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Tratamiento y valorización de aguas residuales y lodos mediante humedales construidos

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Logroño, 20 de Abril de 2016

Research Topics

- Natural wastewater treatment systems
  - Constructed wetlands
  - Microalgae systems

Constructed wetlands

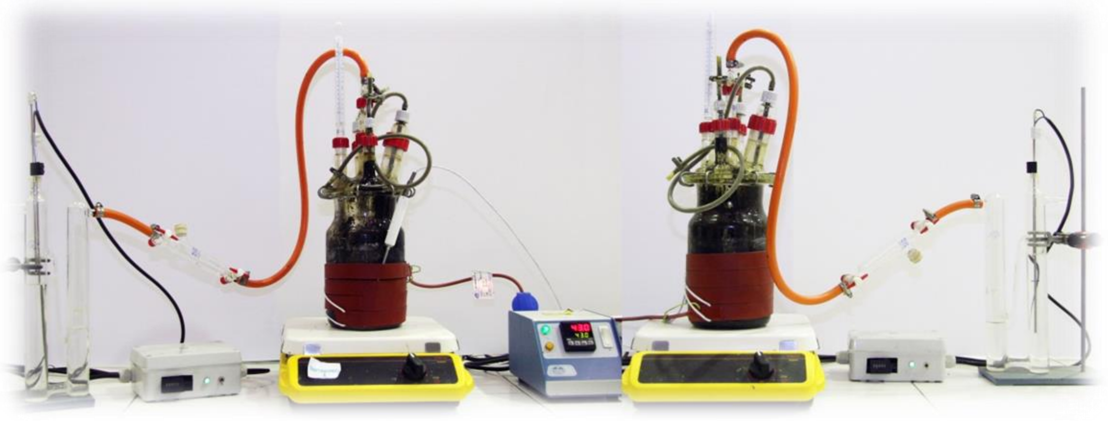
Microalgae
raceway ponds and photobioreacors

Research Topics

- Sludge (and other biomass) treatment systems
  - Constructed wetlands
  - Anaerobic digestion

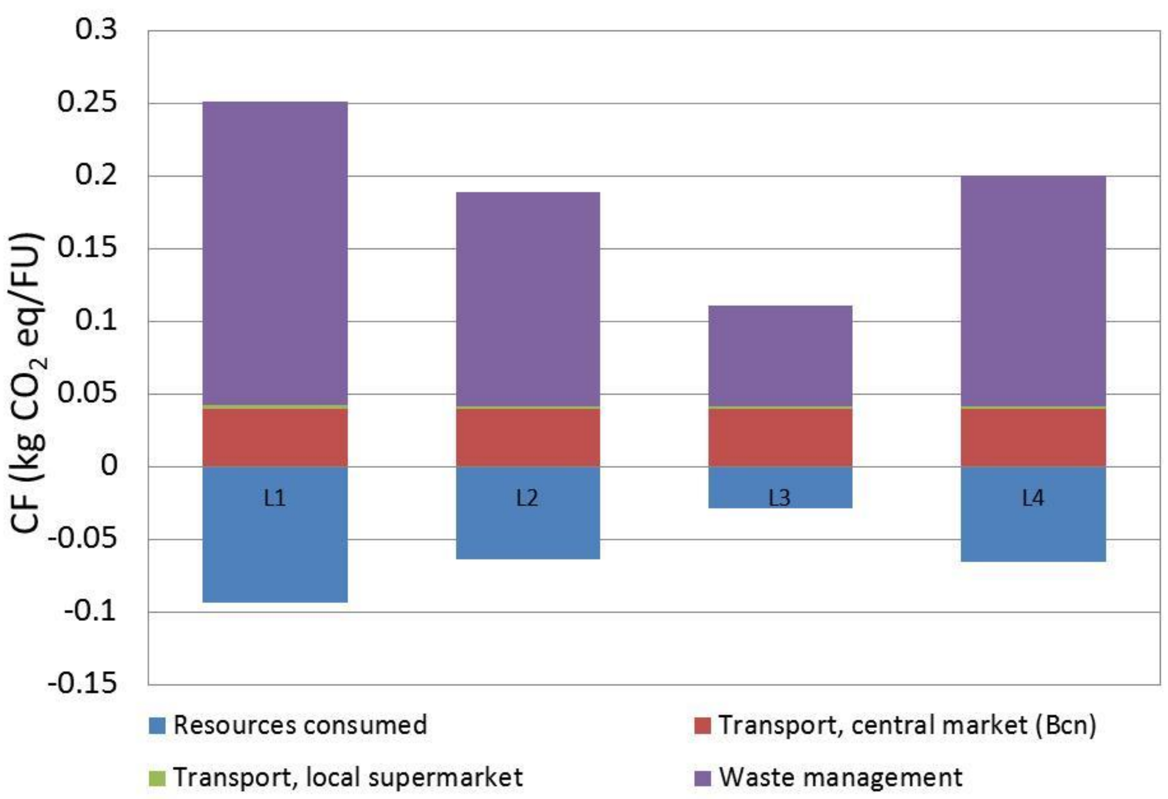
Sludge treatment wetlands

Biogas production



Research Topics

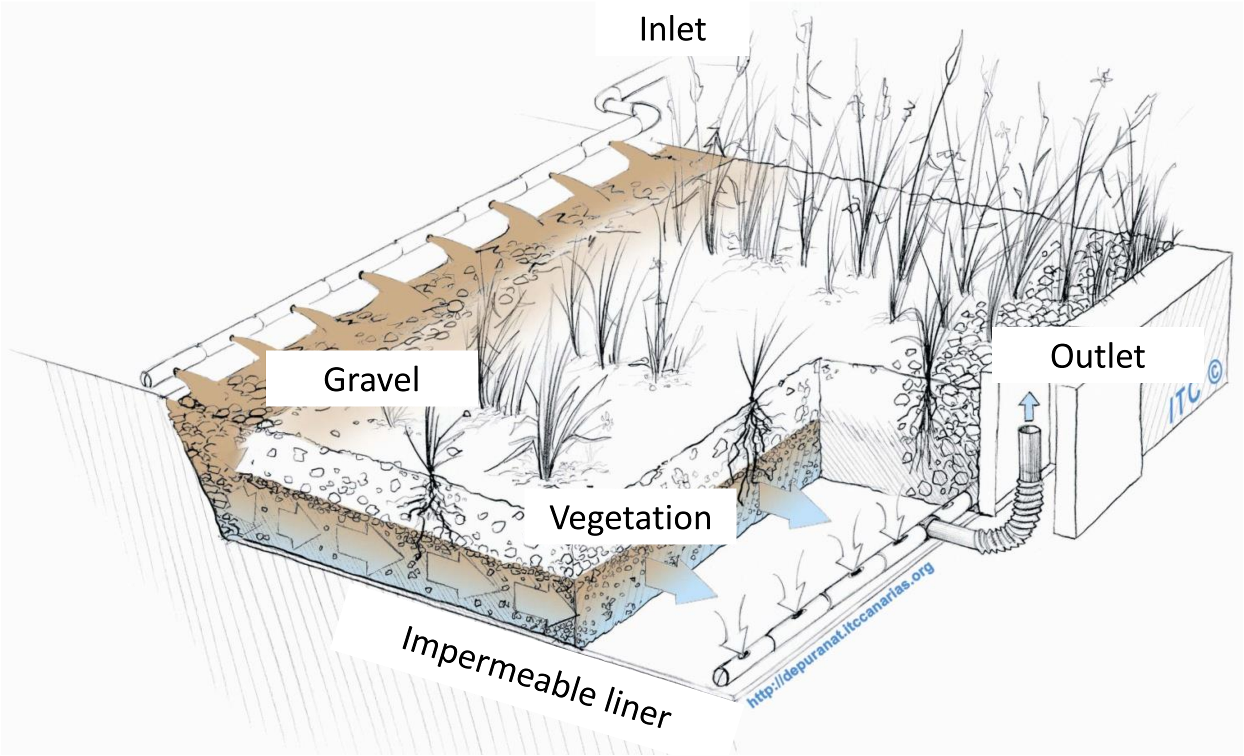
- Mathematical Modelling of biotechnologies (constructed wetlands, microalgae photobioreactors)
- Carbon footprint and Life Cycle Analysis (LCA)



Constructed wetlands

Constructed wetlands (CWs) are natural treatment technologies for household and/or municipal or industrial wastewater.

