Compendium of Sanitation Systems and Technologies

WATER SUPPLY & SANITATION COLLABORATIVE COUNCIL

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Compendium of Sanitation Systems and Technologies

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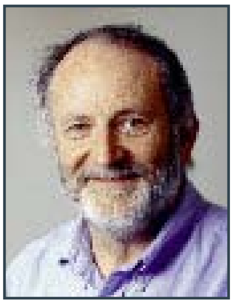
Our special thanks go to:
the NETSSAF Consortium, the GTZ ecosan programme
and the Sustainable Sanitation Alliance (SuSanA).

We would like to thank the following individuals
for their contributions and comments:
Chris Buckley, Pierre-Henri Dodane, Barbara Evans, Doulaye Koné,
Elisabeth Kvarnström, Duncan Mara, Peter Morgan, Arne Panesar,
Eddy Perez, Elias Rosales, Arno Rosemarin, Sören Rud, Darren Saywell,
Margaret Scott, Steven Sugden, Kevin Tayler, Kai Udert,
Carolien van der Voorden, Yvonne Voegeli, Anita Wittmer.

We would like to acknowledge support from:
the Swiss National Centre of Competence in Research (NCCR)
North-South: Research Partnerships for Mitigating Syndromes of
Global Change, co-funded by the Swiss National Science Foundation (SNSF)
and the Swiss Agency for Development and Cooperation (SDC).

Foreword



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Investing in sanitation and hygiene is not only about saving human lives and dignity; it is the foundation for investing in human development, especially in poor urban and peri-urban areas. However, one of the main bottlenecks encountered the world over, is the limited knowledge and awareness about more appropriate and sustainable systems and technologies that keep project costs affordable and acceptable.

Abundant information exists about sanitation technologies but it is scattered throughout dozens of books, reports, proceedings and journals; this Compendium aims to pull the main information together in one volume. Another aim of the Compendium is to promote a systems approach; sanitation devices and technologies should always be considered as parts of an entire system.

In 2005, Sandec and the WSSCC published Provisional Guidelines for Household-centred Environmental Sanitation (HCES), a new planning approach for implementing the Bellagio Principles on Sustainable Sanitation in Urban Environmental Sanitation. The HCES approach emphasizes the participation of all stakeholders – beginning at the household / neighbourhood – in planning and implementing sanitation systems. By ordering and structuring a huge range of information on fully and partly tested technologies into one concise document, this Compendium is an important tool for stakeholders to make well informed decisions during the planning process.

Although this source book is primarily addressed to engineers and planners dealing with infrastructure delivery, the technology sheets also allow non-experts to understand the main advantages and limitations of different technologies and the appropriateness of different system configurations. It is our hope that this Compendium will allow all stakeholders to be involved in selecting improved sanitation technologies and to help promote people-centred solutions to real sanitation problems.

This is the first edition of the Compendium and we are looking forward to receiving your feedback – experiences and suggestions for a next edition are very welcome!

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Introduction

Background

This document was developed in the context of the Household Centered Environmental Sanitation (HCES) planning approach shown in Figure 1. The HCES approach is a 10-step multi-sector and multi-actor participatory planning process. The guidelines for implementing HCES are available from www.sandec.ch.

Enabling Environment

Government Support — Legal Framework — Credit and other Finacial Arrangements — Institutional Arrangements — Required Skills

The 10-Step process

1 Request for assistance
2 Launch of the planning and consultative process
3 Assessment of current status
4 Assessment of user priorities
5 Identification of options
6 Evaluation of feasible service combinations
7 Consolidated UESS plans for study area
8 Finalizing of consolidated UESS plans
9 Monitoring (internal) evaluation and feedback
10 Implementation

Figure 1. The 10-step process in the HCES planning approach (EAWAG, 2005)

The first four steps of the HCES planning approach define the project-specific social, cultural, economic, health and environmental priorities which will influence technology selection and the system design. The goal of steps five (5) and six (6) is to identify specific technological options and to evaluate feasible service combinations. The following steps, seven (7) through ten (10), lead to the formulation or design of a comprehensive Urban Environmental Sanitation Services (UESS) plan.

This Compendium is designed to serve as a resource tool during steps 5 and 6 of the HCES planning approach. It is presupposed that the user of this Compendium has a well-developed awareness of the context and priorities of the community and other stakeholders as the social-cultural elements of sanitation planning are not explicitly addressed in this document.

Target User of the Compendium

This Compendium is intended to be used by engineers, planners and other professionals who are familiar with sanitation technologies and processes. It is not a training manual or stand-alone resource for people with no experience in sanitation planning.

The user of this document must have an interest in learning more about alternative or novel technologies which may not be part of the common suite employed or taught in the local context. The approach and information presented herein is meant to broaden the spectrum of innovative and appropriate technologies considered for sanitation planning.

Objective of the Compendium

The objective the Compendium is threefold:

1. Expose the Compendium user to a broad range of sanitation systems and innovative technologies;
2. Help the Compendium user understand and work with the system concept, i.e. the process of building a complete system, by iteratively choosing and linking appropriate technologies;
3. Describe and fairly present the technology-specific advantages and disadvantages.

Structure of the Compendium

The Compendium is divided into 2 Parts; (1) the **System Templates** and a description about how to use them; and (2) the **Technology Information Sheets.**

It is recommended that the Compendium user reviews Part 1: Sanitation Systems to become familiar with the terminology and structure of the System Templates and their components. The user can then familiarize themselves with the technologies of interest in Part 2: Technology Information Sheets. The user can move between the System Templates and the Technology Information Sheets (they are cross-referenced) until he/she has identified some systems and/or technologies that could be appropriate for further investigation. Eventually, the user should be able to develop one, or several system configurations that can be presented to the community. The Compendium can then be used, following the community's suggestions, to re-evaluate and redesign the system accordingly.

Part 1: **System Templates**

This Compendium defines sanitation as a multi-step process in which wastes are managed from the point of generation to the point of use or ultimate disposal. A sanitation system is comprised of **Products** (wastes) which travel through **Functional Groups** which contain **Technologies** which can be selected according to the context. A sanitation system also includes the management, operation and maintenance (O&M) required to ensure that the system functions safely and sustainably. **By selecting a Technology for each Product from each applicable Functional Group, one can design a logical sanitation system.**
The purpose of this Part is to clearly explain the System Templates by describing what they consist of, what qualities they have and how they are to be used.

This Compendium describes eight (8) different System Templates.
System 1: Single Pit System
System 2: Waterless System with Alternating Pits
System 3: Pour Flush System with Twin Pits
System 4: Waterless System with Urine Diversion
System 5: Blackwater Treatment System with Infiltration
System 6: Blackwater Treatment System with Sewerage
System 7: (Semi-) Centralized Treatment System
System 8: Sewerage System with Urine Diversion

A System Template defines a suite of compatible Technology combinations from which a system can be designed. Each System Template is distinct in terms of the characteristics and the number of **Products** generated and processed. The System Templates present logical combinations of Technologies, but the planner must not lose a rational, engineering perspective. It must also be noted that although this Compendium is thorough, it is not an exhaustive list of Technologies and/or associated systems.

Although the System Templates are predefined, the Compendium user must select the appropriate Technology from the options presented. The choice is context specific and should be made based on the local environment (temperature, rainfall, etc.), culture (sitters, squatters, washers, wipers, etc.) and resources (human and material).
System templates 1 to 8 range from simple (with few Technology choices and Products) to complex (with multiple Technology choices and Products).
The first section of this chapter defines the parts of the System Templates. Products, Functional Groups, and Technologies are explained.
The second part of this chapter explains how the System Templates can be read, understood, and used to build a functional Sanitation System.
The final section of this Chapter presents a description of how the system works, what are the main considerations, and what type of applications that system is appropriate for.

Products

Products are materials that are also called 'wastes' or 'resources'. Some Products are generated directly by humans (e.g. urine and faeces), others are required in the functioning of Technologies (e.g. flush water to move excreta through sewers) and some are generated as a function or storage or treatment (e.g. faecal sludge).

For the design of a robust sanitation system, it is necessary to define all of the Products that are flowing into (Inputs) and out (Outputs) of each of the sanitation Technologies in the system. The Products referenced within this text are described below.

Urine is the liquid waste produced by the body to rid itself of urea and other waste Products. In this context, the urine Product refers to pure urine that is not mixed with faeces or water. Depending on diet, human urine collected during one year (ca. 500 L) contains 2–4 kg nitrogen. With the exception of some rare cases, urine is sterile when it leaves the body.

Faeces refers to (semi-solid) excrement without urine or water. Each person produces approximately 50 L per year of faecal matter. Of the total nutrients excreted, faeces contain about 10% N, 30% P, 12% K and have 10^7–10^9 faecal coliforms / 100 mL.

Anal cleansing water is water collected after it has been used to cleanse oneself after defecating and/or urinating. It is only the water generated by the user for anal cleansing and does not include dry materials. The volume of water collected during anal cleansing ranges from 0.5 L to 3 L per cleaning.

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

Greywater is the total volume of water generated from washing food, clothes and dishware as well as from bathing. It may contain traces of excreta and therefore will also contain pathogens and excreta. Greywater accounts for approximately 60% of the wastewater produced in households with flush toilets. It contains few pathogens and its flow of nitrogen is only 10–20% of that in blackwater.

Flushwater is the water that is used to transport excreta from the User Interface to the next technology. Freshwater, rainwater, recycled greywater, or any combination of the three can be used as a Flushwater source.

Organics refers here to biodegradable organic material that could also be called biomass or green organic waste. Although the other Products in this Compendium contain organics, this term refers to undigested plant material. Organics must be added to some technologies in order for them to function properly (e.g. composting chambers). Organic degradable material can include but is not limited to leaves, grass and market waste.

Dry Cleansing Materials may be paper, corncobs, rags, stones and/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. Although extremely important, we have not included a separate Product name for menstral hygiene products like sanitary napkins and tampons. In general (though not always), they should be treated along with the Dry Cleansing Materials that are described here.

Blackwater is the mixture of urine, faeces and flushwater along with anal cleansing water (if anal cleansing is practiced) and/or dry cleansing material (e.g. toilet paper). Blackwater has all of the pathogens of faeces and all of the nutrients of urine, but diluted in flushwater.

Faecal Sludge is the general term for the raw (or partially digested) slurry or solid that results from the storage of blackwater or excreta. The composition of faecal sludge varies significantly depending on the location, the water content, and the storage. For example, ammonium (NH_4-N) can range from 300–3000 mg/L while Helminth eggs can reach up to 60,000 eggs/L. The composition will determine the type of treatment that is possible and the end-use possibilities.

