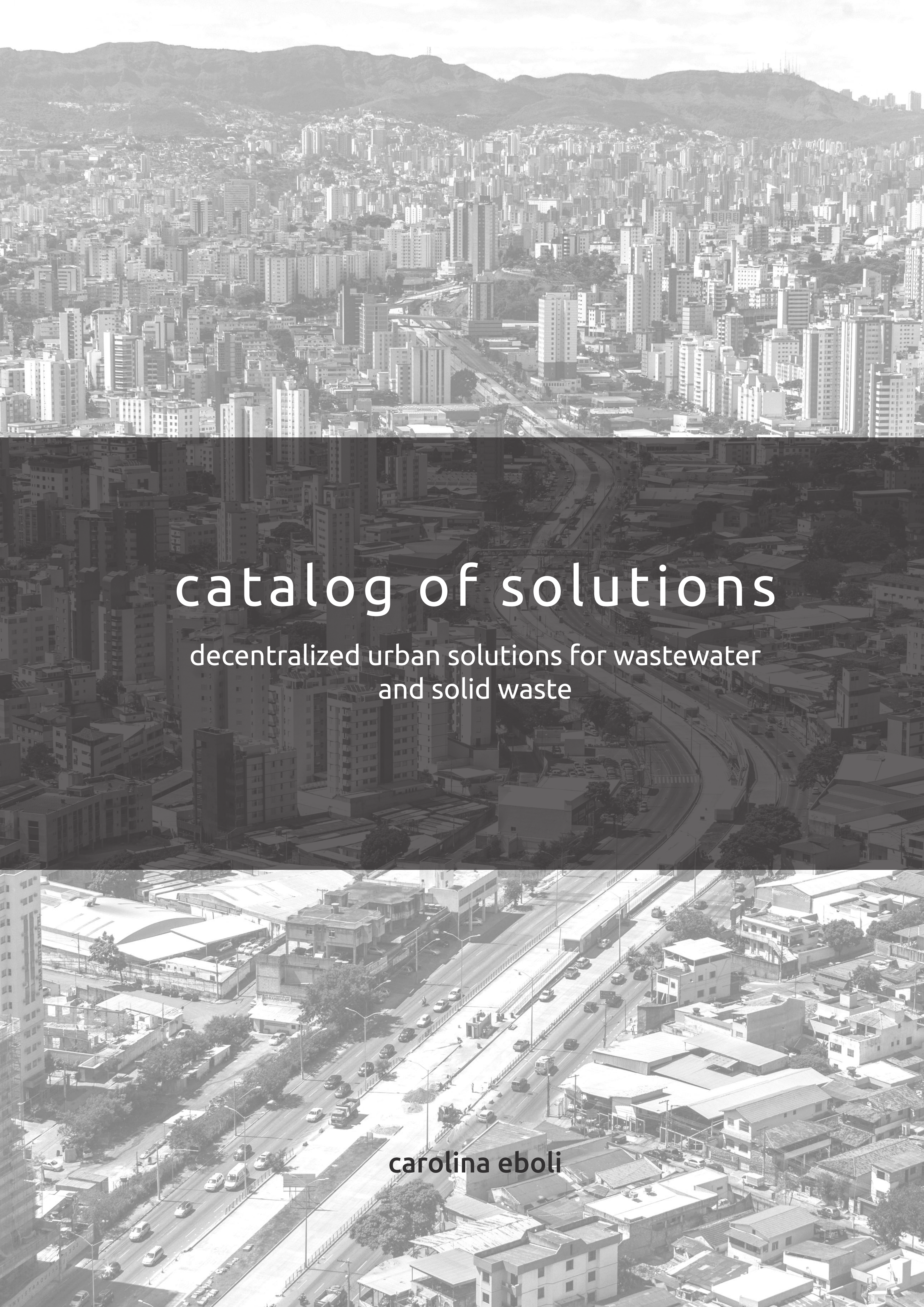

catalog of solutions

decentralized urban solutions for wastewater and solid waste

carolina eboli

Catalog of Solutions: decentralized urban solutions for wastewater and solid waste
Integral part of MSc Thesis - Metabolic Horizon

July, 2018

Carolina Eboli
caroleboli@gmail.com

1st mentor: Ulf Hackauf
2nd mentor: Lidewij Tummers

Research Group: Smart Cities and Urban Metabolism
Msc Architecture, Urbanism and Building Sciences - Track Urbanism
Faculty of Architecture and the Built Environment
Delft University of Technology

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catalog of solutions

decentralized urban solutions for wastewater and solid waste

Carolina C. P. Eboli

Delft University of Technology | Faculty of Architecture and the Built Environment | MSc Urbanism

July, 2018 | Delft, Netherlands

Index

Images

Diagrams

1 | introduction

This catalog is the result of an inventory of decentralized solutions for wastewater and solid waste. Each chapter provides an overview of elected solutions specific to each flow, based on literature research. In addition, in the beginning of each chapter, a diagram highlights how the solutions relate to treatment phases and the by-products they produce. The purpose of these catalogs is to provide substantiation for comparing the solutions and support design decisions. Therefore, a matrix comparing the solutions is also provided at the end of each chapter. This matrix includes technical information present in this catalog (such as area requirement), as well as other criteria related to the urban environment, defined for the purpose of this thesis.

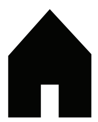
It should be noted that there may be other solutions not included in this inventory. Moreover, some solutions presented here can also be applied in centralized systems.

2 | wastewater

Each solution is given the following parameters: description, scale, area, restrictions, pros, cons and costs in a qualitative way. Whenever possible, these parameters are expanded, incorporating quantities. A typical scheme of each system and/or examples are also provided.

The scales indicated refer to the most suitable situation for each solution. However, it does not exclude the possible implementation on different scales.

Literature: for the description given in this annex, four main sources were used: Hoffmann et al., 2011; Pötz, 2016; Sasse, 1998 and Tilley et al., 2014. However, other literature was also used during the research phase, including the Flemish Department of Agriculture and Fisheries (Vlaanderen Department Landbouw en Visserij) and the BORDA approach (http://en.borda.de/)


household


neighborhood


city

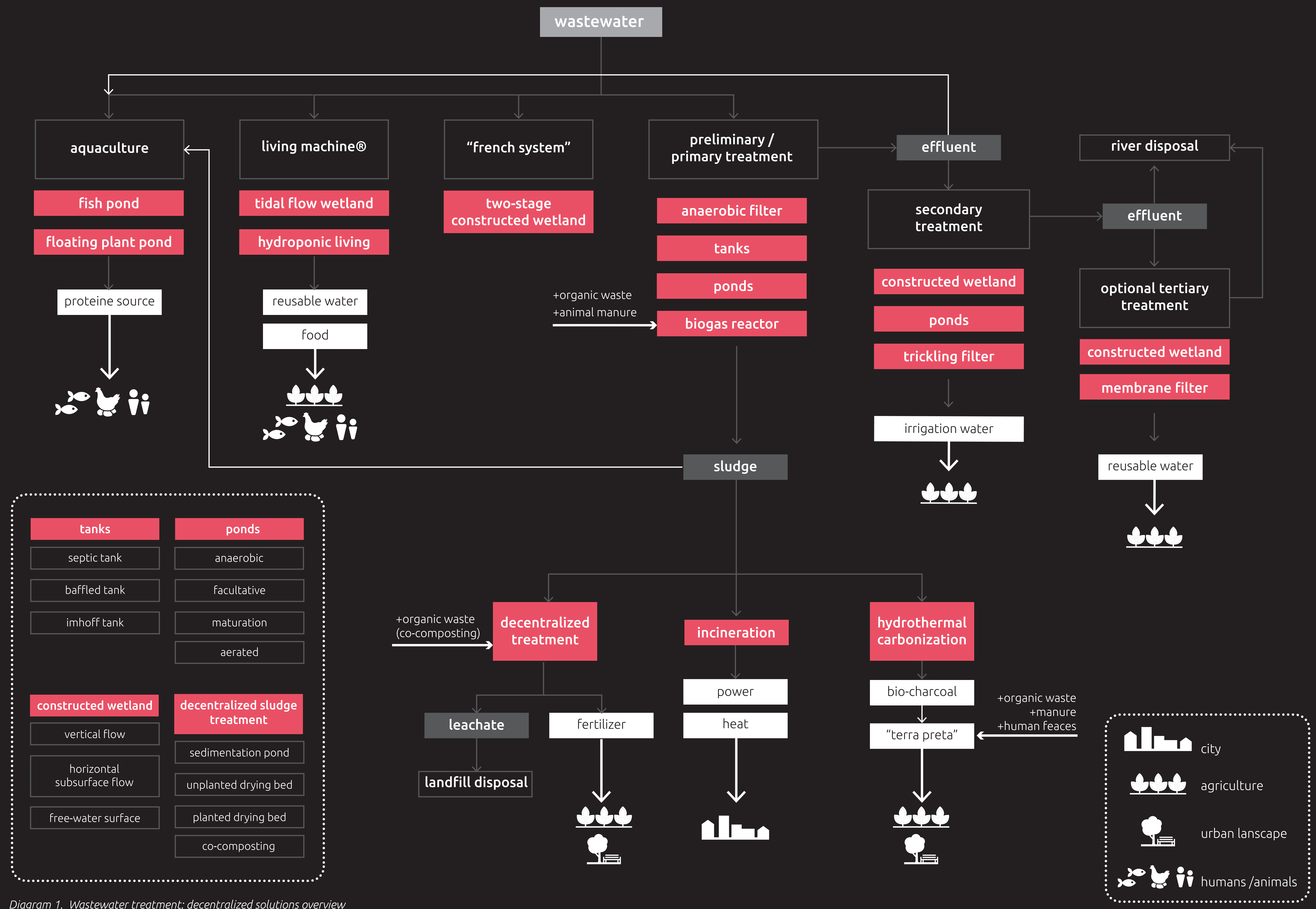
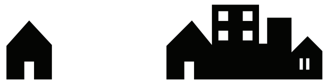


Diagram 1. Wastewater treatment: decentralized solutions overview

septic tank

Description: A septic tank is a combination of at least two chambers where occur pre-treatment (settling – heavy particles sink and scum floats) and primary treatment (anaerobic digestion of the solids) (Tilley et al., 2014). This process has biogas as by-product, but usually it is not possible to be collected. (Sasse, 1998).

