### Technical/Environmental Factors

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### Option-Specific

- **Capital costs**
  - a) Requires a considerable space available for construction
- **System robustness**
  - b) Requires access for emptying sludge
  - c) Difficulties for excavation. Special attention to the costs. Not recommended
- **Ease of construction**
  - d) Depending on the size of the tank, space availability could be a problem
  - e) Ensure sealing of the tank. Risk of water infiltration and overflow as well as leaking and groundwater pollution
- **Pathogens removal**
- **BOD**
- **TSS**
- **Energy input**
Description: An Anaerobic Baffled Reactor (ABR) is an improved septic tank because of the series of baffles over which the incoming wastewater is forced to flow. The increased contact time with the active biomass (sludge) results in improved treatment.

The majority of settleable solids are removed in the sedimentation chamber at the beginning of the ABR, which typically represents 50% of the total volume. The 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 0.6m/h and the number of up-flow chambers (2 to 3).

Adequacy: This technology is easily adaptable and can be applied at the household level or for a small neighbourhood (refer to Technology Information Sheet S10: Anaerobic Baffled Reactor for information about applying an ABR at the household level).

A (semi-) centralized ABR is appropriate when there is an already existing Conveyance technology, such as a Solids-Free Sewer (C5). 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.

This technology can be efficiently designed for a daily inflow of up 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.

Because the ABR must be emptied regularly, a vacuum truck should be able to access the location. ABRs can be installed in every type of climate although the efficiency will be affected in colder climates.

Advantages:
1. Resistant to organic and hydraulic shock loads
2. No electrical energy required
3. Greywater can be managed concurrently
4. Can be built and repaired with locally available materials
5. Long service life
6. No real problems with flies or odours if used correctly
7. High reduction of organics
8. Moderate capital costs, moderate operating costs depending on emptying; can be low cost depending on number of users

Disadvantages:
1. Requires constant source of water
2. Effluent requires secondary treatment and/or appropriate discharge
3. Low reduction pathogens
4. Requires expert design and construction
5. Pre-treatment is required to prevent clogging

Pre-treatment is required to prevent clogging

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 wastewater 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 annually using a vacuum truck to ensure proper functioning of the ABR.

Costs: the costs will be dealt with in future updates

References:
## T.2 ANAEROBIC FILTER

### (Semi-) Centralized Treatment

#### Technical/Environmental Factors

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#### Site-Specific

- **NOTES:**
  - a) Requires a considerable space available for construction
  - b) Requires access for emptying sludge
  - c) Difficulties for excavation. Special attention to the costs. Not recommended
  - d) Depending on the size of the tank, space availability could be a problem
  - e) Ensure sealing of the tank. Risk of water infiltration and overflow as well as leaking and groundwater pollution

#### Option-Specific

- **Inputs:**
  - Blackwater

- **Outputs:**
  - Effluent
  - Sludge

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**WASTE**

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**Description:** An Anaerobic Filter is a fixed-bed biological reactor. As wastewater flows through the filter, particles are trapped and organic matter is degraded by the biomass that is attached to the filter material.

This technology consists of a sedimentation tank or septic tank (refer to Technology Information Sheet S9: Septic Tank) followed by one to three filter chambers. Filter material commonly used includes gravel, crushed rocks, cinder, or specially formed plastic pieces. Typical filter material sizes range from 12 to 55mm in diameter. Ideally, the material will provide between 90 to 300m² of surface area per 1m³ of reactor volume. By providing a large surface area for the bacterial mass, there is increased contact between the organic matter and the active biomass that effectively degrades it.

The Anaerobic Filter can be operated in either upflow or downflow mode. The upflow mode is recommended because there is less risk that the fixed biomass will be washed out. The water level should cover the filter media by at least 0.3m to guarantee an even flow regime. Pre-treatment is essential to remove settleable solids and garbage which may clog the filter. Studies have shown that the HRT is the most important design parameter influencing filter performance. An HRT of 0.5 to 1.5 days is a typical and recommended. A maximum surface-loading (i.e. flow per area) rate of 2.8m³/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 (refer to Technology Information Sheet S11: Anaerobic Filter for information about applying an Anaerobic Filter at the household level). 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 system is immediate. Once working at full capacity it is a stable technology that requires little attention. The Anaerobic Filter should be watertight but it should still not be constructed in areas with high groundwater tables or where there is frequent flooding.

**Advantages:**
1. Resistant to organic and hydraulic shock loads
2. No electrical energy required
3. Can be built and repaired with locally available materials
4. Long service life
5. No real problems with flies or odours if used correctly
6. Moderate capital costs, moderate operating costs depending on emptying; can be lowered depending on the number of users
7. High reduction of BOD and solids

**Disadvantages:**
1. Requires constant source of water
2. Effluent requires secondary treatment and/or appropriate discharge
3. Low reduction pathogens and nutrients
4. Requires expert design and construction
5. Long start up time

**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.

**Costs:** the costs will be dealt with in future updates

**Health Aspects/Acceptance:** Because the Anaerobic Filter is underground, users should 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.

To prevent the release of potentially harmful gases, the Anaerobic Filters should be vented. The desludging of the filter is hazardous and appropriate safety precautions should be taken.

**Technical drawing of a filter**

**References:**
- Sandec/Eawag (2008). *Compendium of Sanitation Systems and Technologies*
### Technical/Environmental Factors

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### Option-Specific

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### NOTES:

- a) Requires a large space available for construction
- b) High risk of leakage pollution and overflow
- c) Requires large land relatively flat
- d) Requires access for desludging
- e) Difficulties for excavation. Special attention to the costs. Not recommended
- f) Depending on the size of the ponds, space availability could be a problem
- g) Ensure lining of the ponds. Risk of water infiltration and overflow as well as leaking and groundwater pollution
Description: Waste Stabilization Ponds (WSPs) are large, manmade water bodies. The ponds are filled with wastewater that is then treated by naturally occurring processes. The ponds can be used individually, or linked in a series for improved treatment. There are three types of ponds, (1) anaerobic, (2) facultative and (3) aerobic (maturation), each with different treatment and design characteristics. For the most effective treatment, WSPs should be linked in a series of three of more with effluent being transferred from the anaerobic pond to the facultative pond and finally the aerobic pond. The anaerobic pond reduces solids and BOD as a pre-treatment stage. The pond is a fairly deep man-made lake where the entire depth of the pond is anaerobic. Anaerobic ponds are built to a depth of 2 to 5m and have a relatively short detention time of 1 to 7 days. The actual design will depend on the wastewater characteristics and the loading; a comprehensive design manual should be consulted for all types of WSPs. Anaerobic bacteria convert organic carbon into methane and in the process, remove up to 60% of the BOD. Anaerobic ponds are capable of treating strong wastewaters. In a series of WSPs the effluent from the anaerobic pond is transferred to the facultative pond, where further BOD is removed. A facultative pond is shallower than an anaerobic pond and both aerobic and anaerobic processes occur within the pond. The top layer of the pond receives oxygen from natural diffusion, wind mixing and algaedriven photosynthesis. The lower layer is deprived of oxygen and becomes anoxic or anaerobic. Settleable solids accumulate and are digested on the bottom of the pond. The aerobic and anaerobic organisms work together to achieve BOD reductions of up to 75%. The pond should be constructed to a depth of 1 to 2.5m and have a detention time between 5 to 30 days. Following the anaerobic and the facultative ponds can be any number of aerobic (maturation) ponds to achieve a highly polished effluent. An aerobic pond is commonly referred to as a maturation, polishing, or finishing pond because it is usually the last step in a series of ponds and provides the final level of treatment. It is the shallowest of the ponds, usually constructed to a depth between 0.5 to 1.5m deep to ensure that the sunlight penetrates the full depth for photosynthesis. Because photosynthesis is driven by sunlight, the dissolved oxygen levels are highest during the day and drop off at night. Whereas anaerobic and facultative ponds are designed for BOD removal, maturation ponds are designed for pathogen removal. Dissolved oxygen in the lake is provided by natural wind mixing and by photosynthetic algae that release oxygen into the water. If used in combination with algae and/or fish harvesting, this type of pond is effective at removing the majority of nitrogen and phosphorus from the effluent.

Advantages:
1. High reduction in pathogens
2. Can be built and repaired with locally available materials
3. Construction can provide short-term employment to local labourers
4. Low operating cost
5. No electrical energy required
6. No real problems with flies or odours if designed correctly

Disadvantages:
1. Requires expert design and supervision
2. Variable capital cost depending on the price of land
3. Requires large land area
4. Effluent/sludge requires secondary treatment and/or appropriate discharge

To prevent leaching, the ponds should have a liner. The liner can be clay, asphalt, compacted earth, or another impervious material. To protect the pond from runoff and erosion, a protective berm should be constructed around the pond using the excavated material.

Adequacy: WSPs are among the most common and efficient methods of wastewater treatment around the world. They are especially appropriate for rural communities that have large, open unused lands, away from homes and public spaces. They are not appropriate for very dense or urban areas. WSPs work in most climates, but are most efficient in warm, sunny climates. In the case of cold climates, the retention times and loading rates can be adjusted so that efficient treatment can be achieved.

Health Aspects/Acceptance: Although effluent from aerobic ponds is generally low in pathogens, the ponds should in no way be used for recreation or as a direct source of water for consumption or domestic use.

Upgrading: Ideally, several aerobic ponds can be built in series to provide a high level of pathogen removal. A final aquaculture pond can be used to generate income and supply a locally grown food source.

Maintenance: To prevent scum formation, excess solids and garbage from entering the ponds, pre-treatment (with grease traps) is essential to maintain the ponds. The pond must be desludged every 10 to 20 years. A fence should be installed to ensure that people and animals stay out of the area and excess garbage does not enter the ponds. Rodents may invade the berm and cause damage to the liner. Raising the water level should prompt rodents to evacuate the berm. Care should be taken to ensure that plant material does not fall into the ponds. Vegetation or macrophytes that are present in the pond should be removed as it may provide a breeding habitat for mosquitoes and prevent light from penetrating the water column.

Costs: the costs will be dealt with in future updates

References:
## T.4 AERATED POND

*(Semi-) Centralized Treatment*

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### Site-Specific

10 Space requirement
11 Capital costs
12 O&M costs
13 System robustness
14 System upgradability
15 Ease of construction
16 Ease of operation
17 Reuseability of products
18 Health implications
19 Treatment efficiency
  19.1 Pathogens removal
  19.2 BOD
  19.3 TSS
20 Energy input

### Option-Specific

**NOTES:**

- a) Requires a large space available for construction
- b) High risk of leakage pollution and overflow
- c) Requires large land relatively flat
- d) Requires access for desludging
- e) Difficulties for excavation. Special attention to the costs. Not recommended
- f) Depending on the size of the pond, space availability could be a problem
- g) Ensure lining of the ponds. Risk of water infiltration and overflow as well as leaking and groundwater pollution

**- Sanitation -**

- **Decision Support Tool**

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Description: An Aerated Pond is a large, outdoor, mixed aerobic reactor. Mechanical aerators provide oxygen and keep the aerobic organisms suspended and mixed with the water to achieve a high rate of organic degradation and nutrient removal.

Increased mixing and aeration from the mechanical units means that the ponds can be deeper and can tolerate much higher organic loads than a maturation pond. The increased aeration allows for increased degradation and increased pathogen removal. As well, because oxygen is introduced by the mechanical units and not by light-driven photosynthesis, the ponds can function in more northern climates. Influent should be screened and pre-treated to remove garbage and coarse particles that could interfere with the aerators. Because the aeration units mix the pond, a subsequent settling tank is required to separate the effluent from the solids.

The smaller area requirement (compared to a maturation pond) means that it is appropriate for both rural, and peri-urban environments. The pond should be built to a depth of 2 to 5m and should have a detention time of 3 to 20 days. To prevent leaching, the pond should have a liner. The liner can be clay, asphalt, compacted earth, or another impervious material. Using the fill that is excavated, a protective berm should be built around the pond to protect it from runoff and erosion.

Adequacy: A mechanically aerated pond can efficiently handle high concentration influent and can reduce pathogen levels significantly. It is especially important that electricity service is uninterrupted and that replacement parts are available to prevent extended downtimes that may cause the pond to turn anaerobic.

Aerated lagoons can function in a larger range of climates than WSPs. They are most appropriate for regions with large areas of inexpensive lands that are away from homes and businesses.

Advantages:
1. Good resistance against shock loading
2. High reduction in pathogens
3. Construction can provide short-term employment to local labourers
4. Requires large land area
5. No real problems with insects or odours if designed correctly

Disadvantages:
1. Effluent/sludge requires secondary treatment and/or appropriate discharge
2. Requires expert design and construction supervision
3. Requires full time operation and maintenance by skilled personnel
4. Not all parts and materials may be available locally
5. Constant source of electricity is required
6. Moderate-high capital and variable operating costs depending on the price of land, electricity

Health Aspects/Acceptance: The pond is a large expanse of pathogenic wastewater; care must be taken to ensure that no one comes in contact with, or goes into the water.

