Eawag:
Swiss Federal Institute of Aquatic Science and Technology

Sanitation Systems and Technologies

Part 1 : From user interface to conveyance

3rd October 2024

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Eawag-Sandec
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Today's lecturer:

Abishek S Narayan

Education:

PhD Env. Engg (ETHZ)

MSc Env. Policy (Oxford)

BTech Chemical Engg (Anna Uni)

Experience:

Eawag, World Bank, 100RC-Rockefeller., IHE Delft, TU Munich, ETH & EPF

Interests:

WASH Planning, Integration, Sci-Policy Transformation, Sci-Comm, Youth Engagement

Where work takes me:

By end of today's session

Our agreement:

- Know how to use this seemingly complex compendium of sanitation
- Understand what can work so that your sanitation system doesn't flood the lanes, or lakes
- Prove that you can engineer the sh*t out of sanitation

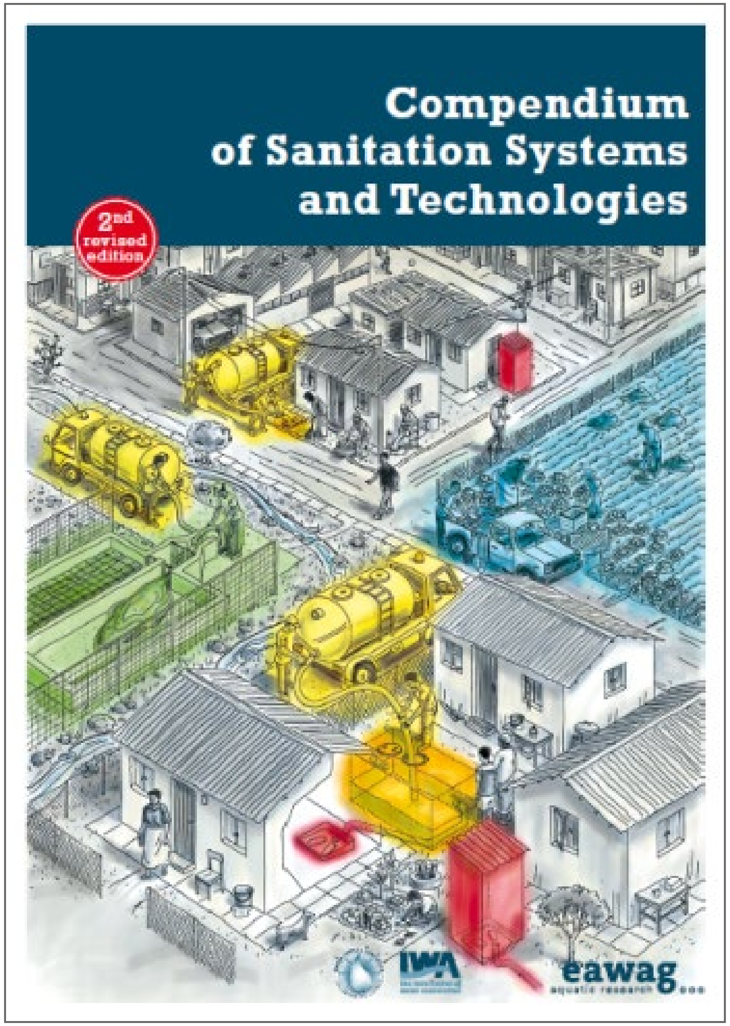
Not a lecture but a 2 way "interaction"

Rules of the game:

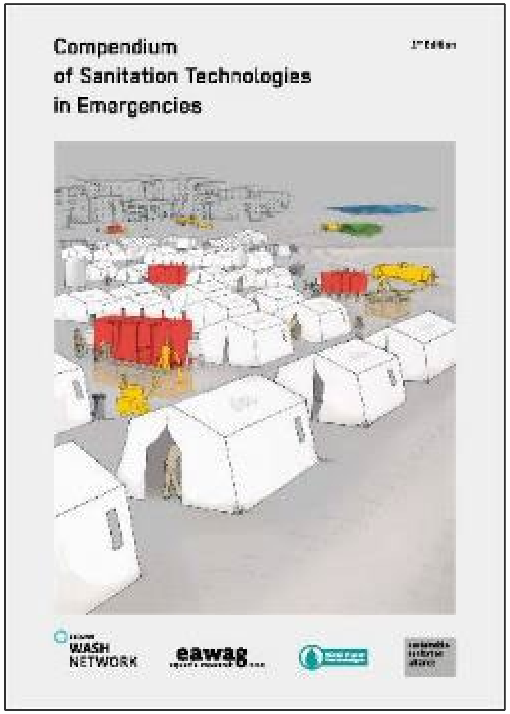
- Put on your **creative** hats and your **logical** hats
- Answer each question – group discussion allowed
- Incentives for **Correct** answers or **Funny** answers
- How to declare the winner of today?
    - Most number of points get the big prize

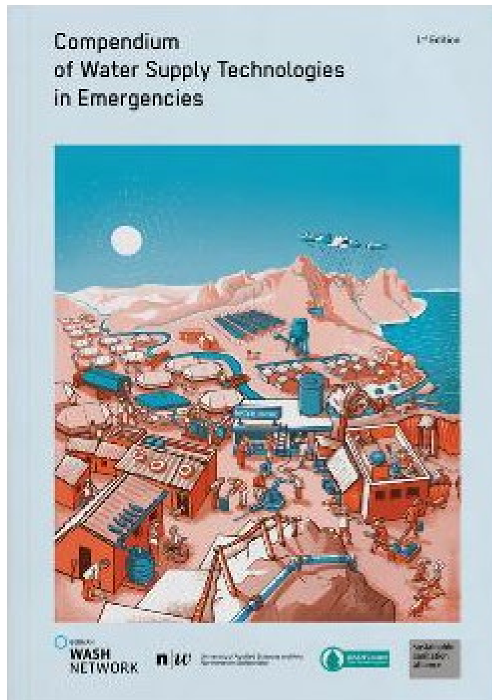
Compendium of Sanitation Systems and Technologies

sandec.ch/compendium



Compendiums of WASH in Emergencies



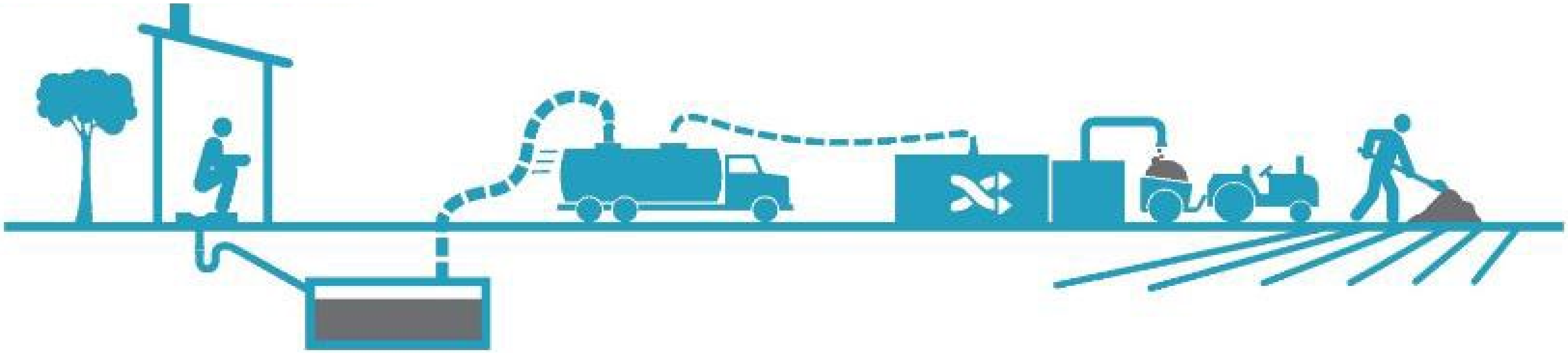


A tool for WASH planning

A teaching & training tool

Compendium follows the sanitation service chain

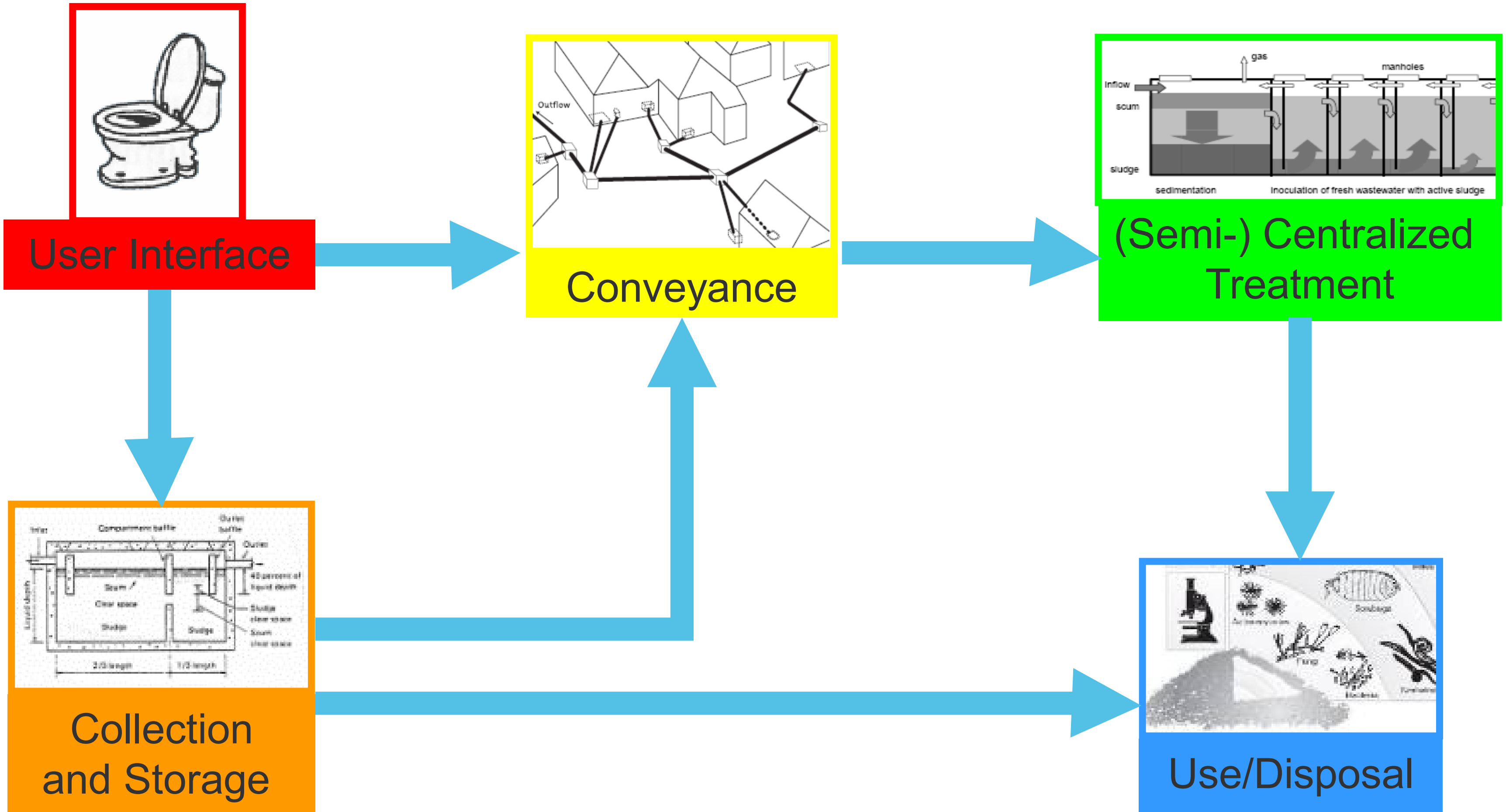
A system's approach to understand the various stages of the services and infrastructure required.



USER INTERFACE > COLLECTION & STORAGE > CONVEYANCE > TREATMENT > REUSE & DISPOSAL

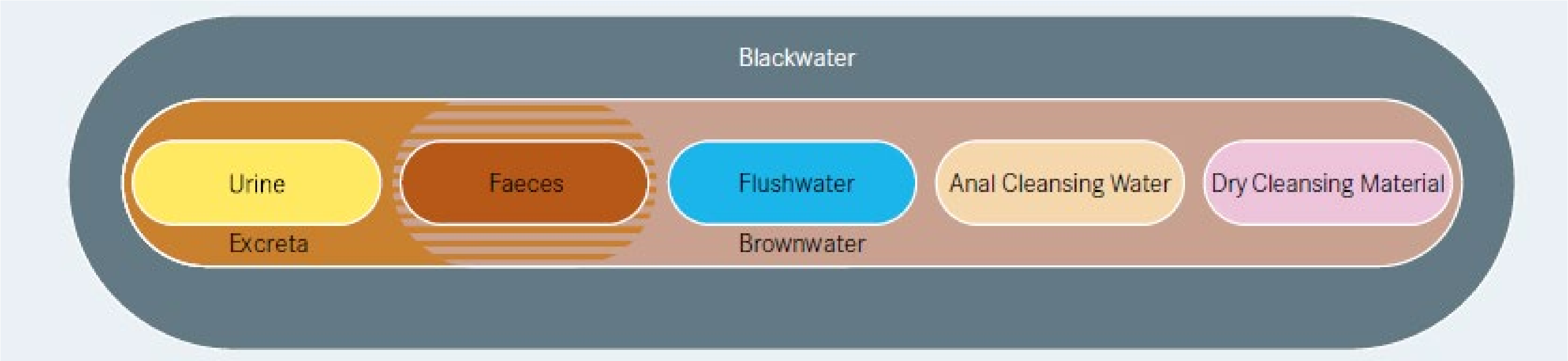
The Systems approach

Five functional groups



What are waste streams we have to manage?