Scale:



5-200 inhabitants (Hoffmann et al., 2011)

Area: 0,5 m²/m³ daily flow (Sasse, 1998)

[0,08m²/person equivalent (160L/day)]

Restrictions:

- requires further treatment of effluent and sludge;
- in high-density areas, infiltration is not adequate;
- not appropriate for flooding areas or areas with high ground water table;
- requires regularly desludging

(Tilley et al., 2014)

Pros x Cons:

\+

- simple construction
- durable
- little space requirement (underground)
- low costs
- no electrical energy use

−

- low pathogen reduction
- effluent with odor
- requires regular desludging
- requires further treatment of effluent and sludge

(Sasse, 1998; Tilley et al., 2014)

Costs: $

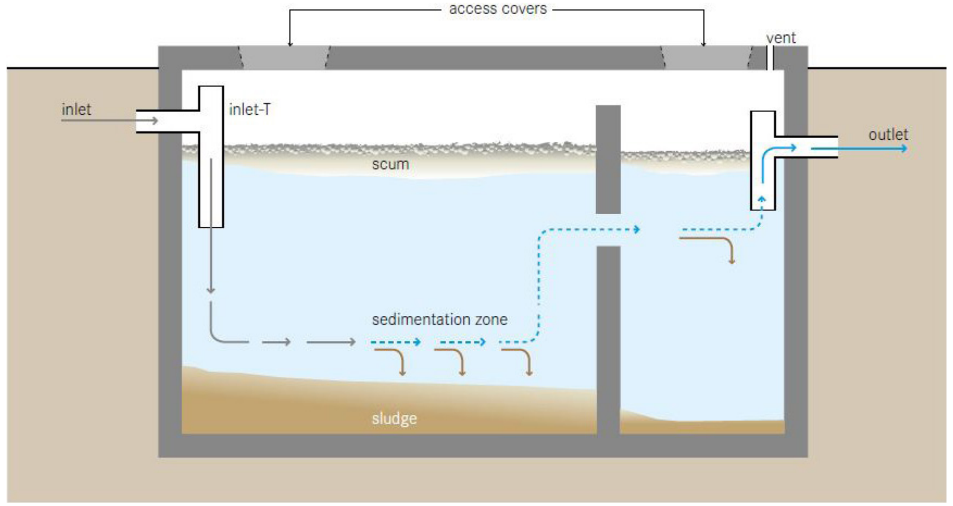


Figure 1. Septic tank scheme
Source: Tilley et al., 2014

Figure 2. Concrete septic tank
Picture: James Clarke

baffled tank

Description: A baffled tank, or anaerobic baffled reactor, uses the same principle of a septic tank. It has additional baffles (barriers) to guide the wastewater flow, increasing the contact with the active biomass and improving the treatment results (Tilley et al., 2014). This process also produces biogas, but given its insufficient production, it is not collected (Tilley et al., 2014).

Scale:

200-2.500 inhabitants (Hoffmann et al., 2011)

Area: 1 m²/m³ daily flow (Sasse, 1998)

[0,16m²/person equivalent (160L/day)]

Restrictions:

- requires further treatment of effluent and sludge;
- implementation should take in consideration odors nuisance;
- desludging frequency depends on the chosen pre-treatment;

(Tilley et al., 2014)

Pros x Cons:

+	−
• simple and adaptable • durable • little space requirement (underground) • low operational costs • no electrical energy use • high efficiency (reduction of BOD and low sludge production) • copes with organic and hydraulic fluctuation loads	• low pathogen and nutrients reduction • long start-up period • requires technical knowledge for design and construction • requires further treatment of effluent and sludge

(Sasse, 1998; Tilley et al., 2014)

Costs: $

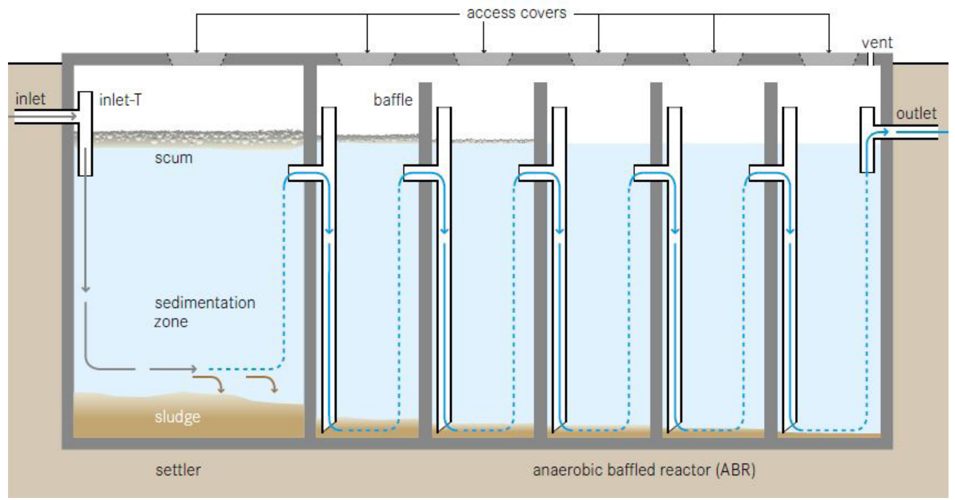


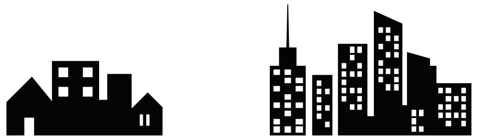
Figure 3. Baffled tank scheme
Source: Tilley et al., 2014

Figure 4. Baffled tank under construction
Picture: Moses Wakala

imhoff tank

Description: A Imhoff tank is a two-stage anaerobic system for primary treatment, where solids and liquids are digested in separate compartments, mixing with incoming sewage (Hoffmann et al., 2011; Tilley et al., 2014). This process also produces biogas, but given its insufficient production, it is not collected (Hoffmann et al., 2011).

Scale:



500-20.000 inhabitants (Hoffmann et al., 2011)

Area: 0,5 m²/m³ daily flow (Sasse, 1998)

[0,08m²/person equivalent (160L/day)]

Restrictions:

- pre-treatment is recommended (bar screen or grit chamber);
- underground construction is restricted to areas with low groundwater tables and no flooding risks;
- requires further treatment of effluent and sludge;

(Tilley et al., 2014)

Pros x Cons:

\+

- durable
- little space requirement (underground)
- odorless effluent
- low operational costs
- combines multiple treatment steps in one unit
- copes with organic fluctuation loads

−

- low pathogen reduction
- requires regular desludging
- requires technical knowledge for design and construction
- requires further treatment of scum, effluent and sludge
- possible conflicts with groundwater table
- robust (high) infrastructure when above ground

(Sasse, 1998; Tilley et al., 2014)

Costs: $

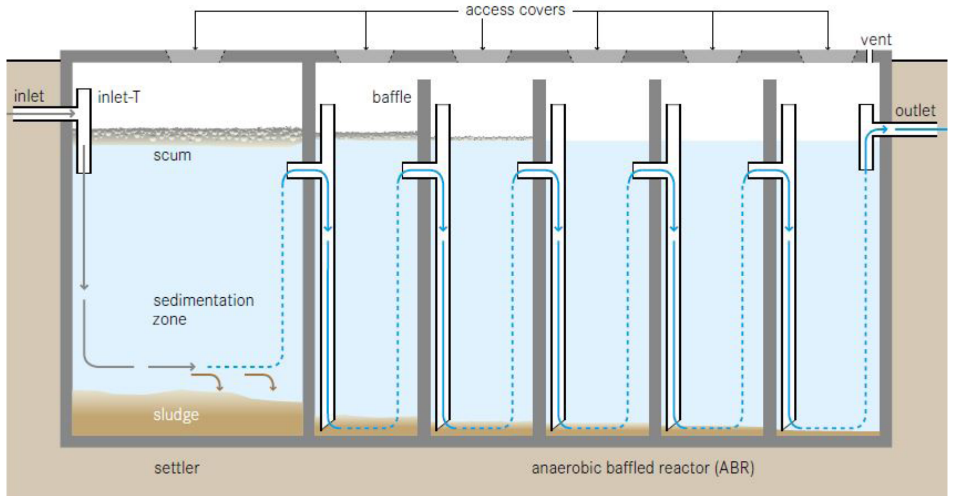


Figure 5. Imhoff tank scheme
Source: Tilley et al., 2014

Figure 6. Imhoff tank under construction
Source: Acogei

anaerobic filter

Description: An anaerobic filter, also known as fix-bed or fixed-film reactor, uses filter materials such as gravel, crushed rocks and bricks, to trap and digest organic matter using the growing active biomass in the system. (Tilley et al., 2014). It can be used as a secondary or tertiary treatment as well. (Tilley et al., 2014)

Scale: 

Area: 1 m^2/m^3 daily flow (Sasse, 1998)

[0,16m^2/person equivalent (160L/day)]

Restrictions:

- requires pre-treatment (can be associated or separated);
- more appropriate in areas with constant amount of wastewater;
- if used as primary treatment, the effluent requires further treatment;

(Tilley et al., 2014)

Pros x Cons:

+

- simple and adaptable
- durable
- little space requirement (underground)
- low operational costs
- no electrical energy use
- high efficiency (reduction of BOD, solids and low sludge production)

−

- requires technical knowledge for design and construction
- requires further treatment of effluent and sludge
- effluent with slight odor
- low pathogen and nutrients reduction
- clogging risk (pre-treatment dependent)