Treated Sludge is the general term for partially digested or fully stabilized faecal sludge. The US Environmental Protection Agency has strict criteria to differentiate between degrees of treatment and consequently, how those different types of sludges can be used. 'Treated Sludge' is used in the System Templates and in the Technology Information Sheets as a general term to indicate that the sludge has undergone some level of treatment, although it should not be assumed that 'treated sludge' is fully treated or that it is automatically safe. It is meant to indicate that the sludge has undergone some degree of treatment and is no longer raw. It is the responsibility of the user to inquire about the composition, quality and therefore safety of the local sludge.

Excreta consists of urine and faeces that is not mixed with any flushing water. Excreta is small in volume, but concentrated in nutrients and pathogens. Depending on the quality of the faeces it is solid, soft or runny.

Brownwater consists of faeces and flushwater (although in actual practice there is always some urine, as only 70–85% of the urine is diverted). Brownwater is generated by urine-diverting flush toilets and therefore, the volume depends on the volume of the flushwater used. The pathogen and nutrient load of faeces is not reduced, only diluted by the flushwater.

Dried faeces are faeces that have been dehydrated at high temperatures (and high pH) until they become a dry, sanitized powder. Very little degradation occurs during dehydration and this means that the dried faeces are still rich in organic material. Faeces will reduce in volume by around 75%. There is a small risk that some organisms can be reactivated in the right environments.

Stored urine is urine that has been hydrolyzed naturally over time, i.e. the urea has been converted by enzymes into carbon dioxide and ammonia. Stored urine has a pH of approximately 9. After 6 months of storage, the risk of pathogen transmission is reduced considerably.

Effluent is the general term for liquid that has undergone some level of treatment and/or separation from solids. It originates at either a Collection and Storage/Treatment or a (Semi-) Centralized Treatment Technology. Depending on the type of treatment, the effluent may be completely sanitized or may require further treatment before it can be used or disposed of.

Compost/EcoHumus is the earth-like, brown/black material that is the result of decomposed organic matter. Generally Compost/EcoHumus has been hygienized sufficiently that it can be used safely in agriculture. Because of leaching, some of the nutrients are lost, but the material is still rich in nutrients and organic matter.

Biogas is 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.

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

This Compendium is primarily concerned with systems and Technologies directly related to excreta and does not address the specifics of greywater or stormwater management but shows when they can be co-treated with excreta. So although greywater and stormwater are shown as Products in the System Templates, the related Technologies are not described in detail. For a more comprehensive summary of dedicated greywater Technologies refer to the following resource:

- Morel A. and Diener S. (2006). *Greywater Management in Low and Middle-Income Countries, Review of different treatment systems for households or neighbourhoods.* Swiss Federal Institute of Aquatic Science and Technology (Eawag). Duebendorf, Switzerland.
  Available free for download: www.eawag.ch

Functional Groups

A **Functional Group** is a grouping of technologies which perform a similar function. There are five (5) different **Functional Groups** from which the technologies used to build a system are chosen. It is not necessary for a Product to pass through a technology from each Functional Group; however, the ordering of the Functional Groups should usually be maintained regardless of how many of them are included within the sanitation system. Also, each Functional Group has a distinctive colour; technologies within a given Functional Group share the same colour code so that they are easily identifiable.
The five (5) Functional Groups are:

U **User Interface** (Technologies U1–U6): Red

S **Collection and Storage/Treatment** (Technologies (S1–S12): Orange

C **Conveyance** (Technologies C1–C8): Yellow

T **(Semi-) Centralized Treatment** (Technologies T1–T15): Green

D **Use and/or Disposal** (Technologies D1–D12): Blue

Each technology within a given Functional Group is assigned a reference code with a single letter and number; the letter corresponds to the Functional Group (e.g. U for User Interface) and the number, going from lowest to highest, indicates approximately how resource intensive (i.e. economic, material and human) the technology is.

U **User Interface (U)** describes the type of toilet, pedestal, pan, or urinal that the user comes in contact with; it is the way that the user accesses the sanitation system. In many cases, the choice of User Interface will depend on the availability of water. Note that greywater and stormwater do not originate at the User Interface, but may be treated along with the Products that originate at the User Interface.

S **Collection and Storage/Treatment (S)** describes the ways of collecting, storing, and sometimes treating the Products that are generated at the User Interface. Treatment that is provided by these Technologies is often a function of storage and usually passive (e.g. no energy inputs). Thus, Products that are 'treated' by these Technologies often require subsequent treatment before use or disposal.

C **Conveyance (C)** describes the transport of Products from one Functional Group to another. Although Products may need to be transferred in various ways between Functional Groups, the longest, and most important gap is between Collection and Storage/Treatment and (Semi-) Centralized Treatment; thus, for simplicity, conveyance is limited to transporting Products at this point.

T **(Semi-) Centralized Treatment (T)** refers to treatment Technologies that are generally appropriate for large user groups (i.e. multiple households). The operation, maintenance, and energy requirements for Technologies within this Functional Group are more intensive. The Technologies are divided into 2 groups: Technologies T1–T10 are primarily for the treatment of blackwater, whereas Technologies T11–T15 are primarily for the treatment of sludge.

D **Use and/or Disposal (D)** refers to the methods in which Products are ultimately returned to the environment, as either useful resources or reduced-risk materials. Furthermore, Products can also be cycled back into a system (e.g. the use of treated greywater for flushing).

Technologies

Technologies are defined as the specific infrastructure, methods, or services that are designed to contain, transform, or transport Products to another Functional Group. There are between 6 and 15 different technologies within each Functional Group. The Technology Information Sheets located in Part 2 provide a detailed description of each technology identified within each System Template.

Using the System Templates

Each system is a matrix of **Functional Groups** (columns) and **Products** (rows) that are linked together where logical connections exist. Where these logical connections exist, a Technology choice is presented (i.e. for a certain Product (row) intersecting a specific Functional Group (column)).

Each Functional Group is colour-coded and the same colour code is used within a System Template. To facilitate efficient reference between System Templates and Technology Information Sheets the Technologies within each Functional Group adopt the same colour-code. The colour-code for each Functional Group within the System Template is presented below in Figure 2.

Figure 3 is an example from a System Template. A bold colour-coded box indicates a Technology choice within a given Functional Group. This System Template shows how three Products (Faeces, Urine and Flushwater) enter into a User Interface (Pour Flush Toilet and sometimes a Urinal) and emerge as Blackwater. Blackwater then enters the Collection and Storage/Treatment Functional Group and is transformed in the Twin Pits for Pour Flush into Compost/EcoHumus and Effluent. The Compost/EcoHumus is transported (Human Powered) to a final point of use and the Effluent is absorbed by the soil (Disposal/Recharge).

Bold lines with arrows are used to link the most appropriate Functional Groups for a given Product. Thin lines indicate other flow paths which are possible, but not always common or recommended (see Figure 4).

Figure 2. System Template header with colour-code for the Functional Groups

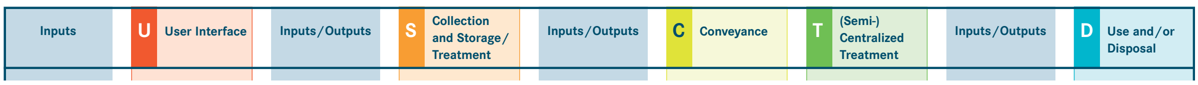
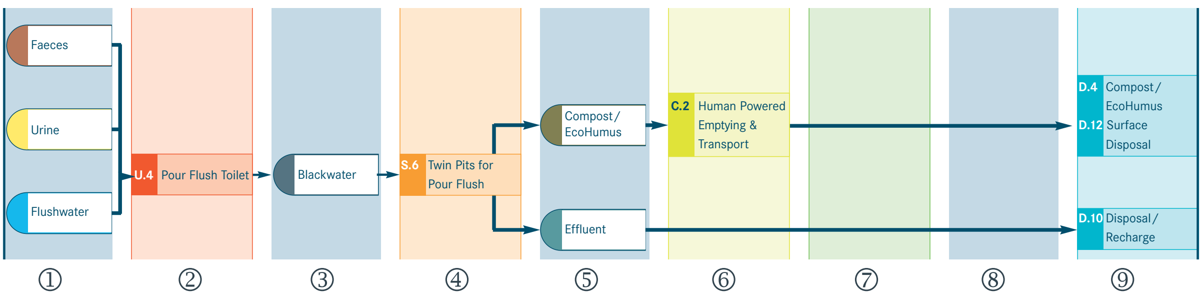


Figure 3. System Template: how Inputs enter into Functional Groups and are transformed



① Three Inputs (Faeces, Urine and Flushwater) enter into ② Functional Group U "User Interface" (Pour Flush Toilet). The Blackwater generated ③ then enters into ④ Functional Group S "Collection and Storage/Treatment" (Twin Pits For Pour Flush Latrine) and is transformed into ⑤ Compost/EcoHumus and Effluent. The Compost/EcoHumus enters into ⑥ Functional Group C "Conveyance" (Human Powered Emptying & Transport) and passes ⑦ Functional Group T "(Semi-) Centralized Treatment" without treatment with no further ⑧ Inputs/Outputs. Compost/EcoHumus is transported directly to the final ⑨ Functional Group D "Use and/or Disposal" (Compost/Eco-Humus, Surface Disposal).
The ⑤ Effluent does not enter into ⑥ Functional Group C nor ⑦ Functional Group T (therefore there are ⑧ no Inputs/Outputs) but the Effluent is directly discharged ⑨ in Functional Group D (Disposal/Recharge).

Although the most logical combinations are presented herein, the Technologies and associated links are not exhaustive. The designer should attempt to minimize redundancy, optimize existing infrastructure and make use of local resources.