Let's start with user interface levels



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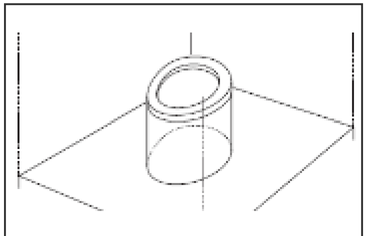
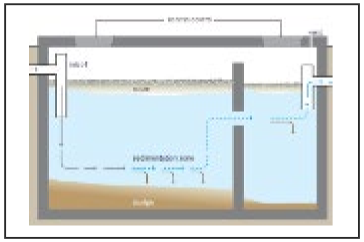
Overview of Functional Groups and Sanitation Technologies

User Interface



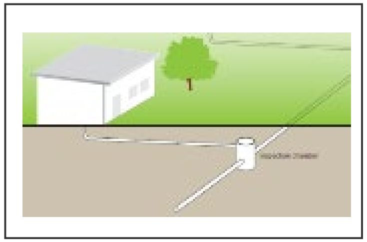
- Dry Toilet
- Urine Diverting Dry Toilet (UDDT)
- Urinal
- Pour Flush Toilet
- Cistern Flush Toilet
- Urine Diverting Flush Toilet

Collection and Storage / Treatment



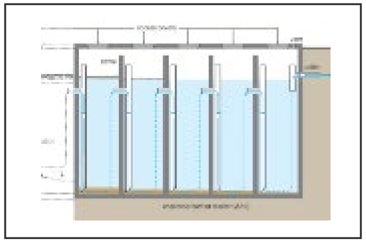
- Urine Storage Tank / Container
- Single Pit
- Single Ventilated Improved Pit (VIP)
- Double Ventilated Improved Pit (VIP)
- Fossa Alterna
- Twin Pits for Pour Flush
- Dehydr. Vaults
- Composting Chamber
- Septic Tank
- Etc.

Conveyance



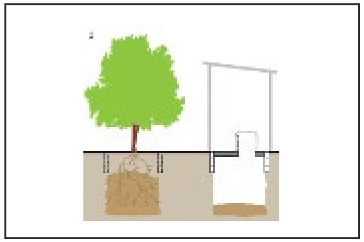
- Jerry can / Tank
- Human-Powered Emptying and Transport
- Motorized Emptying and Transport
- Simplified Sewer
- Solids-Free Sewer
- Conventional Gravity Sewer
- Transfer Station (Holding Tank)

(Semi-) Centralised Treatment



- Anaerobic Baffled Reactor (ABR)
- Anaerobic Filter
- Waste Stabilization Ponds
- Aerated Pond
- Constructed Wetland
- Trickling Filter
- Activated Sludge
- Drying Beds
- Co-composting
- Biogas Reactor
- Etc.

Use and / or Disposal



- Fill and Cover / Arborloo
- Applic. of Urine
- Application of Dehydr. Faeces / Compost/Sludge
- Irrigation
- Soak Pit
- Leach Field
- Fish Pond
- Floating Plant Pond
- Water Disposal / Groundwater Recharge
- Surface Disposal
- Biogas Combust.

How is the Compendium organised?

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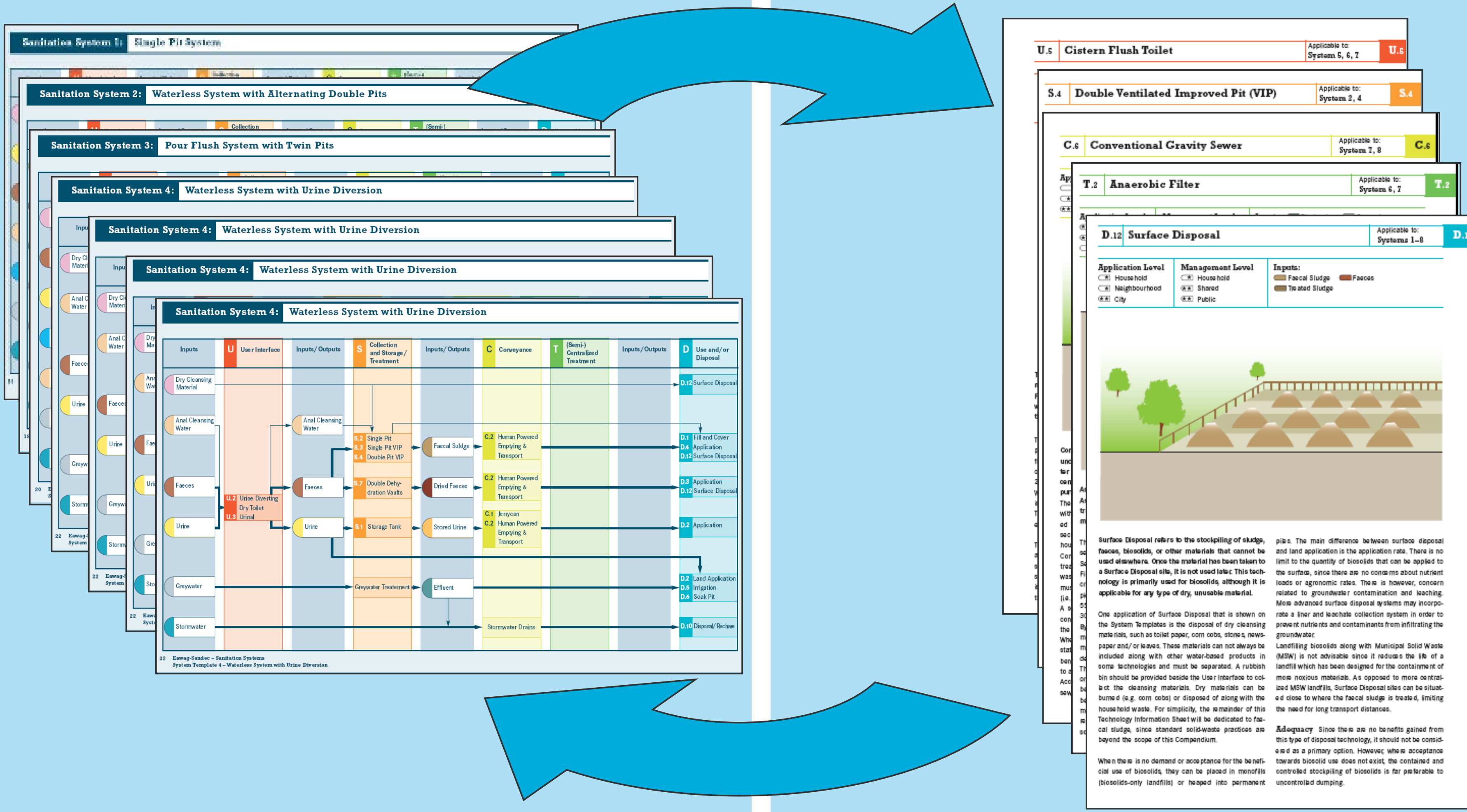
Part 1:
Sanitation System Templates

Part 2:
Technology Information Sheets



Part I: Sanitation System Templates

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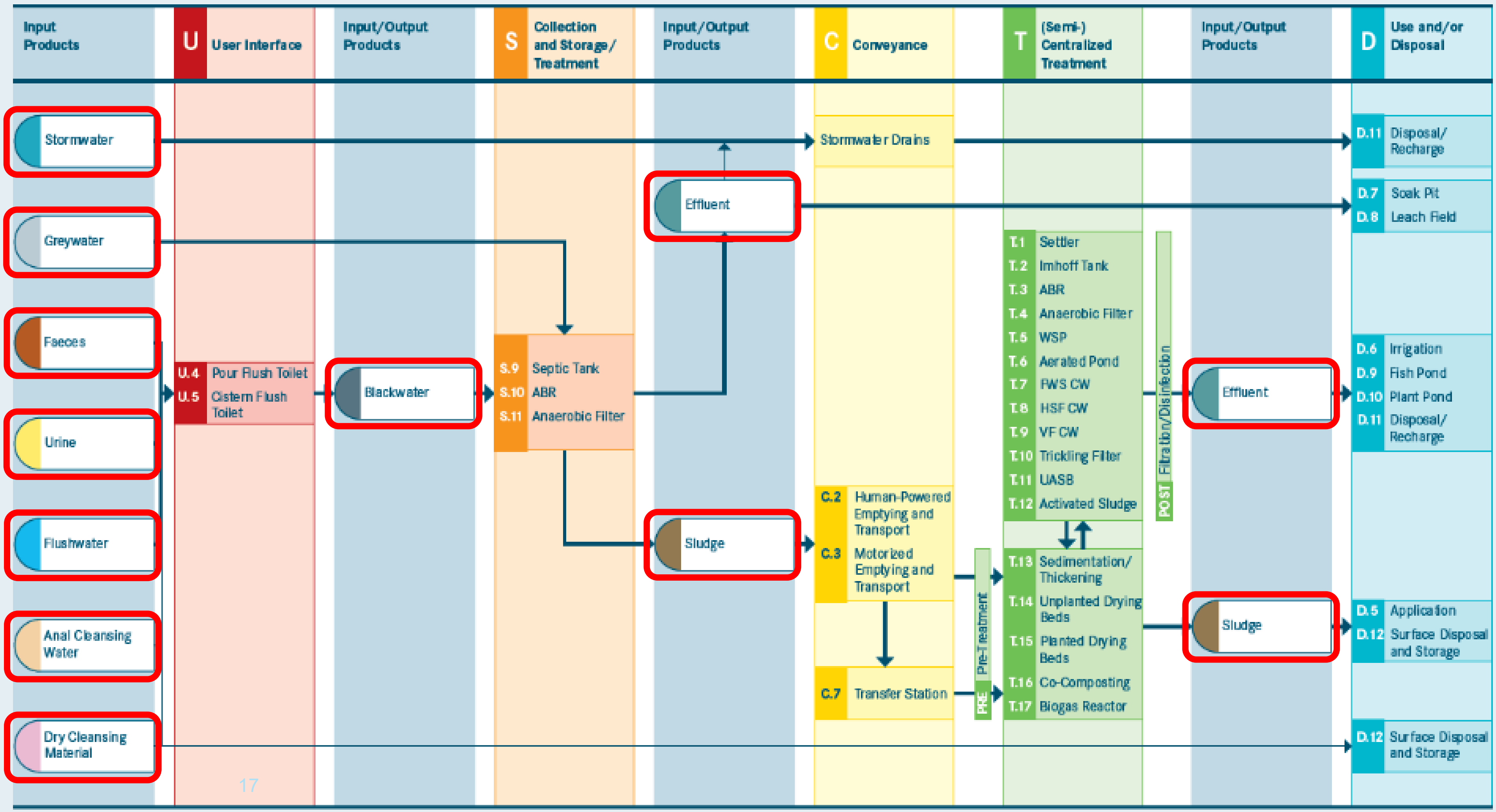
9 most common sanitation systems described

System 1:	Single Pit System
System 2:	Waterless Pit System without Sludge Production
System 3:	Pour Flush Pit System without Sludge Production
System 4:	Waterless System with Urine Diversion
System 5:	Biogas System
System 6:	Blackwater Treatment System with Infiltration
System 7:	Blackwater Treatment System with Effluent Transport
System 8:	Blackwater Transport to (Semi-) Centralized Treatment System
System 9:	Sewerage System with Urine Diversion

