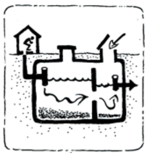
Working Principle	Two leach pits (twin pits) are linked to a pour-flush toilet with a Y junction. Only one pit is used at a time as the Y junction is blocked for the other. When it is full, the pit is sealed and the other is brought in use. The excreta in the sealed pit will decompose by composting and anaerobic digestion. After two years, the maturated sludge is safe but rich in nutrients and can be used in agriculture.
Capacity/Adequacy	Can be built in rural and urban areas if water and space are available. But in regions prone to flooding or with rocky soils, groundwater pollution can occur. Also, if too many soak pits are installed densely, they can rapidly overflow or lead to groundwater pollution, as the soil matrix cannot absorb all the leachate.
Performance	Liquids, if filtered through underground infiltration will by purified without having been in contact with humans or animals. The faeces hygienisation takes relatively long (2 years) as it is a water-reliant process but the end product is safe.
Costs	Moderate to high investment costs; very low operation and maintenance costs
Self-help Compatibility	Can be constructed with local manpower, but skilled design is required.
O&M	Control of Y junction; Desludging every two years.
Reliability	High, if well maintained.
Main strength	Easy to use and high comfort (anal cleansing with water, no odour).
Main weakness	Requires water for flushing, otherwise it clogs; Risk of groundwater pollution.

Table 8-3: Advantages and disadvantages Twin Leaching Pits

Advantages	**Disadvantages**
• Maturated faeces can be used as soil fertilizer • Does not require adaption to standard practice (i.e anal cleansing water can be poured into the toilet and odour and flies are prevented due to water seal) • Can be built and repaired with locally available materials) • Removal of solids is relatively easy as excreta will be dry • No or low operating costs if self-emptied • Possible location inside the house • No odour or fly and mosquito breeding • Low level of municipal involvement • Low annual costs • Ease of construction and maintenance • Very high potential for upgrading to flushing with	• Relatively high investment costs • Requires space • If not enough flushing water is available, the toilet gets easily blocked • Not applicable in hard rock soil, high ground water levels or areas that are prone to flooding (groundwater pollution) • Not suitable for areas inaccessible to vacuum trucks (unless can be self-emptied) • Water-based technology, thus long retention times for treatment of waste • The maturated excreta needs to be dug out manually • Maturated sludge may need secondary treatment (e.g. drying, composting)

Advantages	Disadvantages
a cistern rather than pour-flush.	• Separate grey water disposal required

8.3. (Low cost) Septic Tank with infiltration system



A (low cost) septic tank is a good way to replace existing cesspits in urban villages with piped water supply where desludging services are available. See Figure 8-8.

Figure 8-8: Typical urban area suitable for septic tanks (UNICEF/Spit, 2012)

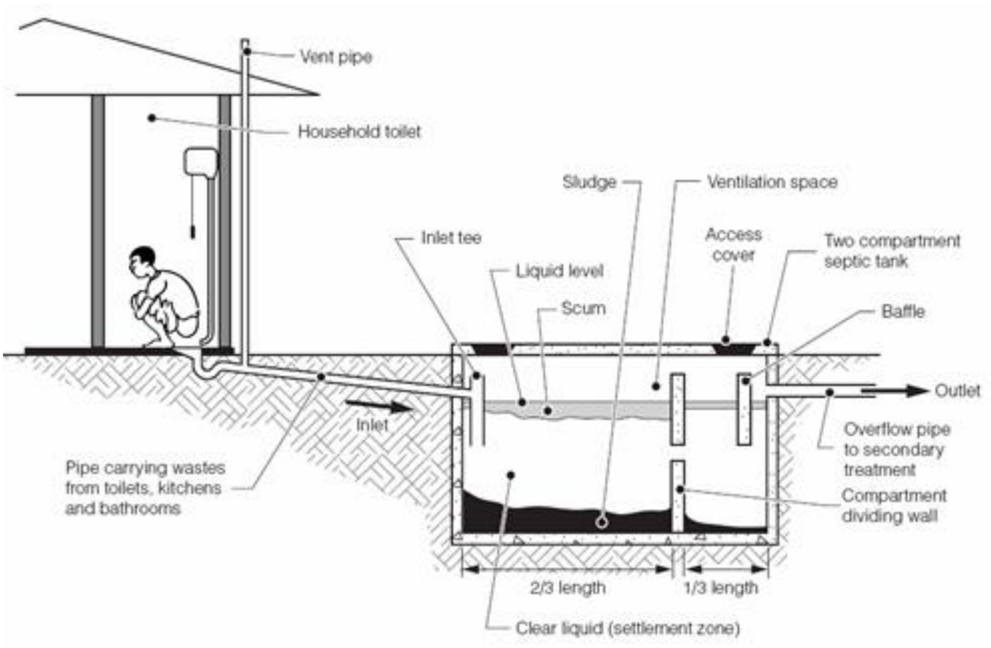
A Septic Tank[11] is a watertight chamber made of concrete, fibreglass, PVC or PE, for the storage and treatment of black water only or a combination of black and grey water. Settling and anaerobic processes reduce solids and organics, but the treatment is only moderate.

A Septic Tank (Figure 8-9 and Figure 8-12) 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[12]. . 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

11 After Tilley (2008)
12 http://en.wikipedia.org/wiki/Septic_tank

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.

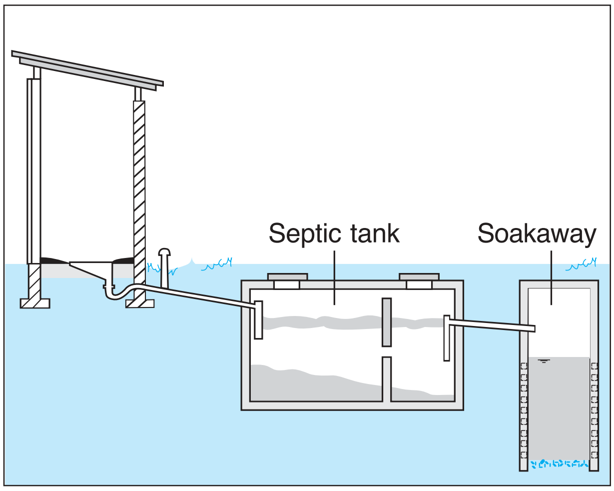
Figure 8-9: Septic tank with vent pipe (Practical Action[13])



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 (see section 10.2) or Small Bore sewers (see section 10.2).

[13] *http://practicalaction.org/sanitation-technologies-answers*

Figure 8-10: Septic tank and soakaway (WSP, 2008)



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

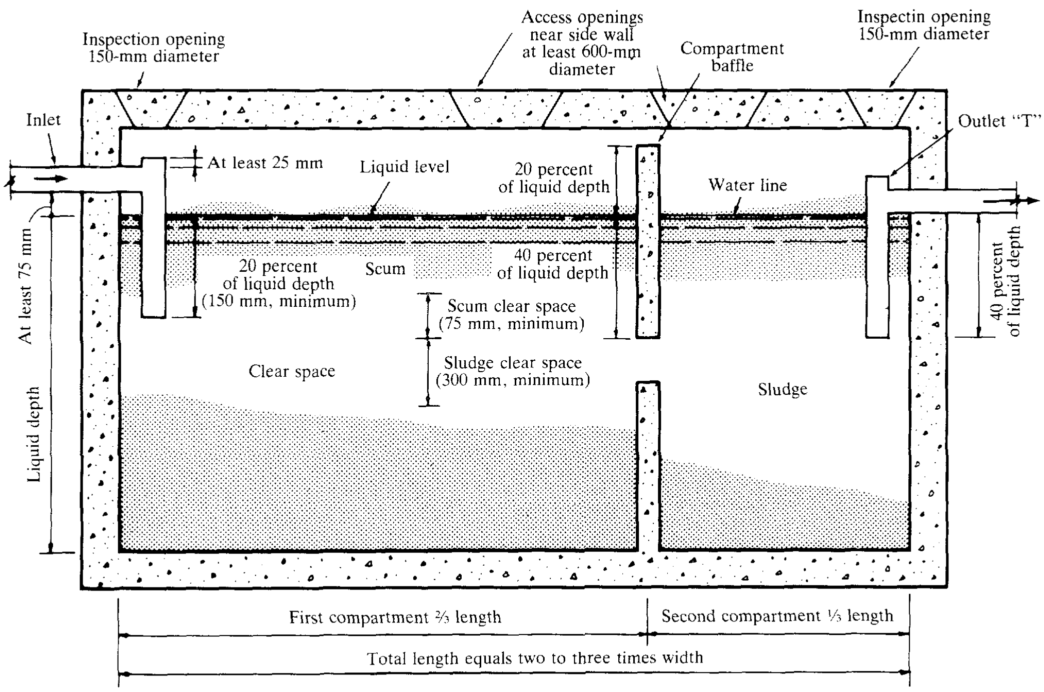
Figure 8-101: HDPE Septic Tank (UNICEF/Spit, 2012)

Adequacy 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.

Figure 8-112: Specification conventional septic tank (Kalbermatten, 1982)

Figure 14-1. *Schematic of Conventional Septic Tank*
(millimeters)



Note: If vent is not placed as shown on figure 13-2, -3, and -4, septic tank must be provided with a vent.

Health Aspects/Acceptance 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.

Figure 8-123: Low cost septic tank for black water only (Yayasan Dian Desa/Spit, 2012)

Upgrading A Septic Tank that is connected to a Leach Field or a Soak Pit can later be connected to a neighbourhood sewerage system (see section 10.2) if/when one is installed.

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[14] 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

[14] Pickford, J. Low Cost Sanitation. IT Publications. 1995.

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 section 4.3;
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'.

Further reading. The reader is invited to learn more on these systems by consulting:

- Appendix 2-2: WASTE DST Collection Storage and Treatment;
- Appendix 3-7: WWSP Septic Tank.

Table 8-4: Advantages and disadvantages Septic Tank

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

Table 8-5: 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.

