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Network for the development of Sustainable approaches for large Scale Implementation of Sanitation in Africa-

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Evaluation of existing low cost conventional as well as innovative sanitation system and technologies

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PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Introduction

Looking at sanitation systems rather than sanitation technologies

A sanitation system - contrary to a sanitation technology - considers all components of adequate management of human waste. Each system represents a configuration of different *technology components* at the different spatial levels with their various management, operation and maintenance conditions. For example, starting at the household level with its waste generation the system can include storage and potentially also treatment and reuse of all *waste goods* such as urine, excreta, as well as greywater, rainwater/stormwater or even solid waste. However problems can often not be solved at the household level alone. The household “exports” waste to the neighbourhood, town, city and so on up to a larger jurisdiction. In such cases it is crucial that the sanitation system boundary be extended to include these larger spatial sections hereby also taking into account technology components for storage, collection, transport, treatment, discharge or reuse at these levels. A “good” sanitation system minimizes or removes health risks and avoids negative impacts on the environment. Ensuring good sanitation systems for protection of public health and the environment is of public interest and therefore a key duty of the public sector. This duty comprises providing the enabling framework as well as control and supervision to ensure these conditions are met for all users. “Sustainable” sanitation however goes a step further. Sustainable systems take into account economic aspects (financial capital investments required as well as recurring operation and maintenance costs, affordability), institutional aspects (organisational set-up, opportunities for public-private partnership), environmental aspects (minimum energy requirements, opportunities for resource recovery and reuse, environmental impact) and finally social aspects (convenience, dignity, acceptability, and willingness to pay or operate).

Many different reasons have been identified why the sanitation situation in many countries has not improved or been replicated on large scale over the last ten years. One of the most important reasons was the general prevailing assumption that the conventional (centralised) water borne sewer system can be the solution in all contexts and to all sanitation problems in urban and peri-urban or even rural areas irrespective of the big differences in the physical and socio-economic conditions. It is only quite recently that research and development is targeting alternative approaches and solutions to the environmental sanitation problem.

This document attempts to systematize distinct sanitation systems. Discussion on the systematization took place at in email exchange as well as at the NETSSAF meetings in Eschborn, Germany (22-23 February 2007) and Ouagadougou (27 February - 1 March 2007). The consensus of the consortium is to focus on 7 main systems.

Main two criteria for subdividing the systems are WET <-> DRY as well as the various degrees of separating waste flowstreams.

no.	System name	Waste flowstreams
1	Wet mixed systems with on-site or off-site treatment	▪ mixed wastewater flowstream ▪ faecal sludge flowstream
2	Wet blackwater systems (blackwater separated from greywater)	▪ blackwater flowstream ▪ faecal sludge flowstream ▪ greywater flowstream
3	Wet urine diversion system	▪ urine flowstream ▪ brownwater mixed with greywater flowstream ▪ faecal sludge flowstream
4	Wet urine & greywater diversion system	▪ urine flowstream ▪ brownwater flowstream ▪ faecal sludge flowstream ▪ greywater flowstream
5	Dry greywater separate system	▪ excreta flowstream ▪ greywater flowstream
6	Dry urine & greywater diversion system	▪ urine flowstream ▪ faeces flowstream ▪ greywater flowstream
7	Dry all mixed systems	▪ excreta mixed with greywater flowstream

The systems take into account the individual waste flowstreams depending on the degree of separation. The flowstream of stormwater drainage (rainwater) although shown in the system description is only referred to if required necessary. Also flowstream of solid waste is referred to only if certain technologies require or allow joint handling and treatment.

The following chapters briefly describe the various systems and their main characteristics. For each system the various relevant flowstreams are listed.

Tables of technology assessment

Technology components related to the various flowstreams are assessed for the various process steps (as listed below) using selected assessment criteria which were developed in Workpackage 1 and further refined and summarized for Workpackage 3.

Process step	Abbreviation
▪ Collection and on-site storage	[C]
▪ Transport	[TP]
▪ Treatment on-site	[on-TM]
▪ Treatment off site	[off-TM]
▪ Reuse	[RE]
▪ Disposal	[DP]

Assessment by eliciting expert judgement

In the planning and selection process for sanitation systems and respective technologies, the wide range of stakeholders have an equally wide range of interests and differing objectives on how the improved sanitation system should look like and what it should achieve. In the decision making process on which sanitation system and technology components are best suited it is therefore of utmost importance to understand the drivers for improved sanitation in function of the respective stakeholders while taking into consideration their interests, importance and influence. For instance, individual residents and households typically want improved sanitation not primarily to reduce their health risk, but for them more importantly to improve privacy, safety, comfort, cleanliness or their status/image or even to make better use of the nutrient or water resources. Often the decision making process is dominated by one particular stakeholder and decision maker.

This document contains assessment by expert judgement and does not take into account the above mentioned circumstance specific needs or interests of the users and stakeholders.

In the assessment table the following descriptors are used:

Qualitative Descriptor	Meaning
+ +	the criterion is very well fulfilled by this technology
+	the criterion is fulfilled by this technology
o	the criterion is neutral to this technology
-	the technology does not well fulfil this criterion
- -	the technology does not at all fulfil this criterion
n.a.	the criterion does not relate to this technology (not relevant)

The whole range of technologies for the flowstream and process step are assessed using comparative judgement. The “worst” technology for one flowstream and process step receives a “--" evaluation and the “best” technology a “++”. A compilation of technology components and their description including advantages and disadvantages follows in the last part. Technology components are listed in the categories “collection, transport, on-site & off-site treatment, reuse and finally disposal”

Terminology

Excreta	urine and faeces
Faeces	solid human excrement
Urine	liquid human excrement
Mixed Wastewater	mixed flow stream including greywater, urine, faeces and flushing water
Greywater	domestic wastewater without urine or faeces
Blackwater	faeces, urine and flushing water
Yellowwater	urine and flushing water
Brownwater	faeces and flushing water

PART 1 System Description

1.1 Wet mixed wastewater system

Wet mixed systems collect, transport and treat all wastewater flowstreams which are created by households, institutions, and commercial and industrial establishments without stream separation. The system is characterised by flush toilets (full/low/pour flush toilets) for collection. This mixed wastewater can be treated either close to where it is generated (**on-site-treatment**) or transported via a network of pipes and pumping stations to a larger centralised treatment plant (**off-site-treatment**). These two options of off-site and on-site treatment are described below as two subsystems. It is however obvious that a mix of these two subsystems is also feasible.

There are different technologies available for collection of mixed wastewater. These can be by full, low or pour flush toilets. After collection, mixed wastewater may be transported with different technical options to the treatment plant. Transport technologies may be in pipes with gravity flow, pressure flow, or using vacuum systems. The system shown below (Figure 1) describes a **seperate sewer system** where drainage of rainwater is not fed into the sewer. Including rainwater from stormwater drainage into the sewer system - call mixed sewer system - may also be an option, however is not recommended as it significantly increases complexity of the system (pipe diameters and treatment plants).

There are different technology options for wastewater treatment. Typically, sewage treatment involves up to three stages, called *primary*, *secondary* and *tertiary* treatment. During the primary (mechanical) treatment the solids are separated from the wastewater stream. The dissolved biological matter is progressively converted into a solid mass (faecal sludge or biosolids) by water-borne flora in the secondary (biological) treatment.

Effluent discharged by the wastewater treatment plant can be either reused (irrigation purposes) or discharged into the environment depending on the level of treatment and legal requirements. In certain cases the effluent from one treatment plant may be further treated (e.g. by lagoons, wetlands or micro-filtration).

The *biosolids* (sludge) from the wastewater treatment plant can either be disposed of (e.g. disposal or incineration) or undergo further treatment (e.g. composting) and be re-used (agriculture).

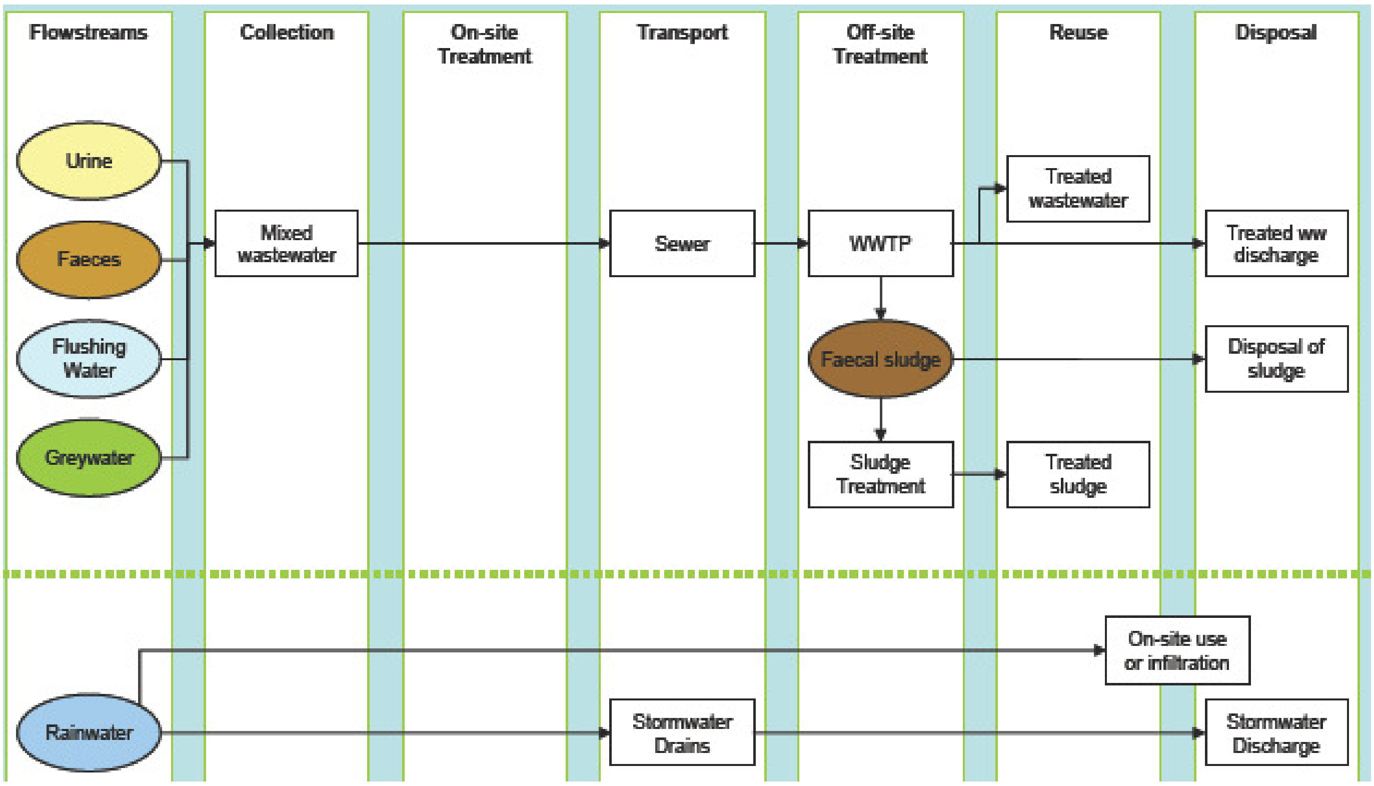

Figure 1: Wet mixed wastewater system with centralised wastewater treatment.

The "**On-site-treatment**" subsystem - similarly to the off-site-treatment - is characterised by flush toilets (full, low, or pour flush toilets) for collection. Here however, a treatment plant is located close to the source of waste generation. Transport is limited to short distances mostly by gravity sewers. There are various technology options for on-site wastewater treatment which differ from those typically used for off-site centralised technologies. Examples are septic tanks, anaerobic baffled reactors, biogas plants, and others.

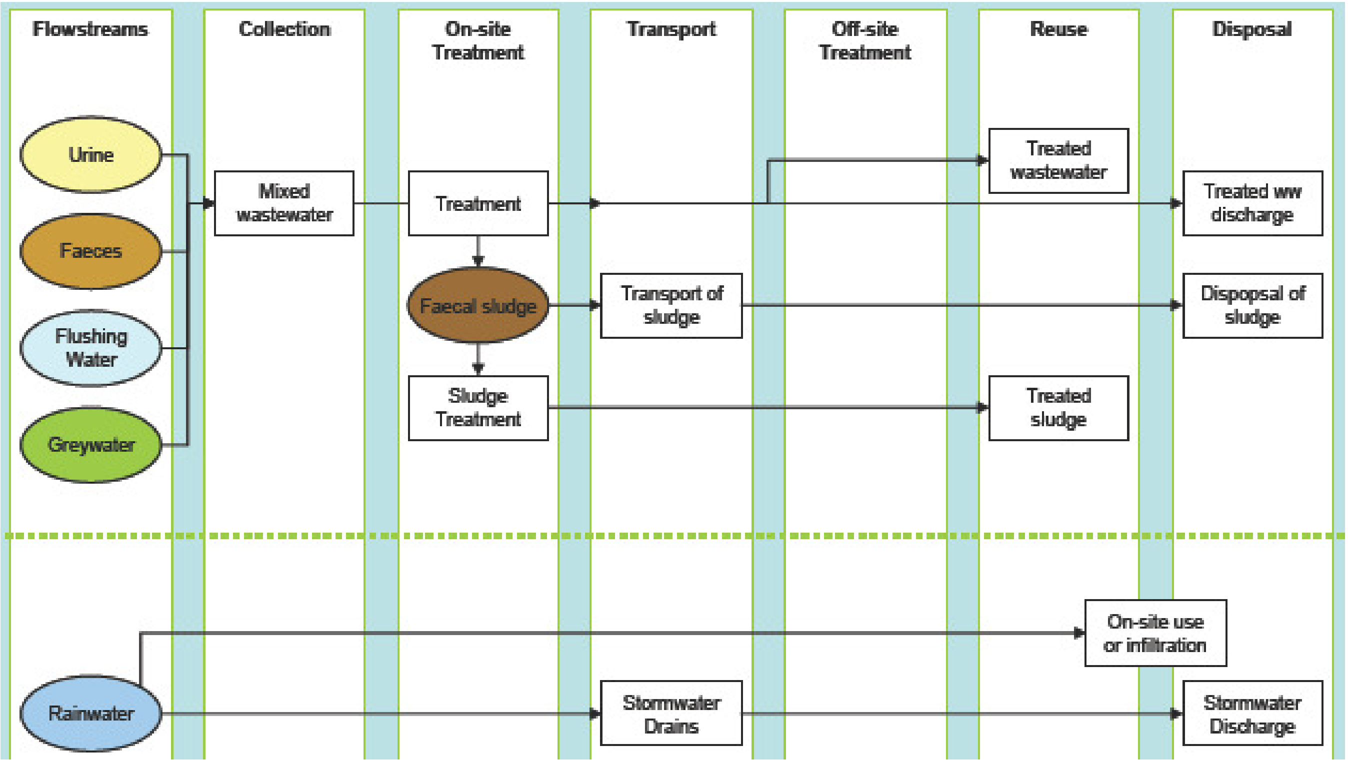

Figure 2: Mixed wastewater system with on-site wastewater treatment.

Relevant Flowstreams

Mixed wastewater flowstream

Mixed wastewater flowstream consists of a mix of urine, faeces, flushing water, and greywater. As mentioned already above, rainwater from stromwater drainage may or may not be diverted into the sewer and mixed with wastewater. A sewer which includes rainwater from stormwater drainage is known as mixed sewer system. On the other hand a separate sewer system is one in which stormwater is kept away from the sewer pipes. Mixed wastewater flowstream involves collection using toilet facilities which use water as flushing and transport media. This collected mixed wastewater is then transported to the treatment facility which can either be on-site (close to the source of waste generation) or off-site (in a centralized treatment plant). Wastewater treatment will produce biosolids which must undergo further management (collection, transport and treatment). This is comprised in the faecal sludge flowstream as described below. Finally effluent (liquid fraction exiting the wastewater treatment plant) can be either reused or discharged into the environment.

Faecal sludge flowstream

In a wet mixed wastewater system, sludge or "biosolids" are the byproduct of the treatment of domestic wastewater in a wastewater treatment plant. This sludge can be further treated to reduce pathogens and vector attraction by a variety of methods. Sewage sludge which derives not only household wastewater but also industrial wastewater may contain high levels of toxic chemicals which are not removed during treatment. Depending on their level of treatment and resultant pollutant content, biosolids can be used in regulated applications ranging from soil conditioning to fertilizer for food or non-food agriculture or distribution for unlimited use.

1.2 Wet blackwater system

This system collects, transports and treats urine, faeces and flushing water (blackwater) together, however keeps greywater separate from this toilet wastewater. As greywater accounts for 60% of the wastewater produced in homes this separation simplifies the respective blackwater management. Separated greywater contains little or no pathogens. Because of this, it does not require the same treatment processes as blackwater or mixed wastewater. Greywater can be recycled for irrigation, toilet flushing, and exterior washing, resulting in water conservation. Most frequent practice in developing countries shows that greywater - if kept separate from blackwater - is discharged either indiscriminately onto soil where it either infiltrates into the subsurface or runs off as surface water into a neighboring stormwater drain or water body. Blackwater on the other hand - similar to mixed wastewater described above - is collected, transported and treated on- or off-site. Again here faecal sludge management must be taken into account and effluent from the treatment process may be reused or discharged into the environment.