The aeration units can be dangerous to humans and animals. Fences, signage, or other measures should be taken to prevent entry to the area.

Maintenance: A permanent skilled staff is required to repair and maintain aeration machinery. The pond must be desludged once every 2 to 5 years.

Care should be taken to ensure that the pond is not used as a garbage dump, especially considering the damage that could be done to the aeration equipment.

Costs: the costs will be dealt with in future updates

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### Option-Specific

- **Space requirement**
  - **NOTES:**
    - a) Requires a large space available for construction
    - b) High risk of leakage pollution and overflow
    - c) Requires large land relatively flat
    - d) Requires access for O&M
    - e) Difficulties for excavation. Special attention to the costs. Not recommended

- **O&M costs**
- **System robustness**
- **System upgradability**
- **Ease of construction**
- **Ease of operation**
- **Reusability of products**
- **Health implications**
- **Treatment efficiency**
- **Pathogens removal**
- **BOD**
- **TSS**
- **Energy input**

- **NOTES:**
  - f) Depending on the size of the wetlands, space availability could be a problem
  - g) Ensure lining of the wetlands. Risk of water infiltration and overflow as well as leaking and groundwater pollution
Description: A Free-Water Surface Constructed Wetland is a series of flooded channels that aims to replicate the naturally occurring processes of a natural wetland, marsh or swamp. As water slowly flows through the wetland, particles settle, pathogens are destroyed, and organisms and plants utilize the nutrients.

Unlike The Horizontal Subsurface Flow Constructed Wetland (T6), the Free-Water Surface Constructed Wetland allows water to flow above ground, exposed to the atmosphere and direct sunlight. The channel or basin is lined with an impermeable barrier (clay or geotextile) covered with rocks, gravel and soil and planted with native vegetation (e.g. cattails, reeds and/or rushes).

The wetland is flooded with wastewater to a depth of 10 to 45cm above ground level. As the water slowly flows through the wetland, simultaneous physical, chemical and biological processes filter solids, degrade organics and remove nutrients from the wastewater. Raw blackwater should be pretreated to prevent the excess accumulation of solids and garbage. Once in the pond, the heavier sediment particles settle out, also removing nutrients that are attached to particles.

Plants, and the communities of microorganisms that they support (on the stems and roots), take up nutrients like nitrogen and phosphorus. Chemical reactions may cause other elements to precipitate out of the wastewater. Pathogens are removed from the water by natural decay, predation from higher organisms, sedimentation and UV irradiation. Although the soil layer below the water is anaerobic, the plant roots exude (release) oxygen into the area immediately surrounding the root hairs, thus creating an environment for complex biological and chemical activity.

The efficiency of the Free-Water Surface Constructed Wetland also depends on how well the water is distributed at the inlet. Wastewater can be input to the wetland using weirs or by drilling holes in a distribution pipe to allow it to enter in even spaced intervals.

Adequacy: Free-Water Surface Constructed Wetlands can achieve high removals of suspended solids and moderate removal of pathogens, nutrients and other pollutants such as heavy metals. Shade from plants and protection from wind mixing limit the dissolved oxygen in the water, therefore, this technology is only appropriate for low strength wastewater. Usually this requires that Free-Water Surface Constructed Wetlands are only appropriate when they follow some type of primary treatment to lower the BOD.

Depending on the volume of water, and therefore the size, wetlands can be appropriate for small sections of urban areas or more appropriate for peri-urban and rural communities. This is a good treatment technology for communities that have a primary treatment facility (e.g. Septic Tanks (S9)). Where land is cheap and available, it is a good option as long as the community is organized enough to thoroughly plan and maintain the wetland for the duration of its life.

This technology is best suited to warm climates but can be designed to tolerate some freezing and periods of low biological activity.

Health Aspects/Acceptance: The open surface can act as a potential breeding ground for mosquitoes. However, good design and maintenance can prevent this. The Free-Water Surface Constructed Wetlands are generally aesthetically pleasing, especially when they are integrated into pre-existing natural areas. Care should be taken to prevent people from coming in contact with the effluent because of the potential for disease transmission and the risk of drowning in deeper waters.

Maintenance: Regular maintenance should ensure that water is not short-circuiting, or backing up because of fallen branches, garbage, or beaver dams blocking the wetland outlet. Vegetation may have to be cut back or thinned out periodically.

Advantages:
1. Aesthetically pleasing and provides animal habitat
2. High reduction in BOD and solids; moderate pathogen removal
3. Can be built and repaired with locally available materials
4. Construction can provide short-term employment to local labourers
5. No electrical energy required
6. No real problems with flies or odours if used correctly

Disadvantages:
1. May facilitate mosquito breeding
2. Long start up time to work at full capacity
3. Requires large land area
4. Requires expert design and supervision
5. Moderate capital cost depending on land, liner, etc.; low operating costs

Costs: the costs will be dealt with in future updates

References:

www.waste.nl
www.akvo.org
## Technical/Environmental Factors

<table>
<thead>
<tr>
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<th>Space availability</th>
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### Site-Specific Factors

- Requires a large space available for construction
- High risk of leakage pollution and overflow
- Requires large land relatively flat
- Requires access for O&M
- Difficulties for excavation. Special attention to the costs. Not recommended
- Depending on the size of the wetlands, space availability could be a problem
- Ensure lining of the wetlands. Risk of water infiltration and overflow as well as leaking and groundwater pollution

### Option-Specific Factors

- Sanitation - Decision Support Tool

www.waste.nl
www.akvo.org
**Description:** A Horizontal Subsurface Flow Constructed Wetland is a large gravel and sand-filled channel that is planted with aquatic vegetation. As wastewater flows horizontally through the channel, the filter material filters out particles and microorganisms degrade organics.

The water level in a Horizontal Subsurface Flow Constructed Wetland is maintained at 5 to 15 cm below the surface to ensure subsurface flow. The bed should be wide and shallow so that the flow path of the water is maximized. A wide inlet zone should be used to evenly distribute the flow. Pre-treatment is essential to prevent clogging and ensure efficient treatment.