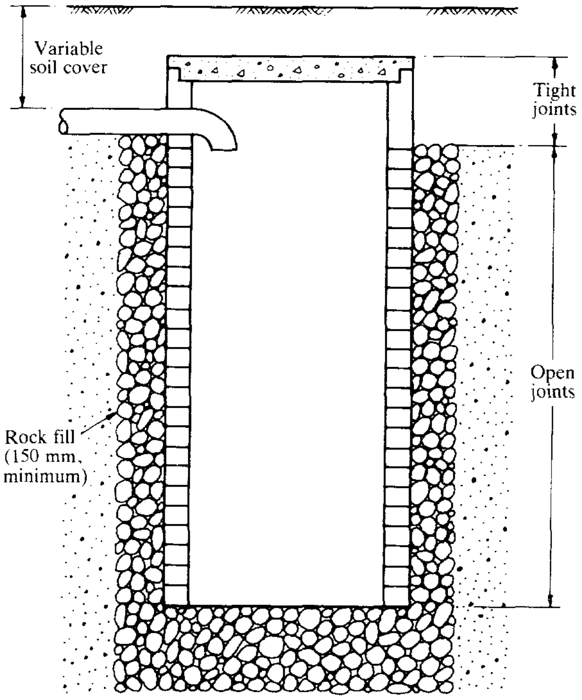
Effluent quality. As explained, the BOD and pathogen removal of a septic tank is limited:

- BOD removal efficiency 30%-50%. At a removal efficiency of 40%, the effluent of a Septic Tank that holds black and grey water (see section 2.3) 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 10^5 E-coli/100 ml, the bacteriologic quality of the effluent is $10^{(5-1)} = 10^4$ E-coli/100ml.

8.4. Soakaway

When the soil is sufficiently permeable, the septic tank effluent can be discharged in a soakaway / soak pit. A soakaway (see Figure 8-13) is a covered, porous-walled chamber 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 organics are digested by microorganisms. Thus, soakaways are best suited to soils with good absorptive properties; clay, hard packed or rocky soils are not appropriate.

Figure 8-14: 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.

Table 8-6: Advantages and disadvantages Soakaway

Advantages	Disadvantages
• Can be built and maintained with locally available materials • Small land area required • Low capital cost; low operating cost • Simple technique for all users	• Pre-treatment is required to prevent clogging, although eventual clogging is inevitable • May negatively affect soil and groundwater properties

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 section 4.3.

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 $l/m^2/day$ (I = 25), Infiltration area (F) is:

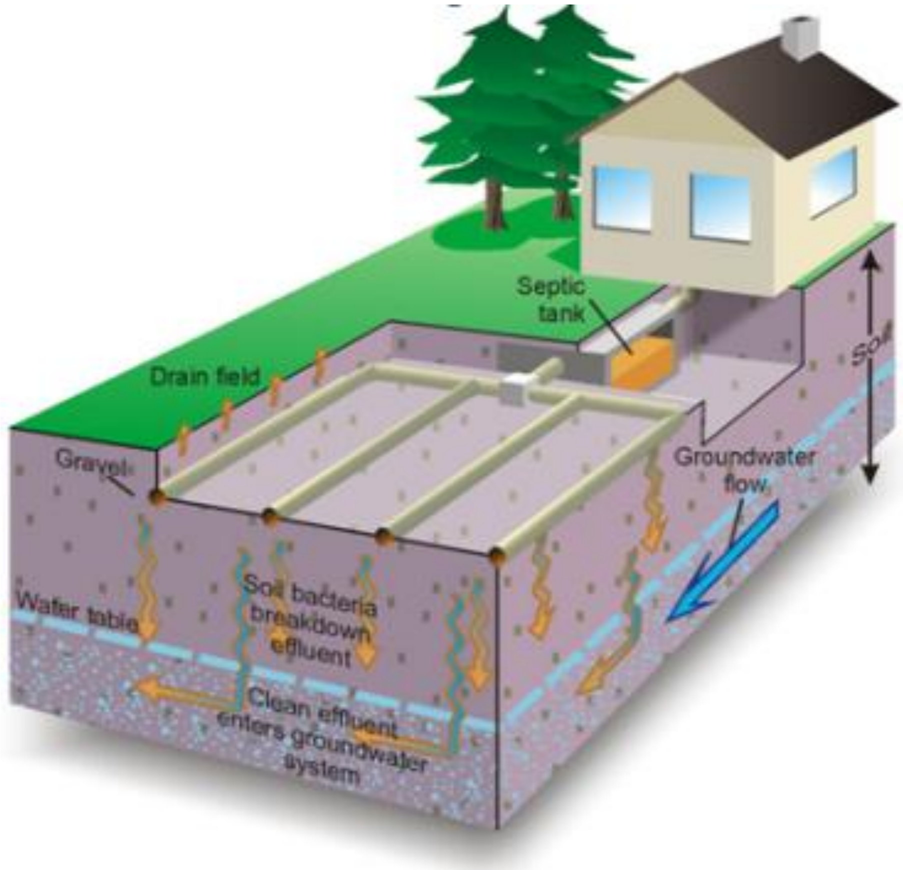
- F = 8 * 30 / 25 = 9.6 m^2, hence a liquid depth of 1.6 m' in a square soakaway of 1.5 m' wide and 1.5 m' long: 9.6/(4*1.5) = 1.6 m'.

8.5. 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. See Figures 8-15 through 8-18. Effluent is fed into a distribution box, which directs the flow into several parallel channels. A small dosing system releases the pressurized 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 utilized 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.

Figure 8-135: Functioning Leach Field



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.

Upgrading A Leach Field should be laid out such that it would not interfere with a future sewer connection.

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 section 4.3.

For a trench with an effective depth of 0.6 m' (D = 0.6 m', see Figure 8-15), 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.

Figure 8-16: Cross section trench

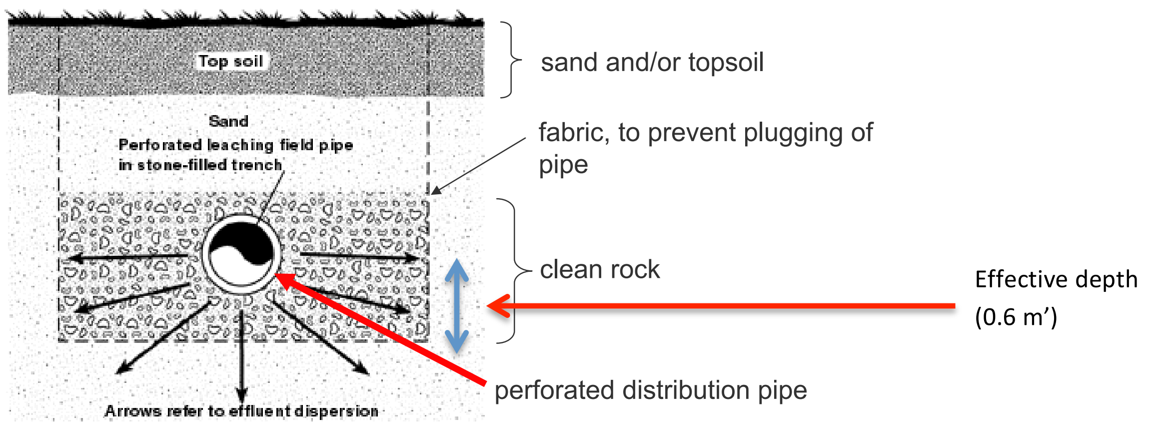
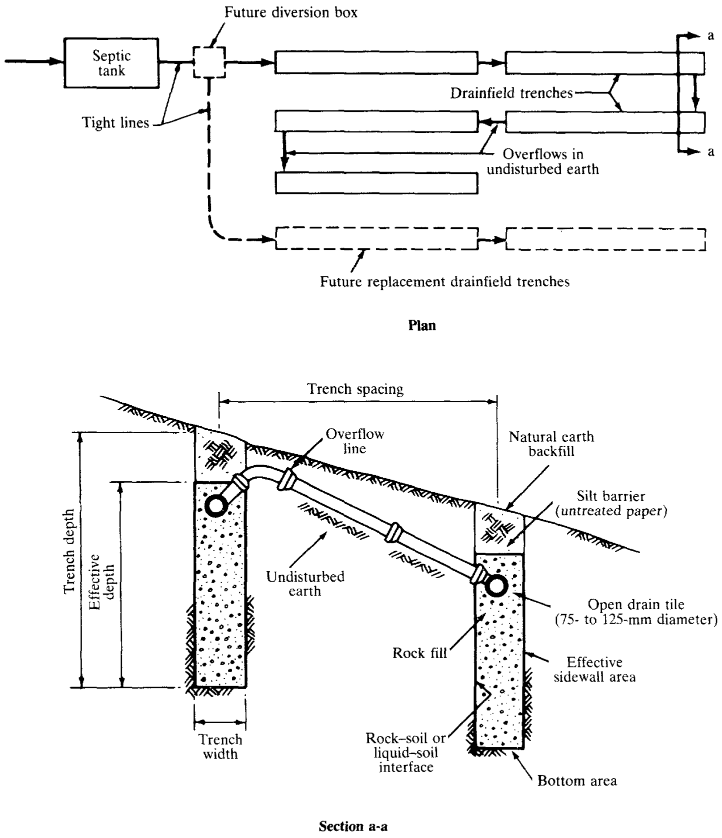


Table 8-7: Advantages and disadvantages Leach Field

Advantages	Disadvantages
• 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	• 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

Figure 8-17: Leach Field (Kalbermatten, 1982)