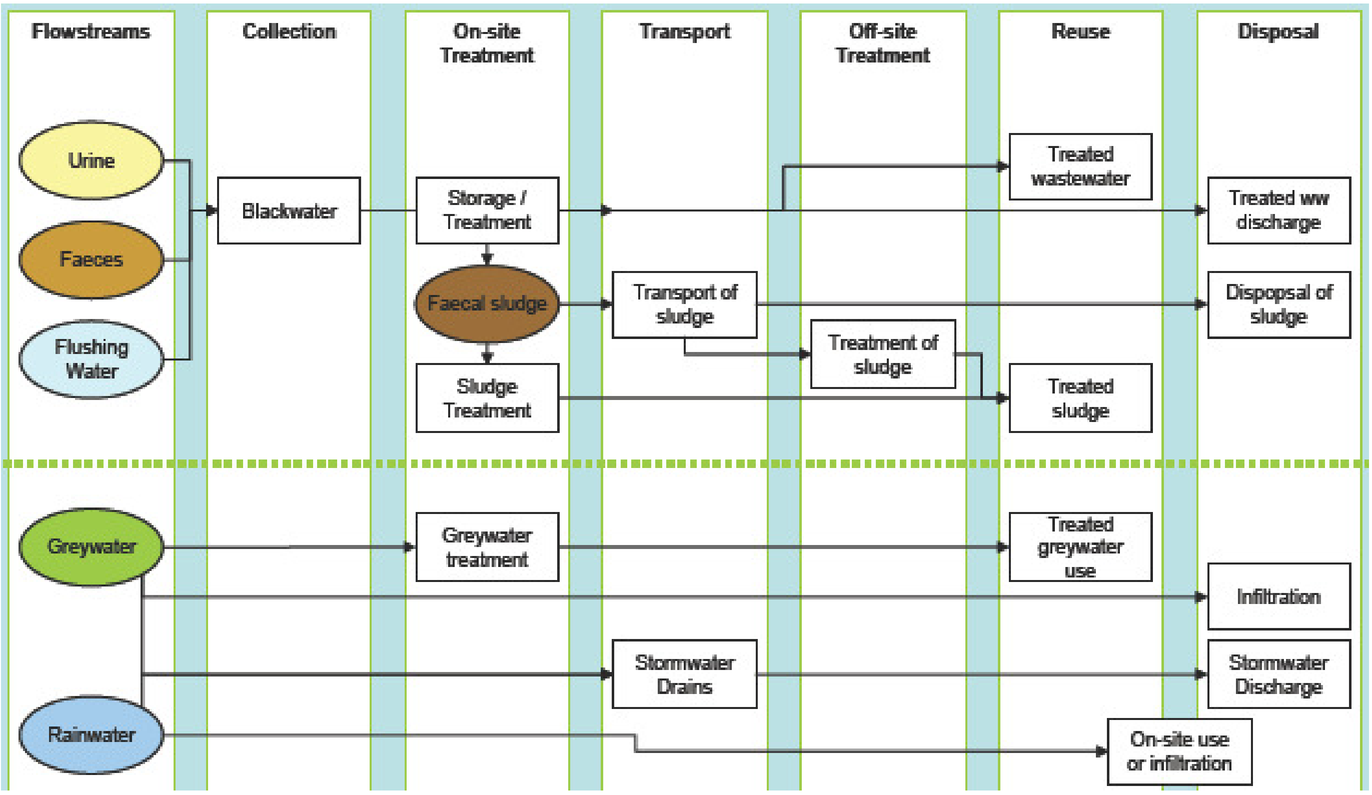

Figure 3: Wet blackwater system where greywater is transported, treated, reused or disposed of separately.

Relevant Flowstreams

Blackwater flowstream

Blackwater flowstream consists of a mix of urine, faeces, and flushing water. Lack of greywater in this flowstream may limit self-cleansing velocity in a sewer network given the reduced liquid content. Blackwater may also be stored/treated on-site. On-site storage/treatment most often entails settling of the solid fraction, and partial treatment of the liquid as well as solid fraction. The liquid fraction may then be transported further to treatment plants, infiltration, reuse, or discharged whereas the solids remain to be handled separately in the faecal sludge flowstream.

Faecal sludge flowstream

In a wet blackwater system, faecal sludge, or "biosolids," as mentioned in the previous system, can be the byproduct of the treatment step or else result from intermediate blackwater storage. The accumulating sludge in these facilities must be emptied, treated and reused on-site or transported to an off-site treatment plant and then reused or simply disposed. Treatment of faecal sludge has the objective of reducing pathogens and stabilizing the organic matter. With regulated treatment, applications may range from soil conditioning to fertilizer for food or non-food agriculture or distribution for unlimited use.

Greywater flowstream

Greywater is wastewater from kitchen, bathtub, cleansing facilities, sinks, and laundry and dish washing. Greywater accounts for 60% of the outflow produced in homes. It contains little or no pathogens and 90% less nitrogen than blackwater (toilet water). Because of this, it does not require the same treatment processes as blackwater or mixed wastewater. Greywater can be recycled for irrigation, toilet flushing, and exterior washing, resulting in water conservation. When planned into habitat construction, the home's wastewater treatment system can be significantly reduced, resulting in cost and space savings. Often, in existing practice greywater is discharged indiscriminately into open drains, onto land for infiltration or fed into soak pits or infiltration trenches. Greywater treatment and reuse systems generally consist of a preliminary treatment to hold back sand, grit and fat with a subsequently treatment technology followed by infiltration into subsurface, discharge into surface waters or irrigation purpose.

1.3 Wet urine diversion system

This system collects transports and treats faeces and flushing water and greywater together however keeps urine separate from this toilet wastewater (i.e. brownwater with greywater). The diversion of urine from the other flowstreams needs specific sanitary installations at the household (known as urine diverting toilets). The separation of urine has the objective of keeping the nutrient rich urine, free of pathogens to thus facilitate its reuse. In this wet urine diverting system, the faeces are flushed with water. Urine, after separation may either be used directly (with dilution) however it is recommended that urine be stored (which can be considered as a treatment step) before reuse. Brownwater mixed with greywater, which comprises faeces, flushing water and greywater is of similar nature than mixed wastewater. However, given the lack of urine which contains most nutrients, brownwater mixed with greywater will obviously have much lower nutrients values than mixed wastewater or blackwater.

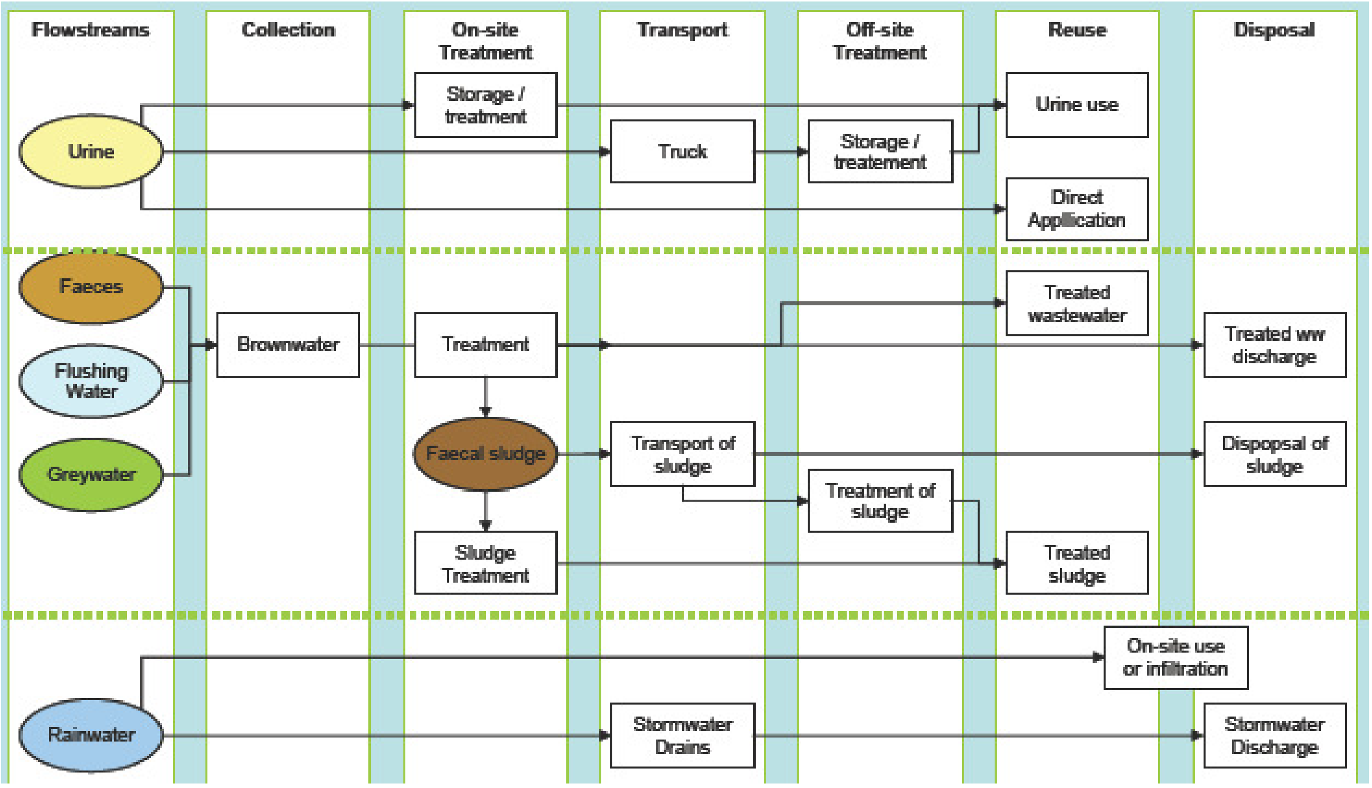

Figure 4: Wet blackwater system where greywater is transported, treated, reused or disposed of separately.

Relevant Flowstreams

Urine flowstream

Urine diverting systems avoid urine coming into contact with faeces thus eliminating potential pathogen contamination and enhancing safe reuse opportunities. Urine is collected separately in a reservoir or canister and stored, and treated and/or transported before reused in agriculture. Urine is an excellent fertilizer. Urine is rich in nitrogen, potassium and phosphorus. The nutrients and minerals, which plants need for growing, are available in a good balance. Separated urine of a healthy person does not contain pathogens. However urine may still be contaminated easily by traces of faeces. For safety reasons it is recommendable to store urine for 1 - 6 months before application. Depending on the diet, human urine collected during one year (ca. 500 liters) contains 4 -5 kg nitrogen, but faeces (ca. 50 kg) only approx. 0,5 kg nitrogen. The urine from 30 persons collected during one year can fertilize one-hectare farmland, which is equal to an application of 120 –150 kg Nitrogen per hectare. Or in other words, the daily urine from one person contains enough nutrients for fertilising approximately 1 m2 field. Nitrogen characteristics of urine are comparable with that of artificial fertiliser and therefore there is a danger to apply too much or too concentrated urine to plants.

Brownwater mixed with greywater flowstream

Brownwater consists of faeces and flushing water without urine. In this system this flowstream is mixed with greywater. By separation of urine, brownwater contains less nutrients. This aspect is further enhanced by mixing with greywater with even lower nutrient contents.

Faecal sludge flowstream

Similar to the systems already described in the previous chapters, in this wet urine diverting system faecal sludge, or "biosolids," will be the byproduct of the treatment step or else result from intermediate excreta storage facilities. At on-site facilities, this sludge must be emptied, treated and reused on-site or transported to an off-site treatment plant and subsequently reused or disposed. Treatment of faecal sludge has the objective of reducing pathogens and stabilizing the organic matter. With regulated treatment, applications may range from soil conditioning to fertilizer for food or non-food agriculture or distribution for unlimited use.

1.4 Wet urine & greywater diversion system

The system uses flushing water and separates all flow streams (urine, faeces and greywater), which can be treated on-site and/or off-site. It presents a reuse potential (with urine as fertiliser, faecal sludge as soil conditioning and greywater for irrigation or water service), even when some process products (treated wastewater and sludge from the faeces on-site treatment) could be disposed. Greywater can be treated separately or together with rainwater.

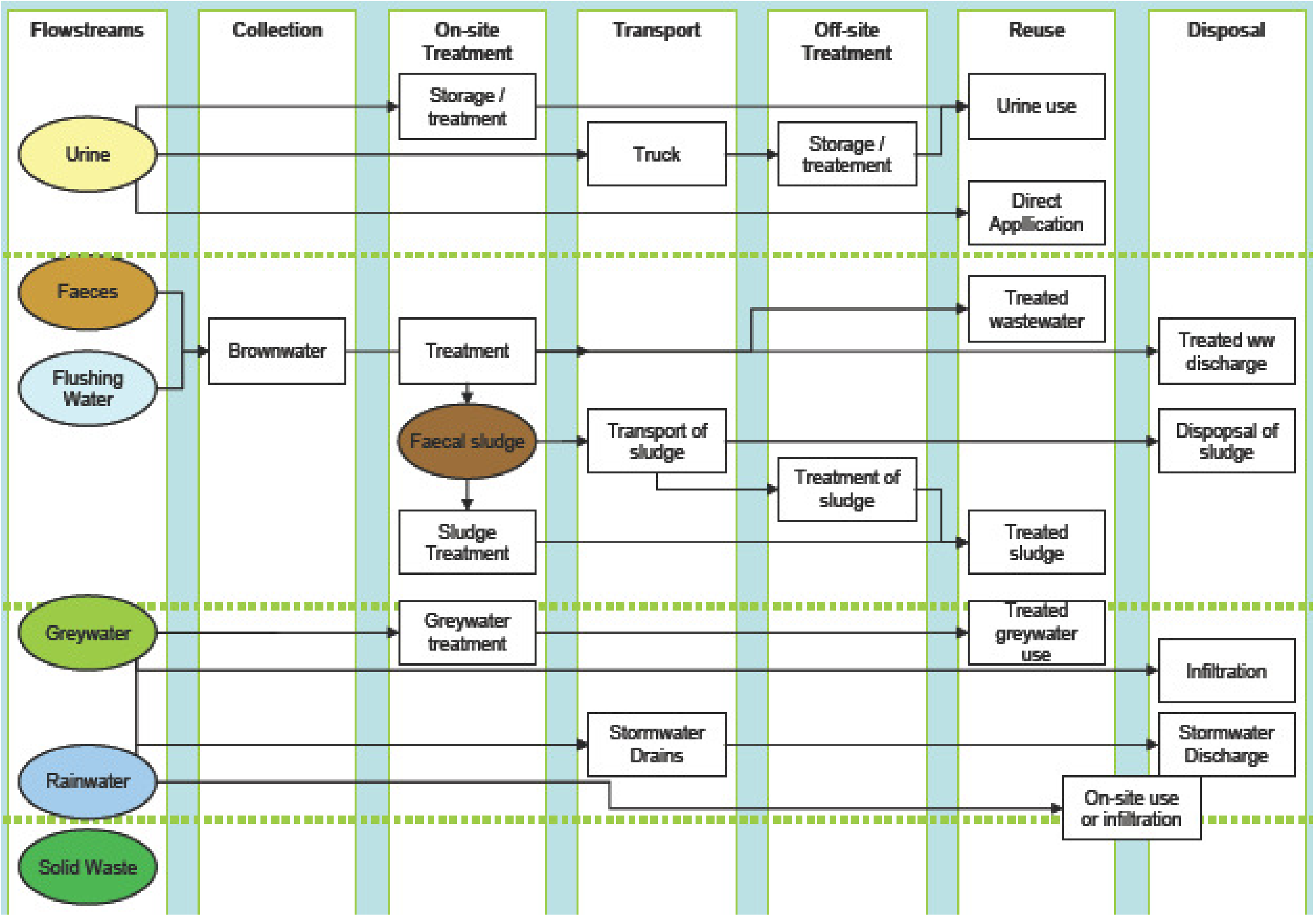

Figure 5: Wet urine and greywater diversion system where each flowstream is handled separately.

Relevant Flowstreams

Urine flowstream

Urine diverting systems avoid urine coming into contact with faeces thus eliminating potential pathogen contamination and enhancing safe reuse opportunities. Urine is collected separately in a reservoir or canister and stored, and treated and/or transported before reused in agriculture. Urine is rich in nitrogen, potassium and phosphorus. The nutrients and minerals, which plants need for growing, are available in a good balance. Separated urine of a healthy person does not contain pathogens. However urine may still be contaminated easily by traces of faeces. For safety reasons it is recommendable to store/treat urine for 1 - 6 months before application. Urine can be used for self use on small plots, on-site, for also off site on large agricutural areas. For off-site reuse a transport (by truck) and centralized storage may be necessary before large scale application.Depending on the diet, human urine collected during one year (ca. 500 liters) contains 4 -5 kg nitrogen, but faeces (ca. 50 kg) only approx. 0,5 kg nitrogen. The urine from 30 persons collected during one year can fertilize one-hectare farmland, which is equal to an application of 120 – 150 kg Nitrogen per hectare. Or in other words, the daily urine from one person contains enough nutrients for fertilising approximately 1 m2 field. Nitrogen characteristics of urine are comparable with that of artificial fertiliser and therefore there is a danger to apply too much or too concentrated urine to plants.

Brownwater flowstream

The brownwater flowstream consist of faeces and flushing water. “Drop and store” latrine types are mostly used for this flowstream. Storage can result in partial dehydration and thus characterize a treatment process. Nevertheless brownwater can also be collected and transported to an off-site centralized treatment facility. However assuring transport with only flushing water as transport media may in some cases result in limiting flow velocities especially when sewer pipes are not ideally laid and flushing volumes are low.

Greywater flowstream

Greywater is wastewater from kitchen, bathtub, cleansing facilities, sinks, and laundry and dish washing. Greywater accounts for 60% of the outflow produced in homes. It contains little or no pathogens and 90% less nitrogen than blackwater (toilet water). Because of this, it does not require the same treatment processes as blackwater or mixed wastewater. Greywater can be recycled for irrigation, toilet flushing, and exterior washing, resulting in water conservation. When planned into habitat construction, the home's wastewater treatment system can be significantly reduced, resulting in cost and space savings. Often, in existing practice greywater is discharged indiscriminately into open drains, onto land for infiltration or fed into soak pits or infiltration trenches. Greywater treatment and reuse systems generally consist of a preliminary treatment to hold back sand, grit and fat with a subsequently treatment technology followed by infiltration into subsurface, discharge into surface waters or irrigation purpose.

Faecal sludge flowstream

In a wet urine and greywater diverting system faecal sludge will be fairly dry as faeces are only mixed with flushing water. , or "biosolids," can be the byproduct of the treatment step or else result from intermediate excreta storage facilities. This sludge must be emptied, treated and reused on-site or transported to an off-site treatment plant and subsequently reused or disposed. Treatment of faecal sludge has the objective of reducing pathogens and stabilizing the organic matter. With regulated treatment, applications may range from soil conditioning to fertilizer for food or non-food agriculture or distribution for unlimited use.

1.5 Dry greywater separate system

Dry systems are those which do not use water for flushing. Nevertheless some water may be used for anal cleansing. Dry greywater separate systems collect, transport and treat all flow streams which are created by households, institutions, and commercial establishments, whereby faeces and urine are mixed and greywater is the only stream separated. As the lack of flushing water does not allow generation of blackwater and thus hinders possible transport in pipes, the system is typically characterised by "drop and store" latrine types. The separate greywater can be treated either close to where it is generated (on-site-treatment) or collected and transported via a network of pipes or by motorized means of transport to a larger centralised treatment plant (off-site-treatment). The excreta fraction (urine in combination with faeces) may be to some extent treated off-site as well (in the faecal sludge flowstream). Generally, this off-site treatment process is only performed to increase the level of hygienization of the material, since all types of collection infrastructure have some on-site treatment included. Proper use, and taking into account the issues in the areas of operation and maintenance are influencing the performance of these facilities significantly. The reuse of resources (greywater and/or treated excreta/sludge) can as well be performed.