(Sasse, 1998; Tilley et al., 2014)

Costs: $

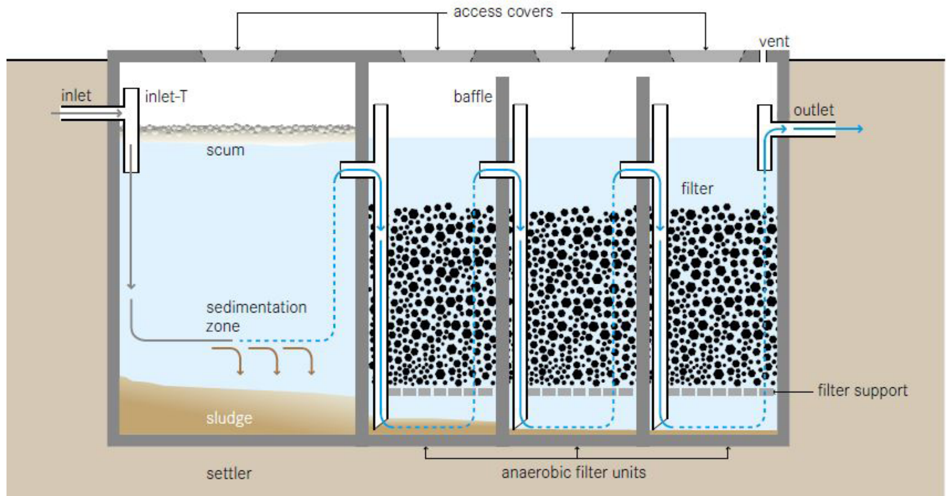


Figure 7. Anaerobic filter scheme
Source: Tilley et al., 2014

Figure 8. Fixed film reactor
Picture: Process Wastewater Technologies LLC, Baltimore, MD

trickling filter

Description: A trickling filter is a biological reactor that uses filter material (gravel, rocks, shredded PVC) to allow biofilm creation. Wastewater is sprayed over this filter and digested by the organisms that grow on it (Tilley et al., 2014).

Scale:

Area: 64 to 480kg BOD_5/100m³ (EPA, 2000)

[0,6-7m²/person equivalent]

Restrictions:

- requires primary treatment;
- requires trained maintenance staff and constant energy source and wastewater flow;

(Tilley et al., 2014)

Pros x Cons:

+

- smaller space requirement (compared to constructed wetlands)
- high efficiency (nitrification)
- copes with wide range of organic and hydraulic loads

−

- requires technical knowledge for design and construction
- clogging risk (primary treatment dependent)
- costly
- odor and mosquitoes problems
- systems part may not be locally available
- requires trained maintenance staff and constant energy source and wastewater flow;

(Tilley et al., 2014)

Costs: $ $ $

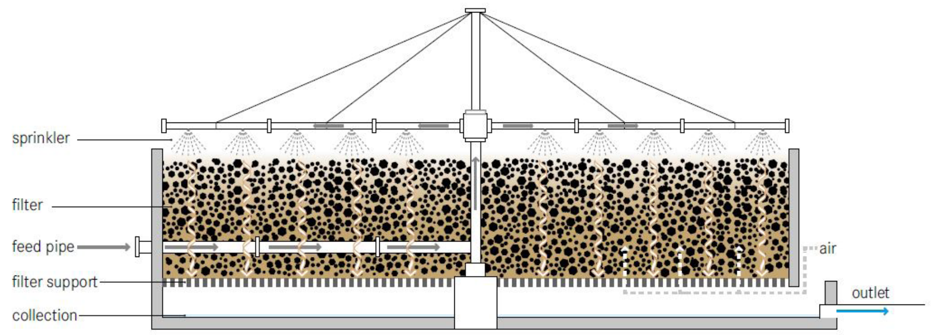


Figure 9. Trickling filter scheme

Source: Tilley et al., 2014

Figure 10. Trickling filter

Picture: Ingreenion

stabilization ponds

Description: Stabilization ponds are artificial water bodies subdivided in anaerobic, facultative and aerobic (maturation or oxidation). They can be associated to each other or function individually (Tilley et al., 2014). The anaerobic pond corresponds to the primary treatment, where the sedimentation and anaerobic digestion take place. The facultative and aerobic ponds correspond to secondary treatment, but the last can also be used for tertiary treatment (Tilley et al., 2014).. These ponds use "oxygen from natural diffusion, wind mixing and algae-driven photosynthesis" for BOD and pathogens removal (Tilley et al., 2014).

Scale:

Area:

anaerobic: 4 m²/m³ daily flow (Sasse, 1998) [0,64m²/PE(160L/day)]

aerobic: 25 m²/m³ daily flow (Sasse, 1998) [4m²/PE(160L/day)]

Restrictions:

- requires pre-treatment;
- not appropriate for high-density or urban areas;
- human, animal and waste contact should be prevented;
- may require algae control;

(Tilley et al., 2014)

Pros x Cons:

+

- simple / flexible degree of treatment / reliable
- low operational costs / little maintenance
- no electrical energy use
- high efficiency (reduction of BOD, solids and pathogens) and nutrient removal when combined with aquaculture)
- possible landscape integration
- copes with organic and hydraulic fluctuation loads

−

- large space requirement
- requires further treatment of sludge
- possible odor and mosquitoes problems if not designed and maintained properly
- requires technical knowledge for design and construction

(Sasse, 1998; Tilley et al., 2014)

Costs: $ $

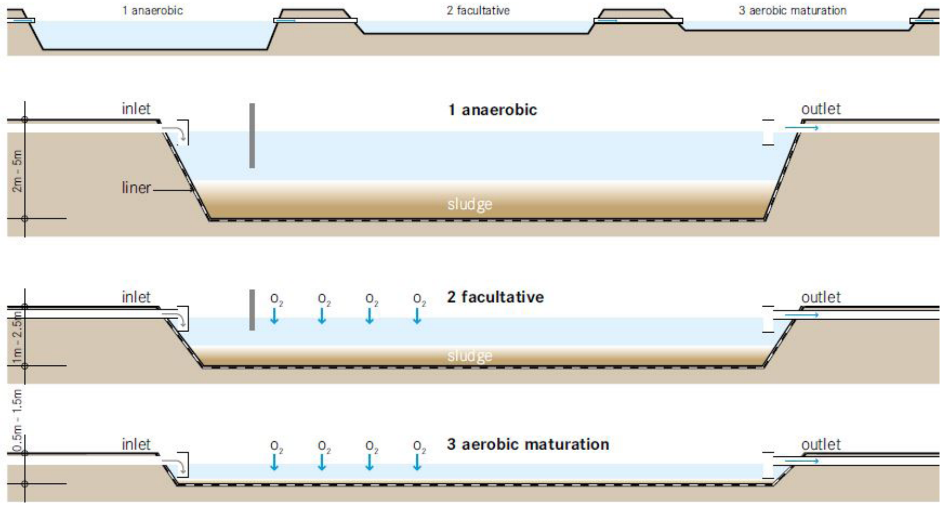


Figure 11. Stabilization ponds scheme
Source: Tilley et al., 2014

Figure 12. Stabilization ponds
Source: Multi-Flow LDVS

aerated pond

Description: An aerated pond is similar to stabilization ponds, with the addition of mechanical aerators that add oxygen to the system and increases mixing, assuring higher treatment efficiency (Tilley et al., 2014).

Scale:

Area: 25 m²/m³ daily flow (considered similar as aerobic ponds)

[4m²/person equivalent (160L/day)]

Restrictions:

- requires pre-treatment;
- requires constant electric source and skilled staff
- not appropriate for high-density or urban areas;
- human, animal and waste contact should be prevented;

(Tilley et al., 2014)

Pros x Cons:

+

- no electrical energy use
- high efficiency (reduction of BOD, solids and pathogens)
- copes with organic and hydraulic fluctuation loads
- when designed properly, no odors and mosquitoes problems

−

- large space requirement
- requires further treatment of sludge and effluent
- costly
- high energy consumption
- requires technical knowledge for design and construction
- materials might not be found locally

(Sasse, 1998; Tilley et al., 2014)

Costs: $ $ $

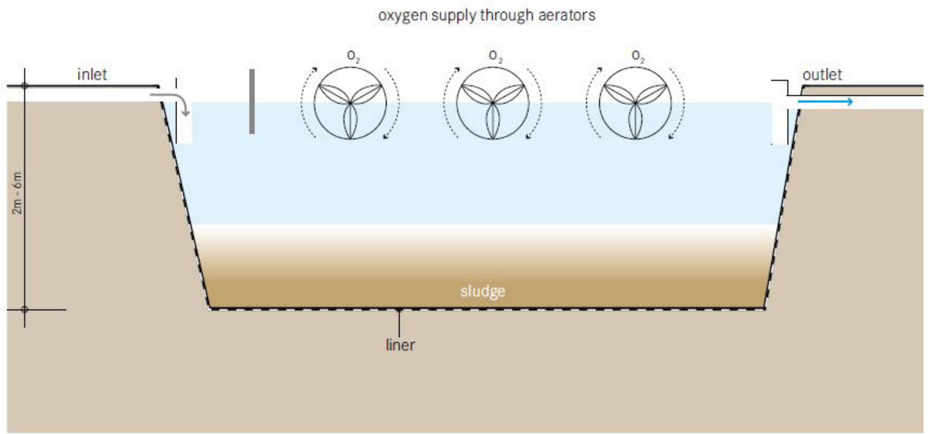


Figure 13. Aerated pond scheme
Source: Tilley et al., 2014

Figure 14. Aerated pond
Source: Napier-Reid

biogas bioreactor

Description: A biogas reactor, also known as anaerobic digestor, is an airtight chamber that uses anaerobic degradation to treat wastewater and/ or biodegradable waste (Tilley et al., 2014). It has by-products that can be used as fertilizer (digestate) or energy (biogas). (Tilley et al., 2014)

Scale:

Area:

0,06m²/person (Van Leer, 2016)

Reactor: 100 to 100.000L

Human yield 0,12-0,6kg / Biogas production 20-150L/kg feces

(Eawag & Spuhler, n.d.)