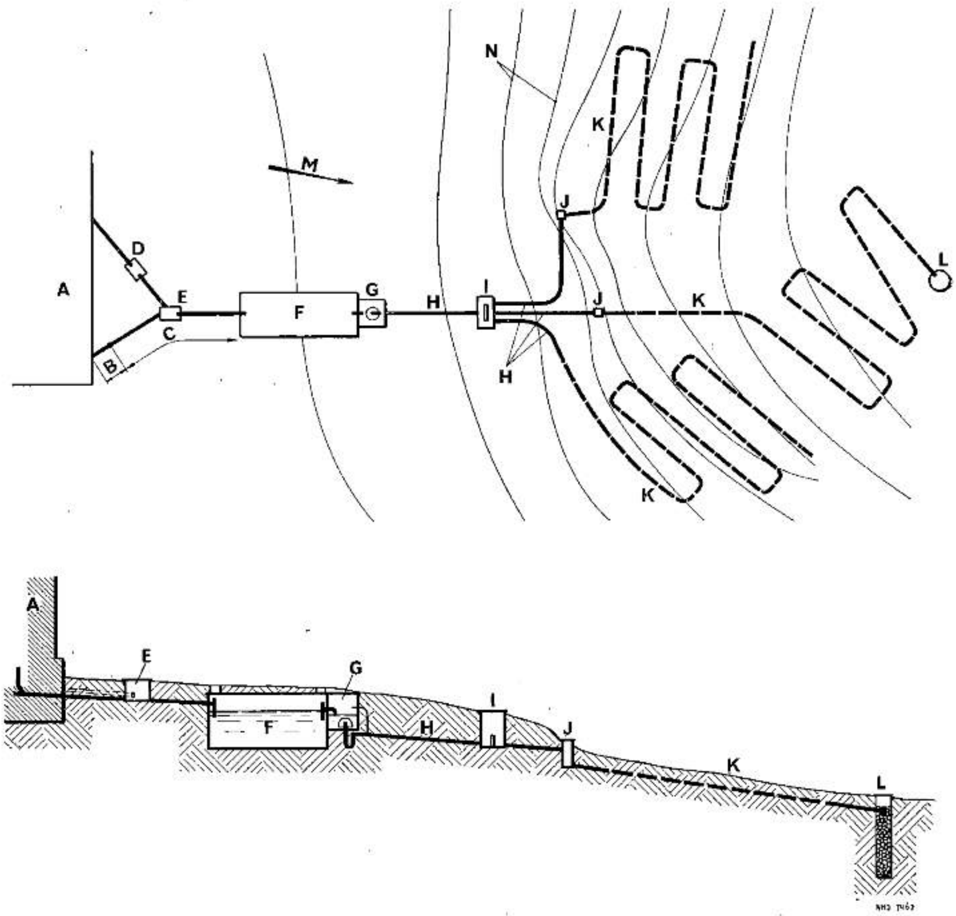


Further reading. The reader is invited to learn more on these systems by consulting:

- Appendix 2-5: WASTE DST Reuse and Disposal;
- Appendix 3-8: WWSP Leach Fields.

Figure 8-18: Typical lay out leach field (Kalbermatten, 1982)

FIG. 63. TYPICAL LAYOUT OF SEPTIC-TANK SYSTEM

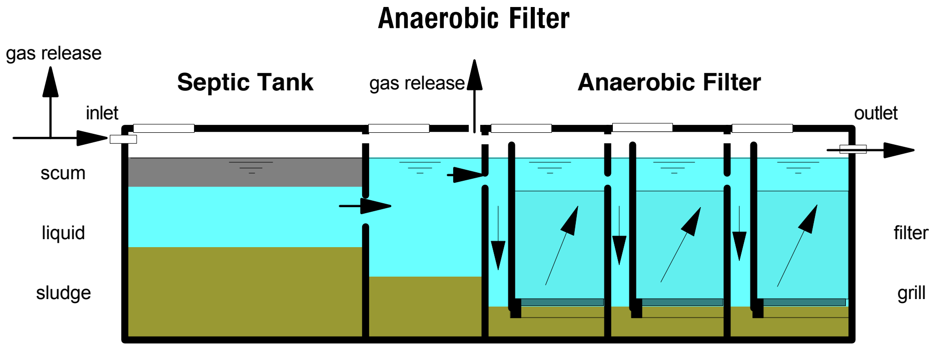


A = Private house or public institution
B = House sewer
C = Building sewer
D = Grease interceptor on pipe line from kitchen
E = Manhole
F = Septic tank
G = Dosing chamber and siphon
H = Pipes laid with tight joints
I = Distribution box
J = Drop-boxes or terracotta L's
K = Absorption tile lines
L = Seepage pit, when required
M = Slope of ground surface
N = Topographic contour lines

8.6. Anaerobic Upflow Filter[15]

In section 2.3 we showed that the wastewater in oPt is relatively strong. Anaerobic processes are the most efficient when dealing with strong water (see section 2.4). An Anaerobic Upflow Filter (UAF) is a fixed-bed biological reactor. As wastewater flows through the filter material, particles are trapped and organic matter is degraded by the bio-mass that is attached to the filter material. See Figure 8-19. 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 (see Figure 8-20). The AUF most commonly used in oPt applies crushed rocks, see Figure 8-20. These rocks may be subject to decomposition due to the low pH of the wastewater.

Figure 8-149: 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 m^2 of surface area per 1 m^3 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 down flow 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).

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. Depending on land availability and the hydraulic gradient of the sewer (if applicable), the Anaerobic Filter can be built above or below ground.

[15] After Tilley (2008)

Figure 8-20: Plastic media AUF (Sasse, 1998)

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 appropri- ate 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. See Figure 8-21.

Figure 8-21: Crushed Stone Anaerobic Upflow Filter (Burnat, 2010)

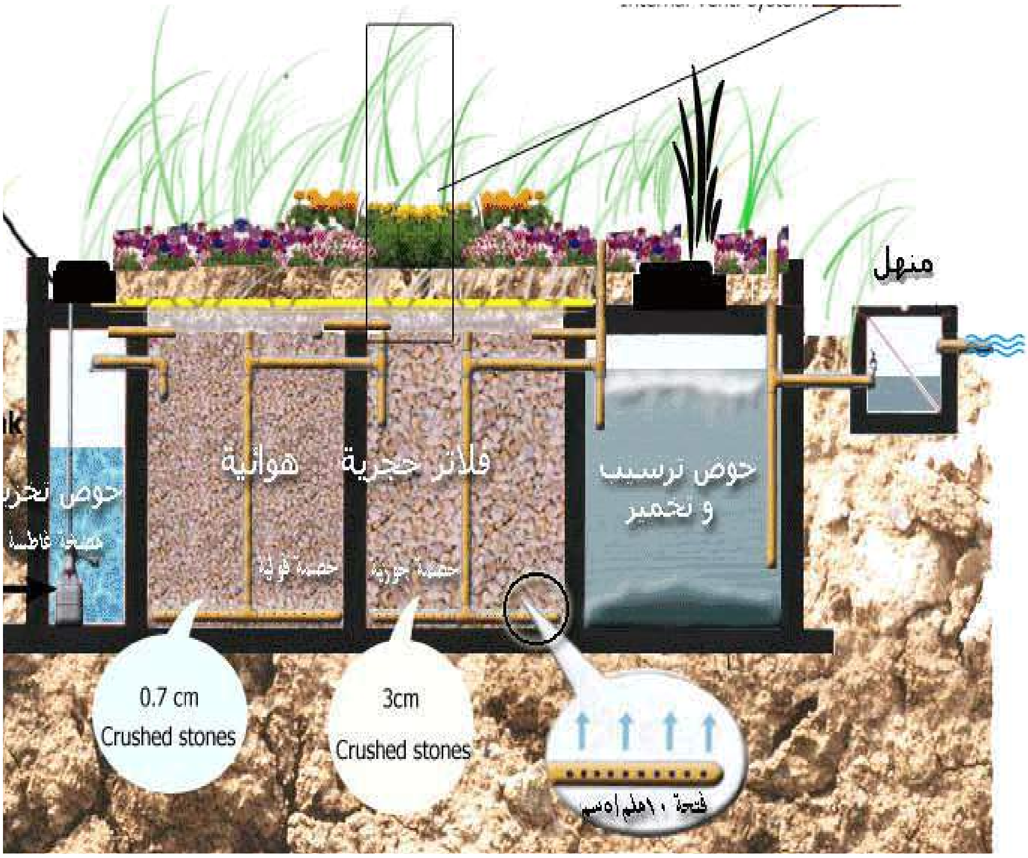


Figure 8-152: Pre-cast concrete slabs to cover AUF (WEDC, accessed April 2012)

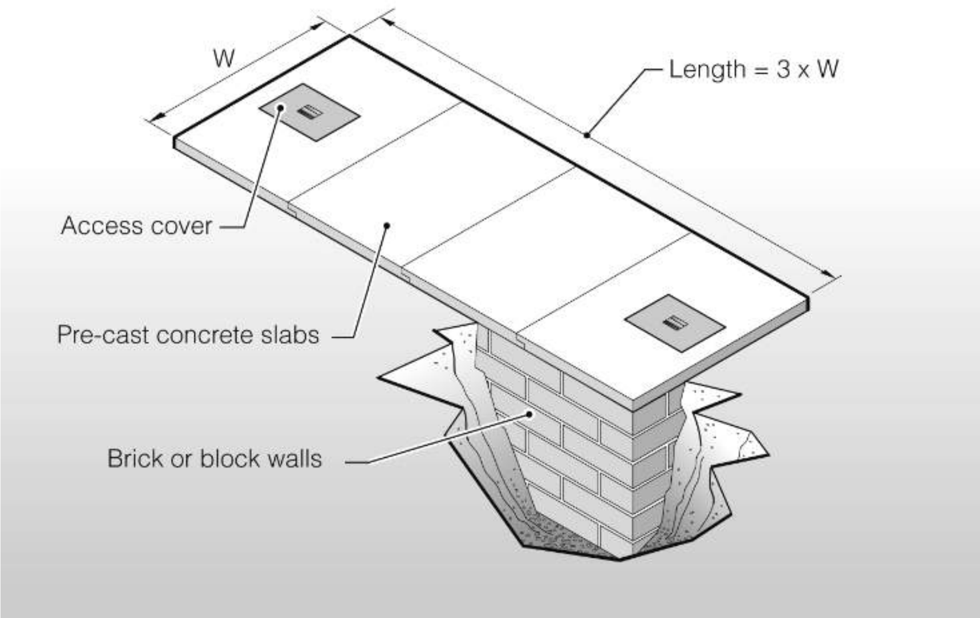


Table 8-8: AUF at a glance

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.

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 (see 8.3) is (100%-75%) * 320 mgBOD/l = 80 mgBOD/l;
- E-coli removal: log 2 units. At an influent quality 10^4 E-coli/100 ml (see 8.3), the bacteriologic quality of the effluent is $10^{(4-2)}$= 100 E-coli/100ml.