The bed should be lined with an impermeable liner (clay or geotextile) to prevent leaching. Small, round, evenly sized gravel (3–32 mm in diameter) is most commonly used to fill the bed to a depth of 0.5 to 1 m. To limit clogging, the gravel should be clean and free of fines. Sand is also acceptable, but is more prone to clogging. In recent years, alternative filter materials such as PET have been successfully used.

The removal efficiency of the wetland is a function of the surface area (length multiplied by width), while the cross-sectional area (width multiplied by depth) determines the maximum possible flow. A well-designed inlet that allows for even distribution is important to prevent short-circuiting. The outlet should be variable so that the water surface can be adjusted to optimize treatment performance.

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. Although facultative and anaerobic bacteria degrade most organics, the vegetation transfers a small amount of oxygen to the root zone so that aerobic bacteria can colonize the area and degrade organics as well. The plant roots play an important role in maintaining the permeability of the filter.

**Adequacy:** Clogging is a common problem and therefore the influent should be well settled with primary treatment before flowing into the wetland.

**Advantages:**
1. Requires less space than a Free-Water Surface Constructed Wetland
2. High reduction in BOD, suspended solids and pathogens
3. Does not have the mosquito problems of the Free-Water Surface Constructed Wetland (T5)
4. Can be built and repaired with locally available materials
5. Construction can provide short-term employment to local labourers
6. No electrical energy required

**Disadvantages:**
1. Requires expert design and supervision
2. Moderate capital cost depending on land, liner, fill, etc.; low operating costs
3. Pre-treatment is required to prevent clogging

**Health Aspects/Acceptance:** The risk of mosquito breeding is reduced since there is no standing water compared to the risk associated with Free-Water Surface Constructed Wetlands (T5). The wetland is aesthetically pleasing and can be integrated into wild areas or parklands.

**Maintenance:** With time, the gravel will clog with accumulated solids and bacterial film. The filter material will require replacement every 8 to 15 or more years. Maintenance activities should focus on ensuring that primary treatment is effective at reducing the concentration of solids in the wastewater before it enters the wetland. Maintenance should also ensure that trees do not grow in the area as the roots can harm the liner.

**Costs:** The costs will be dealt with in future updates

**References:**
- Sandec/Eawag (2008). *Compendium of Sanitation Systems and Technologies*
## Technical/Environmental Factors

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### Site-Specific

- **Water supply**: none
- **Space availability**: large
- **Flood prone**: not affected
- **Groundwater table**: < 2 m.
- **Terrain/Topography/Slope**: flat
- **Vehicular accessibility**: no access
- **Soil type**: clayey
- **Roads/paths system**: irregular/unplanned
- **Anal cleansing method**: water

### Option-Specific

- **Space requirement**: NOTES:
  - Requires a large space available for construction
  - High risk of leakage pollution and overflow
  - Requires large land relatively flat
  - Requires access for O&M
  - Difficulties for excavation. Special attention to the costs. Not recommended
- **Treatment efficiency**: NOTES:
  - Depending on the size of the wetlands, space availability could be a problem
  - Ensure lining of the wetlands. Risk of water infiltration and overflow as well as leakage and groundwater pollution

### NOTES:

- **Stop: Not Applicable**
- **Go: Applicable**
- **Caution: Applicable with corrective measures**
- **Not a factor to consider**
Description: A Vertical Flow Constructed Wetland is a filter bed that is planted with aquatic plants. Wastewater is poured or dosed onto the wetland surface from above using a mechanical dosing system. 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. 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. Structurally, there is a layer of gravel for drainage (a minimum of 20cm), 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 Echinocloa 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 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.

Advantages:
1. Does not have the mosquito problems of the Free-Water Surface Constructed Wetland
2. Less clogging than in a Horizontal Flow Constructed Wetland
3. Requires less space than a Free-Water Surface Constructed Wetland
4. High reduction in BOD, suspended solids and pathogens
5. Construction can provide short-term employment to local labourers
6. Constant source of electrical energy required

Disadvantages:
1. Not all parts and materials may be available locally
2. Requires expert design and supervision
3. Moderate capital cost depending on land, liner, fill, etc.; low operating costs
4. Pre-treatment is required to prevent clogging
5. Dosing system requires more complex engineering

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. blackwater). This is a good treatment for communities that have primary treatment (e.g. Septic Tanks (S9) or WSPs (T3)) but are looking to achieve a higher quality effluent. 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 warm climates but can be designed to tolerate some freezing and periods of low biological activity.

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.

Costs: the costs will be dealt with in future updates

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**NOTES:**

a) Requires a relatively small space available for construction

b) Requires access for desludging

g) Depending on the size of the filter, space availability could be a problem
Description: A Trickling Filter is a fixed bed, biological filter that operates under (mostly) aerobic conditions. Pre-settled wastewater is ‘trickled’ or sprayed over the filter. As the water migrates through the pores of the filter, organics are degraded by the biomass covering the filter material. The Trickling Filter is filled with a high specific surface area material such as rocks, gravel, shredded PVC bottles, or special pre-formed filter material. A material with a specific surface area between 30 and 900m²/m³ is desirable. Pre-treatment is essential to prevent clogging and to ensure efficient treatment. The pre-treated wastewater is ‘trickled’ over the surface of the filter.

Organisms that grow in a thin biofilm over the surface of the media oxidize the organic load in the wastewater to carbon dioxide and water while generating new biomass. The incoming wastewater is sprayed over the filter with the use of a rotating sprinkler. In this way, the filter media goes through cycles of being dosed and exposed to air. However, oxygen is depleted within the biomass and the inner layers may be anoxic or anaerobic. The filter is usually 1 to 3m deep but filters packed with lighter plastic filling can be up to 12m deep. The ideal filter material has a high surface to volume ratio, is light, durable and allows air to circulate. Whenever it is available, crushed rock or gravel is the cheapest option. The particles should be uniform such that 95% of the particles have a diameter between 7 and 10cm. Both ends of the filter are ventilated to allow oxygen to travel the length of the filter. A perforated slab that allows the effluent and excess sludge to be collected supports the bottom of the filter.

With time, the biomass will grow thick and the attached layer will be deprived of oxygen; it will enter an endogenous state, will lose its ability to stay attached and will slough off. High-rate loading conditions will also cause sloughing. The collected effluent should be clarified in a settling tank to remove any biomass that may have dislodged from the filter. The hydraulic and nutrient loading rate (i.e. how much wastewater can be applied to the filter) is determined based on the characteristics of the wastewater, the type of filter media, the ambient temperature, and the discharge requirements.

