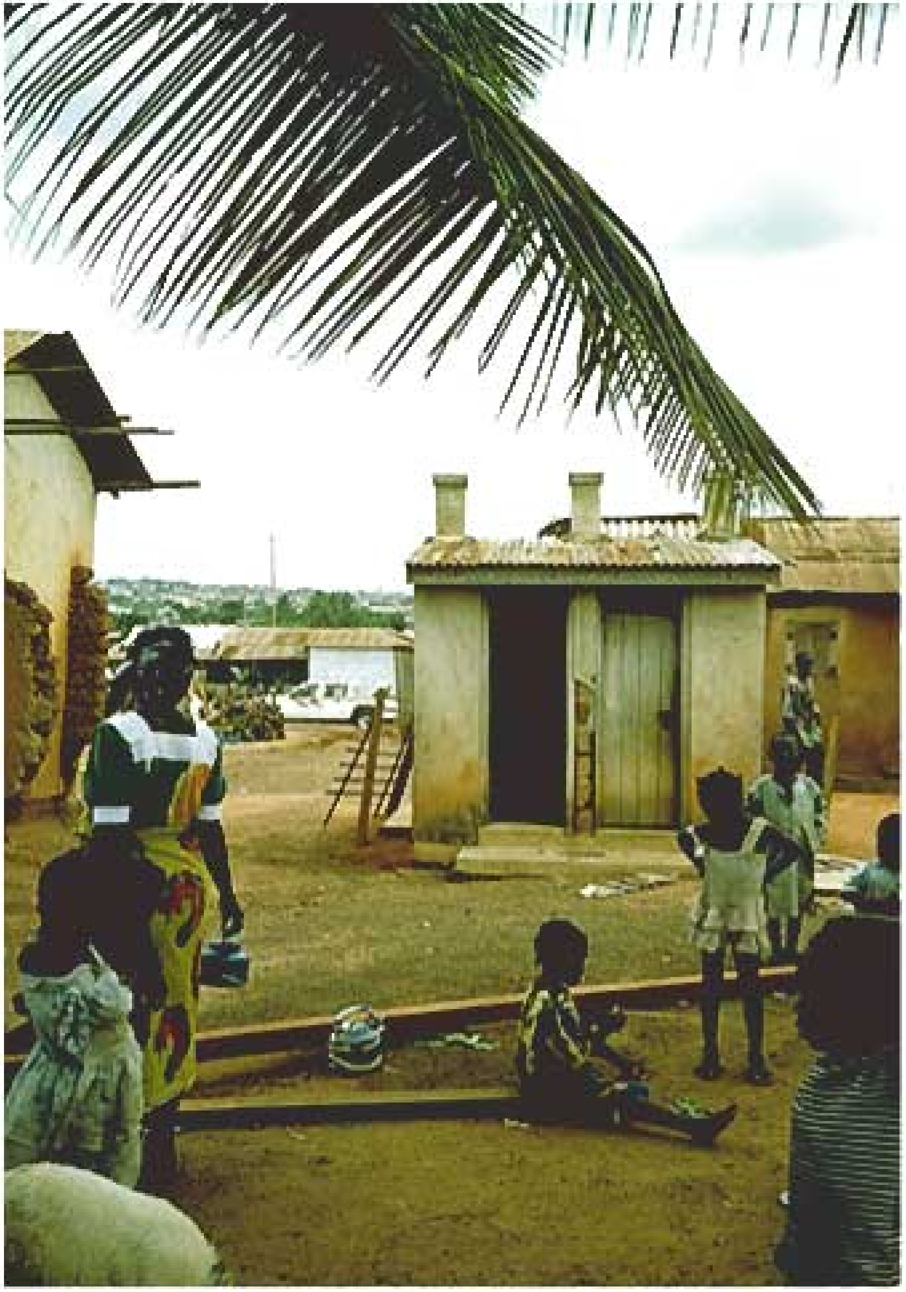
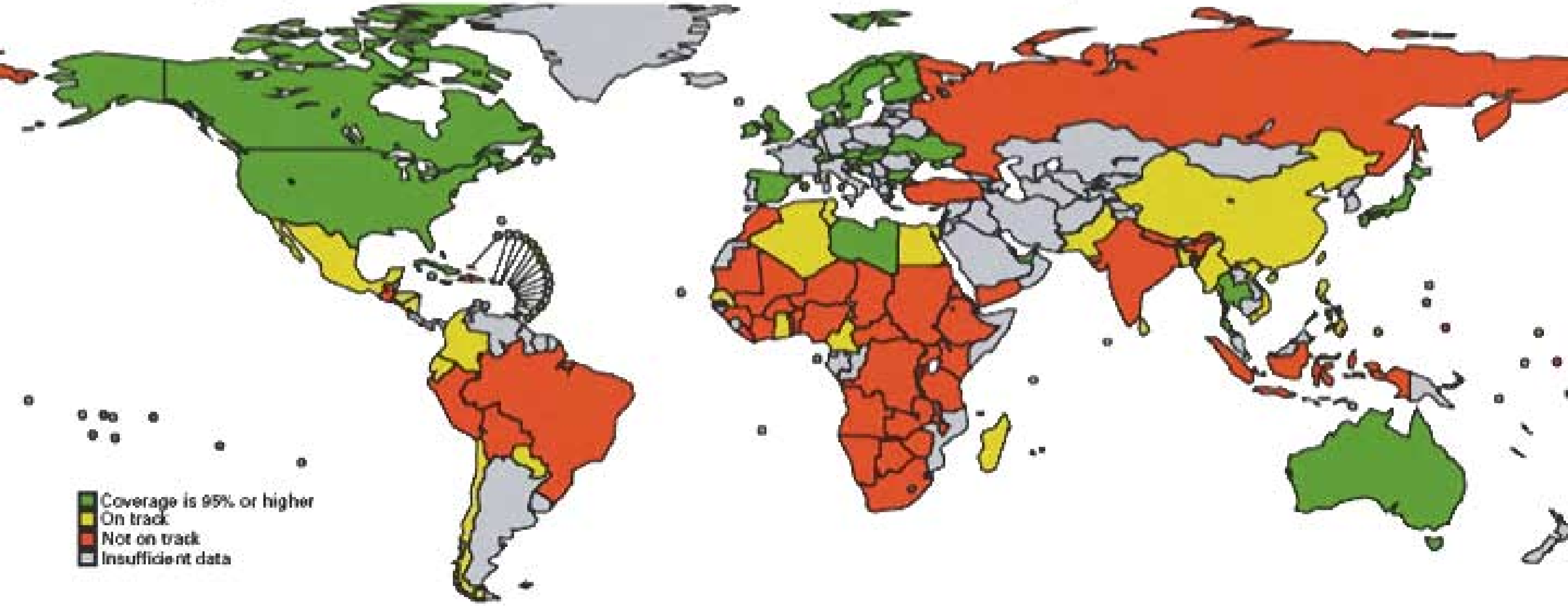
Household and neighbourhood Sanitation in developing countries



Chris Zurbrügg
Sandec/EAWAG
March, 2009

Can we achieve the sanitation targets of the MDG?

- **MDG Goal 7:** Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation.
- What **progress** have we made so far? (1990-2002)



2.6 billion people still lack improved sanitation !

What is considered as "access to improved sanitation"?

For monitoring purposes "access to improved sanitation" is defined in terms of the **types of technology and levels of service afforded**.

improved technologies:	▪ connection to a public sewer ▪ connection to a septic system ▪ pour-flush latrine ▪ simple pit latrine ▪ ventilated improved pit latrine (VIP)
not improved technologies:	▪ bucket latrines ▪ public latrines ▪ open latrines

This classification is used to measure coverage and progress of global sanitation.

Partially sewered cities

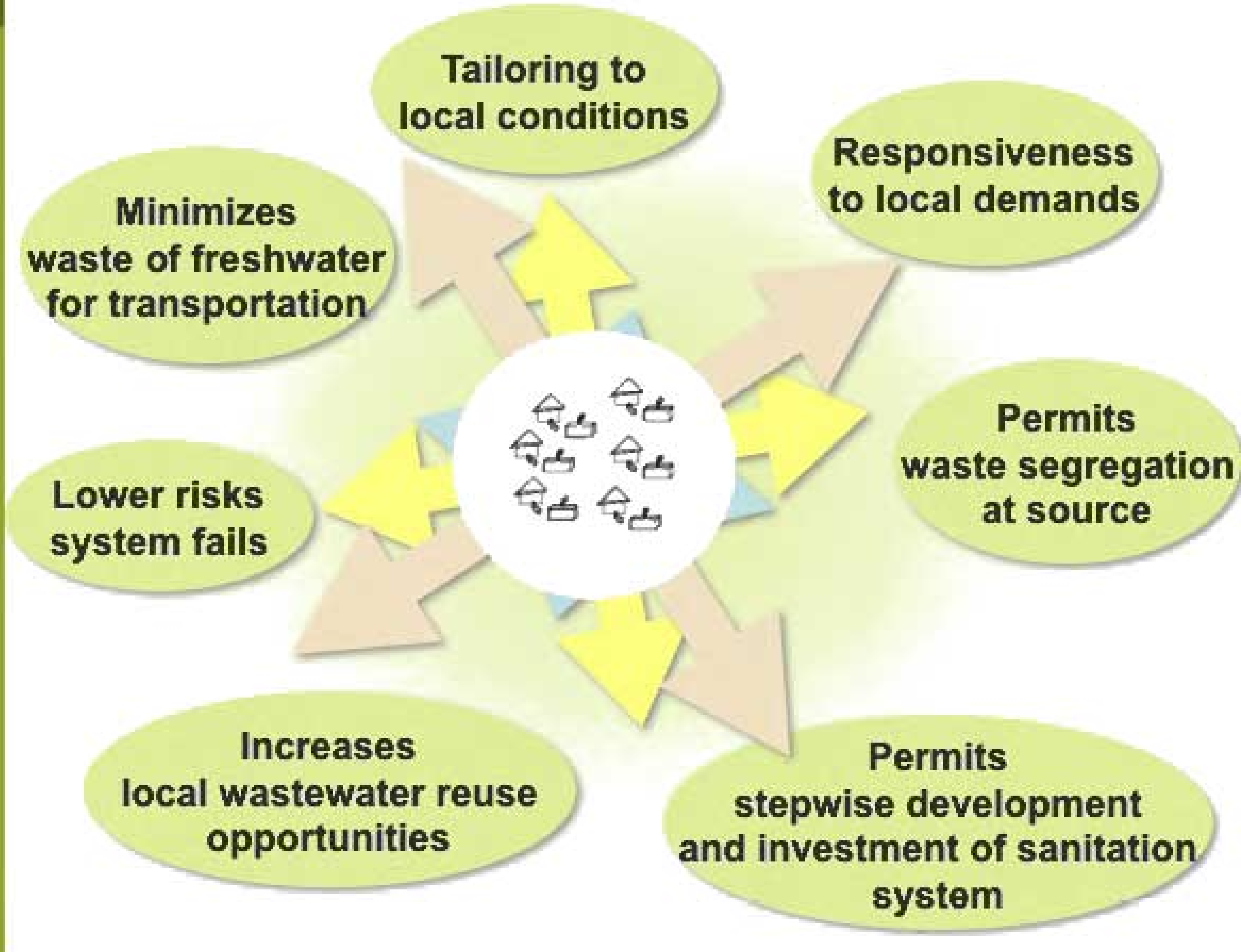
- Business centre of large cities with high water consumption rate
- Lack of treatment sites and wastewater treatment plants
- Discharge of wastewater into natural water bodies and open canals



Cities without sewers

- Represent more than 90% of cities in developing countries
- Are very heterogeneous in urban infrastructure
- Often lack financial and human resources for sanitation development and upgrading

Potential of decentralized sanitation systems



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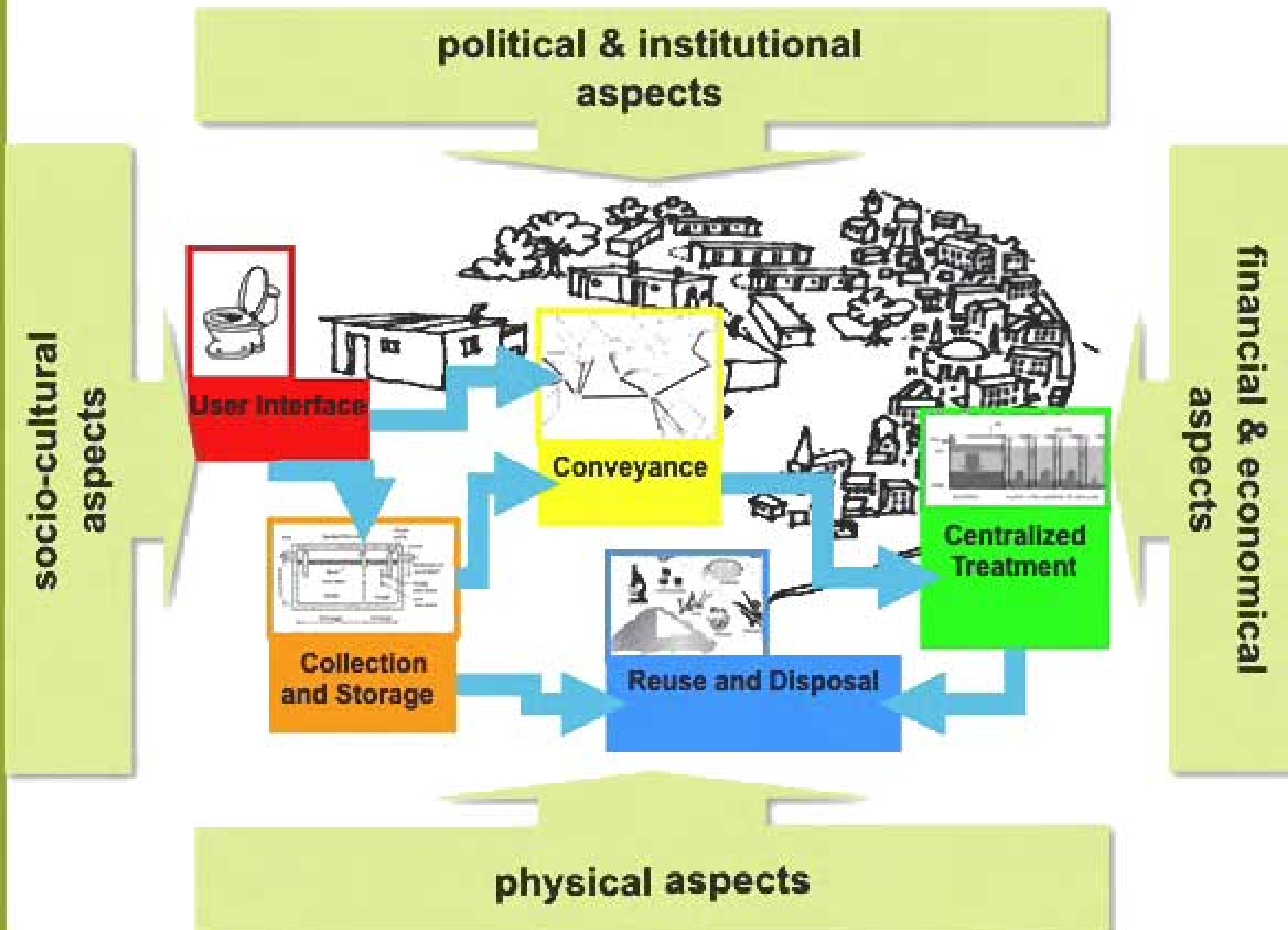
Criteria influencing the selection of sanitation systems



Criteria influencing the selection of sanitation systems

Physical aspects

- Availability of space (pit emptying)
- Groundwater level
- Availability of water
- Climate (temperature, rainfall)
- Soil (rock, sand, loam, ...)

Criteria influencing the selection of sanitation systems

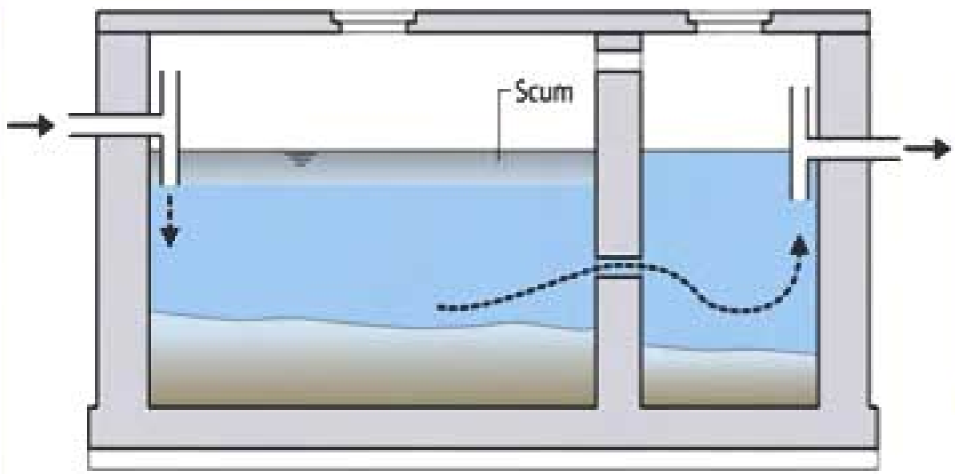
Socio-cultural aspects

- Defecating posture (sitting/ squatting)
- Type of anal cleansing material used
- Gender aspect & privacy
- Different cultural groups do not use same latrines
- Location of the facility relative to the house and its orientation
- Practices and taboos on using and handling waste

Collection and storage technologies

Septic tank

= sedimentation tank in which settled sludge is partially stabilised by anaerobic digestion



- most frequent onsite treatment unit worldwide
- Consists of 2 to 3 compartments

\+ simple, little space required because of being underground
\+ low O&M costs

\- little removal of dissolved and suspended matter (COD removal approx. 50%)
\- high investment costs

Criteria influencing the selection of sanitation systems

Political & institutional aspects

- Regulations and standards
- Organizational setup and responsibilities
- Political will and support
- Bureaucracy

Criteria influencing the selection of sanitation systems

Financial & economical aspects

- Availability of local skills, manpower & resources
- Availability of local materials and tools
- Affordable technology
- Willingness to pay and appropriate service level
- Operation and maintenance
- Availability of credits and loans

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Designing a Sanitation System

- To design a robust system we must consider
  - What goes in
  - What comes out
  - What needs to be collected, stored, transported, processed, disposed of
  - What technologies can perform the required tasks
  - How we can link the required technologies
- **Consider all the parts or you may be in deep….**

What goes IN and OUT of a sanitation system?

Inputs:

- **Urine- undiluted urine that is not mixed with faeces or water**
- **Faeces- (semi-) solid excretement without any urine or water**
- **Excreta- mixture of urine and faeces without water**
- **Greywater- used for the watshing of food, clothes, dishes, people and things. It does not contain excreta but it still contains pathogens and organics**
- **Organics- the bulky, carbonaceous material that is required for it's chemical and structural properties in some technologies**
- **Flushwater- the water that is used to move excreta, urine or faeces and create a water-seal**
- **Dry Cleansing Material- material used to wipe oneself after urinating or defecating, e.g. paper, leaves, corncobs, rocks, etc.**
- **Anal Cleansing Water- the water used to wash oneself after urinating or defecating**

What goes IN and OUT of a sanitation system?