Figure 8-22 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.

Figure 8-163: Section Anaerobic Filter 25 m³/day (Sasse, 1998)

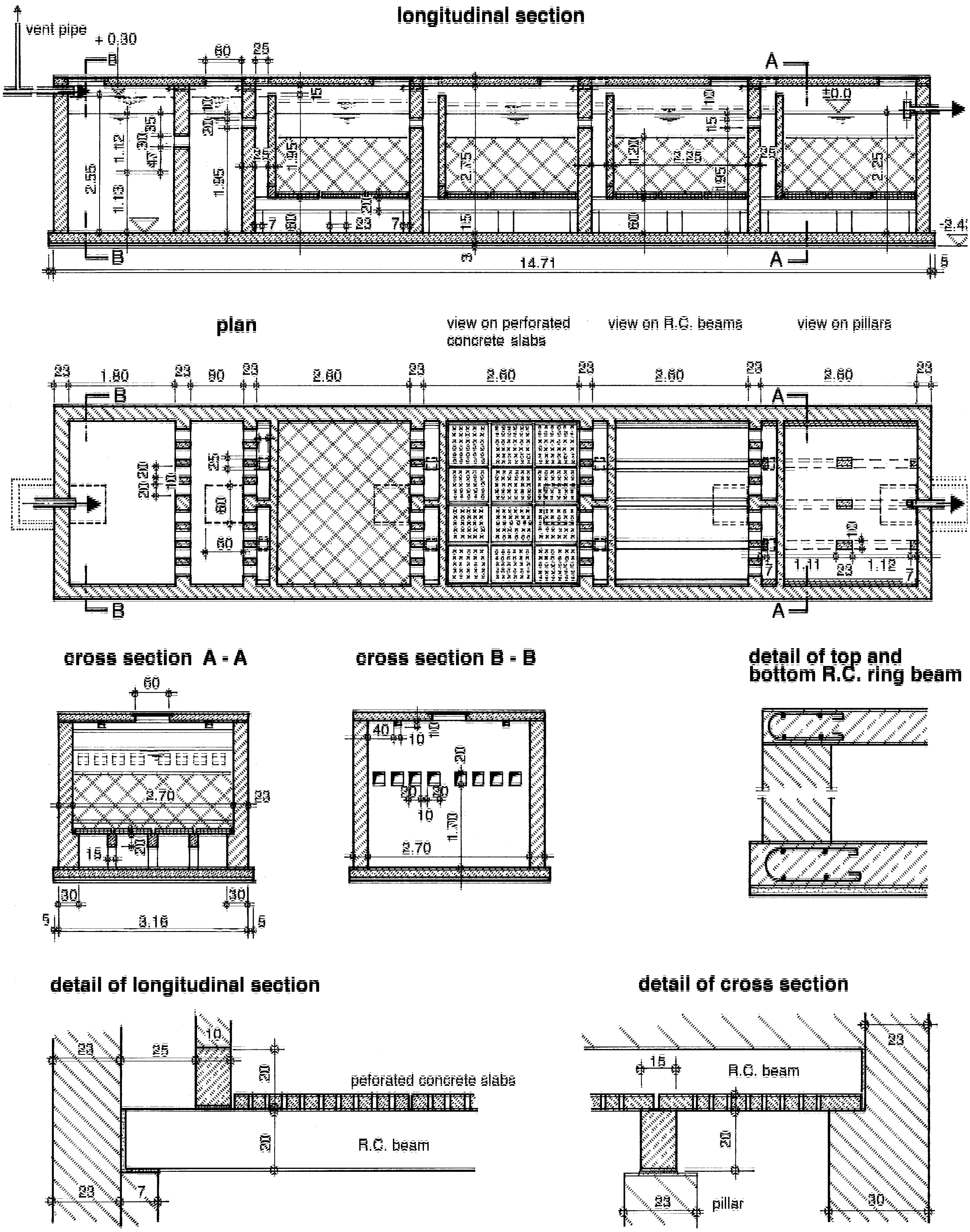


Fig. 23.
Anaerobic filter. Dimensions have been calculated for 25 m^3 domestic wastewater per day.

Table 8-9: Advantages and disadvantages AUF

Advantages	**Disadvantages**
• 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	• 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

Further reading:
Appendix 2-4: WASTE DST Treatment;
Appendix 3-9: SSWM Anaerobic Filter.

Figure 8-174: Household grey water anaerobic upflow filter (UNICEF/Spit, 2012)

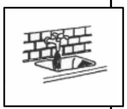
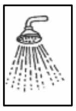
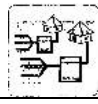
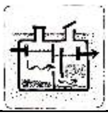
Figure 8-185: Village grey water anaerobic upflow filter (UNICEF/Spit, 2012)

9. Grey water management systems

9.1. Introduction

In section 4.2 we provided a technology selection menu. The menu of selected grey water management systems is presented in Figure 9-1.

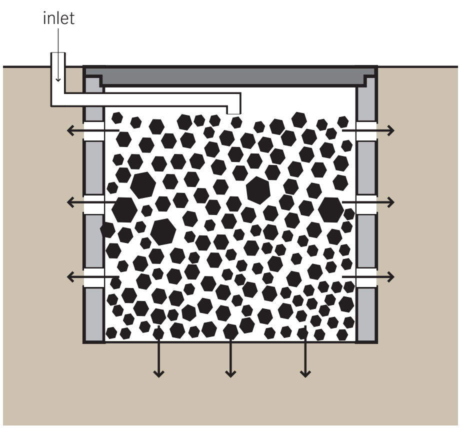
Figure 9-1: Technology selection menu grey water management systems

	User interface	Emptying conditions	Soil conditions	Collection Storage / Local Treatment	Transport/ Conveyance	Treatment	Reuse/ Disposal
Grey Water	 		Permeable soil	Soakaway			
			Low permeability	Leach field			
			Any soil	Constructed Wetland			Irrigation 
				Anaerobic Upflow Filter (AUF)			Disposal
				Evapotranspiration field			

9.2. Soakaway

The soakaway is a simple method to dispose of grey water without reuse in permeable soils. We refer to section 9.2 for a description of the soakaway. A soakaway for grey water is often filled with gravel to provide extra treatment. See Figure 9-2.

Figure 9-2: Gravel filled soakaway (Tilley, 2008)



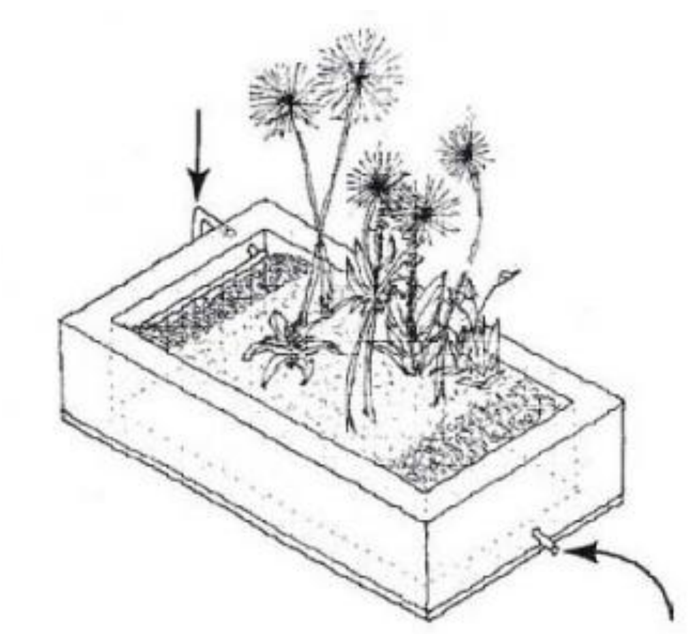
9.3. Leaching Field

A leaching field is a simple method to dispose of grey water without reuse in less permeable soils. We refer to section 9.3 for a description of the leaching field. See Figure 9-2

9.4. Evaporation Field

An evaporation field is a simple method to dispose of grey water without reuse in impermeable soils. The wastewater effluent is discharged into sealed up receptacles where the water evaporates from the soil or transpires from the plants growing there. Bacteria remove the dissolved organic matter and plants take up the remaining nutrients. See Figure 9-3.

Figure 9-3: Evaporation field (SSWM, accessed April 2012)



Evaporation fields are a low-cost technology that allows for a secondary treatment of grey water. The grey water can be discharged by gravity into sealed up planting beds, containers, inverted tires or the like where it will be absorbed by soil particles and moves both horizontally and vertically through the soil pores. The liquid fraction moves upwards by capillary action and either evaporates at the surface or is taken up by plants or trees and transpires. The plants/trees take up the remaining nutrients and bacteria living in the soil remove the dissolved organic material in the effluent. Eucalyptus trees are well suited for evaporation fields and known for this in oPt.

Design. The approximate dimension of the evaporation field can be calculated as a function of the following equations:

- E = N * q / iE

Where:
E = Evaporation area (m^2);
N = Number of users (capita);
q = Amount of grey water (lcd, litres / cap / day);
iE = Evaporation rate (mm/day = l/m^2/day).

When no local evaporation rates are known, they can be estimated by the rates provided by the FAO:

- Evapotranspiration rates (FAO):
    - Cool (~10°C): 2-4 mm/day
    - Moderate (20°C): 4-6 mm/day
    - Hot (30°C): 6-8 mm/day
- (source: http://www.fao.org/docrep/x0490e/x0490e04.htm , accessed 8 April 2012)

Hence, for a family of 8 persons (N=8), a per capita grey water effluent of 60 lcd (q = 60), and an evaporation rate of 8 mm/day (iE = 8), Evaporation area (E) is:

- E = 8 * 60 / 8 = 60 m^2.

Table 9-1: Advantages and disadvantages evaporation field

Advantages	Disadvantages
• Low-cost solution • Easy to construct • Easy to use • Easy to repair if damage occurs	• Tends to clog or overflow • May constitute a risk during the presence of small children • Tends to smell slightly • May attract insects • Evaporation process requires time

Further reading:

- Appendix 3-10: SSWM Evaporation Field.