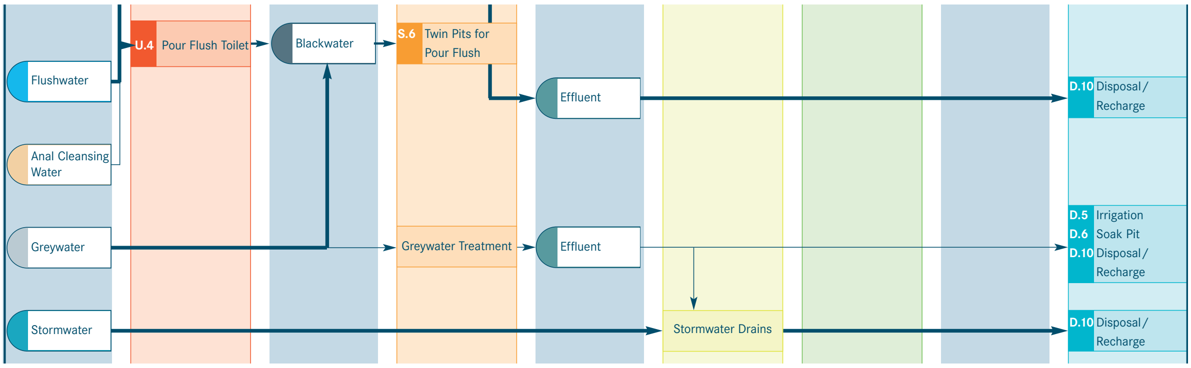
This methodology should be followed for each area (region or planning zone) under consideration. However, any number of systems can be chosen and it is not necessary that each home, compound, or community within the area choose the same Technologies. Some Technologies may already exist; in that case it is the goal of the planners and engineers to optimize existing infrastructure and reduce redundancy but maintain flexibility with user satisfaction as the primary goal.

Steps for selecting a System Template:

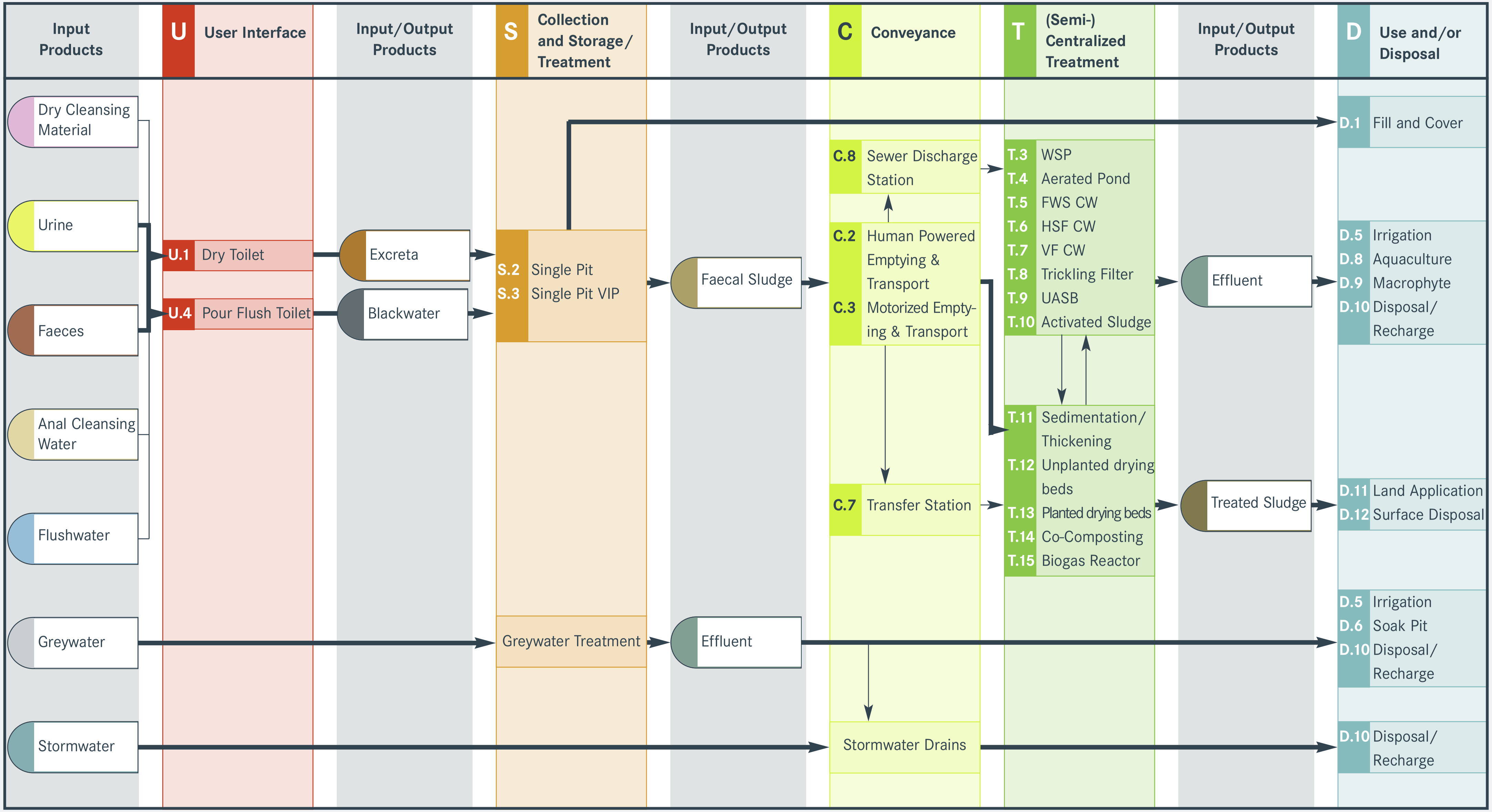
a) Identify the Products that are generated and/or are available locally (e.g. Anal Cleansing Water or Flushwater).
b) Identify the System Templates that process the defined Products
c) For each template, select a Technology from each Functional Group where there is a Technology choice presented (bold coloured box); the series of Technologies makes up a System
d) Compare the systems and iteratively change individual Technologies or use a different System Template based on user priorities, economic constraints, and technical feasibility.

> The eight System Templates are presented and described on the following pages. Each System Template is explained in detail.

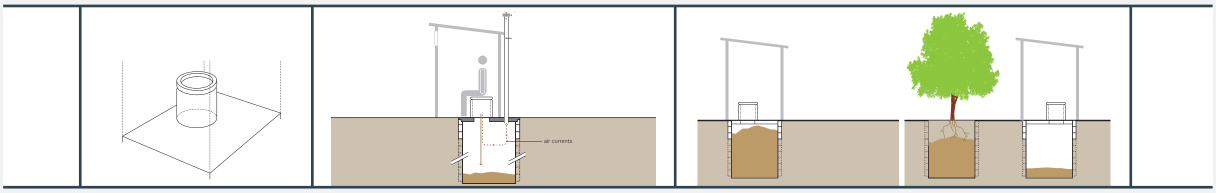
Figure 4. Bold lines with arrows are used to link the most appropriate Functional Groups for a given Input or Output. Thin lines indicate other flowstreams which are possible.



Sanitation System 1: Single Pit System



System 1: Single Pit System



This system is based on the use of a single pit to collect and store the excreta. The system can be used with or without Flushwater depending on the User Interface.

The inputs to the system can include Urine, Faeces, Anal Cleansing Water, Flushwater and Dry Cleansing Materials. The use of Flushwater and/or Anal Cleansing Water will depend on water availability and local habit.

There are two different User Interfaces for this system, which include a Dry Toilet (U1) or a Pour Flush Toilet (U4). The User Interface is directly connected to a Collection and Storage/Treatment Technology: a Single Pit (S2) or a Single Ventilated Improved Pit (VIP) (S3).

When the pit is full there are several options. If there is space, the pit can be filled with soil and planted with a tree, as per the Fill and Cover (D1), and a new pit built. This is generally only possible when the superstructure is mobile. Alternatively, the Faecal Sludge that is generated from the Collection and Storage/Treatment Technology has to be removed and transported for further treatment. The Conveyance Technologies that can be used include Human Powered Emptying and Transport (E&T) for solid sludge (C2) or Motorized E&T for liquid sludge (C3). When the Faecal Sludge is thinner, it must be emptied with a vacuum truck. As the Faecal Sludge is highly pathogenic prior to treatment, human contact and agricultural applications should be avoided. When it is not feasible to empty the full pit, (Semi-) Centralized Treatment can be omitted and the pit can be filled and covered with a suitable material for decommissioning (Fill and Cover: D1). The decommissioned pit can be planted with a fruit or flowering tree since it will thrive in the nutrient rich environment.

Faecal Sludge that is removed can be transported to a dedicated Faecal Sludge treatment facility (Technologies T11 to T15). In the event that the treatment facility is not easily accessible, the Faecal Sludge can be discharged to either a Sewer Discharge Station (C8) or a Transfer Station (C7). From the Sewer Discharge Station, the Faecal Sludge is transported by the sewer and is co-treated with the Blackwater flowing in the sewer network (Technologies T1 to T10). The Faecal Sludge from the Sewer Discharge station is released either directly into the sewer or at timed intervals. If sludge is introduced directly into a sewer, there must be enough water to adequately dilute and transport the sludge to the treatment facility. From the Transfer Station the Faecal Sludge must be transported to a dedicated Faecal Sludge treatment facility (Technologies T11 to T15) by a motorized vehicle (C3).

All (Semi-) Centralized Treatment Technologies, T1 to T15, produce both Effluent and Faecal Sludge, which require further treatment prior to Use and/or Disposal. Technologies for the Use and/or Disposal of the treated Effluent include Irrigation (D5), Aquaculture (D8), Macrophyte Pond (D9) or Discharge to a water body or Recharge to groundwater (D10).