Products:

Blackwater

- **Blackwater- the mixture of urine, faeces and flushing water + anal cleansing water / dry cleansing material**

Faecal sludge

- **Faecal Sludge- is the general term for the undigested, or partially digested slurry or solid that results from the storage or treatment of blackwater or excreta**

Compost/ Humus

- **Compost/Humus is the earth-like, brown/black material that is the result of decomposed organic matter**

> - Usually only blackwater is considered in sanitation planning-
> - Sanitation systems must be designed by keeping all inputs and products in mind
> - Faecal sludge is commonly ignored/forgotten

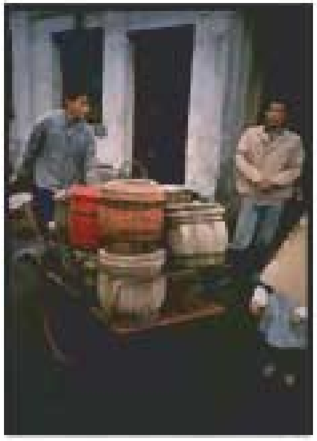
Characteristics of Products

	Total	Greywater***	Urine	Faeces
Volume [l/ cap·yr]	25'000-100'000	**25'000-100'000**	500	50
Nutrients Nitrogen	2 - 4 kg/ cap·yr	5%	**85%**	10%
Phosphorous	0.3 - 0.8 kg/ cap·yr	10%**	**60%**	30%
Potassium	1.4 - 2.0 kg/ cap·yr	34%	**54%**	12%
COD	30kg/cap·yr	**41%**	12%	**47%**
Faecal coliforms	-	**10^4-10^6 / 100ml**	0*	**10^7-10^9 / 100ml**

* healthy people
** can be as high as 50%, depending on washing and dish-washing powder used
*** values representative for industrialized countries

Urine: liquid gold

- Contains almost all the **nitrogen** and large parts of the **potassium** and **phosphorous** excreted by humans
- Urine is usually sterile (except for rare diseases and urinary tract infections)
- urine contains pharmaceutical residues (hormones, antibiotics)
- *Still unknown: effect of these micro-pollutants on environment.*



Faeces

- ➢**Contains mainly undigested organic matter**
- ➢**Faeces contain almost all types of pathogens:**
  - •bacteria (e.g. faecal coliforms, vibro cholerae)
  - •viruses (e.g. rota virus)
  - •protozoa (e.g. amoeba hystolitica)
  - •helminths (e.g. Ascaris eggs)

- •**Low nutrient content, but good characteristics as soil conditioner:**
  - •increase the organic matter content
  - •improve the water holding capacity

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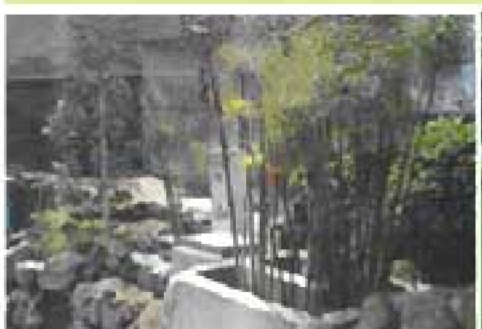
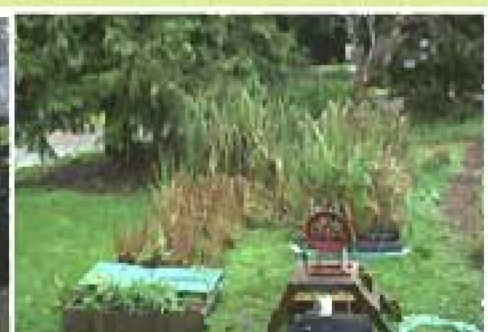
- Definitions
- **Introduction**
- Technologies
- Non-technical Aspects
- Review

Greywater- Big volumes, big reuse potential

- Water from baths, showers, hand basins, washing machines, dishwashers, laundries and kitchen sinks
- Greywater is traditionally "**forgotten**" in sanitation projects
- Big quantities with relatively low nutrient contents
- Main issue: **fats and oils** from kitchen, can affect natural treatment and disposal systems; Toxic substances (organic compounds, metals, chlorine etc.)
- **Source control** very important component of greywater management system





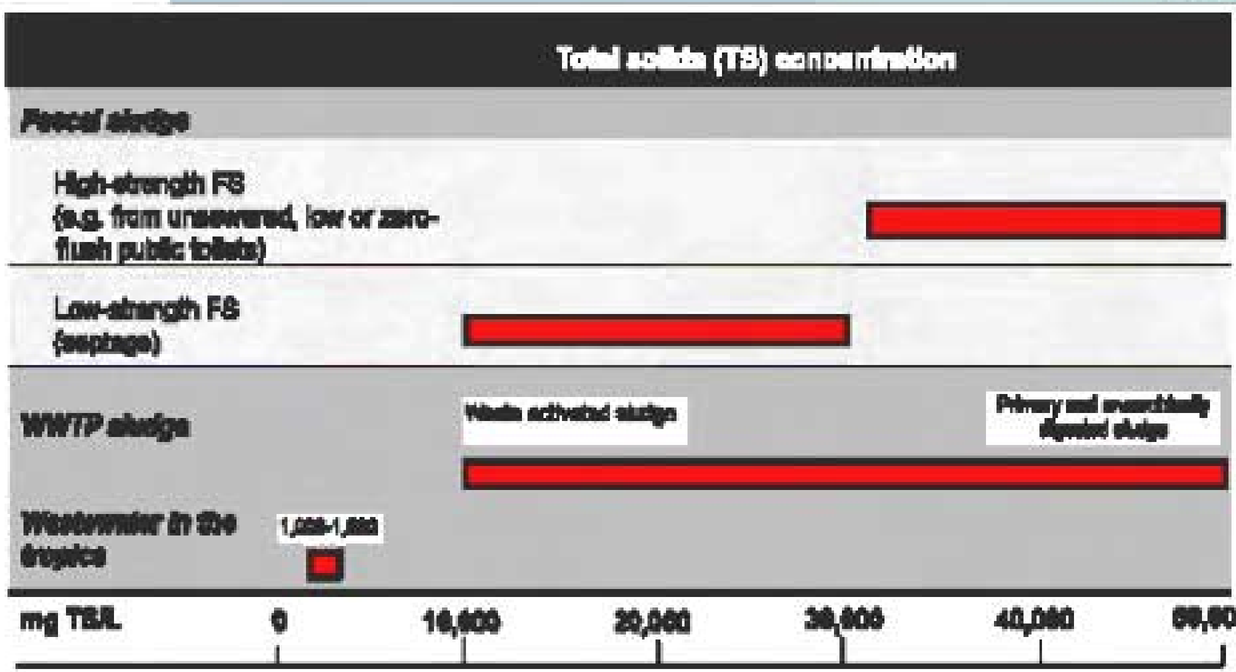
Faecal Sludge- Nobody's friend

- **THICK and yellow-** from unsewered family toilets emptied every few weeks: unstable sludge

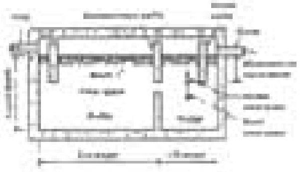
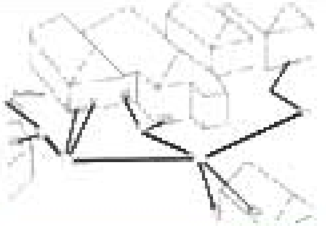
- **Thin and BLACK- sludge that is ‚'septic' and is emptied after years of storage: partially stable**

Faecal Sludge Characteristics

Location	Accra (Ghana)	Accra (Ghana)	Alcorta (Argentina)	Ouagadougou (Burkina Faso.)	Bangkok (Thailand)
TS (mg/L)	52,500	12,000	(6,000 – 35,000 SS)	19,000	15,350 (2,200 – 67,200)
COD (mg/L)	49,000	7,800	4,200	13,500	15,700 (1,200 – 76,000)
NH_4-N (mg/L)	3,300	330	150	-	415 (120 – 1,200)

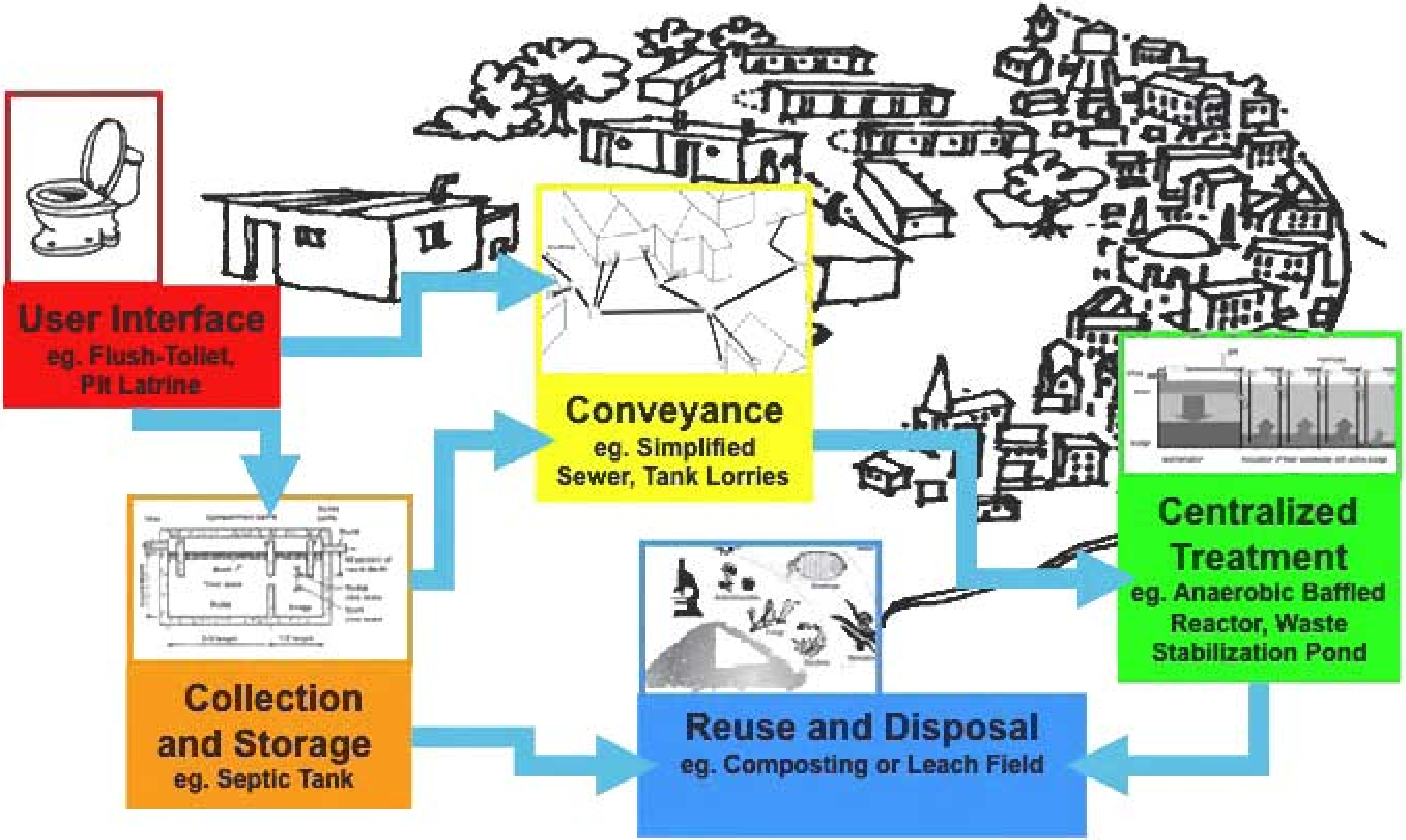


What are the parts of a sanitation system?

User Interface	Collection and Storage	Conveyance	(Semi-) Centralised Treatment	Reuse and Disposal
				
-Dry Toilet -Urine Diverting Dry Toilet -Urinal -Pour Flush Toilet -Flush Toilet	-Single Pit -Single Pit VIP -Alternating Dry Double Pit -Alternating Wet Double Pit -Double Dehydr. Vaults -Aquaprivy -Septic Tank -Composting Chamber	-Manual Emptying -Mechanical Emptying -Simplified Sewers -Small-Bore Sewer -Conventional Gravity Sewer -Jerry can/tank	-Imhoff Tank -Anaerobic Baffled Reactor -Anaerobic Filter -Trickling Filter -Waste Stabilization Ponds -Finishing Pond -Constructed Wetland -Co-composting etc.	-Application of Urine -Application of Dehydr. Faeces -Compost -Irrigation with Wastewater -Aquaculture -Soak Pit -Leach Field -Incineration -Land application -Surface Disposal

Processes of sanitation systems

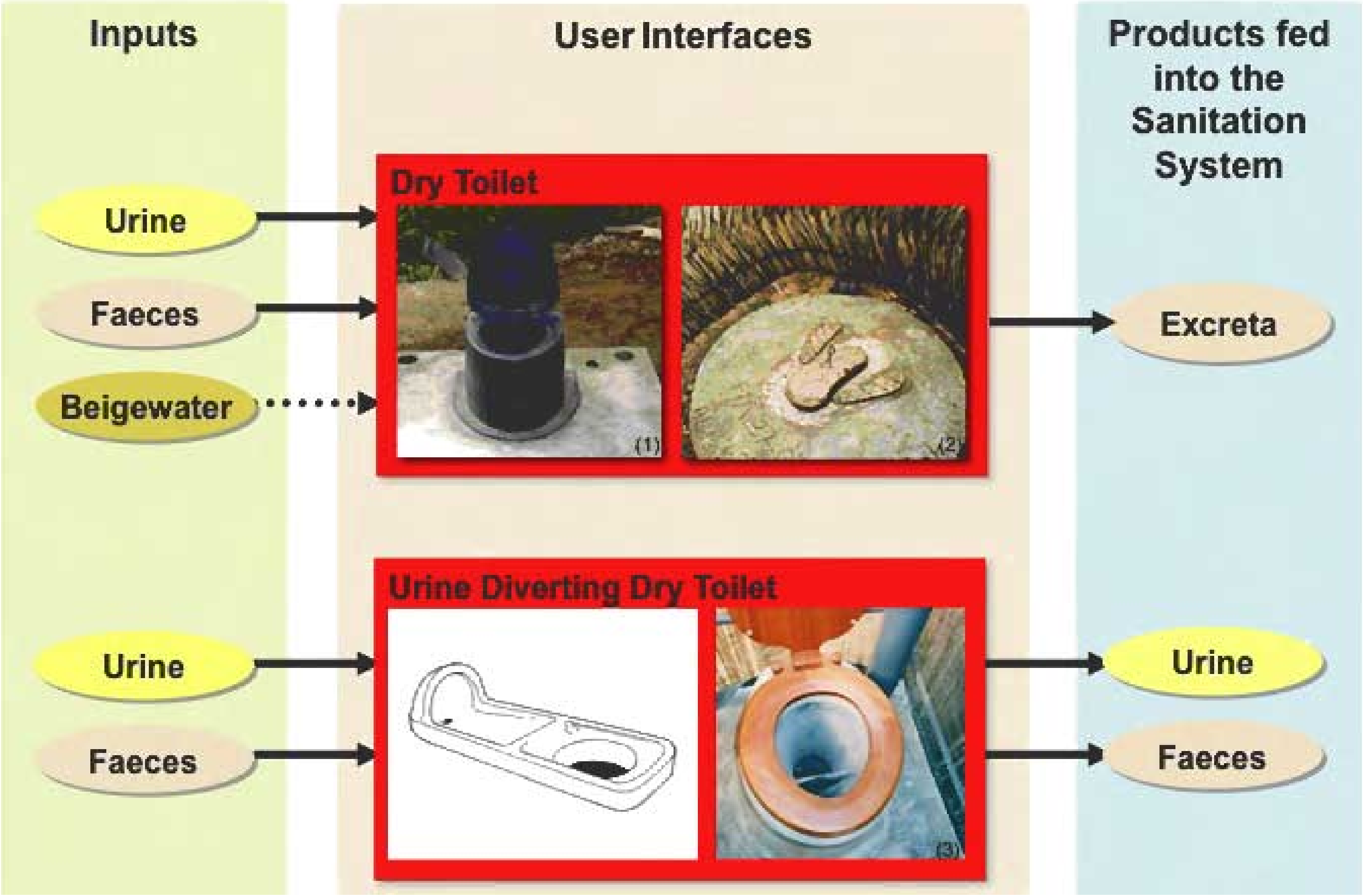
Processes have to be linked to a functional systems



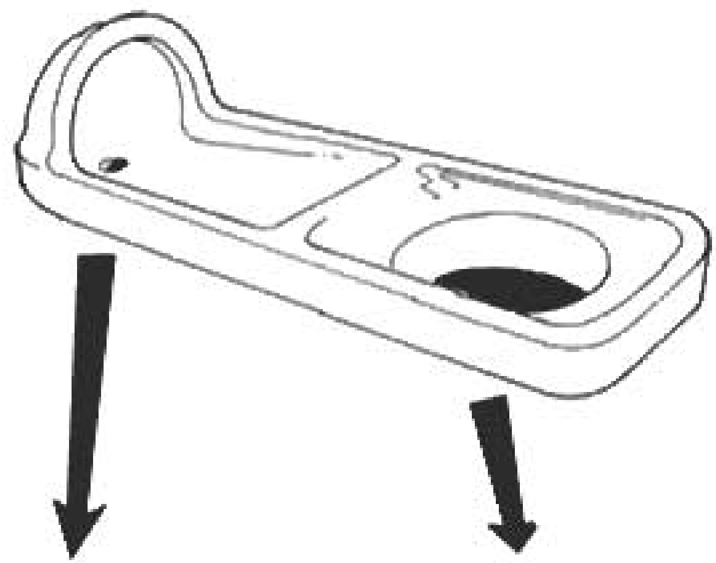
Technologies for the user-interface

User Interface	Collection and Storage	Conveyance	(Semi-) Centralised Treatment	Reuse and Disposal
				
-Bucket Latrine -Dry Toilet -Urine Diverting Dry Toilet -Urinal -Pour Flush Toilet -Flush Toilet	-Bucket Latrine -Single Pit -Single Pit VIP -Alternating Dry Double Pit -Alternating Wet Double Pit -Double Dehydr. Vaults -Aquaprivy -Septic Tank -Composting Chamber	-Manual Emptying -Mechanical Emptying -Simplified Sewers -Small-Bore Sewer -Conventional Gravity Sewer -Jerry can/tank	-Imhoff Tank -Anaerobic Baffled Reactor -Anaerobic Filter -Trickling Filter -Waste Stabilization Ponds -Finishing Pond -Constructed Wetland -Co-composting etc.	-Application of Urine -Application of Dehydr. Faeces -Compost -Irrigation with Wastewater -Aquaculture -Soak Pit -Leach Field -Incineration -Land application -Surface Disposal