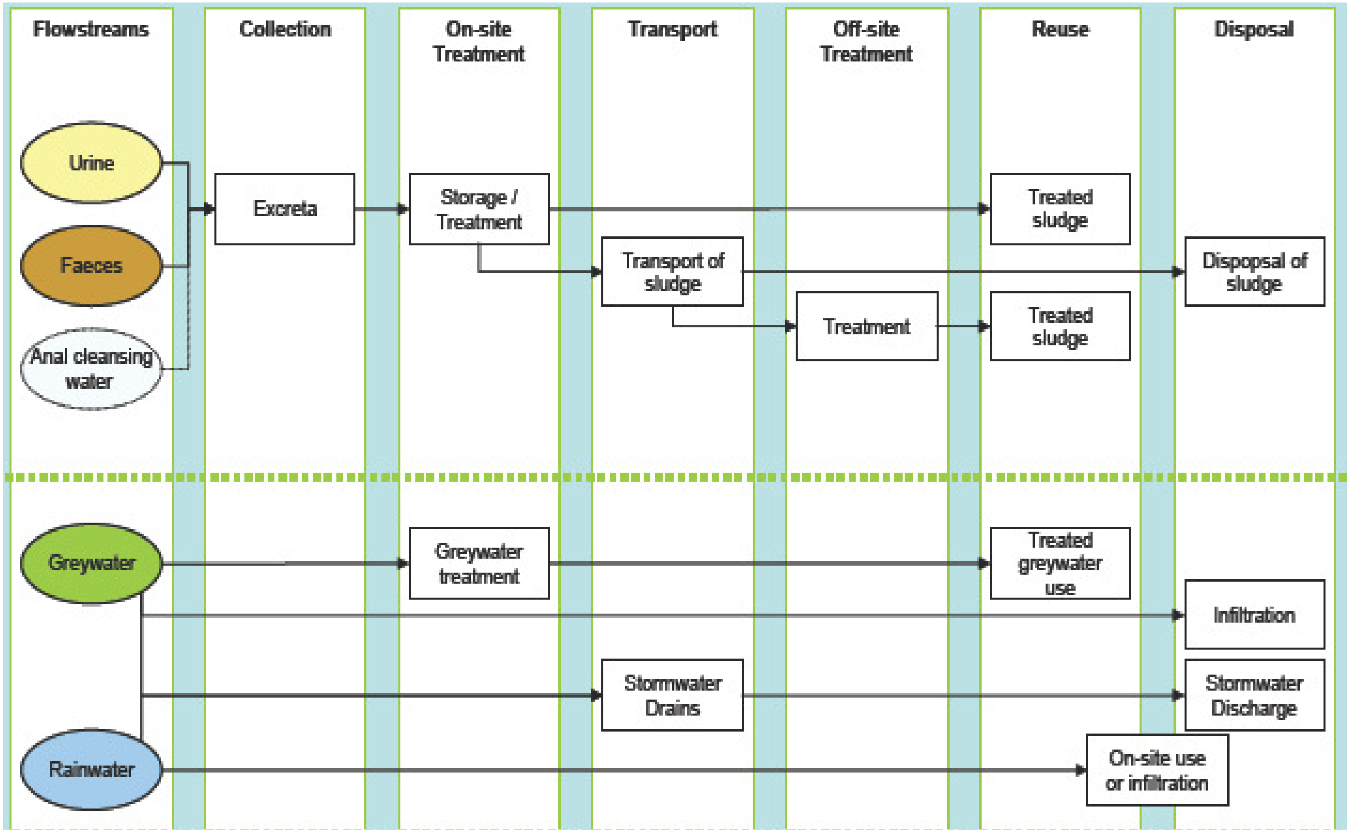

Figure 6: Dry greywater diversion system.

Relevant Flowstreams

Excreta flowstream

As a dry system without flushing water this flowstream consists of faeces and urine. Given the low liquid content technology components comprise on-site storage and treatment facilities. In rural non-densely populated areas where availability of space is not an issue, the drop and store facilities are closed when full and new pits are constructed. In areas of higher density with scarcity of space, either double pits are often observed which are used alternately or an emptying service of excreta must be ensured. Excreta can be co-treated together with solid waste (co-composting), or dried in order to eliminate pathogens before reuse.

Greywater flowstream

Greywater is wastewater from kitchen, bathtub, cleansing facilities, sinks, and laundry and dish washing. Greywater is collected and can be treated and recycled for irrigation and washing. Often, in existing practice greywater is discharged indiscriminately into open drains, onto land for infiltration or fed into soak pits or infiltration trenches. Greywater treatment and reuse systems generally consist of a preliminary treatment to hold back sand, grit and fat with a subsequently treatment technology followed by infiltration into subsurface, discharge into surface waters or for irrigation purpose.

1.6 Dry urine & greywater diversion system

Dry urine and greywater diversion systems are characterized by the diversion of urine, faeces and greywater into three different flow streams. The rationale behind this flowstream diversion is based on the different character of the fractions, when it comes to volumetric flow, nutrient and pathogen content and handling characteristics. The diversion into flow streams facilitates adaptive treatment and end use of the different fractions.

The first unit in the system is a toilet with two outlets. Through the front outlet the urine is collected and conveyed to a storage container (a tank in larger or more expensive systems or a jerry can in smaller, simpler systems) or possibly a soak pit, if the urine is not brought to use. The front outlet is sometimes equipped with a flushing device for rinsing the urine bowl. Through the rear outlet the faeces is collected in a container located underneath the toilet. Wiping material, such as tissue paper or similar, can be dropped through the rear outlet. Where water is used for anal cleansing an additional outlet is provided for collecting anal cleansing water.

The urine can be used as a fertilizer for crop production. Hygiene and sanitation guidelines on how urine as a safe fertilizer for crop production has been published by WHO. In larger systems the urine needs to be sanitized through storage, while in one family systems, the urine can be used directly but the time from fertilizing until harvesting the crop should be at least one month.

The faecal fraction needs to be sanitized, go through a secondary treatment, before being used for crop production. The secondary treatment can be either on-site or off-site. Guidelines how faecal fractions can be sanitized and used in an hygienic way has been published by WHO. The sanitization of the faecal fraction can be combined with the treatment of the organic solid waste fraction.

The greywater can be treated either on-site or off-site after which reuse for irrigation purposes, following the WHO guidelines.

This system is more common in single housing settings but functions also for apartment complexes.

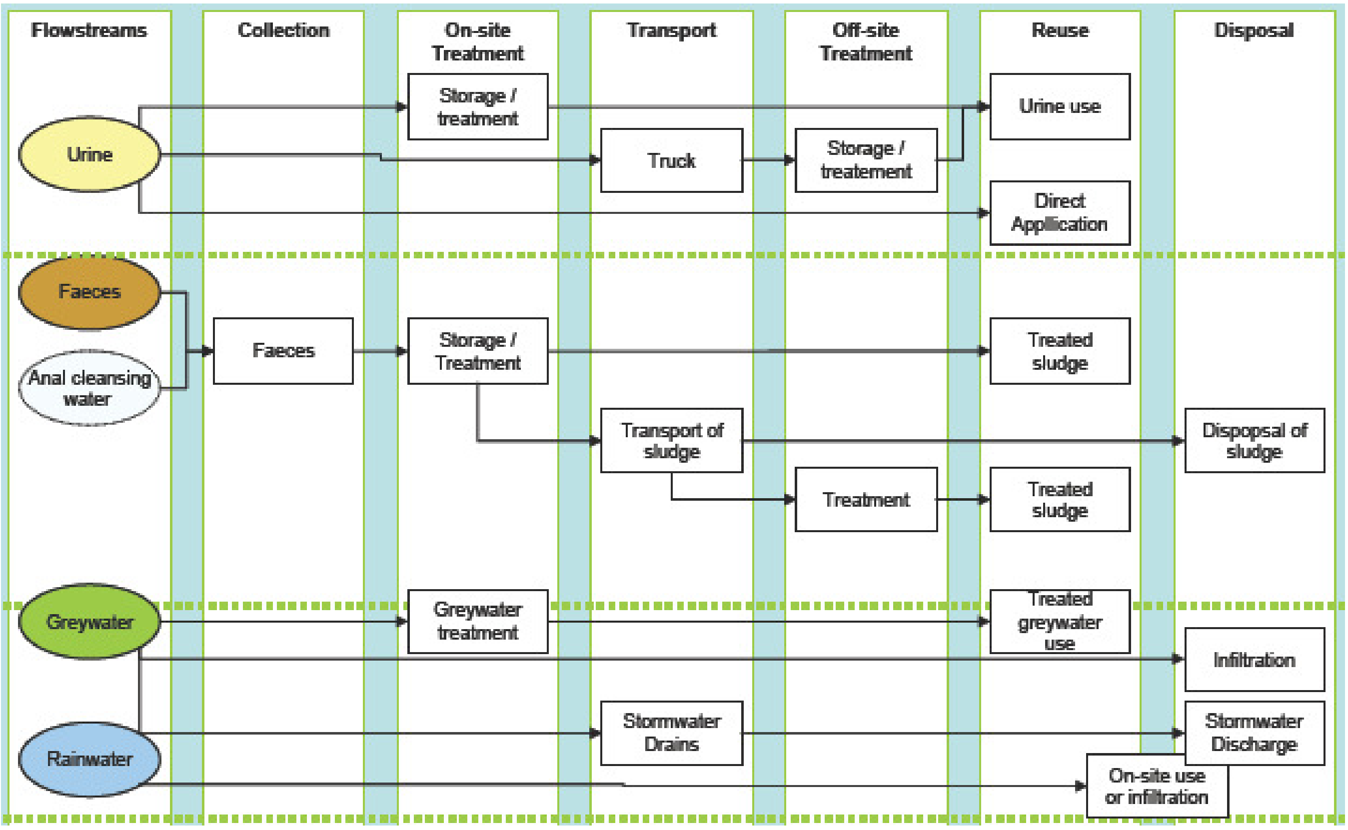

Figure 7: Dry urine and greywater diversion system.

Relevant Flowstreams

Urine flowstream

Urine diverting systems avoid urine coming into contact with faeces thus eliminating potential pathogen contamination and enhancing safe reuse opportunities. Urine is collected separately in a reservoir or canister and stored, and treated and/or transported before reused in agriculture. Urine is an excellent fertilizer. Urine is rich in nitrogen, potassium and phosphorus. The nutrients and minerals, which plants need for growing, are available in a good balance. Separated urine of a healthy person does not contain pathogens. However urine may still be contaminated easily by traces of faeces. For safety reasons it is recommendable to store urine for 1 - 6 months before application. Depending on the diet, human urine collected during one year (ca. 500 liters) contains 4 -5 kg nitrogen, but faeces (ca. 50 kg) only approx. 0,5 kg nitrogen. The urine from 30 persons collected during one year can fertilize one-hectare farmland, which is equal to an application of 120 –150 kg Nitrogen per hectare. Or in other words, the daily urine from one person contains enough nutrients for fertilising approximately 1 m2 field. Nitrogen characteristics of urine are comparable with that of artificial fertiliser and therefore there is a danger to apply too much or too concentrated urine to plants.

Faeces flowstream

The faeces flowstream consist of faeces only. In some cases anal cleansing water may also be included in this flowstream. The relative low liquid content of this flowstream give rise to technologies of storage. Storage may result in dehydration and thus characterize a treatment process. Other on-site treatment steps can be conceived such as composting together with organic solid waste.

Greywater flowstream

Greywater is wastewater from kitchen, bathtub, cleansing facilities, sinks, and laundry and dish washing. Greywater accounts for 60% of the outflow produced in homes. It contains little or no pathogens and 90% less nitrogen than blackwater (toilet water). Because of this, it does not require the same treatment processes as blackwater or mixed wastewater. Greywater can be recycled for irrigation, toilet flushing, and exterior washing, resulting in water conservation. When planned into habitat construction, the home's wastewater treatment system can be significantly reduced, resulting in cost and space savings. Often, in existing practice greywater is discharged indiscriminately into open drains, onto land for infiltration or fed into soak pits or infiltration trenches. Greywater treatment and reuse systems generally consist of a preliminary treatment to hold back sand, grit and fat with a subsequently treatment technology followed by infiltration into subsurface, discharge into surface waters or irrigation purpose.

1.7 Dry all mixed system

This system is characterized by mixing of urine, faeces and greywater in the same facility and can be very frequently observed in rural and peri-urban areas of West Africa. The system is applied in areas where water is scarce or not reliable water supply in sufficient quantity is available. As a dry system it does not use flushing water however may contain anal cleansing water if used in the specific socio-cultural context. Given the lack of flushing water, such a system is not based on waste transport by water and most often the facilities consist of “drop and store” latrine types where the liquid fraction infiltrates into the subsurface. In rural non-densely populated areas where availability of space is not an issue, the drop and store latrine facilities are closed when full and new pits are constructed. In areas of higher density with scarcity of space, either double pits are often observed which are used alternately or regular emptying of faecal sludge must be ensured. Collected sludge then needs be handled in the faecal sludge flowstream.

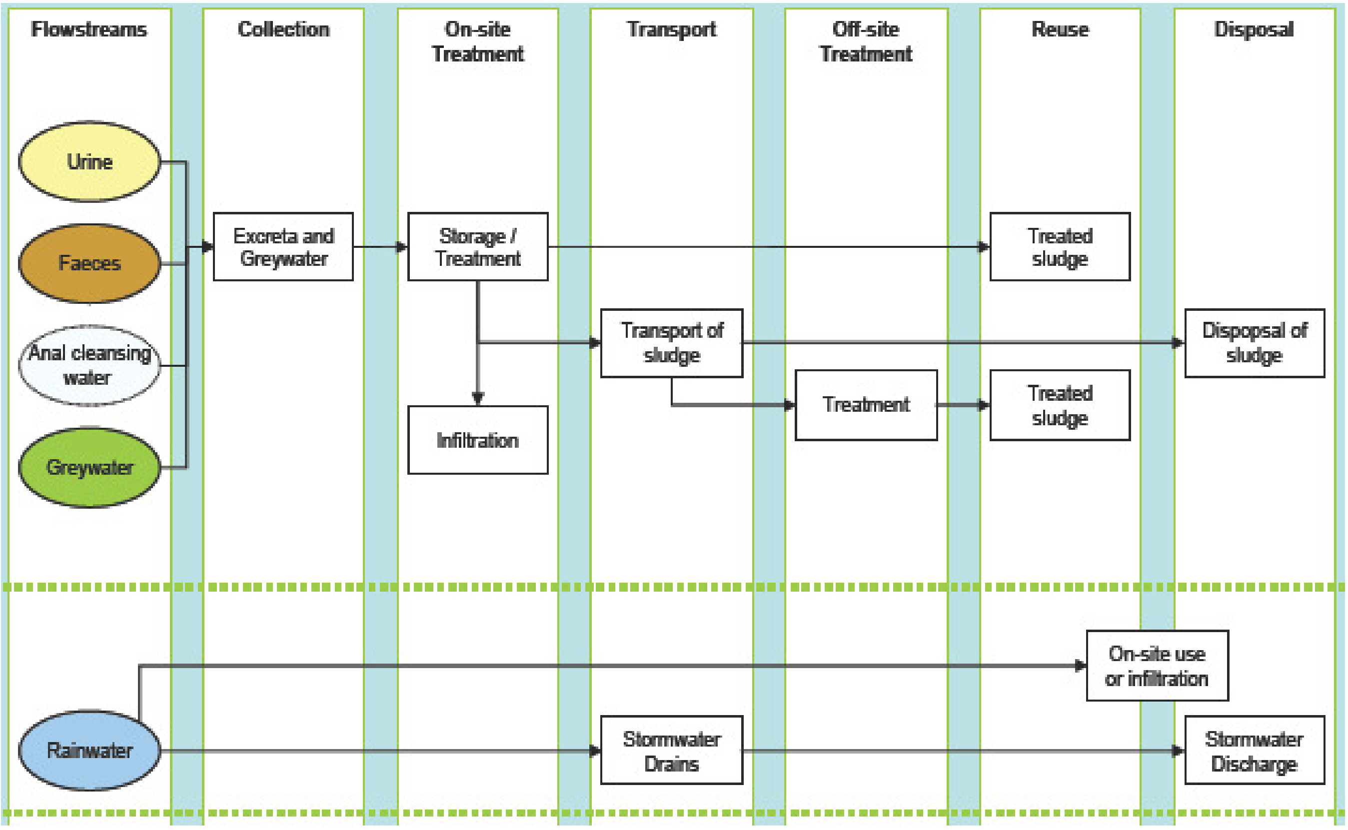

Figure 8: Dry system with all flowstreams mixed (excluding stormwater drainage).

Relevant Flowstreams

Mixed excreta and greywater flowstream

This flowstream consist of mixing of urine, faeces and greywater in the same facility and can be very frequently observed in rural and peri-urban areas of West Africa. Drop and store facilities will need high infiltration rates to avoid rapid filling and overflowing through large volumes of greywater. In areas of higher density with scarcity of space, either double pits are often observed which are used alternately or an emptying service of excreta must be ensured. Faecal sludge, if removed from the pit can undergo specific treatment in feacal sludge treatment plants. Co-treatment together with solid waste (co-composting), dewatering, dehydration, humification, or tretament in pond systems are viable oiptions.