Restrictions:

- requires storage and transport and/or use of the digestate outside the site;
- functions better with regular feeding;
- the amount of biogas production depends on concentrated substrates (animal manure, organic market or household waste);

(Tilley et al., 2014)

Pros x Cons:

+

- durable
- little space requirement (underground)
- low operational costs
- no electrical energy use
- nutrients conservation (digestate can be used as fertilizer)
- clean energy production

−

- requires technical knowledge for design and construction
- requires further treatment of the digestate
- incomplete pathogen removal
- not suitable for "weak" wastewater

(Sasse, 1998; Tilley et al., 2014)

Costs: $$

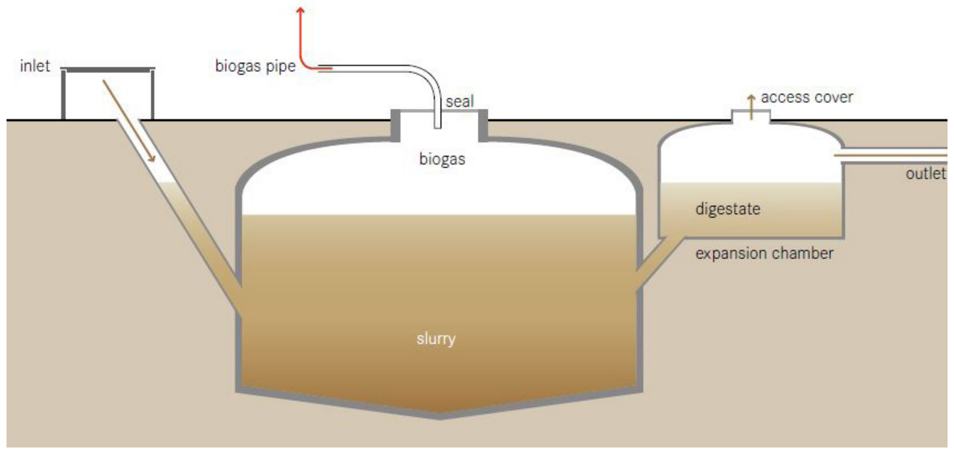


Figure 15. Biogas reactor scheme
Source: Tilley et al., 2014

Figure 16. Biogas reactor
Source: Veolia

horizontal subsurface constructed wetland

Description: A horizontal subsurface constructed wetland is a form of secondary treatment. This system uses gravel and sand as filtering materials that allow bacteria attachment and act as base for appropriated planted vegetation. The horizontal flow allows the filtering of particles and degradation of organics (Tilley et al., 2014). Alternative filtering materials, such as PET and coconut, can also be used (Flanders Department of Agriculture and Fisheries. n.d.; Tilley et al., 2014).

Scale:

Area: 5 to 10m²/person equivalent (Tilley et al., 2014)

consider +30% of area for landscape integration

Restrictions:

- requires pre- and primary treatment (Tilley et al., 2014)
- should not be placed in flooding or protected areas
- to use gravity - slopes of 10-20%
- requires desludging every 10 years

Pros x Cons:

+

- does not suffer from mosquito problems
- low operational costs
- no electrical energy use
- high efficiency (reduction of BOD, suspended solids and pathogens)
- possible landscape integration
- simpler construction (without pipes/pumps)

−

- large space requirement
- little nutrient removal
- clogging risk (pre- and primary treatment dependent)
- requires large amount of gravel supply for construction

(Pötz, 2016; Tilley et al., 2014)

Costs: $ $

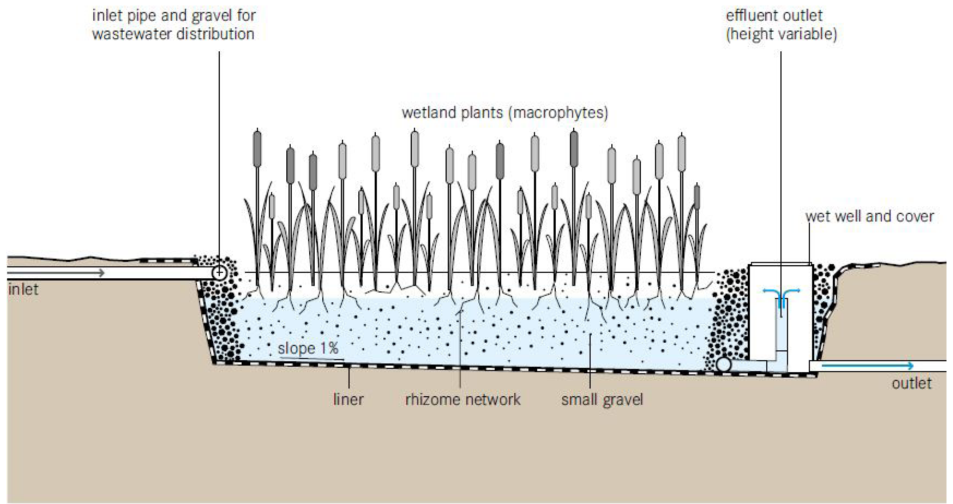


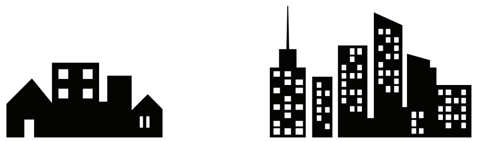
Figure 17. Horizontal subsurface constructed wetland scheme
Source: Tilley et al., 2014

Figure 18. Horizontal constructed wetland in Changshu, China
Picture: M. Blumberg

vertical flow constructed wetland

Description: A vertical flow constructed wetland is constructed wetland for secondary treatment. This system uses a filter bed with planted vegetation that vertically receives water in intermittently doses (Tilley et al., 2014).. The filter bed allows bacteria attachment and act as base for appropriated planted vegetation.(Tilley et al., 2014).

Scale:



Area: 1 to 3m²/person equivalent (Tilley et al., 2014)

Restrictions:

- requires pre- and primary treatment;
- requires trained maintenance staff, constant power supply, and spare parts of the system should be available;
- the liner should be protected from tree roots;

(Tilley et al., 2014)

- should not be placed in flooding or protected areas
- to use gravity - slopes of 10-20%
- requires desludging every 10 years

Pros x Cons:

+

- does not suffer from mosquito problems
- low operational costs
- high efficiency (reduction of BOD, suspended solids and pathogens)
- possible landscape integration

−

- large space requirement
- requires technical knowledge for design and construction
- little nutrient removal
- clogging risk (pre- and primary treatment dependent)
- long start-up period
- requires large amount of gravel supply for construction

(Tilley et al., 2014)

Costs: $ $

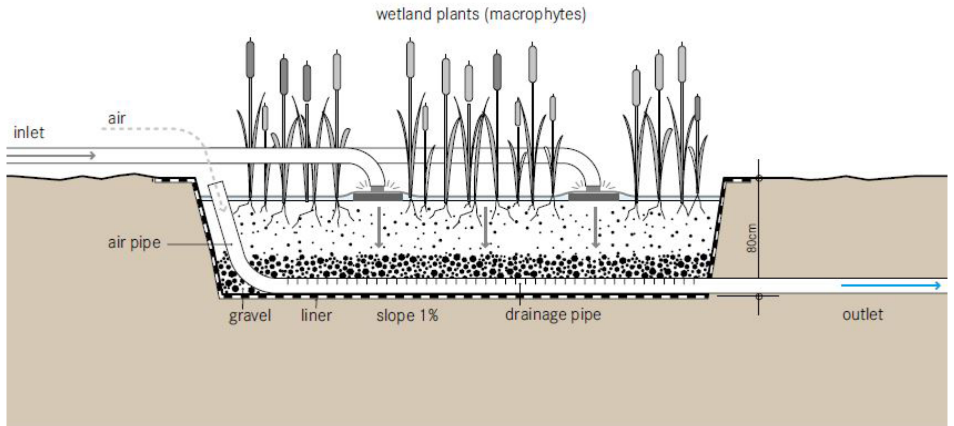


Figure 19. Vertical flow constructed wetland scheme
Source: Tilley et al., 2014

Figure 20. Vertical helophyte filters in Shenyang, China
Picture: Ingenieurbüro Blumberg

“french system”

Description: A “french system” is when a vertical flow constructed wetland is used in a two-stage system, removing the necessity of pre-treatment. The first stage include three different vertical filter beds (gravel), whereas the second only two (sand) (Tilley et al., 2014).

Scale:

Area: first stage: 1,2m²/person equivalent
second stage: 0,8m²/person equivalent (Hoffmann et al., 2011)

Restrictions:

- requires trained maintenance staff, constant power supply, and spare parts of the system should be available;
- the liner should be protected from tree roots;
(Tilley et al., 2014)
- should not be placed in flooding or protected areas
- to use gravity - slopes of 10-20%
- requires desludging every 10 years

Pros x Cons:

+	−
• does not require pre-treatment	• large space requirement
• does not produce primary sludge	• requires technical knowledge for design and construction
• does not suffer from mosquito problems	• requires pumping stations (energy consumption)
• low operational costs	• little nutrient removal
• high efficiency (reduction of BOD, suspended solids and pathogens)	• long start-up period
• possible landscape integration	• possible low social acceptance
	• requires large amount of gravel supply for construction

(Hoffmann et al., 2011 ; Tilley et al., 2014)

Costs: $$

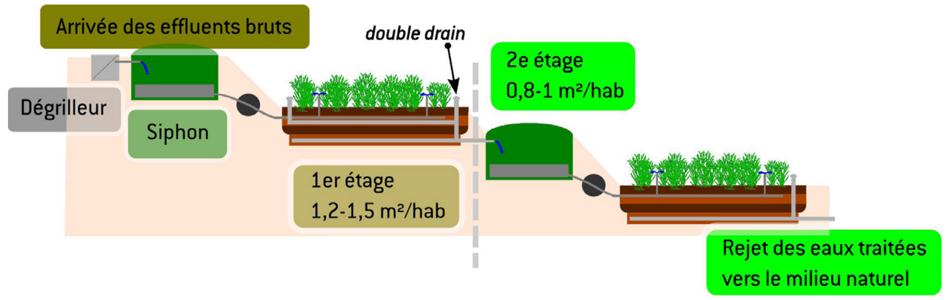


Figure 21. French system: two-stage vertical flow constructed wetland scheme
Source: (Florent Chazarenc, n.d.)