User-interface Technologies



Urine-Diverting Dry Toilet- Sit or Squat

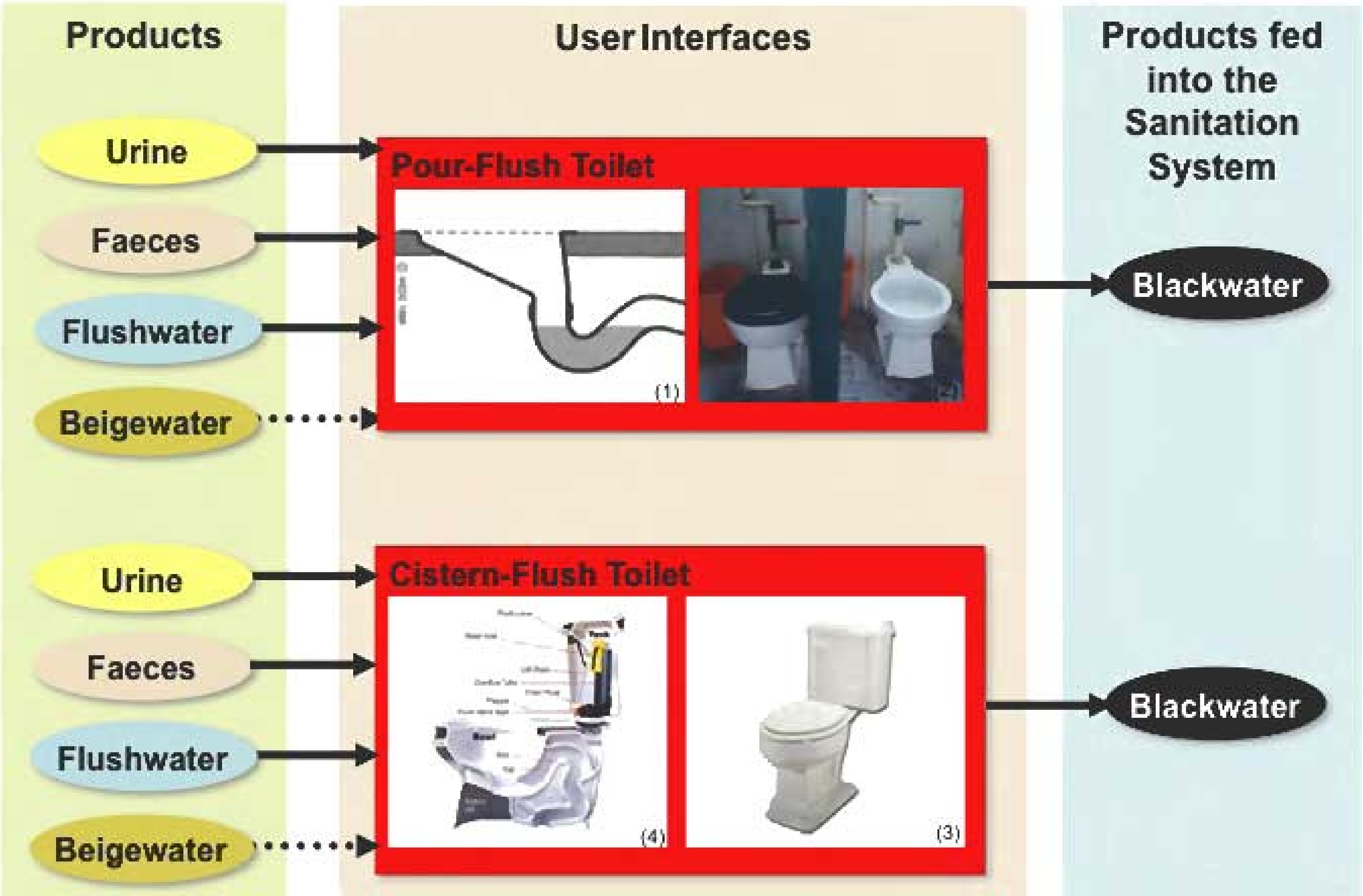


Urine
1-2 l per day
sterile
high nutrient content
directly reused as fertiliser

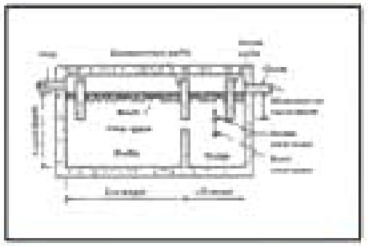
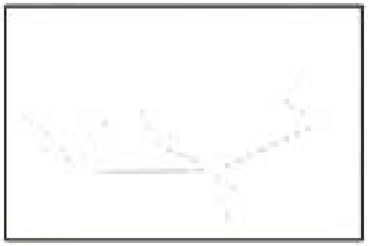
Faeces
0.2 l per day
hygienically precarious
high carbon content
applied as soil conditioner after
on-site treatment

➡ No blackwater (toilet wastewater) contaminating water bodies
➡ Safe reuse of human waste in agriculture

User-interface technologies



Technologies for the collection and storage

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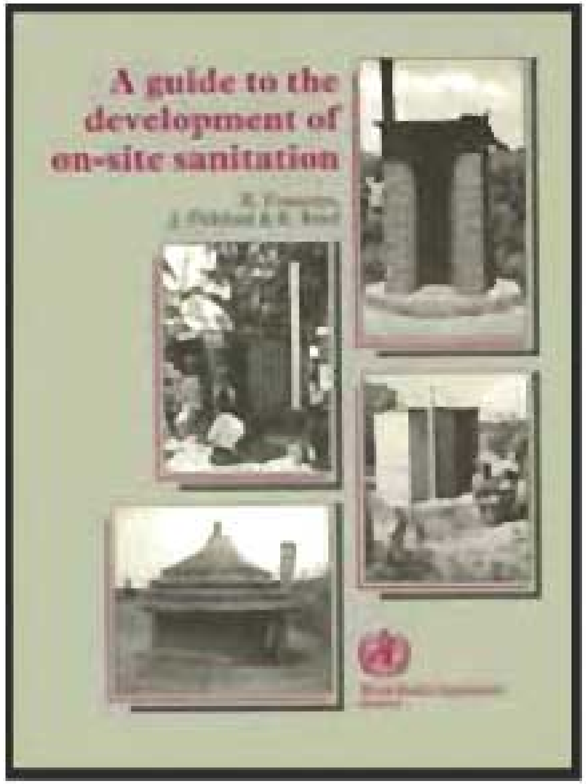
Collection and storage technologies



R Franceys, J Pickford & R Reed
ISBN 92 4 154443 0

Price: Sw. fr. 47 - Price in developing countries : Sw. fr. 32.90

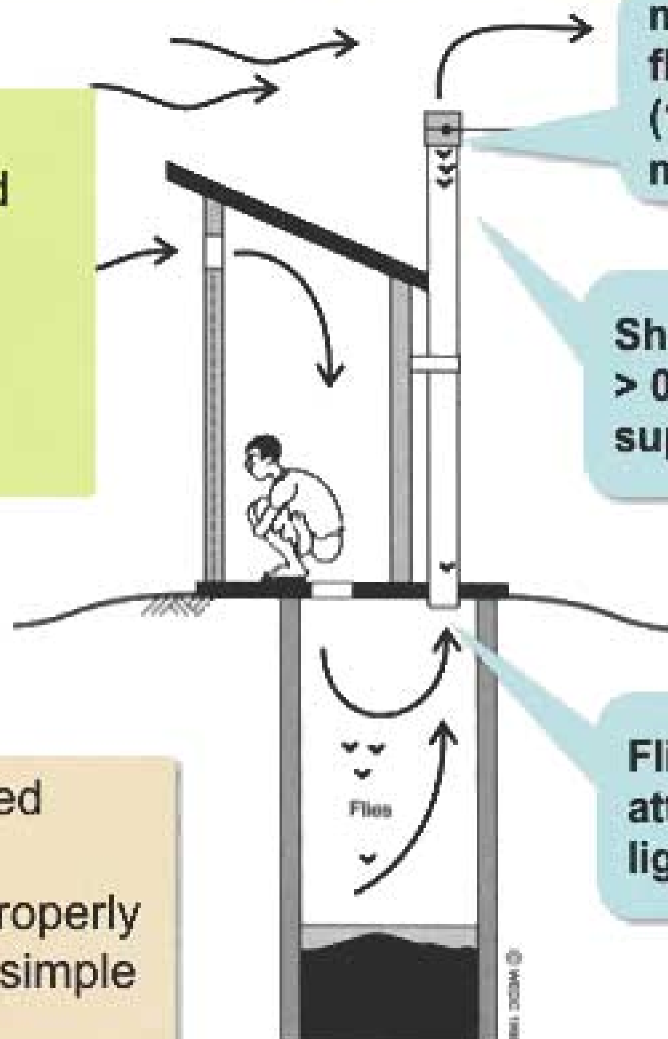
http://www.who.int/water_sanitation_health/hygiene/envsan/onsitesan/en/index.html

Collection and storage technologies

VIP latrine (ventilated improved pit latrine)

Naturally induced ventilation with screened ventilation pipe

→ removes odor and prevents escape of flies



mesh traps flies (1.2-1.5 mm mesh) size

Should extent > 0.5 m above superstructure

Flies are attracted by light from pipe

+ odors and flies reduced

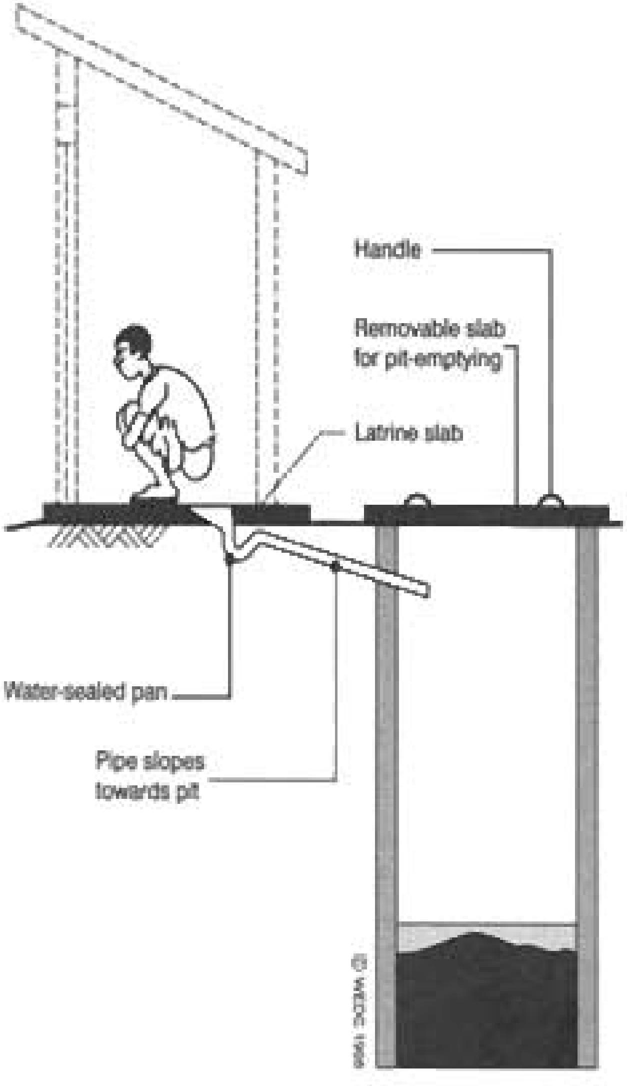
- difficult to construct properly
- more expensive than simple pit latrine

Collection and storage technologies

Twin-Pit Pour Flush

- flushing of excreta with 2-3 L
- water seal forms barrier
- permanent pit(s)
- constant operation

+ reduced odour
- higher investment costs
- water must be available



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Collection and storage technologies

Pit design

Site

- Distance and position relative to housing: depending on cultural habits
- at least 20 m from surface water sources
- **easily accessible** for all users (children, women, old people, disabled)

Construction materials

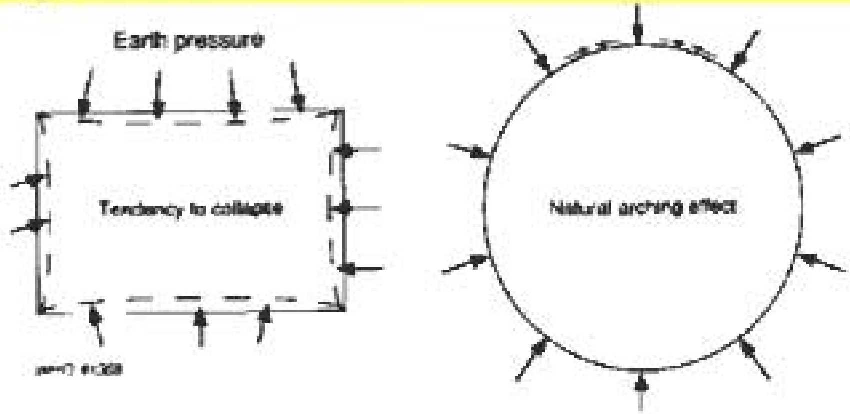
- local availability
- stable and durable
- esthetic considerations

Superstructure design

- depending on cultural habits (open or closed)
- protect from rain, stormwater runoff, ...
- **superstructure = important factor influencing the use** (essential that users are involved in design)

Collection and storage technologies

Pit design



- Round pits are more suitable to distribute evenly earth pressure (natural arching effect)
- Hand-washing facilities must be provided!

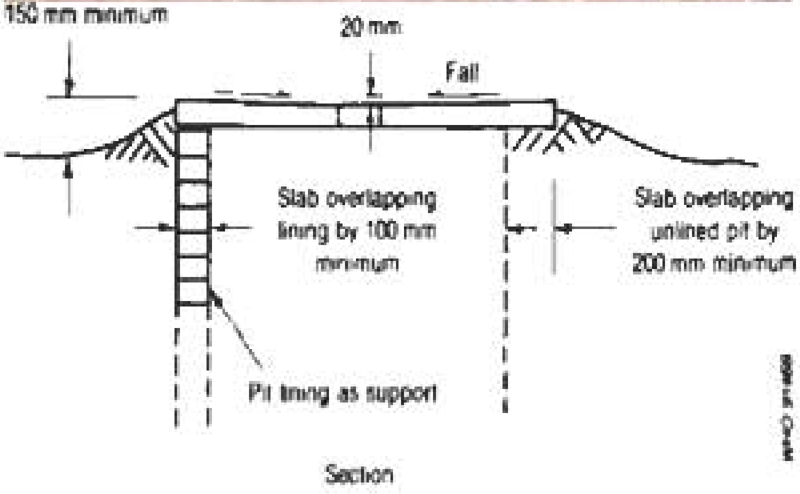
Collection and storage technologies

Pit design

Ventilation pipes
- 15-20 cm diameter
- 0.5m higher than superstructure
- orientation

Pit excavation and lining
- top 0.5 m usually lined (bricks, blocks, etc.)

No movable parts!



Collection and storage technologies

Pit design

$$V = N \times S \times D / 1000 \qquad \text{and} \qquad F = N \times W / I$$

V: pit Volume (m^3)
N: no. of users
S: sludge accumulation rate (litres/cap year)
D: design life (years)
- 2-3 years for single pits (where emptying required)
- 1-2 years for double pits
- 0.5 -1 year with urine separation

F: Infiltration area (m^2); (water depth = F / pit circumference)
W: Amount of water used for flushing (liters/cap day)
I: Infiltration rates (liters/m2 day)

- Sand 40
- Sandy loam 25
- Silt loam 20
- Clay loam 8
- Clay unsuitable

Collection and storage technologies

Sludge accumulation rates

Wastes deposited and conditions	Sludge accumulation rate "S" (litres per capita per year)
Wastes retained in water where degradable anal cleaning materials are used	40
Wastes retained in water where non-degradable anal cleaning materials are used	60
Wastes retained in dry conditions where degradable anal cleaning materials are used	60
Wastes retained in dry conditions where non-degradable anal cleaning materials are used	90

In emergency situations (rapid accumulation) these rates have to be multiplied by 150-200%

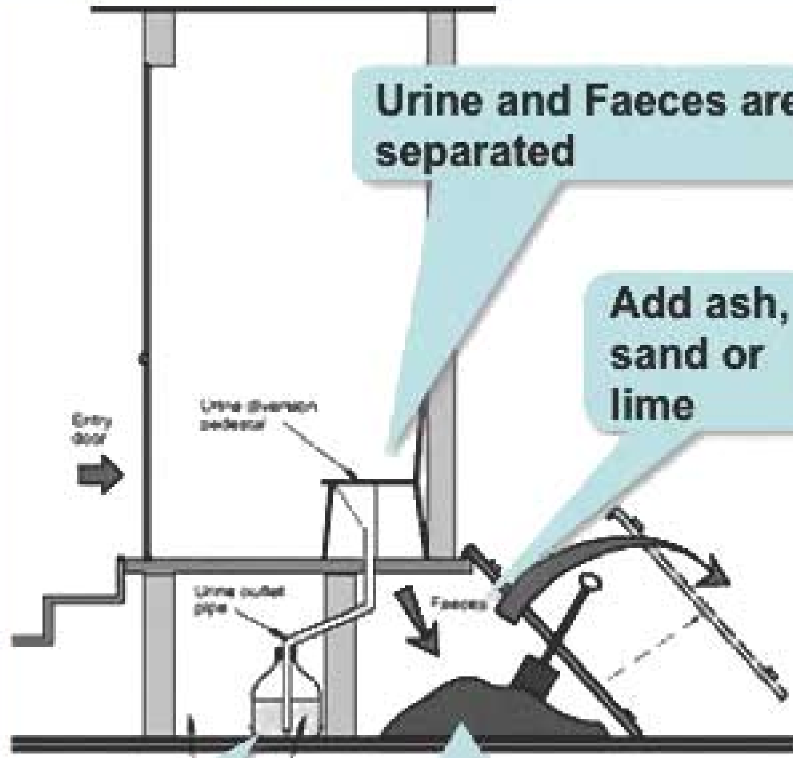
Collection and storage technologies

Deyhdration vaults

+ no waste, but fertilizer
+ simple to design
+ little flies or odours if used correctly
+ easy and safe handling of dried material

Requires:

- special squatting pan/seat
- education and acceptance
- constant source of ash, sand etc.
- a use or discharge point for urine



Urine and Faeces are separated

Add ash, sand or lime

Urine is collected in tanks and is reused as liquid fertilizer

Faeces are dehydrated in 2 alternating chambers and used as soil conditioner

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Collection and storage technologies

- Two chambers (vaults) each one 0.5-1m3
- Each chamber is accessed from a separate door
- Urine flows into a jerry can, soak pit, garden, etc.
- Vent pipe to improve drying, remove smells
- Addition of ash, lime, sawdust, etc. helps dehydration, pH balance
- Toilet paper will not decompose and should be collected separately