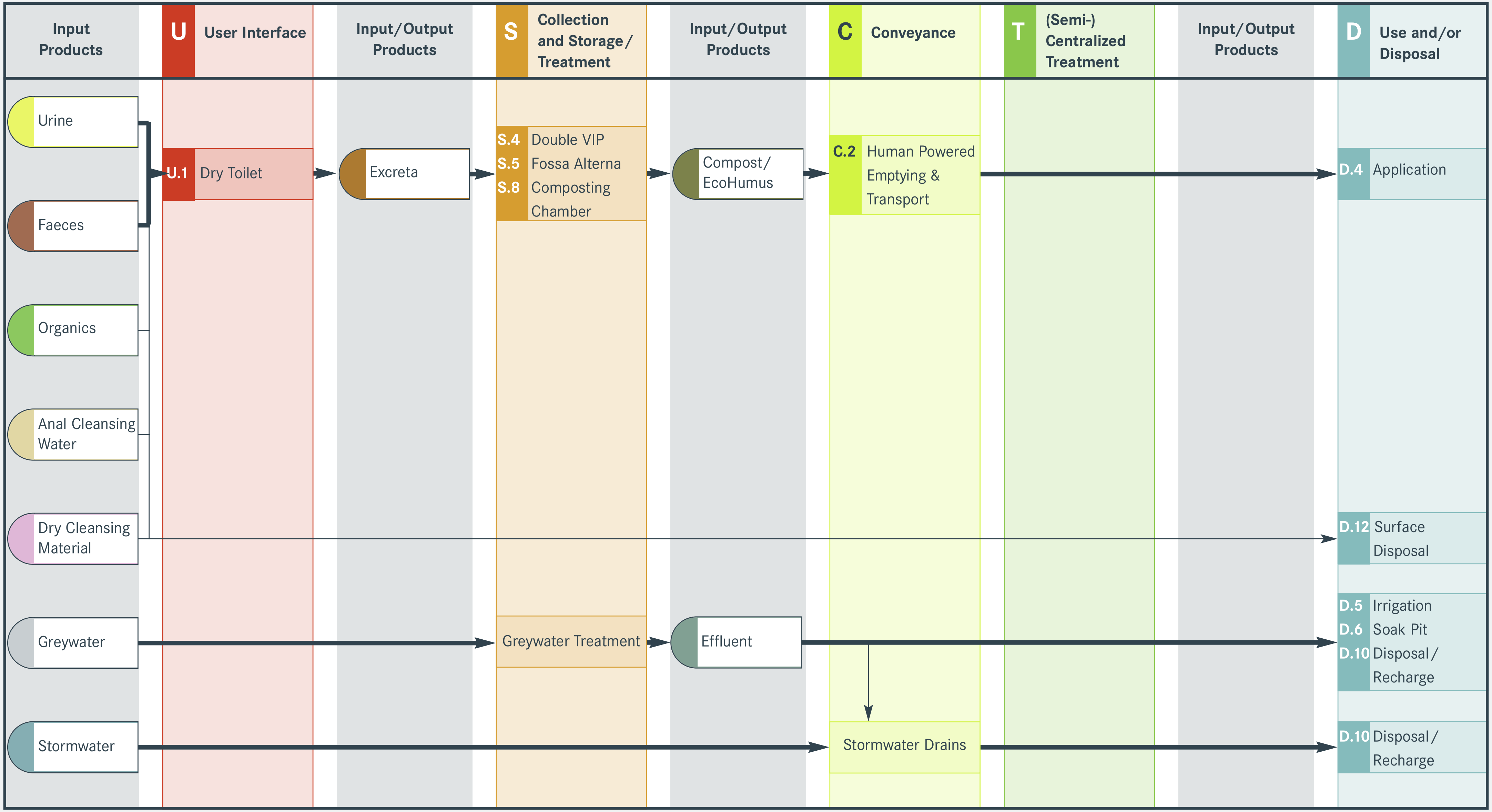
Considerations This system is best suited to rural and peri-urban areas where there is appropriate soil for digging and absorbing the Effluent from the pit. This system should be chosen only where there is either space to continuously dig new pits or when there is an appropriate manner of emptying and disposing of the Faecal Sludge. In dense urban settlements, there may not be sufficient transportation or access to empty or move to another pit. This system is also best suited to areas that are not prone to heavy rains or flooding, which may cause the pits to overflow. Some Greywater in the pit may help degradation, but excessive additions of Greywater may shorten the life of the pit.

Although different types of pits are common in most parts of the world, a well designed pit-based system with appropriate transport, treatment and use or disposal, is still very rare.

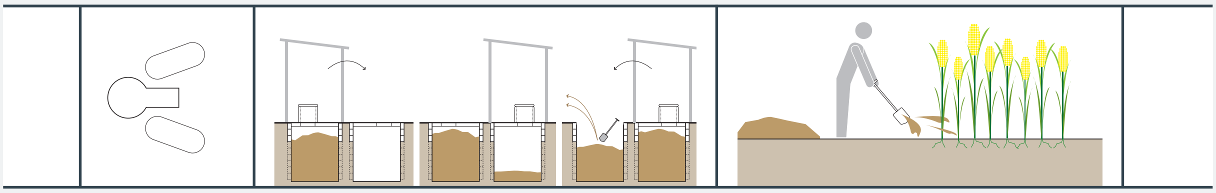
This system is one of the least expensive to construct (capital cost) however the maintenance costs may be considerable, depending on the depth of the pit and how often it must be emptied. If the ground is appropriate, i.e. good absorptive capacity, the pit may be dug very deep (e.g. >5m) and can be used for several years (up to 30 years) without emptying.

All types of solid cleansing materials can be discarded into the pit, although they may shorten the life of the pit and make pit emptying more difficult. Whenever possible, solid cleansing materials should be disposed of separately.

Sanitation System 2: Waterless System with Alternating Pits



System 2: Waterless System with Alternating Pits



This system is designed to produce a dense, compost-like material by using alternating pits without the addition of Flushwater.

The inputs to the system can include Urine, Faeces, Organics, Anal Cleansing Water, and Dry Cleansing Materials.

A Dry Toilet (U1) is the only recommended User Interface for this system. A Dry Toilet does not require water to function and in fact, water should not be input into this system; Anal Cleansing Water should be kept to a minimum or even excluded from this system if possible. Depending on the Collection and Storage/Treatment Technology, the Dry Cleansing Materials can be added to the pit, otherwise they should be collected separately and directly transferred for disposal (D12).

Excreta is produced at the User Interface. The User Interface is connected directly to a Collection and Storage/Treatment Technology: a Double VIP (S4), Fossa Alterna (S5) or a Composting Chamber (S8). Alternating the pits gives the material an opportunity to drain, degrade, and transform into a nutrient-rich, hygienically-improved, humic material that can be used or disposed of safely. While one pit is filling with Excreta (and potentially organic material), the other pit remains out of service. When the first pit is full, it is covered and temporarily taken out of service. The drained and degraded Excreta within the second pit is emptied and the pit is put back into service. The second pit collects Excreta until it is filled, covered and taken out of service and the cycle is repeated indefinitely. Although a 'Composting Chamber' is not strictly an alternating pit technology, it can have multiple chambers and produces a safe, useable compost-Product. For these reasons it is included in this System Template.

The Compost/EcoHumus that is generated from the Collection and Storage/Treatment Technology can be removed and transported for Use and/or Disposal manually using a Human Powered E&T (C2) Conveyance Technology. Since it has undergone significant degradation, the humic material is quite safe to handle and use in agriculture. If there are concerns about the quality, it can be composted further in a dedicated composting facility but there is no need to transport the Compost/EcoHumus to a (Semi-) Centralized Treatment facility as decomposition of the Excreta takes place onsite.

For the Use and/or Disposal of Compost/EcoHumus, the Application of Compost/EcoHumus (D4) Technology is utilized.

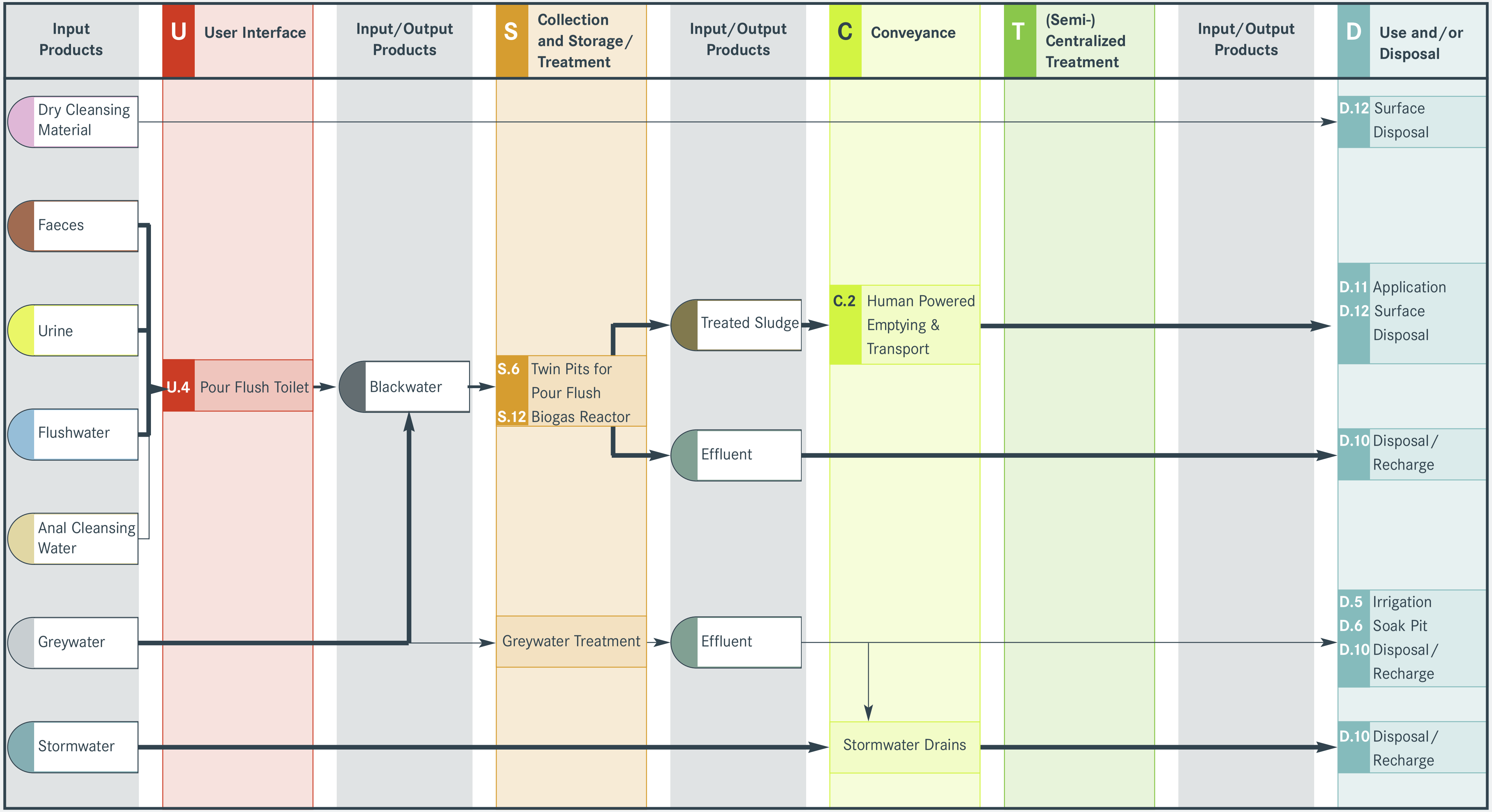
This system is different than System 1 because of the Conveyance and Use and/or Disposal options: in the previous system, the sludge requires further treatment before it can be used, whereas the Compost/EcoHumus produced in this system is ready for Use and/or Disposal following Collection and Storage/Treatment.

Considerations Because the system is permanent and can be used indefinitely (as opposed to some single pits, which may be filled and covered), it can be used where space is limited. Additionally, because the Product must be removed manually, this system is appropriate for dense areas that do not have access to mechanical emptying/trucks.