9.5. Grey water reuse[16]

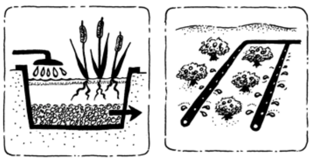
Grey water reuse should be a key consideration, particularly in oPt where water scarcity is pronounced. Many farmers are actually already using grey water but in an uncontrolled and untreated manner. The best estimate there is comes from the Department of Statistics in Jordan whose 2001 Amman census revealed that 40 per cent of the population use grey water, to some extent, to irrigate their gardens. This amounts to 500,000 people in the city alone. The main reasons for the use of grey water are the potential nutrient benefits leading to increased harvests, as well as savings in terms of fertilizer and water costs. It can safely be said that the proportion of use may be higher in rural areas where access to potable water and sanitation is more infrequent. A number of jurisdictions outside oPt have developed policies on grey water use. These policies can be simple and straightforward and are being applied. With appropriate knowledge on the origins, quality

[16] After McLlwaine (2010)

and practices associated with grey water, the same potential of its use can be released for oPt. The low-cost treatment options discussed in this chapter negate health risks and improve the quality of grey water. However, agreement is still elusive on what kinds of low- cost technologies are feasible within certain social and economic contexts. In other words, we need to answer the question of what would drive farmers already using grey water to apply even a simple practice or technical solution to reduce health risk, when they may not see this intervention as necessary. Much of the work associated with grey water treatment is site specific. This suggests that there is a potential for mitigation and some opportunities that planners and managers may be able to take advantage of to maximize the benefit and minimize the risks associated with grey water use. The consensus is clear that wastewater use under controlled conditions is now an accepted and responsible method of achieving water savings. The 2006 WHO Guidelines for the Safe Use of Wastewater, Excreta and Grey water (see section 3.4) clearly state that grey water contains nutrients and water, which make them valuable resources' (vol. 4: 8).

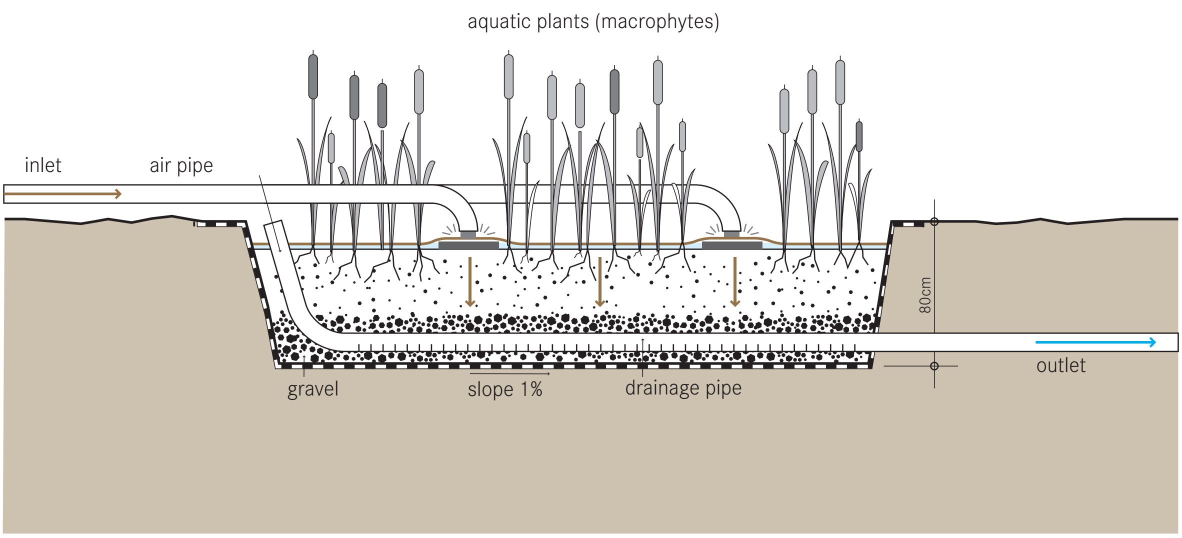
Methods to facilitate the reuse of grey water in oPt are the vertical flow constructed wetland (see section 9.6) and the anaerobic upflow filter (see section 9.7).

9.6. Vertical Flow Constructed Wetland



A Vertical Flow Constructed Wetland is a filter bed that is planted with aquatic plants. See Figure 9-4 and Figure 9-5. Wastewater is poured or dosed onto the wetland surface from above using a mechanical dosing system or a siphon (see Figure 9-6). The water flows vertically down through the filter matrix. The important difference between a vertical and horizontal wetland is not simply the direction of the flow path, but rather the aerobic conditions.

Figure 9-4: Vertical Flow Constructed Wetland (Tilley, 2008)



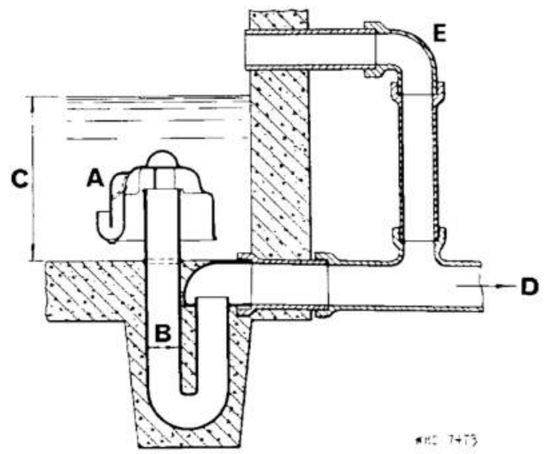
By dosing the wetland intermittently (four to ten times a day), the filter goes through stages of being saturated and unsaturated, and accordingly, different phases of aerobic and anaerobic conditions. The frequency of dosing should be timed such that the previous dose of wastewater has time to percolate through the filter bed so that oxygen has time to diffuse through the media and fill the void spaces. The Vertical Flow Constructed Wetland can be designed as a shallow excavation or as an above ground construction. Each filter should have an impermeable liner and an effluent collection system. Vertical Flow Constructed Wetlands are most commonly designed to treat wastewater that has undergone primary treatment.

Figure 9-5: Jericho Constructed Wetland (Wael, 2012)

Structurally, there is a layer of gravel for drainage (a minimum of 20 cm), followed by layers of either sand and gravel (for settled effluent) or sand and fine gravel (for raw wastewater). The filter media acts as both a filter for removing solids, a fixed surface upon which bacteria can attach and a base for the vegetation. The top layer is planted and the vegetation is allowed to develop deep, wide roots, which permeate the filter media. Depending on the climate, Phragmites australis, Typha cattails or Echinochloa Pyramidalis are common options. The vegetation transfers a small amount of oxygen to the root zone so that aerobic bacteria can colonize the area and degrade organics. However, the primary role of vegetation is to maintain permeability in the filter and provide habitat for microorganisms. During a flush phase, the wastewater percolates down through the unsaturated bed and is filtered by the sand/gravel matrix. Nutrients and organic material are absorbed and degraded by the dense microbial populations attached to the surface of the filter media and the roots. By forcing the organisms into a starvation phase between dosing phases, excessive biomass growth can be decreased and porosity increased. A drainage network at the base collects the effluent. The design and size of the wetland is dependent on hydraulic and organic loads. Pathogen removal is accomplished by natural decay, predation by higher organisms, and sedimentation.

Figure 9-6: Dosing Siphon (Kalbermatten, 1982)

FIG. 69. TYPICAL DOSING SIPHON



A = Miller siphon
B = Diameter of siphon, dependent upon population served
C = Maximum drawing depth of water in dosing chamber
D = Discharge to distribution box and absorption lines
E = Overflow pipe

Adequacy. Clogging is a common problem. Therefore, the influent should be well settled with primary treatment before flowing into the wetland. This technology is not appropriate for untreated domestic wastewater (i.e. black water). This is a good treatment for grey water to be used in agriculture. This is a good option where land is cheap and available, although the wetland will require maintenance for the duration of its life. There are many complex processes at work, and accordingly, there is a significant reduction in BOD, solids and pathogens. In many cases, the effluent will be adequate for discharge without further treatment. Because of the mechanical dosing system, this technology is most appropriate for communities with trained maintenance staff, constant power supply, and spare parts. Vertical Flow Constructed Wetlands are best suited to oPt.

Figure 9-7: Constructed wetland under construction

Health Aspects/Acceptance. The risk of mosquito breeding is low since there is no standing water. The system is generally aesthetic and can be integrated into wild areas or parklands. Care should be taken to ensure that people do not come in contact with the influent because of the risk of infection.

Maintenance. With time, the gravel will become clogged with accumulated solids and bacterial film. The material may have to be replaced every 8 to 15 or more years. Maintenance activities should focus on ensuring that primary treatment effectively lowers organics and solids concentrations before entering the wetland. Testing may be required to determine the suitability of locally available plants with the specific wastewater. The vertical system requires more maintenance and technical expertise than other wetland technologies.

Table 9-2: Vertical Flow Constructed Wetland at a glance

Working Principle	Pre-treated grey- or blackwater is applied intermittently to a planted filter surface, percolates through the unsaturated filter substrate where physical, biological and chemical processes purify the water. The treated wastewater is collected in a drainage network (adapted from MOREL and DIENER 2006).
Capacity/Adequacy	It can be applied for single households or small communities as a secondary or tertiary treatment facility of grey- or blackwater. Effluent can be reused for irrigation or is discharged into surface water (MOREL and DIENER 2006).
Performance	BOD = 75 to 90%; TSS = 65 to 85%; TN < 60%; TP < 35%; FC ≤ 2 to 3 log; MBAS ~ 90%; (adapted from: MOREL & DIENER 2006)
Costs	The capital costs of constructed wetlands are dependent on the costs of sand and gravel and also on the cost of land required for the CW. The operation and maintenance costs are very low (MOREL and DIENER 2006).
Self-help Compatibility	O&M by trained labourers, most of construction material locally available, except filter substrate could be a problem. Construction needs expert design. Electricity pumps may be necessary.
O&M	Emptying of pre-settled sludge, removal of unwanted vegetation, cleaning of inlet/outlet systems.
Reliability	Clogging of the filter bed is the main risk of this system, but treatment performance is satisfactory.
Main strength	Efficient removal of suspended and dissolved organic matter, nutrients and pathogens; no wastewater above ground level and therefore no odour nuisance; plants have a landscaping and ornamental purpose (MOREL and DIENER 2006).
Main weakness	Even distribution on a filter bed requires a well-functioning pressure distribution with pump or siphon. Uneven distribution causes clogging zones and plug flows with reduced treatment performance; high quality filter material is not always available and expensive; expertise required for design, construction and monitoring (MOREL and DIENER 2006).