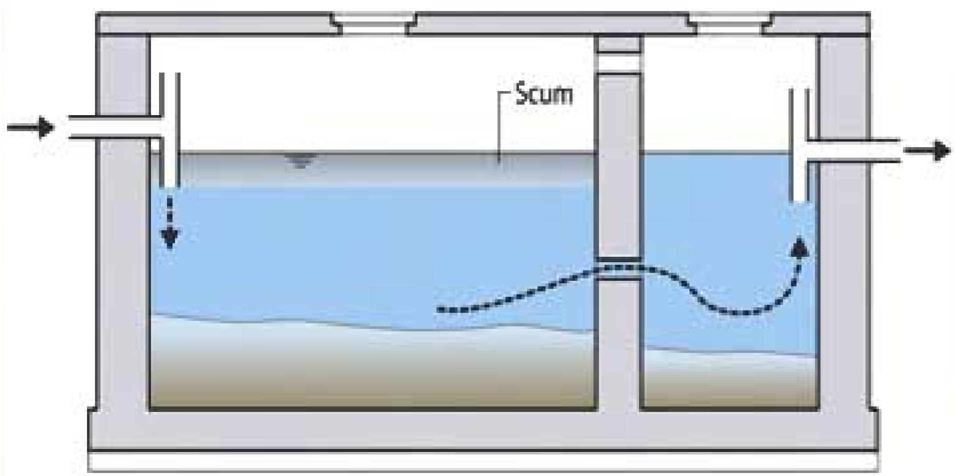
Collection and storage technologies

- One chamber is in use while the other dehydrates
- Chambers must be water-tight
- Any moisture will allow pathogens to live, reproduce and SMELL
- Doors must be tightly sealed against surface water and rainwater
- Doors can be sealed in place with weak mortar
- Design chambers to accommodate 100-150L/ year per person

Collection and storage technologies

Septic tank

= sedimentation tank in which settled sludge is partially stabilised by anaerobic digestion



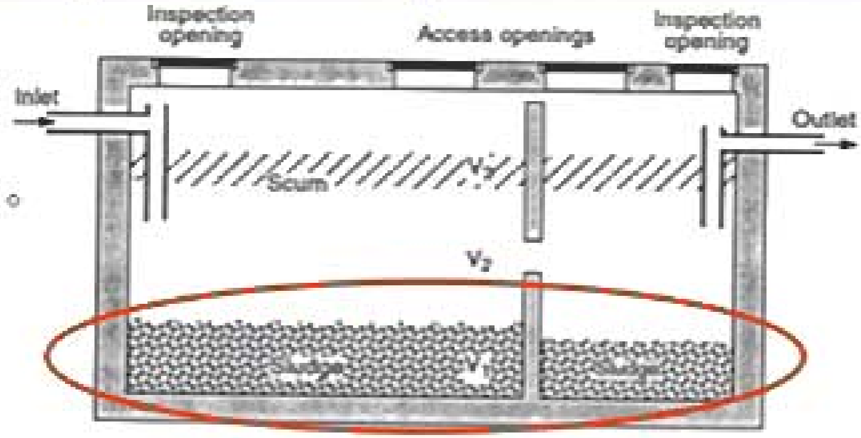
- most frequent onsite treatment unit worldwide
- Consists of 2 to 3 compartments

+ simple, little space required because of being underground
+ low O&M costs

- little removal of dissolved and suspended matter (COD removal approx. 50%)
- high investment costs

Collection and storage technologies

Septic tank design



$V=V_1 + V_2 + V_3$

$V_1=P*E*A$

V_1: Sludge accumulation volume

P: Number of Users

E: Emptying Interval, E> 1 year

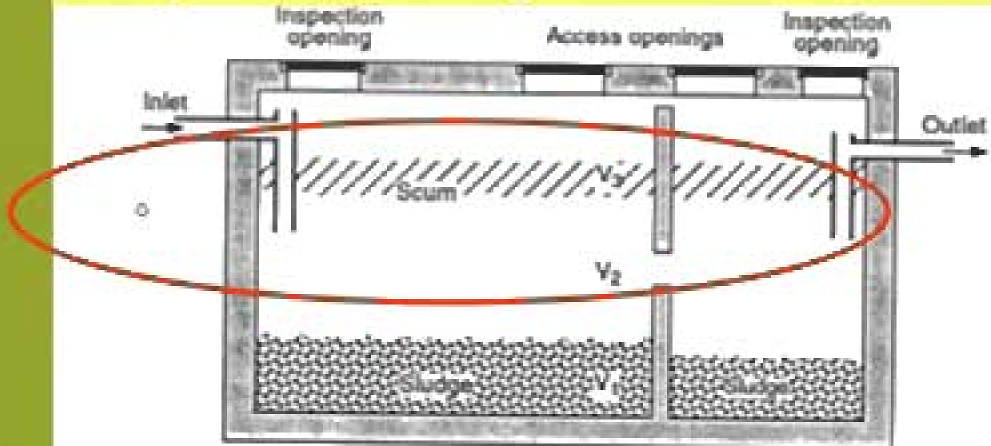
A: Sludge Accumulation Rate [l/cap*a]

A = f(E-> WW type)

blackwater and greywater (E=1): A=50l/cap*a
blackwater only (E=1): A=30l/cap*a

Collection and storage technologies

Septic tank design



$$V = V_1 + V_2 + V_3$$

V2: calculated based on the recommended minimum hydraulic retention time

$$V_2 = P * R * q$$

P: Number of Users

R: Minimum Hydraulic Retention Time

R=2-3 d if $Q<6m^3/d$
R=1-2 d if $Q>14m^3/d$

q: Daily discharge [l/cap*d]

India: 180l/cap*d
USA: 260l/cap*d
q=100...300l/cap*d

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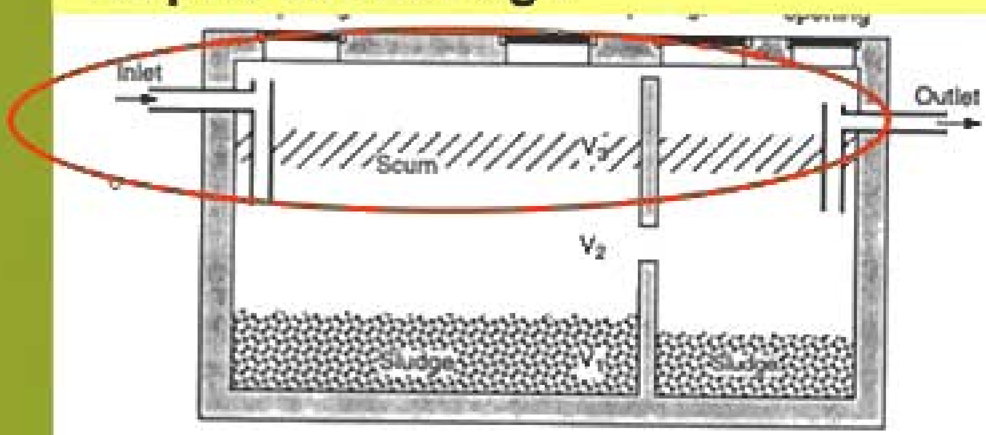
Collection and storage technologies

Septic tank design



$$V = V_1 + V_2 + V_3$$

$$V_3 = F*h$$

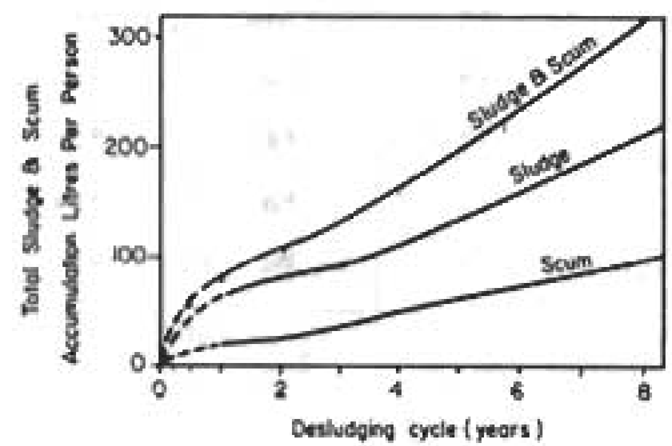
h=20-30cm

V_3: scum layer

h: height of the scum layer

F: surface of the tank

V_1 and V_3 can also be estimated based on existing figures:



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Collection and storage technologies

Septic tank design

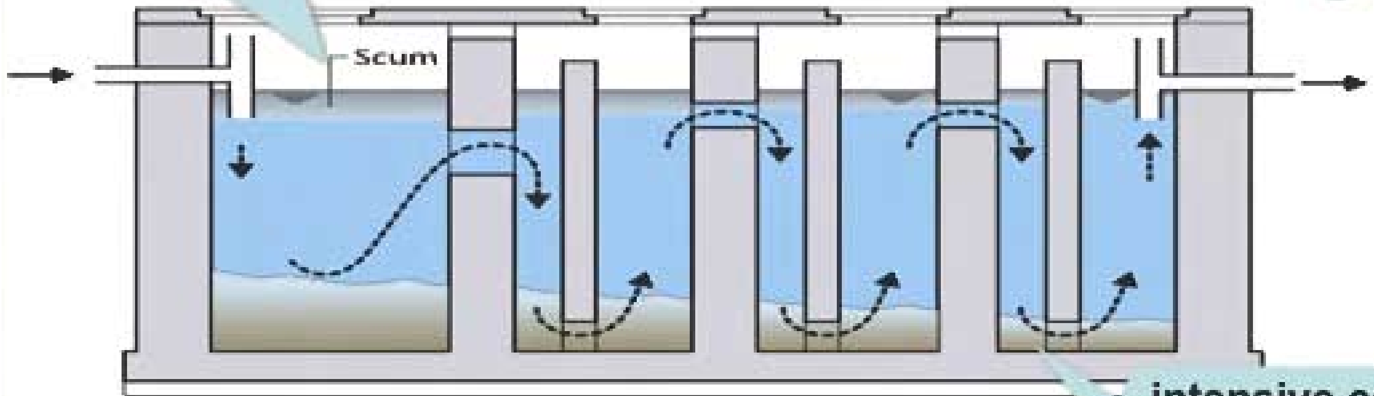
- **Mainly rectangular (some exceptions if prefabricated)**
- **Length to width ratio is 3:1**
- **Depth is 1-2.5m**
- **First chamber is at least 50% of the total volume**
    - For 2 chambers, first chamber is 2/3 Vt
    - For 3 chambers, first chamber is ½ Vt
- **Manholes in the cover slab: one above each inlet and outlet and one at each partition wall**
- **Tank must be watertight and stable**
- **Materials include**
    - Reinforce concrete (most common)
    - Steel (corrosion problems)
    - Polyethylene, fibreglass (cheap)

Collection and storage technologies

Anaerobic baffled reactor (baffled septic tank)

Sedimentation chamber for removal of solids

2 to 5 anaerobic chambers for removal and digestion of organics



intensive contact between resident sludge and fresh influent

- Improvement of a septic tank
- Treatment efficiency: 65 to 90% COD removal

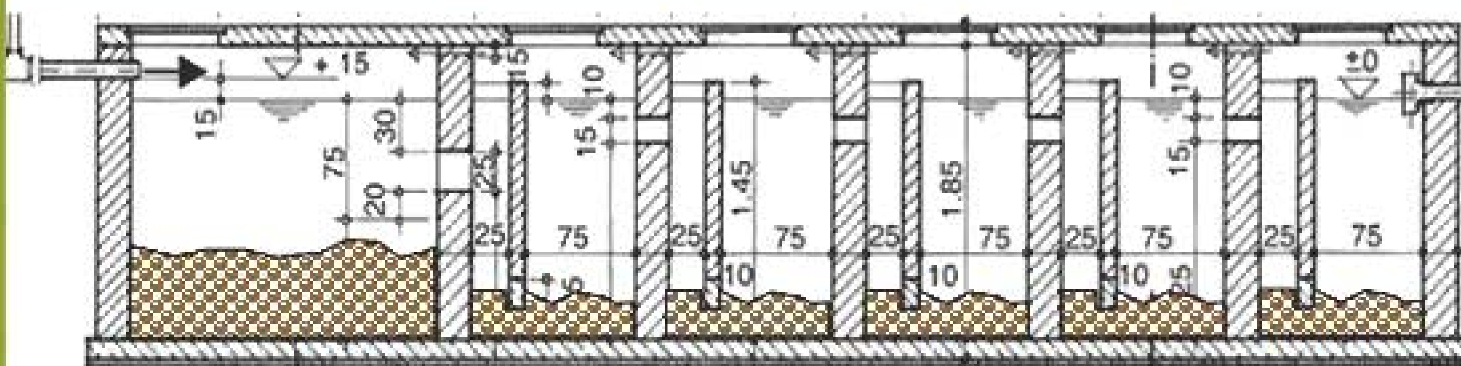
\+ simple, **high treatment efficiency**, hardly any blockage

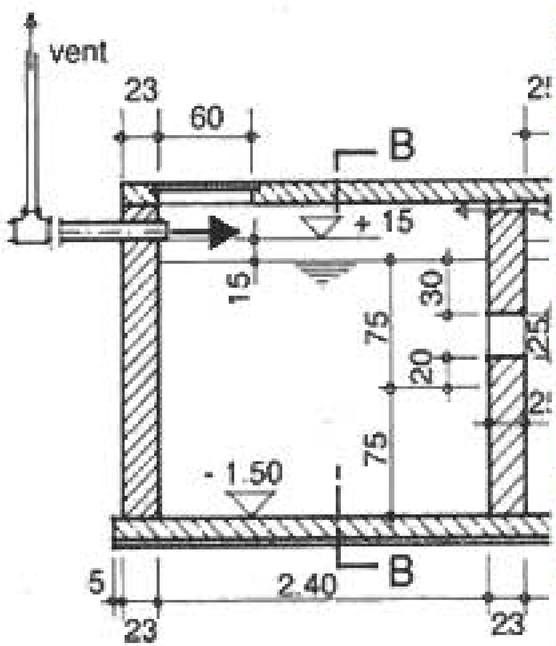
\+ high removal efficiencies, also for suspended and dissolved solids

\- construction and maintenance **more complicated** than conventional septic tank

Collection and storage technologies

Anaerobic baffled reactor (baffled septic tank)



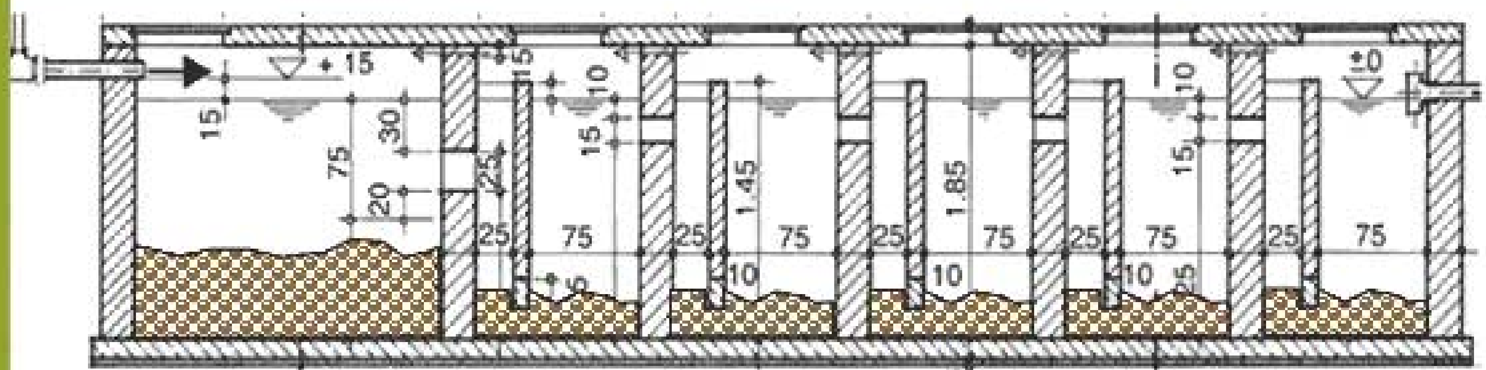


Settling chamber:

- settling of larger solids
- Sludge volume: approx. 20l/cap
- Scum volume: approx. 10l/cap
- **Hydraulic retention time: 5-10h**
- Typical depth: 1.5 – 2.5 m
- length to width ratio: approx. 1:1 to 2:1
- length to height ratio: approx. 1.5:1
- **(see also septic tank design)**

Collection and storage technologies

Anaerobic baffled reactor (baffled septic tank)



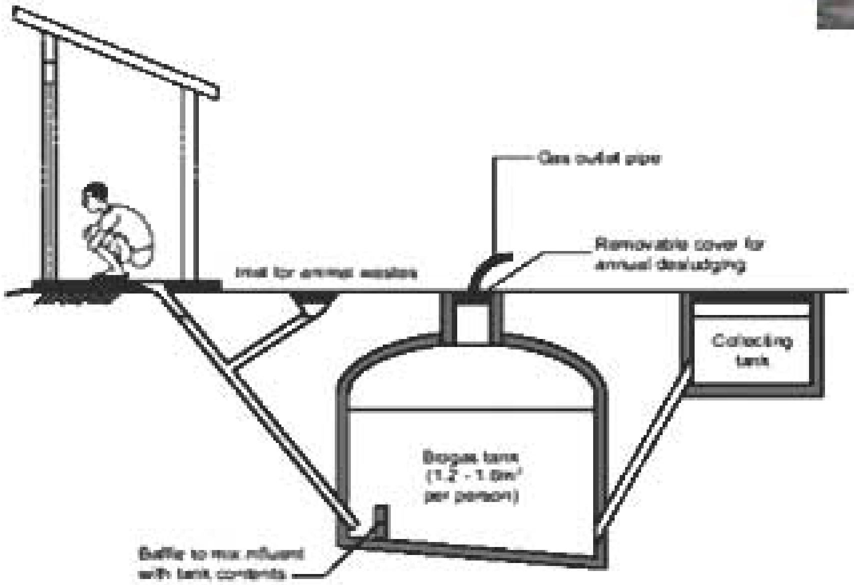
- **Up-flow chambers:**
- short compartments to ensure good distribution of wastewater → l:h = 0.5 – 0.6
- **Up-flow velocity < 0.5 – 1.5m/h**
- organic load < 3-4kg COD/m3*d
- Hydraulic retention time approx. 48-72 hours (whole system)

Septic Tanks/ABRs

Symptom	Immediate cause
Odour nuisance	1.inadequate ventilation of drains 2.blocked drainage field 3.inadequate drainage field
Backing up of wastewater	1.sagging or blocked inlet drains 2.blocked drainage field 3.inadequate drainage field 4.tank full of sludge
Surface flooding	1.sagging or blocked inlet drains 2.blocked drainage field 3.inadequate drainage field 4.tank full of sludge
Solids discharge	1.tank full of sludge 2.insufficient emptying frequency 3.inefficient or undersized tank
Local watercourse pollution	1.blocked drainage field 2.inadequate drainage field 3.tank full of sludge 4.deliberate overflow connection made 5.proliferation of tanks discharging to land which quickly drains to watercourse
Tank full of groundwater or lifting of tank	1.high water table
Groundwater pollution	1.drainage field operating properly but system in unsuitable location 2.proliferation of tanks in sensitive area

anaerobic treatment with biogas production

small-scale biogas plants: decentralised treatment of household wastewater with agricultural waste