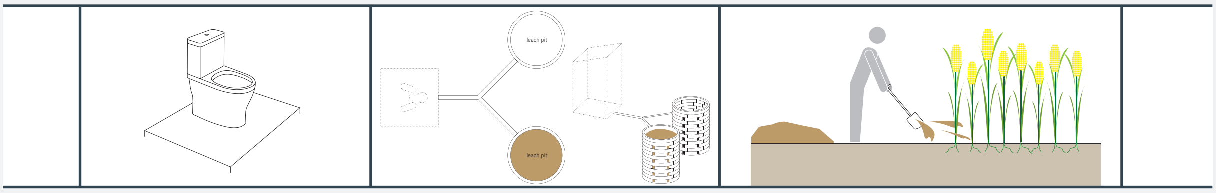
The success of this system depends on an extended storage period. If a suitable and continuous source of soil, ash or organic matter (leaves, grass clippings, coconut or rice husks, woodchips, etc.) is available, the decomposition process is enhanced and the storage period can be reduced. The storage period can be minimized if the material in the pit remains well aerated and not too moist. Therefore, the Greywater must be collected and treated separately. Too much moisture in the pit will fill the air-voids and deprive the microbes of oxygen, which may impair the degradation process.

This system is especially appropriate for water-scarce areas and where there is an opportunity to use the humic material. Dry cleansing materials can be discarded into the pit/chamber, especially if they are carbonaceous (e.g. toilet paper, newsprint, corncobs, etc.) as this may help with degradation and airflow.

Sanitation System 3: Pour Flush System with Twin Pits



System 3: Pour Flush System with Twin Pits



This is a water-based system utilizing the Pour Flush Toilet (pedestal or squat pan) to produce a partially digested, humus-like Product, which can be used as a soil amendment. If water is not available, please refer to Systems 1, 2 and 4. Greywater can be used in system and does not require separate treatment.

The inputs to the system can include Faeces, Urine, Flushwater, Anal Cleansing Water, Dry Cleansing Materials and Greywater.

The User Interface Technology for this system is a Pour Flush toilet (U4). A Urinal (U3) should only be used in addition to, and not instead of, the Pour Flush Toilet.

Twin Pits for Pour Flush (S6) is one of the technologies used for the Collection and Storage/Treatment of the Blackwater output from the User Interface. The Twin Pits are lined with a porous material that allows the Effluent to infiltrate into the ground while solids accumulate and degrade at the bottom of the pit. While one pit is filling with Blackwater, the other pit remains out of service. When the first pit is full, it is covered and temporarily taken out of service. It should take a minimum of two (2) years to fill a pit. When the second pit is full, the first pit is re-opened and the contents are removed. The Treated Sludge that is generated in the pit after two (2) years is removed and transported for Use and/or Disposal manually using a Human Powered E&T (C2) Conveyance Technology. Since it has undergone significant degradation, it is not as pathogenic as raw, undigested sludge. There is no need to transport the treated sludge to a (Semi-) Centralized Treatment facility as treatment of the Blackwater takes place onsite.

Dry Cleansing Materials may clog the pit and prevent water from infiltrating into the soil and so it should be collected separately and transferred for Surface Disposal (D12).

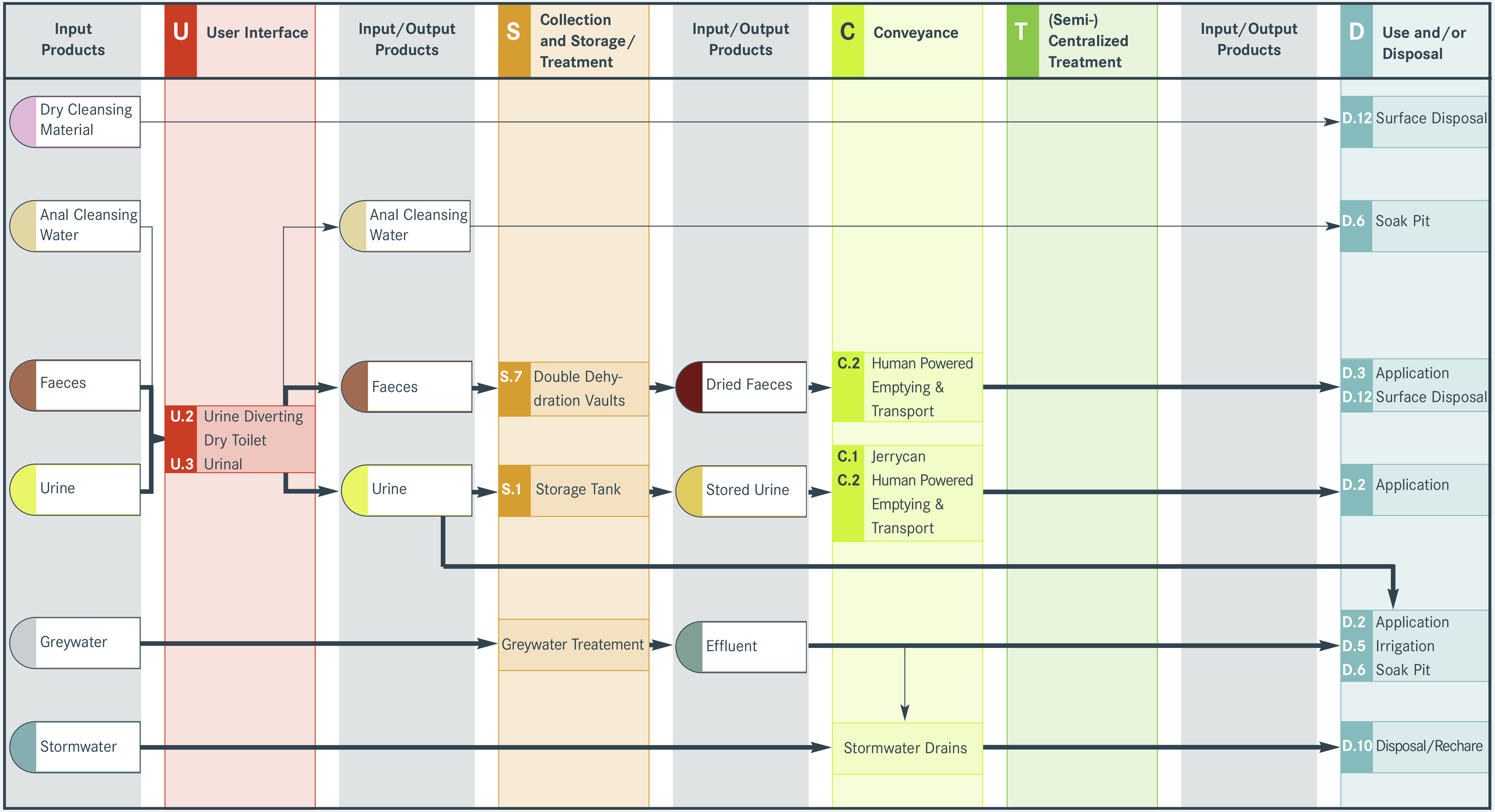
Alternatively, the blackwater can be directed towards an Anaerobic Biogas Reactor (S12). The reactor will function better if animal manure and organic waste are also added; liquid imputs like Greywater should be kept to a minimum. The Biogas that is generated (not shown) can be used for cooking, and the Treated Sludge can be used as a soil amendment.

For the Use and/or Disposal component of the System Template, the Application of Sludge (D11) Technology is utilized. Effluent from the Twin Pits for Pour Flush (S6) is directly Infiltrated into the soil (D10) onsite from each pit. Therefore, this system should only be installed where there is a low groundwater table that is not at risk of contamination from these pits.

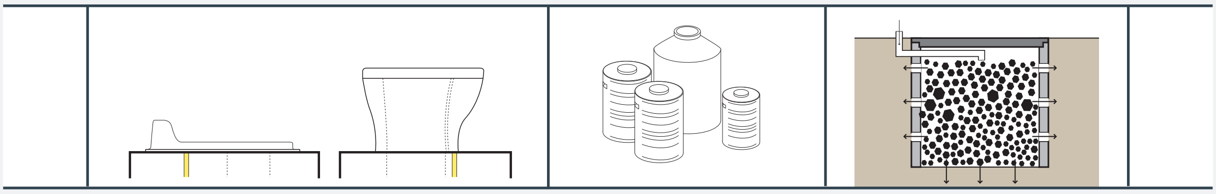
Considerations Depending on the Collection and Storage/Treatment technology chosen, the system will depend on different criteria. In the case of the double pits, the system will depend on soil which can continually and adequately absorb moisture; clayey or densely packed soils are not appropriate. The material that is removed should be in a safe, useable form, although the task of removing, transporting and using it may not be favourable in some circumstances. The use of a household biogas digester is best suited to peri-urban or rural areas where there is a source of organic and/or animal waste material and a need for the digested sludge. The piping system for the gas must be well maintained to prevent leaks and potential explosions.

This system is well-suited for anal cleansing with water. Dry cleansing materials should be disposed of separately because they could easily clog the pit or the reactor (D12).

Sanitation System 4: Waterless System with Urine Diversion



System 4: Waterless System with Urine Diversion



This system is designed to separate Urine and Faeces to allow Faeces to dehydrate and/or recover the Urine for beneficial use. This system can be used anywhere, but it is especially appropriate for rocky areas where digging is difficult, where there is a high groundwater table, or in water-scarce regions.

The inputs to the system can include Faeces, Urine, Anal Cleansing Water and Dry Cleansing Materials.

There are two User Interface Technologies for this system; a Urine Diverting Dry Toilet (UDDT) (U2) or a Urinal (U3). UDDTs with a third diversion for Anal Cleansing Water are not common, but can be manufactured locally or ordered depending on local washing customs. Dry cleansing materials will not harm the system, but they should be collected separately from the UDDT (U2) and directly transferred for Surface Disposal (D12).

Double Dehydration Vaults (S7) are used for the Collection and Storage/Treatment Technology for Faeces. Anal Cleansing Water should never be put into Dehydration Vaults, but it can be diverted and put into a Soak Pit (D6). When storing the Faeces in chambers, they should be kept as dry as possible to encourage dehydration and hygienization. Therefore, the chambers should be watertight and care should be taken to ensure that no water is introduced during cleaning.

Also important is a constant supply of ash, lime, or dry earth to cover the Faeces to minimize odours and provide a barrier between the Faeces and potential vectors (flies). The pH increase will also help to kill organisms.

A separate Greywater system is required since it should not be introduced into the Dehydration Vaults and preferably not into the pits.