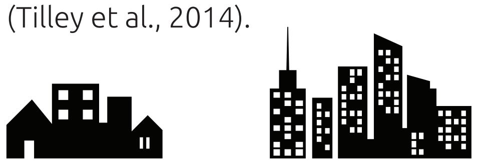
Figure 22. Fist stage of the French System for wastewater treatment
Picture: SuSanA Secretariat

Figure 23. Second stage of the French System for wastewater treatment
Picture: SuSanA Secretariat

free-water surface constructed wetland

Description: A free-water surface constructed wetland is a form of secondary or tertiary treatment. It recreates the natural conditions of a wetland, promoting particles settlement, pathogens destruction and nutrients absorption by the plants in the system (Tilley et al., 2014). In this configuration, these processes take place simultaneously, by exposing the water to sunlight and its slow flow through the wetland (Tilley et al., 2014).

Scale:



Area: 1 to 3m²/person equivalent (considered similar as vertical wetlands)

Restrictions:

- requires primary treatment;
- appropriate for low-strength wastewater;
- when used as secondary treatment human exposure to pathogens should be prevented;
- requires proper design and maintenance to assure no odors issues

(Tilley et al., 2014)

Pros x Cons:

\+

- higher efficiency (BOD reduction and solids)
- moderate pathogen removal
- no electrical energy use
- low costs
- can be built using local materials
- provides animal habitat
- possible landscape integration

−

- large space requirement
- mosquitoes problems
- requires technical knowledge for design and construction
- long start-up time

(Tilley et al., 2014)

Costs: $

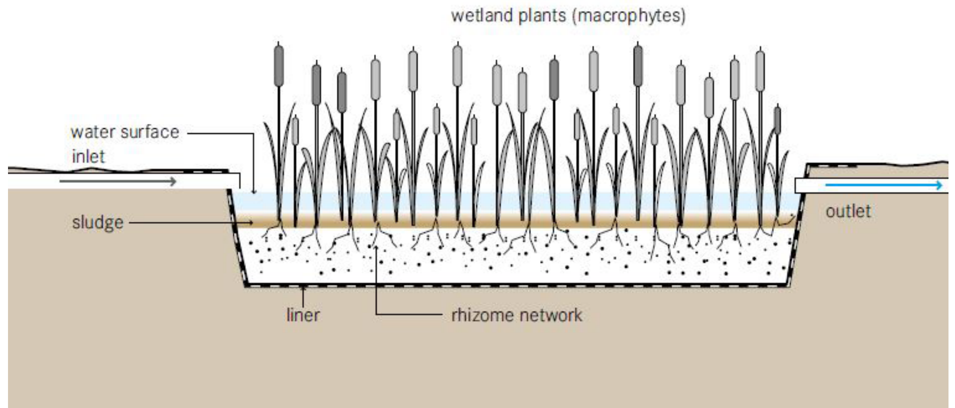


Figure 24. Free-water constructed wetland scheme
Source: Tilley et al., 2014

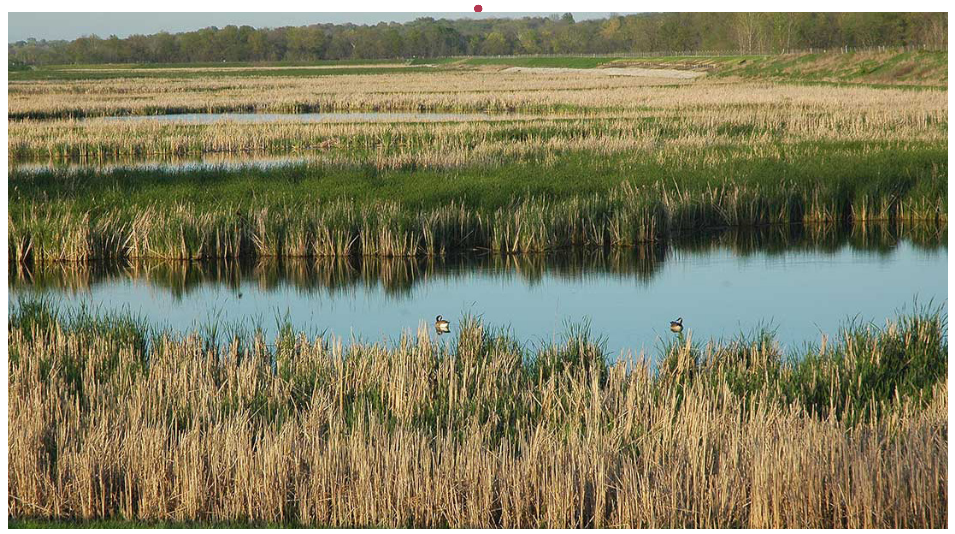


Figure 25. Free-water constructed wetland near Columbia Missouri
Picture: Austin

membrane filter

Description: A membrane filter is a tertiary treatment (surface filtration) in order to achieve higher water quality. The particles are removed as the water is mechanically sieved through the membrane (Tilley et al., 2014).

Scale: 

Area: n/d

Restrictions:

- requires primary and secondary treatment;
- requires constant monitoring;

(Tilley et al., 2014)

Pros x Cons:

\+

- higher efficiency (pathogens and chemical contaminants)
- possible direct use of the treated water

−

- costly
- requires technical knowledge for design and construction
- membrane requires regular replacement
- technology and skill might not be available locally
- requires constant source of energy

(Tilley et al., 2014)

Costs: $ $ $ $

Figure 26. Membrane filter at Puur Waterfabriek Nieuw-Amsterdam
Picture: Logisticon, n.d.

sedimentation pond

Description: Sedimentation pond is a system for sludge treatment. This system consists of a basin where sludge is able to stabilize before dehydration processes (Tilley et al., 2014).

Scale:

Area: 0,006m²/ cap (considering 1l of fecal sludge/cap/day)

(Strauss, Heinss, & Larmie, 1998)

Restrictions:

- excessive rain may harm the process;
- should be located far from residential areas;

(Tilley et al., 2014)

Pros x Cons:

+

- low costs
- no electrical energy use
- facilitates further sludge treatment
- can be built using local materials

−

- large space requirement
- odor and mosquitoes problems
- requires technical knowledge for design and construction
- requires further treatment of effluent and sludge
- long storage periods

(Tilley et al., 2014)

Costs: $

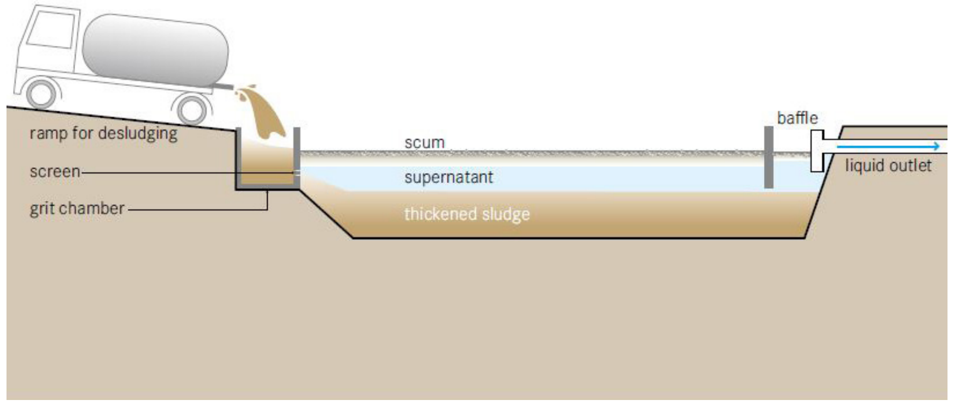


Figure 27. Sedimentation pond scheme
Source: Tilley et al., 2014

Figure 28. Sedimentation pond
Picture: Blumberg Engineers

unplanted drying bed

Description: An unplanted drying bed consists of a permeable bed with layers of gravel and sand that promotes sludge evaporation and collects percolated leachate. (Tilley et al., 2014).

Scale: 

Area: 0,05m²/ cap (considering 1l of fecal sludge/cap/day)

(Strauss, Heinss, & Larmie, 1998)

Restrictions:

- excessive rain may harm the process;
- should be located far from residential areas;

(Tilley et al., 2014)

Pros x Cons:

+

- good dewatering efficiency
- low costs
- no electrical energy use
- can be built using local materials
- simple operation

−

- large space requirement
- odor and mosquitoes problems
- requires technical knowledge for design and construction
- requires further treatment of leachate
- sludge and leachate removal are labor intensive

(Tilley et al., 2014)

Costs: $

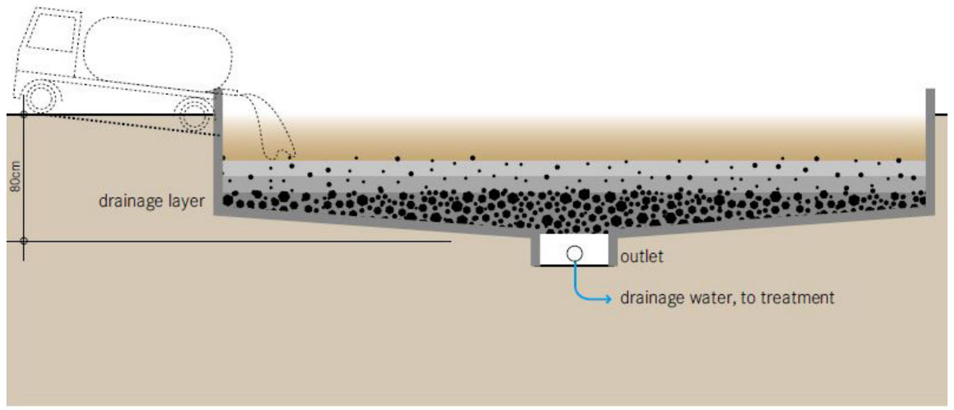


Figure 29. Unplanted drying bed scheme
Source: Tilley et al., 2014

Figure 30. Desluding of a unplanted drying bed
Source: UNESCO-IHE

planted drying bed

Description: A planted drying bed follows the same principle of the unplanted drying bed with the inclusion of adequate vegetation. The plants associated with filtering layers stabilize and dewater sludge, without the need of further desludging. This system is similar with constructed wetlands, with the difference of applying sludge instead of effluent on the surface and drainage operation (Tilley et al., 2014).