Advantages:
1. Can be operated at a range of organic and hydraulic loading rates
2. Small land area required compared to Constructed Wetlands

Disadvantages:
1. High capital costs and moderate operating costs
2. Requires expert design and construction
3. Requires constant source of electricity and constant wastewater flow
4. Flies and odours are often problematic
5. Not all parts and materials may be available locally
6. Pre-treatment is required to prevent clogging
7. Dosing system requires more complex engineering

Adequacy: This technology can only be used following primary clarification since high solids loading will cause the filter to clog. A skilled operator is required to monitor and repair the filter and the pump in case of problems. A low-energy (gravity) trickling system can be designed, but in general, a continuous supply of power and wastewater is required. Compared to other technologies (e.g. WSPs), trickling filters are compact, although they are still are best suited for peri-urban or large, rural settlements. Trickling Filters can be built in almost all environments, although special adaptations for cold climates are required.

Health Aspects/Acceptance: The odour and fly problems require that the filter be built away from homes and businesses. There must be appropriate measures taken for pre-treatment, effluent discharge and solids treatment, all of which can still pose health risks.

Maintenance: The sludge that accumulates on the filter must be periodically washed away to prevent clogging. High hydraulic loading rates can be used to flush the filter. The packing must be kept moist. This may be problematic at night when the water flow is reduced or when there are power failures.

Costs: the costs will be dealt with in future updates

References:
**UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR (UASB)**

*Technical/Environmental Factors*

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**NOTES:**

a) Requires a relatively small space available for construction

b) Requires access for desludging

f) Depending on the size of the reactor, space availability could be a problem

**Option-Specific**

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<tr>
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<td>Energy input</td>
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**Inputs:**

- Blackwater

**Outputs:**

- Effluent
- Treated Sludge
- Biogas

**www.waste.nl**

**www.akvo.org**

**WASTE**

- Sanitation -
  - Decision Support Tool
Description: The Upflow Anaerobic Sludge Blanket Reactor (UASB) is a single tank process. Wastewater enters the reactor from the bottom, and flows upward. A suspended sludge blanket filters and treats the wastewater as the wastewater flows through it. The sludge blanket is comprised of microbial granules, i.e. small agglomerations (0.5 to 2mm in diameter) of microorganisms that, because of their weight, resist being washed out in the upflow. The microorganisms in the sludge layer degrade organic compounds. As a result, gases (methane and carbon dioxide) are released. The rising bubbles mix the sludge without the assistance of any mechanical parts. Sloped walls deflect material that reaches the top of the tank downwards. The clarified effluent is extracted from the top of the tank in an area above the sloped walls. After several weeks of use, larger granules of sludge form which in turn act as filters for smaller particles as the effluent rises through the cushion of sludge. Because of the upflow regime, granule-forming organisms are preferentially accumulated as the others are washed out. The gas that rises to the top is collected in a gas collection dome and can be used as energy (biogas). An upflow velocity of 0.6 to 0.9m/h must be maintained to keep the sludge blanket in suspension.

Adequacy: A UASB is not appropriate for small or rural communities without a constant water supply or electricity. A skilled operator is required to monitor and repair the reactor and the pump in case of problems. Although the technology is simple to design and build, it is not well proven for domestic wastewater, although new research is promising. The UASB reactor has the potential to produce higher quality effluent than septic tanks (S9), and can do so in a smaller reactor volume. Although it is a wellestablished process for large-scale industrial wastewater treatment processes, its application to domestic sewage is still relatively new. Typically it is used for brewery, distillery, food processing and pulp and paper waste since the process can typically remove 85% to 90% of Chemical Oxygen Demand (COD). Where the influent is low strength, the reactor may not work properly. Temperature will also affect performance.

Advantages: 1. High reduction in organics 2. Can withstand high organic loading rates (up to 10kg BOD/m3/d) and high hydraulic loading rates 3. Low production sludge (and thus, infrequent desludging required) 4. Biogas can be used for energy (but usually requires scrubbing first)

Disadvantages: 1. Difficult to maintain proper hydraulic conditions (upflow and settling rate must be balanced) 2. Long start up time 3. Treatment may be unstable with variable hydraulic and organic loads 4. Constant source of electricity is required 5. Not all parts and materials may be available locally 6. Requires expert design and construction supervision

Health Aspects/Acceptance: UASB is a centralized treatment technology that must be operated and maintained by professionals. As with all wastewater processes, operators should take proper health and safety measures while working in the plant. Maintenance: Desludging is infrequent and only excess sludge is removed once every 2 to 3 years. A permanent operator is required to control and monitor the dosing pump.

Costs: the costs will be dealt with in future updates

References:

www.waste.nl
www.akvo.org
## Technical/Environmental Factors

### Site-Specific

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<thead>
<tr>
<th></th>
<th>Water supply</th>
<th>Space availability</th>
<th>Flood prone</th>
<th>Groundwater table</th>
<th>Terrain/Topography/Slope</th>
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<th>Soil type</th>
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### NOTES:

- **a)** Requires a relatively large space available for construction
- **b)** Requires access for desludging
- **f)** Depending on the size of the filter, space availability could be a problem
Description: Activated Sludge is a multi-chamber reactor unit that makes use of (mostly) aerobic microorganisms to degrade organics in wastewater and to produce a high-quality effluent. To maintain aerobic conditions and to keep the active biomass suspended, a constant and well-timed supply of oxygen is required. Different configurations of the Activated Sludge process can be employed to ensure that the wastewater is mixed and aerated (with either air or pure oxygen) in an aeration tank. The microorganisms oxidize the organic carbon in the wastewater to produce new cells, carbon dioxide and water. Although aerobic bacteria are the most common organisms, aerobic, anaerobic, and/or nitrifying bacteria along with higher organisms can be present. The exact composition depends on the reactor design, environment, and wastewater characteristics. During aeration and mixing, the bacteria form small clusters, or flocs. When the aeration stops, the mixture is transferred to a secondary clarifier where the flocs are allowed to settle out and the effluent moves on for further treatment or discharge. The sludge is then recycled back to the aeration tank, where the process is repeated.

To achieve specific effluent goals for BOD, nitrogen and phosphorus, different adaptations and modifications have been made to the basic Activated Sludge design. Aerobic conditions, nutrient-specific organisms (especially for phosphorus), recycle design and carbon dosing, among others, have successfully allowed Activated Sludge processes to achieve high treatment efficiencies.