A CW is a shallow basin filled with some sort of filter material (substrate), usually sand or gravel, and planted with vegetation.



Constructed wetlands

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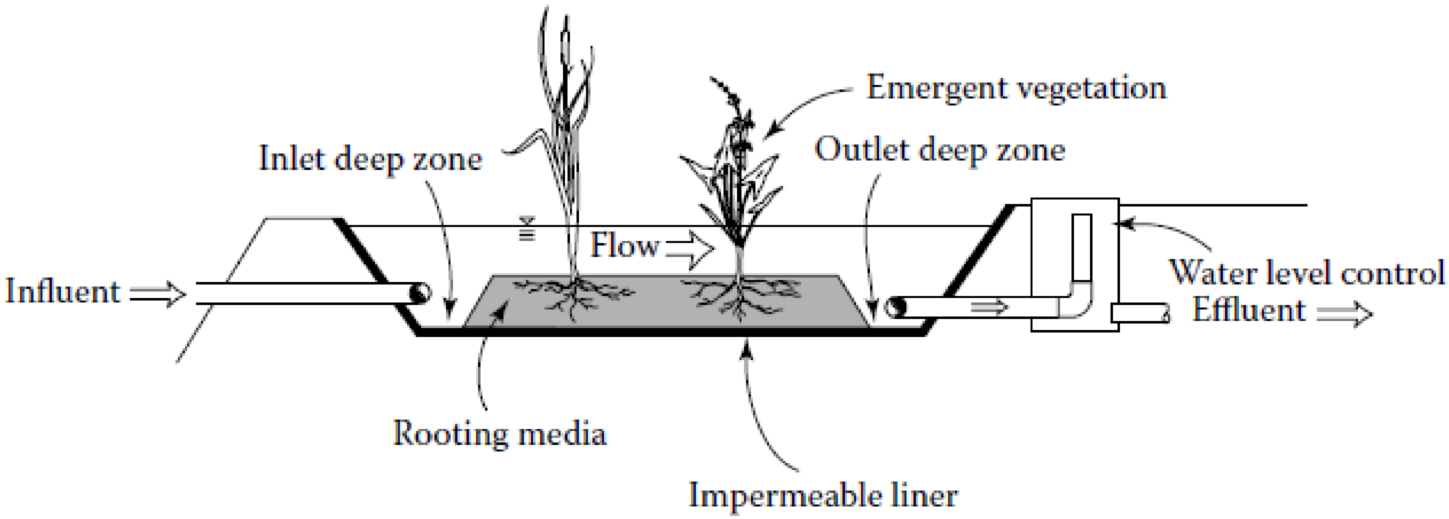
Wastewater is introduced into the basin and flows over the surface or through the substrate.



The mechanisms that occur in CW systems for wastewater treatment are complex and include *chemical*, *physical* and *biological* processes (sedimentation, filtration, oxidation, reduction, adsorption, precipitation, pathogen removal)

Constructed wetlands

Advantages	Limitations
Effective wastewater treatment by removing broad spectrum of contaminants	Temperature sensitive; cold temperatures reduce contaminant removal efficiency
Low costs of investment, operation and maintenance	Clogging
Water reuse	Pretreatment required at least to remove excess suspended solids
Integration into the landscape; restored habitat for native and migratory wildlife	Large land requirement
Low environmental impacts; low energy requirement	Low phosphorous removal

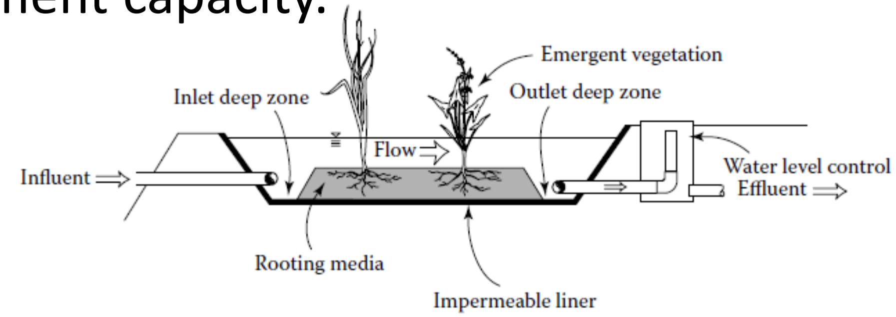
- Land Requirement

2-5 m^2 $p.e.^{-1}$ CW systems vs. < 1 m^2 $p.e.^{-1}$ Conventional WWTP

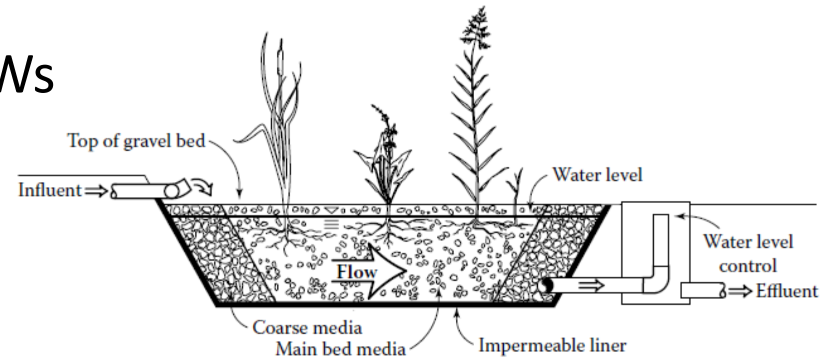
Constructed wetlands

Three types of wetlands to emphasize specific characteristics of wetland ecosystems for improved treatment capacity.