Urine can be disposed of easily and without risk to the environment because it is generated in relatively small volumes and is nearly sterile. The Urine can be diverted directly to the ground for Use and/or Disposal as Land Application (D2), Irrigation (D5) or soil infiltration through a Soak Pit (D6). Storage Tanks (S1) can be used for the Collection Storage/Treatment of Urine.

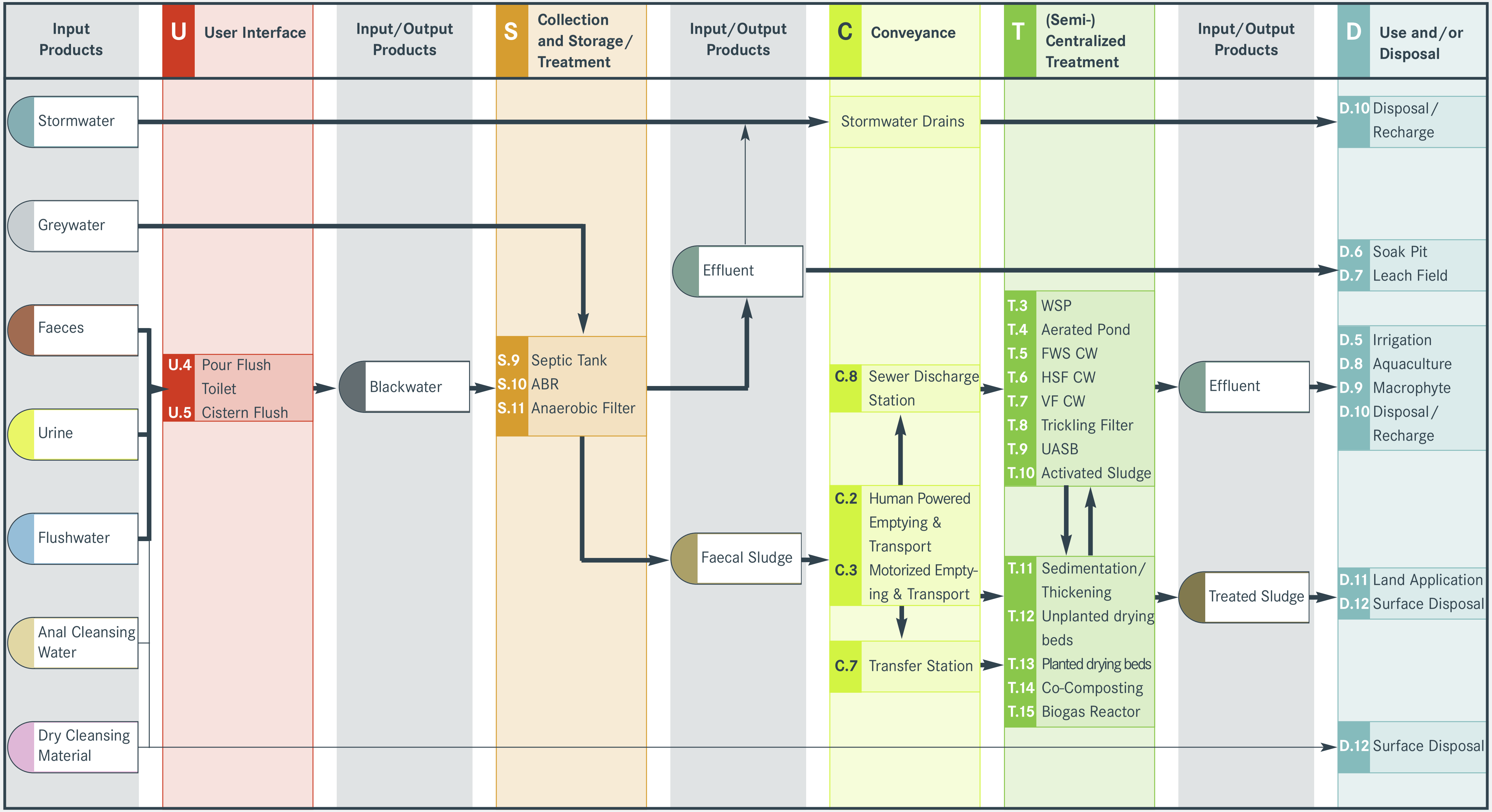
The Dried Faeces that are generated from the Collection and Storage/Treatment Technology can be removed and transported for Use and/or Disposal. The Conveyance Technology that can be used is Human Powered E&T (C2). The Dried Faeces pose little human health risk. Stored Urine can be transported for Use and/or Disposal using either the Jerrycan (C1) or Motorized E&T (C3) Technologies.

Guidelines for the safe use of Excreta, Faecal Sludge and Urine have been published by the World Health Organization (WHO) and are referenced on the relevant Technology Information Sheets.

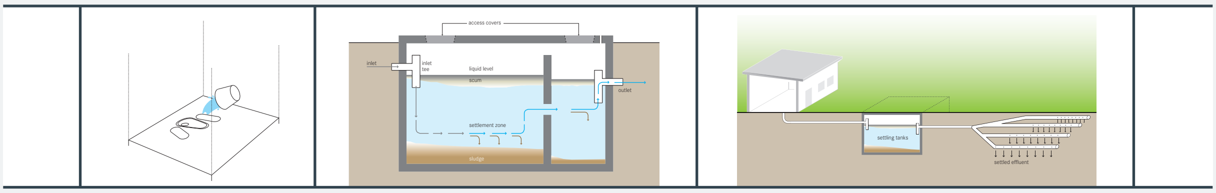
Considerations The success of this system depends on the efficient separation of urine and faeces as well as the use of a suitable drying agent; a dry, hot climate can also contribute considerably to the rapid dehydration of the faeces. The system can be used regardless of the users' acceptance to Urine use; it can be adapted to suit the agricultural and cultural needs of the users.

All types of solid cleansing materials can be used, although they should be discarded separately. Anal Cleansing Water must be separated from the Faeces although it can be mixed with the Urine before it is transferred to the Soak Pit (not shown in the System Template). If Urine is used in agriculture, Anal Cleansing Water should be kept separate and treated along with Greywater.

Sanitation System 5: Blackwater Treatment System with Infiltration



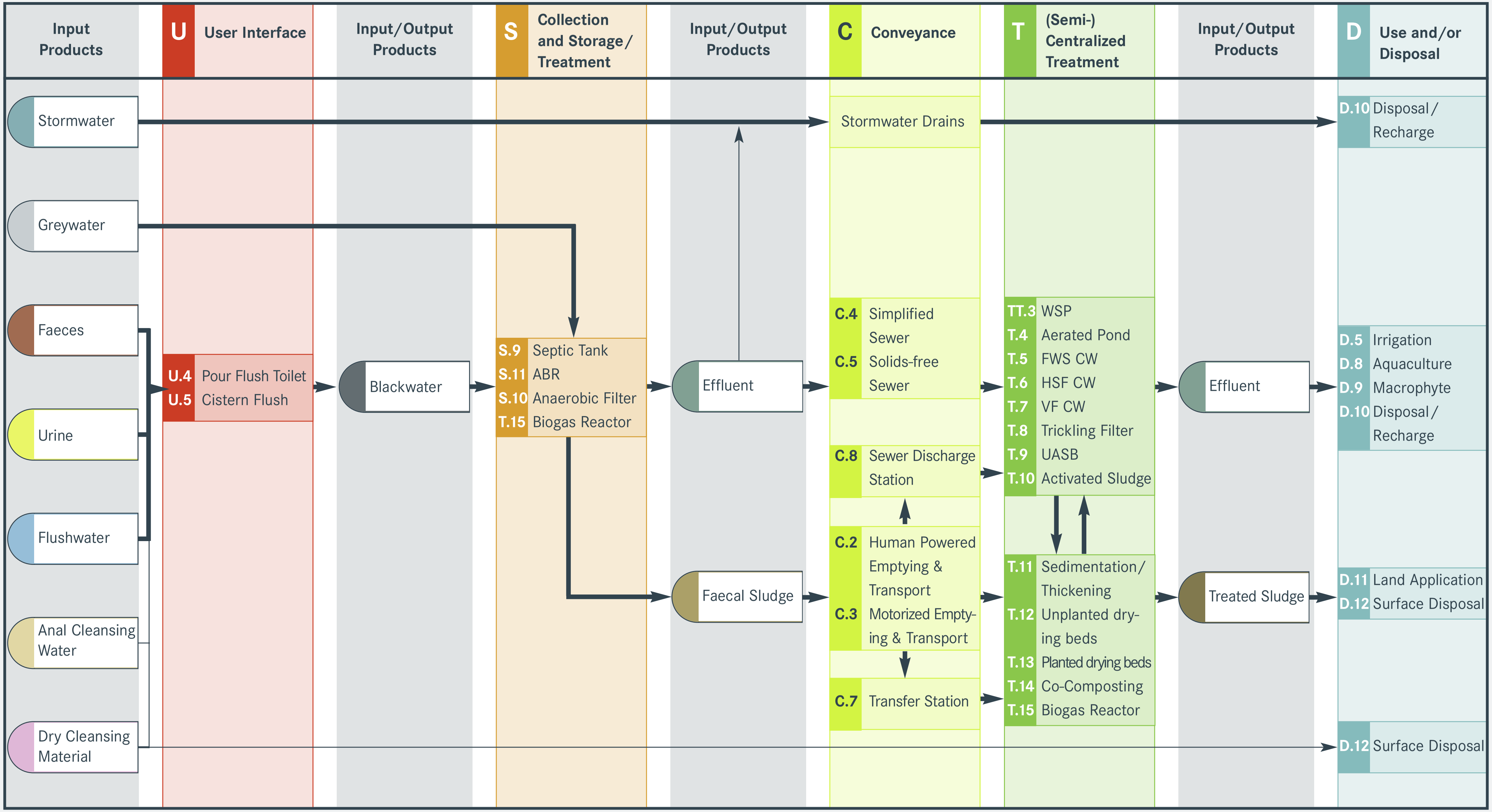
System 5: Blackwater Treatment System with Infiltration