Adequacy: Activated Sludge is only appropriate for a centralized treatment facility with a well-trained staff, constant electricity and a highly developed centralized management system to ensure that the facility is operated and maintained correctly. Activated Sludge processes are one part of a complex treatment system. They are used following primary treatment (that removes settleable solids) and before a final polishing step. The biological processes that occur are effective at removing soluble, colloidal and particulate organic materials for biological nitrification and denitrification and for biological phosphorus removal. This technology is effective for the treatment of large volumes of flows: 10,000 to 1,000,000 people. Highly trained staff is required for maintenance and trouble-shooting. The design must be based on an accurately compressed rate estimation of the wastewater composition and volume.

Treatment efficiency can be severely compromised if the plant is under- or over-designed. An Activated Sludge process is appropriate for almost every climate.

Health Aspects/Acceptance: Because of space requirements, Centralized treatment facilities are generally located away from the densely populated areas that they serve. Although the effluent produced is of high quality, it still poses a health risk and should not be handled directly.

Maintenance: The mechanical equipment (mixers, aerators and pumps) must be maintained constantly. As well, the influent and effluent must be monitored constantly to ensure that there are no abnormalities that could kill the active biomass and to ensure that detrimental organisms have not developed that could impair the process (e.g. filamentous bacteria).

Advantages:
1. Good resistance against shock loading
2. Can be operated at a range of organic and hydraulic loading rates
3. High reduction of BOD and pathogens (up to 99%)
4. Can be modified to meet specific discharge limits

Disadvantages:
1. Prone to complicated chemical and microbiological problems
2. Effluent might require further treatment/disinfection before discharge
3. Not all parts and materials may be available locally
4. Requires expert design and supervision
5. High Capital cost; high operation cost
6. Constant source of electricity is required
7. Effluent and sludge require secondary treatment and/or appropriate discharge

Costs: the costs will be dealt with in future updates

References:

www.waste.nl
www.akvo.org
### Technical/Environmental Factors

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### Notes:

- a) Requires a large space available for construction
- b) High risk of leakage pollution and overflow
- c) Requires large land relatively flat
- d) Requires access for desludging
- e) Difficulties for excavation. Special attention to the costs. Not recommended
- f) Depending on the size of the ponds, space availability could be a problem
- g) Ensure lining of the ponds. Risk of water infiltration and overflow as well as leaking and groundwater pollution
Description: Sedimentation or Thickening Ponds are simple settling ponds that allow the sludge to thicken and dewater. The effluent is removed and treated, while the thickened sludge can be treated in a subsequent technology. Faecal sludge is not a uniform product and therefore, its treatment must be specific to the characteristics of the specific sludge. In general, there are two types of faecal sludges: high strength (originating from latrines and unsewered public toilets) and low strength (originating from Septic Tanks (S9)). High strength sludge is still rich in organics and has not undergone significant degradation, which makes it difficult to dewater. Low strength sludge has undergone significant anaerobic degradation and is more easily dewatered. In order to be properly dried, high strength sludges must first be stabilized. Allowing the high strength sludge to degrade anaerobically in Settling/Thickening Ponds can do this. The same type of pond can be used to thicken low strength sludge, although it undergoes less degradation and requires more time to settle. The degradation process may actually hinder the settling of low strength sludge because the gases produced bubble up and re-suspend the solids. To achieve maximum efficiency, the loading and resting period should not exceed 4 to 5 weeks, although much longer cycles are common. When a 4-week loading, and 4-week resting cycle is used, total solids (TS) can be increased to 14% (depending on the initial concentration). As the sludge settles and digests, the supernatant must be decanted and treated separately. The thickened sludge can then go on to be dried or composted further.

Adequacy: Settling/Thickening Ponds are appropriate where there is inexpensive, available space that is far from homes and businesses; it should be on the edge of the community. The sludge is not hygienized and requires further treatment before disposal. Ideally this technology should be coupled with an onsite Drying (T13) or Co-Composting (T14) facility to generate a hygienic product. Trained staff for operation and maintenance is required to ensure proper functioning. This is a low-cost option that can be installed in most hot and temperate climates. Excessive rain may prevent the sludge from properly settling and thickening.

Advantages:
1. Can be built and repaired with locally available materials
2. Low capital cost; low operating cost
3. Potential for local job creation and income generation
4. No electrical energy required

Disadvantages:
1. Requires large land area
2. Odours and flies are normally noticeable
3. Long storage times
4. Requires front-end loader for monthly desludging
5. Requires expert design and operation

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: Maintenance is an important aspect of a well-functioning pond, although it is not intensive. The discharging area must be maintained and kept clean to reduce the potential for disease transmission and nuisance (flies and odours). Grit, sand, and solid waste that are discharged along with the sludge must be removed. The thickened sludge must be removed mechanically (front end loader or specialized equipment) when the sludge has thickened sufficiently.

Costs: the costs will be dealt with in future updates

References:

Drawing of
# UNPLANTED DRYING BEDS

**(Semi-) Centralized Treatment**

**Inputs:**
- Sludge

**Outputs:**
- Sludge
  - Effluent

---

**- Sanitation -**

**Decision Support Tool**

- [www.waste.nl](http://www.waste.nl)
- [www.akvo.org](http://www.akvo.org)

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### Technical/Environmental Factors

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### NOTES:
- **Stop: Not Applicable**
- **Go: Applicable**
- **Caution: Applicable with corrective measures**

- **a)** Requires a large space available for construction
- **b)** High risk of leakage pollution and overflow
- **c)** Requires large land relatively flat
- **d)** Requires access for desludging
- **e)** Difficulties for excavation. Special attention to the costs. Not recommended
- **f)** Depending on the size of the drying beds, space availability could be a problem
- **g)** Ensure lining of the ponds. Risk of water infiltration and overflow as well as leaking and groundwater pollution
**Description:** 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. Approximately 50% to 80% of the sludge volume drains off as liquid. The sludge however, is not stabilized or treated. 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 (T14), 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 periurban areas. If it is designed to service urban areas, it should be on the edge of the community. The sludge is not hygienized and requires further treatment before disposal. Ideally this technology should be coupled with a Co-Composting (T14) facility to generate a hygienic product. Trained staff for operation and maintenance is required to ensure proper functioning. This is a low-cost option that can be installed in most hot and temperate climates. Excessive rain may prevent the sludge from properly settling and thickening.