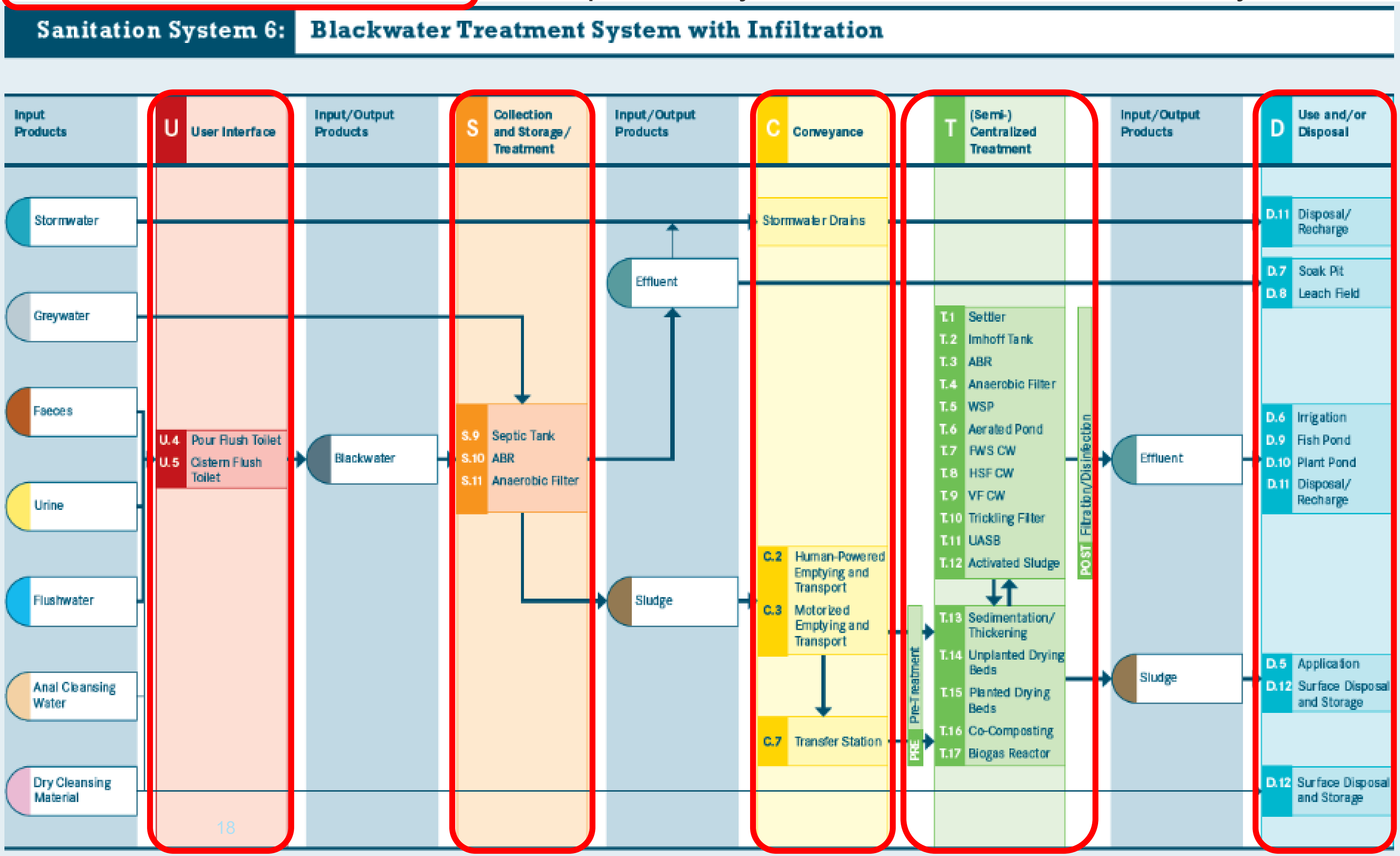
Products

Sanitation System 6: Blackwater Treatment System with Infiltration



Functional Groups

https://www.youtube.com/watch?v=nQ63nGy-fnM



Part II: Technology Information Sheets

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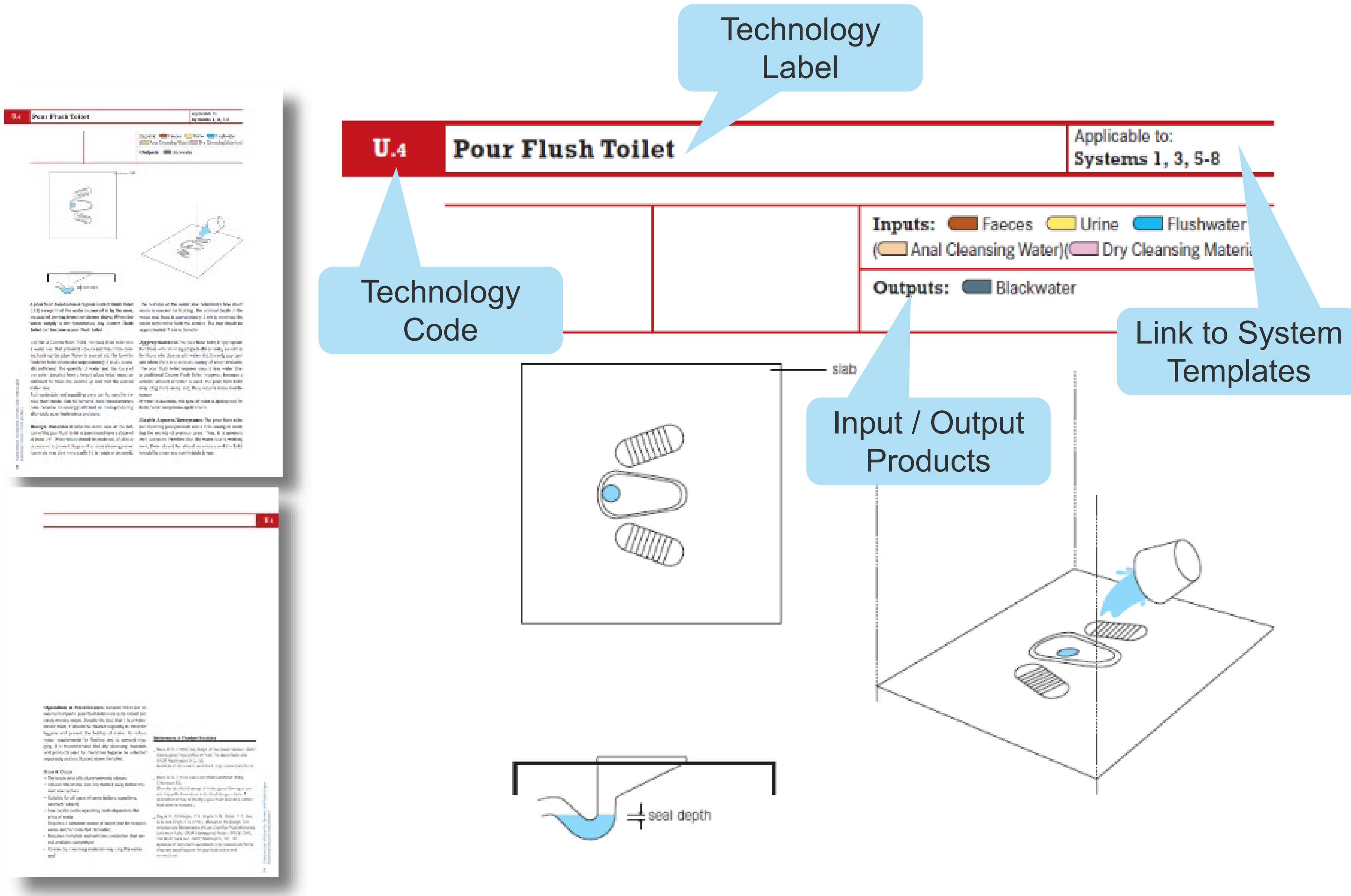

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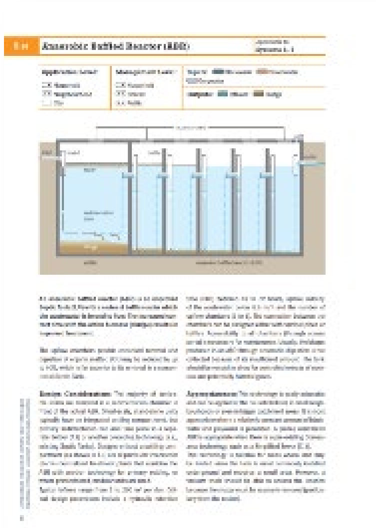

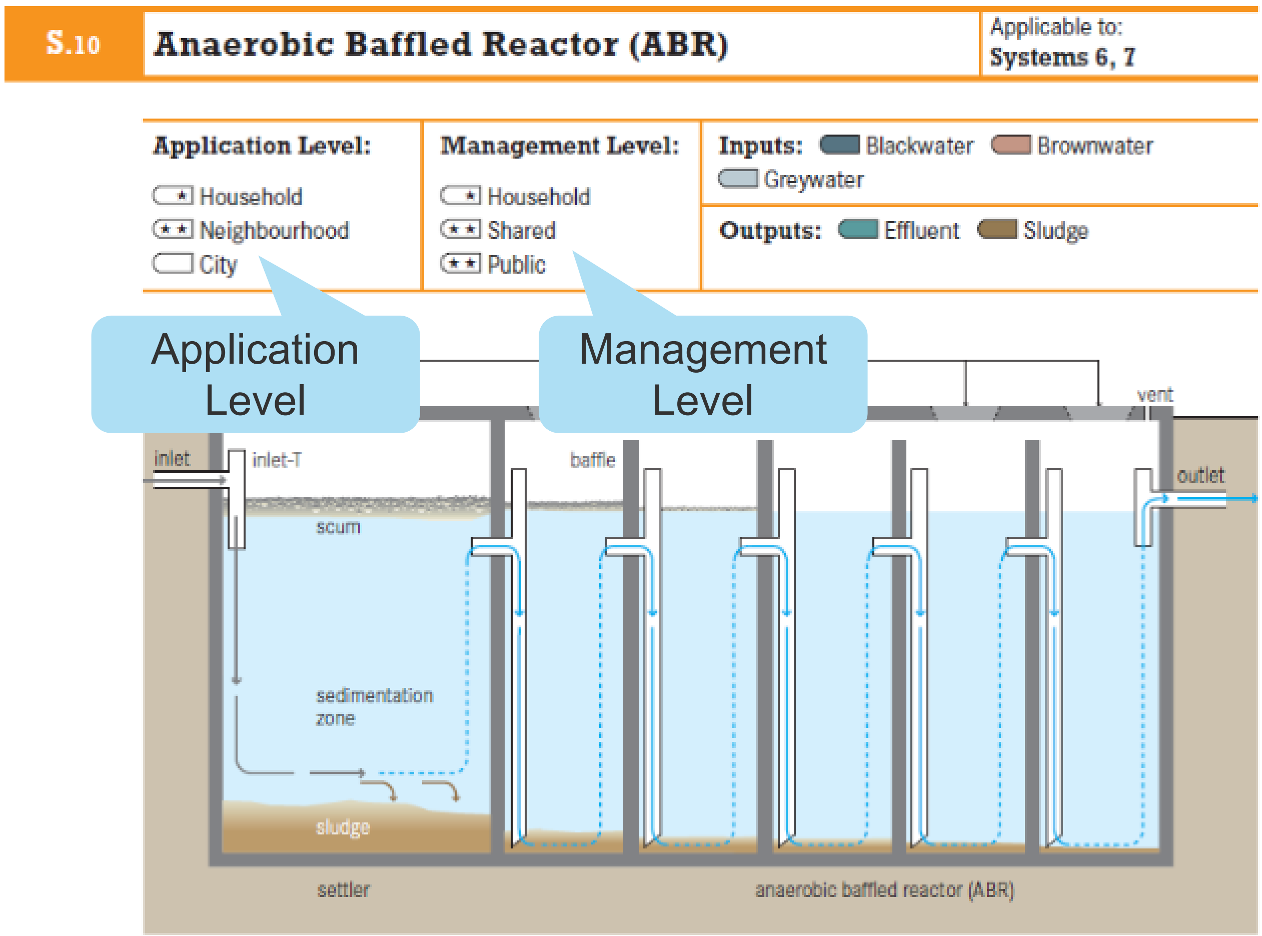

Why is the Biogas Reactor shown 2x: S.12 and T.17 ?

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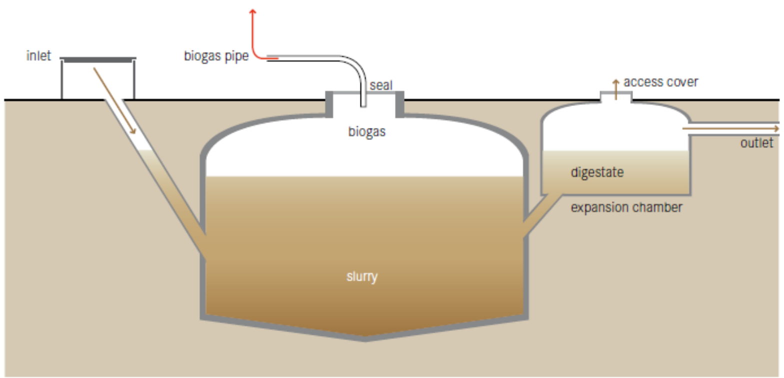
S.12 Biogas Reactor

Applicable to:
System 5

Application Level:	Management Level:	Inputs / Outputs
Household	Household	**Inputs:** Sludge, Blackwater, Brownwater, Organics
Neighbourhood	Shared	**Outputs:** Sludge, Biogas
City	Public	



A biogas reactor or anaerobic digester is an anaerobic treatment technology that produces (a) a digested slurry (digestate) that can be used as a fertilizer and (b) biogas that can be used for energy. Biogas is a mix of methane, carbon dioxide and other trace gases which can be converted to heat, electricity or light.

exerts a pressure and displaces the slurry upward into an expansion chamber. When the gas is removed, the slurry flows back into the reactor. The pressure can be used to transport the biogas through pipes. In a floating dome reactor, the dome rises and falls with the production and withdrawal of gas. Alternatively, it can expand (like a balloon). To minimize distribution losses,

T.17 Biogas Reactor

Applicable to:
Systems 1, 6-9

Application Level:	Management Level:	Inputs / Outputs
Household	Household	**Inputs:** Sludge, Blackwater, Brownwater, Organics
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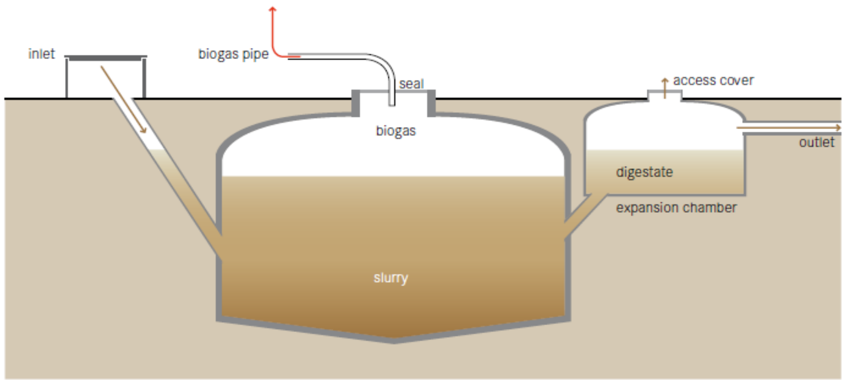

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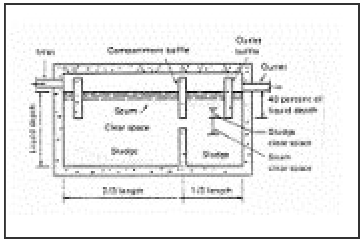
User Interface

- Dry Toilet
- Urine Diverting Dry Toilet (UDDT)
- Urinal
- Pour Flush Toilet
- Cistern Flush Toilet
- Urine Diverting Flush Toilet

Collection and Storage / Treatment



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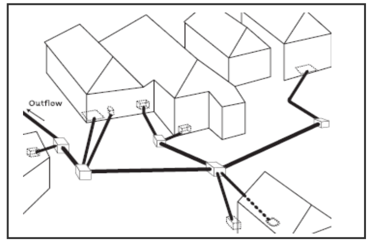
- Etc.