Scale:

Area: 0,05m²/ cap (considered similar as unplanted drying bed)

Restrictions:

- requires trained maintenance and operation;
- effluent should be properly collected and disposed of
- drains require maintenance
- requires minimum vegetation growth before sludge application

(Tilley et al., 2014)

Pros x Cons:

+

- copes with high loads
- higher efficiency
- no electrical energy use
- low costs
- can be built using local materials
- allows growing of fruit or forage

−

- large space requirement
- odor and mosquitoes problems
- requires technical knowledge for design and construction
- requires further treatment of leachate
- long storage periods
- sludge and leachate removal are labor intensive

(Tilley et al., 2014)

Costs: $

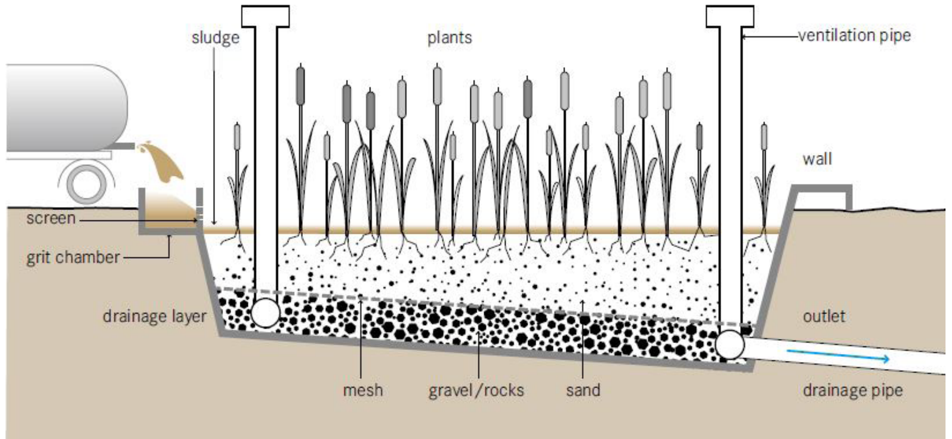


Figure 31. Planted drying bed scheme
Source: Tilley et al., 2014

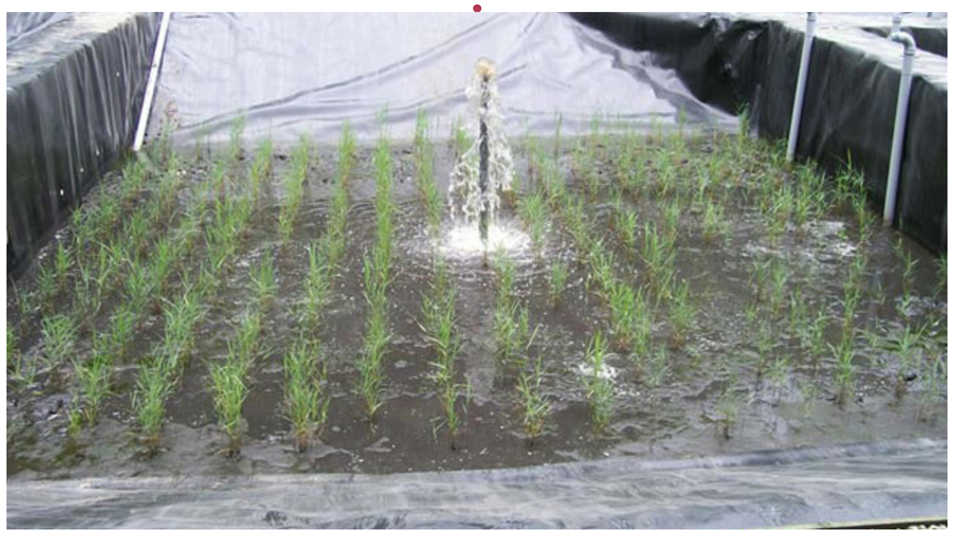
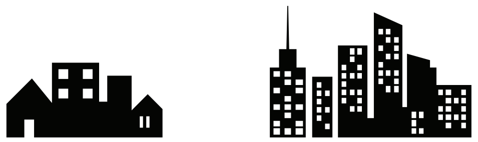


Figure 32. Planted drying bed
Source: Ecotech systems

co-composting

Description: Co-composting is a combined system of sludge with organic solid waste that together create an aerobic degradation process. Decentralize systems operate in open composting mixed piles left for decomposing (Tilley et al., 2014).

Scale:



Area: 800m² for 3 ton/day plant
(a plant can receive 10 to 200ton/day)

(Tilley et al., 2014)

Restrictions:

- requires well-sorted biodegradable solid waste;
- the system should be closer to sludge and organic waste sources, but not close to residential areas;
- in areas with heavy rainfall, the system should covered;
- for dewatered sludge - 1:2 ratio / for liquid sludge 1:5 - 1:10 ratio

(Tilley et al., 2014)

Pros x Cons:

\+

- simple
- creates valuable product for local agriculture/food production
- no electrical energy use
- low costs
- can be built using local materials

−

- large space requirement
- requires technical knowledge for design and construction
- long storage periods
- labor intensive

(Tilley et al., 2014)

Costs: $

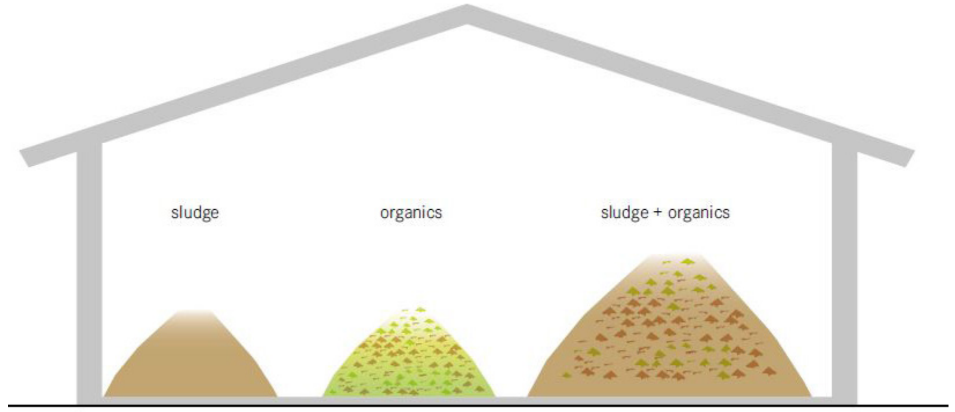


Figure 33. Co-composting scheme
Source: Tilley et al., 2014

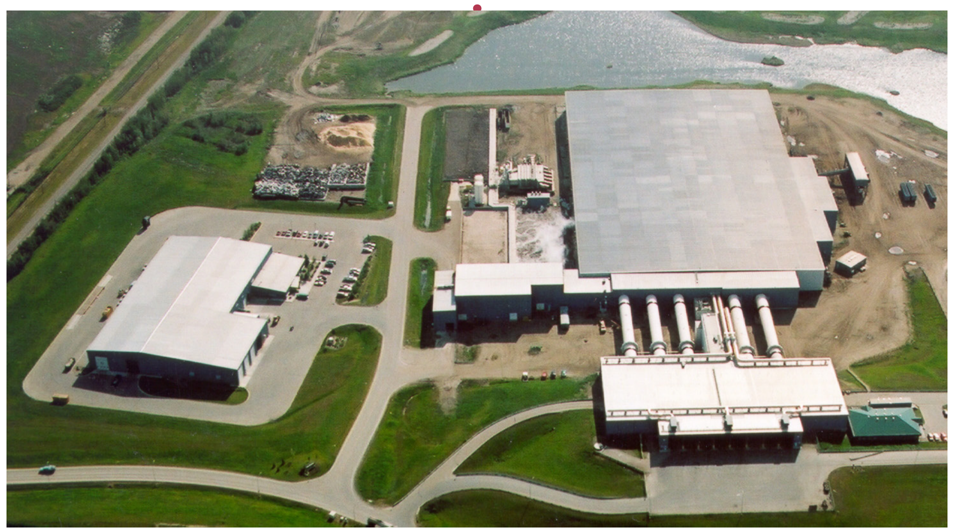


Figure 34. Edmonton Co-composting facility - Canada
Picture: Public Domain

fish pond

Description: A fish pond is a system that receives sewage water and where fishes feed from organisms that grow in nutrient-rich water (such as algae). The fish are responsible, thus, for the removal of nutrients and can be consumed afterwards (Tilley et al., 2014). It can also be associated with aerobic ponds (Tilley et al., 2014).