Conveyance technologies

User Interface	Collection and Storage	Conveyance	(Semi-) Centralised Treatment	Reuse and Disposal
				
-Dry Toilet -Urine Diverting Dry Toilet -Urinal -Pour Flush Toilet -Flush Toilet	-Single Pit -Single Pit VIP -Alternating Dry Double Pit -Alternating Wet Double Pit -Double Dehydr. Vaults -Aquaprivy -Septic Tank -Composting Chamber	**-Manual Emptying** **-Mechanical Emptying** **-Simplified Sewers** **-Small-Bore Sewer** **-Conventional Gravity Sewer** **-Jerry can/tank**	-Imhoff Tank -Anaerobic Baffled Reactor -Anaerobic Filter -Trickling Filter -Waste Stabilization Ponds -Finishing Pond -Constructed Wetland -Co-composting etc.	-Application of Urine -Application of Dehydr. Faeces -Compost -Irrigation with Wastewater -Aquaculture -Soak Pit -Leach Field -Incineration -Land application -Surface Disposal

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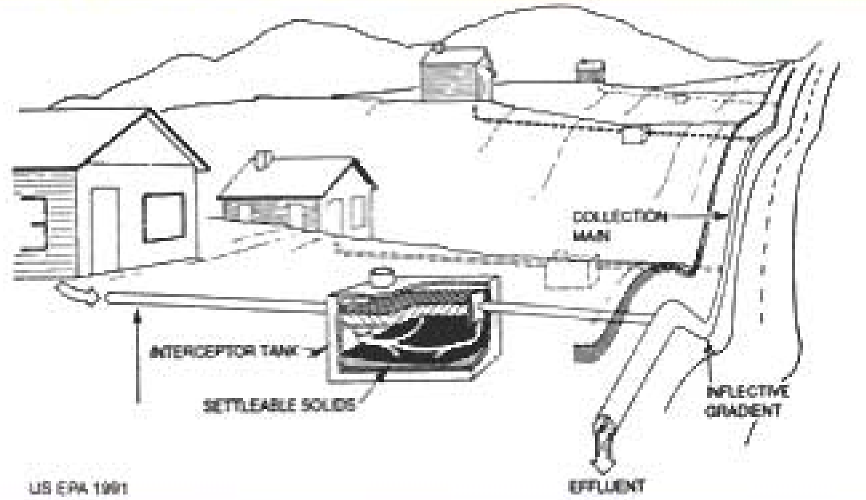
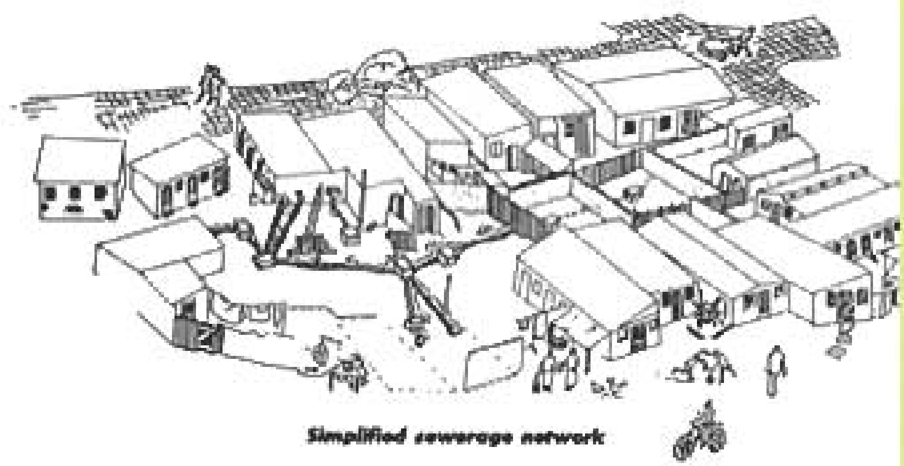
Conveyance technologies

Settled sewer



- especially adequate where septic tanks already exist.
- Less strict- negative gradients
- relies on good solid removal in septic or interceptor tanks

Simplified sewer



- **Simplified** eg. fewer manholes, smaller pipe diameters, flatter gradients, shallow etc.
- sewers laid inside housing blocks or under pavements.

\+ **cheaper**

Transport systems

Simplified vs. conventional sewerage

Item	Simplified	Conventional
Minimum pipe diameter:	Min. ∅	Min. ∅
• House connection	75 mm	120-150 mm
• Block or street collector	100 mm	200-300 mm
• Collector in solids-free sewerage	50 mm	---
Gradient of collectors:		
• For unsettled wastewater	Continuous	Continuous
• For settled wastewater	Can be inflective	---
Min. gradient		
• House connection	1 - 2 %	2 %
• Block or street collector	0.6%	1 %
Minimum velocity	0.3 - 0.5 m/s	0.7 - 0.9 m/s
Sewer layout	Usually under backyards or sidewalks	Usually underneath street
Peak : average design flow ratio	≤ 2	≤ 4
Minimum pipe cover	30 cm (no traffic load)	≥ 80 cm (traffic load)

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Conveyance technologies

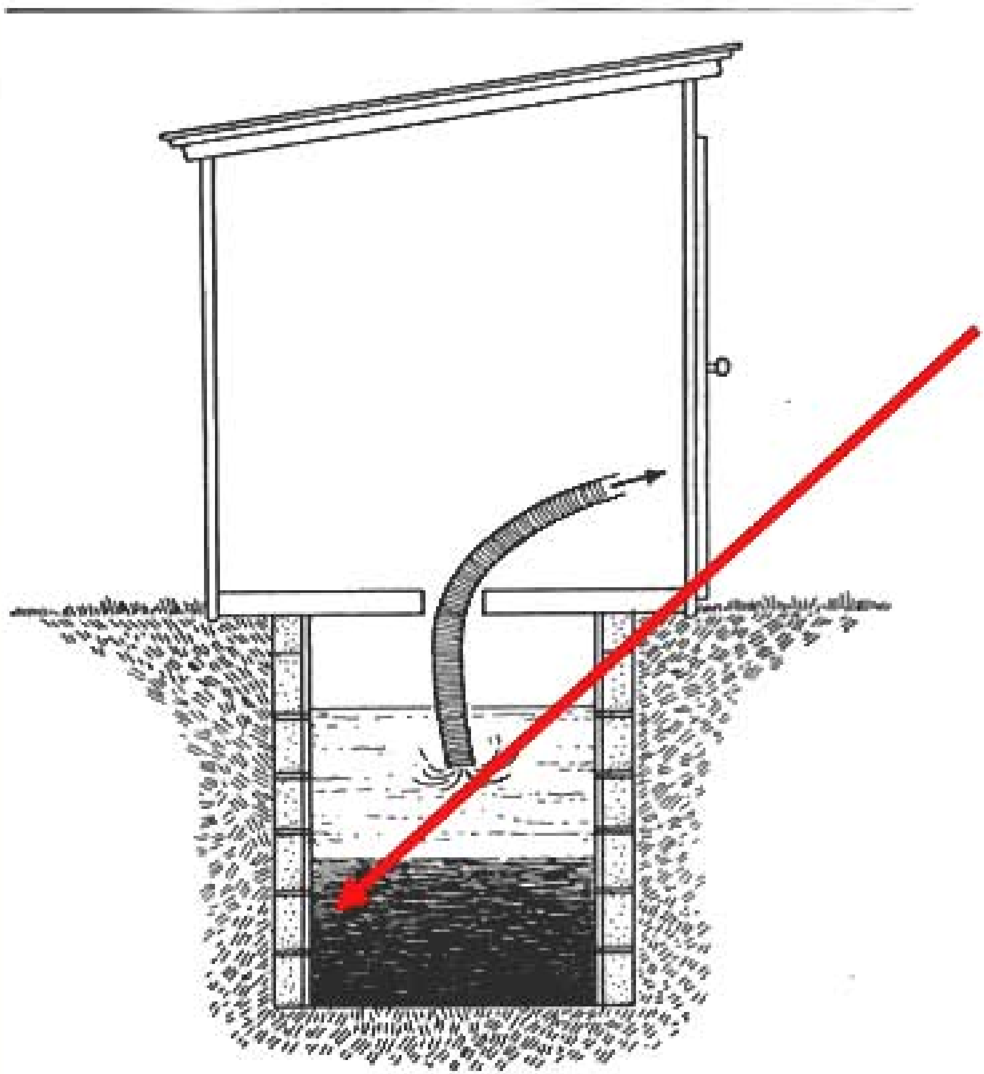
Mechanized FS Emptying and Transport

+ high efficiency
- High O&M and capital cost
- Spare parts often lacking
- **Difficulty in manoeuvring** (vehicle size, traffic congestion, infrastructure)

Manual FS Emptying and Transport

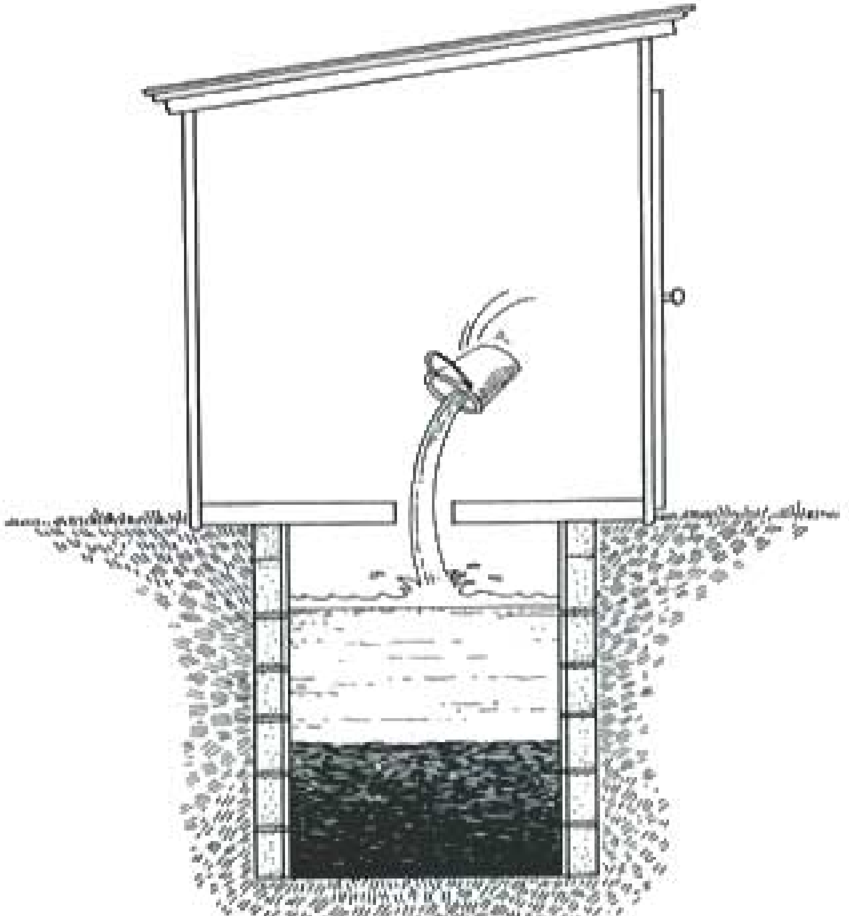
+ Low-cost operation and maintenance
+ Maintenance skills and spare parts available
- **Limited efficiency**

Sucking from Top Leaves Dense Sludge



Does not remove consolidated sludge!

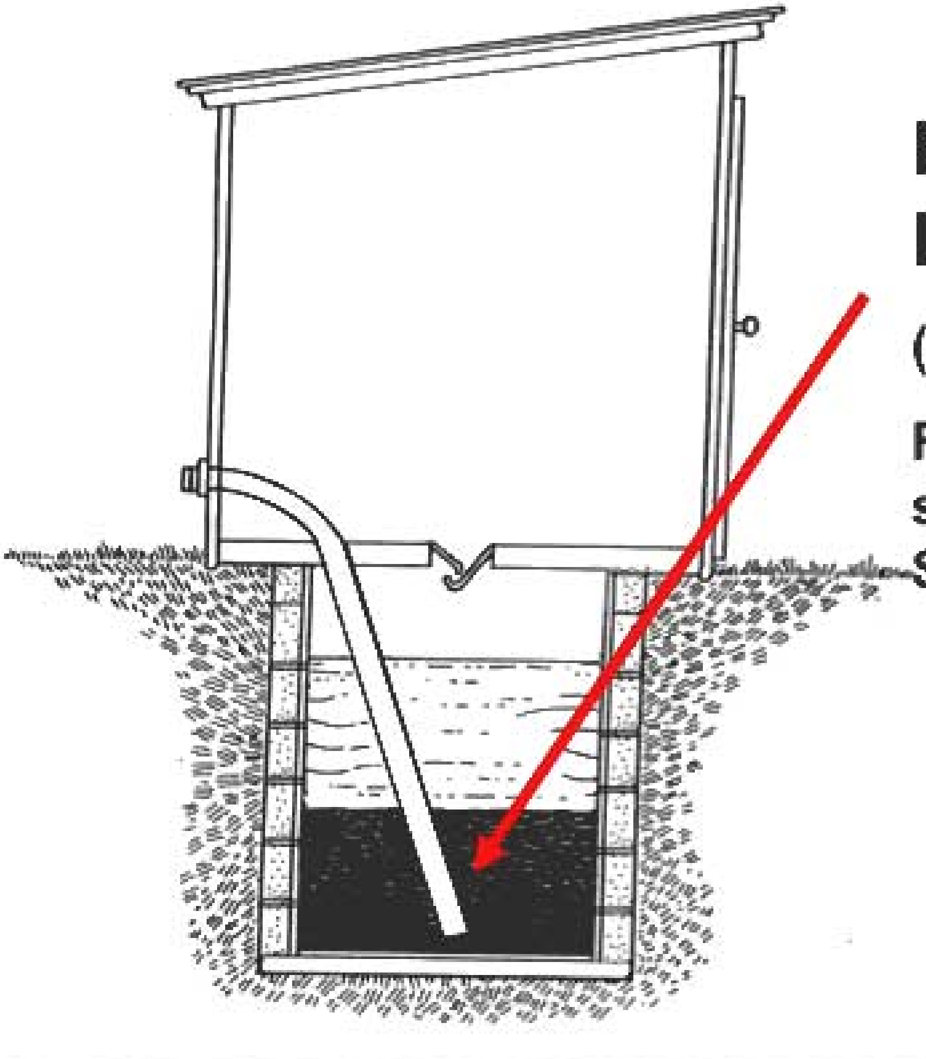
Water Added from Top Does Not Mix



Hand Stirring is Not Effective

Manual FS Emptying and Transport- Frogmen

Sucking from Bottom Removes Sludge First



New concept of Latrine!

(Manus Coffey, 2006

FSM international symposium, Dakar, Senegal May 2006)

Manual FS Emptying and Transport- GULPER

Photo: Steve Sugden

Gulper

(Steven Sugden London School of Hygiene and Tropical Medicine)

Design specification for improved emptying device

- Access without demolition
- Shit handling without direct contact
- Local manufacturing and maintenance
- Less than $200
- Light weight, carried across the shoulder
- One man operation
- Allow for huge neglect and misuse
- Capable of emptying at least the top meter of the pit.

(1.4 metres wide)

Vacutug Specifications

- **WEIGHT: 950 KG**.
- **SIZE :** L 3900mm X W 1350-mm X H 2000 mm
- **SPEED: 5 Km/hr**
- **ENGINE**: Four stroke 8 HP HONDA models GX240 petrol engine with Electronic ignition.
- **VACUUM PUMP**
- **TANK** : 500 liters capacity
- **CAPITAL COST of MARK II:** USD $ 5,100 (excluding freight)

UN-Habitat Vacutug

- **ADVANTAGES:**
  - Costs 20% of the cost of a truck vacuum tanker
  - Has a width of only 1.4 metres
  - Can turn within its own length
  - Has a low tank height and better suction performance
  - Can discharge its load into a higher transfer vehicle
  - Can be manufactured locally
- **DISADVANTAGES:**
  - Tank capacity only 500 litres
  - Road speed only 5 kph
  - The Vacutug by itself is therefore a short haul vehicle but can operate with a larger ‘mother’ vehicle for longer distances

- **A Vietnamese model**

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Tractor Trailed Vacuum Tanker

Locally manufactured cesspits trucks

- Low-cost operation and maintenance
- Maintenance skills and spare parts available
- Limited efficiency

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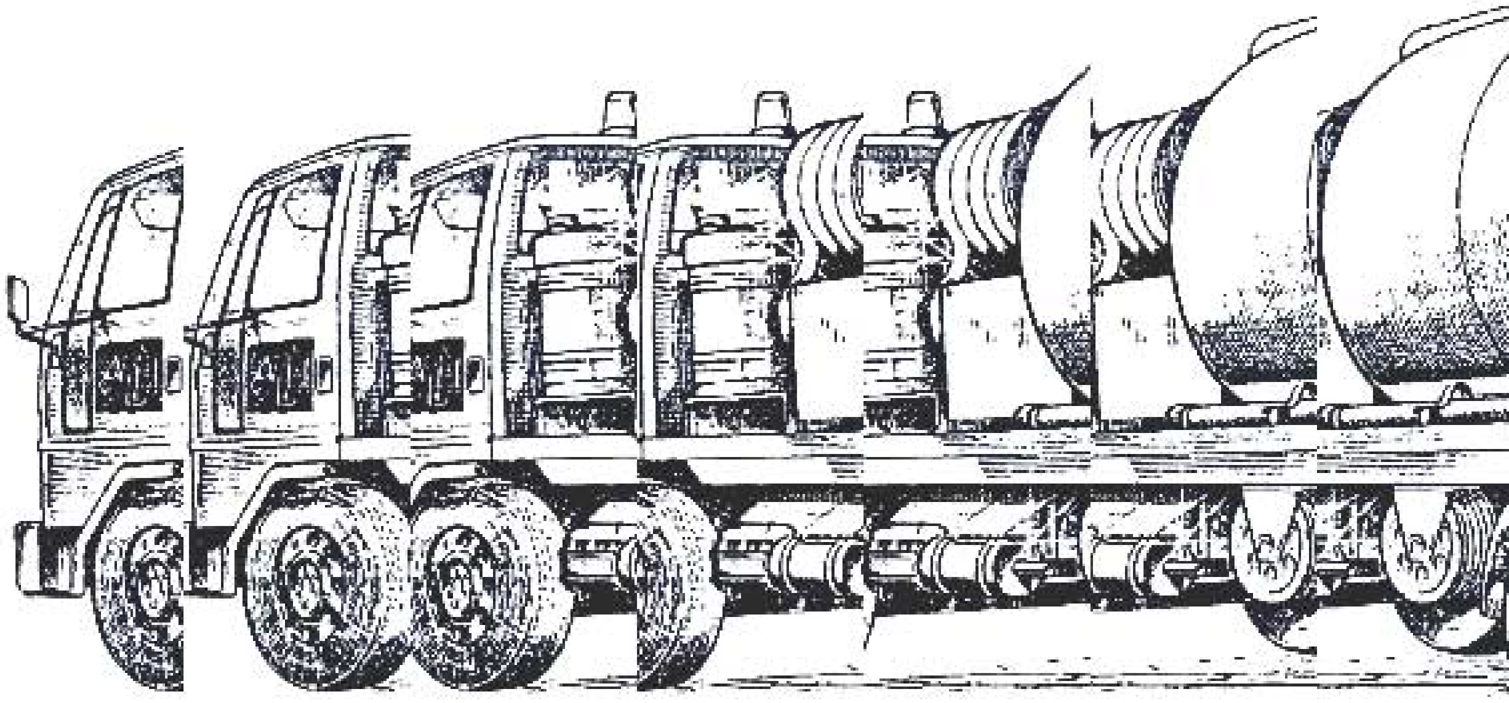
Truck mounted vacuum tanker (only suitable for wide roads)