Design. The approximate area of the wetland can be calculated as a function of the following equation:

- A = N * q * HRT /1000 / p / D

Where:
A = Wetland area (m^2);
N = Number of users (capita);
q = Amount of wastewater (lcd, litres / cap / day);
HRT = Hydraulic Retention Time (days);
p = pore space (%);
D = Effective depth (m').

The wetland area for a family of 8 persons (N=8), grey water disposal of 60 lcd (q = 60), a Hydraulic Retention Time of 1 day (HRT=1), a pore space of 40% (p=0.40) and an effective depth of 60 cm (D=0.6 m'):

- A = 8 * 60 * 1 / 1000 / 0.40 / 0.6 = 2 m^2.

Effluent quality:

- At a BOD grey water: 280 mgBOD/l
- Removal BOD: 90%
- BOD effluent: (100%-90%)*280 = 28 mg BOD/l
- E-coli in grey water: 10^5 / 100 ml
- Removal: 3 log units
- E-coli effluent: $10^{(5-3)} = 10^2$ / 100ml
- → Unrestricted irrigation (WHO, 2006)

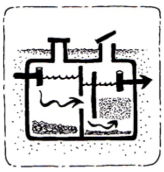
Table 9-3: Advantages and disadvantages Vertical Flow Constructed Wetland

Advantages	Disadvantages
• Utilisation of natural processes • No chemical & electrical energy required • Low operation and maintenance • Can be built and repaired with locally available materials • Does not have mosquito or odour nuisance problems since there is no surface water Less clogging than in a horizontal flow constructed wetland • High reduction in BOD, suspended solids and pathogens • Construction can provide short-term employment to local labourers	• Long start up time to work at full capacity • Requires large land area • Requires expert design and supervision • High quality filter material is not always available and expensive • Moderate capital cost depending on land, liner, fill, etc.; low operating costs • Pre-treatment is required to prevent clogging • Dosing system requires more complex engineering except when siphons are used

Further reading:

- Appendix 2-4: WASTE DST Treatment
- Appendix 3-11: SSWM Constructed Wetland

9.7. Anaerobic Upflow Filter and reuse



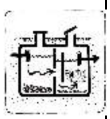
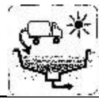

Given the relative strength of the grey water. An Anaerobic Upflow Filter is an appropriate system to treat the grey water. See section 8-6.

10. Neighborhood based (Urban Village) Sewerage and Sewage Management

10.1. Introduction

In section 4.2 we provided a technology selection menu. The menu of selected grey water management systems is presented in Figure 10-1.

Figure 10-1: Technology selection menu grey water management systems

	User interface	Emptying conditions	Soil conditions	Collection Storage / Local Treatment	Transport/ Conveyance	Treatment	Reuse/ Disposal
Combined water	Wet 	No desludging services	Piped Water supply 	None	Shallow Sewers 	AUF ABR-UASB-AS / CW 	Disposal
		Desludging services 	Piped water supply 	Septic Tank 	Small Bores Sewers / SBS 	   	Irrigation  

10.2. Neighborhood sewerage



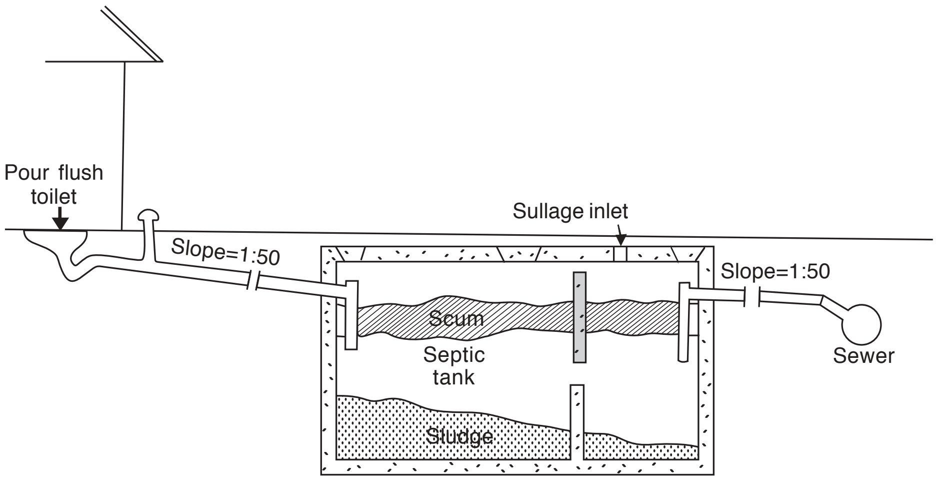
Sewerage is implemented for user convenience and can have environmental benefits if operated well on a municipal scale. However, a well-designed, well-operated on-site system can have more environmental benefits than a poorly managed sewerage system that discharges its effluent untreated into the wadis or sea. **Combined Conventional Gravity Sewers** are large networks of underground pipes that convey black water, grey water and stormwater from individual households to a centralized treatment facility using gravity (and pumps where necessary).

Separate Conventional Gravity Sewers are large networks of underground pipes that convey only black water and grey water. **Shallow Sewers** or Simplified Sewers describe a sewerage network that is constructed using smaller diameter pipes laid at a shallower depth and at a flatter gradient than conventional sewers. The Simplified Sewer allows for a more flexible design associated with lower costs and a higher number of connected households. See Figure 10-3.

A **Small Bore Sewer** is a network of small diameter pipes that transports solids-free or pre-treated wastewater (such as septic tank or settling tank effluent) to a treatment facility for further treatment or to a discharge point. Small Bore Sewers are also referred as settled, Solids-Free, small-diameter, variable grade gravity, or septic tank effluent gravity sewers. See Figure 10-2. A Small Bore Sewer is a good way to upgrade areas with septic tanks in future. Given the relative absence of septic tanks and given the topography both in Gaza and the West Bank, most sewers are already designed as shallow sewers. The design on shallow sewers is beyond the aim of this manual. Reference is made to two design manuals that are made available:

- Mara, Duncan (2001), Andrew Sleigh and Kevin Tayler: PC--based Simplified Sewer Design, School of Civil Engineering University of Leeds and GHK Research & Training, London;
- Bakalia, Alexander (1994), Albert Wright, Richard Otis and Jose de Azevedo Netto, Simplified Sewerage, Design Guidelines, UNDP/World Bank.

Figure 10-2: Small Bore Sewerage (Kalbermatten, 1982)



Source: After Kalbermatten et al. 1982.

Figure 10-3: Shallow Sewerage (SSWM, 2012)

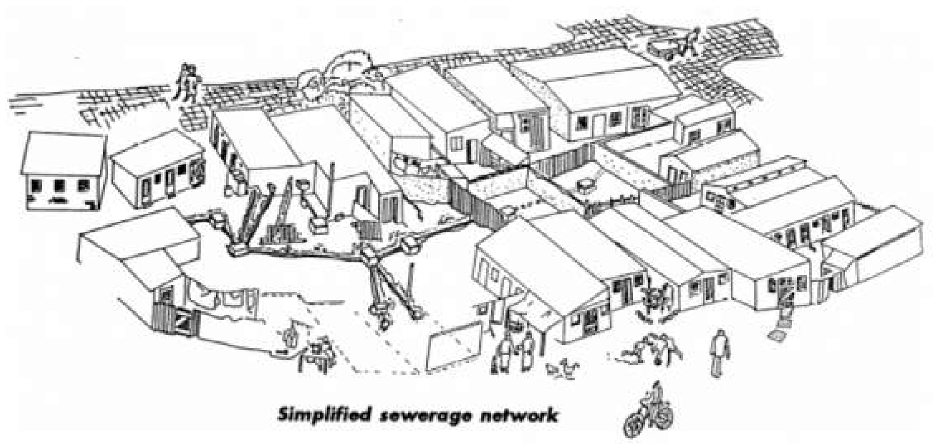


Table 10-1: Advantages and disadvantages Small Bore Sewerage

Advantages	Disadvantages
• Grey water can be managed at the same time • Can be built and repaired with locally available materials • Construction can provide short-term employment to local labourers • Capital costs are less than for conventional gravity sewers • Can be extended as a community changes and grows • Appropriate for densely populated areas with sensitive groundwater or no space for a soak pit or leaching field	• Requires repairs and removals of blockages more frequently than a conventional gravity sewer • Requires expert design and construction supervision • Requires education and acceptance to be used correctly • Effluent and sludge (from interceptors) requires secondary treatment and/or appropriate discharge • The interceptor tanks can overflow when they have not been desludged in time • The system can become blocked because of illegal connections that by-pass the interceptor tank • Small-bore sewerage systems are basically only suitable where there are interceptor tanks, septic tanks or other on-site pre-treatment systems • The need to desludge the interceptor tank regularly requires the involvement of a well-organized sewerage department

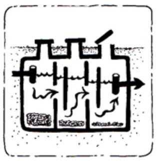
Table 10-2: Advantages and disadvantages Shallow Sewerage

Advantages	Disadvantages
• Can be built and repaired with locally available materials • Construction can provide short-term employment to local labourers • Capital costs are between 30% than conventional gravity sewers • Can be extended as a community changes and grows	• Requires enough water for flushing • Requires expert design and construction supervision • Requires repairs and removals of blockages more frequently than a conventional gravity sewer •

Further reading:

- Appendix 2-4: WASTE DST Treatment
- Appendix 3-12: SSWM Solid Free Sewers
- Appendix 3-13: SSWM Shallow Sewerage

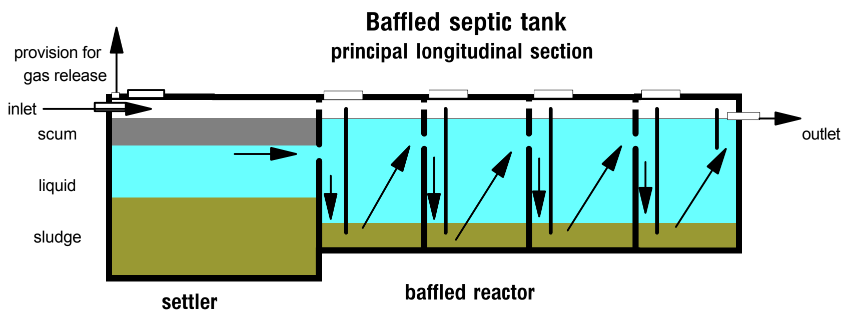
10.3. Neighborhood Sewage Treatment: Anaerobic Baffle Reactor



Given the relative strength of the wastewater in oPt, anaerobic treatment in an Anaerobic Baffle Reactor is the most appropriate treatment system. When it is followed by a Vertical Flow Constructed Wetland (See section 9.6 and see Figure 10-4) the effluent is fit for reuse in agriculture. 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. See Figure 10-5.