Scale: 

Area: 25 m²/m³ daily flow (considered similar as aerobic ponds)

[4m²/person equivalent (160L/day)]

Restrictions:

- for human consumption preferably move the fish to clear water pond;
- wastewater additions should be limited to maintain aerobic conditions;
- preferable conditions: high rainfall

(Tilley et al., 2014)

Pros x Cons:

+

- cheap and local protein source
- job creation
- low costs
- can be built using local materials
- can be harvest for human or animal consumption

−

- large space requirement
- requires technical knowledge for design and construction
- requires fresh water abundance
- potential health risk from human consumption
- possible low social acceptance

(Tilley et al., 2014)

Costs: $

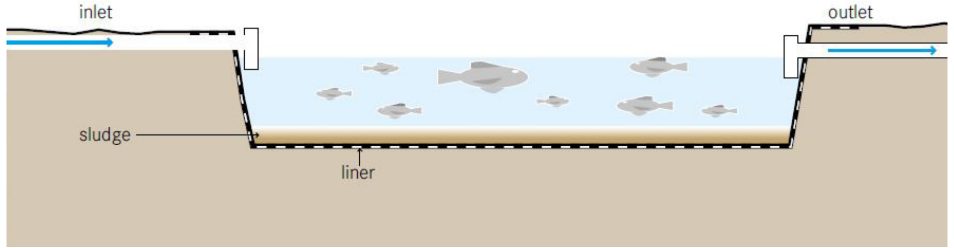


Figure 35. Fish pond scheme
Source: Tilley et al., 2014

Figure 36. Fish pond for wastewater treatment in Lobitos, Peru
Source: Ecoswell, n.d.

floating plant pond

Description: A floating plant pond is similar to a maturation pond with additional plants as part of the system. Wastewater is discharge in the pond where appropriate plants remove nutrients and filters the water (Tilley et al., 2014). Depending on the choice of plants, they can be used as food for fish and poultry or as a fiber source (Tilley et al., 2014).

Scale:

Area: 25 m²/m³ daily flow (considered similar as aerobic ponds)

[4m²/person equivalent (160L/day)]

Restrictions:

- for increased efficiency and space reduction, the ponds can aerated (energy requirement);
- people and animals should not have contact with the water;
- the plants require constant harvesting;
- depending on the load of solids, may require desludging

(Tilley et al., 2014)

Pros x Cons:

+

- some plants have landscape potential
- job creation
- low costs
- can be built using local materials
- high efficiency (BOD reduction and solids)

−

- large space requirement
- low pathogen reduction
- some plants can be become invasive

(Tilley et al., 2014)

Costs: $

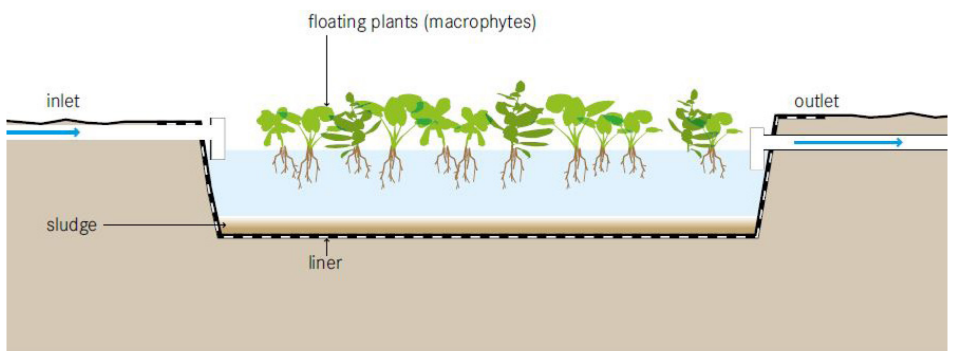


Figure 37. Floating plant pond scheme
Source: Tilley et al., 2014

Figure 38. Maturation pond with floating plants for wastewater treatment in Namibia
Source: Achal Garg, 2012

living machine®

Description: Living Machine is a patent for wastewater treatment. There are two types of systems: Tidal Flow Wetland Living Machine System and Hydroponic Living Machine System. The first one consists of multiple cells that are flooded and drained in turns, mimicking tidal cycles. The nutrients are removed by the micro-ecosystems present in the cells and the effluent also goes through a filtration and disinfection process. The second system is similar to a vertical constructed wetland, where multiple hydroponic reactors take place usually inside a greenhouse (Living Machine®, 2012).

Scale:  

Area: 1m²/person equivalent (Pötz, 2016)

Restrictions:

- requires trained maintenance staff, constant power supply, and spare parts of the system should be available; (Tilley et al., 2014)
- requires primary treatment

Pros x Cons:

+

- does not suffer from mosquito problems
- high efficiency (reduction of BOD, suspended solids and pathogens)
- possible landscape integration
- other plants and animals can be incorporated in the system

−

- requires technical knowledge for design and construction
- large space requirements (less than typical vertical constructed wetlands though)

(Pötz, 2016; Tilley et al., 2014)

Costs: $ $

Figure 39. Hydroponic Living Machine System
Source: Living Machine, 2012

Figure 40. Hydroponic Living Machine in Findhorn
Picture: Findhorn Foundation

Diagram 2. Wastewater treatment: solutions matrix

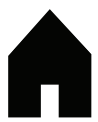
3 | solid waste

Each solution is given the following parameters: description, scale, area, restrictions, pros, cons and costs in a qualitative way. Whenever possible, these parameters are expanded, incorporating quantities. A typical scheme of each system and/or examples are also provided.

The scales indicated refer to the most suitable situation for each solution. However, it does not exclude the possible implementation on different scales.

Main literature for recycling solutions: Van Leer Master Thesis - “Waste Solutions to use in urban districts” (Van Leer, 2016)

Main literature for other solutions: (Ludwig, Hellweg, & Stucki, 2003; McDougall, 2001; Misra et al., 2003; Singh & Singh, 2017)



household

neighborhood

city

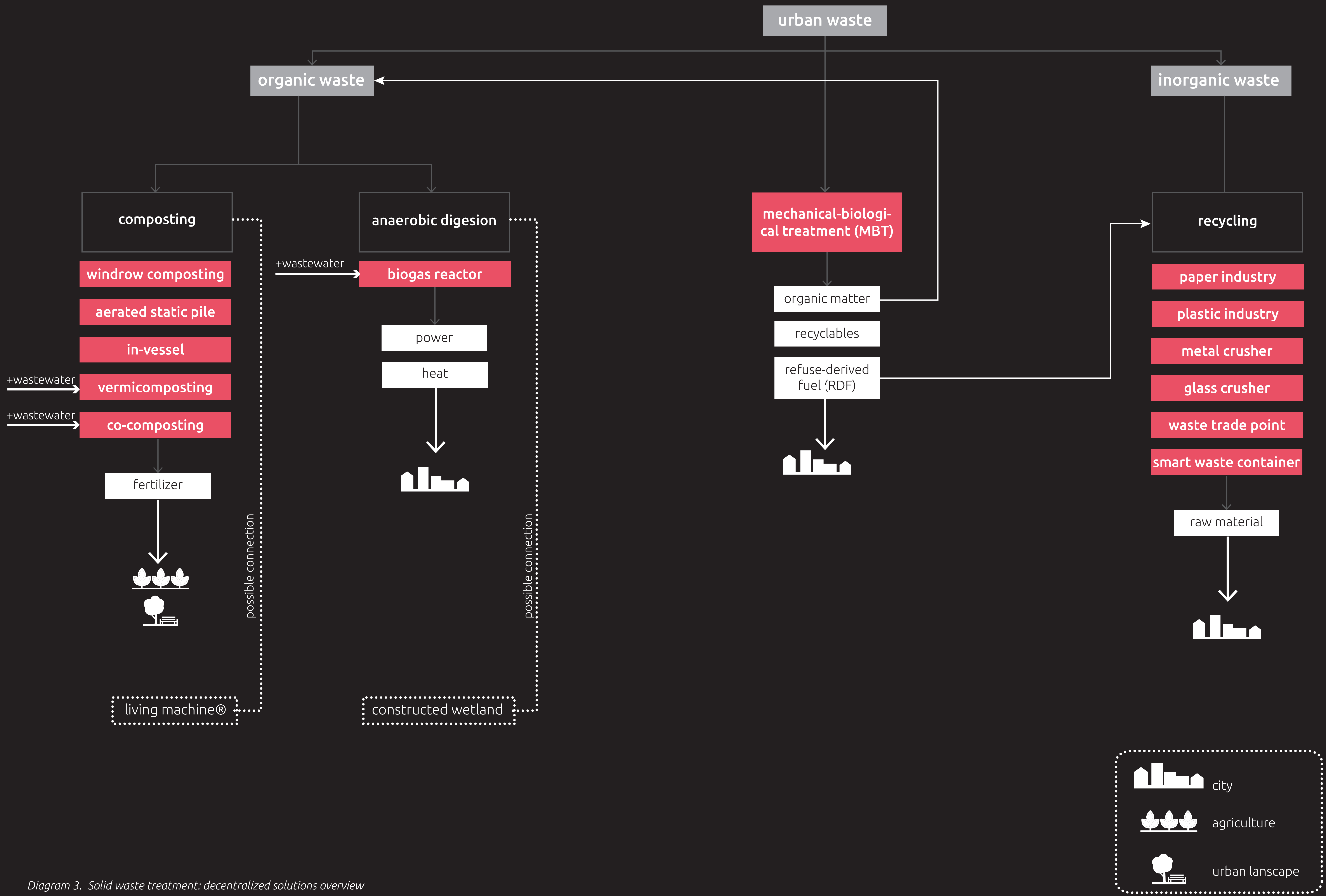


Diagram 3. Solid waste treatment: decentralized solutions overview

paper industry

Description: Small paper industry including a sorting machine and a bailing pressing machine to sort cardboard and paper and transform them into bales.

(Van Leer, 2016)

Scale:

Area: minimum 50m²

Restrictions:

- At least 50m away from housing areas (noise)
- Location close to easy access

(Van Leer, 2016)

Pros x Cons:

\+

- job creation
- can process 0,17kg/day/ person of paper
- the small scale of the industry allows integration with the neighborhood, which also increases awareness

\-

- noise
- transportation requirements (to and from the industry)

(Van Leer, 2016)

Costs: $$

Figure 41. Baling press machine
Source: Sinobaler

plastic industry

Description: Small plastic industry including cleaning and shredding facilities to transform them into bales.