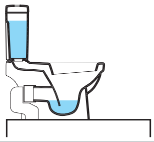
This is a water-based system that requires a flush toilet and a Collection & Storage/Treatment Technology that is appropriate for storing large quantities of water.
The inputs to the system can include Faeces, Urine, Flushwater, Anal Cleansing Water, Dry Cleansing Materials and Greywater.
There are two User Interface Technologies that could be used for this system: a Pour Flush Toilet (U4) or a Cistern Flush Toilet (U5). In the event that Dry Cleansing Materials are collected separately from the flush toilets, they can be directly transferred for Surface Disposal (D12).
The User Interface is directly connected to a Collection and Storage/Treatment Technology for the Blackwater generated: either a Septic Tank (S9), a Anaerobic Baffled Reactor (ABR) (S10), or an Anaerobic Filter (S11) may be used. The anaerobic processes reduce the organic and pathogen load, but the Effluent is still not suitable for direct use. Greywater should be treated along with Blackwater in the same Collection & Storage/Treatment Technology, but if there is a need for water-recovery, it can be treated separately (not shown on the System Template).
Effluent generated from the Collection and Storage/Treatment can be diverted directly to the ground for Use and/or Disposal through a Soak Pit (D6) or a Leach Field (D7). For these Technologies to work there must be sufficient space available and the soil must have a suitable capacity to absorb the Effluent. If this is not the case, refer to System 6: Blackwater Treatment System with Sewerage. Although it is not recommended, the Effluent can also be discharged into the Stormwater Drainage network for Use and/or Disposal as Groundwater Recharge (D10). This should only be considered if the quality of the Effluent is high and there is not capacity for onsite infiltration or transportation offsite.
The Faecal Sludge that is generated from the Collection and Storage/Treatment Technology must be removed and transported for further treatment. The Conveyance Technologies that can be used include Human Powered E&T (C2) or Motorized E&T (C3). As the Faecal Sludge is highly pathogenic prior to treatment, human contact and direct agricultural applications should be avoided.
Faecal Sludge that is removed can be transported to a dedicated Faecal Sludge treatment facility (Technologies T11 to T15). In the event that the treatment facility is not easily accessible, the Faecal Sludge can be discharged to either a Sewer Discharge Station (C8) or a Transfer Station (C7). From the Sewer Discharge Station, the Faecal Sludge is transported by the sewer and is cotreated with the Blackwater flowing in the sewer network (Technologies T1 to T10). The Faecal Sludge from the Sewer Discharge station is released either directly into the sewer or at timed intervals (to optimize the performance of the (Semi-) Centralized Treatment facility). If sludge is introduced directly into a sewer, there must be enough water to adequately dilute and transport the sludge to the treatment facility. From the Transfer Station, the Faecal Sludge must be transported to a dedicated Faecal Sludge treatment facility by a motorized vehicle (Technologies T11 to T15).
All (Semi-) Centralized Treatment Technologies, T1 to T15, produce both Effluent and Faecal Sludge, which require further treatment prior to Use and/or Disposal. Technologies for the Use and/or Disposal of the treated Effluent include Irrigation (D5), Aquaculture (D8), Macrophyte Pond (D9) or Discharge to a water body or Recharge to groundwater (D10). Technologies for the Use and/or Disposal of the treated Faecal Sludge include Land Application (D11) or Surface Disposal (D12).

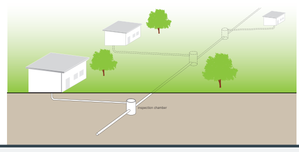
Considerations This system is only appropriate in areas where desludging services are available and affordable and where there is an appropriate way to dispose of the sludge. This system can be adapted for use in colder climates, even where there is ground frost. The system requires a constant source of water.
The capital investment for this system is considerable (excavation and installation of an onsite storage Technology), but the costs can be shared by a number of households if the system is designed for a larger number of users.
This water-based system is suitable for Anal Cleansing Water, and since the solids are settled and digested onsite, easily degradable Dry Cleansing Materials can also be used.

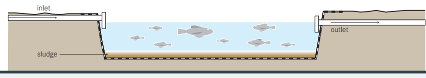
Sanitation System 6: Blackwater Treatment System with Sewerage



System 6: Blackwater Treatment System with Sewerage







This system is characterized by the use of a household-level Technology to remove and digest settleable solids from the Blackwater, and a simplified or settled sewer system to transport the Effluent to a (Semi-) Centralized Treatment facility.

The inputs to the system can include Faeces, Urine, Flushwater, Anal Cleansing Water, Dry Cleansing Materials and Greywater. This system is comparable to System 5: Blackwater Treatment System with Infiltration except the management and processing of the Effluent generated during Collection and Storage /Treatment of the Blackwater is different. As such, please refer to System Template for System 5: Blackwater Treatment System with Infiltration, for a detailed description of the components.

There are two transport pathways for the Effluent generated from the Collection and Storage/Treatment of the Blackwater. Similar to System 5, Effluent can be discharged into the Stormwater Drainage network for Use and/or Disposal as Groundwater Recharge (D10), although this is not the recommended approach. The Effluent should be transported from a Collection and Storage/Treatment facility to a (Semi-) Centralized Treatment facility via a Simplified Sewer network (C4) or a Solids-Free Sewer network (C5). An interceptor tank is required before the Effluent enters the sewer, or alternatively, this system can be used as a way of upgrading under-performing onsite Technologies (e.g. septic tanks) by providing improved, (Semi-) Centralized Treatment. Effluent transported to a (Semi-) Centralized Treatment facility is treated using one of the Technologies T1 to T10.

All (Semi-) Centralized Treatment Technologies, T1 to T15, produce both Effluent and Faecal Sludge, which require further treatment prior to Use and/or Disposal. Technologies for the Use and/or Disposal of the treated Effluent include Irrigation (D5), Aquaculture (D8), Macrophyte Pond (D9) or Discharge to a water body or Recharge to Groundwater (D10). Technologies for the Use and/or Disposal of the treated Faecal Sludge include Land Application (D11) or Surface Disposal (D12).

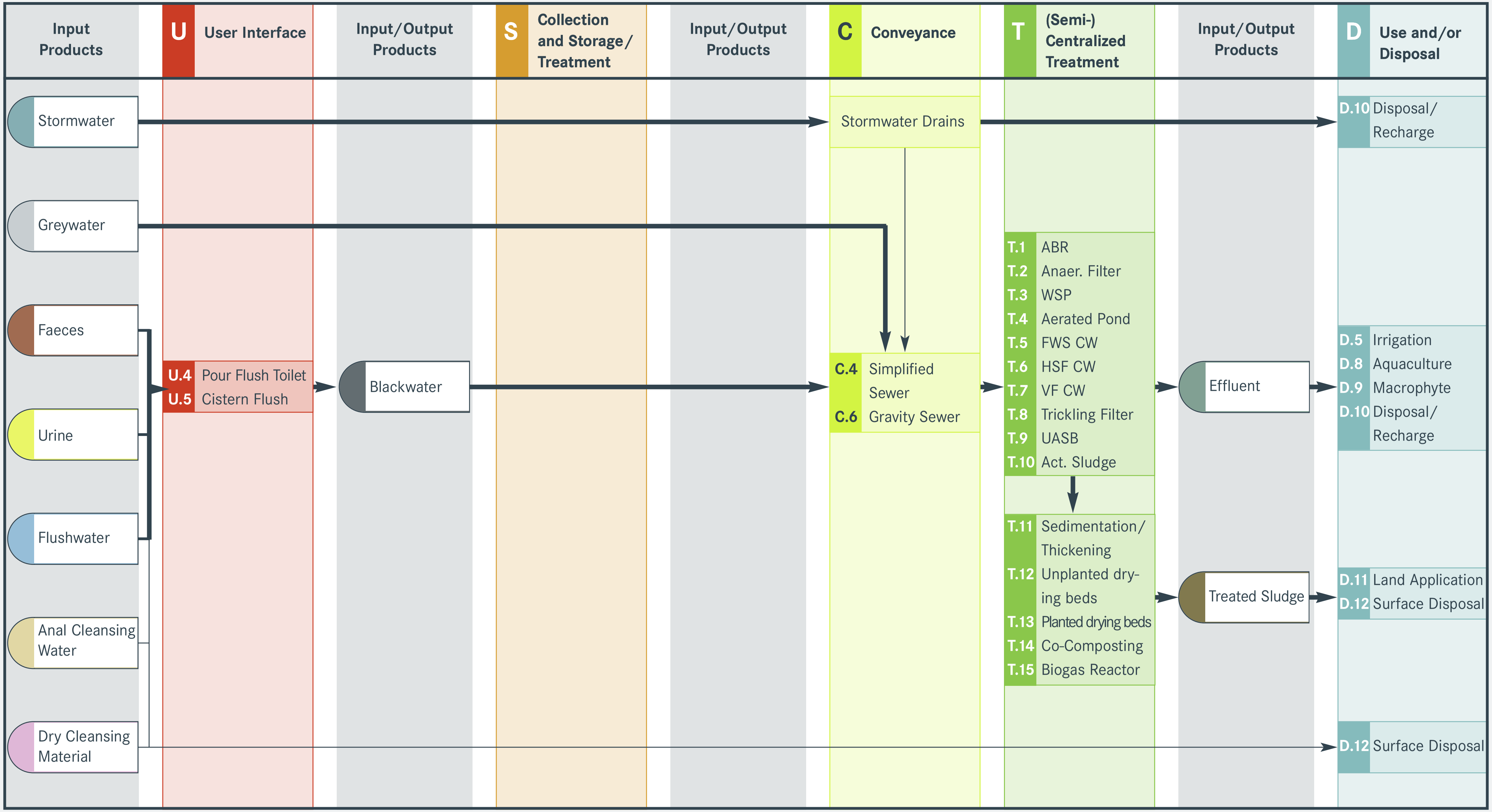
Considerations With the offsite transport of the Effluent to a (Semi-) Centralized Treatment facility, the capital investment for this system is moderate to considerable. Excavation and installation of the onsite storage technology as well as the infrastructure required for the simplified sewer network may be costly (although costs would be considerably less than the design and installation of a conventional sewer network). As well, if there is no pre-existing treatment facility, one must be built to ensure that discharge from the sewer is not directly input to a water body.

The success of this system depends on high user commitment to operation and maintenance of the sewer network; alternatively, a person or organization can be made responsible on behalf of the users. There must be an accessible, affordable and systematic method for desludging the interceptor (or septic) tanks since one user's improperly kept tank could adversely impact the entire community. Also important is a well-functioning and properly managed Centralized Treatment facility; in some cases this will be managed at the municipal /regional level, but in the case of a more local solution (e.g. wetland), there must also be a well-defined structure for operation and maintenance.

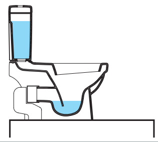
This system is especially appropriate for dense, urban settlements where there is little or no space for onsite storage technologies or emptying. Since the sewer network is shallow and (ideally) watertight, it is also applicable for areas with high groundwater tables.

