Use and/or Disposal

D

This section presents different technologies and methods that use or dispose of the output products in ways that are the least harmful to the user and the environment.

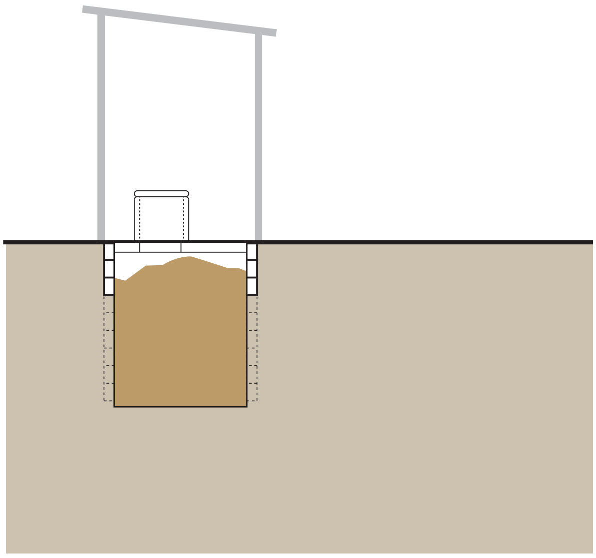
D

D.1 Fill and Cover /Arborloo

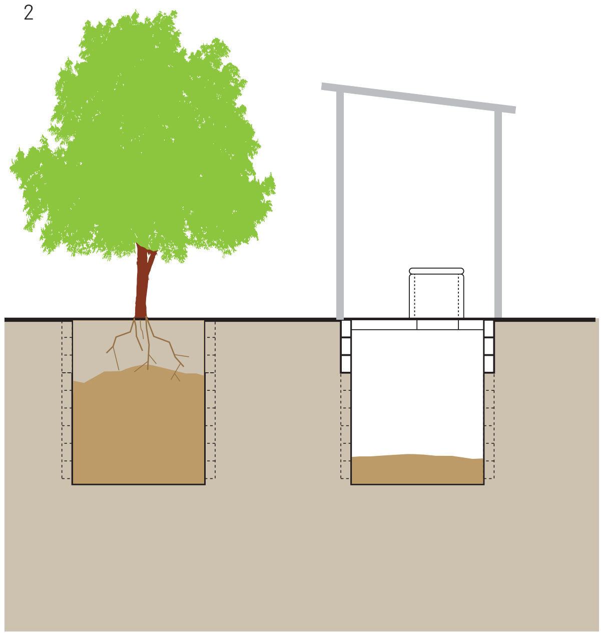
Applicable to:
System 1

Application Level	**Management Level**	**Inputs:**
★★ Household	★★ Household	Excreta, Faeces
★★ Neighbourhood	★ Shared	Compost/EcoHumus
City	Public	

1



2



To decommission a pit, it can simply be filled with soil and covered. Although there is no benefit recovered, the full pit poses no immediate health risk, and with time, the contents will degrade naturally. Alternatively, the 'Arborloo' is a shallow pit that is filled with excreta and soil/ash and then covered with soil; a tree planted on top will grow vigorously in the nutrient-rich pit.

When a single pit or a single VIP is full, and can not be emptied, Fill and Cover, i.e. filling the remainder of the pit and covering it is an option, albeit one with limited benefits to the environment or the user.

In the Arborloo, a tree is planted on top of the full pit while the superstructure, ring beam and slab are continuously moved from pit to pit in an endless cycle (usually moved once every 6 to 12 months). A shallow pit is needed, about 1 m deep. The pit should not be lined as the lining would prevent the tree or plant from growing properly. Before the pit is used, a layer of leaves is put into the bottom. After each defecation, a cup of soil, ash or a mixture should be dumped into the pit to cover the excreta. If they are available, leaves can also be added occasionally to improve the porosity and air content of the pile. When the pit is full, the top 15 cm of the pit is filled with soil and a tree is planted in the soil. Banana, papaya and guava trees (among many) have all proven to be successful. A tree should not be planted directly in the raw excreta. The tree starts to grow in the soil and its roots penetrate the composting pits as it grows. It may be best to wait for the rainy season before planting if water is scarce. Other plants such as tomatoes and pumpkins can also be planted on top of the pit if trees are not available.

Adequacy Filling and covering pits is an adequate solution when emptying is not possible and when there is space to continuously re-dig and fill pits.

The Arborloo can be applied in rural, peri-urban, and denser areas if space is available.

Planting a tree in the abandoned pit is a good way to reforest an area, provide a sustainable source of fresh fruit and prevent people from falling into old pit sites.

Health Aspects/Acceptance There is a minimal risk of infection if the pit is properly covered and clearly marked. It may be preferable to cover the pit and plant a tree rather than have the pit emptied, especial-

ly if there is no appropriate technology available for treating the faecal sludge.
Users do not come in contact with the faecal material and thus there is a very low risk of pathogen transmission. Demonstration projects that allow community members to participate are useful ways of showing both the ease of the system, it's inoffensive nature, and the nutrient value of composted excreta.

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

Pros & Cons:
+ Simple technique for all users
+ Low cost
+ Low risk of pathogen transmission
+ May encourage income generation (tree planting and fruit production)
- Labour intensive

References

_ Morgan, P. (2007). *Toilets that make compost.* Stockholm Environment Institute, Stockholm, Sweden. pp 81–90. Available: www.ecosanres.org

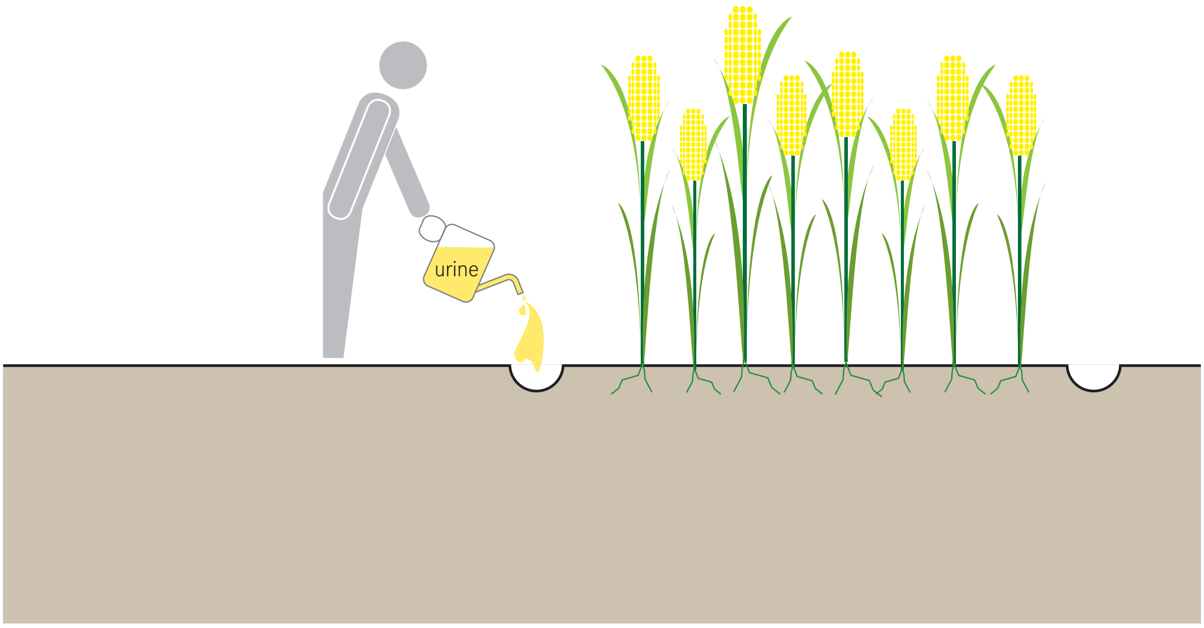
_ Morgan, P. (2004). *An Ecological Approach to Sanitation in Africa: A Compilation of Experiences.* Aquamor, Harare, Zimbabwe. Chapter 10 – The usefulness of urine. Available: www.ecosanres.org

_ NWP (2006). *Smart Sanitation Solutions. Examples of innovative, low-cost technologies for toilets, collection, transportation, treatment and use of sanitation products.* Netherlands Water Partnership, The Netherlands. pp 51.

D.2 Application of Urine

Applicable to:
System 4, 8

Application Level	**Management Level**	**Inputs:**
★★ Household	★★ Household	Stored Urine
★★ Neighbourhood	★★ Shared	
★★ City	★★ Public	



Separately collected, stored urine is a concentrated source of nutrients that can be applied as a liquid fertilizer in agriculture to replace all or some commercial chemical fertilizer.

The guidelines for urine use are based on storage time and temperature (please see WHO guidelines for specific requirements). However, it is generally accepted that if urine is stored for at least 1 month, it will be safe for agricultural application at the household level. If urine is used for crops that are eaten by those other than the urine producer, it should be stored for 6 months. Urine should not be applied to crops within one month before they are harvested.

From normal, healthy people, urine is virtually free of pathogens. Urine also contains the majority of nutrients that are excreted by the body. Urine varies depending on diet, gender, climate and water intake among other facts, but roughly 80% of nitrogen, 60% of potassium and 55% of phosphorus that is excreted from the body is excreted through urine.

Because of its high pH and concentration, stored urine should not be applied directly to plants. Rather it can be used:

1) mixed undiluted into soil before planting;
2) poured into furrows sufficiently away from plant roots and covered immediately (once or twice during the growing season); and
3) diluted several times and used frequently (twice weekly) poured around plants.

To calculate the application rate, one can assume that 1 m^2 of cropland can receive the urine from 1 person per day (1 to 1.5 L), per crop harvested (e.g. 400 m^2 of cropland per year can be fertilized). A 3:1 mix of water and urine is an effective dilution for vegetables, applied twice weekly, although the amount depends on the soil and the type of vegetables. During the rainy season, urine can also be applied directly into small holes near plants, where it will be diluted naturally.

Adequacy Urine is especially beneficial where crops are lacking nitrogen. Examples of some crops that grow well with urine include: maize, rice, millet, sorghum, wheat, chard, turnip, carrots, kale, cabbage, lettuce, bananas, paw-paw, and oranges.

Urine application is ideal for rural and peri-urban areas where agricultural lands are close to the point of urine collection. Households can use their own urine on their own plot of land. Alternatively, if facilities and infrastructure exist, urine can be collected at a semi-centralized location for distribution and transport to agricultural land. Regardless, the most important aspect is that there is a need for nutrients otherwise, the urine can become a source of pollution and nuisance if dealt with improperly.

Health Aspects/Acceptance There is a minimal risk of infection, especially with extended storage. Still, urine should be handled carefully and should not be applied to crops less than one month before they are harvested.
Social acceptance may be difficult. Stored urine has a strong smell and some may find it offensive to work with or be near. If urine is diluted, and/or immediately tilled into the earth, the smells can be reduced. The use of urine may be less accepted in urban or peri-urban areas where household gardens are close to houses than in rural areas, where houses and crop lands are separated.

Maintenance With time, some minerals in urine will precipitate (especially calcium and magnesium phosphates). Any equipment that is used to collect, transport or apply urine (i.e. watering cans with small holes) may become clogged over time. Most deposits can easily be removed with hot water and a bit of acid (vinegar), or in more extreme cases, chipped off manually.

Pros & Cons:
+ Simple technique for all users
+ Low cost
+ Low risk of pathogen transmission
+ Reduces dependence on costly chemical fertilizers
+ May encourage income generation (tree planting and fruit production)
- Urine is heavy and difficult to transport
- Smell may be offensive
- Labour intensive

References

_ Austin, A. and Duncker, L. (2002). *Urine-diversion. Ecological Sanitation Systems in South Africa.* CSIR, Pretoria, South Africa.

_ GTZ (2005). *Technical data sheets for ecosan components-01 Urine Diversion.* GTZ, Germany. Available: www.gtz.de

_ Morgan, P. (2007). *Toilets that make compost.* Stockholm Environment Institute, Stockholm, Sweden. Available: www.ecosanres.org

_ Morgan, P. (2004). *An Ecological Approach to Sanitation in Africa: A Compilation of Experiences.* Aquamor, Harare, Zimbabwe. Chapter 10 – The usefulness of urine. Available: www.ecosanres.org

_ NWP (2006). *Smart Sanitation Solutions. Examples of innovative, low-cost technologies for toilets, collection, transportation, treatment and use of sanitation products.* Netherlands Water Partnership, The Netherlands. pp 51.

_ Schonning, C. and Stenstrom, TA. (2004). *Guidelines for the Safe Use of Urine and Faeces in Ecological Sanitation Systems-Report 2004-1.* EcosanRes, Stockholm Environment Institute, Stockholm, Sweden. Available: www.ecosanres.org

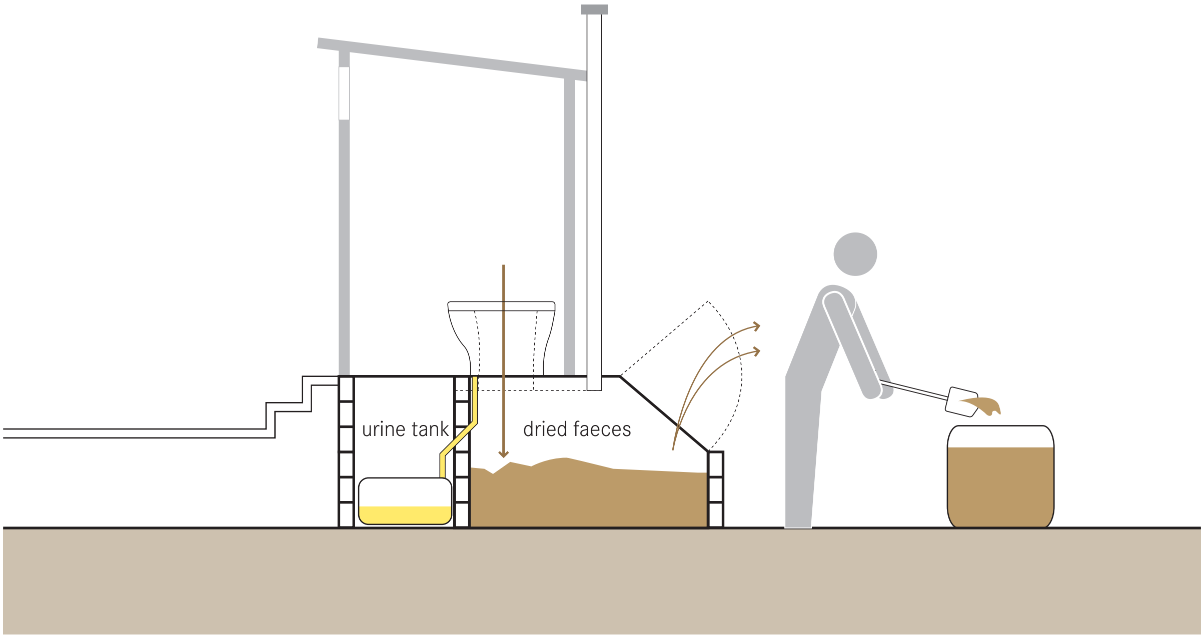
_ Winblad, U. and Simpson-Herbert, M. (eds.) (2004). *Ecological Sanitation- revised and enlarged edition.* Stockholm Environment Institute, Stockholm, Sweden. Available: www.ecosanres.org

_ WHO (2006). *Guidelines for the safe use of wastewater, excreta and greywater – Volume 4: Excreta and greywater use in agriculture.* WHO, Geneva. Available: www.who.int

D.3 Application of Dehydrated Faeces

Applicable to:
System 4

Application Level	Management Level	Inputs:
★★ Household	★★ Household	Dried Faeces
★ Neighbourhood	★★ Shared	
City	★ Public	



When faeces are stored in the absence of moisture (i.e. urine) they dehydrate into a crumbly, white-beige coarse, flaky material or powder. Dehydration means that the moisture naturally present in the faeces evaporates and/or is absorbed by the addition of a drying material (e.g. ash, sawdust, lime).

Dehydration is different from composting because the organic material present is not degraded or transformed; only the moisture is removed. After dehydration, faeces will reduce in volume by about 75%. The shells and carcasses of worms and insects that also dehydrate will remain in the dried faeces.

The degree of pathogen inactivation will depend on the temperature, the pH (e.g. lime raises the pH) and storage time. It is generally accepted that faeces should be stored between 12 to 18 months, although pathogens may still exist after this time.

When the faeces are completely dry they will emerge as a crumbly, powdery substance. The material is rich in carbon and nutrients, but may still contain pathogens or oocysts (spores which can survive extreme environmental conditions and re-animate under favourable conditions). The material can be mixed into soil, either for agriculture or at another site (depending on acceptance).

Faeces that are dried and stored between 2 and 20° C should be stored for between 1.5 to 2 years before they are used at the household or regional level. At higher temperatures (i.e. greater than 20° C) storage over one year is recommended to inactivate Ascaris eggs (a type of parasitic worm). A shorter storage time of six months is required if the faeces have a pH above 9 (i.e. lime will increase the pH of the faeces). The WHO has published guidelines and these should be consulted before using dried faeces.

Adequacy Dried faeces are not as well treated or as useful as a soil amendment as composted faeces. However, they are useful at replenishing poor soils and for boosting the carbon and water-storing properties of a soil with low-risk of pathogen transmission.

Health Aspects/Acceptance The handing and use of dried faeces may not be acceptable to some. However, because the dried faeces should be dry, crumbly, and odour free, the use of dried faeces may be more acceptable than that of manure or sludge. Dry

faeces are a hostile environment for organisms and consequently, they do not survive (for long). If water or urine mixes with the drying faeces, odours and organisms may become problematic; wet faeces allow bacteria to survive and multiply. A warm, moist environment will permit anaerobic processes to generate offensive odours.
When removing the dehydrated faeces from the dehydration vaults, care must be taken to prevent the power from blowing and being inhaled.

Maintenance Faeces should be kept as dry as possible. If by accident, water or urine enters mixes with the drying faeces, more ash, lime or dry soil can be added to help absorb the moisture. Prevention is the best way of keeping the faeces dry.

Pros & Cons:
+ Can improve the structure and water-holding capacity of soil
+ Simple technique for all users
+ Low cost
+ Low risk of pathogen transmission
+ May encourage income generation (tree planting and fruit production)
- Labour intensive
- Pathogens may exist in a dormant stage (oocysts) which may become infectious if moisture is added
- Does not replace fertilizer (N, P, K)

References

_ Austin, A. and Duncker, L. (2002). *Urine-diversion. Ecological Sanitation Systems in South Africa.* CSIR, Pretoria.

_ Schonning, C. and Stenstrom, TA. (2004). *Guidelines for the Safe Use of Urine and Faeces in Ecological Sanitation Systems-Report 2004-1.* EcosanRes, Stockholm Environment Institute, Stockholm, Sweden. Available: www.ecosanres.org

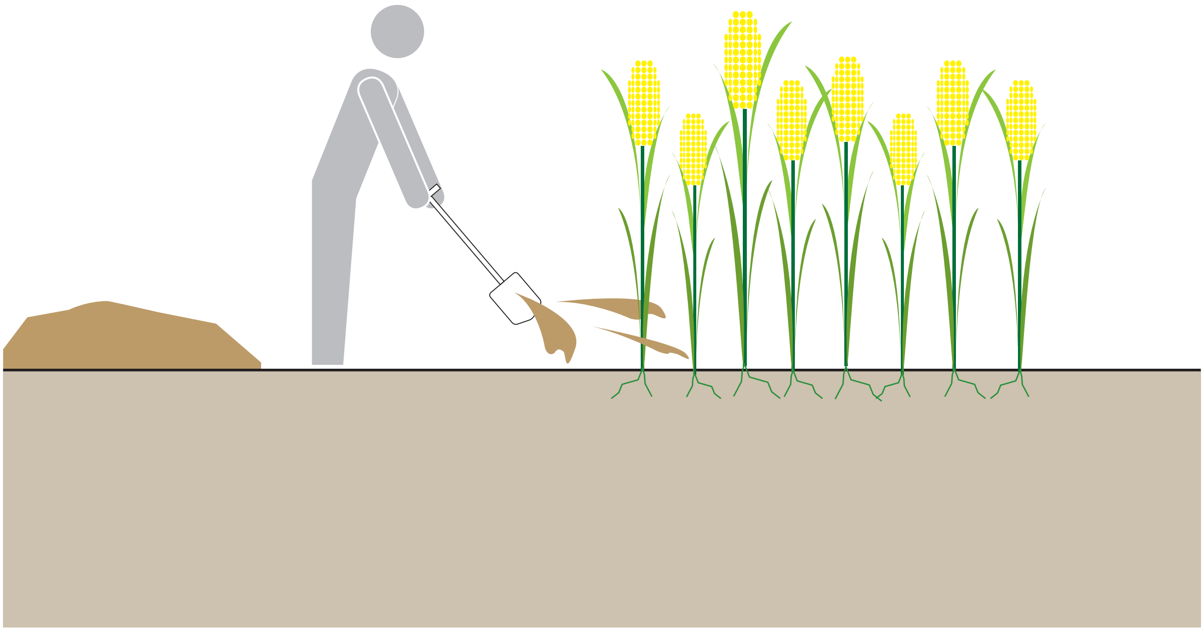
_ WHO (2006). *Guidelines for the safe use of wastewater, excreta and greywater – Volume 4: Excreta and greywater use in agriculture.* WHO, Geneva. Available: www.who.int

_ Winblad, U. and Simpson-Herbert, M. (eds.) (2004). *Ecological Sanitation- revised and enlarged edition.* Stockholm Environment Institute, Stockholm, Sweden. Available: www.ecosanres.org

D.4 Application of Compost/EcoHumus

Applicable to:
System 2

Application Level	**Management Level**	**Inputs:**
★★ Household	★★ Household	Compost/EcoHumus
★★ Neighbourhood	★★ Shared	
★ City	★ Public	



Composting is the term used to describe the controlled aerobic degradation of organics into a soil-like substance called compost. 'EcoHumus' is a term taken from Peter Morgan (see references) and is a more appropriate word to use for the material removed from a Fossa Alterna because it is produced passively underground and has a slightly different composition.

The process of thermophilic composting generates heat (50 to 80° C) which kills the majority of pathogens present. For the composting process to occur there must be adequate carbon, nitrogen, moisture, and air.
The Fossa Alterna (S5) and Arborloo (D1) are ambient-temperature variations of high-temperature composting In these technologies, there is almost no temperature rise because vegetable matter is lacking. For that reason, the material is not actually 'compost' and is therefore referred to as 'EcoHumus'.
The WHO guidelines stipulate that the compost should achieve and maintain a temperature of 50° C for at least one week before it is considered safe (although to achieve this value, a significantly longer period of composting is required). The WHO guidelines should be consulted for detailed information. For systems that generate EcoHumus in-situ (i.e. Fossa Alterna), a minimum of 1 year of storage is recommended to eliminate bacterial pathogens and reduce viruses and parasitic protozoa.
Compost/EcoHumus can be used beneficially to improve the quality of soils by adding nutrients and organics and improving the soil's ability to store air and water. The texture and quality of the EcoHumus depends on the materials which have been added to the excreta (especially the type of soil).

Adequacy Compost/EcoHumus can be mixed into the soil before crops are planted, used to start seedlings or indoor plants or simply mixed into an existing compost pile for further treatment.
For poor soils, equal parts of compost and top soil have shown to improve productivity. The output from one Fossa Alterna should be sufficient for two 1.5 m by 3.5 m beds. Vegetable gardens filled with the EcoHumus from the Fossa Alterna have shown dramatic improvements over gardens planted without compost, and has even made agriculture possible in areas which would have not otherwise supported crops.

Health Aspects/Acceptance A small risk of pathogen transmission exists, but if in doubt, any material removed from the pit can be composted further in a regular compost heap, or mixed with additional soil and put into a 'tree pit', i.e. a nutrient-filled pit used for planting a tree.

As opposed to sludge, which originates from a variety domestic, chemical and industrial sources, compost has very few chemical inputs. The only chemical sources that could contaminate compost might originate from contaminated organic material (e.g. pesticides) or from chemicals that are excreted by humans (e.g. medication). Compared to the cleaning, pharmaceutical and processing chemicals that may find their way into sludge, compost can be considered as a less contaminated product.

Acceptability may be low at first, but demonstration units and hands-on experience are effective ways of demonstrating the non-offensive nature of the material.

Maintenance The material must be allowed to mature adequately before it is removed from the system and then it can be used without further treatment.

Pros & Cons:

+ Potential income generation (improved yield and productivity of plants)
+ Low risk of pathogen transmission
+ Can improve the structure and water-holding capacity of soil
+ Simple technique for all users
+ Low cost
- Requires a year or more of maturation
- Does not replace fertilizer (N, P, K)

References

_ Del Porto, D. and Steinfeld, C. (1999). *The Composting Toilet System Book. A Practical Guide to Choosing, Planning and Maintaining Composting Toilet Systems, an Alternative to Sewer and Septic Systems.* The Center for Ecological Pollution Prevention (CEPP), Massachusetts, USA.

_ Jenkins, J. (1999). *The Humanure Handbook: a Guide to Composting Human Manure. (2nd ed.).* Jenkins Publishing, Grove City, Pa, USA.
Available: www.jenkinspublishing.com

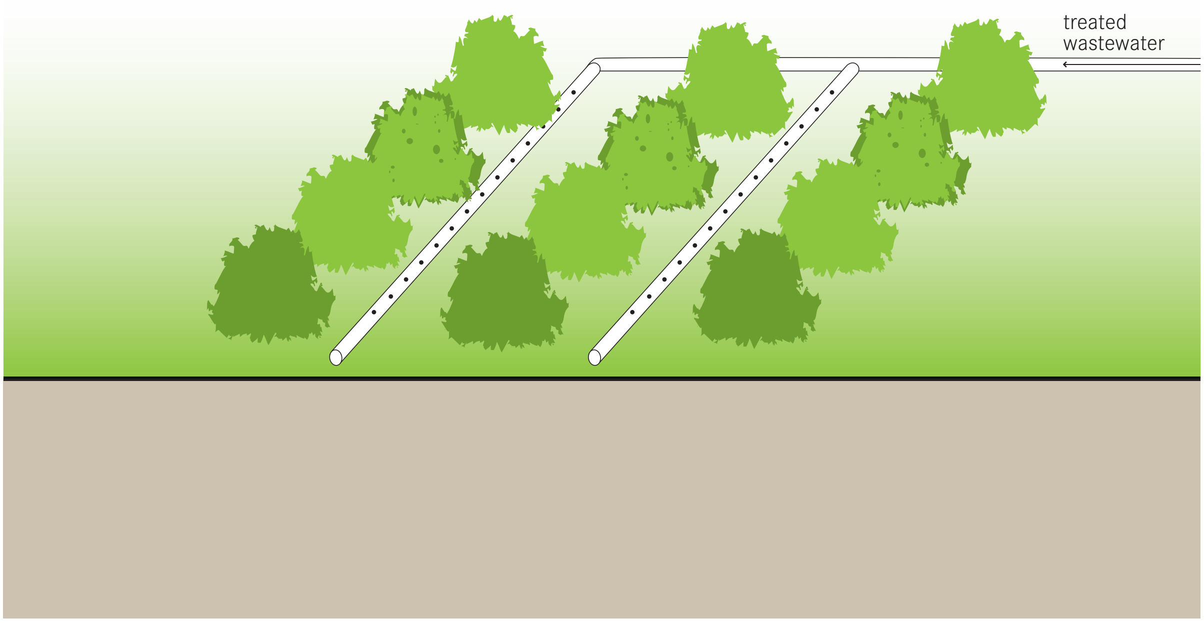
_ Morgan, P. (2004). *An Ecological Approach to Sanitation in Africa: A Compilation of Experiences.* Aquamor, Harare, Zimbabwe.
Available: www.ecosanres.org

_ Morgan, P. (2007). *Toilets that make compost.* Stockholm Environment Institute, Stockholm, Sweden. pp 81 – 90.
Available: www.ecosanres.org

_ NWP (2006). Smart Sanitation Solutions. *Examples of innovative, low-cost technologies for toilets, collection, transportation, treatment and use of sanitation products.* Netherlands Water Partnership, The Netherlands. pp 49.

D.5	Irrigation	Applicable to: **Systems 1–8**

Application Level	**Management Level**	**Inputs:**
★★ Household	★★ Household	Effluent Stormwater
★★ Neighbourhood	★★ Shared	
★★ City	★★ Public	



To reduce dependence on freshwater and maintain a constant source of irrigation water throughout the year, waste waters of varying qualities can be used in agriculture. Generally, only waters that have had secondary treatment (i.e. physical and biological treatment) should be used to limit the risk of crop contamination and the health risk to workers.

There are two kinds of irrigation technologies that are appropriate for using treated wastewaters:

1) Drip irrigation where the water is dripped slowly on or near the root area; and
2) Surface water irrigation where water is routed overland in a series of dug channels or furrows.

To minimize evaporation and contact with pathogens, spray irrigation should be avoided.

Properly treated wastewater can significantly reduce dependence on freshwater, and/or improve crop yields by supplying increased water and nutrients to plants. Raw sewage or untreated blackwater should not be used, and even well-treated water should be used with caution. Long-term use of poorly or improperly treated water may cause long-term damage to the soil structure and its ability to hold water.

Adequacy Generally, drip irrigation is the most appropriate irrigation method; it is especially good for arid and drought prone areas. Surface irrigation is prone to large losses from evaporation but requires little/no infrastructure and may be appropriate in some situations.

Crops such as corn, alfalfa (and other feed), fibres (cotton), trees, tobacco, fruit trees (mangos) and foods requiring processing (sugar beet) can be grown safely with treated effluent. More care should be taken when growing fruits and vegetables that may be eaten raw (e.g. tomatoes) that could come in contact with the water. Energy crops like eucalyptus, poplar, willow, or ash trees can be grown in short-rotation and harvested for biofuel production. Since the trees are not for consumption, this is a safe, efficient way of using lower-quality effluent.

There are potential health risks if water is not properly pre-treated (i.e. inadequate pathogen reduction). Soil quality can be degraded over time (e.g. accumulation of salts) if poorly treated wastewater is applied. The application rate must be appropriate for the soil, crop and climate, or it could be damaging.

Health Aspects/Acceptance Appropriate pre-treatment should precede any irrigation scheme to limit health risks to those who come in contact with the water. As well, depending on the degree of treatment that the effluent has undergone, it may be contaminated with the different chemicals that are discharged into the system. When effluent is used for irrigation, households and industries connected to the system should be made aware of the products that are and are not appropriate for discharging into the system.

Drip irrigation is the only type of irrigation that should be used with edible crops, and even then, care should be taken to prevent workers and harvested crops from coming in contact with the treated effluent.

Despite safety concerns, irrigation with effluent is an effective way to recycle nutrients and water.

Maintenance Drip irrigation systems must be cleaned periodically to remove any built-up solids. The pipes should be checked for leaks as they are prone to damage from rodents and humans.

Drip irrigation is more costly than conventional irrigation, but has improved yields and decreased water/ operating costs.

Pros & Cons:

+ Reduces depletion of ground water and improves availability of drinking water
+ Reduced need for fertilizer
+ Low to moderate capital cost; low to moderate operating cost
+ Potential for local job creation and income generation
+ Low risk of pathogen transmission if water is properly pre-treated
+ Potential to improved health, self-reliance in community
- Must be well settled - very sensitive to clogging
- May require expert design and installation
- Not all parts and materials may be available locally

References

_ Ayers, RS. and Westcot, DW. (1994). *FAO Irrigation and Drainage Paper 29 Rev. 1. Water Quality for Agriculture.* FAO, Rome. Available: www.fao.org

_ Crites, R. and Tchobanoglous, G. (1998). *Small and Decentralized Wastewater Management Systems.* WCB and McGraw-Hill, New York, USA. pp 878 – 886.

_ Mara, DD. (1996). *Low-Cost Urban Sanitation.* Wiley, Chichester, UK. pp 150 – 152.

_ Mara, DD. (2004). *Domestic Wastewater Treatment in Developing Countries.* Earthscan, London. pp 231 – 245.

_ Okun, DA. and Ponghis, G. (1975). *Community Wastewater Collection and Disposal.* WHO, Geneva. pp 211 – 220.

_ Sasse, L. (1998). *DEWATS: Decentralised Wastewater Treatment in Developing Countries.* BORDA, Bremen Overseas Research and Development Association, Bremen, Germany.

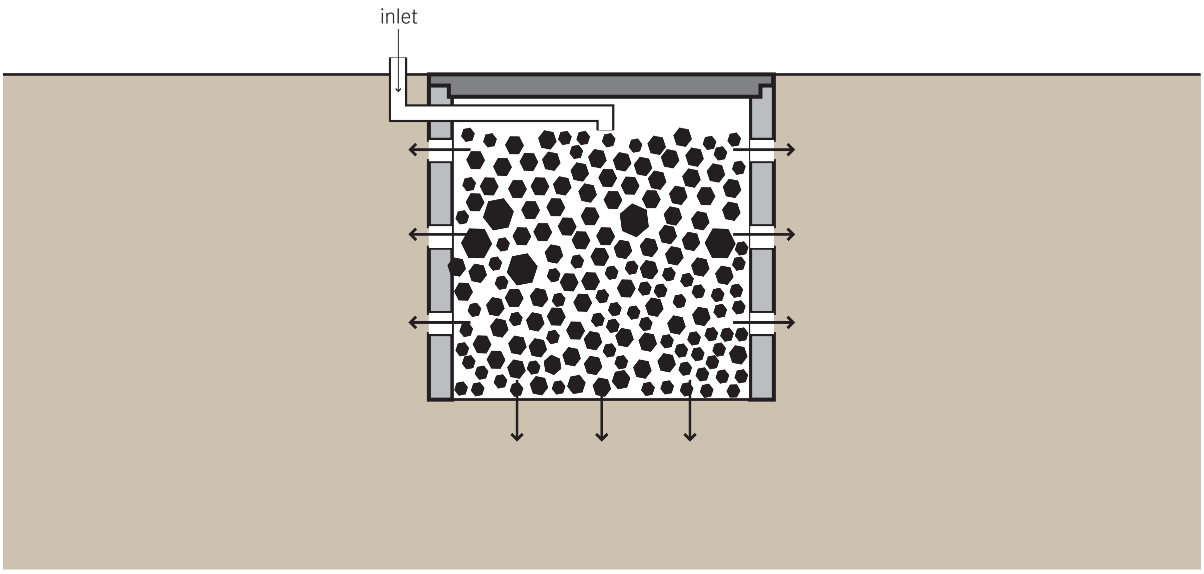
_ WHO (2006). *Guidelines for the safe use of wastewater, excreta and greywater- Volume 2: Wastewater and excreta use in agriculture.* WHO, Geneva.

D.6 Soak Pit

Applicable to:
Systems 1–5

D.6

Application Level	Management Level	Inputs:
★★ Household	★★ Household	Effluent, Greywater
★ Neighbourhood	★★ Shared	Urine, Anal Cleansing Water
City	Public	



A Soak Pit, also known as a soakaway or leach pit, is a covered, porous-walled chamber that allows water to slowly soak into the ground. Pre-settled effluent from a Collection and Storage/Treatment or (Semi-) Centralized Treatment technology is discharged to the underground chamber from where it infiltrates into the surrounding soil.

The Soak Pit can be left empty and lined with a porous material (to provide support and prevent collapse), or left unlined and filled with coarse rocks and gravel. The rocks and gravel will prevent the walls from collapsing, but will still provide adequate space for the wastewater. In both cases, a layer of sand and fine gravel should be spread across the bottom to help disperse the flow. The soak pit should be between 1.5 and 4 m deep, but never less than 1.5 m above the ground water table.
As wastewater (pre-treated greywater or blackwater) percolates through the soil from the Soak Pit, small particles are filtered out by the soil matrix and organics are digested by micro-organisms. Thus, Soak Pits are best suited to soils with good absorptive properties; clay, hard packed or rocky soils are not appropriate.

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

Health Aspects/Acceptance As long as the Soak Pit is not used for raw sewage, and as long as the previous Collection and Storage/Treatment technology is functioning well, health concerns are minimal. The technology is located underground and thus, humans and animals should have no contact with the effluent. It is important however, that the Soak Pit is located a safe distance from a drinking water source (ideally 30 m).
Since the Soak Pit is odourless and not visible, it should be accepted by even the most sensitive communities.

Maintenance A well-sized Soak Pit should last between 3 and 5 years without maintenance. To extend the life of a Soak Pit, care should be taken to ensure that the effluent has been clarified and/or filtered well to

prevent excessive build up of solids. The Soak Pit should be kept away from high-traffic areas so that the soil above and around it is not compacted. When the performance of the Soak Pit deteriorates, the material inside the soak pit can be excavated and refilled. To allow for future access, a removable (preferably concrete) lid should be used to seal the pit until it needs to be maintained.
Particles and biomass will eventually clog the pit and it will need to be cleaned or moved.

Pros & Cons:

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

References

_ Ahrens, B. (2005). *A Comparison of Wash Area and Soak Pit Construction: The Changing Nature of Urban, Rural, and Peri-Urban Linkages in Sikasso, Mali.* Peace Corp, USA. Available: www.cee.mtu.edu/peacecorps/reports/Brooke_Ahrens_Final_Report.pdf
(Detailed construction instructions)

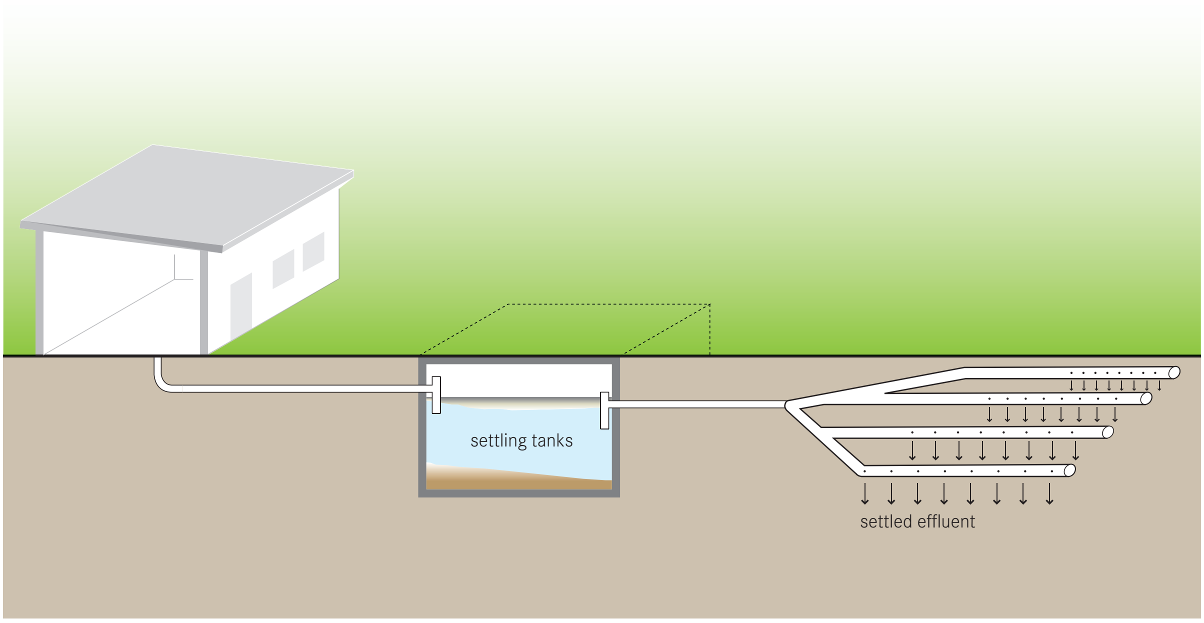
_ Mara, DD. (1996). *Low-Cost Urban Sanitation.* Wiley, Chichester, UK. pp 63–65.
(Dimensioning calculations)

_ Polprasert, C. and Rajput, VS. (1982). *Environmental Sanitation Reviews: Septic Tank and Septic Systems.* Environmental Sanitation Information Center, AIT, Bangkok, Thailand. pp 31–58.

D.7 Leach Field

Applicable to:
System 5

Application Level	Management Level	Inputs:
★★ Household	★★ Household	Effluent
★ Neighbourhood	★★ Shared	
City	★ Public	



A Leach Field, or drainage field, is a network perforated pipes that are laid in underground gravel-filled trenches to dissipate the effluent from a water-based Collection and Storage/Treatment or (Semi-) Centralized Treatment technology.

Effluent is fed into a distribution box which directs the flow into several parallel channels. A small dosing system releases the pressurized effluent into the Leach Field on a timer (usually 3 to 4 times a day). This ensures that the whole length of the Leach Field is utilized and that aerobic conditions are allowed to recover between dosings. Each trench is 0.3 to 1.5 m deep and 0.3 to 1 m wide. The bottom of each trench is filled with about 15 cm of clean rock and a perforated distribution pipe is laid overtop. More rock covers the pipe so that it is completely surrounded. The layer of rock is covered with a layer of geotextile fabric to prevent small particles from plugging the pipe. A final layer of sand and/or topsoil covers the fabric and fills the trench to the ground level. The pipe should be placed 15 cm from the surface to prevent effluent from surfacing. The trenches should be dug no longer than 20 m in length at least 1 to 2 m apart.

Adequacy Leach Fields require a large area and soil with good absorptive capacity to effectively dissipate the effluent.
To prevent contamination, a Leach Field should be located 30 m away from a drinking water supply. Leach fields are not appropriate for dense urban areas. They can be used in almost every temperature, although there may be problems with pooling effluent in areas where the ground freezes.
Homeowners who have a Leach Field must be aware of how it works and what their maintenance responsibilities are. Trees and deep-rooted plants should be kept away from the Leach Field as they can crack and disturb the tile bed.

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

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

The collection technology which precedes the Leach Field (e.g. Septic Tank: S9) should be equipped with a sewer connection so that if, or when, the Leach Field needs to be replaced, the changeover can be done with minimal disruption.

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

Pros & Cons:

+ Can be used for the combined treatment of blackwater and greywater
+ Has a lifespan of 20 or more years (depending on conditions)
+ Low to moderate capital cost, low operating cost
- Requires expert design and construction
- Requires a large area (on a per person basis)
- Not all parts and materials may be available locally
- Pretreatment is required to prevent clogging
- May negatively affect soil and groundwater properties

References

_ Crites, R. and Tchobanoglous, G. (1998). *Small and Decentralized Wastewater Management Systems.* WCB and McGraw-Hill, New York, USA. pp 905–927.

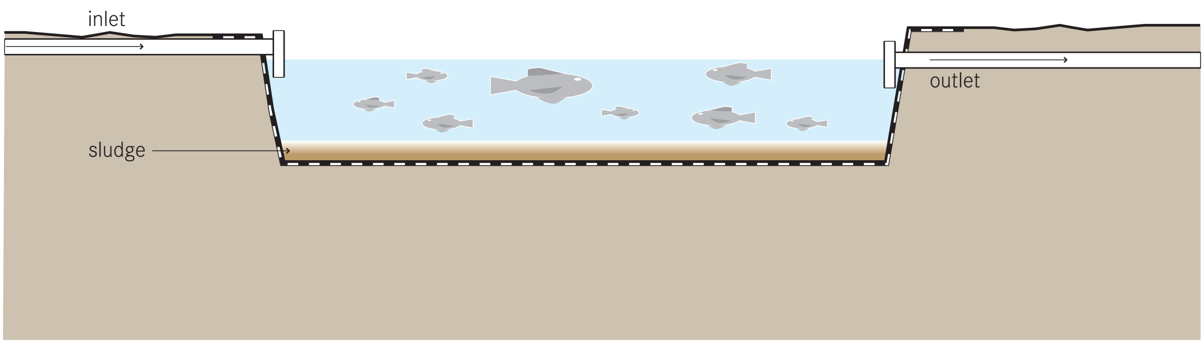
_ Polprasert, C. and Rajput, VS. (1982). *Environmental Sanitation Reviews: Septic Tank and Septic Systems.* Environmental Sanitation Information Center, AIT, Bangkok, Thailand.

_ USEPA (1980). *Design manual- on-site wastewater treatment and disposal systems. EPA-625/1-80-012.* Office of Research and Development, Municipal Environmental Research Laboratory, Cincinnati, Ohio. Available: www.epa.gov

D.8 Aquaculture Ponds

Applicable to:
System 1, 5, 6, 7, 8

Application Level	Management Level	Inputs:
Household	Household	Effluent
★ Neighbourhood	★ Shared	
★★ City	★★ Public	



Aquaculture refers to the controlled cultivation of aquatic plants and animals; this technology sheet refers exclusively to the raising of fish while the following page on Floating Macrophytes (D9) addresses the cultivation of plants. Fish can be grown in ponds where they feed on algae and other organisms that grow in the nutrient-rich water. Through feeding, the nutrients from the wastewater are removed and the fish are eventually harvested for consumption.

Three kinds of aquaculture designs for raising fish exist:
1) fertilization of fish ponds with excreta/sludge;
2) fertilization of fish ponds with effluent; and
3) fish grown directly in aerobic ponds.

When introducing nutrients in the form of effluent or sludge it is important to limit the additions such that aerobic conditions are maintained. BOD should not exceed 1 g/m^{2}d and oxygen should be at least 4 mg/L. Fish introduced to aerobic ponds can effectively reduce algae and help control mosquito populations.

The fish themselves do not dramatically improve the water quality, but because of their economic value they can offset the costs of operating a treatment facility. Under ideal operating conditions, up to 10,000 kg/ha of fish can be harvested. If the fish are not acceptable for human consumption, they can be a valuable source of protein for other high-value carnivores (like shrimp) or converted into fishmeal for pigs and chickens.

Adequacy A fish pond is only appropriate when there is a sufficient amount of land (or preexisting pond), a source of fresh water and a suitable climate. The water that is used to dilute the waste should not be too warm, and the ammonia levels should be kept low or negligible.

Only fish that are tolerant of low dissolved oxygen levels should be chosen. They should not be carnivores and they should be tolerant to diseases and adverse environmental conditions. Different varieties of carp, milkfish and tilapia have been successful, but the specific choice will depend on local preference and suitability.

This technology is only appropriate for warm or tropical climates with no freezing temperatures, and preferably with high rainfall and minimal evaporation.

Health Aspects/Acceptance Where there is no other source of readily available protein, this technology may be embraced. The quality and condition of the fish will also influence local acceptance. There may be concern with contamination of the fish, especially during the harvesting, cleaning and preparation of the fish. If it is cooked well it should be safe, but it is advisable to move the fish to a clear-water pond for several weeks before they are harvested for consumption.

Maintenance The fish need to be harvested when they reach an appropriate age/size. Sometimes after harvesting, the pond should be drained so that (a) it can be desludged and (b) it can be left to dry in the sun for 1 to 2 weeks to destroy any pathogens living on the bottom or sides of the pond.

Pros & Cons:

+ Can provide a cheap, locally available protein source
+ Low to moderate capital cost; operating costs should be offset by production revenue
+ Potential for local job creation and income generation
+ Can be built and maintained with locally available materials
- Fish may pose a health risk if improperly prepared or cooked
- Requires abundance of fresh water
- Requires large land (pond) area
- May require expert design and installation

References

_ Cointreau, S., et al. (1987). *Aquaculture with treated wastewater: a status report on studies conducted in Lima, Perú. Technical Note 3.* UNDP/World Bank, Washington D.C. USA. 1987.

_ Cross, P. and Strauss, M. (1985). *Health Aspects of Nightsoil and Sludge Use in Agriculture and Aquaculture.* International Reference Centre for Waste Disposal, Dübendorf, Switzerland.

_ Edwards, P. and Pullin, RSV. (eds) (1990). *Wastewater-Fed Aquaculture.* Proceedings: International Seminar on Wastewater Reclamation and Reuse for Aquaculture, Calcutta, India.
(Compilation of topical papers)

_ Iqbal, S. (1999). *Duckweed Aquaculture-Potentials, Possibilities and Limitations for Combined Wastewater Treatment and Animal Feed Production in Developing Countries.* Sandec, Dübendorf, Switzerland.

_ Joint FAO/NACA/WHO Study Group (1999). *Food safety issues associated with products from aquaculture.* World Health Organization Technical Report Series No. 883.
Available: www.who.int

_ Mara, DD. (2004). *Domestic Wastewater Treatment in Developing Countries.* Earthscan, London. pp 253–261.

_ Polprasert, C., et al. (2001). *Wastewater Treatment II, Natural Systems for Wastewater Management.* Lecture Notes. IHE, Delft.
Available: www.who.int
(Chapter 8 - Aquaculture and Reuse Aspects).

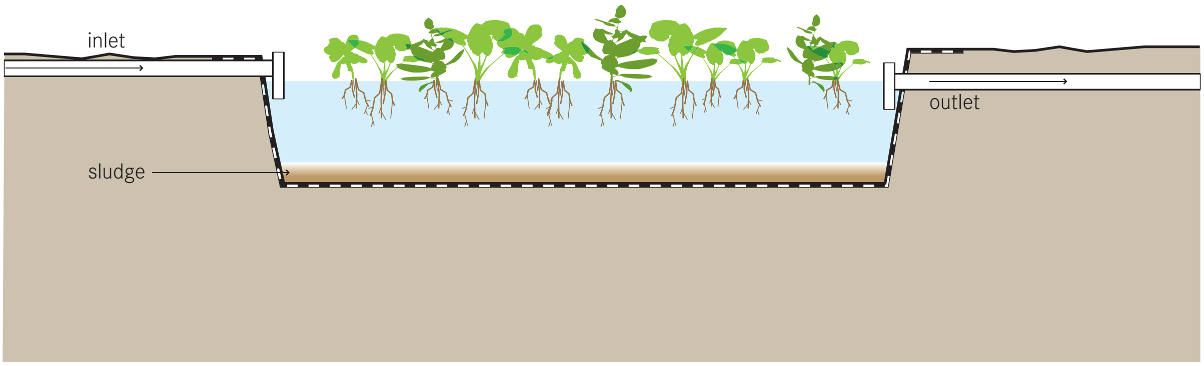
_ Rose, GD. (1999). *Community-Based Technologies for Domestic Wastewater Treatment and Reuse: options for urban agriculture.* IDRC Ottawa.
Available: http://idrinfo.idrc.ca

_ Skillicorn, W., Journey, K. and Spira, P. (1993). *Duckweed aquaculture: A new aquatic farming system for developing countries.* World Bank, Washington, DC.
Available: http://www.p2pays.org/ref/09/08875.htm
(Comprehensive manual)

D.9 Floating Plant (Macrophyte) Pond

Applicable to:
System 1, 5, 6, 7, 8

Application Level	**Management Level**	**Inputs:**
Household	Household	Effluent
★ Neighbourhood	★ Shared	
★★ City	★★ Public	



A floating plant pond is a modified maturation pond with floating (macrophyte) plants. Plants such as water hyacinths or duckweed float on the surface while the roots hang down into the water to uptake nutrients and filter the water that flows by.

Water hyacinths are perennial, freshwater, aquatic macrophytes that grow especially fast in wastewater. The plants can grow large: between 0.5 to 1.2 m from top to bottom. The long roots provide a fixed medium for bacteria which in turn degrade the organics in the water passing by.
Duckweed is a fast growing, high protein plant that can be used fresh or dried as a food for fish or poultry. It is also tolerant of a variety of conditions and can remove significant quantities of nutrients from wastewater.
To provide extra oxygen to a floating plant technology, the water can be mechanically aerated but at the cost of increased power and machinery. Aerated ponds can withstand higher loads and can be built with smaller footprints. Non-aerated ponds should not be too deep otherwise there will be insufficient contact between the bacteria-harbouring roots and the wastewater.

Adequacy The technology can achieve high removal rates of both BOD and suspended solids, although pathogen removal is not substantial.
Harvested hyacinths can be used as a source of fibre for rope, textiles, baskets, etc. Depending on the income generated, the technology can be cost neutral. Duckweed can be used as the sole food source to some herbivorous fish.
This technology is only appropriate for warm or tropical climates with no freezing temperatures, and preferably with high rainfall and minimal evaporation. Different, locally appropriate plants can be selected depending on availability and the wastewater type.
Trained staff is required for the constant operation and maintenance of the pond.

Health Aspects/Acceptance Water hyacinth has attractive, lavender flowers. A well designed and maintained system can add value and interest to otherwise barren land.
Adequate signage and fencing should be used to prevent people and animals from coming in contact with the water.

Maintenance Floating plants require constant harvesting. The harvested biomass can be used for small artisanal businesses, or it can be composted. Mosquito problems can develop when the plants are not harvested regularly. Depending on the amount of solids entering, the pond must be desludged periodically.

Pros & Cons:

+ Water hyacinth grows rapidly and is attractive
+ High reduction of BOD and solids; low reduction of pathogens
+ Low to moderate capital cost; operating cost can be offset by revenue
+ Potential for local job creation and income generation
+ Can be built and maintained with locally available materials
- Can become an invasive species if released into natural environments
- Requires large land (pond) area

References

_ Abbasi, SA. (1987). *Aquatic plant based water treatment systems in Asia.* pp 175–198, In: Aquatic Plants for Water Treatment and Resource Recovery, K.R. Reddy and W.H. Smith (eds.), Magnolia Publishing Inc., Orlando, Florida.

_ Bagnall, LO., Schertz, CE. and Dubbe, DR. (1987). *Harvesting and handling of biomass.* pp. 599–619, In: Aquatic Plants for Water Treatment and Resource Recovery, K.R. Reddy and W.H. Smith (eds.), Magnolia Publishing Inc., Orlando, Florida.

_ Crites, R. and Tchobanoglous, G. (1998). *Small and Decentralized Wastewater Management Systems.* WCB and McGraw-Hill, New York, USA, pp 609–627. (Comprehensive summary chapter including solved problems)

_ Gerba, CP., et al. (1995). *Water-Quality Study of Graywater Treatment Systems.* Water Resources Bulletin 31(1): 109–116.

_ Iqbal, S. (1999). *Duckweed Aquaculture-Potentials, Possibilities and Limitations for Combined Wastewater Treatment and Animal Feed Production in Developing Countries.* Sandec, Dübendorf, Switzerland.

_ McDonald, RD. and Wolverton, BC. (1980). Comparative study of wastewater lagoon with and without water hyacinth. Economic Botany: 34 (2): 101–110.

_ Polprasert, C., et al. (2001). *Wastewater Treatment II, Matural Systems for Wastewater Management.* IHE, Delft. (Comprehensive Design Manual: see Chapter 4 – Water Hyacinth Ponds.)

_ Rose, GD. (1999). *Community-Based Technologies for Domestic Wastewater Treatment and Reuse: options for urban agriculture.* IDRC, Ottawa. Available: http://idrinfo.idrc.ca

_ Skillicorn, W., Journey, K. and Spira, P. (1993). *Duckweed aquaculture: A new aquatic farming system for developing countries.* World Bank, Washington, DC. Available: www.p2pays.org/ref/09/08875.htm (Comprehensive manual)

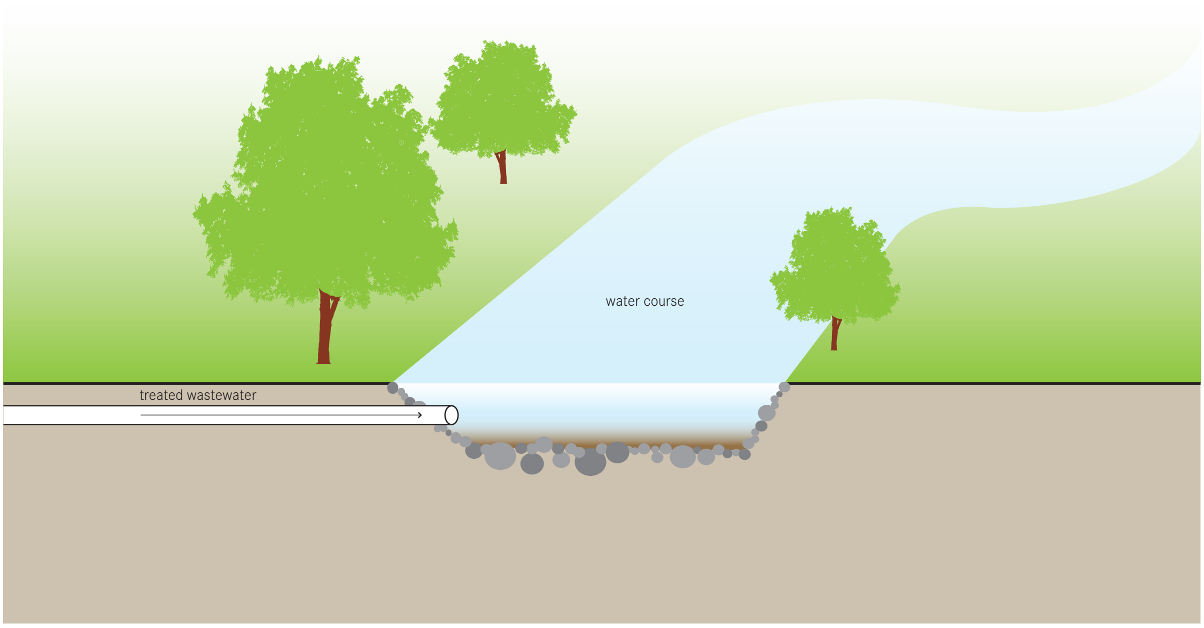
_ US Environmental Protection Agency (1988). *Design Manual: Constructed Wetlands and Aquatic Plant Systems for Municipal Wastewater Treatment.* USEPA, Cincinnati, Ohio. Available: www.epa.gov/owow/wetlands/pdf/design.pdf

D.10 Water Disposal/Groundwater (GW) Recharge

Applicable to:
Systems 1–7

D.10

Application Level	**Management Level**	**Inputs:**
★★ Household	★★ Household	Effluent Stormwater
★★ Neighbourhood	★★ Shared	
★★ City	★★ Public	



Treated effluent and/or stormwater can be discharged directly into receiving water bodies (such as rivers, lakes, etc.) or into the ground to recharge aquifers.

It is necessary to ensure that the assimilation capacity of the receiving water body is not exceeded, i.e. that the receiving body can accept the quantity of nutrients without being overloaded. Parameters such as turbidity, temperature, suspended solids, BOD, nitrogen and phosphorus (among others) should be carefully controlled and monitored before releasing any water into a natural body. The use of the water body, whether it is used for industry, recreation, spawning habitat, etc., will influence the quality and quantity of treated wastewater that can be introduced without deleterious effects.

Local authorities should be consulted to determine the discharge limits for the relevant parameters as they can vary widely. For especially sensitive areas, chlorination may be required to meet microbiological limits.

Alternatively, water can be discharged into aquifers. Groundwater recharge is increasing in popularity as groundwater resources deplete and as saltwater intrusion becomes a greater threat to coastal communities. Although the soil is known to act as a filter for a variety of contaminants, groundwater recharge should not be viewed as a treatment method. Once an aquifer is contaminated, it is next to impossible to reclaim it. The quality of water extracted from a recharge aquifer is a function of the quality of the wastewater introduced, the method of recharge, the characteristics of the aquifer, the residence time, the amount of blending with other waters and the history of the system. Careful analysis of these factors should precede any recharge project.

Adequacy The adequacy of discharge into a water body or aquifer will depend entirely on the local environmental conditions and legal regulations. Generally, discharge to a water body is only appropriate when there is a safe distance between the discharge point and the next closest point of use. Similarly, groundwater recharge is most appropriate for areas that are at risk from salt water intrusion or aquifers that have a long retention time.

Depending on the volume, the point of discharge and/or the quality of the water, a permit may be required.

Health Aspects/Acceptance Generally, cations (Mg^{2+}, K^+, NH_4^+) and organic matter will be retained within a solid matrix, while other contaminants (such as nitrates) will remain in the water. There are numerous models for the remediation potential of contaminants and microorganisms, but predicting downstream, or extracted water quality for a large suite of parameters is rarely feasible. Therefore, potable and non-potable water sources should be clearly identified, the most important parameters modelled and a risk assessment completed.

Maintenance Regular monitoring and sampling is important to ensure compliance with regulations and to ensure public health requirements. Depending on the recharge method, some mechanical maintenance may be required.

Pros & Cons:

+ May provide a 'drought-proof' water supply (from groundwater)
+ May increase productivity of water-bodies by maintaining constant levels
- Discharge of nutrients and micropollutants may affect natural water bodies and/or drinking water
- Introduction of pollutants may have long-term impacts
- May negatively affect soil and groundwater properties

References

_ ARGOSS (2001). *Guidelines for assessing the risk to groundwater from on-site sanitation.* British Geological Survey Commissioned Report, CR/01/142.
Available: www.worldbank.org

_ Seiler, KP. and Gat, JR. (2007). *Groundwater Recharge from Run-off, Infiltration and Percolation.* Springer, The Netherlands.

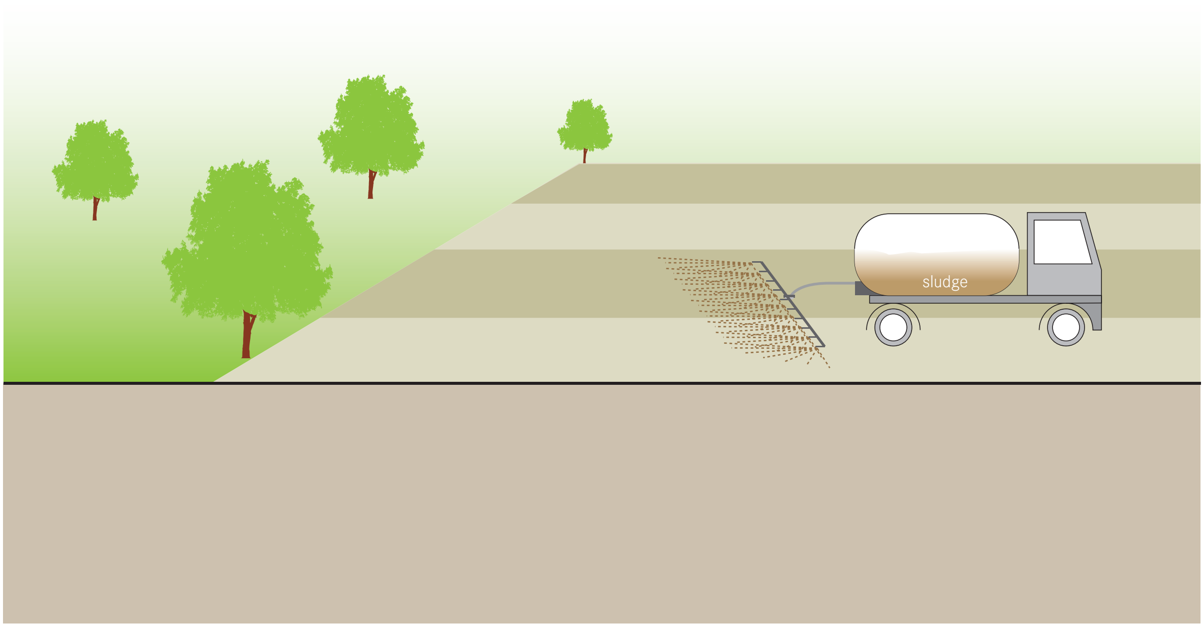
_ Tchobanoglous, G., Burton, FL. and Stensel, HD. (2003). *Wastewater Engineering: Treatment and Reuse, 4th Edition.* Metcalf & Eddy, New York.

_ WHO (2006). *Guidelines for the safe use of wastewater, excreta and greywater- Volume 3: Wastewater and excreta use in aquaculture.* WHO, Geneva.

D.11 Land Application of Sludge

Applicable to:
System 1, 3, 5, 6, 7, 8

Application Level	Management Level	Inputs:
Household	★★ Household	Treated Sludge
★ Neighbourhood	★★ Shared	
★★ City	★★ Public	



Digested or stabilized Faecal Sludge is refered to as 'Biosolids'. Depending on the quality of the biosolids, they can be applied to public or private lands, for landscaping or for agriculture.

The USEPA defines different levels of biosolids depending on the treatment and quality, and therefore the health risk. Class A biosolids (i.e. biosolids that can be sold for public use) can be used with nearly no restrictions. Please consult the guidelines for specific use criteria.
Biosolids can be used in agriculture, home gardening, forestry, sod and turf growing, landscaping, parks, golf courses, mine reclamation, dump cover, or erosion control. Although biosolids have lower nutrient levels than commercial fertilizers (for nitrogen, phosphorus and potassium respectively), they can be used to replace part or all of commercial fertilizers that are used.
Additionally, biosolids have been found to have properties that are superior to those of fertilizers, such as bulking properties, water retention properties and the slow, steady release of nutrients.
Biosolids are spread on the ground surface using conventional manure spreaders, tank trucks or specially designed vehicles. More liquid biosolids (e.g. from anaerobic reactors) can be sprayed onto, or injected into, the ground. Dewatered biosolids may be 'flung', which is most common in forests.

Adequacy Although biosolids are sometimes criticized for containing potentially high levels of metals or contaminants, commercial fertilizers are also contaminated to varying degrees, most likely with cadmium or other heavy metals. Faecal sludge from pit latrines has no, if any, chemical inputs and is therefore not a high risk source of contamination. Faecal sludge that originates at large-scale wastewater treatment plants is more likely to be contaminated since it receives industrial and domestic chemicals, as well as surface water run-off which may contain hydrocarbons and metals. Depending on the sludge source, biosolids can serve as a valuable and often much-needed source of nutrients. Land application of biosolids may be less expensive than disposal.
Application rates and usages for biosolids should take into account not only the presence of pathogens and contaminants, but also the quantity of nutrients such that they are spread at a sustainable and 'agronomic' rate.

Appropriate safety and application regulations should be followed.

Health Aspects/Acceptance The greatest barrier to biosolid use is generally acceptance. However, even when biosolids are not accepted in agriculture or by local industries, they can still be useful for municipal projects and can actually provide significant savings to public projects (e.g. mine reclamation).
Depending on the source of the faecal sludge and on the treatment method, biosolids can be treated to a level where they are generally safe and without significant odour or vector problems.

Maintenance Spreading equipment must be maintained to ensure continued use. The amount and rate of biosolid application should be monitored to prevent overloading and thus, the potential for nutrient pollution.

Pros & Cons:
+ Can accelerate reforestation
+ Can reduce use of chemical fertilizers and improve water retention of soils
+ Can reduce erosion
+ Low cost
- May pose public health risk, depending on the quality and application
- Odours are normally noticeable (depending on prior treatment)
- May require special spreading equipment
- Micropollutants may accumulate in the soil and contaminate groundwater

References

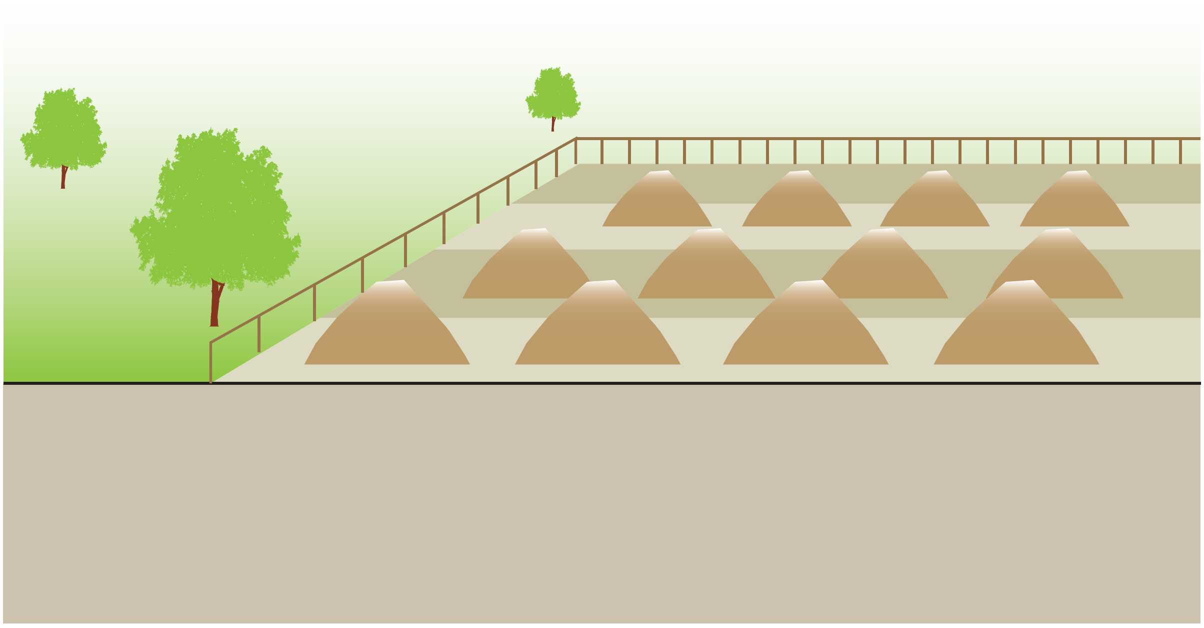
_ U.S. EPA (1999). *Biosolids Generation, Use, and Disposal in the United States, EPA-530/R-99-009.* U.S. Environmental Protection Agency: Washington, D.C.
Available: www.epa.gov

_ U.S. EPA (1994). *A Plain English Guide to the EPA Part 503 Biosolids Rule, EPA832-R-93-003.* U.S. Environmental Protection Agency: Washington, D.C.
Available: www.epa.gov

D.12 Surface Disposal

Applicable to:
Systems 1–8

Application Level	**Management Level**	**Inputs:**	
★ Household	★ Household	Faecal Sludge	Faeces
★ Neighbourhood	★★ Shared	Treated Sludge	Dry Cleansing Material
★★ City	★★ Public		



Surface Disposal refers to the stockpiling of sludge, faeces, biosolids, or other materials that cannot be used elsewhere. Once the material has been taken to a Surface Disposal site, it is not used later. This technology is primarily used for biosolids, although it is applicable for any type of dry, unusable material.

One application of Surface Disposal that is shown on the System Templates is the disposal of dry cleansing materials, such as toilet paper, corn cobs, stones, newspaper and/or leaves. These materials can not always be included along with other water-based products in some technologies and must be separated. A rubbish bin should be provided beside the User Interface to collect the cleansing materials. Dry materials can be burned (e.g. corn cobs) or disposed of along with the household waste. For simplicity, the remainder of this Technology Information Sheet will be dedicated to faecal sludge, since standard solid-waste practices are beyond the scope of this Compendium.

When there is no demand or acceptance for the beneficial use of biosolids, they can be placed in monofills (biosolids-only landfills) or heaped into permanent piles. The main difference between Surface Disposal and Land Application is the application rate. There is no limit to the quantity of biosolids that can be applied to the surface since there are no concerns about nutrient loads or agronomic rates. There is however, concern related to groundwater contamination and leaching. More advanced surface disposal systems may incorporate a liner and leachate collection system in order to prevent nutrients and contaminants from infiltrating the groundwater.
Landfilling biosolids along with Municipal Solid Waste (MSW) is not advisable since it reduces the life of a landfill which has been designed for the containment of more noxious materials. As opposed to more centralized MSW landfills, Surface Disposal sites can be situated close to where the faecal sludge is treated, limiting the need for long transport distances.

Adequacy Since there are no benefits gained from this type of disposal technology, it should not be considered as a primary option. However, where acceptance towards biosolid use does not exist, the contained and controlled stockpiling of biosolids is far preferable to uncontrolled dumping.

Biosolids can be applied in almost every climate and environment, although they should not be stored where there is frequent flooding or where the groundwater table is high.

Health Aspects/Acceptance Since the Surface Disposal site is located far from and protected from the public, there should be no risk of contact or nuisance. Care should be taken to protect the disposal site from vermin and from pooling water, both of which could exacerbate smell and vector problems.

Maintenance Maintenance staff should ensure that only appropriate materials are disposed of at the site, and must maintain control over the traffic and hours of operation.

Pros & Cons:

+ Can make use of vacant or abandoned land
+ Low cost
+ May prevent unmitigated disposal
- Non-beneficial use of a resource
- Odours are normally noticeable (depending on prior treatment)
- May require special spreading equipment
- Micropollutants may accumulate in the soil and contaminate groundwater

References

_ U.S. EPA (1999). *Biosolids Generation, Use, and Disposal in the United States, EPA-530/R-99-009.* U.S. Environmental Protection Agency: Washington, D.C. Available: www.epa.gov

_ U.S. EPA (1994). *A Plain English Guide to the EPA Part 503 Biosolids Rule. EPA832-R-93-003.* U.S. Environmental Protection Agency: Washington, D.C. Available: www.epa.gov

Glossary

Aerobic: means 'requiring oxygen'. Aerobic processes can only function in the presence of molecular oxygen (O_2), and aerobic organisms are those that use oxygen to drive cellular respiration and store energy.

Anaerobic: means 'in the absence of oxygen'. Anaerobic processes are either hindered, or halted by the presence of oxygen. Anaerobic processes are often more foul-smelling than aerobic processes.

Anal cleansing water: is water that is collected after having been used to clean oneself after defecating (and/or urinating). It is generated by those who use water, rather than dry material for anal cleansing.

Anoxic: means 'deficient in oxygen'. Organisms that can live in an anoxic environment can use oxygen that is bound in other molecules (e.g. nitrate, sulphate). Anoxic conditions are often found at the interface between aerobic and anaerobic environments (e.g. in trickling filters or in facultative ponds).

Bacteria: bacteria are simple, single cell organisms. Bacteria obtain nutrients from their environments by excreting enzymes which dissolve complex molecules into more simple ones that can then pass through the cell membrane. Bacteria live everywhere on earth and are essential for maintaining life and performing essential 'services' such as composting, aerobic degradation of waste, and digesting food in our stomachs; some types however can be pathogenic and cause severe illness.

BOD / Biochemical Oxygen Demand: a measure of the amount of oxygen used by bacteria to degrade organic matter in wastewater (expressed in mg/L). It is a proxy measure for the amount of organic material that is present in water: the more the organic content, the more oxygen required to degrade it (high BOD); the lower the organic content, the less oxygen required to degrade it (low BOD).

Biological treatment: the use of living organisms (e.g. bacteria) to treat waste; this is in contrast to chemical treatment which relies on chemicals to transform or remove contaminants from waste.

Biodegradable: a substance that can be broken down into basic molecules (e.g. carbon dioxide, water) by organic processes carried out by bacteria, fungi, and other micro-oganisms.

Biomass: refers to the quantity of living organisms. It is often used to describe the 'active' part of the sludge that is responsible for degrading the organic matter.

Biogas: the common name for the mixture of gases released from anaerobic digestion. Typically biogas is comprised of methane (50–75%), carbon dioxide (25–50%) and varying quantities of nitrogen, hydrogen sulphide, water and other components.

Biosolids: faecal sludge that has been digested/stabilized. Biosolids can be used and applied with reduced risk compared to raw faecal sludge.

Blackwater: the mixture of urine, faeces and flushing water along with anal cleansing water (if anal cleansing is practiced) or dry cleansing material (e.g. toilet paper). It is high in organics and pathogens.

Brownwater: the mixture of faeces and flushing water, but with NO urine.

CBO: Community Based Organization (CBO) is a small organization that does not have the registered status of an NGO (Non-Governmental Organization) but is a structured group of volunteers who work together to achieve a common goal. Anyone can start their own CBO.

Cesspit: a covered hole or pit to receive drainage or sewage.

Chemical treatment: the treatment of wastewater using chemicals to remove pollutants from the wastewater. A common example is the use of alum for coagulation or chlorine for oxidation.

C:N ratio: carbon to nitrogen ratio. This ratio describes the relative amounts of dry available carbon to dry available nitrogen. The ideal value for microbes is around 30:1 (usually expressed as just 30).

Coagulation: the process of forming small clumps so particles so that they may be more easily settled out of wastewater.

COD / Chemical Oxygen Demand: Quantitative measure of the amount of oxygen required for chemical oxidation of carbonaceous (organic) material in a sample by a strong chemical oxidant, expressed in mg/L. COD is always equal to or higher than BOD since it is the sum of the oxygen required for both biological and chemical oxidation.

Combined Sewers: sewers that are designed to carry both blackwater and greywater from homes and stormwater (rainfall). Combined sewers must be larger than Separate Sewers to account for the high volume.

Compost/EcoHumus: the earth-like, brown/black material that is the result of decomposed organic matter; generally is has been hygienized sufficiently that it can be used safely in agriculture.

Composting: the process by which biodegradable components are biologically decomposed under controlled conditions by microorganisms (mainly bacteria and fungi).

Concrete: A mixture of cement, sand, gravel and water that will harden into a solid, stone-like material.

Decentralization: the shift of decision making and responsibility from central authorities to the same level at which the policies are directed.

Decomposition: the transformation of dead organic material (plants, animals, etc.) into more basic compounds and elements.

Desludging: the process of removing sludge from a tank, pit, or other storage unit.

Digestion: similar to decomposition, but usually applied to the decomposition of organic materials (including bacteria) by bacteria, in sludge.

Dry Cleansing Materials: may be paper, corncobs, stones or other dry materials that are used for anal cleansing (instead of water). Depending on the system, the dry cleansing materials may be collected and disposed of separately.

E. Coli: the common abbreviation of *Escherichia Coli.* It is a type of bacteria that inhabits the intestinal tract of humans, and other mammals. It is not necessarily harmful, but it is used to indicate the presence of other, more dangerous bacteria.

Ecological Sanitation: is a term applied to waste treatment technologies when they not only limit the spread of disease, but protect the environment and return nutrients to the soil in a beneficial way.

Effluent: the general name for a liquid that leaves the place or process from where it originated.

Environmental Sanitation: as opposed to simply 'sanitation', seeks to include all aspects of the physical environment which may affect human health and well-being; typical examples of an environmental sanitation program may include potable water, solid waste management, drainage, stormwater management, and sanitation.

Eutrophication: describes excess nutrient concentrations in an aquatic ecosystem which leads to: (i) increased productivity of autotrophic green plants and to the blocking out of sunlight, (ii) elevated temperatures within the aquatic system, (iii) depletion of oxygen, (iv) increased algae growth, and (v) reduction in fauna and flora variety.

Evaporation: the process of water changing from a liquid state to a gaseous state.

Evapotranspiration: evaporation that is facilitated by vegetation. Plants emit water through their stoma (pores) thus providing a greater surface from which water can evaporate.

Excreta: the mixture of urine and faeces that is not mixed with any flushing water.

Faecal Sludge: the general term for the undigested or partially digested slurry or solid that results from the storage or treatment of blackwater or excreta.

Faeces: refers to (semi-solid) excrement without any urine or water.

Filtrate: the liquid that has passed through a filter.

Floatation: The processes whereby lighter fractions of a wastewater, including fats, oils, soaps, etc., rise above the water and the solids, and can thus be separated.

Flushwater: the water that is used to transport excreta, urine and/or faeces from the User Interface to the next Functional Group technology.

Forage: aquatic or other plants that grow in planted drying beds or constructed wetlands and may be harvested for feeding livestock.

Greywater: the total volume of water generated from the washing of food, clothes, dishware and people. It does not contain excreta, but it does contains pathogens and organics.

Groundwater: water that is naturally present beneath the surface of the ground. In some instances groundwater may be found several centimetres below the surface, or it may be up to a hundred metres below the surface. Groundwater is generally quite clean and can be used for drinking water; for this reason care must be taken not to contaminate groundwater with sewage.

HCES: Household-Centred Environmental Sanitation is a 10-step participatory planning process. The goal of the HCES approach is to involve stakeholders to develop an Urban Environmental Sanitation Services Plan which will allow people to lead healthy and productive lives, protect the natural environment while conserving and reusing resources. The guidelines for implementing HCES are available from www.sandec.ch.

Health: "is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." (WHO, 1948).

Helminth: A parasitic worm, i.e. one that lives in or on its host, causing it damage. Examples include especially parasitic worms of the human digestive system, such as roundworm (e.g. Ascaris) or hookworm.

Humus: an earth-like dark brown or black material comprised primarily of decomposed organic material.

Hydraulic Retention Time (HRT): defines the (average) amount of time that a liquid stays in a reactor. It has the unit of time (t) and is calculated by diving the volume of the reactor (m^3) by the flow (m^3/h).

Hydraulic Gradient: the surface slope of a liquid in a pipe, i.e. the liquid will flow along the hydraulic gradient of the system and if there is a inflow that is lower than the gradient, water will flow upwards to meet the gradient line.

Influent: the general name for the liquid that enters into a place or process; the effluent of one process is the influent of the next.

Invert: the bottom of the inside of a pipe. The depth of the invert is especially important when designing sewers.

Leachate: the liquid fraction of a mixed waste that, through gravity or filtration, is separated from the solid component.

Lime: the common name for calcium hydroxide. It is a white, caustic powder that is produced by heating limestone.

Macrophytes: large aquatic plants visible to the naked eye. Their roots and differentiated tissues may be emergent (cattails, bulrushes, reeds, wild rice), submergent (water milfoil, bladderwort) or floating (duckweed, lily pads).

Microbe: general name given to a microorganism; a microscopic bacterium.

Microorganisms: neither plant nor animal, but small, simple unicellular or multicellular organisms such as protozoa, algae, fungi, viruses, and bacteria.

Micropollutants: pollutants which are present in extremely low concentrations, but whose effect is known to be significant. Pharmaceuticals and hormones are two groups of micropollutants which are causing increasing concern for their effects on the endocrine system and sexual development.

Monitoring: the continuous collection and assessment of data (qualitative and quantitative) with the intended goal of optimizing performance and minimizing flaws.

Nightsoil: the name generally given to excrement that may be collected manually. Generally this practice is carried out where there is neither infrastructure for collection and storage or where there is agricultural land that can receive the waste. Unprotected handling and use in agriculture should be treated with caution.

Nutrient: any substance (including protein, fat, carbohydrate, vitamins, or minerals) that is used for growth. In wastewater treatment systems, 'nutrient' usually refers to nitrogen and/or phosphorus since they are primarily responsible for eutrophication.

Oocyst: a thick-walled spore into which different organisms (like Cryptosporidium) can transform as a way of resisting, and surviving through periods of environmentally harsh conditions.

Operation and Maintenance: all work relating to the day-to-day activities that keep a process or system functioning smoothly to prevent delays, repairs and/or downtime.

Organics: general name given to organic materials. An organic is any molecule that contains carbon. Examples of organic compounds are proteins, lipids, amino acids, vitamins, and other building blocks of life. Organics refers to the organic material that must be added to some technologies in order to make them function properly (e.g. composting chambers).

Pathogen: infectious biological agent (bacteria, protozoa, fungi, parasites, viruses) that inflicts disease or illness on its host.

Parasite: any organism that lives on or in another organism and damages its host.

Percolation: the movement of liquid through soil with the force of gravity.

PET: PET is the common name for Polyethylene terephthalate. It is a clear plastic that can be recycled.

pH: the measure of the acidity or alkalinity of a substance. A pH value below 7 indicates that it is acidic, a pH value above 7 indicates that it is basic (alkaline).

Retention time: the theoretic time that one unit of water (or sludge) stays in one tank or pond. When referring to units of water, the term Hydraulic Retention Time is often used (HRT) and is calculated by: HRT= V/Q, where V is the volume of the tank and Q is the rate at which the water leaves (e.g. m^3/h).

Runoff: also referred to as Surface Runoff. It is the quantity of water that falls as precipitation but does not infiltrate to the groundwater table.

Sanitation: general term used to describe a battery of actions that all aim to reduce the spread of pathogens and maintain a healthy living environment. Specific actions related to sanitation include, wastewater treatment, solid waste management and stormwater management.

Scum: general name given to the top, floating layer of material that sits above the water. It is most noticeable in septic tanks where distinct layers of scum, water, and sludge form over time.

Sedimentation: gravity settling of particles in a liquid such that they accumulate. Also called settling.

Septage: 'liquid and solid material pumped from a septic tank, cesspool or other primary treatment source'. (Bellagio, 2005).

Sewage: general name given to the mixture of water and excreta (urine and faeces), although in the Compendium it referred to as blackwater.

Sewer: an open channel or closed pipe used to convey sewage.

Sewerage: all the components of a system used for collecting, transporting and treating sewage (including pipes, pumps, tanks, etc.).

Sitter: the general name given to someone who prefers to sit on the User Interface, rather than squat over it.

Sludge: the thick, viscous layer of materials that settles to the bottom of septic tanks, ponds, and other sewage systems. Sludge is comprised mostly of organics, but also sand, grit, metals, and various chemical compounds.

Specific Surface Area (SSA): describes the property of a solid material. SSA is defined as the ratio of the surface area to the volume in units of m^2/m^3.

Squatter: the general name given to someone who prefers to squat over the User Interface, rather than sit directly on it.

Stabilized: the term used to describe the state of organic material that has been completely oxidized and sterilized. When most of the organic matter has been degraded, bacteria begin to starve and consume their own cytoplasm. The organic matter left by the dead bacteria is then degraded by other organisms, which results in a fully stabilized product.

Stakeholder: any group, person, or agency that has an interest in or is affected by a policy, plan, or project.

Stormwater: the general term for the rainfall that runs off of roofs, roads and other surfaces before flowing towards low-lying land. It is the portion of rainfall that does not infiltrate into the soil.

Sullage: synonym for greywater. It includes wastewater from cooking, washing, and bathing, but does not include any excreta.

Superstructure: name given to the structure that provides privacy to a person using a toilet/bathing facility. A superstructure may be permanent (made of concrete or bricks) or mobile (made of bamboo or cloth).

Surface water: term to describe rainwater that runs overland (i.e. does not infiltrate the ground). Surface water, unlike ground water is generally not safe for consumption as it accumulates pathogens, metals, nutrients and chemicals as it flows across contaminated surfaces.

Sustainability: “meets the needs of the present generation without compromising the ability of future generations to meet their own needs” (Brundtland Commission, 1987).

Sustainable Sanitation: “The main objective of a sanitation system is to protect and promote human health by providing a clean environment and breaking the cycle of disease. In order to be sustainable a sanitation system has to be not only economically viable, socially acceptable, and technically and institutionally appropriate, it should also protect the environment and the natural resources” (SuSanA, 2007).

TS: Total Solids (TS) is the sum of Total Dissolved Solids (TDS) and Total Suspended Solids (TSS). When a water or sludge sample is filtered and dried at 105°C, the residue that remains is referred to as the Total Solids. It is measured in mg/L (mass per volume).

Urea: the organic molecule $(NH_2)_2CO$ that is excreted in urine as a way of ridding the body of excess nitrogen. With time, the urea in urine breaks down into carbon dioxide and ammonia, which is readily used by organisms in soil.

Urine: is the liquid waste produced by the body to rid itself of urea and other waste products.

Vector: the organism that transmits a disease to the host (the vector itself may be a host, but is not the ‘true host’). Flies are vectors as they can transmit pathogens from faeces to humans.

Ventilation: the movement of air; air is both supplied to, and removed from a space.

WC: derived from the words ‘Water Closet’. It is an ambiguous term that can either refer to the actual room where a toilet is located, or the actual toilet itself.

Washer: the general name for those who use water to cleanse after defecating.

Wastewater: traditionally described as any water that has been used and is unfit for further use. The term is applied broadly to all waters originating in toilets, showers, sinks, washing areas, factories, etc. More recently terms such as ‘blackwater’, ‘greywater’ and ‘yellow water’ have been adopted both as a way to describe the composition more accurately, and to emphasize the fact that used waters have nutrients, are valuable, and should not be ‘wasted’.

Water table: the top level of the groundwater; also referred to as the groundwater table. A water table is not static and can vary with season, year, and usage.

Wiper: the general name for those who use solid materials, like paper, to cleanse after defecating.

Yellowwater: is the name for urine combined with flushing water. It is not included in any of the systems in this Compendium.

Bibliographic reference:
Tilley, Elizabeth et al, 2008. Compendium of Sanitation Systems and Technologies. Swiss Federal Institute of Aquatic Science and Technology (Eawag). Dübendorf, Switzerland.

ISBN: 978-3-906484-44-0

Graphic Design: Pia Thür, Zürich
Technical Drawings: Paolo Monaco, Zürich
Photos: Eawag-Sandec
First edition: 2000 copies
Printed by: Mattenbach AG, Winterthur, Switzerland

eawag
aquatic research

WATER SUPPLY & SANITATION COLLABORATIVE COUNCIL