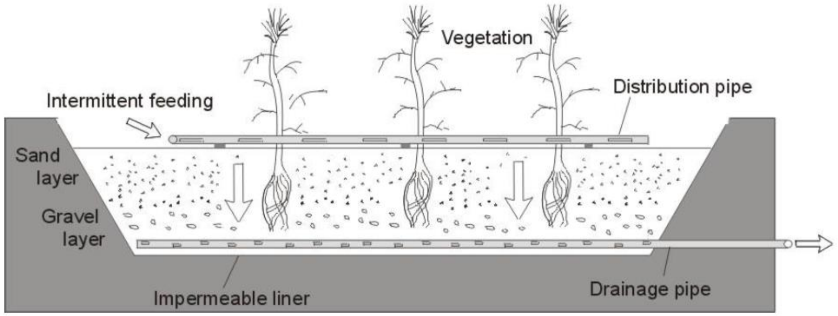
- Free water surface (FWS) CWs



- Horizontal subsurface flow (HSSF) CWs



- Vertical flow (VF) CWs



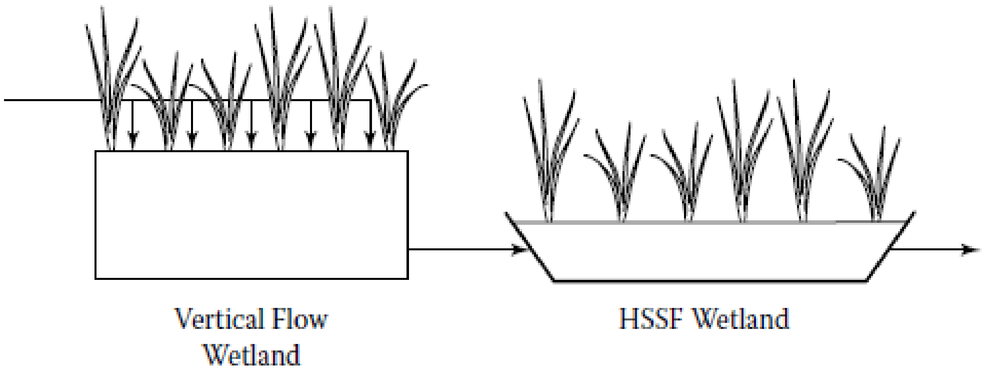
Langergraber and Haberl, 2004

Constructed wetlands

- Hybrid systems

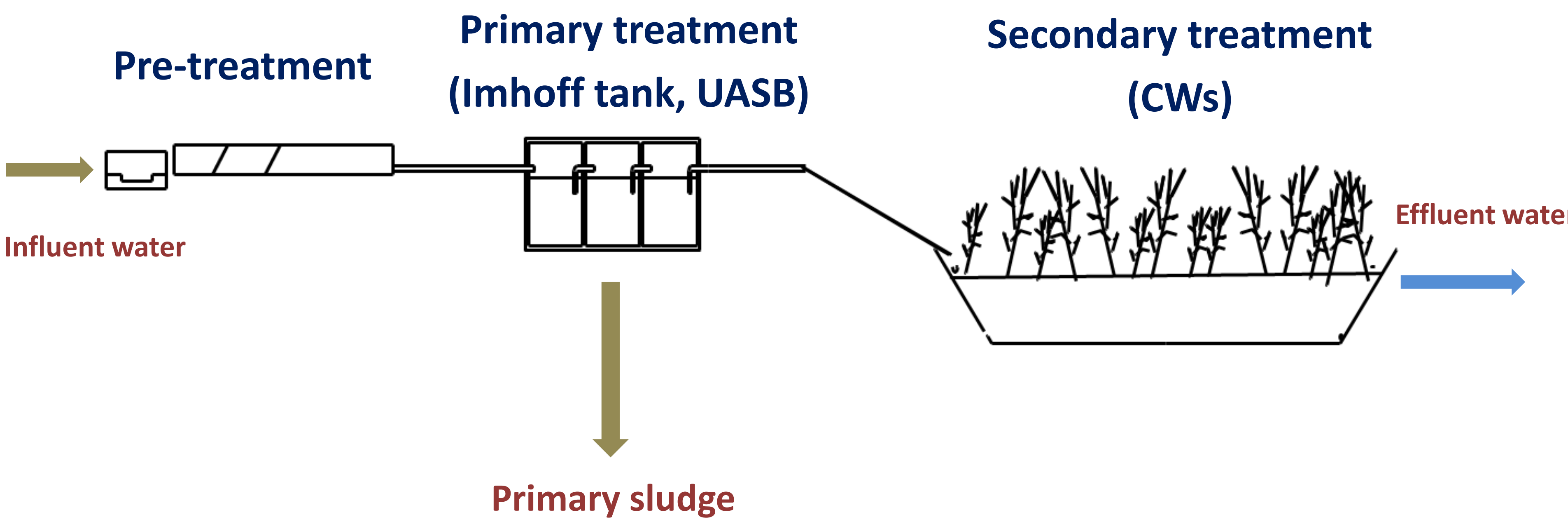
Various constructed wetland configurations may be combined so as to increase their treatment efficiency.

These hybrid systems are normally comprised of vertical flow (VF) and horizontal subsurface flow (HSSF) CW



Constructed wetlands

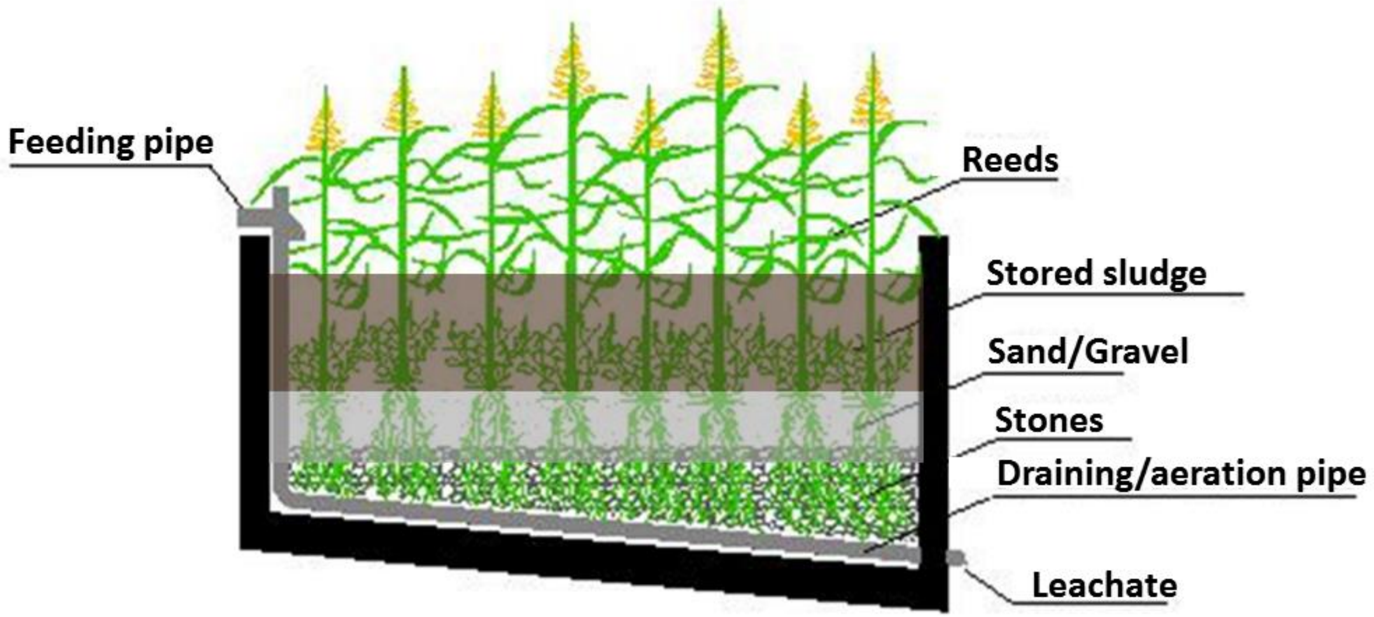
- Pre-treatment and primary treatment



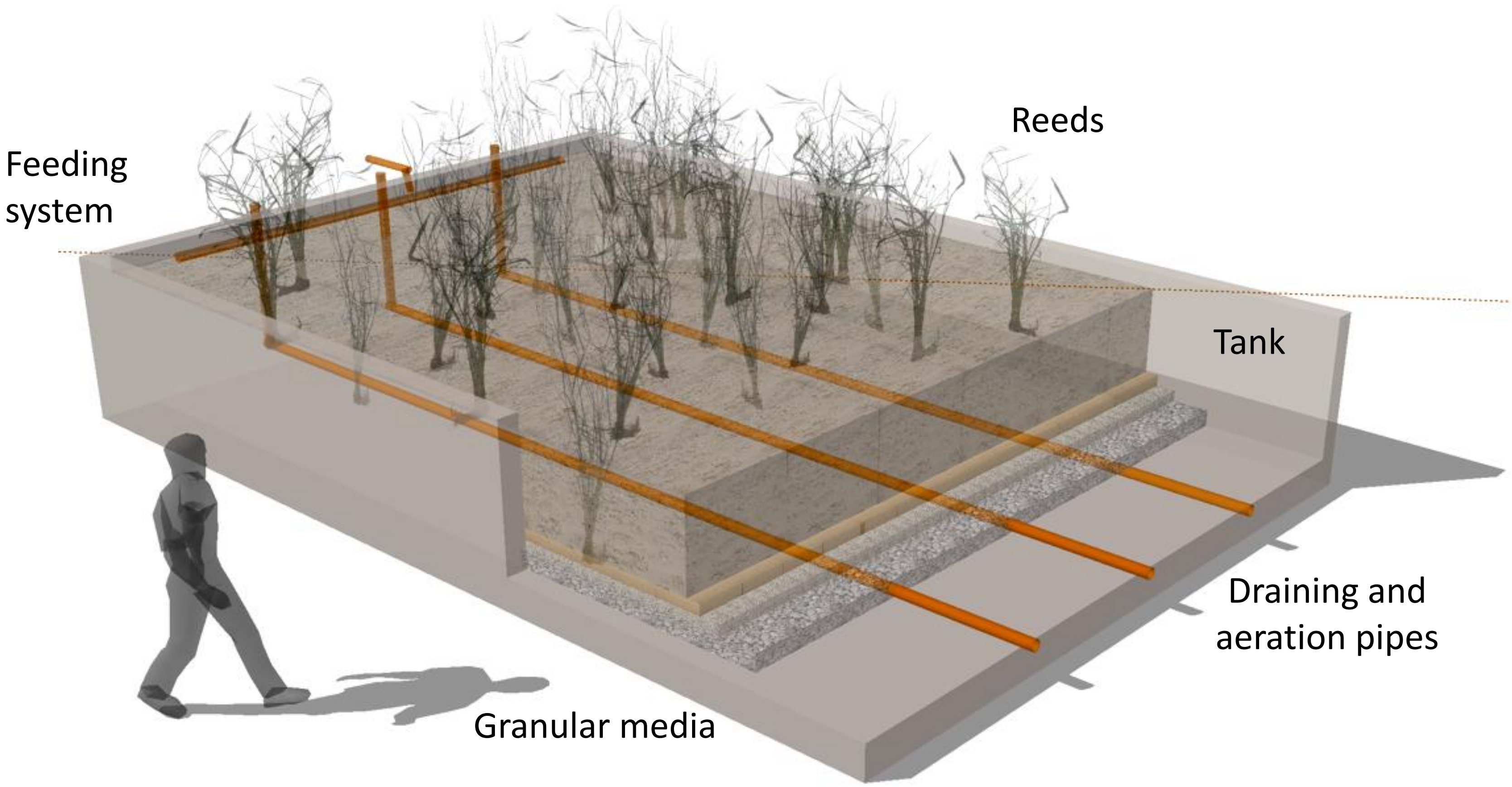
Sludge Treatment Wetlands

- Sludge treatment wetlands

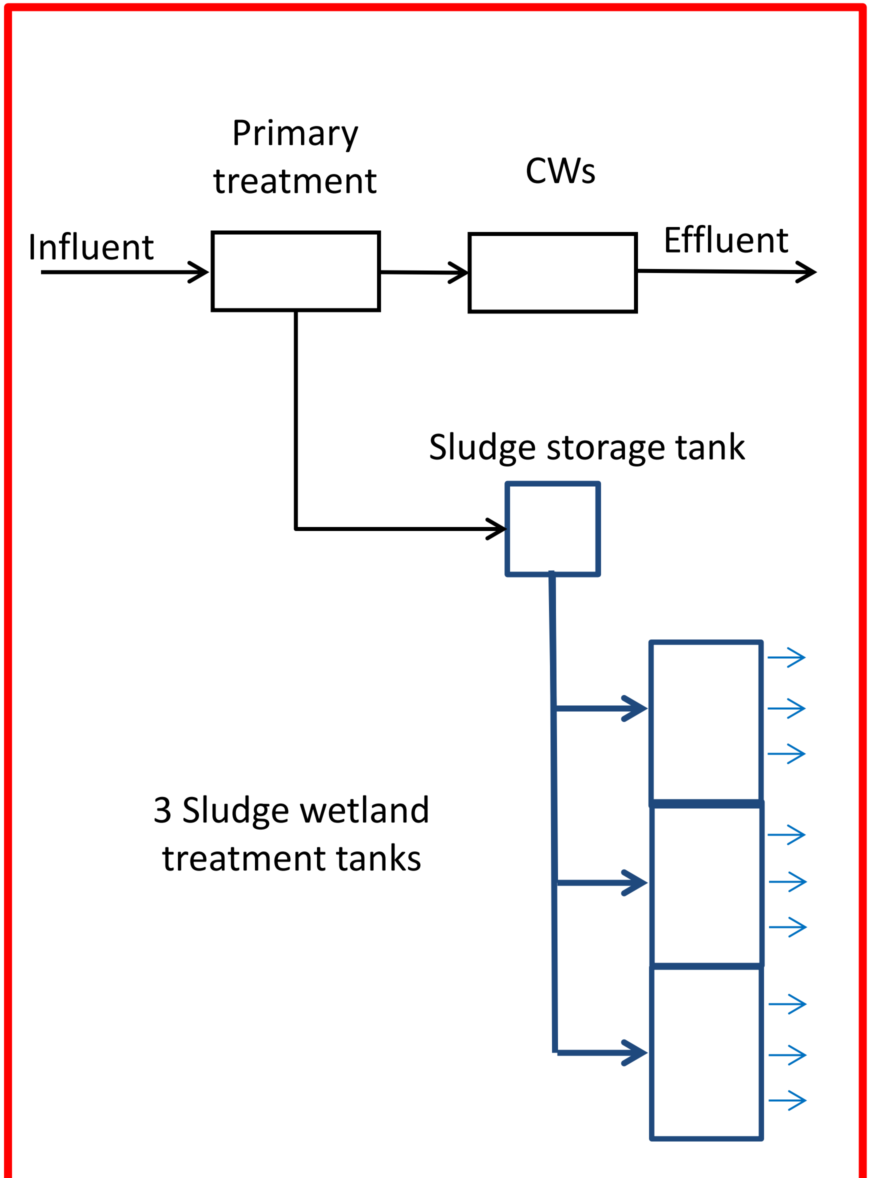
They are low cost technologies for primary and secondary sludge treatment. They are made up of shallow ponds, beds or trenches filled with a gravel layer and planted with emergent rooted wetland vegetation such as *Phragmites australis* (common reed).

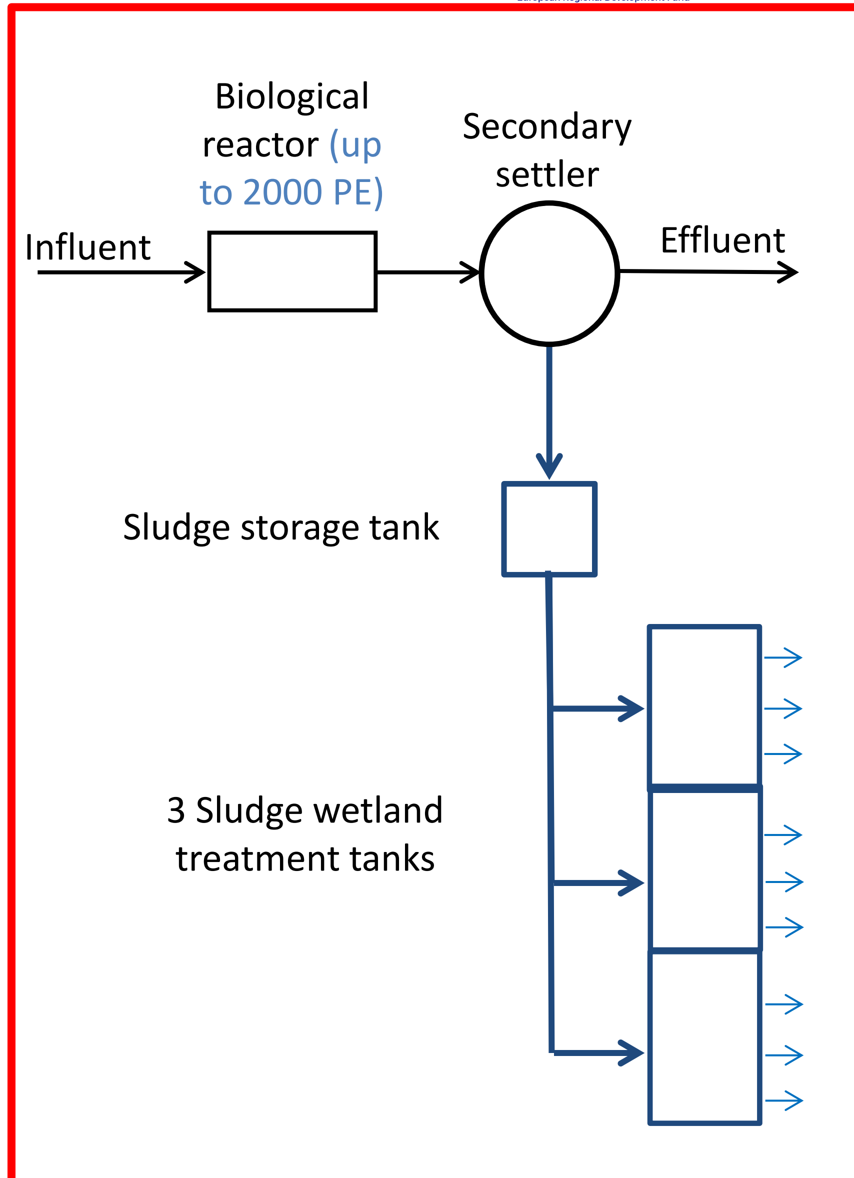


Sludge Treatment Wetlands



Sludge Treatment Wetlands





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Just after feeding

During resting period (observe surface cracking)

Sludge Treatment Wetlands

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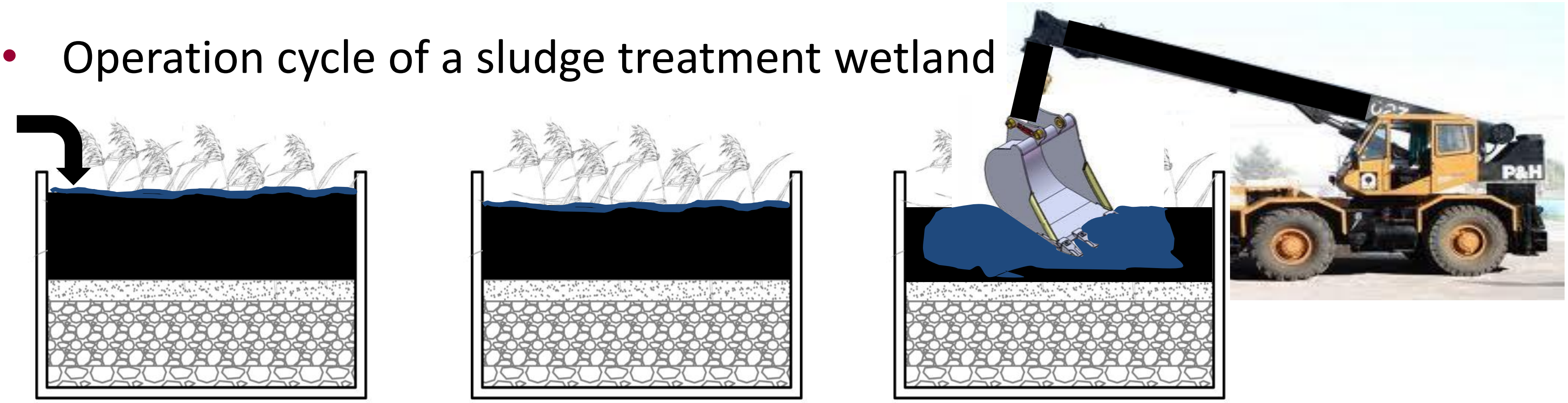
- Operation cycle of a sludge treatment wetland



Feeding period
5-10 years

Final resting period
3-24 months

Biosolids removal

Composting plant

Reuse in agriculture

Sludge Treatment Wetlands

- Treatment processes in sludge treatment wetlands

1. Dewatering
   Drainage and evapotranspiration
   Final product with approximately 30% TS
   Leachate returned to the head of the plant

2. Mineralisation
   Mostly aerobic processes
   Final product with 40-50% VS/TS

3. Hygenisation
   Due to long storage periods
   Absence of faecal indicators

Sludge Treatment Wetlands

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Advantages of sludge treatment wetlands

- This is more than a “drying technology”. Aerobic mineralization and hygienisation are intrinsic processes of this technology.
- Allows storage of sludge for more than 5 years (usually around 10 years).
- No odours because is aerobic.
- Final product can be reused as fertilizer.

Sludge Treatment Wetlands

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Tank

Drainage/aeration pipes

Facility in Seva (Barcelona, Spain). 1500 PE

Picture: Depuradores d'Osona

Sludge Treatment Wetlands

Filter material

Spreading pipes

Facility in Seva (province of Barcelona, Spain). 1500 PE

Picture: Depuradores d'Osona

Sludge Treatment Wetlands

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Planting

Alpens (Barcelona). 400 PE

Sludge treatment wetlands

Sant Boi de Lluçanès (Barcelona). 600 PE

Sludge Treatment Wetlands

Biosolids removal and transportation

Seva (Barcelona). 1,500 P.E.

Constructed Wetlands

Constructed wetlands systems and *sludge treatment wetlands* are competitive with conventional technologies (e.g. activated sludge systems and centrifuge or filters) in terms of treatment efficiency.

Life Cycle Assessment

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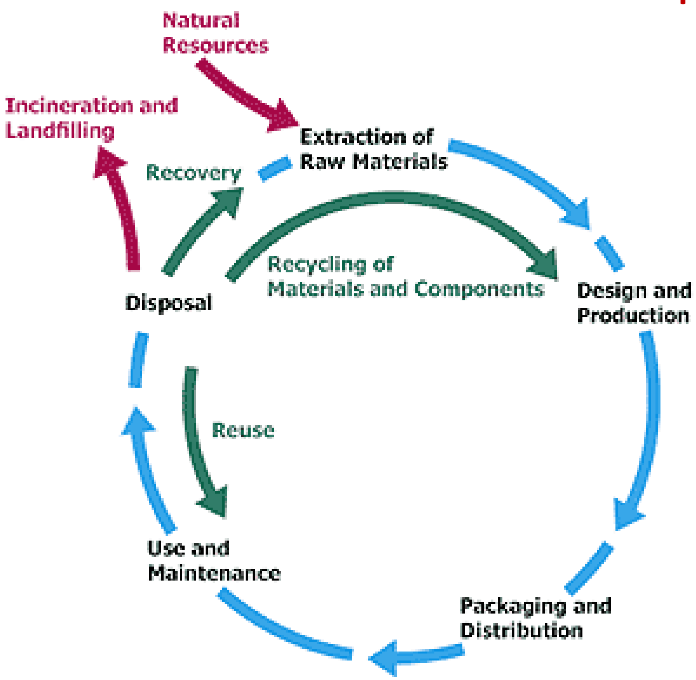
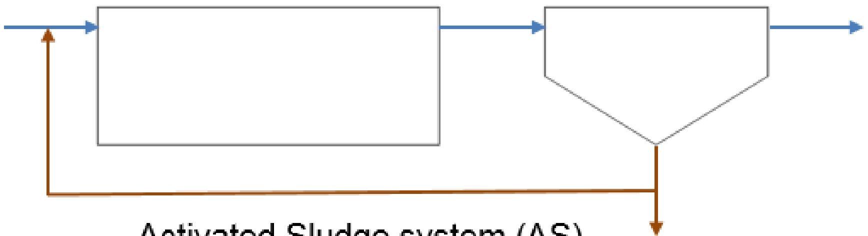
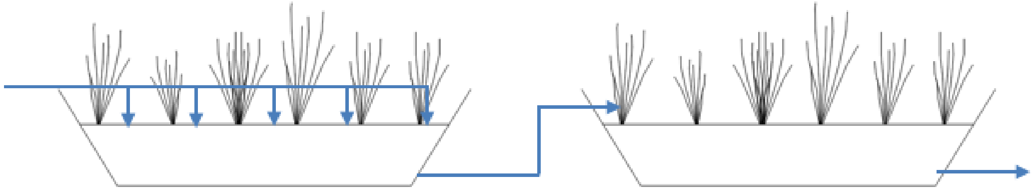
LCA of constructed wetlands systems and activated sludge system for municipal wastewater.







ISO 14040:2006
ISO 14044:2006

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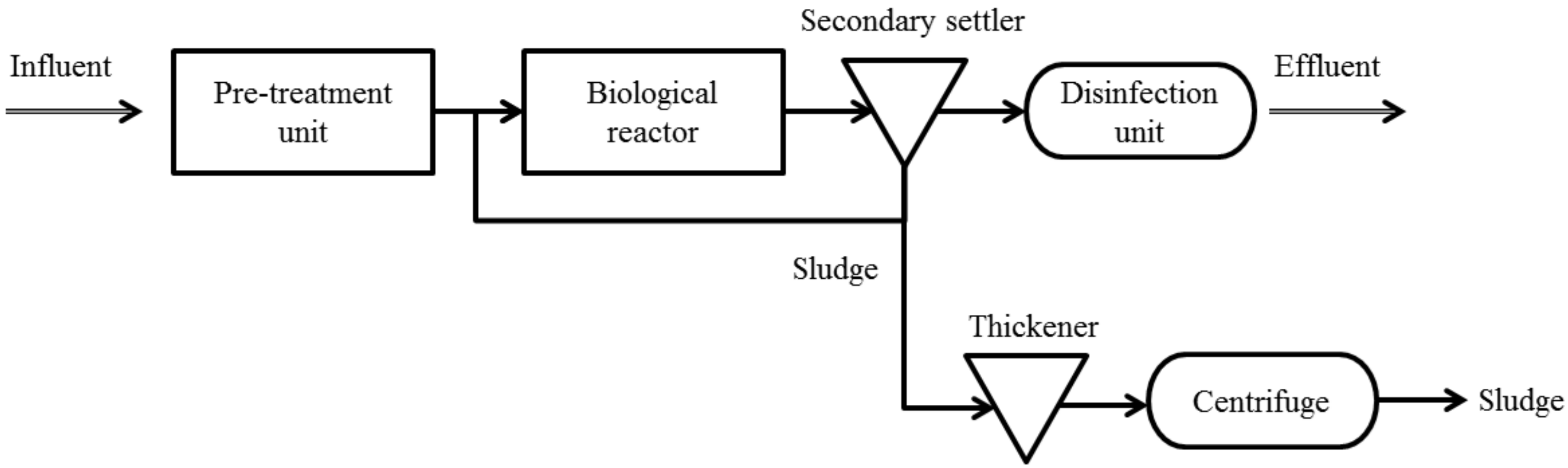
System design

1,500 p.e

292.50 m^3/d

Activated sludge system (AS)



Design and operational parameters: Construction Project (Agencia Catalana del Aigua (ACA))

Garfí et al., 2016

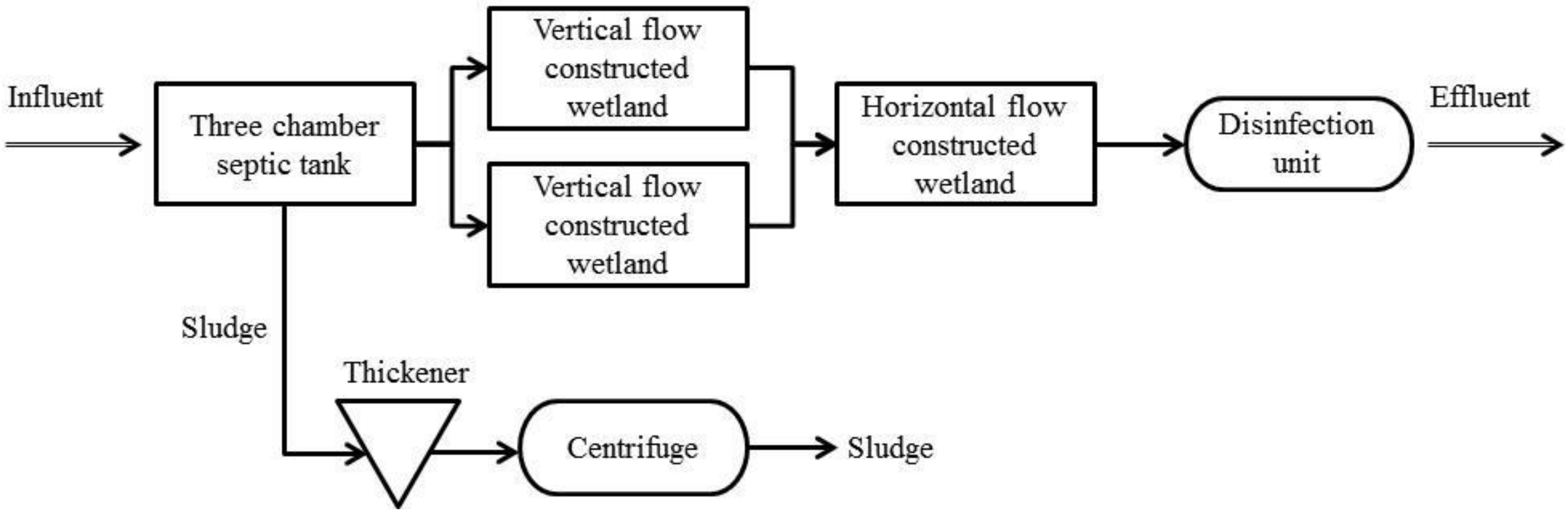
Life Cycle Assessment

System design

1,500 p.e

292.50 m^3/d

Constructed Wetland Systems (CW)



Design and operational parameters: construction project (UPC)

Garfí et al., 2016

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Goal and Scope

FU: 1 m³ of water

System boundaries:

Construction and operation

Inventory

	Unit	AS	CW
Systems characteristics			
Average daily wastewater flow rate	m^{-3} $p.e.^{-1}$ d^{-1}	0.20	0.20
Population equivalent	p.e.	1,500	1,500
Land required	m^2 $p.e.^{-1}$	0.6	3
Inputs			
Construction materials			
Concrete and cement	m^3 m^{-3}	3.11E-02	1.13E-04
Metals	kg m^{-3}	9.72E-03	2.43E-02
Coating (Bituminous coating and basalt)	kg m^{-3}	9.12E-02	4.73E-03
Plastics	kg m^{-3}	8.30E-04	2.80E-03
Gravel and sand	kg m^{-3}	7.19E-02	7.82E-01
Bricks	kg m^{-3}	-	1.66E-02
Glass fibre	kg m^{-3}	-	-
Operation			
Chlorine dioxide	g m^{-3}	1.20E+1	1.20E+1
Polyelectrolyte	kg m^{-3}	9.57E-04	1.53E-06
Coagulant	kg m^{-3}	1.13E-01	-
Electricity	kWh m^{-3}	1.26E+00	2.20E-01
Outputs			
Waste			
Primary Sludge	kg m^{-3}	1.35E-01	3.45E-01
Emissions to air (direct emissions)			
CO_2	g m^{-3}	1.70E-1	9.92E+2
CH_4	g m^{-3}	-	1.09E+1
N_2O	g m^{-3}	1.10E-01	1.69E-02
NH_4^+	g m^{-3}	-	-

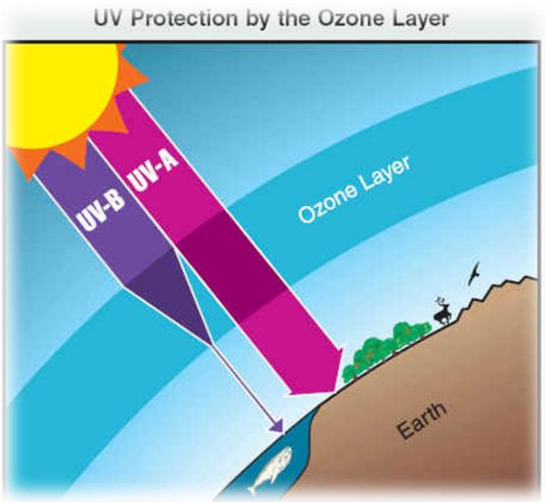
Life Cycle Assessment

Impact assessment

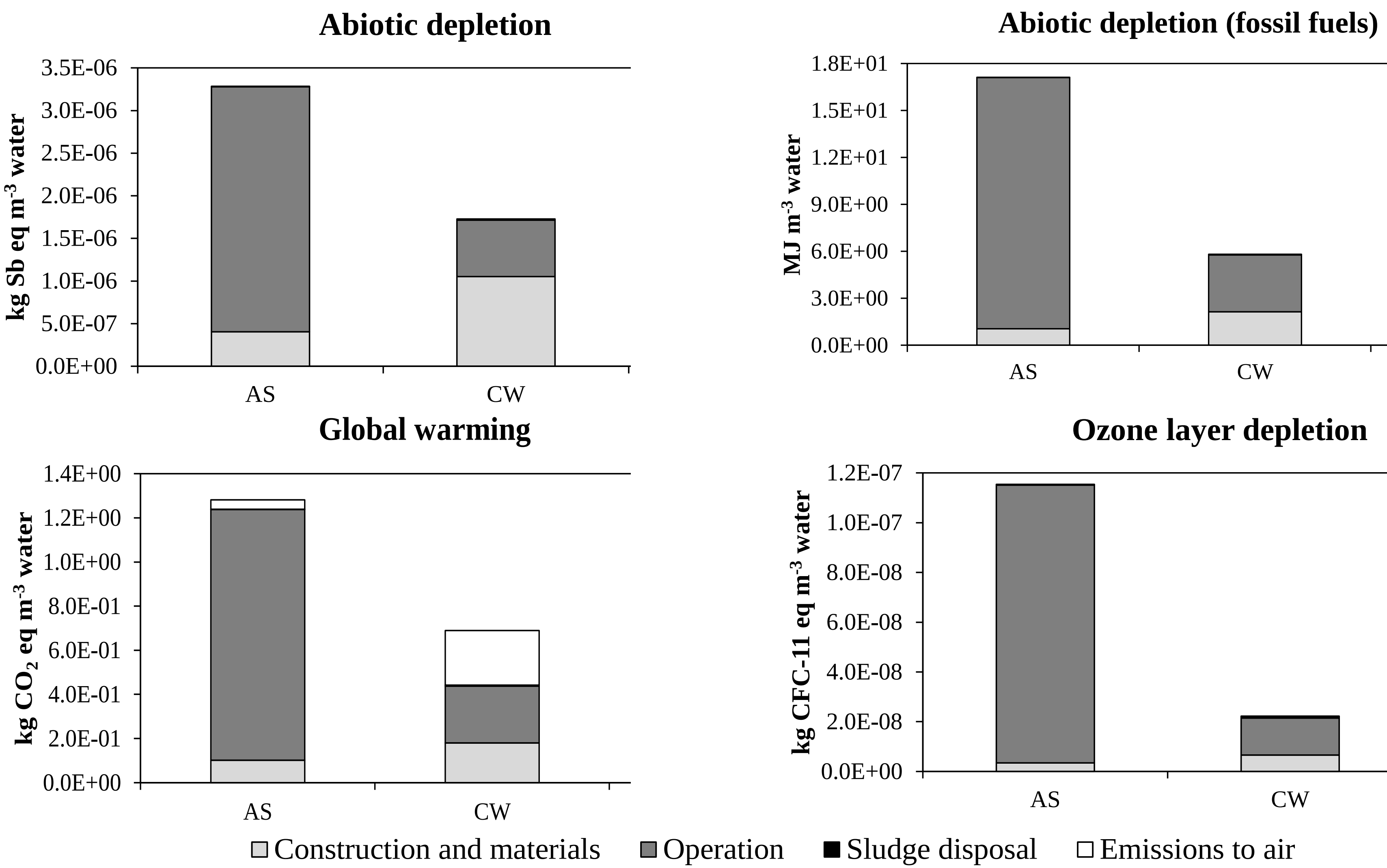
SimaPro® 8 (Pre-sustainability, 2014)
CML-IA baseline method

Impact categories:

- Abiotic Depletion ($kgSb_{equ}$)
- Abiotic Depletion (fossil fuels) (MJ)
- Global Warming Potential ($kgCO_{2equ}$)
- Ozone Layer Depletion ($kgCFC\text{-}11_{equ}$)
- Acidification ($kgSO_{2equ}$)
- Eutrophication ($kgPO_{4equ}$)



Impact assessment results



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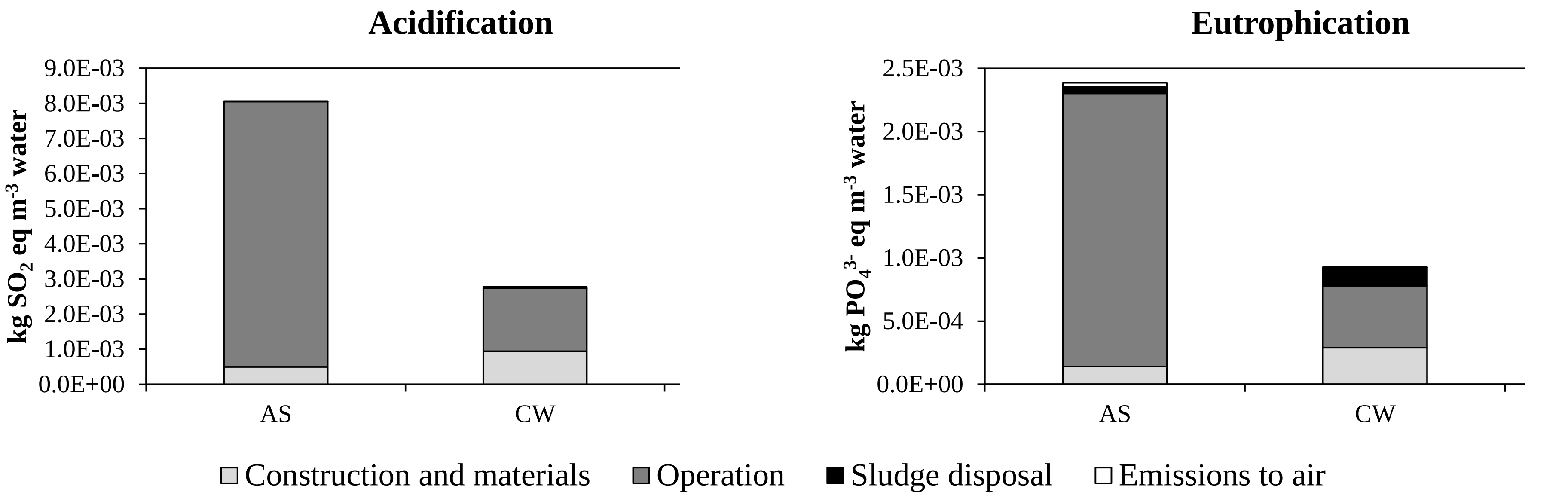
Impact assessment results



The environmental impacts of the conventional wastewater treatment plant (scenario AS) were between *2 and 5 times higher* than those of the CW scenario.

This was mainly due to the high *electricity* and *chemicals* consumption for the operation of the conventional wastewater treatment plant.

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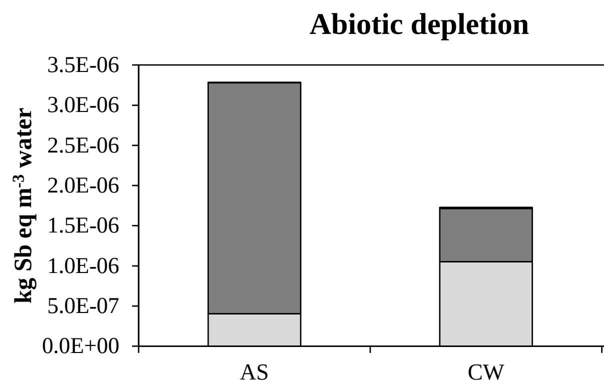
Impact assessment results

In the case of the *AS scenario*, the major impact was due to the *operation phase* (from 87 to 97% of the total impact in all indicators), while the construction phase accounted for less than 12% of the total impact in all indicators.

In the case of the *CW scenario*, the life cycle was influenced by both the *construction and operation* phases.



CWs require a large amount of raw material for their implementation.

Land Requirement

0.6 vs. 3 m^2 $p.e^{-1}$

Life Cycle Assessment

CO_2 emissions reduction

	Unit	AS	CW
CO_2 emissions	$kg_{CO2\ eq}\ m^{-3}$	1.28	0.69
	$kg_{CO2\ eq}\ p.e.^{-1}\ d^{-1}$	0.25	0.13
CO_2 emissions reduction	$kg_{CO2\ eq}\ p.e.^{-1}\ d^{-1}$	-	0.12
	$kg_{CO2\ eq}\ p.e.^{-1}\ year^{-1}$	-	42.14

Life Cycle Assessment

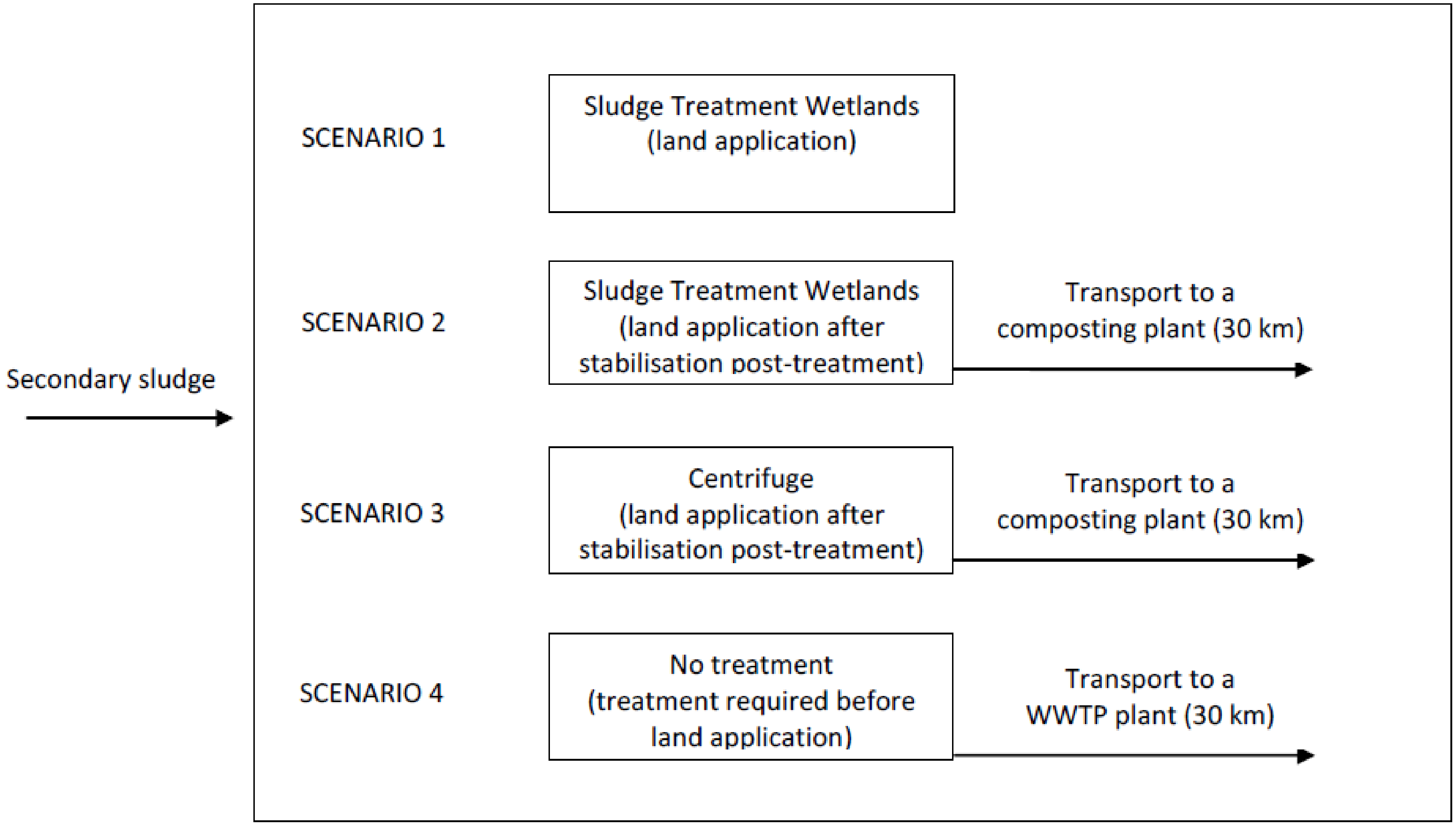
Economic assessment

The conventional wastewater treatment system showed to be between *2 and 3 times more expensive* than the CW system

	Unit	AS	CW
Capital cost	€ p.e.$^{-1}$	540.93	210.36
Operation and maintenance cost	€ m^{-3}	0.79	0.40
Capital cost reduction	€ p.e.$^{-1}$	-	330.57
Operation and maintenance cost reduction	€ m^{-3}	-	0.39
	€ p.e.$^{-1}$ year^{-1}	-	27.76

Life Cycle Assessment

Sludge treatment wetlands



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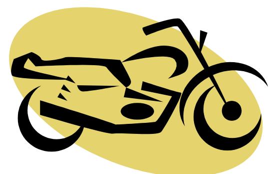
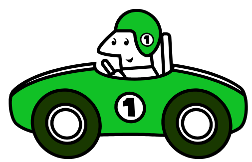
Global warming potential (CO$_2$ equivalent) of 1 ton of sludge

Sludge treament wetlands



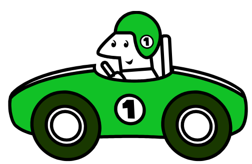
20 km

Sludge treament wetlands + composting



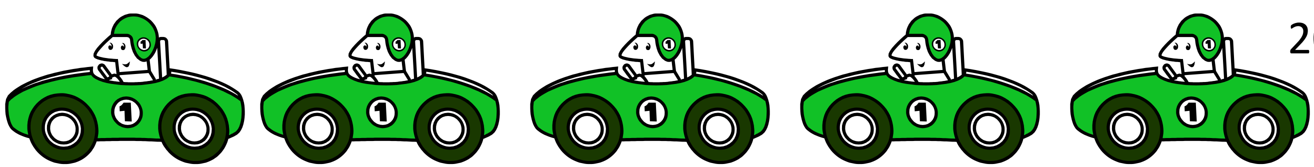
20 km

Centrifuge + composting



20 km

Transport



20 km

Uggetti al., 2014

Final remarks

- Constructed Wetlands and Sludge Treatment Wetlands are *appropriate technologies* for wastewater and sludge treatment in ***small communities***.

- They help to reduce *environmental impacts* and *costs* associated with wastewater and sludge treatment.

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