Conveyance



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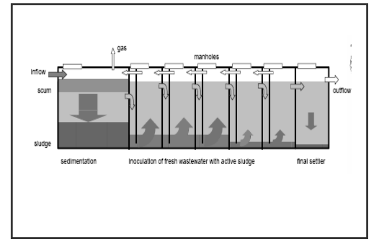

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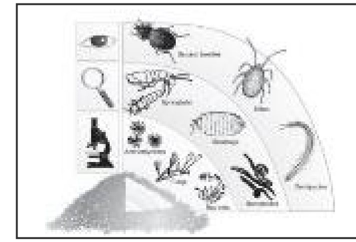

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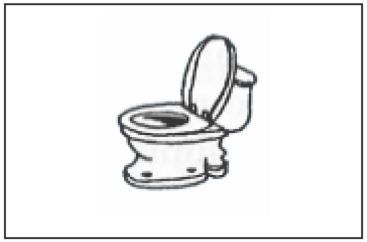

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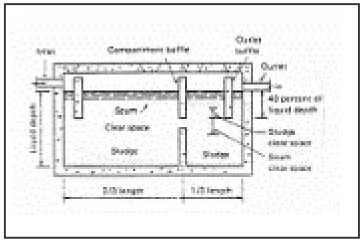

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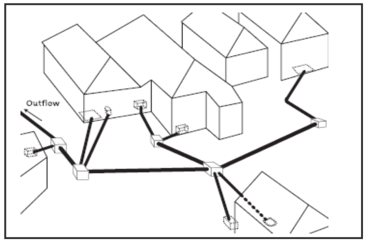

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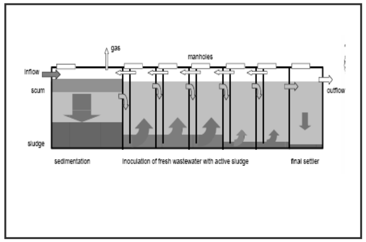

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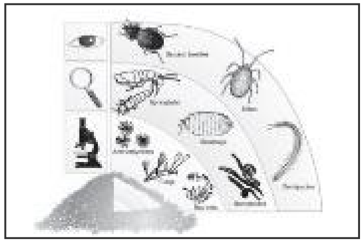

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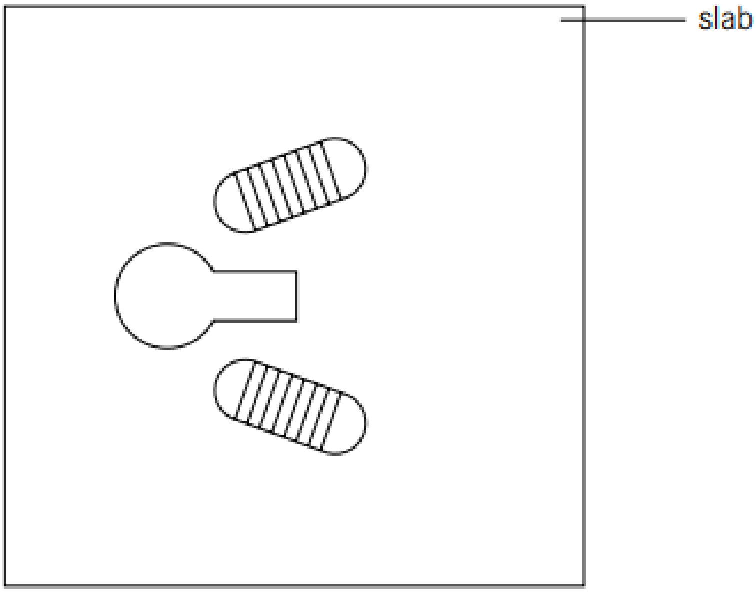
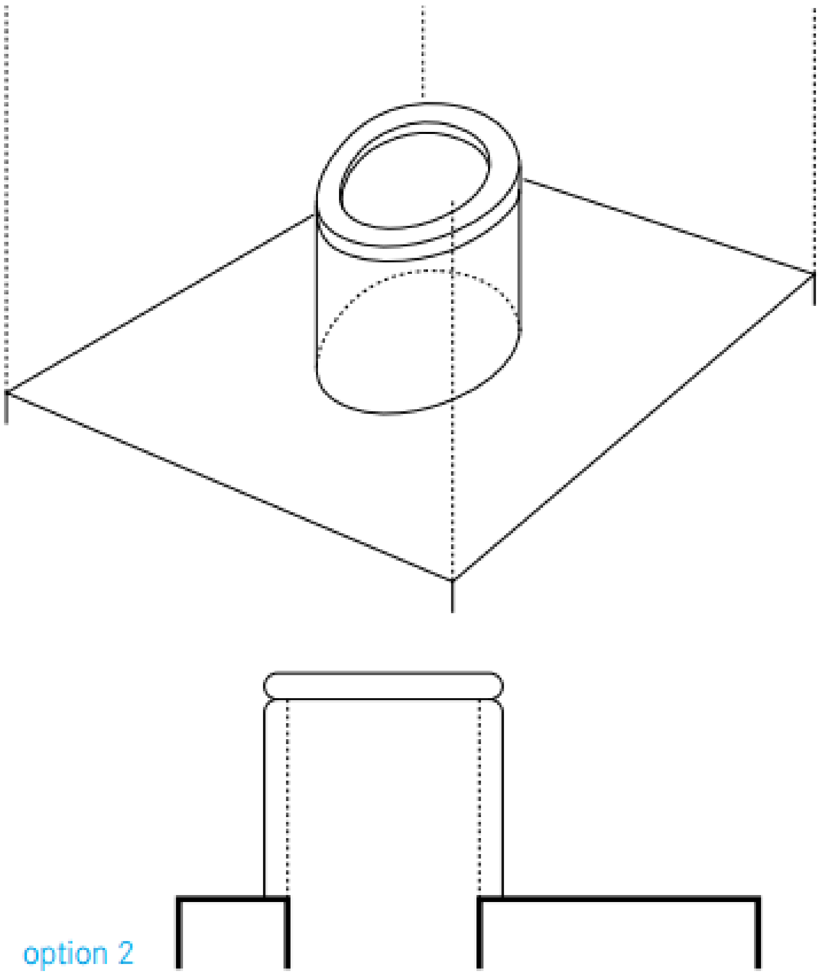
Dry toilets



option 1



option 2

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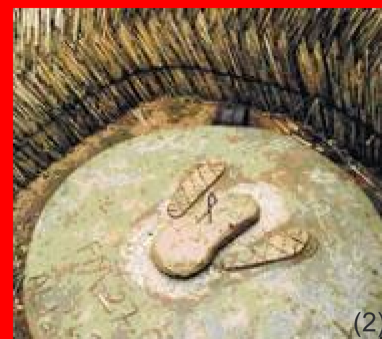
Waterless toilets in Switzerland?

Waterless (Dry) User Interface Technologies

Inputs	User Interface	Outputs
Urine Faeces Cleansing material/water	**Dry Toilet**	Excreta Cleansing material/water
Urine Faeces Cleansing material/water	**Urine Diverting Dry Toilet**	Urine Faeces Cleansing material/water

Dry Toilet


(1)


(2)

Urine Diverting Dry Toilet


(3)

Dry toilets

Dry toilets

+ Does not require a constant source of water

+ Can be built and repaired with locally available materials

+ Low capital and operating costs

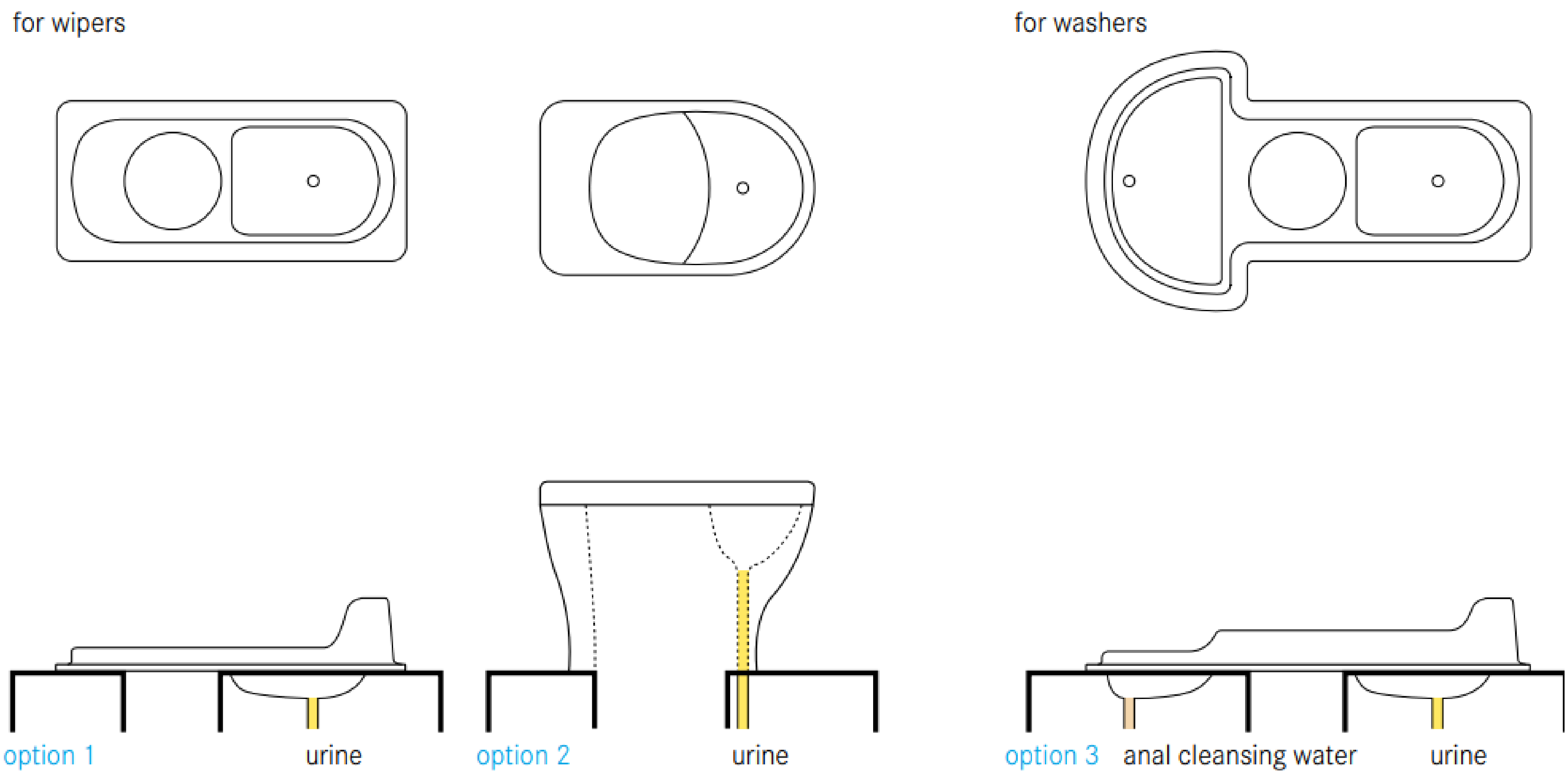
+ Suitable for all types of users (sitters, squatters, washers, wipers)

- Odours are normally noticeable (even if the vault or pit used to collect excreta is equipped with a vent pipe)

- The excreta pile is visible, except where a deep pit is used

- Vectors such as flies are hard to control unless fly traps and appropriate covers are used

Urine-diverting dry toilet (UDDT)



Urine-diverting dry toilet (UDDT)

+ Does not require a constant source of water

+ No real problems with flies or odours if used and maintained correctly

+ Can be built and repaired with locally available materials

+ Low capital and operating costs

+ Suitable for all types of users (sitters, squatters, washers, wipers)

- Prefabricated models not available everywhere

- Requires training and acceptance to be used correctly

- Is prone to misuse and clogging with faeces

- The excreta pile is visible

- Men usually require a separate Urinal for optimum collection of urine

Urine-diverting dry toilet (UDDT)

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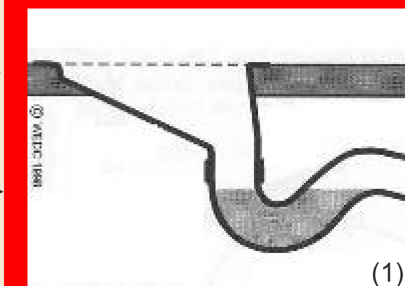
Water-Based User Interface Technologies

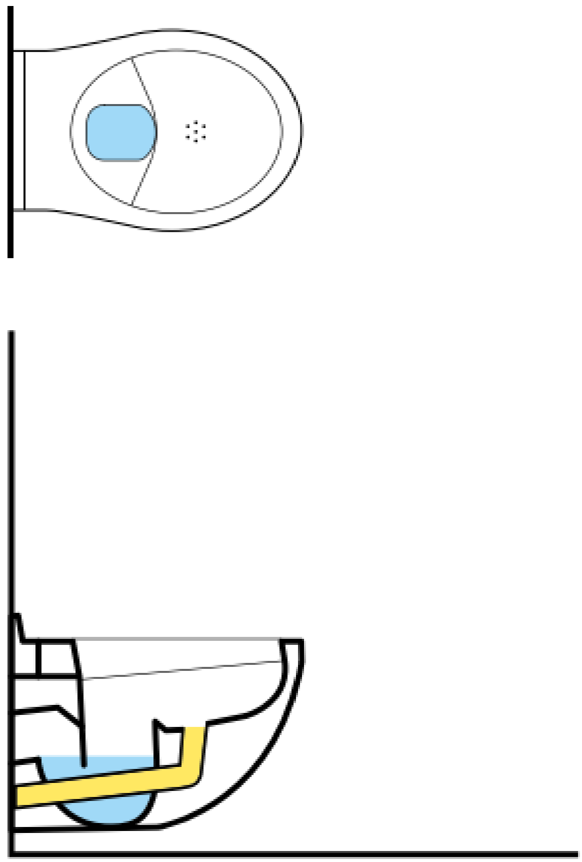
Inputs	User Interface	Outputs
Urine, Faeces, Flushwater, Cleansing material/water	Pour-Flush Toilet	Blackwater
Urine, Faeces, Flushwater, Cleansing material/water	Cistern Flush Toilet	Blackwater

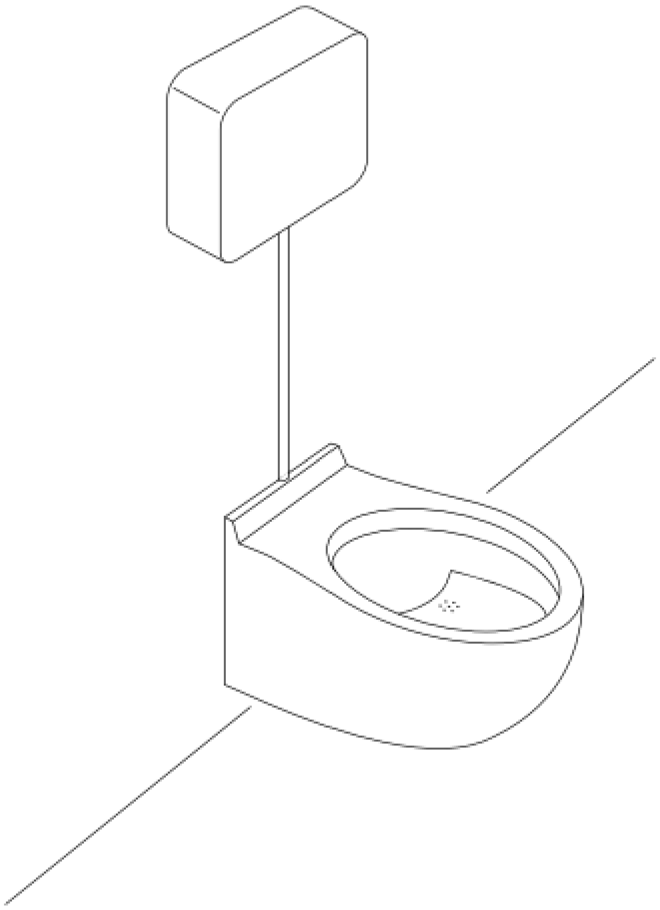
Pour-Flush Toilet



Cistern Flush Toilet

Urine-diverting flush toilet (UDFT)





Urine-diverting flush toilet (UDFT)

+ Requires less water than a traditional Cistern Flush Toilet

+ No real problems with odours if used correctly

+ Looks like, and can be used almost like, a Cistern Flush Toilet

How?

- Limited availability; cannot be built or repaired locally

- High capital costs; operating costs depend on parts and maintenance

- Labour-intensive maintenance

- Requires training and acceptance to be used correctly

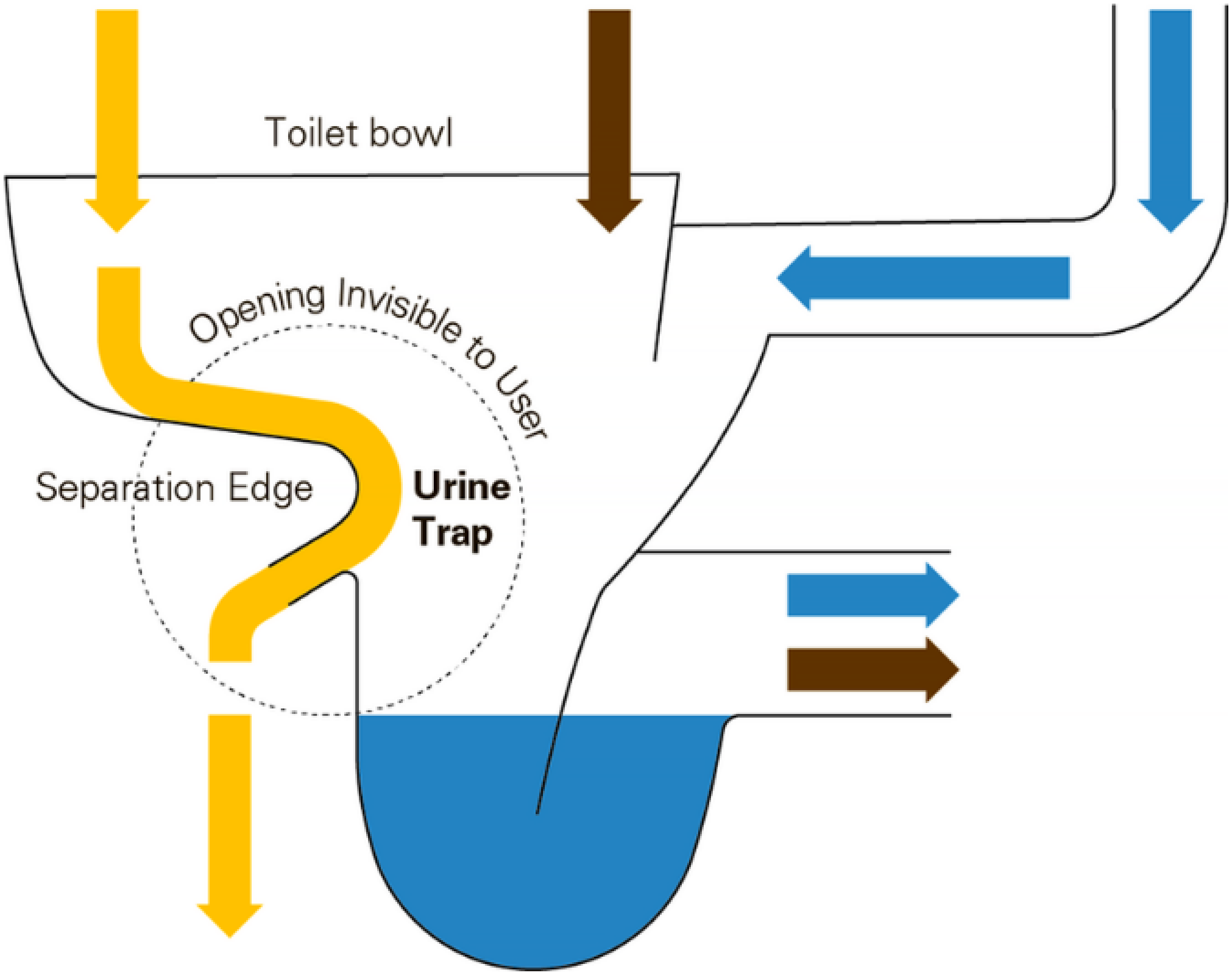
- Is prone to misuse and clogging

- Requires a constant source of water

- Men usually require a separate Urinal for optimum collection of urine

Requires

Advanced Tea Pot Effects



Urine-diverting flush toilet (UDFT)

Toilet Options for Urban Areas

- **Household toilet** – serves a single household
- **Shared toilet** – serves several surrounding households
- **Community toilet** – fixed number of users, usually community-managed
- **Public toilet** – serving any paying customer, either privately or publicly owned and managed

How to choose the right user interface

- Flush water availability
- Habits and preferences of the users
- Local availability of materials
- Compatibility with the subsequent Collection and Storage/Treatment or Conveyance technology
- Special needs of user groups

Inclusive design

- People have different needs at different times in their lives, based on factors like:
  - Age
  - Occupation
  - Location
  - Health
  - Physical ability
  - Mental state
  - Sex and gender

What can go wrong?

Bad piping

Non-intuitive design

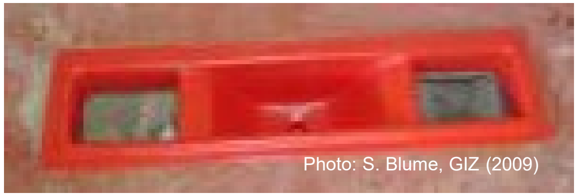


Photo: S. Blume, GIZ (2009)

Poor ventilation design

Difficult to clean

Door interfering

Construction quality and supervision

Interior layout

Low-quality materials

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User Interface

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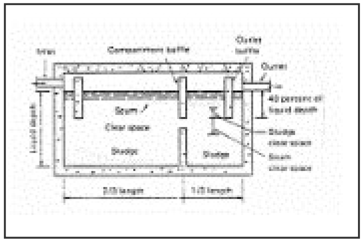

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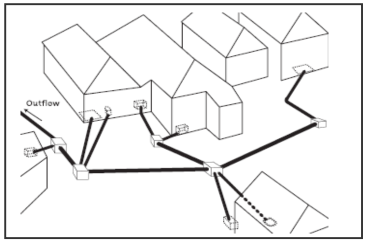
- **Dehydr. Vaults**
- **Composting Chamber**
- **Septic Tank**
- **Etc.**

Conveyance



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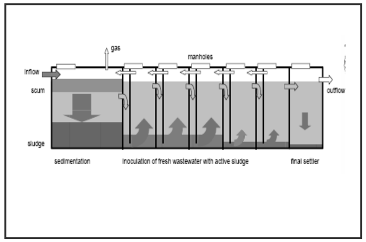
- Sewer Discharge Station

(Semi-) Centralised Treatment



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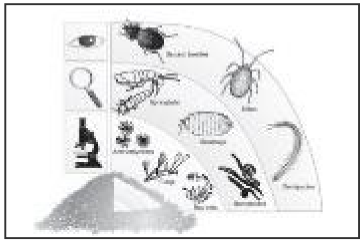

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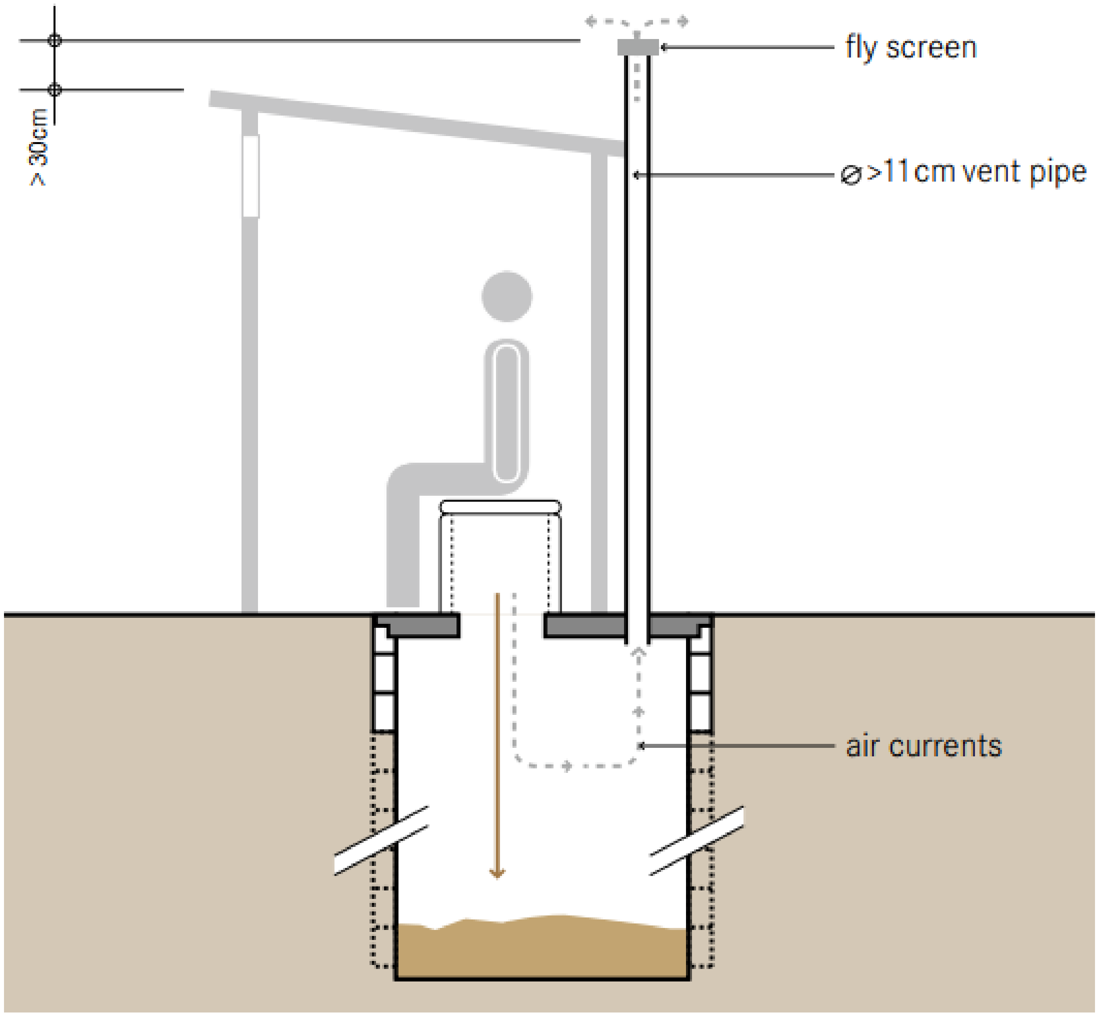
- Land application
- Surface Disposal

Ventilated Improved Pit Latrine (VIP)



Ventilated Improved Pit Latrine (VIP)

+ Flies and odours are significantly reduced (compared to non-ventilated pits)

+ Can be built and repaired with locally available materials

+ Low (but variable) capital costs depending on materials and pit depth

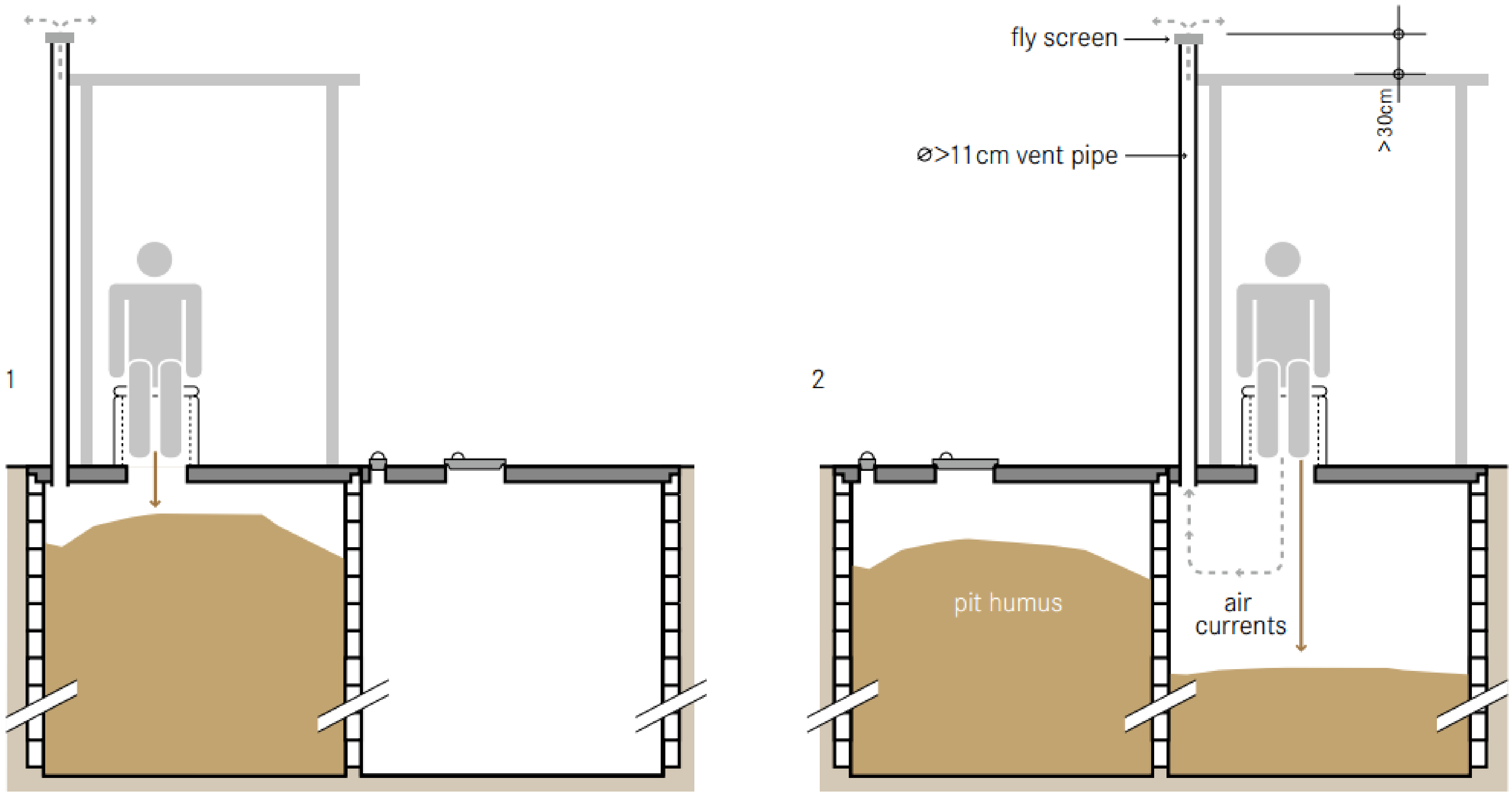
+ Small land area required

- Low reduction in BOD and pathogens with possible contamination of groundwater

- Costs to empty may be significant compared to capital costs

- Sludge requires secondary treatment and/or appropriate discharge

Double Ventilated Improved Pit Latrine (VIP)



Double Ventilated Improved Pit Latrine (VIP)

+ Longer life than Single VIP (indefinite if maintained properly)

+ Excavation of humus is easier than faecal sludge

+ Significant reduction in pathogens

+ Potential for use of stored faecal material as soil conditioner

+ Flies and odours are significantly reduced (compared to non-ventilated pits)

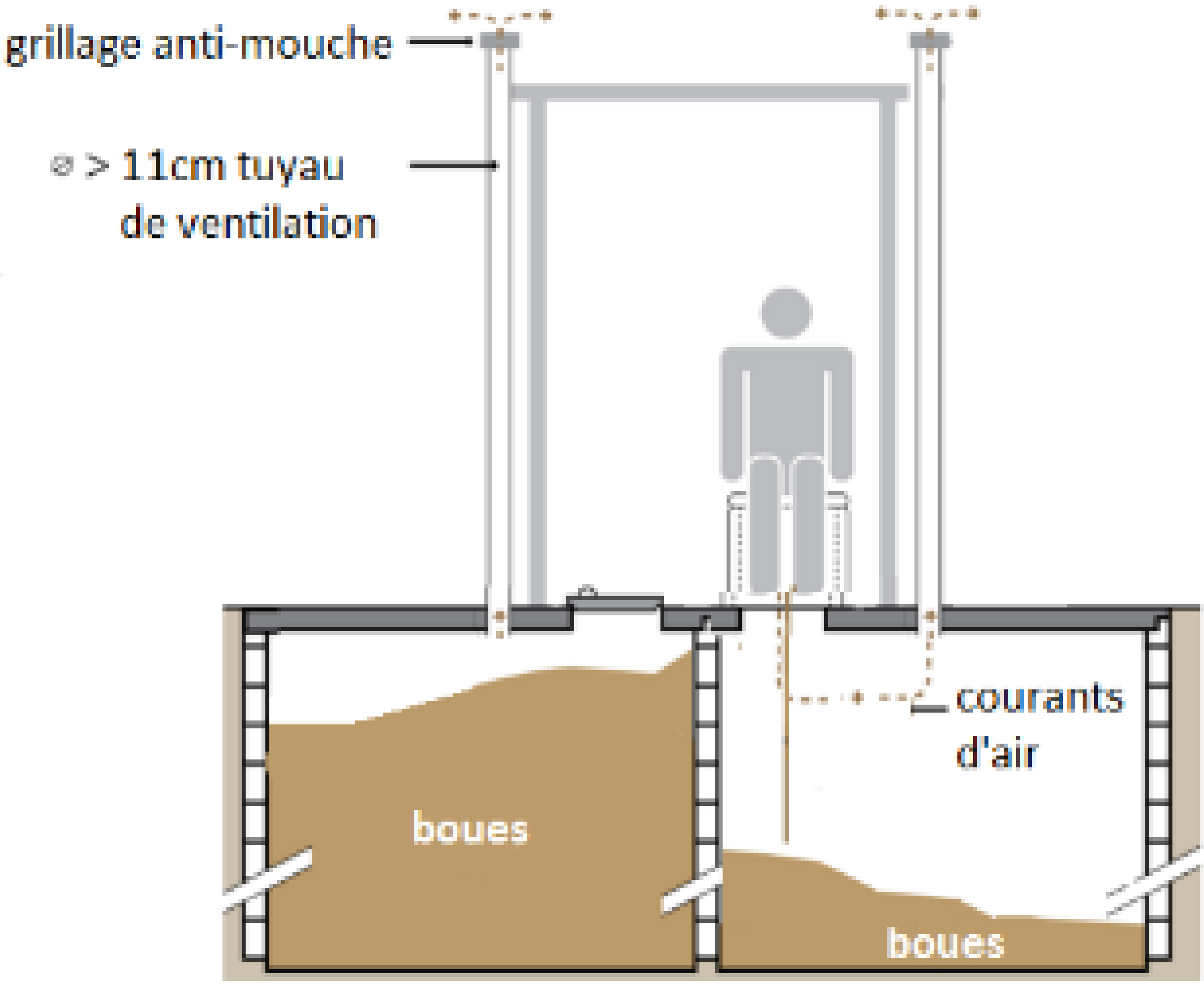
+ Can be built and repaired with locally available materials

- Manual removal of humus is required

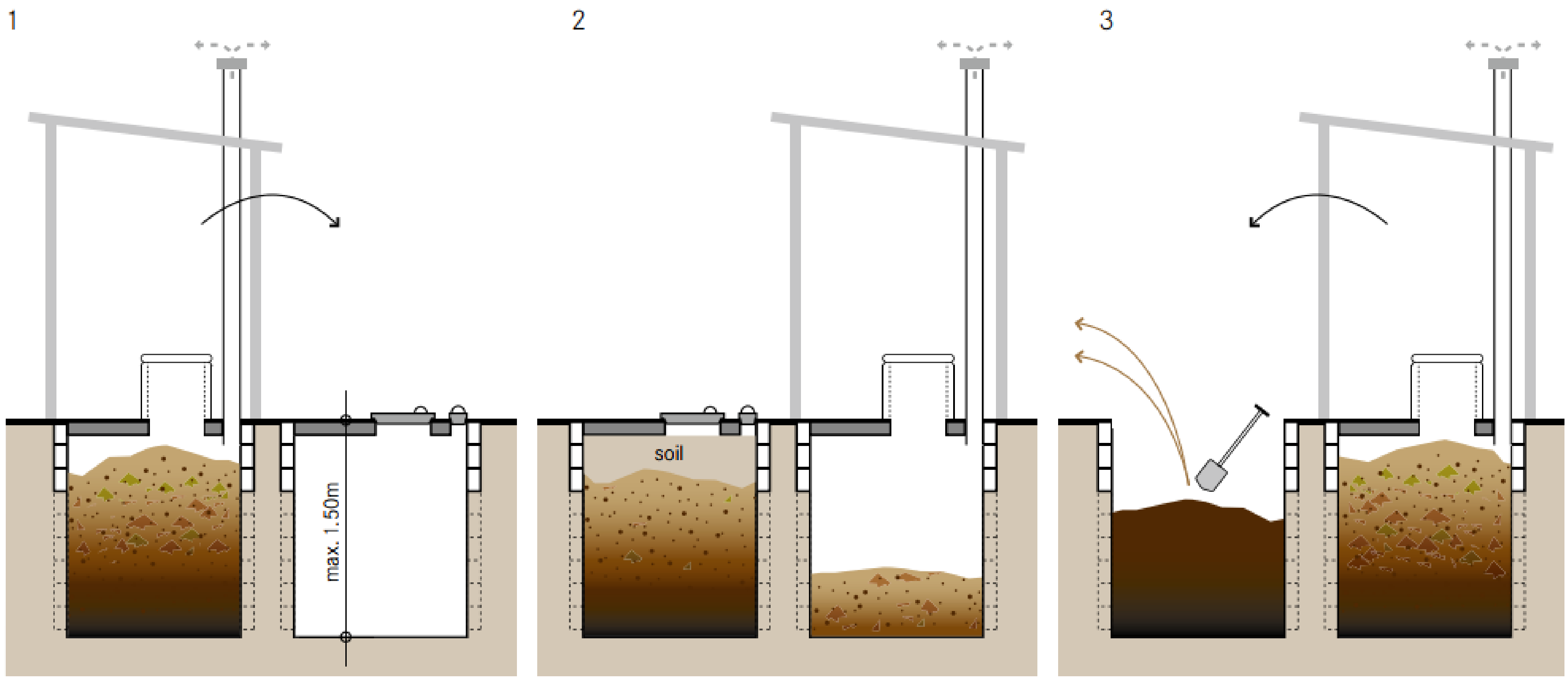
- Possible contamination of groundwater

- Higher capital costs than Single VIP; but reduced operating costs if self-emptied

Double Ventilated Improved Pit Latrine (VIP)



Fossa Alterna



Fossa Alterna

+ Because double pits are used alternately, their life is virtually unlimited
+ Excavation of humus is easier than faecal sludge
+ Significant reduction in pathogens
+ Generates nutrient-rich humus with good potential for use as soil conditioner
+ Flies and odours are significantly reduced (compared to non-ventilated pits)
+ Can be built and repaired with locally available materials
+ Low (but variable) capital costs depending on materials; no or low operating costs if self-emptied

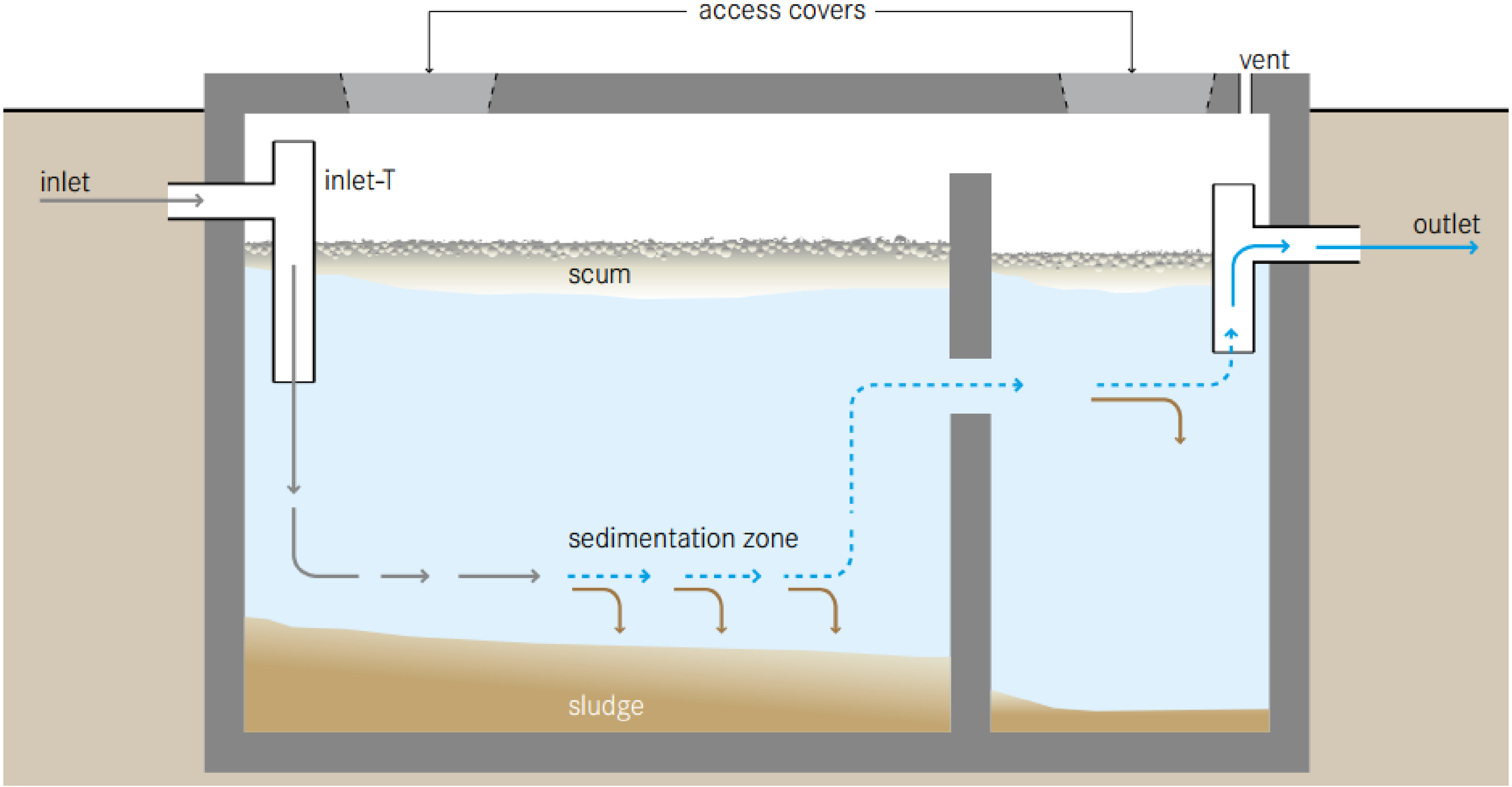
- Requires constant source of cover material
- Manual removal of humus is required
- Garbage may ruin end-use opportunities of the product

Fossa Alterna

Excavating pit compost in Epworth and Hatcliffe, Zimbabwe Harare.

Toilet compost

Septic tank


access covers
vent
inlet
inlet-T
outlet
scum
sedimentation zone
sludge

Septic tank

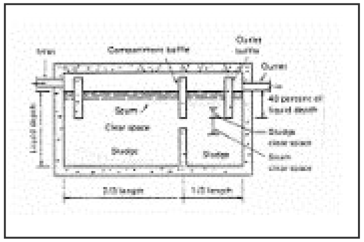
+ Simple and robust technology
+ No electrical energy is required
+ Low operating costs
+ Long service life
+ Small land area required (can be built underground)

- Low reduction in pathogens, solids and organics
- Regular desludging must be ensured
- Effluent and sludge require further treatment and/or appropriate discharge

User Interface

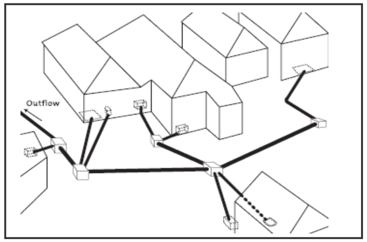
- Dry Toilet
- Urine Diverting Dry Toilet (UDDT)
- Urinal
- Pour Flush Toilet
- Cistern Flush Toilet
- Urine Diverting Flush Toilet

Collection and Storage / Treatment



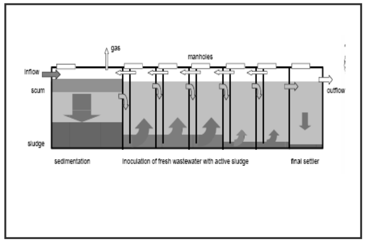
- Urine Storage Tank / Container
- Single Pit
- Single Ventilated Improved Pit (VIP)
- Double Ventilated Improved Pit (VIP)
- Fossa Alterna
- Twin Pits for Pour Flush
- Dehydr. Vaults
- Composting Chamber
- Septic Tank
- Etc.

Conveyance



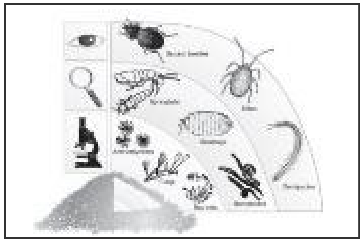
- **Jerry can / Tank**
- **Human-Powered Emptying and Transport**
- **Motorized Emptying and Transport**
- **Simplified Sewer**
- **Solids-Free Sewer**
- **Conventional Gravity Sewer**
- **Transfer Station (Holding Tank)**
- **Sewer Discharge Station**

(Semi-) Centralised Treatment



- Anaerobic Baffled Reactor (ABR)
- Anaerobic Filter
- Waste Stabilization Ponds
- Aerated Pond
- Constructed Wetland
- Trickling Filter
- Activated Sludge
- Drying Beds
- Co-composting
- Anaerobic Biogas Reactor
- Etc.

Use and/or Disposal



- Fill and Cover / Arborloo
- Applic. of Urine
- Application of Dehydr. Faeces / Compost
- Irrigation
- Soak Pit
- Leach Field
- Aquaculture
- Floating Plant Pond
- Water Disposal / Groundwater Recharge
- Land application
- Surface Disposal

Two categories of conveyance / transport systems

- Sewered (e.g. pipes)
- Non-sewered (e.g. containers)

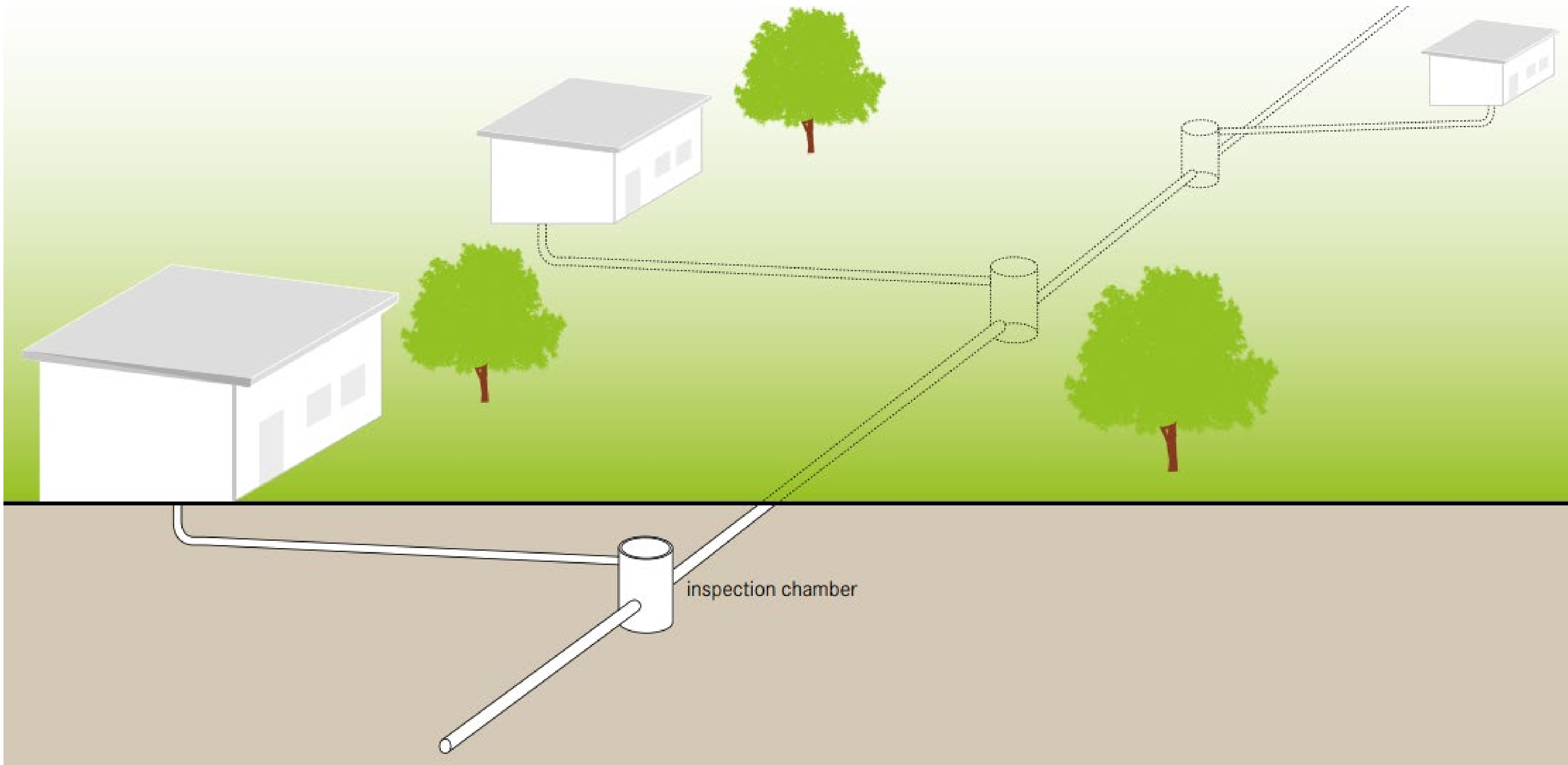
What needs to be transported:

- Blackwater
- Greywater
- Sludge
- Urine
- Dried faeces
- Pit humus
- Etc.

Sewer systems

- Simplified / shallow / condominial sewer
- Solids-free / settled / small-bore sewer
- Conventional gravity sewer

Simplified / shallow / condominial sewer



Simplified / shallow / condominial sewer

+ Can be laid at a shallower depth and flatter gradient than Conventional Sewers

+ Lower capital costs than Conventional Sewers; low operating costs

+ Can be extended as a community grows

+ Greywater can be managed concurrently

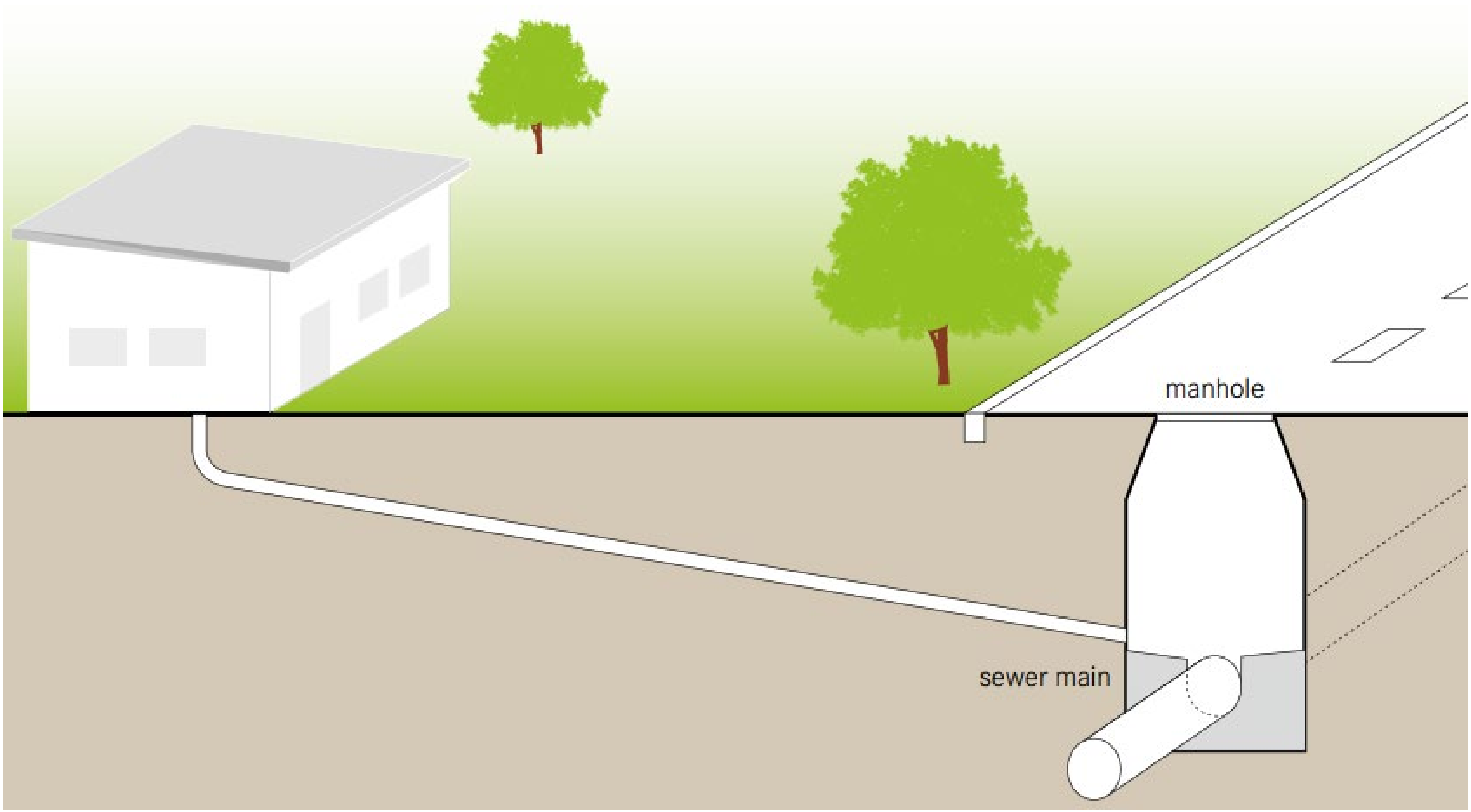
+ Does not require onsite primary treatment units

- Requires repairs and removals of blockages more frequently than a Conventional Gravity Sewer

- Requires expert design and construction

- Leakages pose a risk of wastewater exfiltration and groundwater infiltration and are difficult to identify

Conventional gravity sewers



Conventional gravity sewers

What % of sanitation capex are sewers?

+ Less maintenance compared to Simplified and Solids-Free Sewers

+ Greywater and possibly stormwater can be managed concurrently

+ Can handle grit and other solids, as well as large volumes of flow

- Very high capital costs; high operation and maintenance costs

- A minimum velocity must be maintained to prevent the deposition of solids in the sewer

- Requires deep excavations

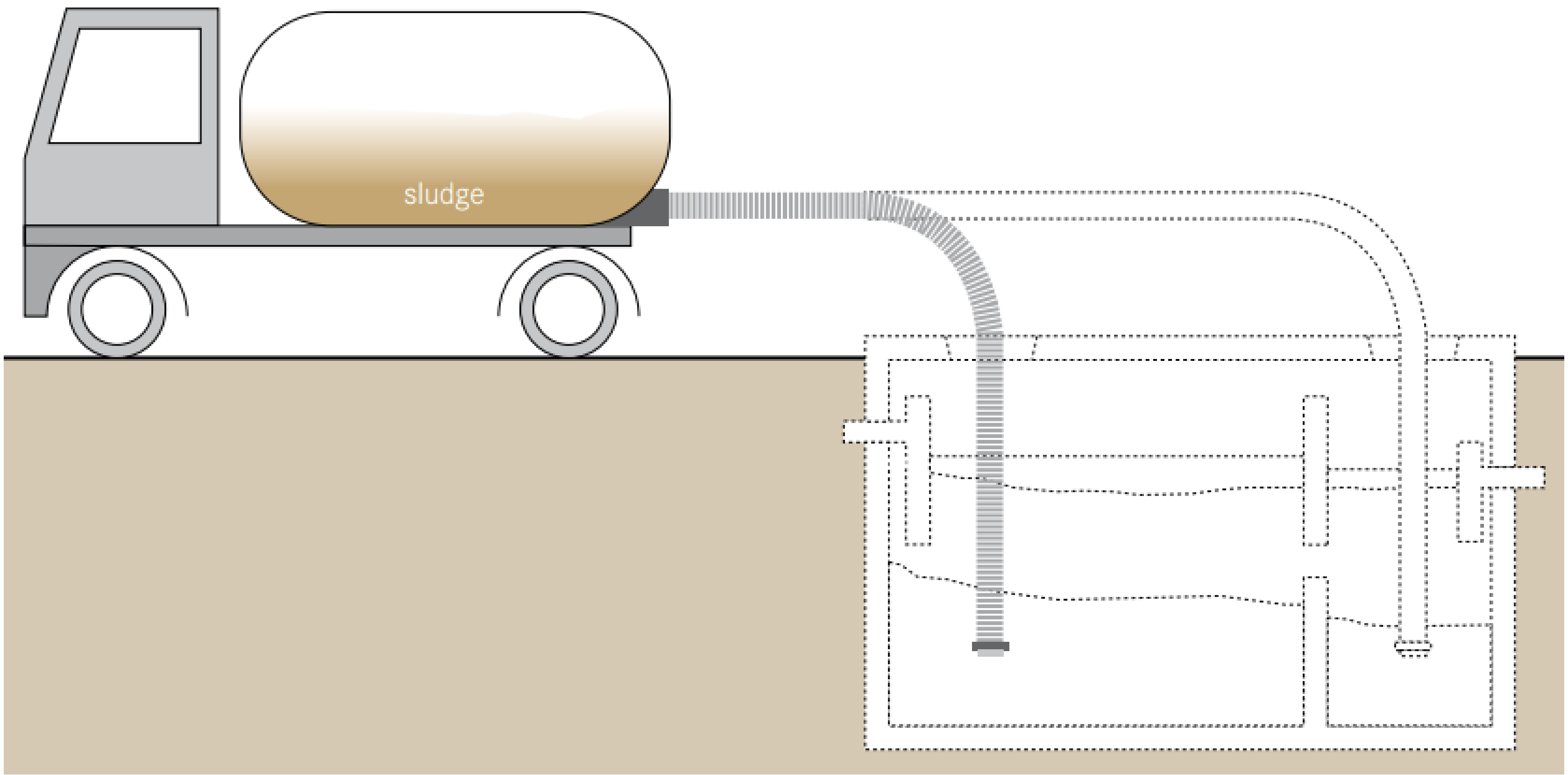
- Difficult and costly to extend as a community changes and grows

- Requires expert design, construction and maintenance

- Leakages pose a risk of wastewater exfiltration and groundwater infiltration and are difficult to identify

Conventional sewers
Nile Delta, Egypt

Motorised Emptying and Transport



Motorised Emptying and Transport

+ Fast, hygienic and generally effective sludge removal

+ Efficient transport possible with large vacuum trucks

+ Potential for local job creation and income generation

+ Provides an essential service to unsewered areas

- Cannot pump thick, dried sludge (must be thinned with water or manually removed)

- Garbage in pits may block hose

- Cannot completely empty deep pits due to limited suction lift

- Very high capital costs; variable operating costs depending on use and maintenance

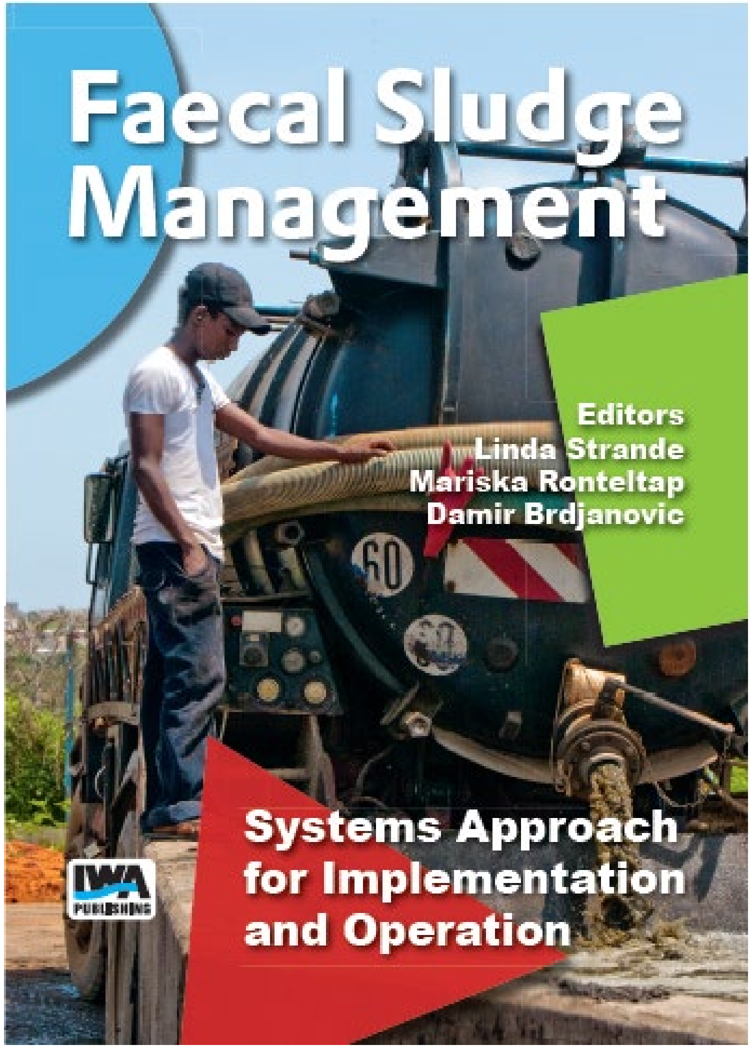
- Hiring a vacuum truck may be unaffordable for poor households

- Not all parts and materials may be locally available

- May have difficulties with access

Non-sewered transport

sandec.ch/fsm_book



eawag
aquatic research

User Interface	Collection and Storage	Conveyance	(Semi-) Centralised Treatment	Reuse and Disposal

Remember:

Only selected combinations of technologies result in functional systems !

User Interface	Collection and Storage	Conveyance	(Semi-) Centralised Treatment	Reuse and Disposal
-Dry -Uri Dry -Uri -Pour Flush Toilet -Flush Toilet	-Alternating Wet Double Pit -Double Dehydr. Vaults -Aquaprivy -Septic Tank -Composting Chamber	-Small-Bore Sewer -Conventional Gravity Sewer -Jerry can/tank	-Trickling Filter -Waste Stabilization Ponds -Finishing Pond -Constructed Wetland -Co-composting Etc.	-Compost -Irrigation with Wastewater -Aquaculture -Soak Pit -Leach Field -Incineration -Land application -Surface Disposal

Questions?

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Email / Twitter / LinkedIn

SWISS WATER PARTNERSHIP YOUTH

www.swisswaterpartnership.ch/youth

- Network
- Mentoring
- Seed Funding
- Global Youth Representation

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- [13] Franceys, R., Pickford, J., & Reed, B. (1992). *A Guide to the Development of on-Site Sanitation*. Geneva, CH: World Health Organisation.
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- [17] Mang, H.-P. and Li, Z. (2010). *Technology review of biogas sanitation. Draft – Biogas sanitation for blackwater, brown water, or for excreta treatment and reuse in developing countries.* Eschborn: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

Further resources

(not compulsory)

- Department Water and Sanitation in Developing Countries at Eawag: www.sandec.ch
- Sustainable Sanitation Alliance: www.susana.org
- Sustainable Sanitation and Water Management Toolbox: www.sswm.info
- Franceys, R., Pickford, J., & Reed, B. (1992). A Guide to the Development of on-Site Sanitation. Geneva, CH: World Health Organisation.
- GIZ Technology reviews (UDDTs and urine diversion components, constructed wetlands, composting toilets, biogas sanitation). http://www.giz.de/Themen/en/9397.htm
- Gutterer, B., Sasse, L., Panzerbieter, T., & Reckerzügel, T. (2009). Decentralised Wastewater Treatment Systems (DEWATS) and Sanitation in Developing Countries - A Practical Guide. (A. Ulrich, S. Reuter, & B. Gutterer, Eds.) (p. 367). Leicestershire, UK: Water, Engineering and Development Centre (WEDC), Loughborough University.
- Morgan, P. (2009). Ecological Toilets - Start simple and upgrade - from Arborloo to VIP (Pre-Produc.). Harare, Zimbabwe: Stockholm Environment Institute, EcoSanRes Programme.
- See also course webpage (Moodle)