PART 2 Flowstreams and technology assessment

This section lists the identified relevant flowstreams which can be observed in different systems. These flowstream can be occurring in different systems depending on the level of separation. The following flowstreams have been identified:

Waste flowstreams	Description
mixed wastewater flowstream	Mixed wastewater flowstream consists of a mix of urine, faeces, flushing water, and greywater. Rainwater from stromwater drainage may or may not be diverted into the sewer and mixed with this flowstream (mixed sewer system or separate sewer system) *in: System 1 (chapter 1.1.)*
blackwater flowstream	Blackwater flowstream consists of a mix of urine, faeces, and flushing water. Lack of greywater in this flowstream may limit self-cleansing velocity in a sewer network given the reduced liquid content. Blackwater however may also be stored/treated on-site in appropriate facilities. Such on-site storage/tretament most often entails settling of the solid fraction, and a partial treatment of the liquid as well as solid fraction. The liquid fraction may then be infiltrated into the subsurface or be transported further to treatment plants, and subsequently , reused, or discharged whereas the solids remain to be handled separately as faecal sludge flowstream. *in: System 2 (chapter 1.2.)*
brownwater mixed with greywater flowstream	Faeces, flushing water and greywater are the components of this flowstream. Given its compostition it is similar to a mixed wastewater flowstream with the exception of the missing urine. Thus, on-site treatment or else transport by a sewer and off-site treatment can be options for treatment before reuse of the effluent. On-site storage/treatment facilities most often entail settling of the solid fraction, and a partial treatment of the liquid as well as solid fraction. The solid fraction (faecal sludge) must then be further managed in the faecal sludge flowstream. By separation of urine, brownwater contains less nutrients (as nitrogen and phosphorous is mainly contained in the urine). This aspect of low nutrient content is further enhanced by the inclusion of greywater with even lower nutrient contents. *in: System 3 (chapter 1.3.)*
brownwater flowstream	Brownwater consists of faeces and flushing water without urine or greywater. Given the relative lack of liquids, on-site “drop and store” latrine types are mostly used for storage/treatment of this flowstream. Long term storage may dehydrate and treat the solid fraction. This dehydration and treatment can be enhanced through sunlight (heat), dewatering facilities or by adding solid waste for co-composting. Nevertheless in areas where space is scarce, solids might need to be emptied and treated further (faecal sludge flowstream) *in: System 4 (chapter 1.4.)*
faecal sludge flowstream	In various sanitation systems sludge, or "biosolids," are the byproduct of the treatment of wastewater in a wastewater treatment plant. In on-site sanitation systems which often entail settling of the solid fraction and separation from the liquid fraction, the sludge may be stabilized through storage (on-.site systems such as pits, latrines, or septic tank facilities). Collection of this sludge and its treatment can reduce pathogens and vector attraction by a variety of methods. Sewage sludge which derives not only household wastewater but also industrial wastewater may contain high levels of toxic chemicals which are not removed during treatment. Depending on the origin of the

	wastewater the level of treatment and resultant pollutant content, sludge can be used in regulated applications ranging from soil conditioning to fertilizer for food or non-food agriculture or distribution for unlimited use. *in: System 1 (chapter 1.1.); System 2 (chapter 1.2); System 3 (chapter 1.3); System 4 (1.4); and System 7 (1.7)*
greywater flowstream	Greywater is wastewater from kitchen, bathtub, cleansing facilities, sinks, and laundry and dish washing. Greywater accounts for 60% or more of the outflow produced in homes. Often, in existing practice greywater is discharged indiscriminately into open drains, onto land for infiltration or fed into soak pits or infiltration trenches. Greywater treatment and reuse systems generally consist of a preliminary treatment to hold back sand, grit and fat with a subsequently treatment technology followed by infiltration into subsurface, discharge into surface waters or irrigation purpose. *in: System 2 (chapter 1.2); System 4 (1.4); System 5 (1.5), System 6 (1.6)*
urine flowstream	Urine diverting systems avoid urine coming into contact with faeces thus eliminating potential pathogen contamination and enhancing safe reuse opportunities. Urine is collected separately in a reservoir or canister and stored, and treated and/or transported before reused in agriculture. *in: System 3 (chapter 1.3); System 4 (1.4); System 6 (1.6)*
excreta flowstream	Excreta flowstream results from a dry system without flushing water. This flowstream consists solely of faeces and urine. Given the low liquid content, technology components comprise on-site storage and treatment facilities. In rural non-densely populated areas where availability of space is not an issue, the drop and store facilities are closed when full and new pits are constructed. In areas of higher density with scarcity of space, either double pits which are used alternately or an emptying service of excreta must be ensured. Excreta can be co-treated together with solid waste (co-composting), or dried in order to eliminate pathogens before reuse. *in: System 5 (chapter 1.5)*
faeces flowstream	The faeces flowstream consist of faeces only. In some cases anal cleansing water may also be included in this flowstream. This flowstream resemables the excreta flowstream however with less liquid content (as urine is missing). The relative low liquid content of this flowstream give rise to technologies of storage or composting. Storage may results in dehydration and thus characterize a treatment process. Treatment options may also involve addition of solid waste. *in: System 6 (chapter 1.6)*
excreta mixed with greywater flowstream	This flowstream consists of mixing of urine, faeces and greywater in the same facility. In areas of higher density with scarcity of space, either double pits are used alternately or an emptying service of excreta (faecal sludge) must be ensured. Faecal sludge can be co-treated together with solid waste (co-composting), or dried in order to eliminate pathogens before reuse. *in: System 7 (chapter 1.7)*

		Collection			Transport					on-site storage / treatment					off-site treatment							
Technologies applicable for: ▪ **Mixed Wastewater flowstream** ▪ **Blackwater flowstream** ▪ **Brownwater mixed with Greywater flowstream** ▪ **Brownwater flowstream**		**C1 Cistern Flush toilets**	**C2 - Low-flush toilets**	**C3 - Pour-flush toilets**	**TR1 - Gravity sewers**	**TR2 - Small bore sewers**	**TR3 - Simplified Sewerage**	**TR4 - Vacuum sewerage:**	**TR5 - Open drains**	**on-TM1 - Septic tank:**	**on-TM2 - anaerobic baffled reactor:**	**on-TM3 - Anaerobic digester**	**on-TM4 - Trickling filter:**	**on-TM5 - UASB reactor**	**off-TM1 - Pre-treatment**	**off-TM2 - Waste stabilization ponds**	**off-TM3 - Advanced integrated pond systems (AIPS)**	**off-TM4 - Floating macrophyte ponds**	**off-TM5 - Constructed Wetlands**	**off-TM6 - UASB technologies**	**conventional activated sludge systems**	
Health issues																						
reduces exposure to pathogens	of users	++	++	++	+	-	-	o	--	+	+	o	o	o	o	+	+	-	o	o	+	
	of waste workers				+	-	-	-	--	-	-	+	o	o	+	-	o	-	o	-	-	
	of resource recoverers /reusers								--						+	-	+	+	o	o	o	
	of “downstream” population				-				--						+	+	+	o	+	+	+	
hygienization rate									--	-	-	-	-	-	-	+	+	o	o	+	+	
increases health benefits		+	+	+	+	+	+	+	--	+	+	+	+	+	o	+	+	+	+	+	+	
Impact to environment / nature																						
use of natural resources	needs low land requirements				o	-	-	+	-	+	-	-	-	-	++	--	-	-	-	-	o	
	needs low energy requirements	++	++	++	++	++	++	--	+	+	+	++	-	++	++	++	+	o	o	-	--	
	uses mostly local construction material	-	-	+	+	+	++	--	++	+	+	-	--	--	++	++	+	+	+	--	--	
	low water amounts required	--	+	+	--	-	-	++	+	-	-	--	o	-								
low emissions and impact to the environment	surface water	--	-	+	o	o	o	o	--	-	o				+	+	+	+	+	+	+	
	ground water	--	-	+	-	-			--	-	o				+	-	-	-	+	+	+	
	soil / land								--	o	o				+	-	o	o	-	o	o	
	air								-	--	--				+	-	o	o	o	o	o	
	noise, smell, aesthetics	+	+	+				+	-	--	--	o	-	o	-	--	-	-	+	+	-	
good possibilities for recovering resources	nutrients	-	-	-					+	-	--				+	+						
	energy	-	-	-					+	--	--	++	--	++	--	-						
	organic matter	-	-	-					+	o	o	o	o	o	o	+						
	water	--	-	-					+	+	+	+	+	+	+	++						
Technical characteristics																						
allows simple construction and low level of technical skills required for construction		-	+	+	-	+	+	--	++	+	-	--	--	--	++	+	o	+	+	--	--	
has high robustness and long lifetime/high durability		0	+	++	-	-	-	--	-	+	+	o	-	-	++	+	o	+	+	-	-	

	Collection			Transport					on-site storage / treatment					off-site treatment							
Technologies applicable for: ▪ **Mixed Wastewater flowstream** ▪ **Blackwater flowstream** ▪ **Brownwater mixed with Greywater flowstream** ▪ **Brownwater flowstream**	**C1 Cistern Flush toilets**	**C2 - Low-flush toilets**	**C3 - Pour-flush toilets**	**TR1 - Gravity sewers**	**TR2 - Small bore sewers**	**TR3 - Simplified Sewerage**	**TR4 - Vacuum sewerage:**	**TR5 - Open drains**	**on-TM1 - Septic tank:**	**on-TM2 - anaerobic baffled reactor:**	**on-TM3 - Anaerobic digester**	**on-TM4 - Trickling filter:**	**on-TM5 - UASB reactor**	**off-TM1 - Pre-treatment**	**off-TM2 - Waste stabilization ponds**	**off-TM3 - Advanced integrated pond systems (AIPS)**	**off-TM4 - Floating macrophyte ponds**	**off-TM5 - Constructed Wetlands**	**off-TM6 - UASB technologies**	**conventional activated sludge systems**	
enables simple and low operational procedures and maintenance and low skills required	-	-	+	+	+	+	--	++	+	-	--	--	-	+	+	-	-	-	--	--	
Economical and financial issues																					
has low construction costs (unit cost per household)	-	0	+	-	+	+	--	++	-	-	--	--	--	+	+				--	--	
provides benefits to the local economy (business opportunities, local employment, etc.)	+	+	+	+	+	+	+	++	+	o	o	o	o	o	o	o	o	o	o	o	
has low operation and maintenance costs	-	-	+	-	-	-	--	++	+	o	-	--	--	+	+	+	+	+	--	--	
provides benefits or income generation from reuse								+	o	o	++	-	+	-	+						
Social, cultural and gender																					
delivers high convenience and high level of privacy	++	+	+	+	+	+	+	-	++	+	o	o	o	o	+	+	+	+	+	+	
requires low level of awareness and information to assure success of technology	+	+	+	+	-	-	--	-	+	+	-	o	--	-	+	+	+	+	+	+	
requires low participation and little involvement by the users	+	+	+	+	-	-	--	-	+	+	-	--	--	-	+	+	+	+	+	+	
takes special consideration issues of women, children and elderly	++	++	++	+	+	+	+	-	++	++	o	o	o	o	+						

		Transport		Treatment					Reuse										
Technologies applicable for: ▪ **Faecal sludge flowstream**		**TR9 - Manual emptying and transport**	**TR10 - emptying and transport by suction truck**	**TM9 - Faecal sludge co-composting**	**TM10 - humification beds (constructed wetlands)**	**TM11 - unplanted drying beds**	**TM12 - settling ponds**	**TM13 - anaerobic digestion**	**R4 - Faecal sludge reuse in agriculture**	**R4 - Faecal sludge reuse in aquaculture**									
Health issues																			
reduces exposure to pathogens	of users	--	+	+	+	+	-	+	+	-									
	of waste workers	--	-	-	-	-	o	-	+	o									
	of resource recoverers /reusers	--	-	+	n.a.	+	+	++	++	o									
	of "downstream" population	-	--	+	n.a.	+	-	+	o	o									
hygienization rate		--	--	++	+	+	o	+	-	-									
increases health benefits		-	+	+	+	+	+	+	+	+									
Impact to environment / nature																			
use of natural resources	needs low land requirements	+	+	+	-	--	--	o	n.a.	n.a.									
	needs low energy requirements	++	--	+	+	++	++	++	n.a.	n.a.									
	uses mostly local construction material	++	--	++	+	+	+	--	n.a.	n.a.									
	low water amounts required	++	-	--	+	o	o	--	n.a.	n.a.									
low emissions and impact to the environment	surface water	-	-	n.a.	-	-	-	-	-	-									
	ground water	-	-	n.a.	-	+	n.a.	n.a.	o	o									
	soil / land	--	--	n.a.	+	+	n.a.	+	++	++									
	air	-	-	n.a.	+	+	n.a.	--	o	o									
	noise, smell, aesthetics	--	--	-	+	-	-	-	-	-									
good possibilities for recovering resources	nutrients	++	++	++	--	++	+	o	++	++									
	energy	o	--	--	--	o	o	++	o	o									
	organic matter	++	++	++	--	+	+	++	++	++									
	water	++	++	-	+	+	+	-	++	++									
Technical characteristics																			
allows simple construction and low level of technical skills required for construction		++	+	++	+	+	+	-	n.a.	n.a.									
has high robustness and long lifetime/high durability		-	--	+	+	+	+	-	n.a.	n.a.									

enables simple and low operational procedures and maintenance and low skills required	++	+	+	+	+	+	-	n.a.	n.a.									
	Transport		**Treatment**					**Reuse**										
Technologies applicable for: ▪ **Faecal sludge flowstream**	**TR9 - Manual emptying and transport**	**TR10 - emptying and transport by suction truck**	**TM9 - Faecal sludge co-composting**	**TM10 - humification beds (constructed wetlands)**	**TM11 - unplanted drying beds**	**TM12 - settling ponds**	**TM13 - anaerobic digestion**	**R4 - Faecal sludge reuse in agriculture**	**R4 - Faecal sludge reuse in aquaculture**									
Economical and financial issues																		
has low construction costs (unit cost per household)	++	--	++	-	+	-	--	n.a.	n.a.									
provides benefits to the local economy (business opportunities, local employment, etc.)	+	+	+	+	+	o	o	++	++									
has low operation and maintenance costs	++	--	+	+	o	--	-	+	+									
provides benefits or income generation from reuse	+	+	+	+	+	o	+	++	++									
Social, cultural and gender																		
delivers high convenience and high level of privacy	--	++	+	+	+	+	+	+	+									
requires low level of awareness and information to assure success of technology	--	+	+	+	+	+	+	+	+									
requires low participation and little involvement by the users	-	+	-	+	+	+	+	+	+									
takes special consideration issues of women, children and elderly	o	o	+	+	+	+	+	+	+									

		on-site (off-site) treatment						reuse			disposal		
Technologies applicable for: ▪ **Greywater flowstream**		**on-TM14 - Greywater pre-treatment**	**on-TM15 - Flotation – grease trap**	**on-TM16 - Slow sand filtration**	**on-TM17 - Horizontal subsurface flow constructed wetland system**	**on-TM18 - Horizontal free flow constructed wetland system**	**on-TM19 - Vertical flow constructed wetland system**	**on-TM20 - Greywater garden (mulch trench)**	**on-TM21 - Green walls**	**on-TM22 - Tower garden**	**on-TM23 - Subsurface wastewater infiltration system**	**on-TM24 - Anaerobic filtration**	
Health issues													
reduces exposure to pathogens	of users	o	o	+	++	-	++	-	+	+	++	+	
	of waste workers	o	o	o	o	o	o	o	o	o	o	o	
	of resource recoverers /reusers	-	-	+	++	+	++	-	+	+	+	+	
	of "downstream" population	-	-	o	o	o	o	o	o	o	o	o	
hygienization rate		--	--	++	++	+	++	+	+	+	++	++	
increases health benefits		-	-	++	++	+	++	+	+	+	++	++	
Impact to environment / nature													
use of natural resources	needs low land requirements	+	+	+	-	-	-	o	+	+	+	+	
	needs low energy requirements	++	++	++	++	++	++	++	+	+	++	++	
	uses mostly local construction material	++	++	++	++	++	++	++	++	++	++	++	
	low water amounts required	+	+	+	++	++	++	++	++	++	++	++	
low emissions and impact to the environment	surface water	--	--	++	+	+	++	--	o	o	-	-	
	ground water	-	-	+	+	+	+	+	+	+	--	-	
	soil / land	o	o	o	o	o	o	-	-	-	o	o	
	air	+	+	+	+	+	+	+	+	+	+	-	
	noise, smell, aesthetics	--	--	-	+	-	+	-	-	-	o	o	
good possibilities for recovering resources	nutrients	+	+	-	-	+	+	++	++	++	--	--	
	energy	--	--	-	-	-	-	-	-	-	--	-	
	organic matter	--	--	-	+	+	+	++	++	++	-	-	
	water	+	+	++	++	++	++	o	o	o	--	--	
Technical characteristics													
allows simple construction and low level of technical skills required for construction		+	+	o	+	+	+	+	++	++	+	+	
has high robustness and long lifetime/high		+	+	o	+	+	+	++	++	++	++	+	

durability												
	on-site (off-site) treatment						reuse			disposal		
Technologies applicable for: ▪ **Greywater flowstream**	**on-TM14 - Greywater pre-treatment**	**on-TM15 - Flotation – grease trap**	**on-TM16 - Slow sand filtration**	**on-TM17 - Horizontal subsurface flow constructed wetland system**	**on-TM18 - Horizontal free flow constructed wetland system**	**on-TM19 - Vertical flow constructed wetland system**	**on-TM20 - Greywater garden (mulch trench)**	**on-TM21 - Green walls**	**on-TM22 - Tower garden**	**on-TM23 - Subsurface wastewater infiltration system**	**on-TM24 - Anaerobic filtration**	
enables simple and low operational procedures and maintenance and low skills required	+	+	-	+	+	+	++	++	++	+	-	
Economical and financial issues												
has low construction costs (unit cost per household)	+	+	-	-	-	-	++	++	++	+	o	
provides benefits to the local economy (business opportunities, local employment, etc.)	+	+	o	o	o	o	++	++	++	o	o	
has low operation and maintenance costs	+	+	+	+	+	+	++	++	++	+	o	
provides benefits or income generation from reuse	--	--	o	o	o	o	++	++	++	o	o	
Social, cultural and gender												
delivers high convenience and high level of privacy	o	o	+	+	+	+	+	+	+	+	+	
requires low level of awareness and information to assure success of technology	--	--	+	+	+	+	--	--	--	+	+	
requires low participation and little involvement by the users	-	-	-	-	-	-	--	--	--	+	+	
takes special consideration issues of women, children and elderly	--	--	o	o	o	o	o	o	o	o	o	