(Van Leer, 2016)

Scale:

Area: 300m²

Restrictions:

- At least 50m away from housing areas (noise)
- Location close to easy access
- 3 or 4 people working

(Van Leer, 2016)

Pros x Cons:

+

- job creation
- can process 300kg/hour = 23,5kg/year/person
- the small scale of the industry allows integration with the neighborhood, which also increases awareness

−

- noise and smell
- transportation requirements (to and from the industry)

(Van Leer, 2016)

Costs: $ $

Figure 42. Plastic shredder
Source: Untha

metal crusher

Description: Small metal industry with a shredding facility to reduce volume of denser metals and transform them into bales.

(Van Leer, 2016)

Scale:

Area: minimum 50m²

Restrictions:

- At least 50m away from housing areas (noise)
- Location close to easy access

(Van Leer, 2016)

Pros x Cons:

+

- job creation
- can process 400kg/hour = 10,7kg/year/person
- the small scale of the industry allows integration with the neighborhood, which also increases awareness
- volume reduction in 6 times

−

- noise
- transportation requirements (to and from the industry)
- if upscaled, it can reduce transportation benefits.

(Van Leer, 2016)

Costs: $ $

Figure 43. Metal crusher
Picture: Russ Willcutt

glass crusher

Description: Small glass industry with a shredding facility to reduce volume of glass and transform them into bales for further recycling facilities.

(Van Leer, 2016)

Scale: 

Area: minimum 50m²

Restrictions:

- At least 50m away from housing areas (noise)
- Location close to easy access

(Van Leer, 2016)

Pros x Cons:

+

- job creation
- can process 300kg/hour = 31,8 kg/year/person
- the small scale of the industry allows integration with the neighborhood, which also increases awareness
- volume reduction

−

- noise
- transportation requirements (to and from the industry)
- if upscaled, it can reduce transportation benefits.

(Van Leer, 2016)

Costs: $ $

Figure 44. Glass crusher
Source: KRS Recycling Systems GmbH

waste trade point

Description: Urban facility where you can take your waste and get money. An alternative is to get goods (fruits and vegetables) or public transport tickets.

Scale: 

Area: 30m²

Restrictions:

- Location close to easy access and in dense urban areas

(Van Leer, 2016)

Pros x Cons:

+

- awareness increase
- can be associated with social programs
- separation of household waste

−

- transportation requirements (to and from the waste point)
- can be restrictive on waste types

(Van Leer, 2016)

Costs: $

Figure 45. "Câmbio Verde" in Curitiba
Residents take their waste (back) and get food in return
Picture: Jaelson Lucas

Figure 46. Retourette in Rotterdam - Netherlands
Picture: Richard Stump

smart waste container

Description: Sensors attached to waste containers that are linked to a system and provide information when its full

(Van Leer, 2016)

Scale:  

Area: n/a

Restrictions:

- create and monitor this system

Pros x Cons:

+

- awareness increase
- less transportation trips
- prevention of overfull containers

−

- costly

(Van Leer, 2016)

Costs: $ $ $

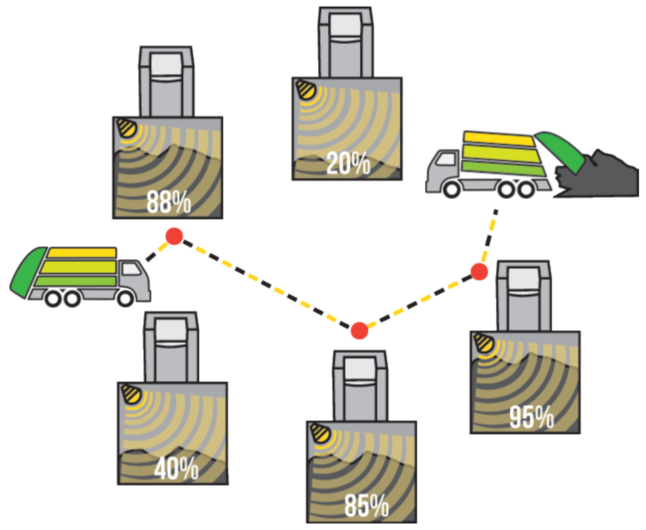


Figure 47. Dynamic waste pick
Source: WasteB®

mechanical-biological treatment (MBT)

Description: An integrated technology that combines mechanical processes (such as sorting and screening) with biological processes (such as composting and anaerobic digestion) (Ludwig, Hellweg, & Stucki, 2003). It is largely used for recovering material for industrial use (in particular refuse-derived fuel - RDF -, a fuel that can substitute fossil fuels) (Ludwig, Hellweg, & Stucki, 2003). There are two main techniques for RDF recovery: two-streams (bio-stabilization) or one stream treatment (bio-drying) (Rada, 2015). However, bio-stabilization results in a contaminated compost, which is not suitable for use (Rada, 2015).

Scale:

Area: 3.000m² (Defra, 2005)

Restrictions:

- minimum capacity for economical operation: 50.000 to 80.000 tons/year

Pros x Cons:

+

- separation of recyclables
- production of usable by-products
- flexible to waste composition and volume
- safer to human health

−

- large space requirement
- costly
- has negative climate effects
- add transportation trips for recyclables

(Ludwig et. al, 2003)

Costs: $ $ $

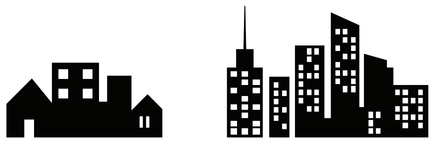
Figure 48. MBT unit
Source: Urbaser

windrow composting

Description: Open-air composting technique with "the mixture of raw materials in long narrow piles called wind-rows"

(Misra, Roy, & Hiraoka, 2003)

Scale:



Area: 1,45 m²/ ton capacity (McDougall, 2001)

Restrictions:

- the desired goal of the output of the compost will determined its inputs restrictions (for example a compost for sale may require specific organic waste separation, whereas if the goal is to minimized landfilling waste, other materials can be included) (McDougall, 2001).
- there has to be a market in place in order to produce the compost regardless of the type (higher or lower quality) (McDougall, 2001).

Pros x Cons:

+	−
• low cost • high quality product • requires regular turning of the composting material	• produce odors when including kitchen waste or when it is too large (above 5.000 to 10.000 ton/year) • limited control of the moisture (temperature and content)

(Ludwig et. al, 2003; McDougall, 2001)

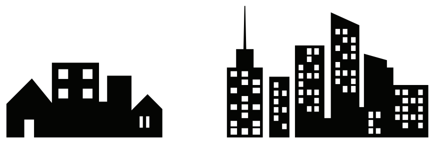
Costs: $

Figure 49. Composting site in Germany
Picture: Crystalclear CC BY-SA 3.0

aerated static pile

Description: Similar to windrow composting, with additional mechanical aeration system

(Misra, Roy, & Hiraoka, 2003)

Scale: 

Area: 1,45 m²/ ton capacity (McDougall, 2001)

Restrictions:
- requires a base structure

(Misra, Roy, & Hiraoka, 2003)

Pros x Cons:

+
- more control of the mix
- allows larger piles and do not required further turning
- faster composting

−
- bulky materials do not get compost (such as straw or wood)
- more sensitive the selection of the materials
- difficult to control odors

(Misra, Roy, & Hiraoka, 2003)

Costs: $

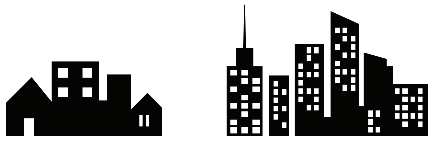
Figure 50. Aerated static pile - California
Picture: Caroll Mortensen

in-vessel composting

Description: Composting techniques that occur in a closed environment (building, container or vessel). They typically use forced aeration and mechanical turning. There are many possible combinations that result in different methods such as bin composting, rectangular agitated beds and rotating drums.

(Misra, Roy, & Hiraoka, 2003)

Scale:



Area: Flexible. For rectangular agitated beds and rotating drums minimum length of 35m

(Misra, Roy, & Hiraoka, 2003)

Restrictions:

- enclosed environment

Pros x Cons:

+	−
• more control of the mix • low noise and more odor control • higher weather tolerance	• higher costs

(McDougall, 2001)

Costs: $ $

Figure 51. In-vessel compositing: container
Source: X-Act Systems

Figure 52. In-vessel compositing: building
Source: South London Waste Partnership

vermicomposting

Description: Composting techniques that uses earthworms. The organic material acts as food for the worms and their excreta is rich in nitrates. The worm's movement is responsible for aerating and turning the mix.

(Misra, Roy, & Hiraoka, 2003)

Scale:

Area: Flexible.
1kg of worms consumes 1kg of waste. A compost heap of 2.4 x 1.2 x 0.6 m can host 50.000 worms (Misra, Roy & Hiraoka, 2003)
1.000 breeders weigh 2,2kg (Appelhof, Olszewski & Stewart, 2017)

Restrictions:

- performance is linked to type of application, substrate and aeration systems

(Singh & Singh, 2017)

Pros x Cons:

+

- earthworms consume a wide range of organic material
- no need for aeration and turning
- superior compost quality
- can be used in wastewater treatment
- contributes for soil remediation and fertility
- can be used as landscaping and biofertilzer
- small space requirement

−

- requires continuous input of water and organic waste, which may also add transportation costs
- low social acceptance
- produce GHG emissions
- in high concentrations may cause harm to soil and plants
- inexistent market
- emits odors

(Singh & Singh, 2017)

Costs: $

Figure 53. Vermicomposting in Kahariam Farms - Phillipines
Source: mindnetworks.blogspot.nl

Diagram 4. Waste disposal: solutions matrix

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