Figure 10-4: ABR and constructed wetland (http://farm6.static.flickr.com/5005/5268650406_6b710f8be8.jpg, accessed April 2012)

Figure 10-5: Anaerobic Baffle Reactor (Sasse, 1998)



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 up- flow 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).

Figure 10-6: ABR under construction (Spit, Surabaya, 2011)

Adequacy. This technology is easily adaptable and can be applied at the household level or for a small neighbourhood (see Figure 10-6). This technology is also appropriate for areas where land may be limited since the tank is installed underground and requires a small area. It should not be installed where there is a high groundwater table as infiltration will 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.

Table 10-3: ABR at a glance

Working Principle	Vertical baffles in the tank force the pre-settled wastewater to flow under and over the baffles guaranteeing contact between wastewater and resident sludge and allowing an enhanced anaerobic digestion of suspended and dissolved solids; at least 1 sedimentation chamber and 2-5 up-flow chambers.
Capacity/Adequacy	Community (and household) level; For pre-settled domestic or (high-strength) industrial wastewater of narrow COD/BOD ration. Typically integrated in DEWATS systems; Not adapted for areas with high ground-water table or prone to flooding.
Performance	70- 95% BOD; 80% - 90% TSS; Low pathogen reduction. HRT: 1 to 3 days
Costs	Generally low-cost; depending on availability of materials and economy of scale.
Self-help Compatibility	Requires expert design, but can be constructed with locally available material.
O&M	Should be checked for water tightness, scum and sludge levels regularly; Sludge needs to be dug out and discharged properly (e.g. in composting or drying bed); needs to be vented.
Reliability	High resistance to shock loading and changing temperature, pH or chemical composition of the influent; requires no energy.
Main strengths	Strong resistance; built from local material; biogas can be recovered.
Main weakness	Long start-up phase.

Table 10-4: Advantages and disadvantages ABR

Advantages	**Disadvantages**
• 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	• 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

Advantages	Disadvantages
• Biogas can be recovered, • Low HRT, long biomass retention time	

Further reading:

- Appendix 2-4: WASTE DST Treatment
- Appendix 3-14: SSWM ABR

Figure 10-7: Dimensions 25 m^3/day ABR (Sasse, 1998)

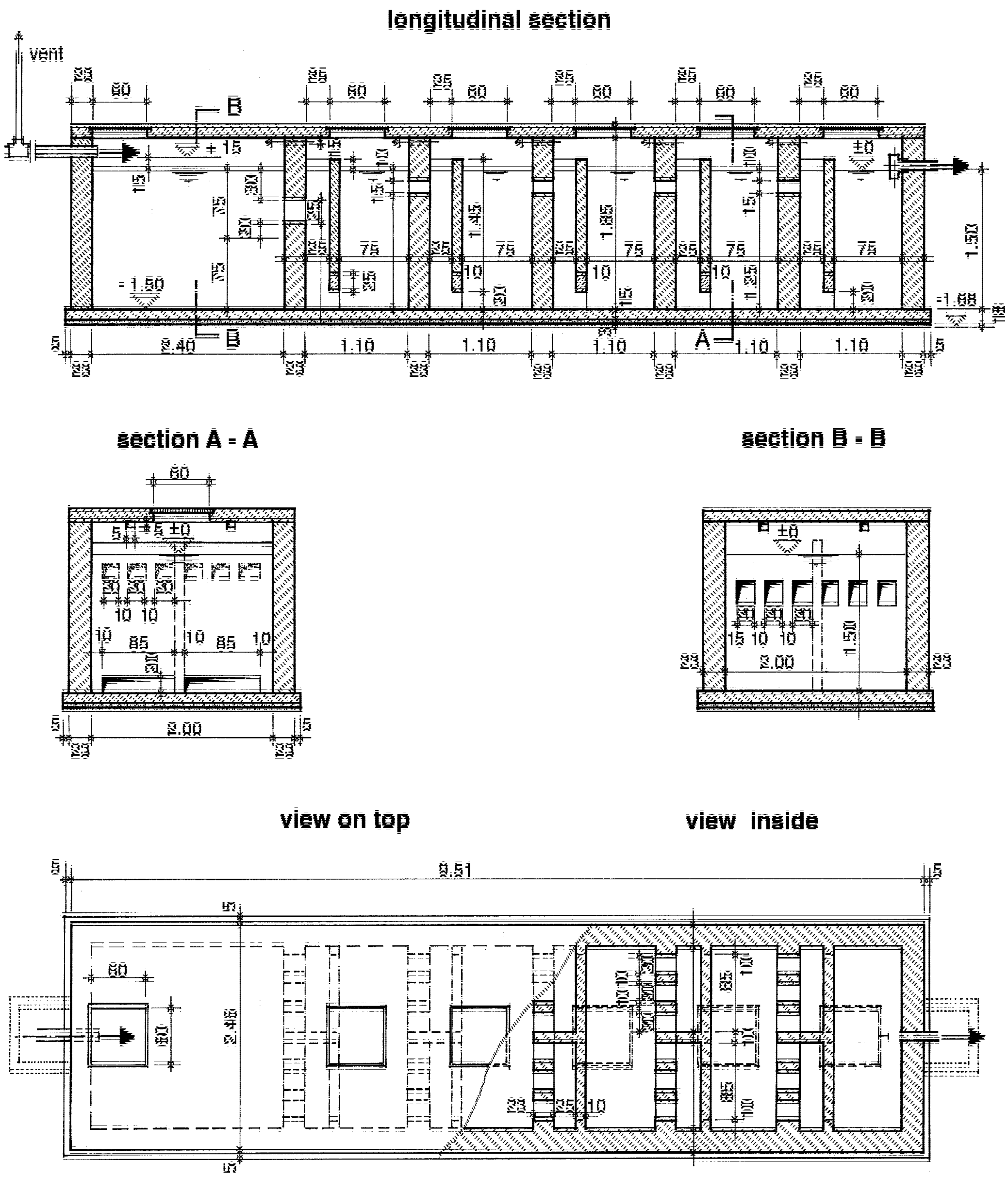


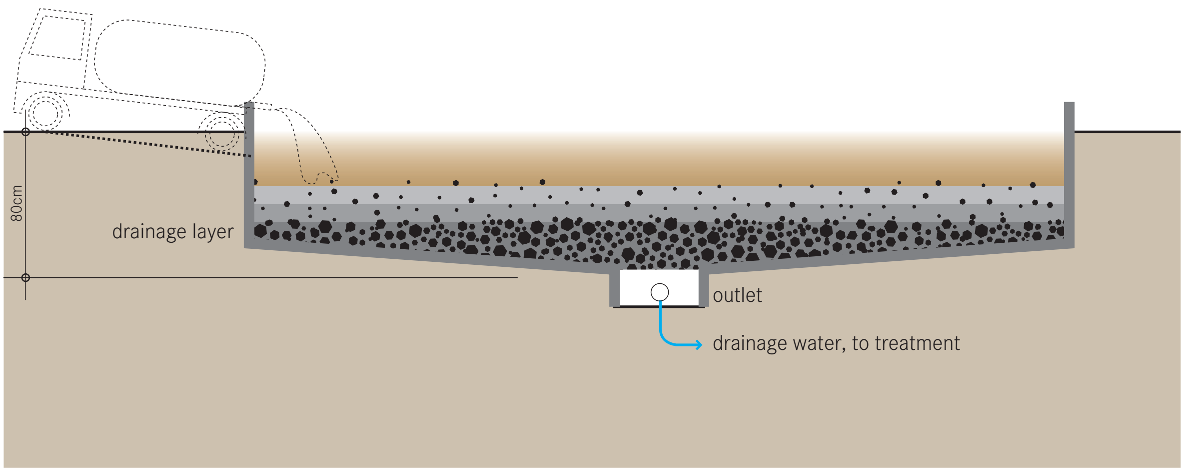
Figure 10-8: Spreadsheet 25 m^3/day ABR (Sasse, 1998)

	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*

11. Septage management: Sludge drying

Given the fact that at the moment sludge is disposed of often in an unregulated manner, a recommended short-term action is to dry it at sludge drying beds. An Unplanted Drying Bed is a simple, permeable bed that, when loaded with sludge, collects percolated leachate and allows the sludge to dry by evaporation. See Figure 11-1. Approximately 50 % to 80 % of the sludge volume drains off as liquid. The sludge however, is not stabilized or treated and should be stored for 2 years to assure die-off of pathogens (see section 4.3). Alternatively it could be transported to Sewage Treatment Plants.