Technologies applicable for: Urine flowstream		collection			transport			on-site treatment			off-site treatment		reuse									
		C4a Low flush urine diverting toilets	C4b - Pour-flush urine diverting toilets	C5 - Urinal	TR6 - Urine pipes	TR7 - Manual urine transport	TR8 - Truck for urine transport	on-TM6a - Urine Long time storage in large storage tank	on-TM6b - Urine Can bucket or container storage	on-TM7 - Urine Desiccation	off TM 11 - Off-site urine storage tank	off-TM12 - Urine MAP-dissipation	R1 - Urine direct application	R2 - Urine on-site reuse	R3 - Urine mechanized off-site reuse							
Health issues																						
reduces exposure to pathogens	of users	0	0	0	++	-	++	0	0	-	0	+	+	-	-							
	of waste workers	n.a.	n.a.	n.a.	+	--	-	0	0	0	0	0	+	n.a.	-							
	of resource recoverers /reusers	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	+	-	-	+	-	0 / +	-	-							
	of "downstream" population	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	+	+	+	+	+	0	0	0							
hygienization rate		n.a.	n.a.	n.a.				+	+	+	+	+										
increases health benefits		n.a.	n.a.	n.a.	0	0	0	0	0	0	0	+	n.a.	n.a.	n.a.							
Impact to environment / nature																						
use of natural resources	needs low land requirements	+	+	++	-	++	++	0	+	0	0	-	+	-	-							
	needs low energy requirements	++	++	++	++	+	--	++	++	0	++	--	++	++	-							
	uses mostly local construction material	-	-	+	-	n.a.	n.a.	+	++	+	+	--	+	n.a.	-							
	low water amounts required	-	-	+	+	n.a.	n.a.	++	++	++	++	+	+	0	0							
low emissions and impact to the environment	surface water	0	+	+	+	+	+	++	++	++	++	++	+	+	+							
	ground water	0	+	+	0	+	+	++	++	++	++	++	+	+	+							
	soil / land	0	0	0	0	+	0	+	++	+	++	++	-	0	0							
	air	0	0	0	+	+	+	++	++	0	++	++	0	0	0							
	noise, smell, aesthetics	0	0	0	+	0	-	0	0	-	0	0	+	+	+							
good possibilities for recovering resources	nutrients	++	++	++	n.a.	n.a.	n.a.	++	++	++	++	++	+	++	++							
	energy	0	0	0	n.a.	n.a.	n.a.	0	0	0	0	-	n.a.	n.a.	n.a.							
	organic matter	++	++	n.a.	n.a.	n.a.	n.a.	0	0	0	0	0	n.a.	n.a.	n.a.							
	water	+	+	+	n.a.	n.a.	n.a.	+	+	0	+	0	n.a.	n.a.	n.a.							
Technical characteristics																						
allows simple construction and low level of technical skills required for construction		-	-	0	-	n.a.	n.a.	+	++	-	+	--	+	++	0							
has high robustness and long lifetime/high durability		0	0	0	0	-	-	+	++	+	+	--										

	collection			transport			on-site treatment			off-site treatment		reuse									
Technologies applicable for: **Urine flowstream**	**C4a Low flush urine diverting toilets**	**C4b - Pour-flush urine diverting toilets**	**C5 - Urinal**	**TR6 - Urine pipes**	**TR7 - Manual urine transport**	**TR8 - Truck for urine transport**	**on-TM6a - Urine Long time storage in large storage tank**	**on-TM6b - Urine Can bucket or container storage**	**on-TM7 - Urine Desiccation**	**off TM 11 - Off-site urine storage tank**	**off-TM12 - Urine MAP-dissipation**	**R1 - Urine direct application**	**R2 - Urine on-site reuse**	**R3 - Urine mechanized off-site reuse**							
enables simple and low operational procedures and maintenance and low skills required	0	0	+	+	-	-	+	+	+	+	--	++	+	-							
Economical and financial issues																					
has low construction costs (unit cost per household)	0	0	+	--	n.a.	n.a.	-	++	0	-	--	+	++	-							
provides benefits to the local economy (business opportunities, local employment, etc.)	+	+	+	0	+	+	0	+	+	0	+	-	-	+							
has low operation and maintenance costs	-	0	+	-	++	--	+	+	-	-	-										
provides benefits or income generation from reuse	++	++	++	n.a.	n.a.	n.a.	++	++	++	++	++										
Social, cultural and gender																					
delivers high convenience and high level of privacy	++	++	++	+	0	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.							
requires low level of awareness and information to assure success of technology	--	--	+	++	0	0	+	+	-	+	--	+	-	-							
requires low participation and little involvement by the users	-	-	+	++	-	-	0	-	-	0	0	0	-	0							
takes special consideration issues of women, children and elderly	0	0	0	0	0	0	n.a.	n.a.	n.a.	n.a.	n.a.	0	0	0							

Technologies applicable for:

- **Excreta flowstream**
- **Faeces flowstream**
- **Excreta mixed with greywater**

		on-site treatment / storage													transport			reuse				
		Pit latrine	Ventilated pit latrine	Double pit latrine	Composting toilet	Arboor Loo	Fossa Alterna	Composting	Co-composting	Worm composting	Anaerobic digestion	Ammonia sanitation	drying and humification	unplanted drying bed	manual transport	non-motorized transport	suction truck	soil conditioner				
Health issues																						
reduces exposure to pathogens	of users	-	-	-	+	+	+	+	+	+	+	+	+	+	n.a.	n.a.	n.a.	+				
	of waste workers	-	-	-	o	o	o	-	-	+	--	o	-	--	o	o	o	+				
	of resource recoverers /reusers	-	-	-	o	o	o	+	+	+	-	o			n.a.	n.a.	n.a.	+				
	of "downstream" population	-	-	-	+	+	+	+	+	+	+	+	+	+	o	o	o	+				
hygienization rate		-	-	-	+	+	+	+	+	+	+	+	+	-	n.a.	n.a.	n.a.	+				
increases health benefits		o	o	o	+	+	+	+	+	+	+	+	+	-	n.a.	n.a.	n.a.	+				
Impact to environment / nature																						
use of natural resources	needs low land requirements	-	-	-	+	o	+	-	-	+	+		-	--	n.a.	n.a.	n.a.	+				
	needs low energy requirements	+	+	+	+	+	+	o	o	+	o		++	++	+	-	--	+				
	uses mostly local construction material	+	+	+	+	+	+	+	+	+	--		+	++	n.a.	+	o	n.a.				
	low water amounts required	+	+	+	+	+	+	-	-	-	--		+	++	n.a.	n.a.	n.a.	++				
low emissions and impact to the environment	surface water	o	o	o	+	+	+	+	+	+	o		-	-	+	+	+	+				
	ground water	-	-	-	+	+	+	o	o	o	o		--	--	+	+	+	+				
	soil / land	-	-	-	+	o	+	+	+	+	o		-	-	o	o	o	+				
	air	o	o	o	o	o	o	+	+	+	--		--	--	+	+	-	+				
	noise, smell, aesthetics	--	--	--	+	+	+	+	+	+	-		--	--	+	-	-	+				
good possibilities for recovering resources	nutrients	-	-	-	++	++	++	++	++	++	-		--	+	n.a.	n.a.	n.a.	++				
	energy	-	-	-	+	+	+				++		-	--	n.a.	n.a.	n.a.	o				
	organic matter	-	-	-	++	++	++	++	++	++	+		-	+	n.a.	n.a.	n.a.	++				
	water	-	-	-	-	-	-				+		+	--	n.a.	n.a.	n.a.	+				
Technical characteristics																						
allows simple construction and low level of technical skills required for construction		+	+	+	+	+	+	+	+	+	--	o	+	++	n.a.	n.a.	n.a.	+				
has high robustness and long lifetime/high durability		-	o	-	+	+	+	n.a.	n.a.	n.a.	-	o	+	++	+	o	-	n.a.				

enables simple and low operational procedures and maintenance and low skills required	+	+	+	+	+	+	-	-	-	--	o	+	++	+	+	o	+				
	on-site treatment / storage													**transport**			**reuse**				
Technologies applicable for: ▪ **Excreta flowstream** ▪ **Faeces flowstream** ▪ **Excreta mixed with greywater**	**Pit latrine**	**Ventilated pit latrine**	**Double pit latrine**	**Composting toilet**	**Arboor Loo**	**Fossa Alterna**	**Composting**	**Co-composting**	**Worm composting**	**Anaerobic diogestion**	**Ammonia sanitation**	**drying and humification**	**unplanted drying bed**	**manual transport**	**non-motorized transport**	**suction truck**	**soil conditioner**				
Economical and financial issues																					
has low construction costs (unit cost per household)	o	-	-	+	+	+	+	+	o	--	o	++	++	n.a.	n.a.	n.a.	+				
provides benefits to the local economy (business opportunities, local employment, etc.)	o	o	o	o	o	o	o	o	o	+	o	o		-	+	+	+				
has low operation and maintenance costs	+	+	+	+	+	+	++	++	++	--	+	+	+	+	-	-	+				
provides benefits or income generation from reuse	-	-	-	+	+	+	++	++	++	++	o	o		n.a.	n.a.	n.a.	++				
Social, cultural and gender																					
delivers high convenience and high level of privacy	-	-	-	+	+	+	n.a.	n.a.	n.a.	o	+	+	+	n.a.	n.a.	n.a.	o				
requires low level of awareness and information to assure success of technology	+	+	+	o	o	o	-	-	-	--	--	+	+	o	o	o	+				
requires low participation and little involvement by the users	+	+	+	-	-	-	--	--	--	--	-	+	+	+	+	+	+				
takes special consideration issues of women, children and elderly	-	-	-	-	-	-	o	o	o	o	o	o	o	o	o	o	-				

PART 3 Technology components

Toilet & collection technolgies [C]

C1 - Cistern-flush toilets

Flush toilets use water to flush human excreta into a storage, treatment or transport facility. After the toilet is used water is poured into the pan to flush the toilet. Flush toilets normally have a U-shaped conduit partly filled with water (U trap) under the pan. The U trap overcomes the problems of flies, mosquitoes, and odor by serving as a water seal. Conventional cistern-flush toilets use between 10 and 20 litres per flush.

C2 - Low-flush toilets

Low flush (or low flow) toilets are designed to use about six litres of water per flush, significantly less water than the conventional flush toilets. This reduces water requirements in single family residences by about 20%. Although a 6-L toilet looks like a conventional toilet, it has several unique features. Most 6-L toilets use gravity to speed the course of water through the bowl and trap. The rim wash comes through an open slot rather than small holes. The bowl may have steep sides and a narrow trap opening. Six-litre flush toilets generally have a smaller pool or "water spot" than that in conventional toilets. In addition there is also the option of dual flush technologies. With this there are two options with the toilet, a full flush and a half flush depending upon whether we need to get rid of solid matter or not. Dual low flush can give you a 6 litre / 3 litre choice.

C3 - Pour-flush toilets

The pour-flush (PF) pan comprises a the latrine pan with its integral waterseal. Below or connected to to the pan by small diameter pipework are single or double leach pits or a cess pit or septic tank. The trap maintains a waterseal, which helps in odor and fly control. The latrine functions as follows: Excreta deposited on the pan are flushed by a low volume of handpoured water through the waterseal and connecting pipework into the collection structure; about 2-3 litres of water are required. The pan is thereby cleaned after each use, while the waterseal is maintained to provide a barrier against odors and insects.

Literature: The Design of Pour-Flush Latrines. D. Mara (1985). Available at: http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2003/03/14/000178830_98101903445990/Rendered/PDF/multi0page.pdf

C4 - Urine diversion toilet

The urine diversion toilet differs from an ordinary toilet as it attempts to collect the urine separately from the faeces for potential reuse applications. It offers the same comfort and functional service as regular toilets. Simple designs of urine diverting seated pedestal toilets and squatting plates are available as self-constructed or prefabricated. Flush and non-flush systems offer appropriate technology options for simple and complex environments. Toilets are commonly constructed of sanitary porcelain, concrete, fibreglass or plastic. These toilets may be introduced with construction of new sanitation systems or complement the existing system with minor modification. Distinguished urine diversion toilet designs include: the *urine diversion flush toilet* (similar to the WC), the *waterless toilet with urine collection funnel*, and a *vacuum toilet system*. Careful planning and appropriate design selection is essential for practical application of urine diversion toilets. Necessary requirements include: water for flush systems, adequate space and structural support, quality materials and workmanship. Metals should be avoided within the system as they are prone to corrosion when in contact with urine. Durable plastics are a viable alternative. Ventilation of urine collection is discouraged to prevent volatile nitrogen losses. Only a small venting for pressure equalisation of the storage containers should be used. Urine diversion flush toilets come as wall-hung and floor models. Specific connections parts may be necessary for proper installation. Installation following manufacturer's instructions is recommended to ensure precise fit. Easily accessible and removable connections can help in case replacement is required.
The choice of toilet design will also influence the system capacity. Urine diversion dry toilets come as pedestal seats and squatting plates, and should be applied in accordance with the cultural norms of the intended user. They may be manufactured or sometimes self constructed from concrete, porcelain, or plastic. Some urine diversion dry toilets require electrical fans for ventilation, thus demanding a reliable source of adequate power.

C4a) Flush toilet with urine diversion

The urine diversion flush toilet has a partition in the toilet bowl isolating a bowl for urine in the front, and a bowl for faeces in the rear. Some designs allow for each bowl to be flushed separately. The collection of undiluted urine is also possible.

C4b) Urine diversion waterless toilet

The urine diversion waterless toilet is a very simple configuration adapted to a drop toilet whereby the urine is captured in a bowl in the front of the toilet and drained off to a storage container or leaching pit. The waterless toilet requires no water for flushing the faecal fraction, although small doses may be used to flush the urine.

C5 - Urinal

A urinal is a specialized toilet designed to be used only for urination by men and boys. It often contains a deodorizing urinal cake contained within a plastic mesh guard container or a plastic mesh guard without a urinal cake. The plastic mesh guard is designed to prevent solid objects such as cigarette butts, feces, or paper from being flushed and possibly causing a plumbing stoppage. Normal urinals use water for flushing.

Squatting-type ladies' urinals are as well available on different international and local markets. The variety of styles ranges from prefabricated versions up to on site designed urinals.
Source: http://www.sphinx.nl (product name "Lady P"); www.ruralsanitation.com; www.eparryware.com; www.hintwarebathrooms.com; www.cera-india.com

a) Waterless urinals have been used for a long time. Their development was particular driven by the needs of arid areas, where water is too vital to waste to simply transport urine. They have also been used for quite some time in industrialised countries. Here the motivation was mainly economic to reduce the costs of water supply, particularly in highly frequented buildings. Waterless urinals collect undiluted urine, which can then be collected, treated and used. Waterless urinals come in many shapes and materials: squatting slabs or wall mounted bowls are available, while materials range from reused plastics vessels, over concrete and high-quality plastics and porcelain to stainless steel. Prefabricated urinals are available both as high quality products and as low-cost options. Self-construction of inexpensive waterless urinals is also possible and easy.

From a functional point of view the main distinguishing feature of urinals is the type of odour trap that prevents the emission of gases and odours from urine pipes. Simple and low cost urinals often have no odour trap. Odour problems therefore may occur but can often be prevented by only having one urinal on each pipe and letting the inlet pipe into the collection vessel go down almost to the bottom, thus forming a liquid trap there. Four types of odour trap are available: membrane barriers, liquid barriers, electromagnetic and hydrostatic float barriers. In urinals with a membrane stench barrier, the odour trap consists of a flat rubber tube. The urine passes through this membrane, which then closes when the urine flow stops and seals the urine outlet, preventing smell. In urinals with liquid odour traps the urine passes through a liquid odour seal made of oil or aliphatic alcohols. The urine, which is heavier than the liquid, sinks down through the liquid and further down to the drain. The sealing liquid is environmentally friendly and for the most part biodegradable. In urinals with electromagnetic float barrier the urine passes into the cylindrical inner part of the pan and from there to the overflow chamber, whereby the float rises and seals the inlet opening against a flexible sealing lip. When the urine in the overflow chamber reaches a certain level it flows into the drain of its own accord. Every time the urinal is used, a sensor activates an electromagnet that draws the float down again to ensure complete emptying of any residual urine. Instead of using a magnetic device driven by electricity, urinals with hydrostatic float barrier are also available. The urine presses down the float and therefore the channel is open and urine flows out. When the urine in the overflow chamber reaches a certain level it overflows. The float trap will move up and close again. It is designed in a way that the float will move downwards even when the pressure from urine received is very small, to ensure that no urine is blocked and remains outside.

b) Low flush urinals are also available, where the urine is diluted with water. There have been no significant acceptance problems with waterless urinals for men as it does not call for any change of behaviour on their part

C6 - Dry toilet squatting slab

A dry toilet is simply without flushing water. The toilet may be raised as a seat or else is a squat pan where the user squats over. Pedestals and squatting platforms can be made locally with only concrete. Dry toilets do not have odour seals. Therefore odour nuisance is frequent. Nevertheless the dry squatting slab is low cost.

C7 - Simple pit latrine

Is the most commonly used sanitation technology. Pit latrines are made of a latrine superstructure and a hole for defecation. A pit cover slab can be used to reduce odour and hinder flies. Average depth is 3 m. The depth is usually limited by the groundwater table or rocky underground. The underground of the latrine should be water pervious. Dry anal cleansing is advantageous to minimise water content.

C8 - Ventilated improved pit latrine (VIP)

Ventilated improved pit (VIP) latrines are designed to reduce two problems frequently encountered by traditional latrine systems—smells and flies or other insects. A VIP latrine differs from a traditional latrine in having a vent pipe covered with a fly screen. Wind blowing across the top of the vent pipe creates a flow of air, which sucks out the foul-smelling gases from the pit. As a result, fresh air is drawn into the pit through the drop hole and the superstructure is kept free from smells. The vent pipe also has an important role to play in fly control. Flies are attracted to light and if the latrine is suitably dark inside, they will fly up the vent pipe to the light. They cannot escape because of the fly screen, so they are trapped at the top of the pipe until they dehydrate and die. Female flies, searching for an egg-laying site, are attracted by the odours from the vent pipe but are prevented from flying down the pipe by the fly screen at its top.

(Brikké, F. (2000): Operation and Maintenance of rural water supply and sanitation systems – A training package for managers and planner. IRC, The Netherlands)

C9 - Double pit latrine

Pit latrines and VIP latrines can also be constructed with a double pit. The latrine has two shallow pits, with/without a vent pipe for every pit and one superstructure. The cover slab has two drop holes, one over each pit. Only one pit is used at a time. When this becomes full, its drop hole is covered and the second pit is used. After a period of at least one year, the contents of the first pit can be removed safely and used as soil conditioner. The pit can be used again when the second pit has filled up.

a) instead of using alternating pits, such an approach can also be used by constructing vaults which are above ground and is known as **double vault latrine.** The vaults (located above ground) are better suited for locations with high groundwater table and also enable easier emptying.

(Brikké, F. (2000): Operation and Maintenance of rural water supply and sanitation systems – A training package for managers and planner. IRC, The Netherlands)

C10 - Composting toilet

The basic principle of a composting toilet system is the biological degradation of excreta (and toilet paper if included) in a specially designed container. Urine can be collected separately, or in some types of composting toilets treated together with faeces. The decomposition process is called “composting”, which is the degradation of organic matter by thermophilic aerobic bacteria and other micro organisms. These bacteria rely on a good aeration of the material, on optimal moisture content and a specific carbon to nitrogen ratio. Thus important factors in composting toilets is water content and carbon to nitrogen ratio. Including urine or even anal cleansing water may result in too high water content which will affect the composting process. As faeces alone have a low carbon content, addition of organic solid waste can improve the carbon nitrogen ratio. Human excreta and food waste alone do not provide those optimum conditions since their water content and the nitrogen content are too high. Therefore an additive or so-called bulking agent is recommended to lower the water content, to improve aeration and to increase the carbon content of the material. Wood, chips, bark chips, sawdust, paper and other substances are commonly used. Since good aeration is very important, the container is usually equipped with a ventilation system that improves aeration of the material and provides odour control. Moreover, with bulking agents, the pore spaces of the composting pile can be increased; hence it will be less compact, leading to better aeration. However, too much air flow can remove too much heat and moisture, therefore the condition within the composter should not be too cool or dry. Another benefit of adding bulking materials is to increase C/N ratio in order to attain the optimum composting condition. Sometimes these bulking materials also have an additional effect on odour control by binding the substances causing bad odours. One main effect of the decomposition process in a composting toilet is the considerable volume reduction (10-30% of the original mass), thus allowing the prolonged storage of waste in the container. The emptying frequency depends on the size of the container, the feeding rate and the composting rate (volume reduction). The decomposition process in a composting toilet is rarely a real thermophilic composting with temperature rising above 50℃, which would guarantee complete pathogen destruction and hygienization of the waste. The pathogen content is reduced considerably in a composting toilet. However, complete pathogen destruction can only be achieved if good process conditions can be guaranteed, e.g. by using an advanced toilet design with insulation for maintaining a high temperature within the whole composting chamber. The end product of a composting toilet is an odourless stabilized material, which is very valuable as soil conditioner. It can be used directly for non-food plants or for agriculture use. Further treatment for hygienization such as additional heap-composting or prolonged storage increases hygienic safety of agricultural use. Although there are many different composting toilet designs that continue to evolve, the basic concept of composting remains the same. A composting toilet has two basic elements: a place to sit (or to squat) and a composting chamber. Apart from those basic elements, a ventilation system is highly recommended in order to stimulate aeration and prevent odour. The system can either be designed with or without urine diversion.

Further readings:
- gtz ecosan data-sheet 03 A: en-ecosan-tds-03-a-composting-toilets-general-description-2006.pdf
- gtz ecosan data-sheet 03 B1: en-ecosan-tds-03-b1-single-vault-composting-toilets-2006.pdf
- gtz ecosan data-sheet 03 B2 : en-ecosan-tds-03-b2-multiple-vault-composting-toilets-2006.pdf
- gtz ecosan data-sheet 03 B3: en-ecosan-tds-03-b3-movable-bin-composting-toilets-2006.pdf
- gtz ecosan data-sheet 03 B4 : en-ecosan-tds-03-b4-mixing-composting-toilets-2006.pdf

C11 - Arbor Loo latrine

For an Aberloo the pit is shallow, about 1.0 to 1.5m deep, and the toilet site is temporary. Excreta, soil, ash and leaves are added to the pit. The toilet - consisting of a ring beam, slab and structure - moves from one site to the next at 6 to 12-month intervals. The old site is covered with soil and left to compost. A tree is planted on the old site, preferably during the rains.

(Morgan, P. (2007): Toilets that make Compost. Low-cost, sanitary toilets that produce valuable compost for crops in an African context. EcoSanRes, Sweden)

C12 - Fossa alterna

For the Fossa alterna there are two permanently sited shallow pits, about 1.5m deep and dug close to each other, which are used alternately (similar to the double pit latrine). For a medium sized family the pit takes about 12 months to fill up and this same period allows sufficient time for the mix of excreta, soil, ash and leaves to form compost which can be excavated. Every year one pit is excavated whilst the other becomes full. If the pits remain stable this process can continue for years.

(Morgan, P. (2007): Toilets that make Compost. Low-cost, sanitary toilets that produce valuable compost for crops in an African context. EcoSanRes, Sweden).

Transport Technologies

TR1 - Gravity sewers

Conventional gravity sewers convey raw, untreated wastewater through pipelines to a treatment facility or lift station. Household sewage is collected by an underground pipe system to treatment facilities or directly into receiving waters. Conventional sewerage consists of individual house connections to a piped reticulation system. The reticulation systems normally include a series of pump stations to convey the sewage through the system, especially on atoll and coastal communities due to flat topography and high groundwater levels. Manholes and other access chambers are required to maintain and clean the sewerage systems. The sewer lines are straight and installed on a specific horizontal and vertical alignment, with interspaced manholes placed at set intervals, at pipe intersections and at changes in pipeline direction. The pipes are installed with uniform gradients sufficient to create a self-cleansing velocity (0.6-0.75 m/sec). Concrete manholes allow access for inspection, cleaning, and repair. Construction of these systems on flat terrain typically use deep excavations (1.5 - 3.8 meters below grade) and proper preparation and bedding materials are required in the pipeline trenches. The excavation of trenches for pipes may be difficult where the ground is rocky, the groundwater table is high, and pipes and cables had previously been installed, particularly where their location is not accurately documented. The sewers and manholes are most typically installed along the centerline of roadways and have service collection laterals extending perpendicular to the roadway alignment. If required, a lift/pump station collects the sewage transported by the collection piping. High degree of operation and maintenance required especially if pumping is required and skilled personnel is required. This may be suitable for wealthy, high-density areas, e.g. the central business districts of major towns but is usually not suitable for rural or poor communities.
Advantages: Convenient for household members
Disadvantages: High costs (operation & maintenance); Sophisticated technology requiring skilled engineers, contractors and operator; Reliable piped water supply required; Adequate treatment and/or disposal/reuse required for a large point source discharge.

Literature: Wastewater technologies and management for pacific islands, UNESCO-IHE - UNEP/GPA

TR2 - Small bore sewers

This technology is also known as settled sewerage or solids-free sewerage. This is a means of conveying domestic sewage which has been settled in a septic tank (sometimes referred to, in this context, as a solids interceptor tank) or to remove the settled wastewater from aqua-privy tanks. Consideration of self-cleansing (or other) velocities is not necessary with settled sewerage since all the solids which would block the sewer are retained in the interceptor tank. This technology may also involve *inflective gradients* where the design of settled sewer roughly follows ground contours and the flow in the sewer is allowed to vary between open channel flow and pressure (full-bore) flow. There must be an overall fall from the upstream end of the sewer to its downstream end. The sewer is divided into sections over which the flow is of the same type (i.e. open channel or pressure flow) and reasonably uniform (i.e. the sewer can be laid at a more or less constant gradient). Choosing a pipe diameter (at least 75 mm), the actual peak flow in each section must be less than the “just full” flow (if it is not, the next larger sewer diameter is selected). In sections where there is pressure flow, the hydraulic gradient cannot rise above the level of the invert of any interceptor tank outlet (if it does, then either select the next larger pipe diameter or increase the depth at which the sewer is laid). Given that existing septic tanks are at the rear of properties, the settled sewer can be laid there, rather than in the road (as in normal with conventional sewerage), and this will result in considerable cost savings (and is in fact analogous to the backyard or condominal variant of simplified sewerage). Manholes are not required at every junction or change of direction; simple cleanouts suffice. Lift stations are only required in very flat areas, but these are simple structures with a water pump, rather than a more expensive sewage pump since there are no solids to be pumped. Small-bore sewers have the following characteristics compared to conventional sewers:

- Smaller pipe diameters
- Flatter pipe gradients
- Shallower pipe depths
- Fewer access chambers (no manholes)

Settled sewerage construction costs are typically 20–50 percent less than those of conventional sewerage in the rural USA. In areas with existing septic tanks, the cost reduction will be higher, 40–70 percent.

Advantages: Lower capital cost than conventional sewerage
Disadvantages: Smaller diameter pipes may result in a higher risk of blockages and thus increased maintenance; High technology requiring skilled engineers, contractors and operators; Reliable piped water supply required

Literature:
http://www.sanicon.net/titles/topicintro.php3?topicId=8.
Wastewater technologies and management for pacific islands, UNESCO-IHE - UNEP/GPA

TR3 - Simplified Sewerage

Simplified sewerage (also known as condominial sewerage) collects all household wastewaters in small-diameter pipes laid at fairly flat gradients—for example, a 100 mm diameter sewer laid at a gradient of 1 in 200 (0.5 percent) will serve around 200 households of 5 people with a wastewater flow of 80 litres per person per day. The sewers are often laid inside the housing block, or in the front garden or under the pavement (sidewalk), rather than in the centre of the road as with conventional sewerage. It is suitable for existing unplanned low-income areas and new housing estates with a more regular layout. Plastic pipes are best used as they are easily jointed correctly, and this essentially eliminates wastewater leakage from the sewer and groundwater getting into it. With simplified sewerage there is no need to have the large expensive manholes of the type used for conventional sewerage—simple brick or plastic junction chambers are used instead. Simplified sewerage is most widely used in Brazil. It has also been used in other South American countries and some Asian countries. Currently, construction costs of simplified sewerage (in Brasília) are around US$ 22–34 per person. Condominial sewerage became cheaper than on-site systems at the quite low population density of *ca.* 160 people per hectare. Good operation and maintenance is essential for the long-term sustainability of simplified sewerage. Models of having one of the villagers employed by the Residents' Association to maintain the sewers and the wastewater treatment plant or having local contracting firms for O&M have shown good results.

Literature:
http://www.sanicon.net/titles/topicintro.php3?topicId=8

TR4 - Vacuum sewerage:

Vacuum sewerage systems consist of: i) the vacuum station, where the vacuum is generated, ii) the vacuum pipeline system; iii) collection chambers with collection sumps and; iv) interface valve units. Batches of wastewater are driven by air streaming from the collection chambers towards the vacuum station. In contrast to conventional gravity sewerage systems with intermediate pumping stations, the pressure within the vacuum system is maintained below atmospheric pressure. The interface valve units are operated pneumatically - no electricity for the operation of the valves is needed. Vacuum systems can, in certain circumstances, significantly reduce investment costs and/or operating expenses, as compared to conventional sewerage systems. Vacuum technology reduces water consumption considerably, enabling flexible installations regardless of topography. In addition, it allows for the use of alternative wastewater handling (black/grey water separation). It is therefore sometimes used in conjunction with urine diverting systems. The vacuum sewerage system can have advantages over conventional sewerage systems especially for the following applications:

- Insufficient natural slope, i.e. flat countryside
- Poor subsoil conditions (i.e. unstable soil or rock, high groundwater table)
- Seasonal operation (e.g. in holiday resorts)
- Frequently flooded areas

However a high degree of operation and maintenance and skilled personnel is required (similarly to conventional sewerage systems)

Advantages:

- Small diameter pipes of PVC or PE reduces costs
- Reduced installation costs, due to narrow and shallow trenches
- No manholes required, due to maintenance free sewer lines
- Exfiltration impossible, thus ideal for water protection areas
- Installations of water supply and vacuum sewer in the same trench allowed

Disadvantages:

- Specialised equipment required; may not be locally available
- Technology requires skilled engineers, contractors and operators, among others for quick detection and repair of leaks.
- Reliable piped water supply and electricity required

The technology implies high capital costs but can be less than conventional sewerage systems, depending on the situation

Literature: Wastewater technologies and management for pacific islands, UNESCO-IHE – UNEP/GPA

TR5 - Open drains

Open drains or open ditches for wastewater transport are frequently observed in developing countries. They may transport all kind of wastewater. Indiscriminately disposed solid waste may cause blockage of drains. Overflowing drains, siltation or standing sullage may result in bad odours and public health risk. Drains may also be partially covered by solid or mobile concrete slabs to prevent blockages by litter and humans from getting in contact with the wastewater. Nevertheless, as they are open, they are also easy to build and easy to maintain.

TR6 - Urine pipes

The toilet is connected to a semi-central collection tank with a pipeline; this option is possible when there are more households using urine diverting toilets. The transport can be either done by gravity or pressure or vacuum pipes. Pipelines imply higher building costs for the infrastructure and need to be maintained. For frequent and high loads of urine in dense areas, this is an applicable solution. The urine piping system will imply an additional piping system. The minimum recommended diameter of the urine gravity sewer is 75 mm, but the optimum range is from 75 mm to preferably 110mm inside houses and where the pipe is easily accessible for cleaning 50 mm can be allowed at the expense of more maintenance. The slope must be at least 1 %. Within these parameters the sludge formed in the system will steadily flow at the bottom of the pipes towards the collection tank. For inspection and cleaning the pipes should have frequent access points. It is essential that the pipe system is tight against ground water, joints in the ground should be avoided, if this is not possible they should be welded or glued. It is also important that the pipes are not ventilated, only pressure equalized.
Pressure and vacuum sewers can have a diameter of 50 mm.

TR7 - Manual urine transport

A donkey or other animal or the user himself or another person transports the urine in a container. .; this transport mean is suitable when the amount of urine is small and a truck is not profitable or in areas that the truck cannot reach. The user can carry or roll (if the container has wheels) the container to reuse or further storage facility (e.g. field or container). The same type of cart used for distribution of water in jerry cans in many places of the world is well suited also for transport of urine. Manual transport is possible when the facility is not far away from the collection point.

TR8 - Truck for urine transport

The on- or off-site collected urine is fetched by a suction truck; An access road for trucks is necessary. The truck is expensive for small urine loads or short distances. If the urine is transported over longer distances and high volumes are transported, this option can be feasible

Further readings:
gtz ecosan data-sheet 01 B.3: en-ecosan-tds-01-b3-urine-diversion-piping-storage-2005.pdf

TR9 - Manual faecal sludge emptying and transport

This can mean two things: i) sludge is being emptyied using buckets, or ii) a portable manually operated pump system is being used (MAPET). The MAPET technology consists of a hand pump connected to a vacuum tank. Depending on the consistency of the sludge, the MAPET can pump up to 3 m in height.

TR10 - Faecal sludge emptying and transport by suction truck

The on-site collected faecal sludge is collected by a motorized suction truck. Often the septic tank opening is not accessible with the suction tube or the truck is located too far away from the suction hole. Such trucks are commercially available.

On-site storage and treatment technolgies

Related to wastewater

on-TM1 - Septic tank:

A septic tank generally consists of a watertight tank which is connected to an inlet wastewater pipe at one end and to a septic drain field at the other. These pipe connections are generally made via a T pipe which allows liquid entry and egress without disturbing any crust on the surface. Today the design of the tank usually incorporates two chambers (each of which is equipped with a manhole cover) which are separated by means of a dividing wall which has openings located about midway between the floor and roof of the tank. 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, depending upon locality. The remaining impurities decompose in the soil, and the water is eliminated through percolation into the soil, and eventually taken up through the root system of plants or added to the groundwater. A piping network, often constructed in a stone filled trench (see weeping tile), distributes the wastewater throughout the field with multiple drainage holes in the network. The size of the leach field is proportional to the volume of wastewater and inversely proportional to the porosity of the drainage field. The entire septic system can operate by gravity alone, or where topographic considerations require, with inclusion of a lift pump.

Advantages: A properly designed and normally operating septic system is odor free and besides periodic inspection and pumping of the septic tank should last for decades with no maintenance. A well designed and maintained concrete, fiberglass or plastic tank should last about 50 years

Disadvantages: Waste that is not decomposed by the anaerobic digestion eventually has to be removed from the septic tank or else the septic tank fills up and undecomposed wastewater discharges directly to the drainage field. Not only is this bad for the environment, but if the sludge overflows the septic tank into the leach field, it may clog the leach field piping requiring expensive repairs.

By careful management many users can reduce emptying to every 3 to 5 years. When emptying a tank, only a small residue of sludge should be left in the tank. Anaerobic decomposition is rapidly re-started when the tank re-fills. How often the septic tank has to be emptied depends on the volume of the tank relative to the input of solids, the amount of indigestible solids and the ambient temperature (as anaerobic digestion occurs more efficiently at higher temperatures). In general it is rare for a septic tank system to require emptying more than once a year.

on-TM2 - Cesspit

A cesspit, or cesspool is a watertight pit, conservancy tank, or covered cistern, which can be used for sewage or refuse. Disadvantages: Because it is sealed, the tank must be emptied very frequently — in many cases as often as weekly. Because of the need for frequent emptying, the cost of maintenance of a cesspit can be very high.

on-TM3 - Anaerobic baffled reactor:

The anaerobic baffled reactor (ABR) can be regarded as an upgraded septic tank. The ABR consists of an initial settler compartment and a second section of a series of baffled reactors. The baffles are used to direct the flow of wastewater in an upflow mode through a series of sludge blanket reactors. This configuration provides a more intimate contact between anaerobic biomass and wastewater, which improves treatment performance. The treatment efficiency achievable is 70-95 % BOD removal, which makes the effluent quality moderate but usually superior to that of a conventional septic tank. As for the septic tank system, sludge removal is also important for the ABR and must be done regularly. Flow regulation is also important as up-flow velocity should not exceed the design value

Advantages:

- Process simplicity
- no electrical requirements
- Construction material locally available
- Low land space required
- Low capital costs

Disadvantages:

- Needs skilled contractors for construction
- Needs strategy for faecal sludge management (effluent quality rapidly deteriorates if sludge not removed regularly)

System requires low to medium capital costs. It may be suitable for relatively wealthy areas with low population density that want to achieve better effluent quality than with conventional septic tank.

Literature:
Wastewater technologies and management for pacific islands, UNESCO-IHE – UNEP/GPA

on-TM4 - Anaerobic digester:

The biogas digester is a facility, in which organic material is broken down under anaerobic conditions (without oxygen). This process produces biogas (consisting about two thirds (by volume) of methane), which can be used for cooking and lighting. In some countries, the biogas digester is commonly introduced for households with husbandry activities, to generate energy (biogas), to cover a daily need (the households often need additional energy sources, especially in colder seasons). But it is also possible to use this technology for domestic wastewater only, especially when the user prefers a low flush toilet, and has other competitive energy sources.
Biogas digesters operate best in warm climates, as high temperatures assure a sufficient production of biogas and destruction of pathogens. The effluent from the reactor, a dark slurry, is a nutrient-rich fertilizer for agriculture and aquaculture, due to conservation of nitrogen during the anaerobic process. To assure hygienic quality, especially when mixing human wastes, a long retention time (>60 days) should be used, and/or a post treatment step (e.g. wetlands, drain fields). This technology can be used to replace existing septic tanks, by integrating the septic tanks as an inlet chamber. There are different designs available, especially in the leading countries for household biogas technology, namely China, India and Nepal. The size ranges commonly from 6 to 10 m^3. Larger biogas digesters serving several households or a whole community are also feasible (up to 50 m^3). Biogas digesters are usually built underground to protect them from temperature variations and also to prevent accidental damage. Hence, they use very little space. Operational requirements are low, due to automatic influent feeding and mixing of animal and toilets wastes. Limited operator skill required (but household members need training to understand the system). The plant needs checking for gas leaks, especially from distribution pipes. Furthermore desludging is occasionally necessary.

Advantages:

- Provides source of biogas, this results in less dependence on fossil fuels, which may not be readily available to households
- Improves the household overall sanitation by treating blackwater, organic wastes, and manure
- Effluent is a nutrient rich fertilizer, and more hygienic than untreated human waste
- Less frequent/ almost no desludging required compared to septic tanks
- Can be built locally
- Through airtight design
- no leakages will occur

Disadvantages:

- Requires good design
- Skilled, trained labour is required for the construction of the biogas digester
- Requires availability of animal excrements for optimal biogas production
- There are sometimes cultural prejudices against using gas from human waste

The system implies medium capital costs, but an additional high revenue by saving of energy costs and higher agricultural yields. The technology is suitable for rural areas, especially when families also have animal waste, and where there is a need for gas for cooking. High ambient temperatures increase biogas production.

Literature:
Wastewater technologies and management for pacific islands, UNESCO-IHE - UNEP/GPA

on-TM5 - Trickling filter:

The Trickling filter consists of either a rock or gravel medium. Organisms that grow in a thin biofilm over the rock or gravel medium oxidise the organic pollution in the wastewater to carbon dioxide and water (and new biomass). Oxygen is obtained by direct diffusion from air into the thin biological film. Preliminary settlement of sewage is required after which it is “trickled” over the surface of the filters, often by using rotating distribution pipes. Typically, 80 % BOD removal can be achieved with a correctly sized trickling filter. Some nitrification can also be achieved, depending on the organic loading rate to the filter. Skilled labour is required to keep the trickling filter running trouble-free: e.g. prevent clogging, ensure adequate flushing, control filter flies.

Advantages: High effluent quality in terms of BOD and suspended solids removal; Low operational costs (low electricity requirements); Simpler process compared to activated sludge process or some package treatment plants

Disadvantages: High operation and maintenance requirements; Needs electrical power; More space required compared to some other technologies; Potential for odour and filter flies

Relative capital costs (compared to similar techniques) are moderate to high.

Literature:
Wastewater technologies and management for pacific islands, UNESCO-IHE - UNEP/GPA

on-TM6 - UASB reactor:

The Upflow Anaerobic Sludge Blanket (UASB) Reactor is a tank filled with anaerobic granular or flocculant sludge with good settling properties (the bacteria may spontaneously agglomerate to form granules). Influent wastewater is distributed at the bottom of the UASB reactor and travels in an upflow mode through the sludge blanket. The anaerobic degradation of organic substrates occurs in this sludge blanket, where biogas is produced. The gases produced under anaerobic conditions (methane and carbon dioxide) serve to mix the contents of the reactor as they rise to the surface. Critical elements of the UASB reactor design are:

- Influent distribution system
- Gas-solid separator
- Effluent withdrawal design

Modifications to the basic UASB design include adding a settling tank or the use of packing material at the top of the reactor. The presence of a settler on the top of the digestion zone enables the system to maintain a large sludge mass in the UASB reactor, while an effluent with low concentrations of suspended solids is discharged. The UASB reactor has the potential to produce higher quality effluent than septic tanks, and can do so in a smaller reactor volume. Whilst it is a well-established process for large-scale industrial effluent treatment processes, its application to on-site domestic sewage is still relatively new. Effluent from the UASB will usually still require further treatment prior to discharge to the environment (similarly to septic tanks). Skilled personnel is required for construction and maintenance and the monitoring and control is critical during the start-up period.
Advantages: Low production of stabilised sludge; Higher treatment efficiency than septic tanks and less space required; No energy required for treatment; Biogas can be used for energy (but usually requires scrubbing first)
Relative capital costs: (compared to similar techniques) are low to medium. Operational cost are low.

Literature:
Wastewater technologies and management for pacific islands, UNESCO-IHE - UNEP/GPA

Related to urine

on-TM7 - Urine Long time storage in different types of containers

If the urine is collected by a urine diversion toilet or urinal, it passes through a separate pipe system to a collection tank which can be connected to just one toilet or to more households. The collection tank can be made of different materials like plastics and steel. The size has to be designed according to the amount of people using the toilet and the needed storage time for hygienisation (urine is usually stored for three to six month).

on-TM7a - Urine long time storage in large storage tank. The urine is collected and removed locally or by a tank or suction truck and can be transported to an agricultural area, where it is used as a fertiliser. In large systems, a secondary storage container, e.g. at the field, is required to further sanitise the urine before use. The collection tank serves as a temporary storage. Where the urine is transported by tank truck, the volume of the collection tank should normally correspond to the tank truck volume for an economical and ecological transport. It is normally placed in or close to the toilet. If the urine is to be use in the household garden, a simple construction is also possible. Large storage tanks can be located near the fields. This is very practical from the farmer's point of view, since they are readily accessible and make it possible to apply the urine directly by means of a feeder hose.

on-TM7b - Urine can, bucket or container storage: For lower volumes urine can be stored in cans, buckets or smaller containers (jerry cans). This is mostly used in rural areas where the toilet is situated outside the house; cheap system that can be build from used jerry cans; easy to handle: has to be emptied more frequently or content has to be stored in bigger central tank or brought to direct application (not recommended due to hygienic reasons)
Bacteria, protozoa and viruses in urine are inactive and die-off gradually with the time of storage. An environment with high temperature, low dilution and high pH level promotes sanitisation of the urine. Therefore, in large systems (more than one household) storage is often used as a convenient and cheap urine treatment measure before its application to the plants. Guidelines for safe use of urine and faeces recommend that urine collected from many households for reuse in agriculture should be stored under temperature of 4-20°C for 1-6 months depending on the types of crops. With average temperatures > 20°C, 1 month of storage is sufficient, except for vegetables eaten raw. Urine collected from individual household can be used directly on crops that are intended for own consumption. In both cases one month between urine application and harvesting is recommended.

Further readings:
gtz ecosan data-sheet 01 B.3: en-ecosan-tds-01-b3-urine-diversion-piping-storage-2005.pdf

on-TM8 - Urine Desiccation

Urine is led to a metal table and sunlight evaporates the water content of the urine; residual crystals are easily handled and reusable as fertilizer. Having this system can result in risk for high level of smell during the drying process. Another method leads urine via a short pipe to a container with wood ash. The ventilation of this container evaporates the water content of the urine; ash and residual crystals are easily handled and reusable as fertilizer.

Related to excreta and faecal sludge

on-TM9 - Faecal sludge co-composting

Faecal sludge (FS) always consists of a solid and liquid fraction. There is the option to co-treat FS in an existing or planned WWTP if the FS loads are small compared to the flow of wastewater. However there are also special technologies to treat FS describe here and below. The optimum conditions for composting are a moisture content of about 50 %, a carbon to nitrogen ratio of about 25 to 30, and temperature of 55 oC. Because wastewater sludge is rich in nutrients, its carbon to nitrogen ratio is low (5 to 10). It is also high in moisture. Addition of dry sawdust, which is very high in carbon to nitrogen ratio (500) can adjust both the moisture and carbon to nitrogen ratio. Other waste materials that can be used for this purpose are mulched garden wastes, forest wastes and shredded newspaper. Faecal sludge can be mixed with organic solid waste and composted in windrows, heaps or boxes for a period of 2-4 months. The water content of faecal matter determines how much material can be added to the solid waste. Therefore drying faecal sludge in drying beds allows using more faecal matter per composting windrow. Heat build-up in the composting heap will ensure hygienisation of the feacal matter.

on-TM10 - Faecal sludge treatment by constructed wetlands (humification)

Constructed wetlands (*Planted dewatering/drying beds)* have been successfully operated for treating Bangkok septage. An optimum loading rate of 250 TS/m2.year was established based on 6 years of field research with 3 pilot constructed wetland beds. The beds were planted with *Typha angustifolia* (narrow-leaved cattail). Each of them has a surface of 25 m2 and was fed with 8 m3 of septage once a week. Ponding periods of 6 days were found optimum. The CW were able to accumulate 70 cm of sludge after 4 years of operation while maintaining their full permeability. The TS content of the dewatered sludge varied from 20-25 % in the uppermost layer (< 20 cm) to 30-35 % in the deeper layers. Under steady loading conditions, the percolate quality was constant.

on-TM11 - Faecal sludge treatment by unplanted drying beds

Unplanted drying beds can be used for dewatering and drying of septage and septage/public toilet sludge mixtures at volumetric ratios > 2:1 as well as primary pond sludges with initial TS content varying from 1.5 to more than 7%. Dewatering performance varies with the initial TS and TVS content and the applied loads. Pescod (1971), in conducting septage dewatering/drying experiments on yard-scale drying beds in Thailand found that 5 to 15 days of dewatering were necessary to reach a TS content of 25% with initial solids loading rates varying from 70 to 475 kg TS/m2/year and a loading depth of 20 cm. In Ghana, a dewatered sludge with 40 % TS was obtained from a mixture of septage/public toilet sludge in 12 days with an initial solids loading rate of 200 TS/m2/year and a loading depth of < 20 cm. With a solids loading rate of 130 TS/m2/year, a sludge with 70% TS was obtained in 9 days and a reduction in the percolating liquid (compared to the raw sludge mixture) of 60% BOD5 and 70 % COD was achieved.

on-TM12 - Faecal sludge treatment by settling ponds

In settling ponds removal efficiencies of suspended solids (SS) can achieve 96 % with two alternating, batch-operated septage sedimentation ponds. Septage deliveries to the pond in operation is suspended and the supernatant transferred to the parallel pond when the settled solids layer has reached 50 cm. The accumulated sludge is let to dewater until a total solids concentration of 20-25 % and, hence, spadability is attained. This lasted up to 6 months Bulking material such as grain husks, sawdust or woodchips could be used under such conditions to shorten the storage and dewatering time. This type of settling pond is designed based on an assumed pond emptying frequency and on the known or expected solids accumulation rate.

on-TM13 - Faecal sludge treatment by anaerobic digestion

Similarly to anaerobic digestion of wastewater, faecal sludge can also be digested to obtain biogas and a slurry digestate which is further composted or dried before reuse. Anaerobic digestion is a bacterial decomposition process that stabilises organic wastes and produces a mixture of methane and carbon dioxide gas (biogas). The heat value of methane is the same as natural petroleum gas, and biogas is valuable as an energy source. Anaerobic digestion is usually carried out in a specially built digester, where the content is mixed and the digester maintained at 35 oC by combusting the biogas produced. After digestion the sludge is passed to a sedimentation tank where the sludge is thickened. Biogas is collected from the digester (Figure 33). The thickened sludge requires further treatment prior to reuse or disposal. Anaerobic digestion can also be carried out at a slower rate in an unmixed tank or pond. Covering is usually by a UV resistant plastic sheet, because of the large area needed to be covered, and biogas is collected from the top of the sheet. Storage of biogas can be in a cylindrical tank with a floating roof. The cylindrical roof floats on water and its position is determined by the volume of the gas stored under the pressure of the roof. Biogas can also be stored in a balloon, but only under low pressure.

Related to greywater

on-TM14 - Greywater pre-treatment (screens, seals, filters)

The pre-treatment of greywater (as well as wastewater) is a combined mechanical and biological treatment. Greywater is fed into one of two filter baskets, made of constructed of welded mesh and lined with filter textile, which hang side by side and are used in an interval of 6-12 months. While trickling through the already retained material the greywater is already biologically treated. Due to the construction of the filter unit aerobic conditions in the filtered material help to reduce smell and minimise organic matter by aerobic degradation.

One of the major advantages of this system over other forms of pre-treatment systems is that it does not deprive agriculture of the valuable nutrients and soil conditioner from human excreta. The retained materials that have already been de-watered and pre-composted in the filter basket for 8-12 months can be further composted with biological kitchen and/or garden waste in a local composter at least for a year and used in agriculture. It avoids expensive tanker-trucks, which are extensively used in conventional system to transport sludge. Moreover, compare to septic tanks methane emission can be very low as outer parts of retained material maintain aerobic condition.

(Deepak Raj Gajurel, D.R, Li, Z. and Otterpohl, R. (2002): Investigation of the effectiveness of source control sanitation concepts including pre-treatment with Rottebehaelter. Technical University Hamburg-Harburg, Germany)

on-TM15 - Flotation – grease trap

Flotation is a physical process by which light components, such as grease, oil and fat, accumulate on the surface of the water. The grease trap is a simple method applied in small-scale greywater treatment systems. Grease traps are typically used as primary treatment units in greywater irrigation systems and as a low-cost alternative to sedimentation or septic tanks. They are often applied as content (e.g. kitchen greywater, restaurant greywater) prior to a secondary treatment step. Stand-alone grease traps for combined greywater are also frequently applied for domestic greywater. Grease traps must be designed to satisfy two basic criteria for effective separation of grease and grit: time/temperature and turbulence.

(Morel A., Diener S. 2006. Greywater Management in Low and Middle-Income Countries,Review of different treatment systems for households or neighbourhoods, Eawag, Switzerland)

on-TM16 - Slow sand filtration

The treatment of water by slow sand filtration combines biological, chemical and physical processes when the water slowly passes downwards through a bed of sand. Fine particles are filtered out, and in the sand and on top of the filter bed a population of micro organisms develops that feed on bacteria, viruses and organic matter in the water. The filter reservoirs have drains on the bottom covered with gravel and sand. Raw water slowly enters the filter through an inlet, and an outlet leads the clean water from the drains to the clean-water mains. During operation, the sand filter is covered with a water layer of 0.3–1.0 m. For the filter to work well, water must flow continuously at a rate of 0.1–0.3 m/hour. For community use, filter reservoirs can be made of concrete, bricks, ferro-cement, etc. At least two filters are needed if clean water is to be provided continuously. When the quality of the raw water is poor, it is recommended that pre-treatment steps be added (e.g. upflow roughing filter). Sometimes, the water is chlorinated after filtration to prevent recontamination. With good O&M, a slow sand filter produces water virtually free of harmful organisms.

(Brikké, F. and Bredero, M. (2003): Linking technology choice with operation and maintenance in the context of community water supply and sanitation. WHO, Switzerland).

on-TM17 - Horizontal subsurface flow constructed wetland system (HSSF CWS)

Horizontal-flow constructed wetlands consist of a bed lined with impermeable material (clay packing, plastic or gum liner) and filled with sand and gravel. The greywater entering the filter bed through an inlet zone devoid of vegetation flows horizontally through the bed. The water line lies below the filter surface and is controlled by an outlet level control arrangement. While the top surface of the filter is kept horizontal to prevent erosion, the bottom slopes preferably 0,5 – 1 % from let to outlet. The grain size of the filter media should allow continuous flow without clogging. In order to guarantee an even distribution of water input the grain size at the input and output zone of the wetland shall be coarser. During the passage of the treatment zone the water comes into contact with a network of aerobic, anoxic and anaerobic zones. The aerobic zones should be around the roots and rhizomes of the wetland plants (e.g. phragmites australis). The mechanisms of bacterial treatment are the same as in conventional wastewater treatment processes i.e. oxidation of organic matter by heterotrophic bacteria, oxidation of ammonium nitrogen to nitrate and nitrite by autotrophic nitrifiers and under anoxic conditions the breakdown of nitrate through nitrite and onto nitrogen gas by heterotrophic bacteria. The treatment level is determined by the hydraulic retention time in the filter system. Horizontal-flow planted wetland systems are very efficient in removing organic matter and suspended solids. Concerning the requirements of operation and maintenance the main focus shall be laid on proper mechanical pre-treatment, the maintenance of the vegetation and the control of the water level.

(Cooper, P.F. et al (1996): Reed beds and constructed wetlands for wastewater treatment, WRc,United Kingdom) .

(Morel A., Diener S. 2006. Greywater Management in Low and Middle-Income Countries, Review of different treatment systems for households or neighbourhoods, eawag, Switzerland)

on-TM18 - Horizontal free flow constructed wetland system (HFF CWS)

In a constructed wetland greywater is treated in a planted filter body made from gravel or sand. There are two different flow directions in the filter: horizontal or vertical. Both flows have advantages and disadvantages. Best would be a combination of two filters comprising both directions. The removal mechanism is mainly biological conversion, physical filtration and chemical adsorption. A proper pre-treatment for the removal of solids is necessary and filters are prone to clogging. Filters need space but fit well in landscape.

In this type, the wastewater is fed in at the inlet and flows slowly through the surface of the plant bed in a horizontal path until it reaches the outlet of zone where it is collected together before leaving via the level control arrangement at the outlet. In a HFF CWS system, the plants can contribute to treatment through uptake of nutrients and other wastewater constitutes, but most important part are the submerged portion of leaves, stalks, and litter, which serves as the substrate for attached microbial growth which occur aerobically. So the system tend to be oxygen-limited since the reeds cannot supply the oxygen at the rate required by the wastewater load and so FWS is similar to natural wetland system as not so efficient for nitrogen removal. A lot has been studied on wetland purification systems (Free water surface, FWS). This system is interesting not only due to its purification effects but also the ability to bring back natural habitats and to certain extend flood control. However, it is difficult to adopt the FWS, wetland system in urban areas or places where land is insufficient or limited, since FWS system requires larger area.

(see: http://www.pwri.go.jp/team/kasenseitai/eng/img/report/contentnew4.pdf)

on-TM19 - Vertical flow constructed wetland system (VF CWS)

Vertical flow constructed wetland systems are shallow excavations or above ground constructions with an impermeable liner, either synthetic or clay. The layer structure of a VF CWS comprises a flat bed of gravel (min. 20 cm) topped with a layer of sand (min. 60 cm), which is again topped by a layer of gravel (min. 15 cm). The reeds which are planted in the top layer of gravel, are the same sort (e.g. phragmites australis) as at horizontal-flow constructed wetland systems. However, these systems are fed intermittently four to six times a day, to safeguard aerobic phases. During a flush phase the greywater percolates down through the unsaturated bed, undergoes filtration, comes into contact with the dense microbial populations on the surface of the filter media and roots and is finally collected by a drainage network at the base. The design and size of a VF CWS is dependent on hydraulic and biological loads. As for HF CWS an efficient mechanical primary treatment for the removal of solids is important to prevent cloggings in the filter media.

(Cooper, P.F. et al (1996): Reed beds and constructed wetlands for wastewater treatment, WRc,United Kingdom) .

(Morel A., Diener S. 2006. Greywater Management in Low and Middle-Income Countries, Review of different treatment systems for households or neighbourhoods, eawag, Switzerland)

on-TM20 - Greywater garden (mulch trench)

Greywater gardens are simple greywater management systems that allow direct utilisation of the water, facilitate breakdown of organic compounds and recover nutrients. If site conditions (e.g.: space available for direct utilisation of greywater, soil conditions, etc.) are favourable, the easiest way to apply greywater for subsurface irrigation purposes is to drain it (without any pre-treatment) to swales or trenches, which are filled with mulch material. Distribution and application may be done either sub-mulch or above the surface. Sub-mulch application means that the greywater outlet points are below the surface of the mulch material. If subsurface distribution is not required, greywater can be discharged 2” (ca. 5 cm) above the surface of mulch into which it quickly disappears. The latter is much simpler to construct and maintain. Decomposing mulch has to be replaced periodically by locally available mulch material such as wood chips, bark chips, rice husk, etc.

on-TM21 - Green walls

Greywater is pumped in to the top box and slowly trickles down through to the bottom box via filtering materials that progressively treat and ‘polish’ the water. Water is stored in a tank underneath the lowest box. Plants in each box have been selected partially to enhance the treatment process but mostly on the basis of being able to survive in a nutrient rich sand base. The sand filter does most of the water treatment work.

Developed by a Swedish horticulturist green walls/vertical gardens are a container gardening system for intensive horticulture for dry tropical areas, based on walls with built-in growth boxes made of hollow concrete blocks.

When building the wall some of the blocks are turned through 90 degrees and the protruding hollow part is provided with a floor and a small hole for drainage. The core of the wall is filled with a weak concrete mixture. The protruding containers are filled with sand on top of a layer of fertilizer. The containers can be arranged in various patterns and the wall can be provided with containers on one or two sides. In the tropics the containers may face any direction and the walls can be quite closely spaced (1.2 -1.5 metres). A variety of vegetables and ornamentals can be grown in the containers.

(Esrey S et al. 1998. Ecological sanitation. SIDA, Sweden,)

on-TM22 - Tower garden

Tower gardens are a user-friendly, low-cost and low-tech greywater reuse system, where gardening does not have to rely on rainfall and where nutrients are derived from greywater originating from washing clothes, kitchen utensils etc The external structure of the greywater garden consists of poles (iron bars or fence posts) and shading material surrounding soil and a central stone-packed drain. The purpose of the stones is to spread the water flow throughout the column. Greywater is poured daily with buckets on top of the central stone core. The water trickles through the stone core and is more or less evenly distributed within the soil column. Leafy vegetables (such as spinach) are planted into slits of the shading material surrounding the soil column. The slits are offset to one another thus giving more space for root development. Tomatoes or onions may be planted on top of the column. The most appropriate filling material mix for the tower should be composed of three parts soil, two parts animal manure and one part wood ash. Tower gardens are best located in the courtyard so as to minimise transport distance of greywater.

(Morel A., Diener S. 2006. Greywater Management in Low and Middle-Income Countries, Review of different treatment systems for households or neighbourhoods, eawag, Switzerland)

on-TM23 - Subsurface wastewater infiltration system (SWIS)

The subsurface wastewater infiltration system (SWIS) receives the effluent pre-treated in the septic tank and purifies it through biological, physical, and chemical reactions as it passes through the unsaturated soil to the ground water. An important component of the infiltration system is the biomat, a layer of organic and inorganic material and bacteria that forms at the interface between the trench and the surrounding soil. The biomat enhances treatment efficiency because it usually slows down the movement of the effluent, provides the flora and fauna necessary to biologically decompose wastes, and enhances the physical and chemical removal of very small particles of matter in the wastewater. Permeable soil textures and structures are required to support these processes.

(http://www.epa.gov/nrmrl/pubs/625r00008/html/tfs13.htm)

on-TM24 - Anaerobic filtration:

Anaerobic filters are widely used as secondary treatment step in household greywater treatment systems. They have been successfully used when placed after a grease trap or septic tank. The anaerobic filter is an attached biofilm system (fixed-film reactor) that aims at removing non-settleable and dissolved solids. It comprises a watertight tank containing several layers of submerged media, which provide surface area for bacteria to settle. As the wastewater flows through the filter – usually from bottom to top (up-flow) – it comes into contact with the biomass on the filter and is subjected to anaerobic degradation. Primary treatment in a septic tank is usually required to eliminate solids of larger sizes before greywater is allowed to pass through the anaerobic filter. Studies showed that the hydraulic retention time is the single most important design parameter influencing filter performance, whereas 0.5–1.5 days can be considered typical retention times. Based on experiences with anaerobic filters a maximum surface loading rate of 2.8 m/d has proofed suitable. The treatment performance of the anaerobic filter as regards suspended solids and BOD removal can be as high as 85–90% and is typically within a 50–80% range. Nitrogen removal is, however, limited and normally does not exceed 15% in terms of total nitrogen (TN). Good filter material provides a specific surface area of 90–300 m2 per m3 of filled reactor volume. Gravel, rocks, cinder or specially formed plastic pieces are used as filter material. With up-flow systems, filter material size decreases from bottom to top. Typical filter material sizes range from 12 to 55 mm. Finally, the water level should cover the filter media by at least 0.3 m to guarantee an even flow regime through the filter. Anaerobic filters produce inflammable gases (methane) and foul odours that need to be controlled and evacuated. The filters may be constructed above ground, but most often they are below the ground surface to provide insulation and protection against severe climates. Access to inlet and outlet should be provided to allow for cleaning and servicing. Cleaning is required when the bacterial film on the filter media becomes too thick. The filter mass is removed and cleaned outside the reactor. More frequently the filter is not removed but cleaned by backwashing.

(Morel A., Diener S. 2006. Greywater Management in Low and Middle-Income Countries, Review of different treatment systems for households or neighbourhoods, eawag, Switzerland)

Treatment Technolgies Off-Site

Related to wastewater

off-TM1 - Pre-treatment

Prior to the treatment in all technologies listed below, the wastewater is first subjected to preliminary or pre-treatment to reduce larger objects, oils, grease, fats, sand, grit, and coarse (settleable) solids of the influent of sewage water. First, the influent is strained to remove all large objects (rags, sticks, condoms, sanitary towels etc.) This is done with a manual or automated mechanically raked screen. Later on in sand or grit channels (detritor, sand catcher) sand grit and stones can settle and be separated. Many wwtp use sedimentation stages (primary clarifiers, primary sedimentation tanks). Here, faecal solids (settlement) and grease and plastics (floating) will be separated and removed (scrapers, scimmers). The target is a homogeneous liquid for further treatment steps.

Advantages:

after correct treatment the wastewater can easily further processed

Disadvantages:
high investment costs for technical equipment, however manually raked screens and manually cleaned constant-velocity grit channels can keep costs low.

off-TM2 - Waste stabilization ponds

WSPs are one of the main natural wastewater treatment methods. They are man-made earthen basins, comprising at any one location one or more series of anaerobic, facultative and, depending on the effluent quality required, maturation ponds. This in turn depends on what is to be done with the effluent: used for restricted or unrestricted irrigation; used for fish or aquatic vegetable culture; or discharged into surface water or groundwater. Prior to treatment in the WSPs, the wastewater is first subjected to preliminary treatment. Basically, primary treatment is carried out in anaerobic ponds, secondary treatment in facultative ponds, and tertiary treatment in maturation ponds. Key advantages: WSPs are particularly suited to tropical and subtropical countries since sunlight and ambient temperature are key factors in their process performance. Anaerobic and facultative ponds remove organic matter, Vibrio cholerae and helminth eggs; and maturation ponds remove of faecal viruses, faecal bacteria, and nutrients (nitrogen and phosphorus). Due to their high removal of excreted pathogens, WSPs produce effluents that are very suitable for reuse in agriculture and aquaculture. Disadvantages: The land take for a WSP system is one of the primary cost factors and can sometimes be a constraint close to big cities. Lower temperatures mean a greater land area. The ponds site should be at least 200 m downwind of the nearest housing (properly designed WSPs produce no offensive odours, but it is not easy to convince local residents ahead of any planned scheme). Sites prone to high winds can also cause difficulties, as hydraulic short-circuiting is a common factor in the underperformance of WSPs. Though pond depths can be varied to suit available land area, and there is flexibility in choice of length-to-breadth ratios, a WSP site needs to be reasonably flat to keep down construction costs. Low permeability is a big advantage, as it avoids the need for an impermeable lining, and the soil needs to be suitable for building embankments with slopes of 1 in 3 externally and 1 in 2 internally. Although they are essentially a simple technology, some mistakes are made during design, construction and operation. WSP design is often poor as too many designers do not understand the microbiological processes occurring in them. They might apply design criteria from temperate climates to the design of WSPs in the tropics.

*Notes on the design and operation of waste stabilization ponds in warm climates of developing countries (available at: http://go.worldbank.org/BVSSYN5G10)

Waste Stabilization Ponds. Miguel Peña Varón and Duncan Mara (2004). (available at: http://www.irc.nl/page/14622

off-TM3 - Advanced integrated pond systems (AIPS)

AIPS were developed from high-rate algal ponds (HRAPs) (Oswald, 1991, 1995). They comprise "advanced" facultative ponds with a submerged anaerobic digestion pit, paddle-stirred HRAP, algal sedimentation ponds and one or more maturation ponds. The original purpose of HRAPs was to maximize the production of algae to recover and use the algal protein (algae are 50–60 percent protein and HRAPs can produce up to 80 tonnes of algal protein/ha year). However, with AIPS no attempt is made to recover the algal protein.

Disadvantages: HRAPs, which are the key component of AIPS, are complex and sensitive reactors which are much more difficult to operate correctly than conventional WSPs (and indeed activated sludge processes). In the real world of wastewater treatment in developing countries, AIPS are too complicated a technology to be considered a viable and sustainable treatment option.

off-TM4 - Floating macrophyte ponds

These ponds contain plants that float on the water with their leaves close to the surface and their roots hanging down into the pond water column to absorb nutrients. Some plant types commonly used are Eichhornia sp. (water hyacinth), Lemna sp. (duckweed), Pistia sp. (water lettuce or water cabbage) and Cyperus sp. (papyrus). The plants shade out the algae, so reducing effluent BOD5 and suspended solids; however, this has the disadvantage that disinfection is reduced, with the result that effluent E. coli numbers are higher. This suggests that floating macrophyte ponds should only be used as a final treatment stage (for nutrient and algal removal) after conventional maturation ponds have reduced E. coli numbers to the required level. However, if the final effluent is used for crop irrigation, nutrient and algal removal is unnecessary and floating macrophyte ponds are therefore not required. A major disadvantage with floating macrophyte ponds is that they encourage mosquito breeding. Culicine mosquitoes, the vector of Bancroftian filariasis, are the principal problem, but Eichhornia ponds permit the breeding of anopheline mosquitoes, the malaria vector, as well.

off-TM5 - Constructed Wetlands

Constructed wetlands are of two basic types: subsurface-flow and surface-flow wetlands. Subsurface-flow wetlands can be further classified as horizontal flow and vertical flow constructed wetlands. Subsurface-flow wetlands move wastewater through a gravel or sand medium on which plants are rooted; surface-flow wetlands move effluent above the soil in a planted marsh or swamp, and thus can be supported by a wider variety of soil types including bay mud and other silty clays. Vegetation in a wetland provides a substrate (roots, stems, and leaves) upon which microorganisms that break down organic materials can grow and contribute to maintain the permeability. Microorganisms and natural chemical processes are responsible for approximately 90 percent of pollutant removal and waste breakdown. The plants remove about 7 to 10 percent of pollutants, and act as a carbon source for the microbes when they decay. Different species of aquatic plants have different rates of heavy metal uptake, a consideration for plant selection in a constructed wetland used for wastewater treatment. In subsurface-flow systems, the effluent may move either horizontally, parallel to the surface, or vertically, from the planted layer down through the substrate and out. Subsurface-flow systems have the advantage of requiring less land area for water treatment, but are not generally as suitable for wildlife habitat as are surface-flow constructed wetlands. Disadvantages: Tend to clog if the ratio of medium permeabilty/bed size/load are not well evaluated. Subsurface horizontal-flow wetlands are less hospitable to mosquitoes, whose populations can be a problem in constructed wetlands (carnivorous plants have been used to address this problem).

Key advantages: they tend to be simple, inexpensive, and environmentally friendly.

off-TM6 - UASB technologies

Upflow Anaerobic Sludge Blanket (UASB) technology, normally referred to as UASB reactor, is a form of anaerobic digester that is used in the treatment of wastewater. A similar but variant technology to UASB is the expanded granular sludge bed (EGSB) digester. UASB uses an anaerobic process whilst forming a blanket of granular sludge and suspended in the tank. Wastewater flows upwards through the blanket and is processed by the anaerobic microorganisms. The upward flow combined with the settling action of gravity suspends the blanket with the aid of flocculants. The blanket begins to reach maturity at around 3 months. Small sludge granules begin to form whose surface area is covered in aggregations of bacteria. In the absence of any support matrix, the flow conditions creates a selective environment in which only those microorganisms, capable of attaching to each other, survive and proliferate. Eventually the aggregates form into dense compact biofilms referred to as "granules" Key advantages The blanketing of the sludge enables a dual solid and hydraulic (liquid) retention time in the digesters. Solids requiring a high degree of digestion can remain in the reactors for periods up to 90 days. Sugars dissolved in the liquid waste stream can be converted into gas quickly in the liquid phase which can exit the system in less than a day. Biogas with a high concentration of methane is produced as a by-product, and this may be captured and used as an energy source, to generate electricity for export and to cover its own running power. The heat produced as a by-product of electricity generation can be reused to heat the digestion tanks.Disadvantages: The technology needs constant monitoring when put into use to ensure that the sludge blanket is maintained, and not washed out (thereby losing the effect).

off-TM7 - Conventional activated sludge systems

The Activated Sludge Process mimics natural processes that occur in soil and water to purify biodegradable wastes. By introducing the presence of oxygen, micro-organisms breakdown complex organic molecules into their simple constituents such as carbon dioxide and water. The oxygen can be supplied from air or pure oxygen. The micro-organisms are concentrated within an aeration tank and this reduces the time for degradation to hours instead of days in the natural state. The Activated Sludge Process has a number of variants in its design and layout, including Extended Aeration and Sequencing Batch Reactor (SBR) technologies. This systems classifies as suspended growth system.

Advantages: Being a suspended growth process, the concentration of micro-organisms can be varied to match the concentration and nature of pollutants of the incoming wastewater. This intensification of the process enables the Activated Sludge Plant to be smaller than those for other processes. The biomass and the water fraction are separated. With biomass recirculation the plant can be optimised in design.

Disadvantages: an aeration source is required therefore requiring equipment and continuous energy supply. Cost tend to be high. Well developed skills and technical ability are required for running the plant.

Integrated Fixed-film Activated Sludge (IFAS). IFAS systems involve the addition of inert media into existing (activated sludge) basins to provide active sites for biomass attachments. This conversion results in a combination of attached growth and suspended growth biomass. Key advantages: maintain a high density of biomass population, increase the efficiency of the system without the need for increasing the mixed liquor suspended solids (MLSS) concentration. Disadvantages: high costs

off-TM9 - Membrane biological reactors

MBR's include a semi-permeable membrane barrier system either submerged or in conjunction with an activated sludge process. The performance of MBR systems is directly proportional to nutrients reduction efficiency of the activated sludge process. Key advantages: guarantees removal of all suspended and some dissolved pollutants, very compact and space saving, high reuse potential of effluent Disadvantages: high investment and operation costs (higher than conventional wwtp).

Related to urine

off TM 11 - Off-site urine storage tank

tank of higher volume where the urine is stored for hygienisation; different materials like plastics and steel are possible; size has to be designed according to the amount of people using the toilet and the needed storage time for hygienisation; The hygienisation time should be 3 to 6 month

off TM12 - Urine MAP-dissipation

high technology components produce dry fertilizer from urine to apply it in agriculture; MAP participation “converts” the liquid urine to a powder that can easier be handled. Advanced technology is needed for this process. an on-site process would probably only be feasible when bigger amounts of urine are produced.

Reuse Technologies [R]

R1 - Urine direct application

From the toilet the urine goes directly to small field where the urine is applied without previous treatment; problems might occur concerning the distribution of urine and a certain “over-fertilization” of small scale fields. Direct application of urine, on-site or off-site, is a practical approach when (i) urine is collected from a household, (ii) the urine is used on crops consumed by the family only, and (iii) storage capacity is limited. The WHO fertilizing guidelines for direct use of urine shall, be followed, in order to minimize health risks. This means that for vegetables eaten raw, at least one month shall elapse from fertilization to harvest. If enough water is available, multiple harvests can be obtained in the West African context.

R2 - Urine on-site reuse

Urine is applied on agricultural fields close to the user of the toilet; this option will probably the most common in rural areas and areas with urban agriculture where the urine is applied with e.g. watering cans to the fields; also the on-site dried urine can be applied as solid fertilizer.

R3 - Urine mechanized off-site reuse:

After collection the urine is applied on fields in larger scale with machinery like e.g. manure trucks; this option will be applicable when there is a collection service or a central collection tank. Trucks will carry the urine to agricultural fields and applied it there. This is also the reuse option for the produced MAP fertilizer from the precipitation process. The fertilizer can be sold and then applied on agricultural areas. This option demands an organisational and logistical system for collection, sanitization and application, and is therefore the presently the most likely for the current West African setting.

R4 - Faecal sludge & excreta use in agriculture

see WHO guidelines

R5 - Effluent (wastewater) application in agriculture

see WHO guidelines Vol II, Chapter 5

R6 - Effluent (wastewater) and faecal sludge (excreta) use in aquaculture

see WHO guidelines Vol III, Chapter 5

Disposal Technologies

D1 - Soakaway pit

The Soakaway pit or trench has the purpose to percolate effluent/wastewater to surrounding subsoil. Soakaway pits should be sufficiently large to avoid flooding and overflow. The minimum capacity of the pit should accommodate all the wastewater produced during one washing or in one day, whichever figure is the greater. Important consideration is the permeability of Soil. If the percolation rate is too high, the wastewater might drain into the nearby watercourses before any effective treatment. If it is too low, the pit/trenches might soon clog up and wastewater would overflow. A site percolation test should be conducted to determine the soil permeability.

D2 - Infiltration trench/ field

An infiltration trench is a long, narrow, rock-filled trench with no outlet that receives effluent. The effluent is stored in the void space between the stones and infiltrates through the bottom and into the soil matrix. Infiltration trenches perform well for removal of fine sediment and associated pollutants. Pretreatment using buffer strips, swales, or detention basins is important for limiting amounts of coarse sediment entering the trench which can clog and render the trench ineffective.