**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.

**Advantages:**
1. Can be built and repaired with locally available materials
2. Moderate Capital Cost; low operating Cost
3. Potential for local job creation and income generation
4. No electrical energy required

**Disadvantages:**
1. Requires large land area
2. Odours and flies are normally noticeable
3. Long storage times
4. Requires expert design and operation
5. Labour intensive removal
6. Leachate requires secondary treatment

**Costs:** the costs will be dealt with in future updates

**References:**
PLANTED DRYING BEDS

(Semi-) Centralized Treatment

- Sanitation -
Decision Support Tool

www.waste.nl
www.akvo.org

<table>
<thead>
<tr>
<th>Technical/Environmental Factors</th>
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<tbody>
<tr>
<td>1 Water supply</td>
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<td>3 Flood prone</td>
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<td>4 Groundwater table</td>
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<td>5 Terrain/Topography/Slope</td>
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<td>6 Vehicular accessibility</td>
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<td>7 Soil type</td>
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<td>8 Roads/paths system</td>
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<td>9 Anal cleansing method</td>
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<tr>
<th>Option-Specific</th>
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<td>11 Capital costs</td>
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<td>13 System robustness</td>
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<td>14 System upgradability</td>
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<tr>
<td>15 Ease of construction</td>
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<td>16 Ease of operation</td>
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<tr>
<td>17 Reuseability of products</td>
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<td>18 Health implications</td>
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<td>19 Treatment efficiency</td>
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<td>19.1 Pathogens removal</td>
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<td>19.2 BOD</td>
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<td>19.3 TSS</td>
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<tr>
<td>20 Energy input</td>
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</tbody>
</table>

NOTES:

a) Requires a large space available for construction
b) High risk of leakage pollution and overflow
c) Requires large land relatively flat
d) Requires access for desludging
e) Difficulties for excavation. Special attention to the costs. Not recommended

f) Depending on the size of the ponds, space availability could be a problem
g) Ensure lining of the ponds. Risk of water infiltration and overflow as well as leaking and groundwater pollution

Outputs:

Treated Sludge
Effluent
Forage
Description: A Planted Drying Bed is similar to an Unplanted Drying Bed (T12) with the benefit of increased transpiration. The key feature is that the filters do not need to be desludged after each feeding/drying cycle. Fresh sludge can be applied directly onto the previous layer; it is the plants and their root systems that maintain the porosity of the filter. This technology has the benefit of dewatering as well as stabilizing the sludge. Also, the roots of the plants create pathways through the thickening sludge to allow water to escape more easily.

The appearance of the bed is similar to a Vertical Flow Constructed Wetland (T7). The beds are filled with sand and gravel to support the vegetation. Instead of effluent, sludge is applied to the surface and the filtrate flows down through the subsurface to collect in drains. A general design for layering the bed is: (1) 250mm of coarse gravel (grain diameter of 20mm); (2) 250mm of fine gravel (grain diameter of 5 mm); and (3) 100–150mm of sand. Free space (1m) should be left above the top of the sand layer to account for about 3 to 5 years of accumulation.

When the bed is constructed, the plants should be planted evenly and allowed to establish themselves before the sludge is applied. Echinochloa pyramidalis, Cattails or Phragmites are suitable plants depending on the climate.

Sludge should be applied in layers between 75 to 100mm and should be reapplied every 3 to 7 days depending on the sludge characteristics, the environment and operating constraints. Sludge application rates of up to 250kg/m2/year have been reported. The sludge can be removed after 2 to 3 years (although the degree of hygienization will vary with climate) and used for agriculture.

Adequacy This is an effective technology at decreasing sludge volume (down to 50%) through decomposition and drying, which is especially important when the sludge needs to be transported elsewhere for direct use, Co-Composting (T14), or disposal. Planted drying beds are appropriate for small to medium communities with populations up to 100,000 people. It should be located on the edge of the community.

The sludge is not hygienized and requires further treatment before disposal. Ideally this technology should be coupled with a Co-Composting (T14) facility to generate a hygienic product. Trained staff for operation and maintenance is required to ensure proper functioning.

Advantages:
1. Can handle high loading
2. Fruit or forage growing can generate income
3. Can be built and repaired with locally available materials
4. Low capital cost; low operating cost
5. Potential for local job creation and income generation
6. No electrical energy required

Disadvantages:
1. Requires large land area
2. Odours and flies are normally noticeable
3. Long storage times
4. Requires expert design and operation
5. Labour intensive removal
6. Leachate requires secondary treatment

Health Aspects/Acceptance: Because of the pleasing aesthetics, there should be few problems with acceptance, especially if located away dense housing. Faecal sludge is hazardous and anyone working with it should wear protective clothing, boots and gloves.

Maintenance: The drains must be maintained and the effluent must be properly collected and disposed of. The plants should be periodically thinned and/or harvested.

Costs: the costs will be dealt with in future updates

References:
- www.waste.nl
- www.akvo.org
# T.14 CO-COMPOSTING

## (Semi-) Centralized Treatment

### Technical/Environmental Factors

<table>
<thead>
<tr>
<th></th>
<th>Water supply</th>
<th>Space availability</th>
<th>Flood prone</th>
<th>Groundwater table</th>
<th>Terrain/Topography/Slope</th>
<th>Vehicular accessibility</th>
<th>Soil type</th>
<th>Roads/paths system</th>
<th>Anal cleansing method</th>
<th>Space requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>none</td>
<td>large</td>
<td>not affected</td>
<td>&lt; 2 m.</td>
<td>flat</td>
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<td>irregular/unplanned</td>
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<td>2 - 5 m.</td>
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<td>silty</td>
<td>regular/planned</td>
<td>soft paper</td>
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<td>&gt; 5 m.</td>
<td>5 - 25%</td>
<td>full</td>
<td>sandy</td>
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<td>6</td>
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### Site-Specific

- Water supply: none, fetched, handpump, standpipe, tanker, connection
- Space availability: large, medium/large, medium, small/medium, small
- Flood prone: not affected, low-laying area, below 1:50 year
- Groundwater table: < 2 m., 2 - 5 m., > 5 m., > 25%
- Terrain/Topography/Slope: flat, < 5%, 5 - 25%, > 25%
- Vehicular accessibility: no access, limited/narrow, full
- Soil type: clayey, silty, sandy, gravelly, rocky
- Roads/paths system: irregular/unplanned, regular/planned
- Anal cleansing method: water, soft paper, hard or bulky

### Option-Specific

- Space requirement
- Capital costs
- O&M costs
- System robustness
- System upgradability
- Ease of construction
- Ease of operation
- Reuseability of products
- Health implications
- Treatment efficiency
- Pathogens removal
- BOD
- TSS
- Energy input