Tank volume: 5-12 m^3



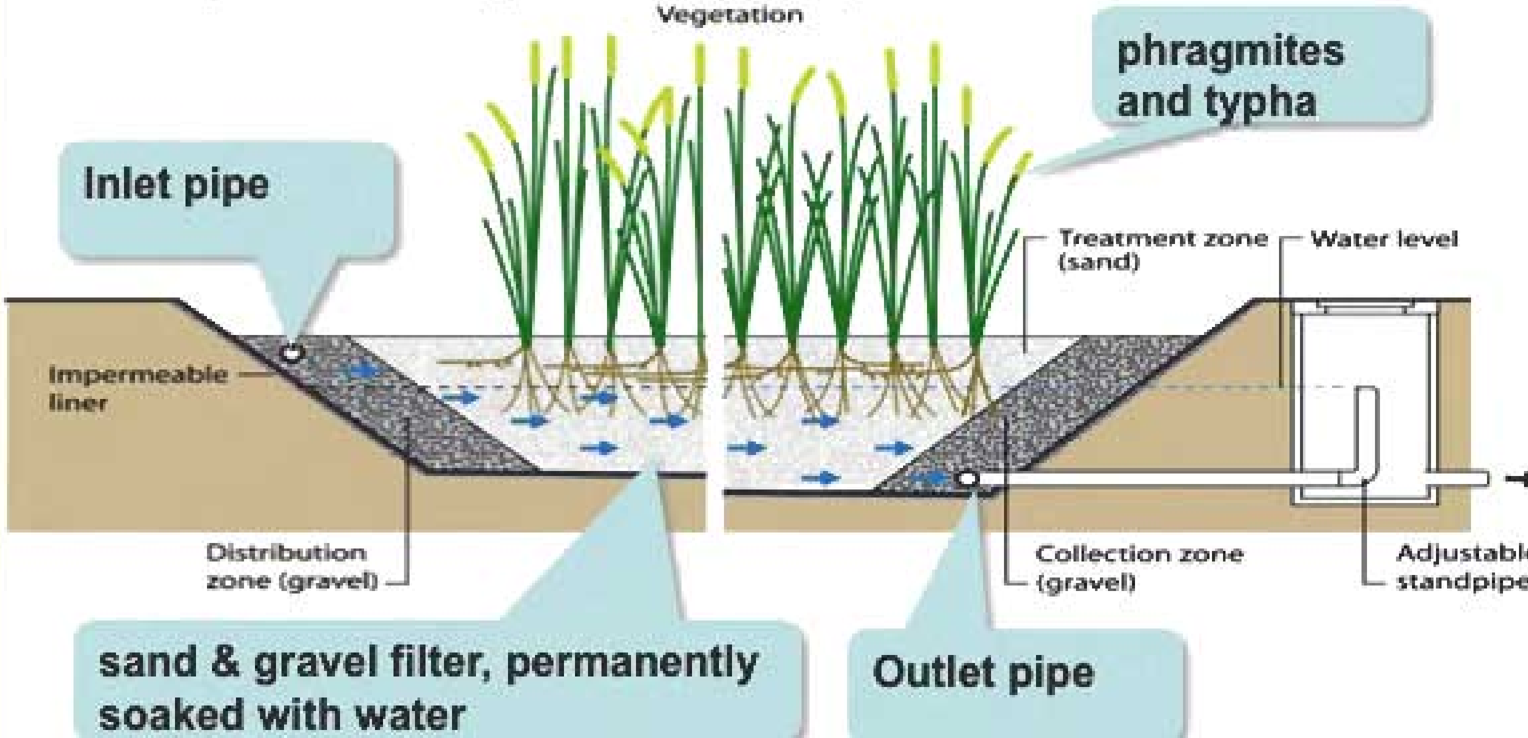
Treatment technologies

User Interface	Collection and Storage	Conveyance	(Semi-) Centralised Treatment	Reuse and Disposal
				
-Dry Toilet -Urine Diverting Dry Toilet -Urinal -Pour Flush Toilet -Flush Toilet	-Single Pit -Single Pit VIP -Alternating Dry Double Pit -Alternating Wet Double Pit -Double Dehydr. Vaults -Aquaprivy -Septic Tank -Composting Chamber	-Manual Emptying -Mechanical Emptying -Simplified Sewers -Small-Bore Sewer -Conventional Gravity Sewer -Jerry can/tank	**-Imhoff Tank** **-Anaerobic Baffled Reactor** **-Anaerobic Filter** **-Trickling Filter** **-Waste Stabilization Ponds** **-Finishing Pond** **-Constructed Wetland** **-Co-composting etc.**	-Application of Urine -Application of Dehydr. Faeces -Compost -Irrigation with Wastewater -Aquaculture -Soak Pit -Leach Field -Incineration -Land application -Surface Disposal

Treatment technologies

Constructed wetlands (here: horizontal sand filter)

→ **For treatment of (pre-settled) domestic or industrial WW**
(COD < 500mg/l and low solids)



\+ **high treatment efficiency** (up to 95% COD removal), no WW above ground, no nuisance of odour, high nutrient removal

\- high **space** requirement, **costly** (gravel), great **care** required during construction

Constructed wetlands (here: horizontal sand filter)

- Area: approx. 5m²/cap
- Hydraulic loading rate: < 30l/m²*d
- Organic loading rate: < 8g BOD/m²*d
- The granular material filters out solids
- Bacteria degrade solids and soluble BOD to inorganic nutrients (ammonia and phosphorous)
- Plants grow in the media, with (limited) assimilation of nutrients
- Role of plants: keep permeability of topsoil, oxygen supply to root zone, surface area for biofilm attachment

+ high treatment efficiency (up to 95% COD removal), no WW above ground, no nuisance of odour, high nutrient removal

- high space requirement, costly (gravel), great care required during construction

→ IWA 2000 *"Constructed wetlands for pollution control"*

Treatment technologies

Waste stabilization ponds

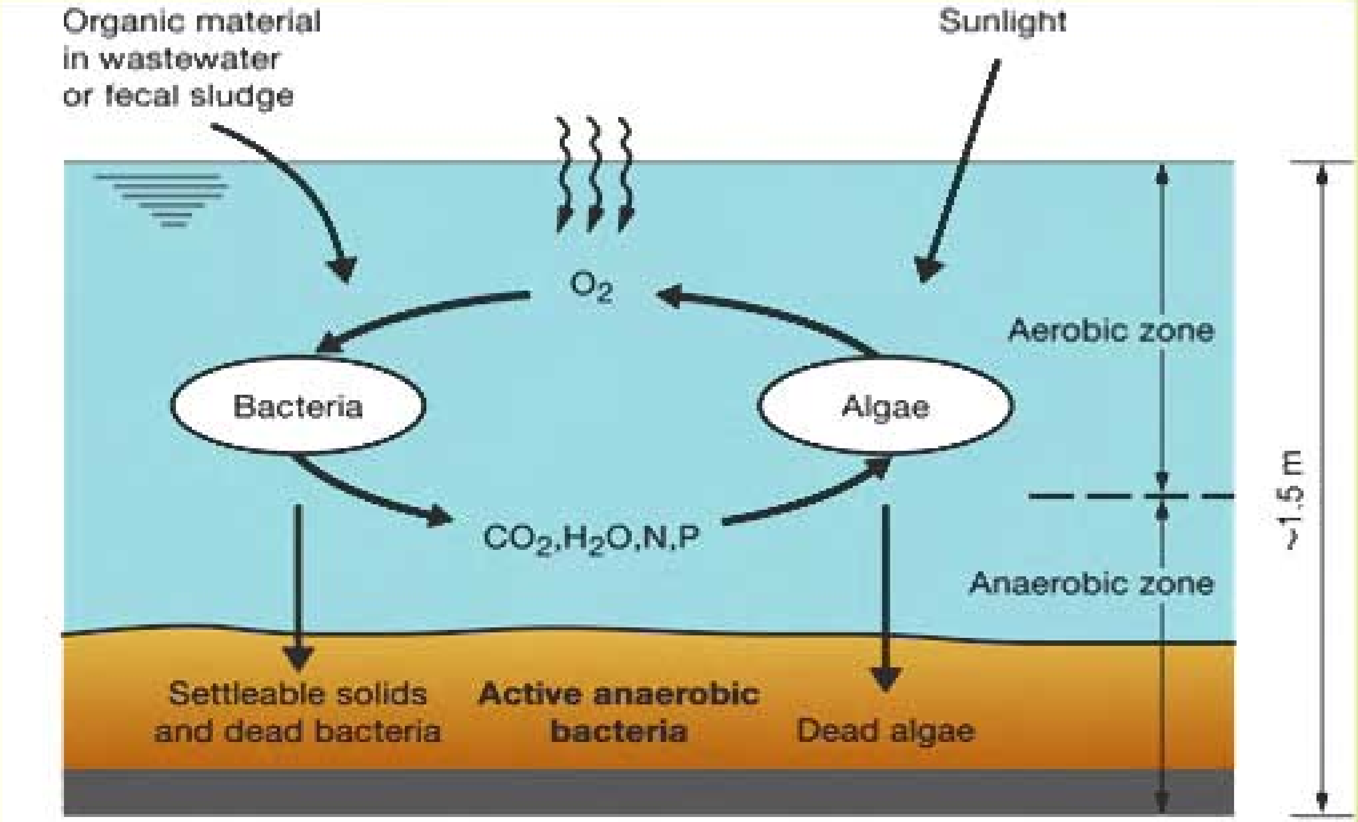
A pond-system comprises: - **anaerobic** sedimentation ponds,
- alternating **facultative** (anoxic) ponds and
- several **maturation** ponds (post-treatment aerobic)

	Anaerobic Pond	Facultative Pond	Maturation Ponds
Design	Deep (2-5m) and highly loaded but rather small area	Shallow (<1.5m) but large → Oxygen supply (algae, wind, artificial aeration)	Shallow (<1m) but large area
Flow	Hydraulic retention time: 1 to 3 days	Hydraulic retention time: 10 to 20 days	Hydraulic retention time: 10 days
Function	Sedimentation and anaerobic stabilisation of sludge (BOD reduction 40-50%) → **settling**	Aerobic degradation of suspended and dissolved matter (BOD reduction 50-70%) → **degradation**	Final sedimentation of suspended solids, bacteria mass and pathogens → **hygienization**

Treatment technologies

Waste stabilization ponds

Degradation of organic substances in facultative ponds:



Treatment technologies

Waste stabilization ponds

Pros and Cons

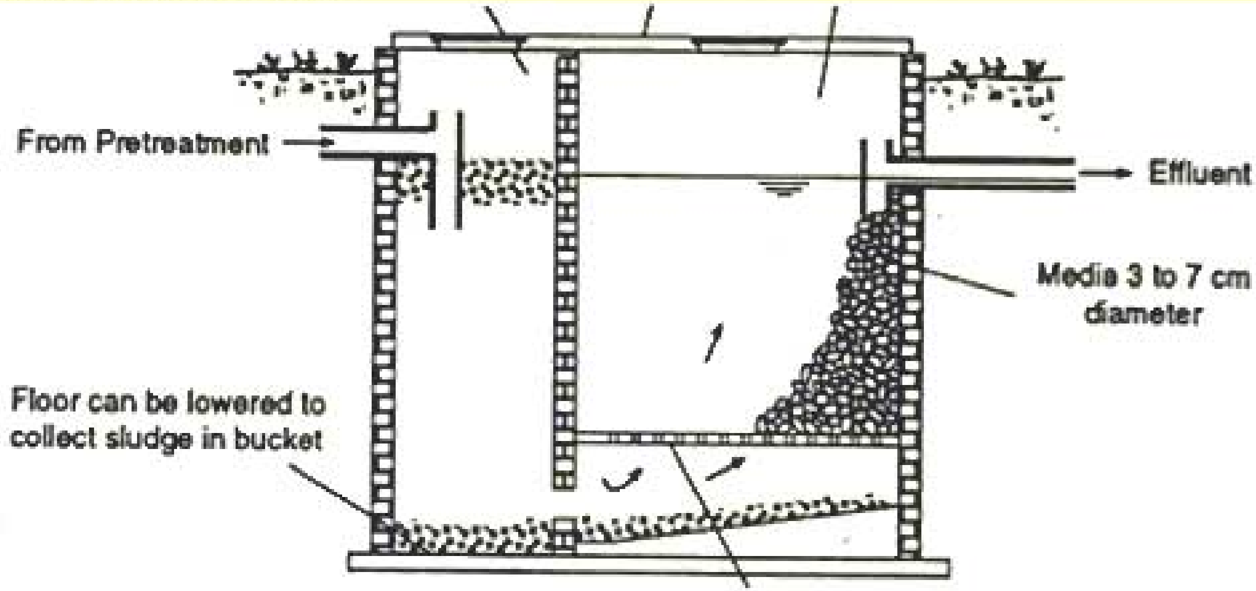
+ Can treat high strength wastewater to high quality effluent
+ Generally reliable and good functioning
+ Very inexpensive compared to other centralized options

- Not always appropriate for colder climates
- Potential for bad odours if poorly designed
- Requires expert design and supervision
- Requires a lot of space

→ **Ideal for developing countries if enough space and supervision available !**

Treatment technologies

Anaerobic Filter



- Used for pre-settled domestic wastewater with low SS concentrations (e.g. greywater)
- Principle: close contact of wastewater with active bacterial mass on filter media

\+ simple and durable if well constructed and wastewater properly pre-treated;
high treatment efficiency; little space requirements
\- high construction costs (filter media); blockage of filter possible
\- maintenance costly and difficult

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Treatment technologies

Anaerobic Filter

HRT ~ 24h

Organic load < 4kg COD/m³*d

$$V_{WW} = V_{tot} - V_{FM}$$

V_{FM}: Volume of filter media

V_{WW}: Volume available for wastewater

V_{tot}: Total Volume of Filter

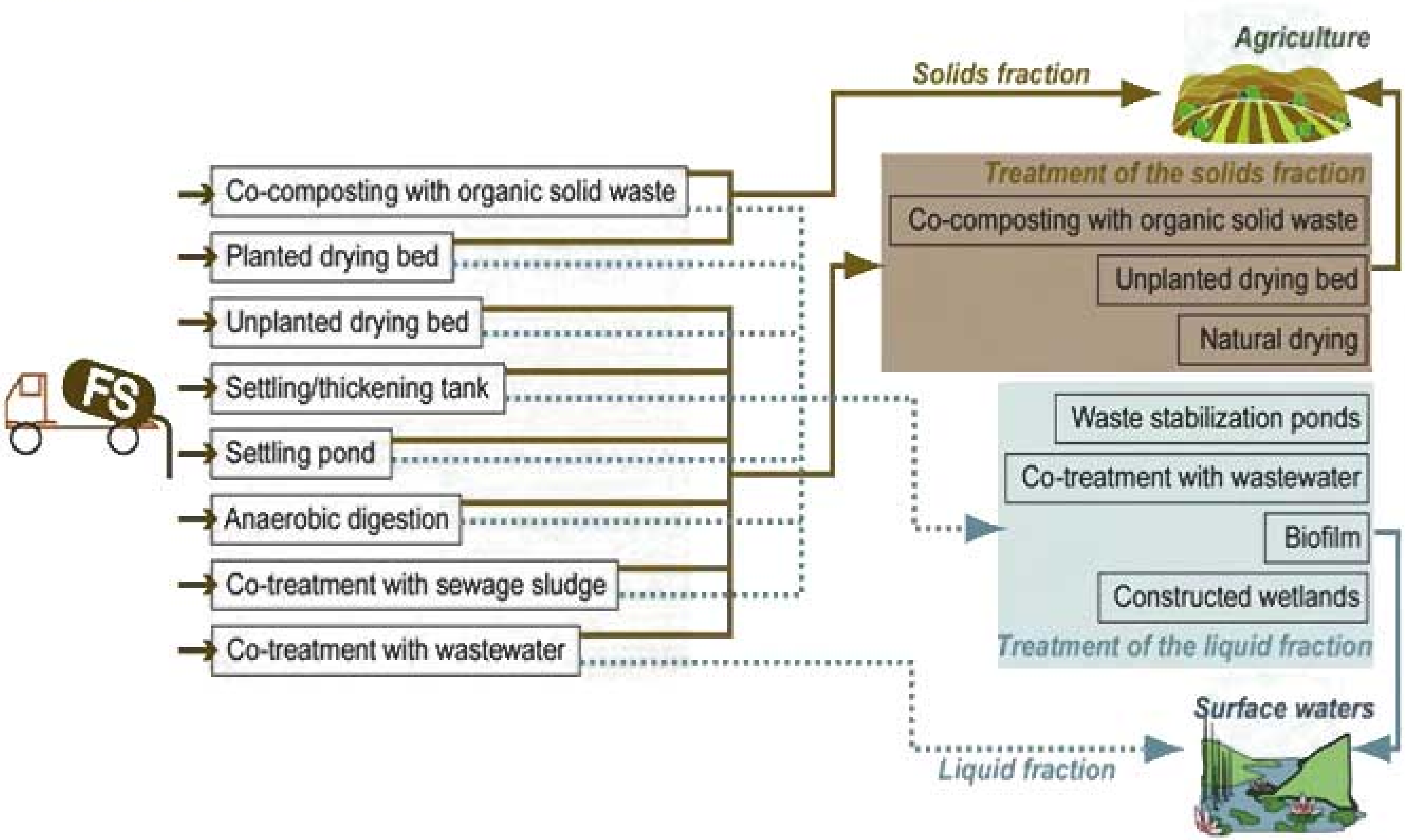
$$V_{FM}=f(FM)$$

Gravel: 35 to 45% void space

Special plastic form peaces: up to 95% void space

- **Length to depth ratio: l < d ;** several filters connected in series
- **filter material surface**: 90 to 300m² per m³
- **Typical water depth: 2-3m**
- **Depth of filter: 1 to 2.5m**
- **Diameter of filter media: 3 to 5cm**
- **Treatment efficiency**: 70 to 90% COD removal
- **Volume**: 0.5-1.0 m³/cap for domestic wastewater

Appropriate sludge treatment options



Selected FS treatment options

Drying bed

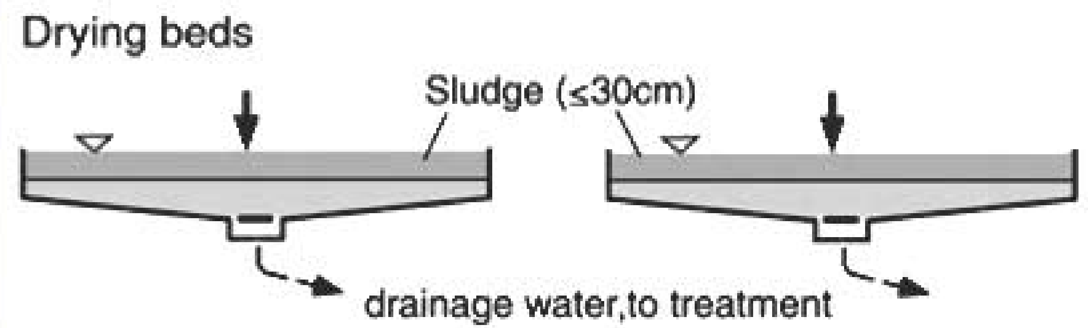
Constructed wetlands

Settling/thickening tank

Co-composting

Drying beds

- The sludge is discharged on a drained sand bed
- It dries some weeks before being emptied



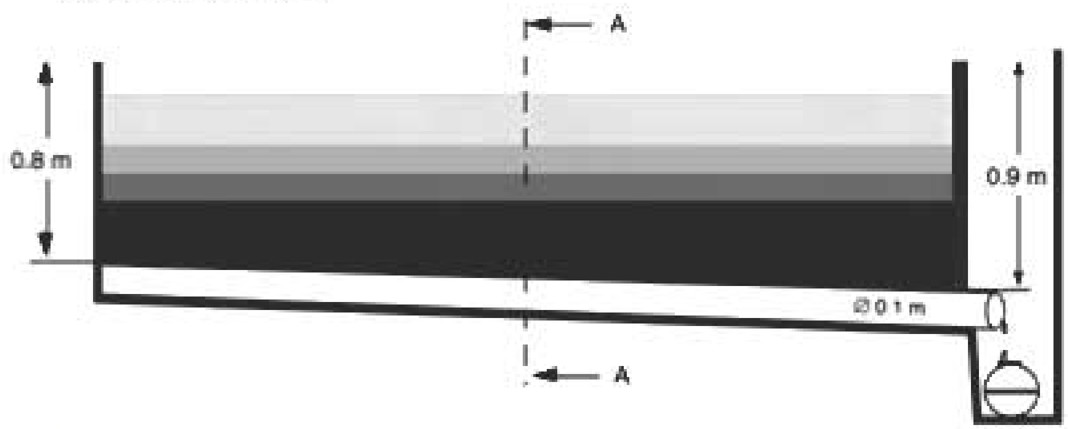
Déposante de Rufisque, Sénég

Drying beds

Design criteria

- Sludge application depth ~ 25-30 cm
- Drying period for 40% solids content ~ 8 - 12 days (dry weather)
- TS loading ~ 100 - 200 kg TS/m2*a

Cross section B-B



Performances

- V percolated = 50-80% V applied
- MES : 60-80 %
- DCO : 70-90 %
- NH4+ : 40-60 %

Sludge: dry matter 40 %

Approximate land requirement

- ~ 0.05 m^2/cap*

* (assuming a 10-day cycle)

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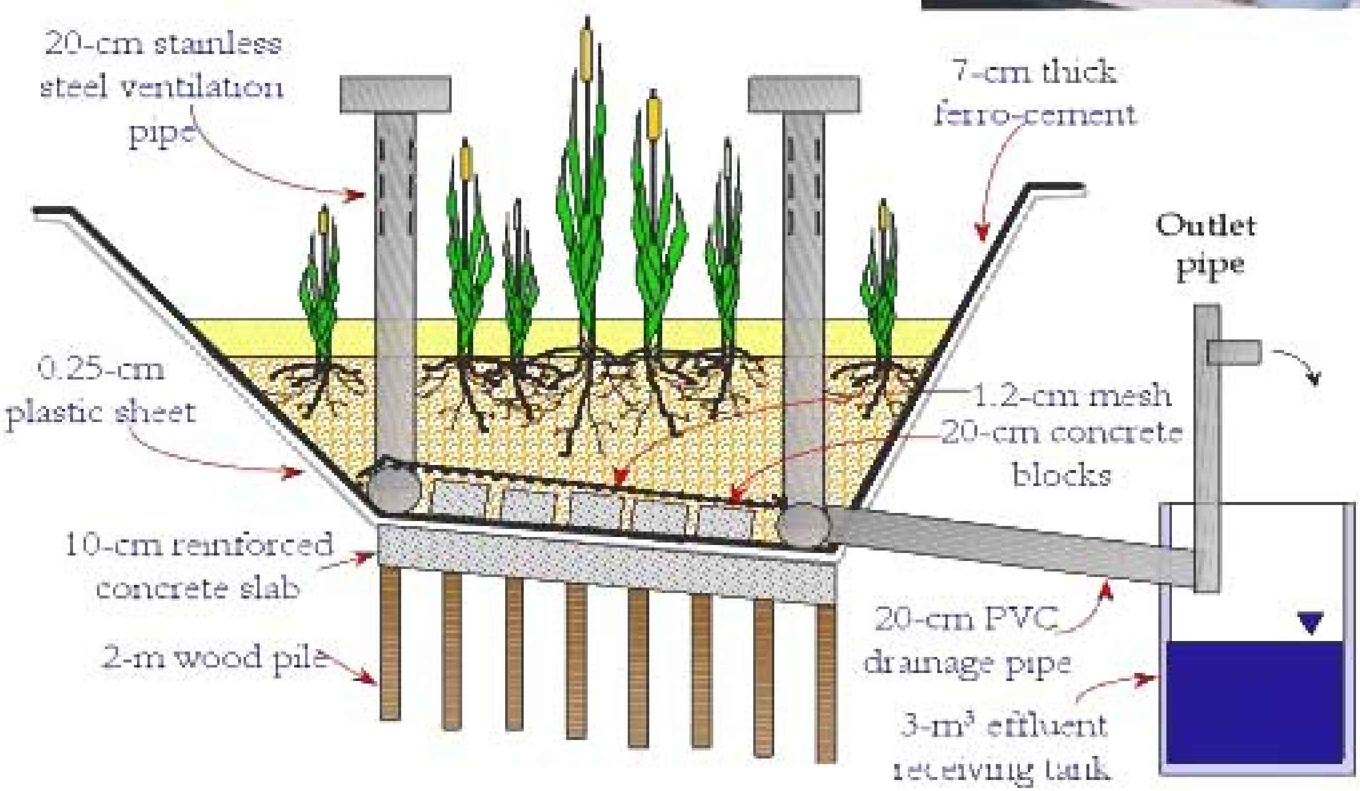
Planted drying bed

Design and Operating criteria

- **Solids loading rate: 125 - 250 kg TS/m2*a**
- **Septage application frequency: 1 - 2/weeks**

Land requirement

- **~ 0.03 m^2/cap**



Reuse and disposal technologies

User Interface	Onsite Storage and Treatment	Conveyance	Treatment	Reuse and Disposal
				
-Dry Toilet -Urine Diverting Dry Toilet -Urinal -Pour Flush Toilet -Flush Toilet	-Single Pit -Single Pit VIP -Alternating Dry Double Pit -Alternating Wet Double Pit -Double Dehydr. Vaults -Aquaprivy -Septic Tank -Composting Chamber	-Manual Emptying -Mechanical Emptying -Simplified Sewers -Small-Bore Sewer -Conventional Gravity Sewer -Jerry can/tank	-Imhoff Tank -Anaerobic Baffled Reactor -Anaerobic Filter -Trickling Filter -Waste Stabilization Ponds -Finishing Pond -Constructed Wetland -Co-composting etc.	**-Application of Urine -Application of Dehydr. Faeces -Compost -Irrigation with Wastewater -Aquaculture -Soak Pit -Leach Field -Incineration -Land application -Surface Disposal**

Wastewater disposal technologies

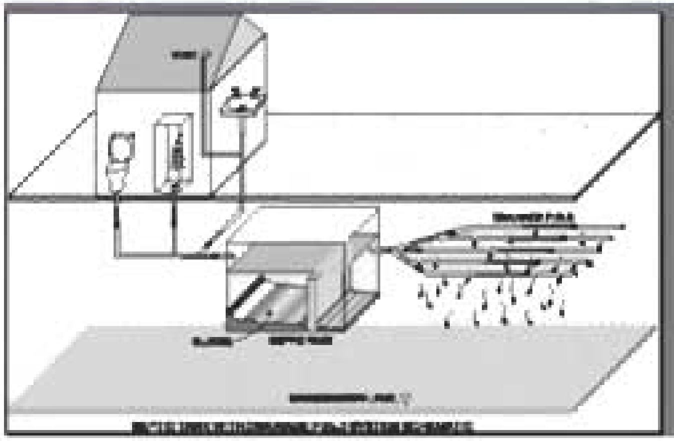
Leaching fields:

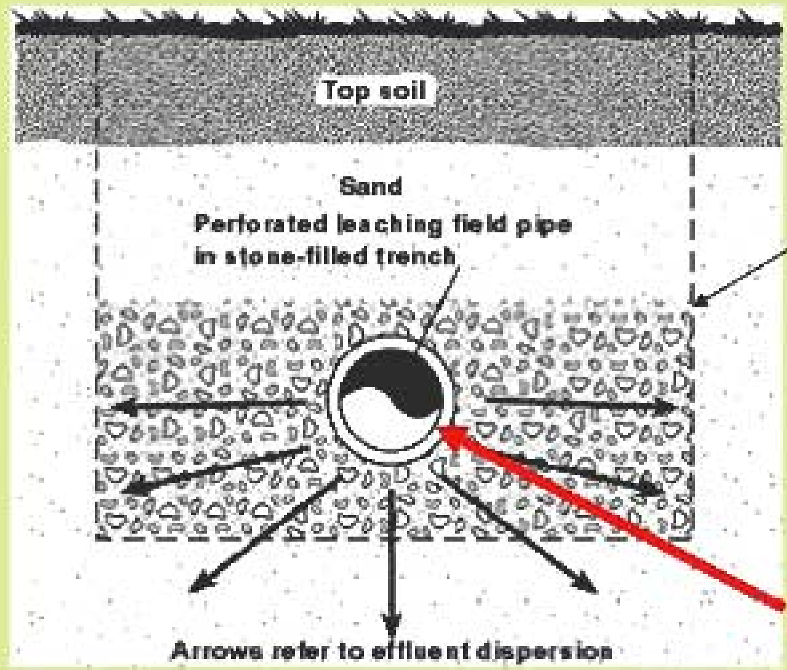
= system of trenches that is used to dissipate the effluent from a septic tank

→ **for discharge of non-solid septic tank effluent**

\+ little maintenance required

\- Space and skills required !





sand and/or topsoil

fabric, to prevent plugging of pipe

clean rock

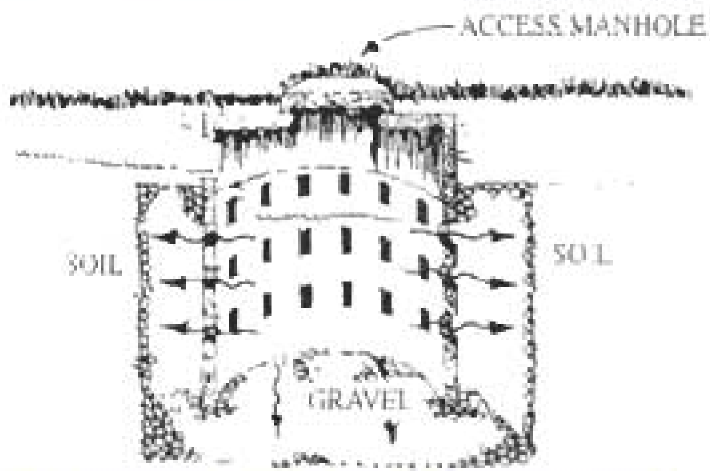
perforated distribution pipe

Wastewater disposal technologies

Soak pits:

= covered, porous-walled chamber that allows water to slowly soak into the ground.

→ **for non-solid septic tank effluent (clogging!)**



Between 1.5 and 4 m deep

+ simple and cheap
+ little space required

- not adequate for shallow ground water table (>1.5 m)
- not adequate in clay or rocky soils

Reuse of waste products

Wastewater irrigation:

Recommendations to limit health risks on farm:

- Use of wastewater only **after secondary treatment** (i.e. physical and biological)
- Use of appriopriate irrigation system:
  1) **Drip irrigation** (ideal, but more costly)
  2) **Furrow irrigation** (cheap, but more evaporation loss)
- **Crop restriction:** Growing e.g. fibres (cotton), tobacco or fruit trees is generally safer than fruits or vegetables
- Increasing the **period between** wastewater **irrigation and harvesting/consumption**

→ Wastewater can be used for irrigating agricultural land, if appropriate precautions have been taken.

Quality standards for reuse of waste products

Waste product	Reuse Application	Guidelines		
Urine	Irrigation of food and fodder crops to be processed	≥1 month storage (4°C)		
	Irrigation of food and f	≥6 month storage	or	≥1 month storage
	I			
Treated Wast	U			
	F			
	Localized irrigation	$\leq 10^6$-10^5 EC/100ml	≤1 Helm.eggs/l	
Greywater	Unrestricted irrigation	$<10^5$-10^6 EC/100ml	<1 Helm.eggs/l	
	Restricted irrigation	$<10^4$-10^3 EC/100ml	<1 Helm.eggs/l	
Excreta (untreated FS)	Agriculture (Soil conditioner)	$<10^3$ EC/g total solids	<1 Helm.eggs/g total solids	
	Aquaculture	$\leq 10^{-6}$ EC/100ml	≤1 Helm.eggs/l	No detectable

Reuse guidelines can be based numeric values but also on risk exposure reduction strategies (see WHO guidelines)

For urine, the only required treatment is storage

All waste products can be reused if safety guidelines are respected.

How to design a sanitation system?

Remember: Only selected combinations of technologies result in functional systems !

User Interface

-Dry Toilet
-Urine Diverting Dry Toilet
-Urinal
-Pour Flush Toilet
-Flush Toilet

Collection and Storage

-Single Pit
-Single Pit VIP
-Alternating Dry Double Pit
-Alternating Wet Double Pit
-Double Dehydr. Vaults
-Aquaprivy
-Septic Tank
-Composting Chamber

Conveyance

-Manual Emptying
-Mechanical Emptying
-Simplified Sewers
-Small-Bore Sewer
-Conventional Gravity Sewer
-Jerry can/tank

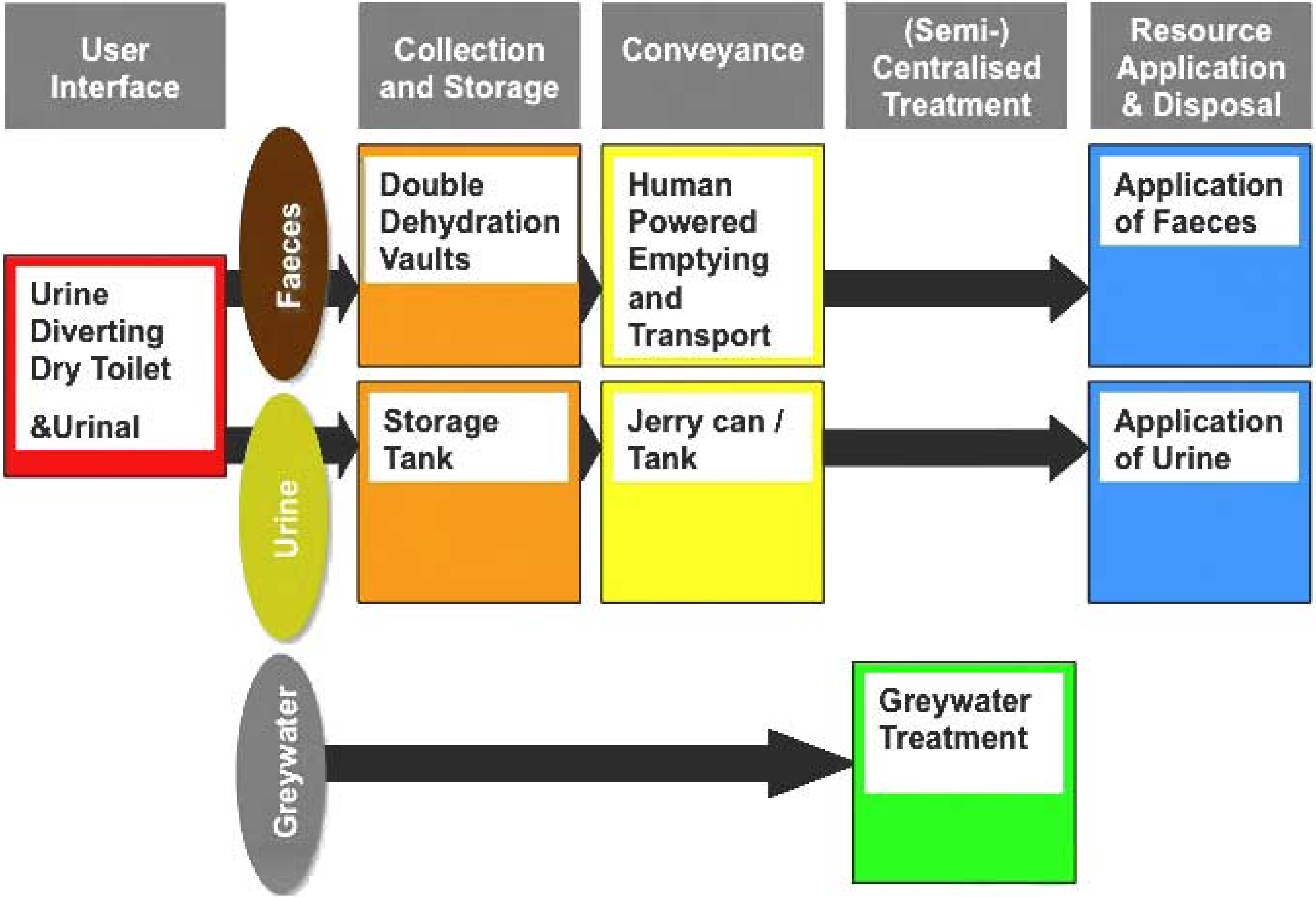
(Semi-) Centralised Treatment

-Imhoff Tank
-Anaerobic Baffled Reactor
-Anaerobic Filter
-Trickling Filter
-Waste Stabilization Ponds
-Finishing Pond
-Constructed Wetland
-Co-composting
Etc.

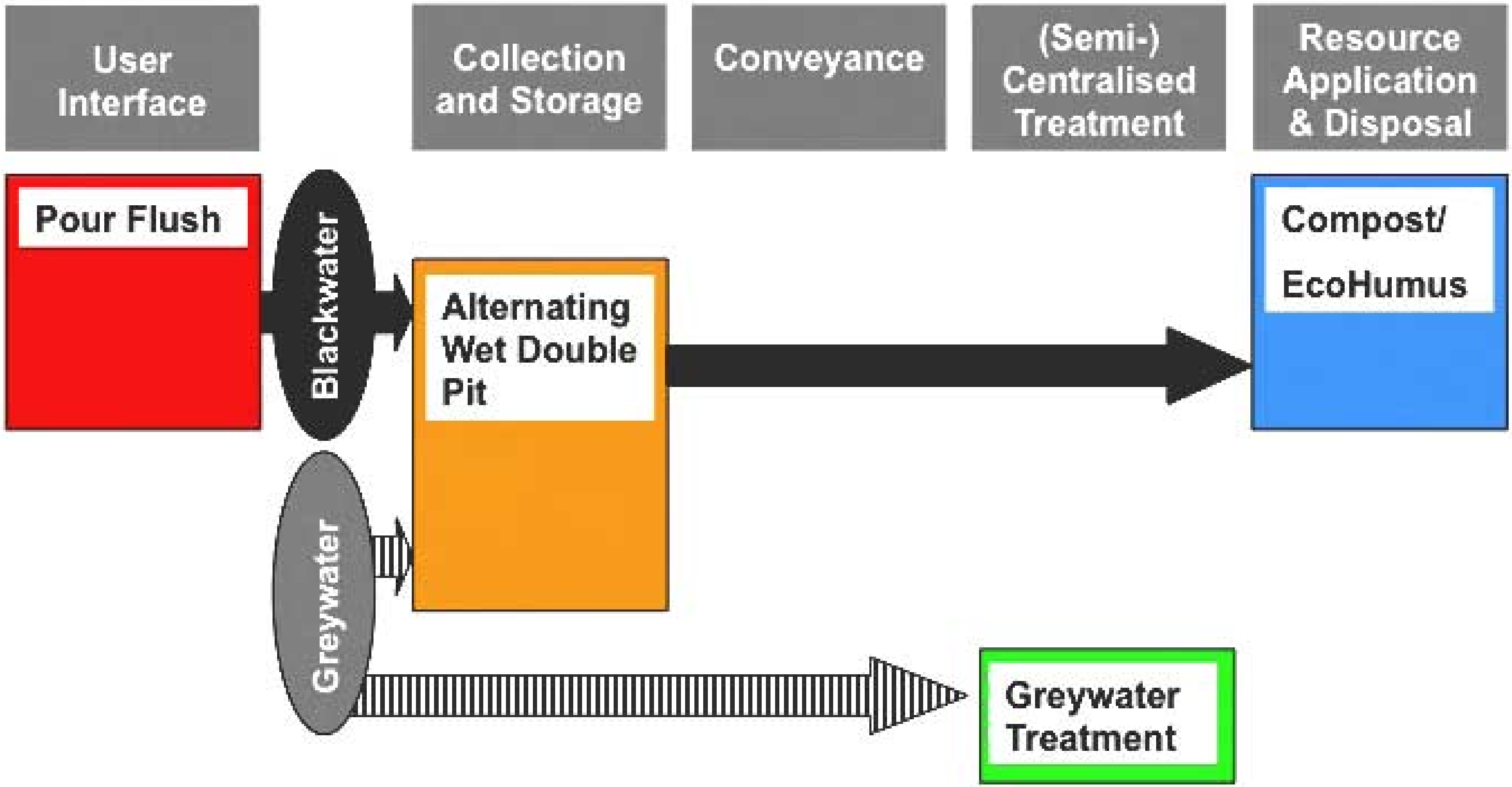
Reuse and Disposal

-Application of Urine
-Application of Dehydr. Faeces
-Compost
-Irrigation with Wastewater
-Aquaculture
-Soak Pit
-Leach Field
-Incineration
-Land application
-Surface Disposal

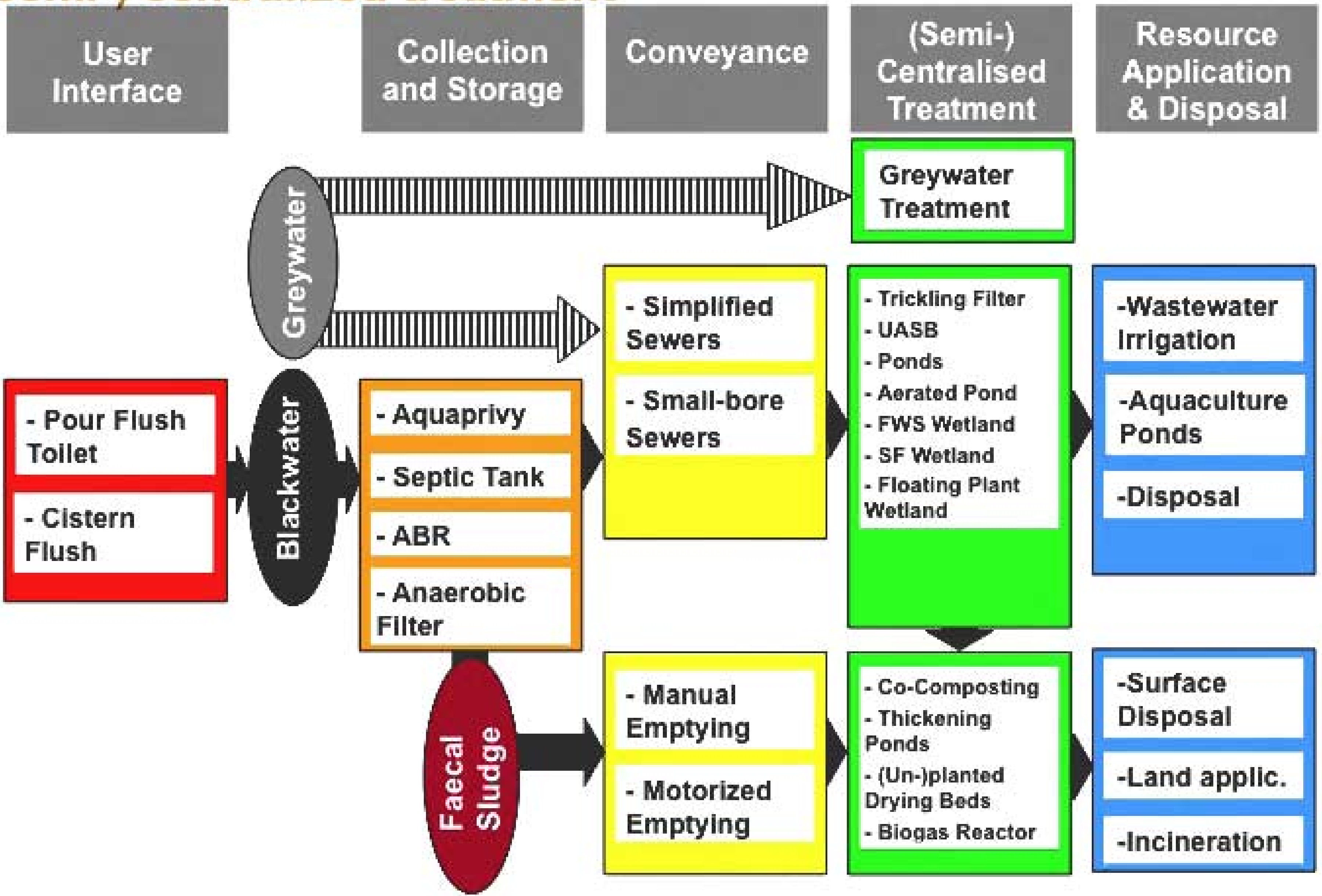
1st Example: Urine separation and application



2nd Example: Water-based alternating double pit



3rd Example: Simplified sewerage with (semi-) centralized treatment



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Emergency sanitaition

Immediate action measures

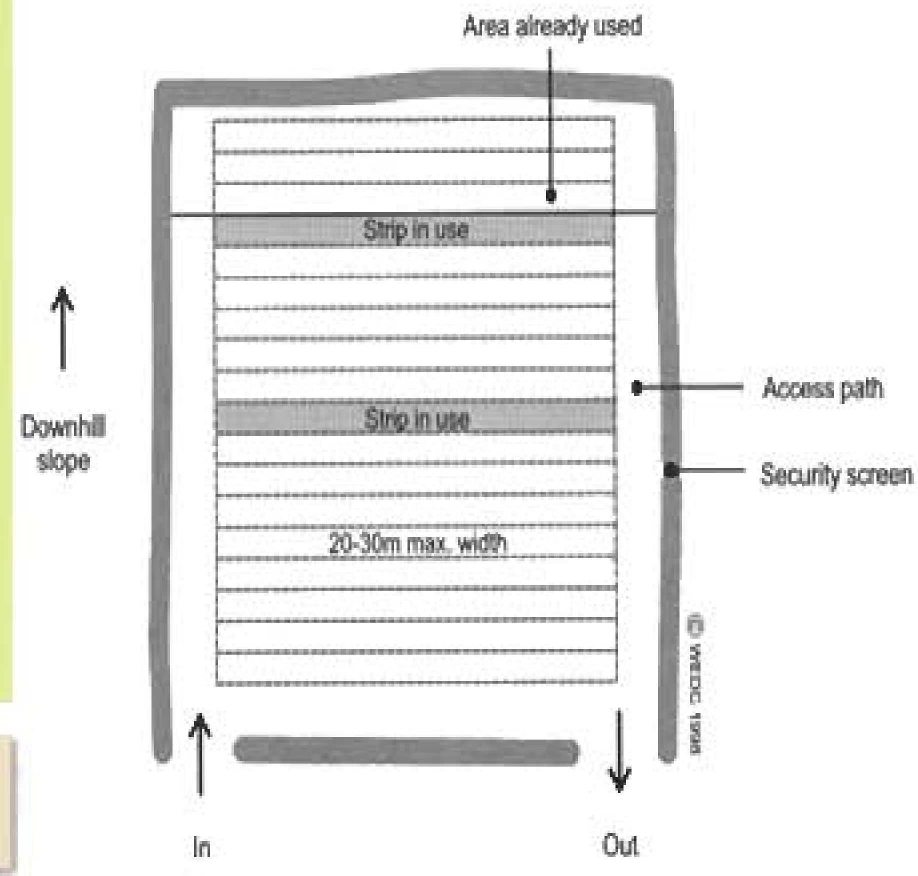
Open field defecation

- First clearing of scattered excreta !

Design criteria:

- Far from water source (50 m) and storage
- downhill of settlements (leakage)
- far from public buildings and roads
- security screen to provide minimum privacy
- including hand washing facilities
- better suited for hot dry climates

+ rapid and easy
- lack of privacy



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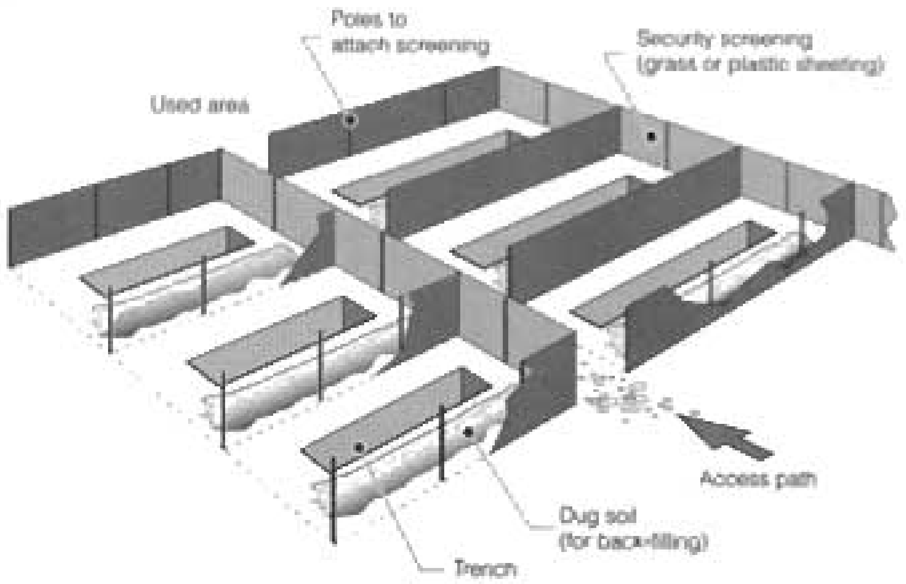
Immediate action measures

Shallow trench defecation

Design criteria:

- 15-60 cm deep
- 20-30 cm wide
- provide shovels to allow each user to cover its excreta with soil



+ rapid (1 worker can dig 50 m of trench per day)
+ covered with soil
- limited privacy
- considerable space required

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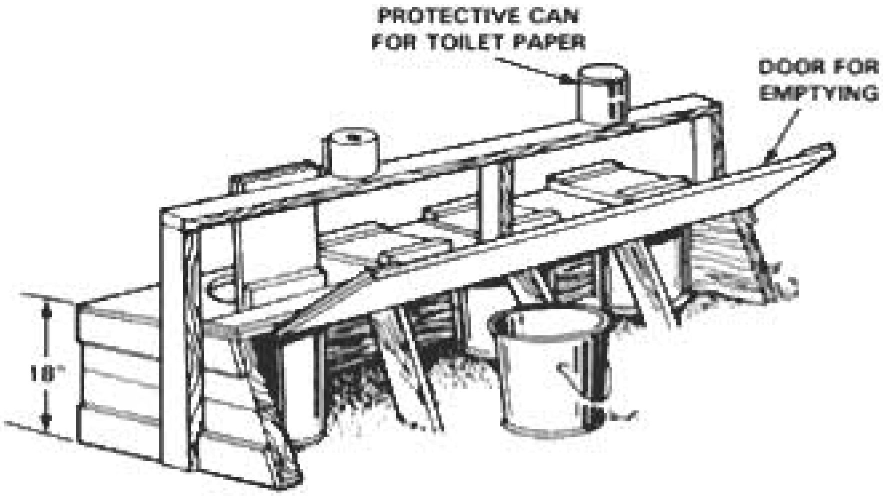
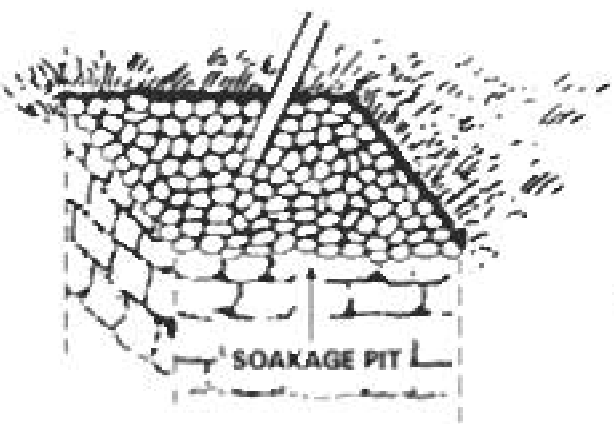
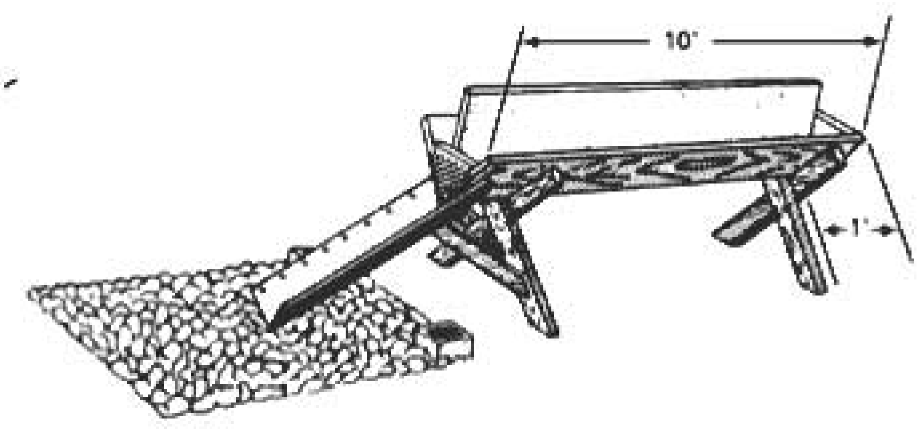
Immediate action measures

- **Bucket / container latrines**
- **Urinals with soakage pit**







Emergency sanitation planning

Recommended minimum objectives for safe excreta disposal

	Immediate (max. 1 month)	**Short-term** (max. 6 months)	**Long-term** (3 years)
Quantity	▪1 cubicle/space to 100 persons	▪1 cubicle/space to 50 persons	▪1 cubicle/space to 20 persons
Maximum walking distance	▪70m (one way)	▪50m (one way)	▪25m (one way)
Quality	▪Technically basic ▪Barely socially and culturally acceptable	▪Technically appropriate ▪Socially and culturally acceptable	▪Technically very appropriate ▪Very socially and culturally acceptable
Access to facilities	▪50% of affected population	▪75% of affected population	▪95% of affected population

Open/trench defecation field → **Communal pit latrines** → **Household pit latrines**

How to finance a sanitation programme?

Two financial tools:	Concerns:
Subsidies	
→ Paid directly to user? → subsidising only components? → subsidising only overhead costs of sanitation programme?	- expensive (realistic?) - feeling of ownership and responsibility?
Loans	
Can users pay interest rate? Possibility: → subsidized rate of interest	- Who will get loans? - is money lent actually spent on sanitation? → organization and control needed !

eawag
aquatic research

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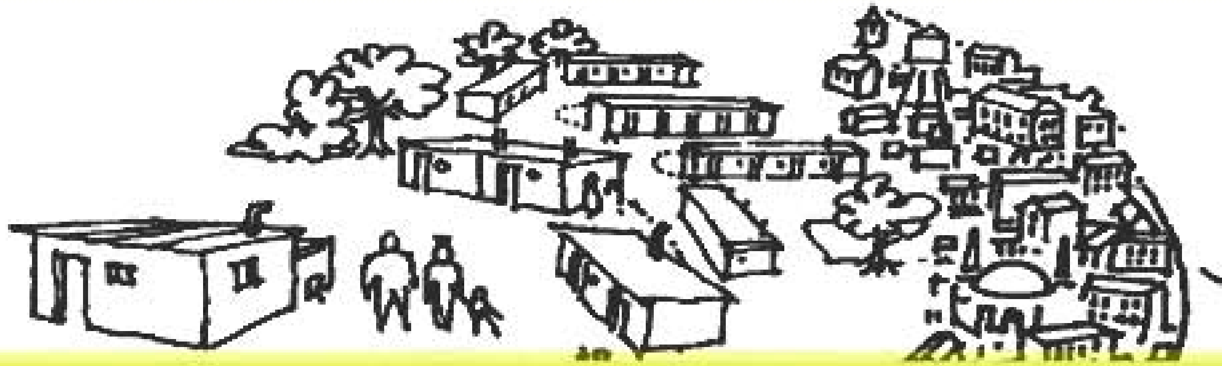
Water and Sanitation in Developing Countries

Definitions
Introduction
Technologies
Non-technical Aspects
Review

Review



- ✓ Sanitation involves both, **facilities and behaviour.**
- ✓ A sanitation system should include **all waste products, *from cradle to grave***.
- ✓ **Only selected combinations** of technologies result in a functional sanitation system.
- ✓ The most appropriate system option has to be **selected on a case-to-case basis**, considering hard and soft aspects.
- ✓ **Decentralized systems** are often more appropriate in developing countries.
- ✓ **Waste products are valuable** and should be considered as resources.

THANK
YOU