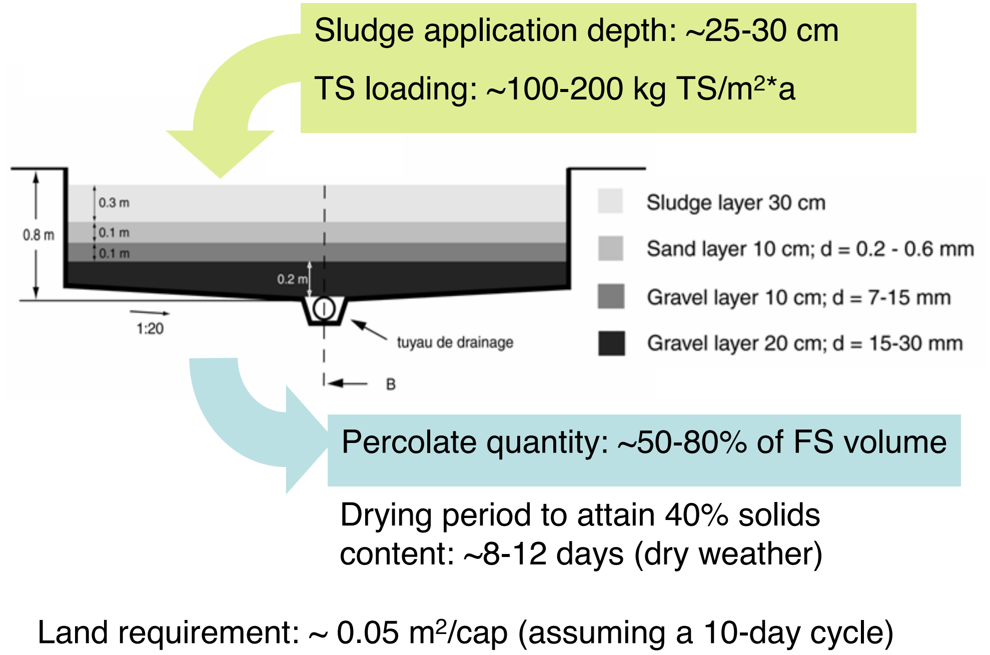
Figure 11-1: Sludge drying bed (Tilley, 2008)



The bottom of the drying bed is lined with perforated pipes that drain away the leachate. On top of the pipes are layers of sand and gravel that support the sludge and allow the liquid to infiltrate and collect in the pipe. The sludge should be loaded to approximately 200kg TS/m2 and it should not be applied in layers that are too thick (maximum 20cm), or the sludge will not dry effectively. The final moisture content after 10 to 15 days of drying should be approximately 60%. A splash plate should be used to prevent erosion of the sand layer and to allow the even distribution of the sludge. When the sludge is dried, it must be separated from the sand layer and disposed of. The effluent that is collected in the drainage pipes must also be treated properly. The top sand layer should be 25 to 30cm thick as some sand will be lost each time the sludge is manually removed.

Adequacy. Sludge drying is an effective way of decreasing the volume of sludge, which is especially important when it requires transportation elsewhere for direct use, Co-Composting, or disposal. The technology is not effective at stabilizing the organic fraction or decreasing the pathogenic content. Sludge drying beds are appropriate for small to medium communities with populations up to 100,000 people and there is inexpensive, available space that is far from homes and businesses. It is best suited to rural and peri- urban areas. If it is designed to service urban areas, it should be on the edge of the community. The sludge is not sanitised and requires further treatment before disposal. Ideally this technology should be coupled with a Co-Composting facility to generate a hygienic product. Trained staff for operation and maintenance is required to ensure proper functioning.

Figure 11-2: Main Features Sludge drying



Health Aspects/Acceptance The incoming sludge is pathogenic, so workers should be equipped with proper protection (boots, gloves, and clothing). The thickened sludge is also infectious, although it is easier to handle and less prone to splashing and spraying. The pond may cause a nuisance for nearby residents due to bad odours and the presence of flies. Therefore, the pond should be located sufficiently away from urban centres.

Maintenance The Unplanted Drying Bed should be designed with maintenance in mind; access for humans and trucks to pump in the sludge and remove the dried sludge should be taken into consideration.
Dried sludge must be removed every 10 to 15 days. The discharge area must be kept clean and the effluent drains should be flushed regularly. Sand must be replaced when the layer gets thin.

Table 11-1: Sludge drying at a glance

Working Principle	Drying beds are simple sealed shallow ponds filled with several drainage layers. Sludge is applied on the top and dried by percolation and evaporation. In planted drying beds, the plants maintain the porosity of the soil and enhance the evaporation by transpiration (evaporation). Dried sludge can be used as biosolid in agriculture.
Capacity/Adequacy	Requires large land-surfaces and can cause odour; therefore generally installed in rural areas.
Performance	Depends strongly on the local climate (rain, runoff); TS content of 20 to 70 % can be achieved. Some of NH4 is lost to air. Pathogen removal is moderate for unplanted beds with short retention time, but high for planted drying beds with long retention times.
Costs	Moderate investment costs and low operation costs
Self-help Compatibility	Can be produced with locally available material, but requires expert design. Operation is simple but staff/community should be trained.
O&M	Application of sludge, desludging, control of drainage system and of the secondary treatment for percolate or dried sludge. Desludging for unplanted beds every one to several weeks and every 5 to 10 years for planted drying beds.
Reliability	High, if the area is kept dry (rain, runoff).
Main strength	Low-tech and no requirement of energy.
Main weakness	Requires space; odour can occur; (and frequent desludging in the case of unplanted beds).

Table 11-2: Advantages and disadvantages Sludge Drying

Advantages	Disadvantages
• Dried sludge can be used as fertiliser (either directly in the case of planted beds or after composting in the case of unplanted beds) • Easy to operate (no experts, but trained community required) • High reduction of sludge volume • Can achieve pathogen removal • Can be built with locally available materials	• Requires large land area • Requires treatment of percolate • Only applicable during dry seasons or needs a roof and contour bund • Manual labour or specialised equipment is required to remove dried sludge from beds • Can cause odour problems

Further reading:

- Appendix 2-5: WASTE DST Treatment
- Appendix 3-15: SSWM Sludge drying

References

BAKALIA, ALEXANDER (1994), Albert Wright, Richard Otis and Jose de Azevedo Netto, Simplified Sewerage, Design Guidelines, UNDP/World Bank

BURNAT, JAMAL (2010): The Practical Manual For Installation of the Household Grey Wastewater Treatment System, FAO – Project No:- OSRO/GAZ/909/SPA

EAWAG (2005): Household-Centred Environmental Sanitation, Implementing the Bellagio Principles in Urban Environmental Sanitation, Provisional Guideline for Decision-Makers, Eawag: Swiss Federal Institute of Aquatic Science and Technology.

HEYNES, FRANS (1985): Twin Leaching Pits Toilets, Design and Construction Manual, Puslitbang Pemukiman, UNDP Low Cost Sanitation Investment Project INS/81/002, Bandung, Indonesia.

GET and IDE (2010): Easy Latrine Shelter Handbook, Cambodia.

KALBERMATTEN JOHN M, DEANNE S. JULIUS, CHARLES G. GUNNERSON (1982): Appropriate Sanitation Alternatives, A Technical and Economic Appraisal, World Bank.

KALBERMATTEN, JOHN M., DEANNE S. JULIUS, CHARLES G. GUNNERSON, AND D. DUNCAN MARA (1982): Appropriate Sanitation Alternatives, A Planning and Design Manual, World Bank.

KEARSLEY, EP (2011): Lightweight moveable superstructures for VIP toilets, Water Research Commission, South Africa.

MARA, DUNCAN (1976): Sewage treatment in hot climates, John Wiley & Sons, Chichester.

MARA, DUNCAN (2001), Andrew Sleigh and Kevin Tayler: PC--based Simplified Sewer Design *School of Civil Engineering University of Leeds* and *GHK Research & Training*, London

MCLLWAINE STEPHEN (2010) AND MARK REDWOOD, Grey water Use in the Middle East Technical, Social, Economic and Policy Issues

MOGHEIR (2004), Treated Wastewater Reuse in Palestine

NAZZAL, YASSER, MOHAMMED MANSOUR, MOHAMMAD AL NAJJAR AND PETER MCCORNICK (2010): Wastewater Reuse Law And Standards In The Kingdom Of Jordan, The Ministry of water and irrigation Amman, Jordan

SASSE, LUDWIG (1998): DEWATS Decentralized Wastewater Treatment in Developing Countries, Borda.

TILLEY, E.; LUETHY, C.; MOREL, A.; ZURBRUEGG, C.; SCHERTENLEIB, R. (2008): Compendium of Sanitation Systems and Technologies. Duebendorf and Geneva: Swiss Federal Institute of Aquatic Science and Technology (EAWAG).

TILLEY, ELIZABETH AND SYLVIE PETERS (2008): Sandec Training Tool: Module 4 Sandec: Department of Water and Sanitation in Developing Countries, Sanitation Systems & Technologies EAWAG.

UDERT, KAI AND TILLEY, ELIZABETH (2008), Sanitation systems and technologies for developing countries, EAWAG, 2010

UNICEF (2010): Core Commitments for Children in Humanitarian Action, www.unicef.org, accessed April 2012

WASTE (2006): Smart Sanitation Solutions, NWP, The Hague, The Netherlands

WHO (2006): Guidelines for the safe use of wastewater, excreta and grey water

WSP (2007): Philippines Sanitation Sourcebook and Decision Aid

ZIMMO, OMAR (2005), Prospects of Efficient Wastewater Management and Water Reuse in Palestine, EM Water Project

Appendices (see separate documents)

Appendix 1-1: Terms of Reference

Appendix 1-2: Cambodia Case studies

Appendix 2-1: Waste Decision Support Tool (DST) User Interface

Appendix 2-2: Waste DST Collection Storage and Treatment

Appendix 2-3: Waste DST Conveyance

Appendix 2-4: Waste DST Treatment

Appendix 2-5: Waste DST Reuse and Disposal

Appendix 3-1: SSWM Arborloo

Appendix 3-2: SSWM Fossa Alterna

Appendix 3-3: SSWM UDDT

Appendix 3-4: SSWM Compost Filters

Appendix 3-5: SSWM Terra Preta Sanitation

Appendix 3-6: SSWM Twin Leaching Pits

Appendix 3-7: SSWM Septic Tank

Appendix 3-8: SSWM Leach Field

Appendix 3-9: SSWM Anaerobic Filter

Appendix 3-10: SSWM Evaporation Field

Appendix 3-11: SSWM Constructed Wetland

Appendix 3-12: SSWM Solid Free Sewers

Appendix 3-13: SSWM Simplified Sewerage

Appendix 3-14: SSWM ABR