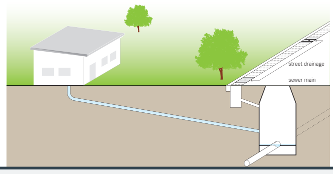
This water-based system is suitable for Anal Cleansing Water inputs, and, since the solids are settled and digested in one of the Collection and Storage/Treatment Technologies, easily degradable Dry Cleansing Materials can also be used. However, durable materials (e.g. leaves, rags) could clog the system and cause problems with emptying and therefore, should not be used.

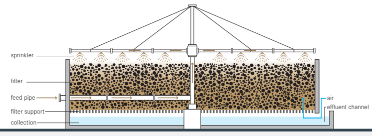
Sanitation System 7: (Semi-) Centralized Treatment System



System 7: (Semi-) Centralized Treatment System







This is a water-based sewer system in which Blackwater is transported to a centralized treatment facility. The important characteristic of this system is that there is no Collection and Storage/Treatment.

The inputs to the system include Faeces, Urine, Flushwater, Anal Cleansing Water, Dry Cleansing Materials, Stormwater, and Greywater.

There are two User Interface Technologies that can be used for this system, a Pour Flush Toilet (U4) or a Cistern Flush Toilet (U5). Dry Cleansing Materials can be handled by the system or they can be collected separately and directly transferred for Surface Disposal (D12).

The Blackwater generated at the User Interface is directly connected to a (Semi-) Centralized Treatment facility by a Simplified Sewer network (C4) or a Gravity Sewer network (C6). Greywater is co-treated with the Blackwater. Stormwater collected within the Stormwater drains can be input to the Gravity Sewer network, although Stormwater overflows are required.

As there is no Collection and Storage/Treatment, all of the Blackwater is transported to a (Semi-) Centralized Treatment facility. The inclusion of Greywater in the Conveyance Technology helps to prevent solids from accumulating in the sewers. One of the Technologies T1 to T10 is required for the treatment of the transported Blackwater. The Faecal Sludge generated from the treatment of the Technologies T1 to T10 must be further treated in a dedicated Faecal Sludge treatment facility (Technologies T11 to T15) prior to Use and/or Disposal.

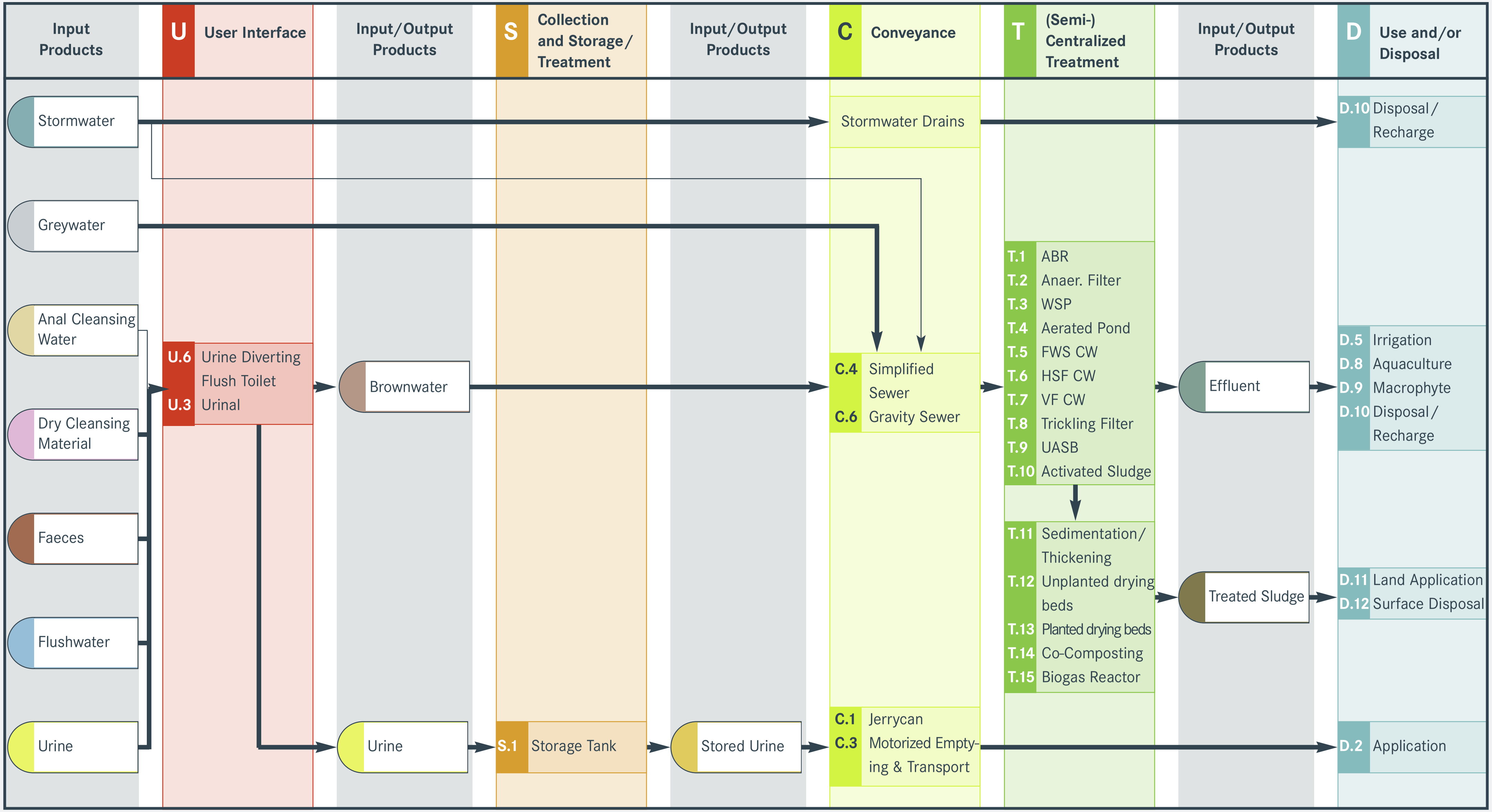
All (Semi-) Centralized Treatment Technologies, T1 to T15, produce both Effluent and Faecal Sludge. Technologies for the Use and/or Disposal of the treated Effluent include Irrigation (D5), Aquaculture (D8), Macrophyte Pond (D9) or Discharge to a water body or Recharge to groundwater (D10). Technologies for the Use and/or Disposal of the treated Faecal Sludge include Land Application (D11) or Surface Disposal (D12).

Considerations The capital investment for this system can be high; gravity sewers require extensive excavation and installation can be expensive, whereas Simplified Sewers are generally less expensive if the site conditions permit a condominial design. This system is only appropriate when there is a high willingness to pay for the capital investment and maintenance costs and where there is a pre-existing treatment facility that has the capacity to accept additional flow.

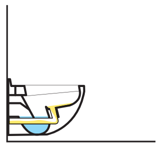
Depending on the type of sewers used, this system can be adapted for both dense urban and peri-urban areas. It is not well-suited to rural areas. There must be a constant supply of water to ensure that the sewers do not become blocked. Users may be required to pay user-fees to pay for the centralized treatment and maintenance.

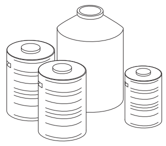
Depending on the sewer type and management structure (simplified vs gravity, city-run vs community operated) there are varying degrees of operation or maintenance responsibilities for the homeowner.

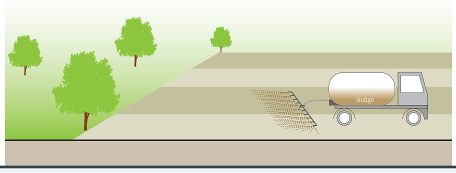
Sanitation System 8: Sewerage System with Urine Diversion



System 8: Sewerage System with Urine Diversion







This is a water-based sewer system that requires a Urine Diverting Flush Toilet (UDFT). The UDFT is a special User Interface that allows for the separation and collection of Urine without water, but that also uses water to flush Faeces.
The inputs to the system can include, Faeces, Urine, Flushwater, Anal Cleansing Water, Dry Cleansing Material, Stormwater, and Greywater.
There are two User Interface Technologies that can be used for this system, a UDFT (U6) and a Urinal (U3). The Urinal however, should be used in conjunction with the UDFT, as an alternative for men who do not wish to sit on the pedestal.
Both Brownwater and Urine are separated at the User Interface. Brownwater bypasses a Collection and Storage/Treatment facility and is conveyed directly to a (Semi-) Centralized Treatment facility using a Simplified Sewer network (C4) or a Gravity Sewer network (C6). Greywater is also transported in the sewer and is not treated separately. In some circumstances, Stormwater can be connected to a Gravity Sewer network, although Stormwater overflows are required.
Urine separated at the User Interface is directly linked to a Storage Tank (S1). The Stored Urine is transferred for Use and/or Disposal using a Jerrycan (C1) or Motorized E&T (C3) for Urine Application to agricultural lands (D2).
Brownwater is treated at a (Semi-) Centralized Treatment facility using one of the Technologies T1 to T10. The Faecal Sludge generated from the treatment of the Technologies T1 to T10 must be further treated in a dedicated Faecal Sludge treatment facility (Technologies T11 to T15) prior to using the Land Application (D11) or Surface Disposal (D12) Use and/or Disposal technologies. Technologies for the Use and/or Disposal of the treated Effluent collected from one of the Technologies T1 to T10 include Irrigation (D5), Aquaculture (D8), Macrophyte Pond (D9) or Discharge to a water body or Recharge to Groundwater (D10).

Considerations UDFTs are not common and the capital cost for this system can be high. This is partly due to the fact that there is limited competition in the market and also because high quality plumbing is required for the dual plumbing system. The Gravity Sewers require extensive excavation and installation can be expensive, whereas Simplified Sewers are generally less expensive if the site conditions permit a condominial design. This system is only appropriate when there is a need for the separated Urine and/or when there is a desire to limit water consumption by collecting Urine without flushing water. The system still requires a constant source of water and uses significantly more than a waterless system.
Depending on the type of sewers used, this system can be adapted for both dense urban and peri-urban areas. It is not well-suited to rural areas. There must be a constant supply of water to ensure that the sewers do not become blocked. This system is appropriate where there is a need and a desire to collect, transport and use the Urine. There may also be benefits to the treatment plant if it is normally overloaded; the reduced nutrient load (by removing the Urine) could optimize treatment. However, if the plant is currently, underloaded (i.e. the plant has been overdesigned) then this system could further aggravate the problem.
Depending on the sewer type and management structure (simplified vs gravity, city-run vs community operated) there will be varying degrees of operation or maintenance responsibilities for the homeowner.