### NOTES:

- a) Requires a relatively large space available for construction
- b) High risk of leakage pollution
- c) Requires large land relatively flat
- d) Requires access for O&M
- e) Depending on the size of the facility, space availability could be a problem
- f) Ensure leakage control. Risk of leaking and groundwater pollution

### Outputs:

Compost/EcoHumus

- Sanitation - Decision Support Tool
  - www.waste.nl
  - www.akvo.org

### Inputs:

- Sludge
- Organics
Description: Co-Composting is the controlled aerobic degradation of organics using more than one feedstock (Faecal sludge and Organic solid waste). Faecal sludge has a high moisture and nitrogen content while biodegradable solid waste is high in organic carbon and has good bulking properties (i.e., it allows air to flow and circulate). By combining the two, the benefits of each can be used to optimize the process and the product. For dewatered sludges, a ratio of 1:2 to 1:3 of dewatered sludge to solid waste should be used. Liquid sludges should be used at a ratio of 1:5 to 1:10 of liquid sludge to solid waste. There are two types of Co-Composting designs: open and in-vessel. In open composting, the mixed material (sludge and solid waste) is piled into long heaps called windrows and left to decompose. Windrow piles are turned periodically to provide oxygen and ensure that all parts of the pile are subjected to the same heat treatment. Windrow piles should be at least 1m high, and should be insulated with compost or soil to promote an even distribution of heat inside the pile. Depending on the climate and available space, the facility may be covered to prevent excess evaporation and protection from rain. In-vessel composting requires controlled moisture and air supply, as well as mechanical mixing. Therefore, it is not generally appropriate for decentralized facilities. Although the composting process seems like a simple, passive technology, a well-working facility requires careful planning and design to avoid failure.

Adequacy: A Co-Composting facility is only appropriate when there is an available source of well-sorted biodegradable solid waste. Mixed solid waste with plastics and garbage must first be sorted. When done carefully, Co-Composting can produce a clean, pleasant, beneficial product that is safe to touch and work with. It is a good way to reduce the pathogen load in sludge. Depending on the climate (rainfall, temperature and wind) the Co-Composting facility can be built to accommodate the conditions. Since moisture plays an important role in the composting process, covered facilities are especially recommended where there is heavy rainfall. The facility should be located close to the sources of organic waste and faecal sludge (to minimize transport) but to minimize nuisances, it should not be too close to homes and businesses.

Advantages:
1. Easy to set up and maintain with appropriate training
2. Provides a valuable resource that can improve local agriculture and food production
3. High removal of helminth eggs possible (< 1 egg viable egg/g TS)
4. Can be built and repaired with locally available materials
5. Low capital cost; low operating cost
6. Potential for local job creation and income generation
7. No electrical energy required

Health Aspects/Acceptance: Although the finished compost can be safely handled, care should be taken when handling the faecal sludge. Workers should wear protective clothing and appropriate respiratory equipment if the material is found to be dusty.

Upgrading: Robust grinders for shredding large pieces of solid waste (i.e., small branches and coconut shells) and pile turners help to optimize the process, reduce manual labour, and ensure a more homogenous end product.

Maintenance: The mixture must be carefully designed so that it has the proper C:N ratio, moisture and oxygen content. If facilities exist, it would be useful to monitor helminth egg inactivation as a proxy measure of sterilization. Maintenance staff must carefully monitor the quality of the input materials, keep track of the inflows, outflows, turning schedules, and maturing times to ensure a high-quality product. Manual turning must be done periodically with either a front-end loader or by hand. Forced aeration systems must be carefully controlled and monitored.

Costs: the costs will be dealt with in future updates

References:
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### Site-Specific

- **NOTES:**
  - a) Requires a relatively small space available for construction
  - b) Requires access for desludging
  - c) Depending on the size of the reactor, space availability could be a problem
  - d) Not recommended in potential flooding areas and high groundwater level. Possible above ground
  - e) Difficulties for excavation. Possible above ground

### Options-Specific

#### 10 Space requirement

- **NOTES:**
  - Requires a relatively small space available for construction

#### 11 Capital costs

#### 12 O&M costs

#### 13 System robustness

#### 14 System upgradability

#### 15 Ease of construction

#### 16 Ease of operation

#### 17 Reusability of products

#### 18 Health implications

#### 19 Treatment efficiency

#### 19.1 Pathogens removal

#### 19.2 BOD

#### 19.3 TSS

#### 20 Energy input
Description: An Anaerobic Biogas Reactor is an anaerobic treatment technology that produces (a) a digested slurry to be used as a soil amendment and (b) biogas which can be used for energy. Biogas is a mix of methane, carbon dioxide and other trace gases that can be easily converted to electricity, light and heat.

Advantages:
1. Generation of a renewable, valuable energy source
2. Low capital costs; low operating costs
3. Underground construction minimizes land use
4. Long life span
5. Can be built and repaired with locally available materials
6. Low capital cost; low operating cost
7. No electrical energy required

Disadvantages:
1. Requires expert design and skilled construction
2. Gas production below 15°C, is not longer economically feasible
3. Digested sludge and effluent still requires further treatment

Adequacy: This technology is easily adaptable and can be applied at the household level or a small neighbourhood (refer to Technology Information Sheet S12: Anaerobic Biogas Reactor for information about applying an Anaerobic Biogas Reactor at the household level). Biogas reactors are best used for concentrated products (i.e. rich in organic material). If they are installed at a public toilet, for example, and the sludge is too dilute, additional organic waste (e.g. from the market) can be added to improve the efficiency. Because they are compact and can be built underground, biodigestors are appropriate for dense housing areas or public institutions that generate a lot of sludge, but where space is limited. To minimize distribution losses, the reactors should be installed close to where the gas can be used. Biogas reactors are less appropriate for colder climates as gas production is not economically feasible below 15°C.

Health Aspects/Acceptance: The digested slurry is not completely sanitized and still carries a risk of infection. There are also dangers associated with the flammable gases that, if mismanaged could be harmful to human health.

Maintenance: The Anaerobic Biogas Reactor must be well built and gas tight for safety. If the reactor is properly designed, repairs should be minimal. To start the reactor, active sludge (e.g. from a septic tank) should be used as a seed. The tank is essentially selfmixing, but it should be manually stirred once a week to prevent uneven reactions. Gas equipment should be cleaned carefully and regularly so that corrosion and leaks are prevented.

Costs: The costs will be dealt with in future updates

References: