Wastewater treatment of small and medium size communities

Pascal Molle

Stéphanie Prost-Boucle

Irstea – Lyon

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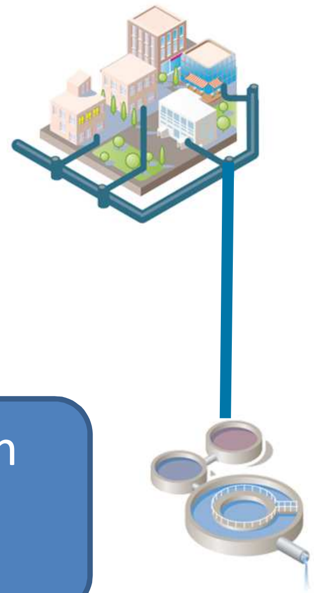
www.irstea.fr

Needed data before starting

Loads to treat
- Organic, hydraulic
- Rain events
- Loads variations
- Increase population rate
- …



Valorization
- REUSE
- energy
- …

Final sludge valorization
- Land disposal
- …

Outlet quality
- Carbon, nitrogen, Phosphorus
- REUSE
- …

Needed data before starting

Loads to treat

- Organic, hydraulic
- Rain events
- Loads variations
- Increase population rate

Parameters		BOD_5	COD	TSS	KN	$N\text{-}NH_4$	TP
Average (mg/l)		265	646	288	67,3	54,9	9,4
Range	sup.	570	1341	696	123,1	98,3	18,4
	inf.	39	122	53	14,1	12	2
Ratio / PE.j		**60g**	**150 g**	**75 g**	**15 g**		**2,1 g**

Needed data before starting

Loads to treat

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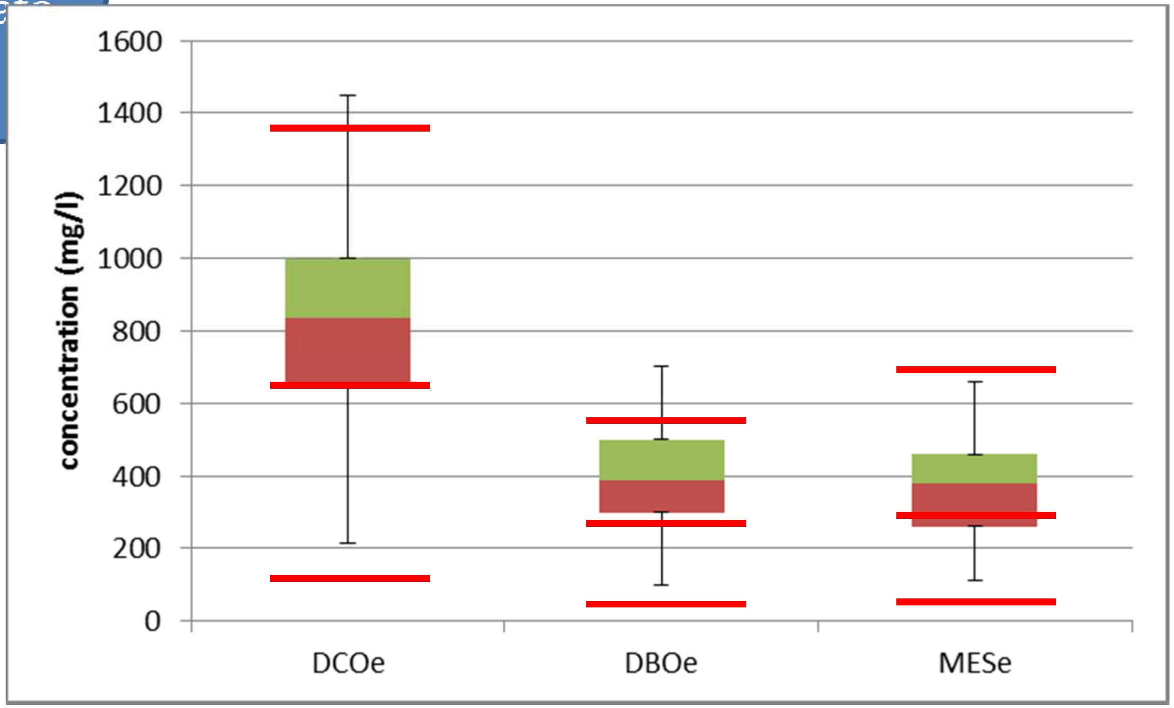
Maroc



Needed data before starting

Loads to treat

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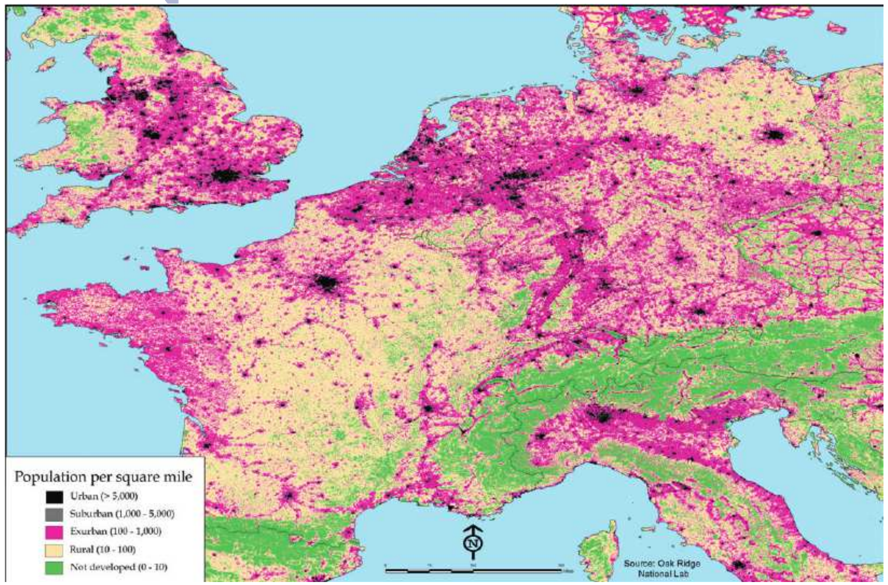
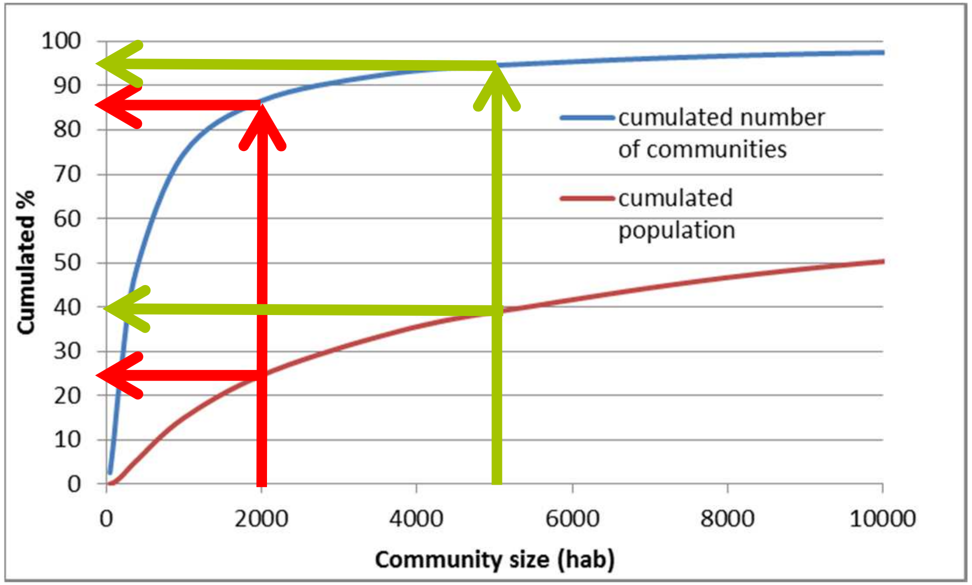
- …

	DBO_5	MES	DCO	NTK	NH_4
Rejet pour un EH en métropole	60	72	157,2	15,5	11,5
Rejet pour un EH dans les DOM	60	61	127,6	16,9	12,7
Unité	g d'O2/jour	g de MES/jour	g d'O2/jour	g de N/jour	g de N/jour

Maroc 30 $gBOD_5$ 70 l/PE/j

France : rural theritory





25 % of the population live in communities < 2,000 habitants. Represents 86 % of the municipalities

39 % of the population live in communities < 5,000 habitants. Represents 95 % of the municipalities

Number of WWTP

2015:

- **21 079 WWTP**
- **17 284 WWTP < 2 000 EH**

82 %

New construction

Retrofiting

Small size

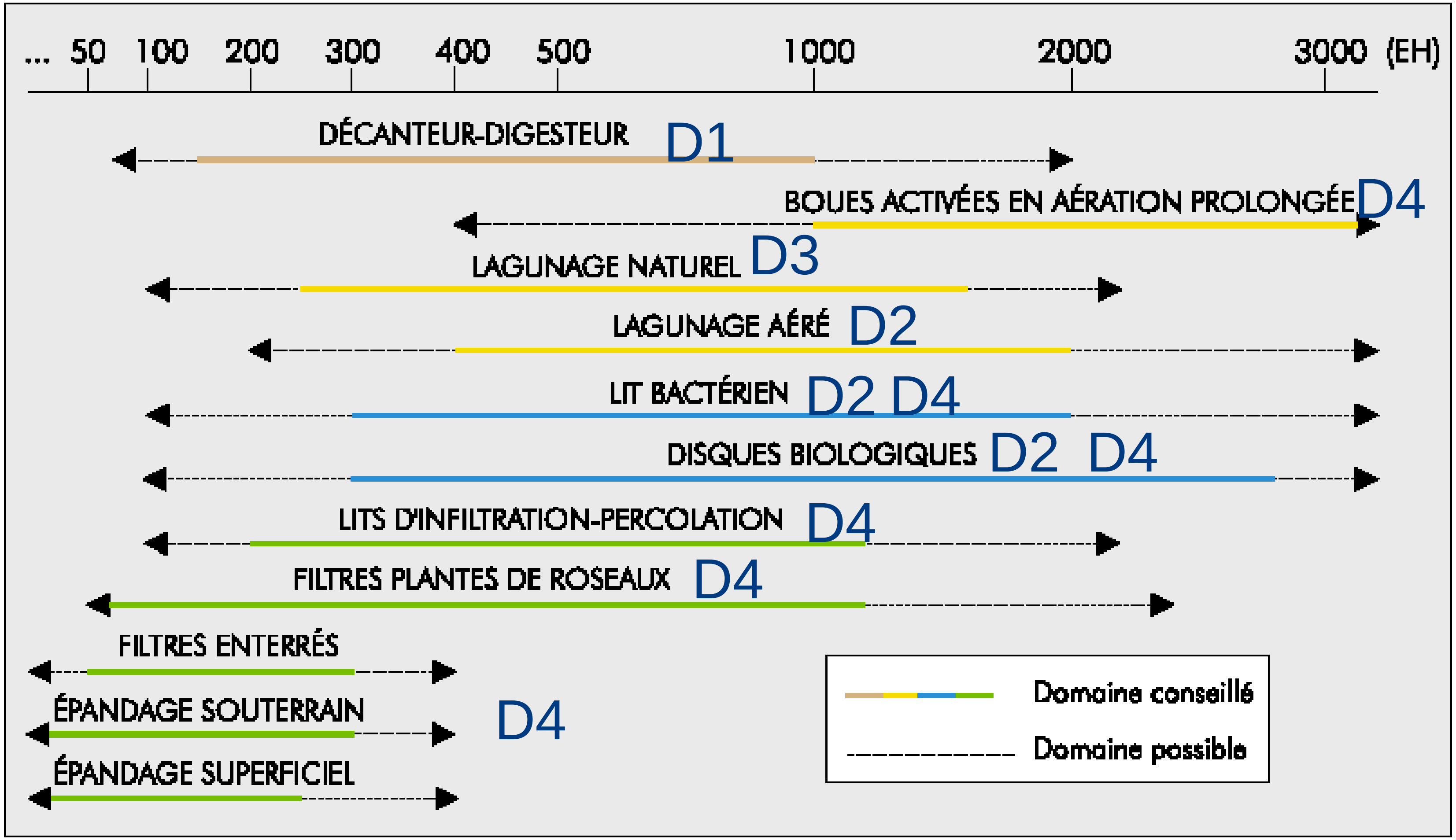
550 WWTP/y

Which process to choose

Intensive systems | **Conventional systems** | **Extensives systems**

Which process to choose

FNDAE n°22, 1998

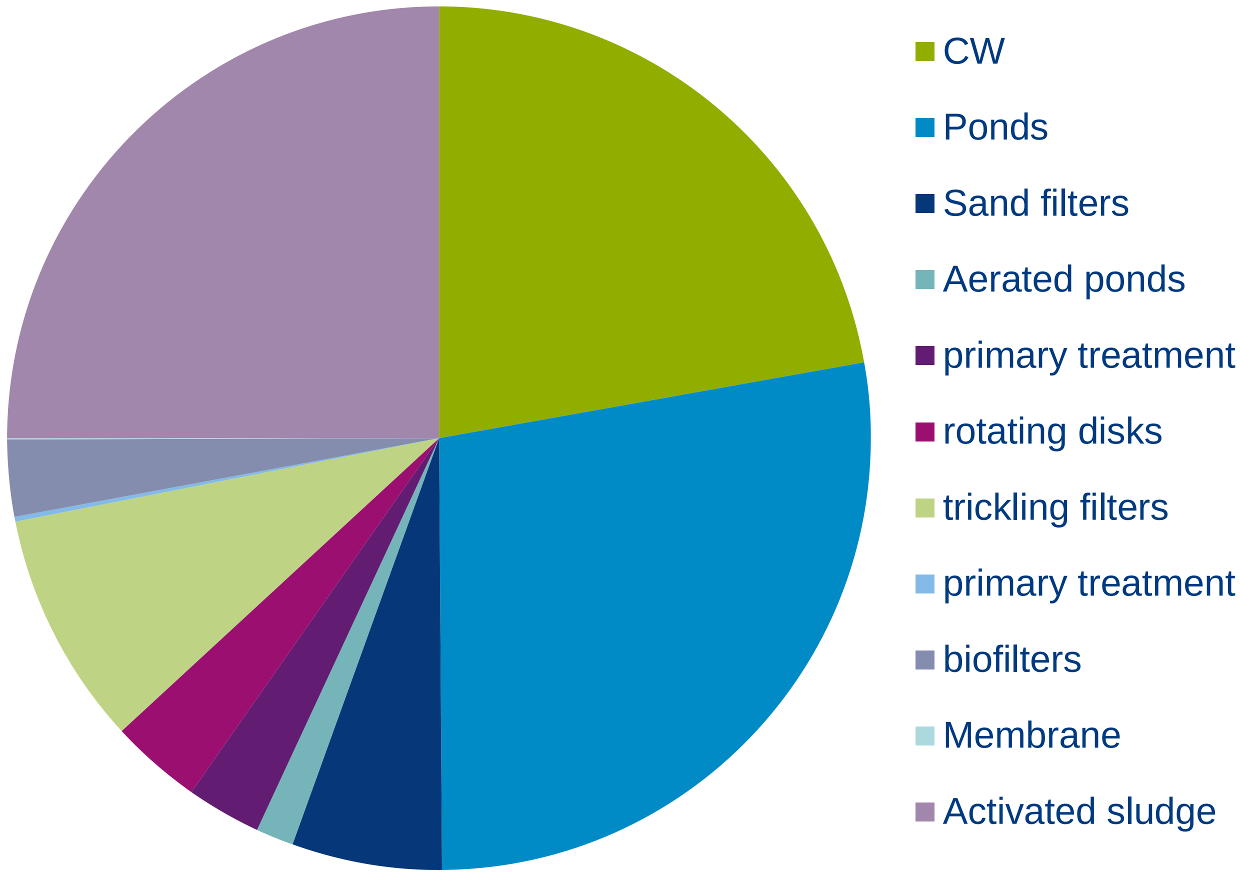


WW treatment of small and medium size communities

EPNAC

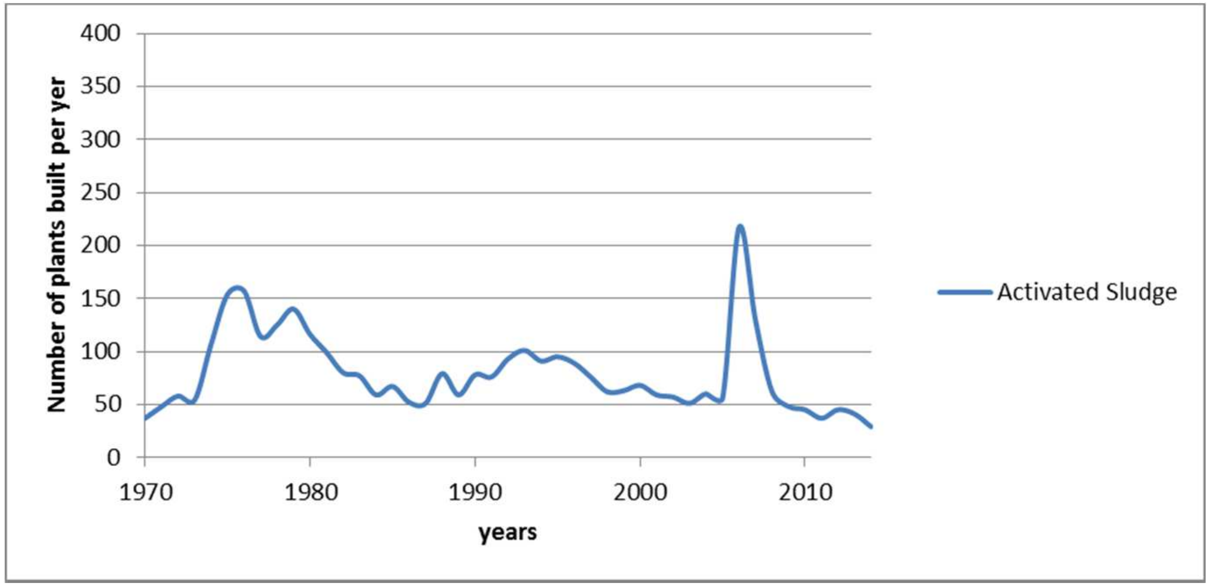
http://epnac.irstea.fr

The different systems implemented in France

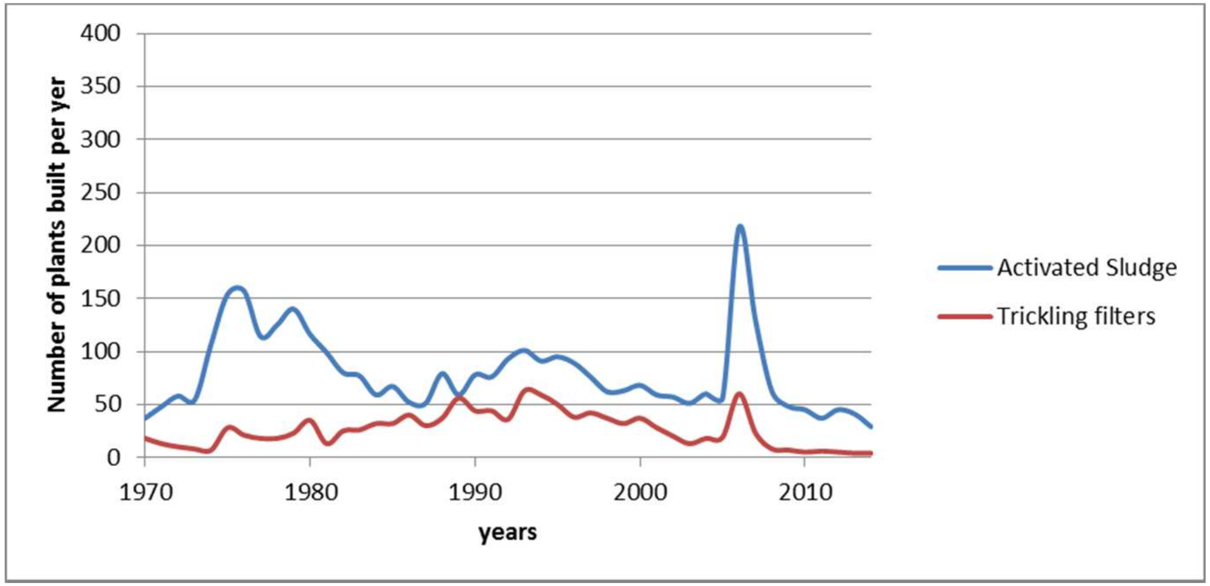


Below 2000 p.e.

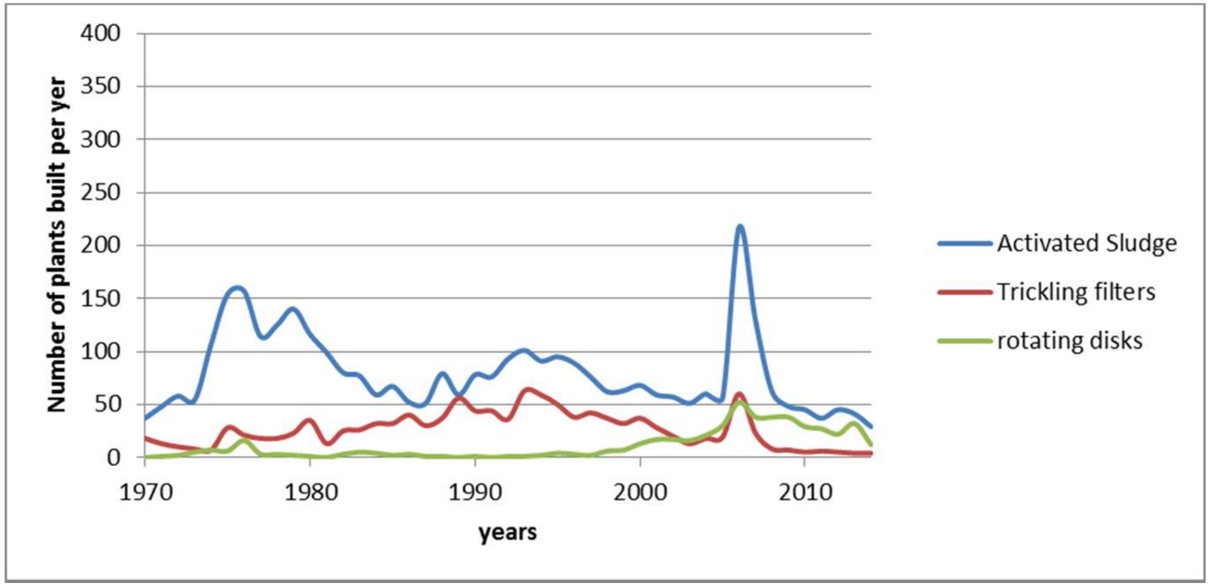
Technology waves



Technology waves



Technology waves



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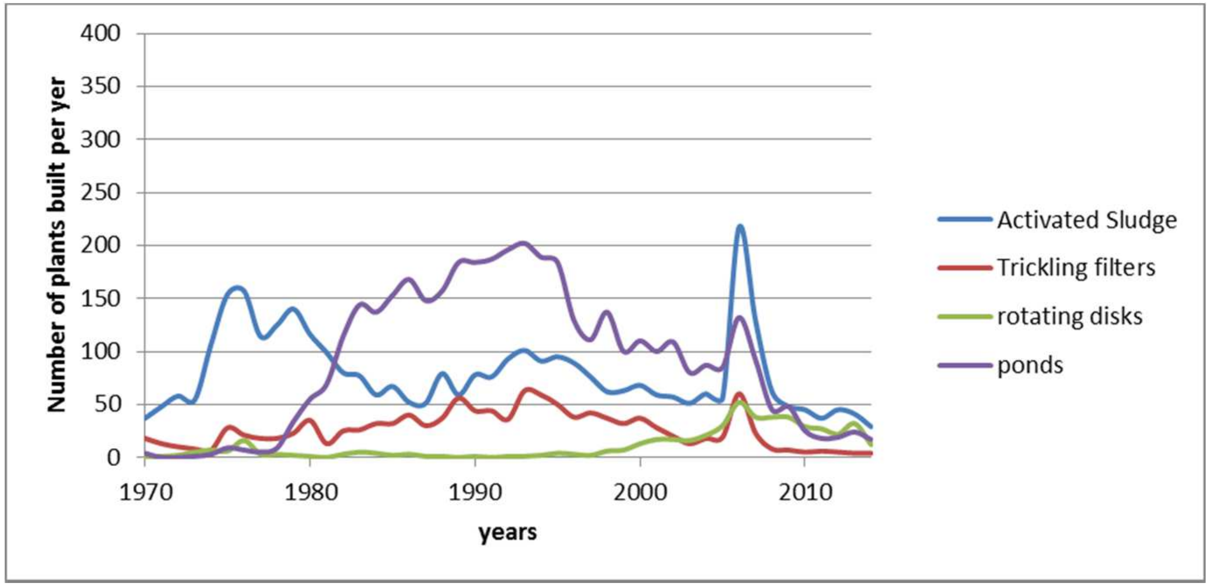
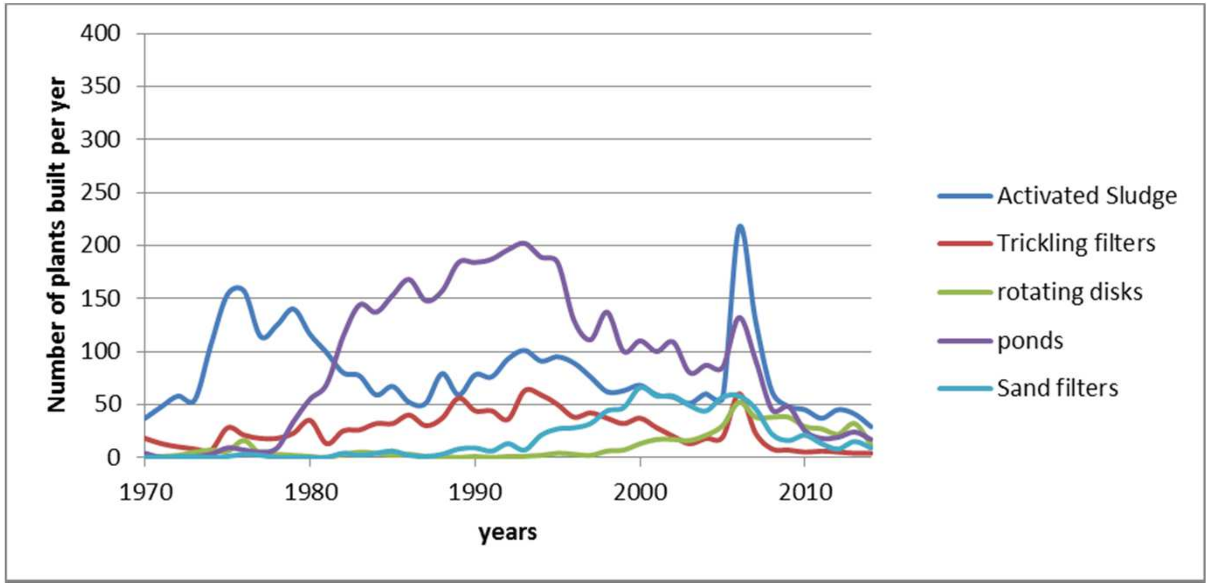
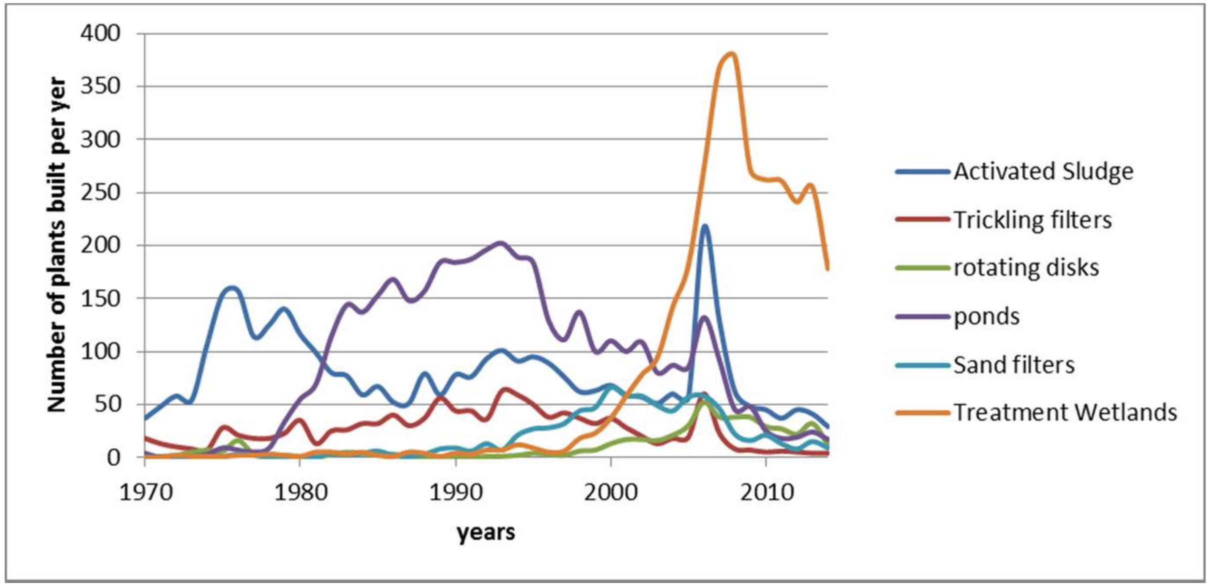
Technology waves



Technology waves



Technology waves



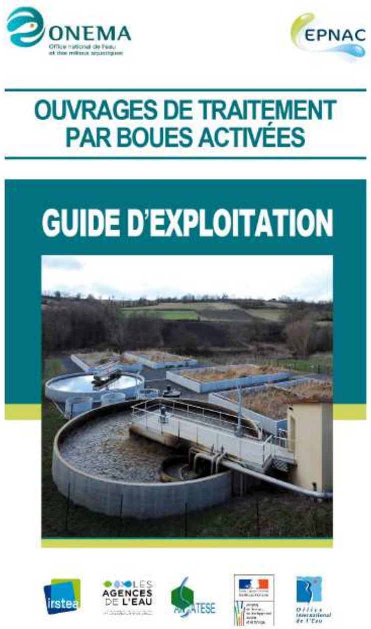
Technology choice

A temporal necessity

consequences

Why these waves ?

- Biggest capacities
- Not easy to operate
- Sludges looses



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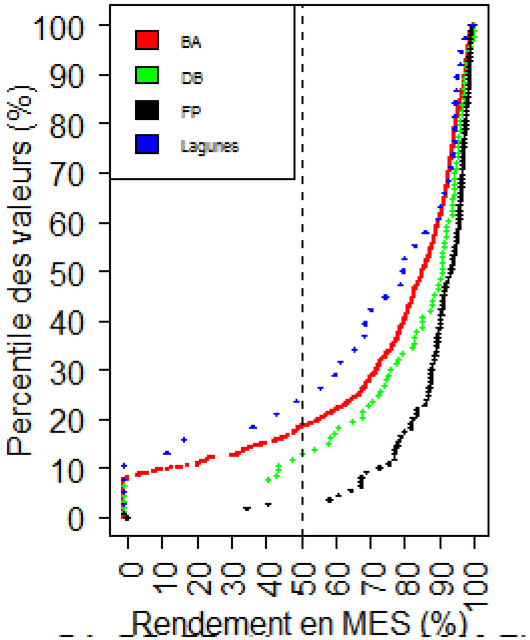
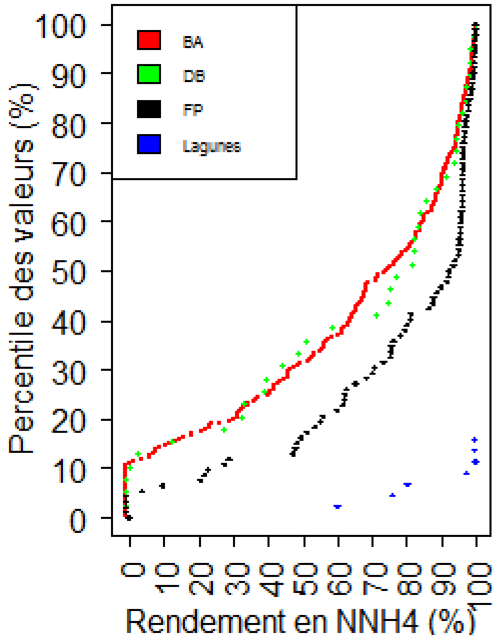




Why these waves ?

- **Limited economical interest**

		Bases de dimensionnement selon les objectifs		
	paramètre	DBO < 25 mg/l	DBO < 35 mg/l	Lit à deux étages (1^{er})
Lit bactérien	charge organique kg DBO/m^3.j	0.4	0.7	1 - 1.2
Clarificateur	Vitesse ascensionnelle m^3/m^2.h	1	1.2	1.5

Why these waves ?

- Strong dysfunction in the 80s
- Came back in 2000
- Limited economical interest

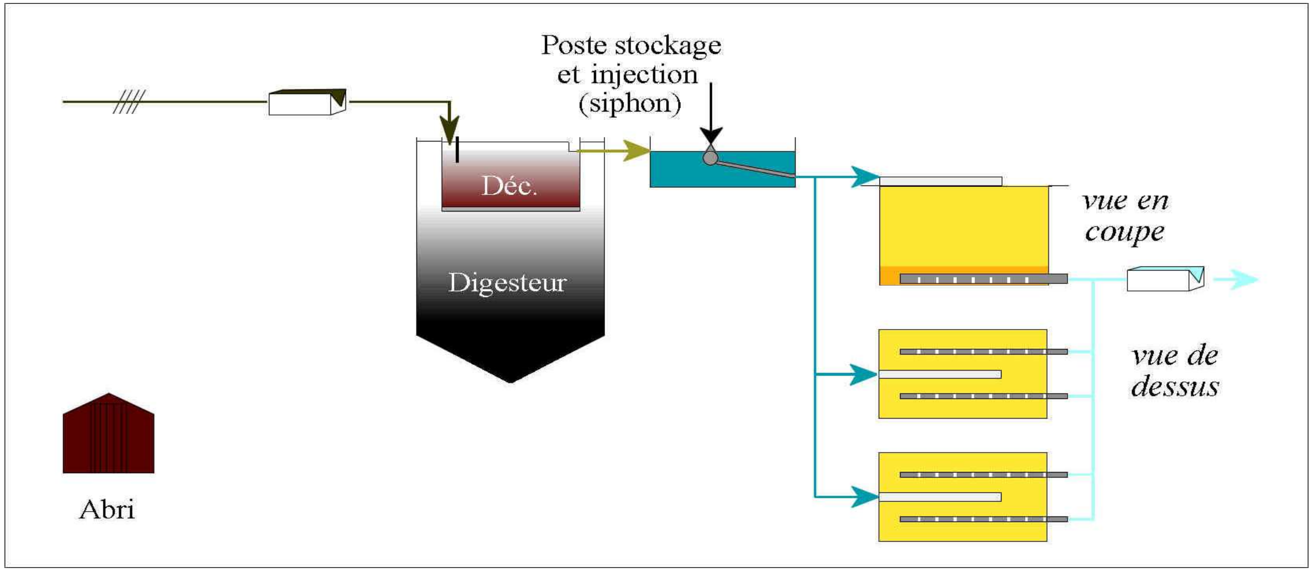
Why these waves ?

- Strong dysfunction in the 80s
- Came back in 2000
- Limited economical interest

- **7 - 8 g of BOD/m^2 to reach < 35 mg.L^{-1} of BOD**
- **5 g of BOD /m^2 to reach < 25 mg.L^{-1} of BOD**
- **2.5 g of BOD /m^2 to reach nitrification (< 5 mg.L^{-1} N-NH_4^+)**

Why these waves ?

- Sensitive to clogging
- Many clogged
- Do not support hydraulic overloads



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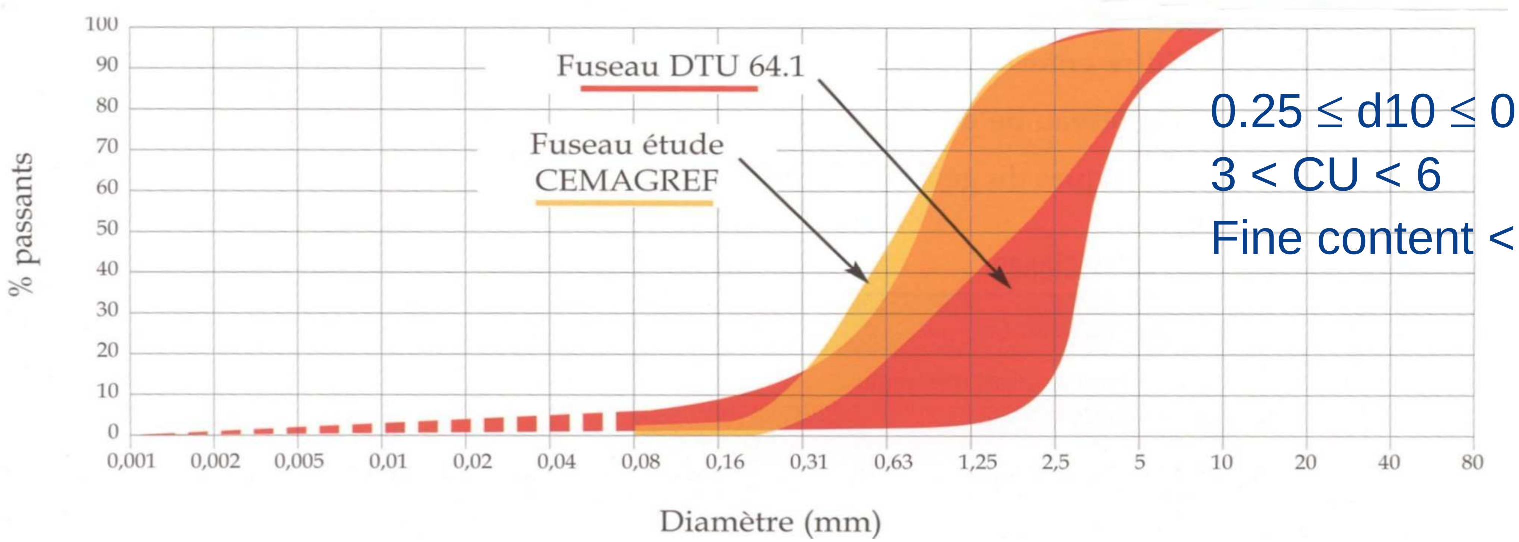


$0.25 \leq d10 \leq 0.40$ mm

$3 < CU < 6$

Fine content < 3 %

Why these waves ?

- **Sensitive to clogging**
- **Many clogged**
- **Do not support hydraulic overloads**

Partenariat 2011 - *Domaine Ecotechnologies et pollutions*
Action 25 « Conception et exploitation des stations de traitement des eaux usées des petites et moyennes collectivités »

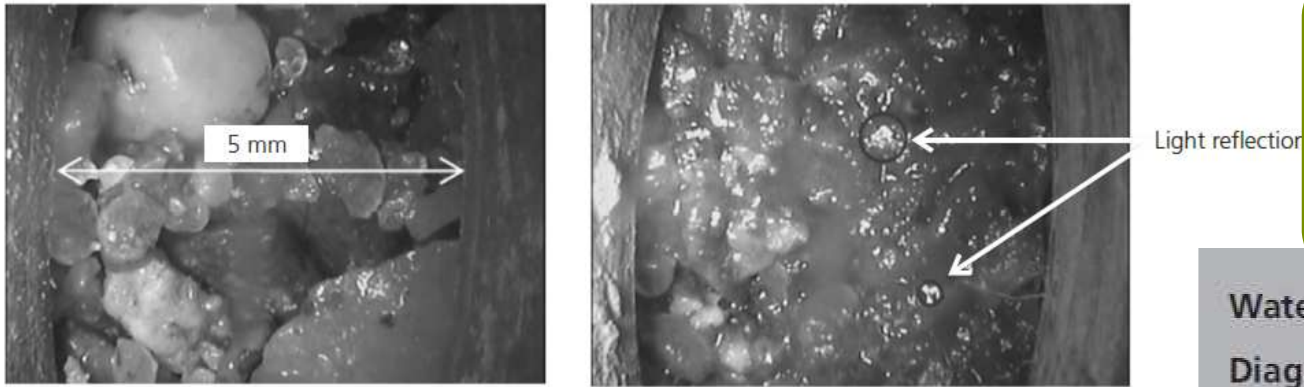
État des lieux des systèmes de traitement des eaux usées de type cultures fixées sur supports fins en assainissement collectif : filtres enterrés (sable ou zéolithe) et bassins d'infiltration-percolation

Expériences de leur réhabilitation

Rapport final

Atelier thématique du Groupe de travail EPNAC
(Evaluation des Procédés d'Assainissement des petites et moyennes Collectivités)

Mars 2012



Healthy sand

Clogged sand

Méthode de diagnostic et réhabilitation de filtres à sable.

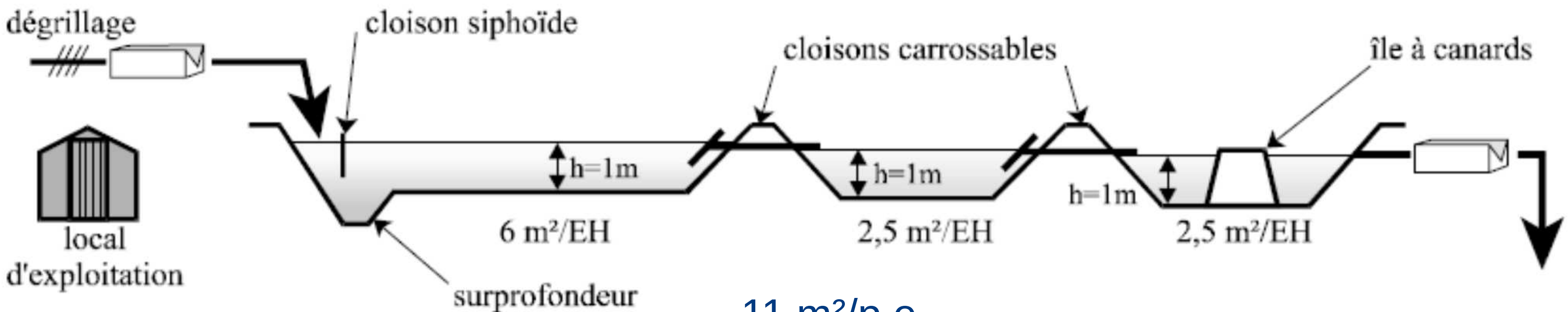
Water Management

Diagnosis of domestic wastewater sand filters

Breul, Bouteldja, Boissier *et al.*

Why these waves ?

- Not able to reach low outlet quality
- High footprint
- Sludge withdrawal is difficult



11 m²/p.e.

Why these waves ?

- Not able to reach low outlet quality
- High footprint
- Sludge withdrawal is difficult

Improvement of ponds water quality has become a research topic

WATER RESEARCH 43 (2009) 1851–1858

Available at www.sciencedirect.com

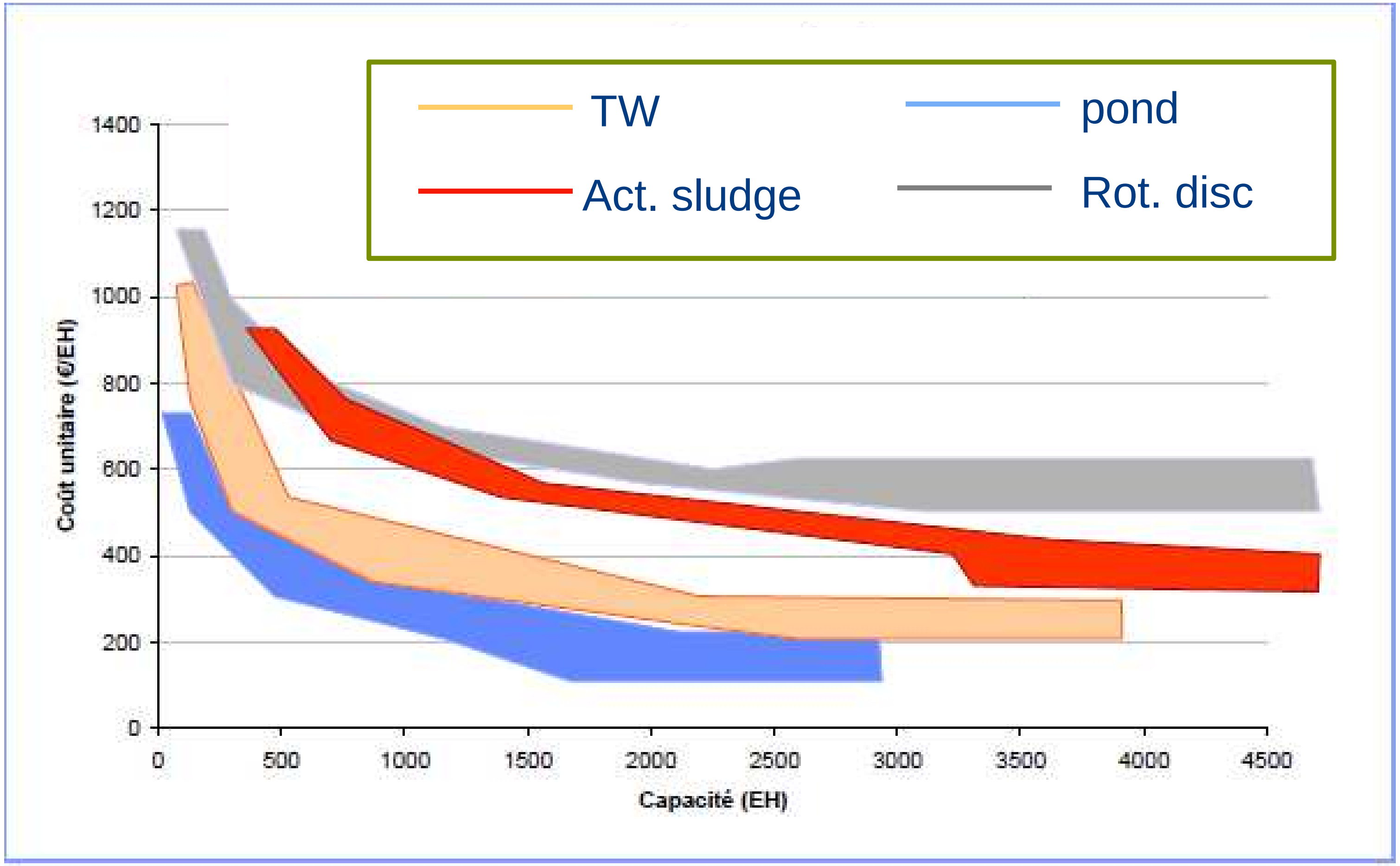
ScienceDirect

journal homepage: www.elsevier.com/locate/watres

Impact of design and operation variables on the performance of vertical-flow constructed wetlands and intermittent sand filters treating pond effluent

Antonina Torrens[a,*], *Pascal Molle*[b], *Catherine Boutin*[b], *Miquel Salgot*[a]

Investment costs



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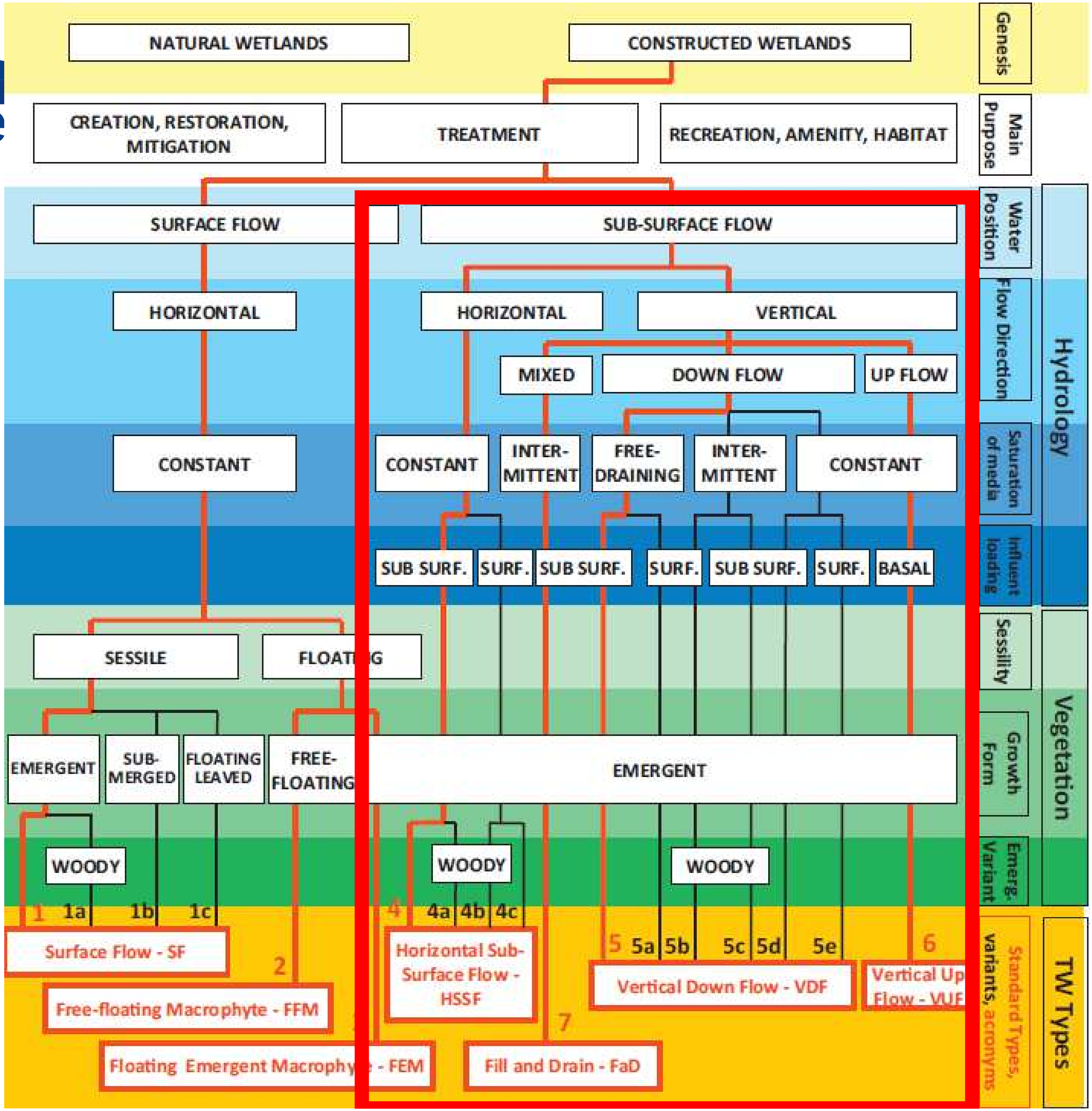
Treatment wetlands

A process family

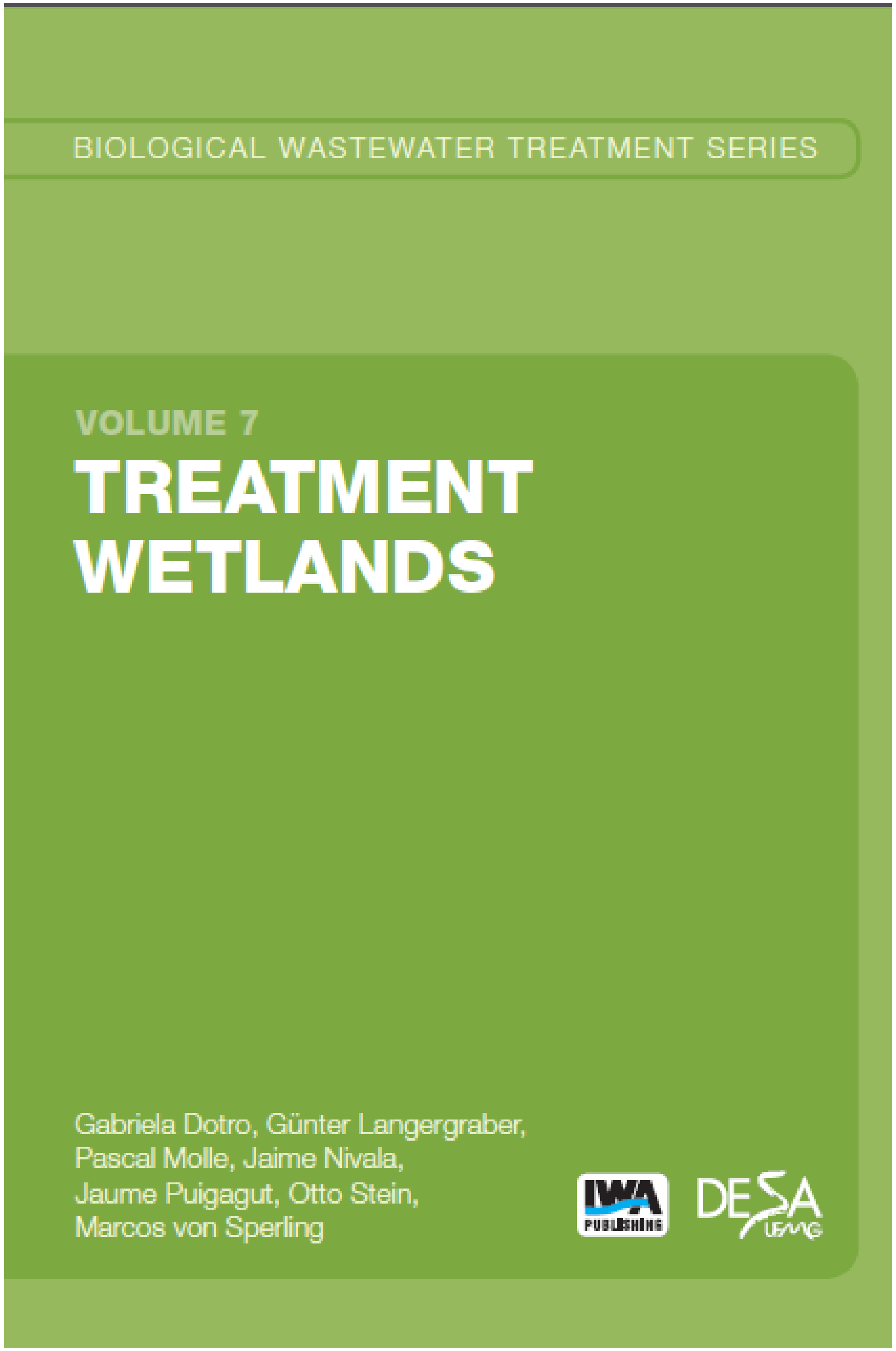


NATURAL WETLANDS
CONSTRUCTED WETLANDS
Genesis
CREATION, RESTORATION, MITIGATION
TREATMENT
RECREATION, AMENITY, HABITAT
Main Purpose
SURFACE FLOW
SUB-SURFACE FLOW
Water Position
HORIZONTAL
HORIZONTAL
VERTICAL
Flow Direction
MIXED
DOWN FLOW
UP FLOW
CONSTANT
CONSTANT
INTER-MITTENT
FREE-DRAINING
INTER-MITTENT
CONSTANT
Saturation of media
SUB SURF.
SURF.
SUB SURF.
SURF.
SUB SURF.
SURF.
BASAL
Influent loading
Hydrology
SESSILE
FLOATING
Sessility
EMERGENT
SUB-MERGED
FLOATING LEAVED
FREE-FLOATING
EMERGENT
Growth Form
WOODY
WOODY
WOODY
Emerg. Variant
Vegetation
1 1a 1b 1c
2
4 4a 4b 4c
5 5a 5b 5c 5d 5e
6
7
Surface Flow - SF
Free-floating Macrophyte - FFM
Floating Emergent Macrophyte - FEM
Horizontal Sub-Surface Flow - HSSF
Fill and Drain - FaD
Vertical Down Flow - VDF
Vertical Up Flow - VUF
Standard Types, variants, acronyms
TW Types

Classical international TW system

http://wio.iwaponline.com

ISBN: 9781780408774 (eBook)



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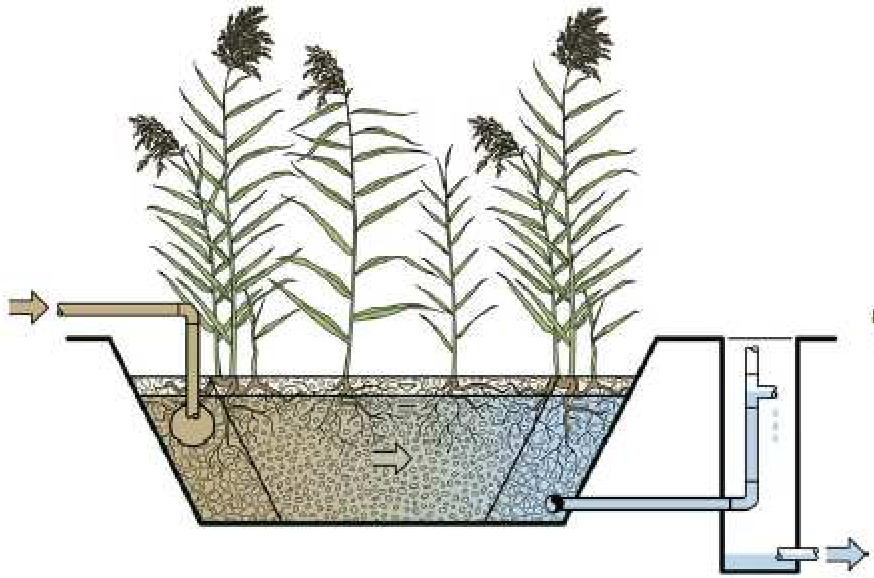
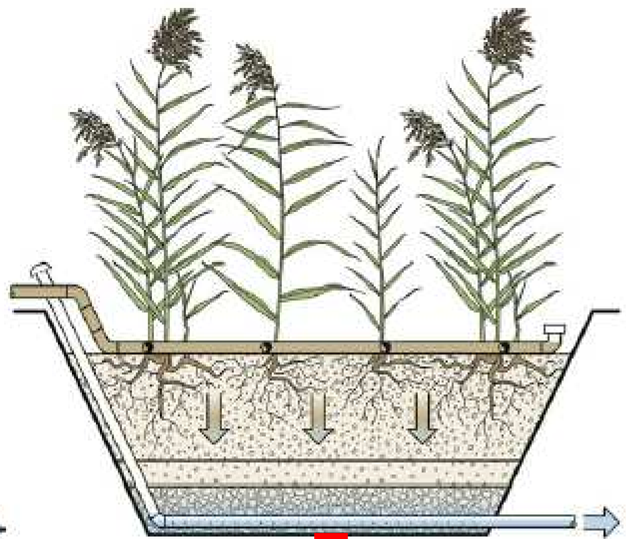
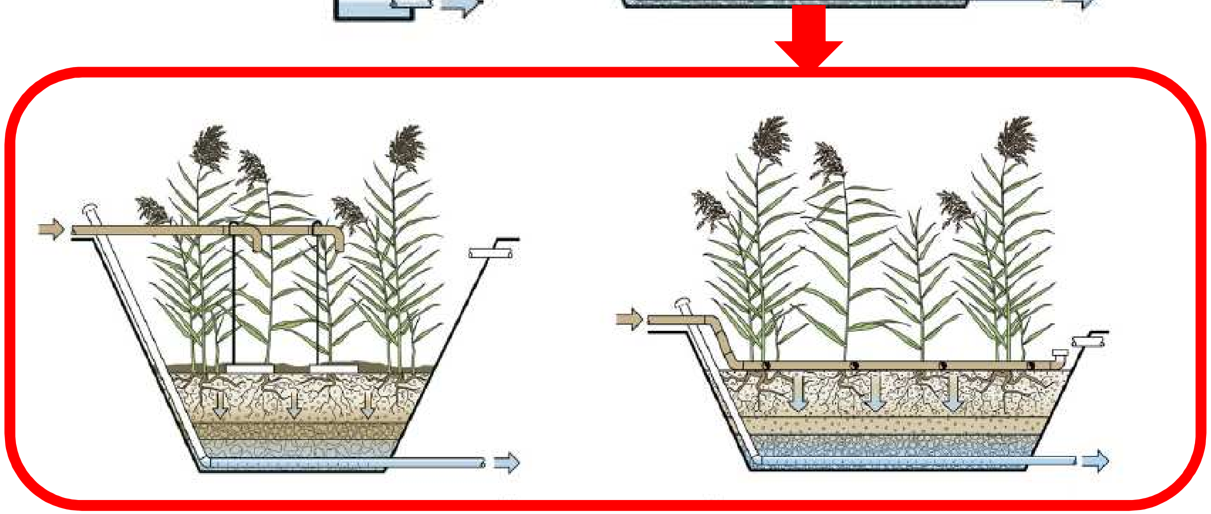
The main systems

Horizontal subsurface flow TW



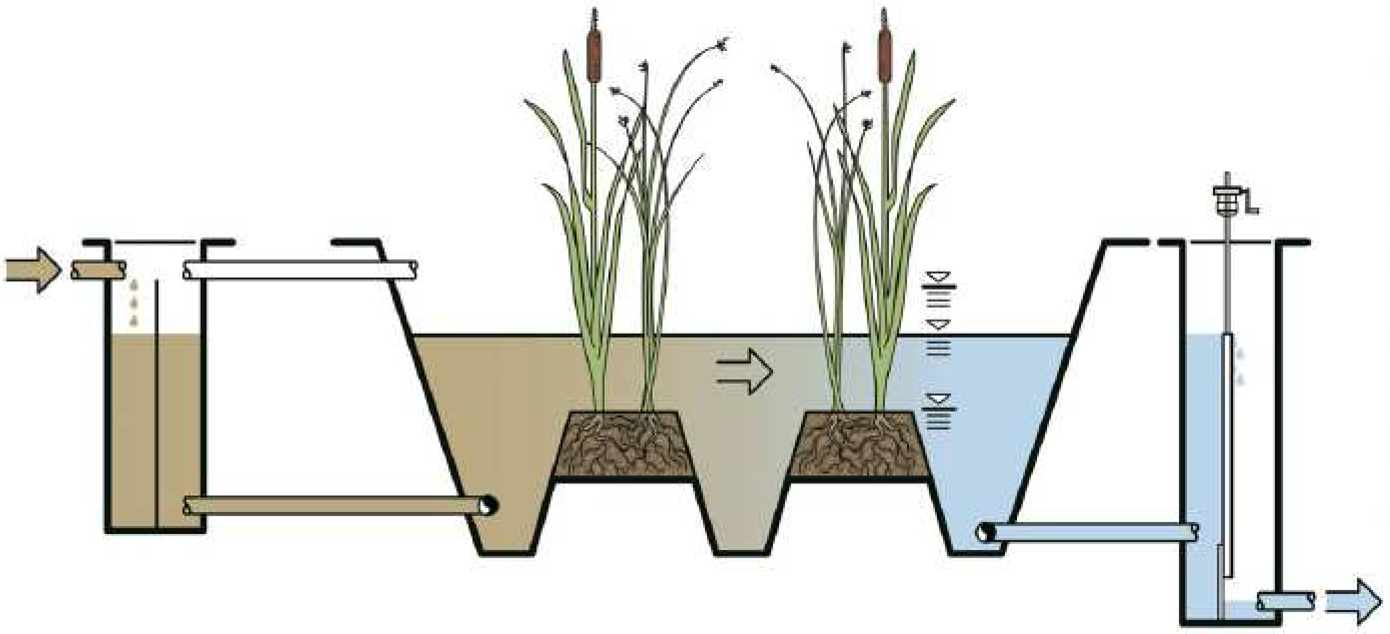
Vertical subsurface flow TW





The main systems

Free water surface



High footprint, low applied loads

Used for tertiary treatment

Design rules

	Vertical SSF TW	Horizonta SSF and Free WS TW
Surface	Surfacic loads	Simplified models
	Clogging managment	$A = \frac{PQ_i}{k_A}\left(\left(\frac{C_i - C*}{C_o - C*}\right)^{\frac{1}{P}} - 1\right) = \frac{PQ_i}{k_V h}\left(\left(\frac{C_i - C*}{C_o - C*}\right)^{\frac{1}{P}} - 1\right)$
Climate	Loads and number of filters	$k_T = k_{20}\theta^{(T-20)}$
media	Particle size and depth	Particle size

Application

Wastewater | **Sludge** | **Storm water**

Process association
compactness
Rain events
P and TN treatment
Loads variations

Activated sludge
septage

Performances

design

operation Climate Plants Clogging Design tools

Application

Wastewater | **Sludge** | **Storm water**


ONEMA
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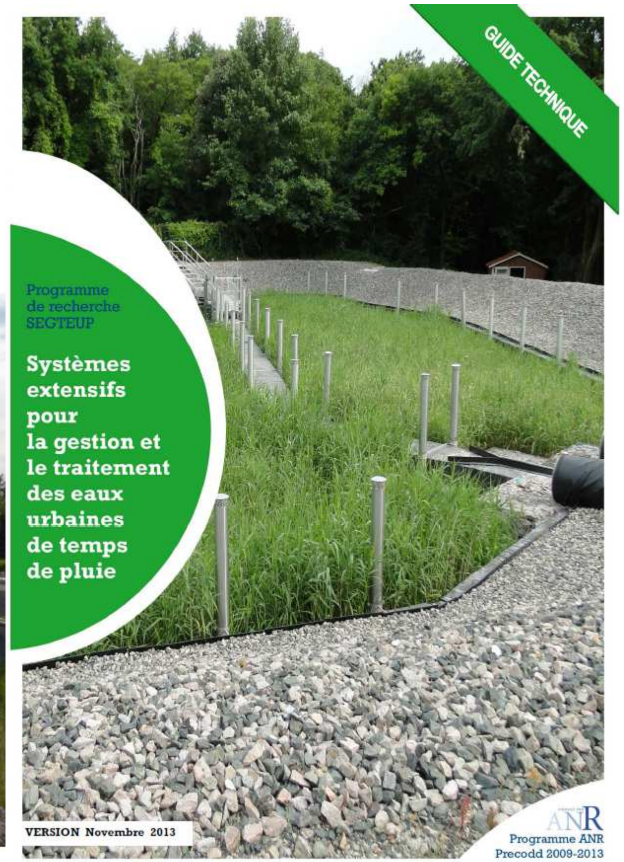
2011 – Ecotechnologies et pollutions- Action 30
Les lits de séchage de boues plantés de roseaux pour le traitement des boues et des matières de vidange
Guide de dimensionnement et de gestion
Pascal Molle
Julie Vincent
Stéphane Troesch
Gilles Malamaire
Décembre 2013


GUIDE TECHNIQUE
Programme de recherche SEGTEUP
Systèmes extensifs pour la gestion et le traitement des eaux urbaines de temps de pluie
VERSION Novembre 2013
ANR
Programme ANR Precodd 2009-2013

Process association
compactness
Rain events
P and TN treatment
Loads variations

operation Climate Plants Clogging Design tools

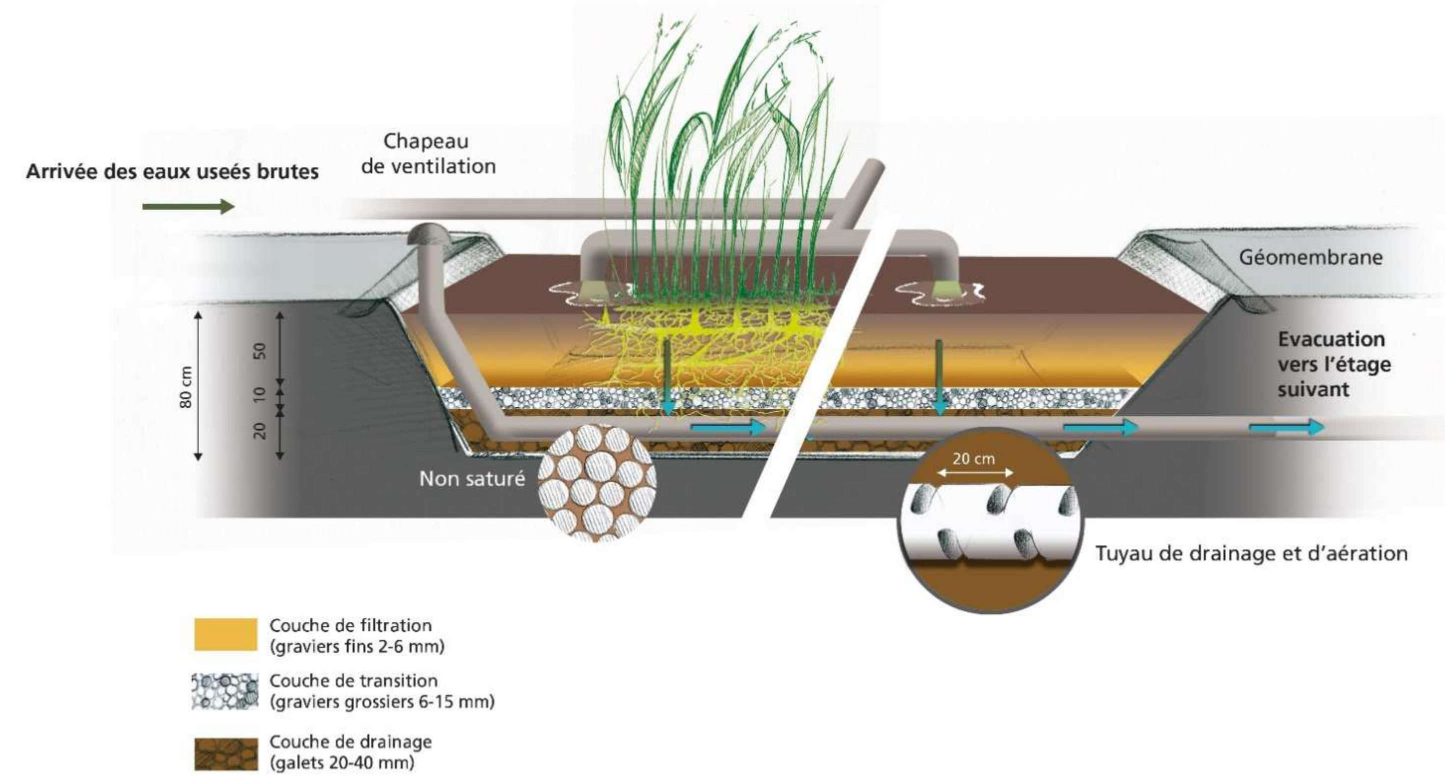
Systems developped in France : Vertical FSS TW

Fed with raw wastewater

Organic deposit on the top

Treatment of WW and sludge

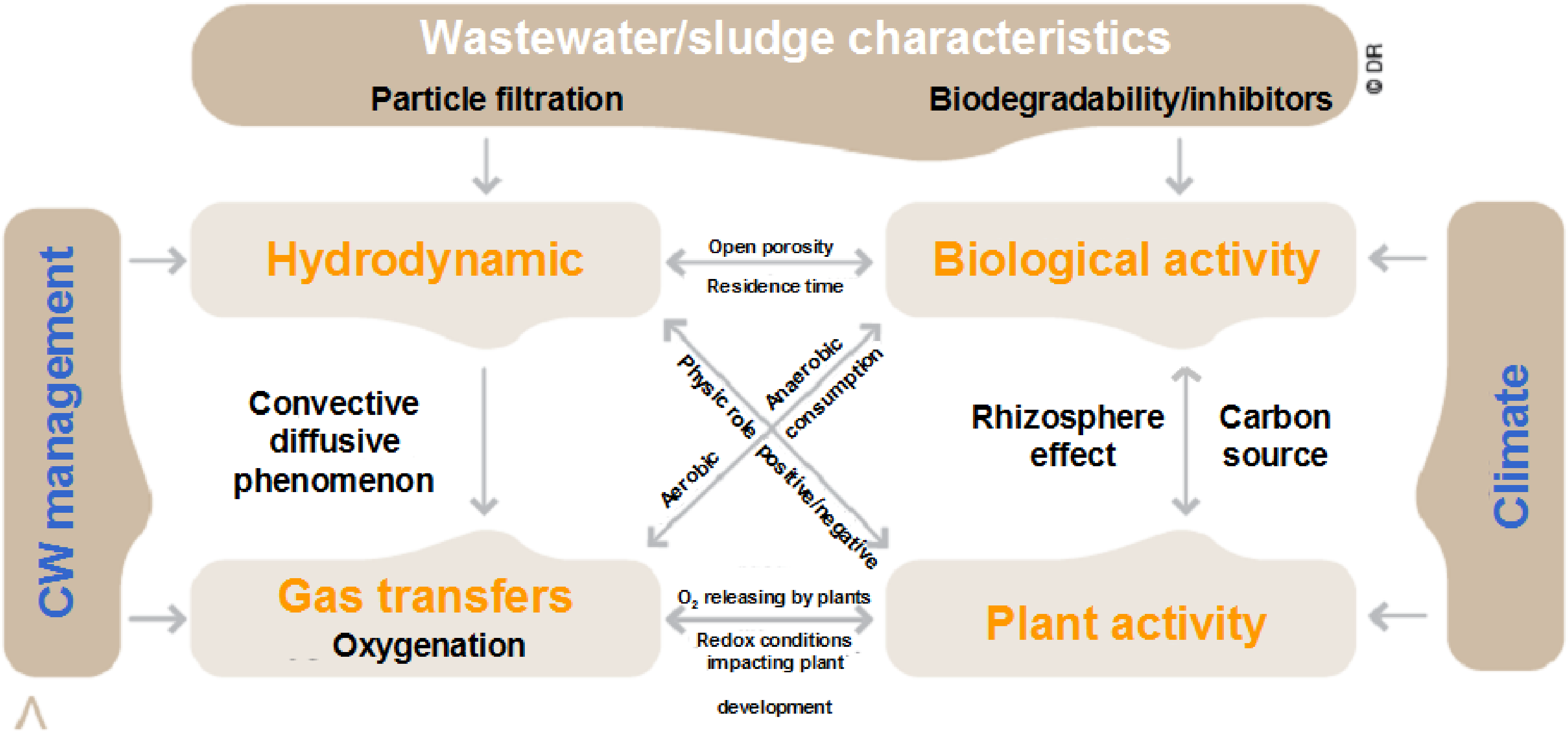
Vertical FSS TW



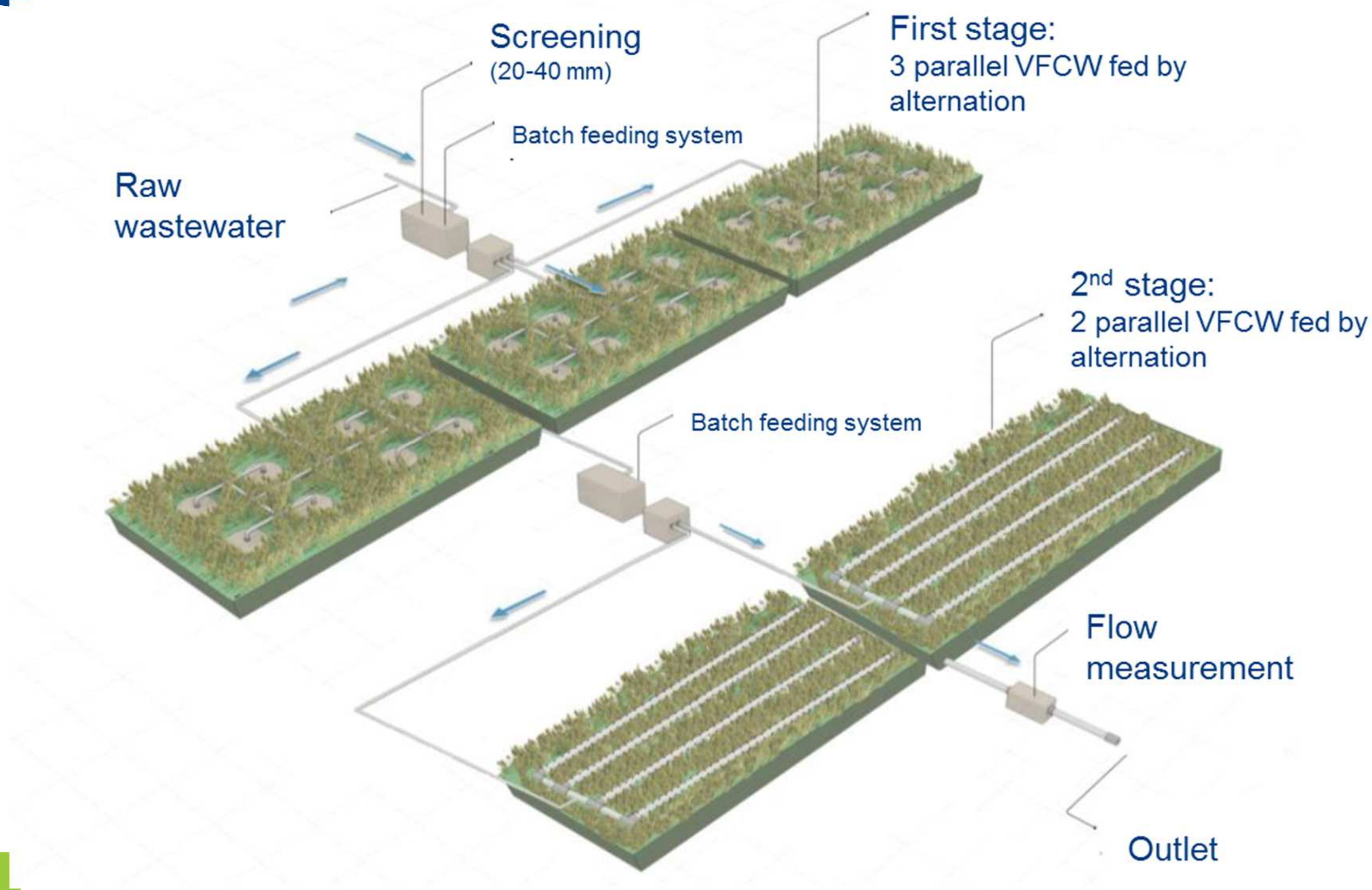
Fed with raw wastewater: co-treatment water + sludge

Vertical flow, unsaturated → aerobic processes → ~~smells~~

A complex equilibrium to respect



Classical scheme



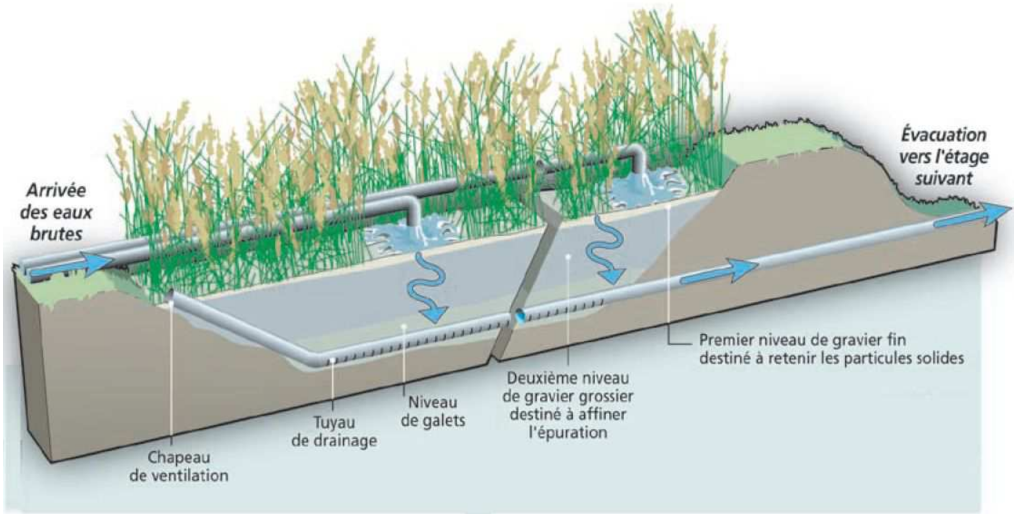
Screening

→ Pre-treatment = screening only

- Water velocity in the screening between 0.3 and 1.2 m/s
- Distance between bars of **20 to 40 mm** (when 20 mm, use automatic screening);
- **emergency canal** in case of clogging ;
- **cleaning by a rake** adapted to the screening size ;
- Debris dewatering system (water comes back to the treatment line) and waste storage system.

Design

- **Based on a organic load**

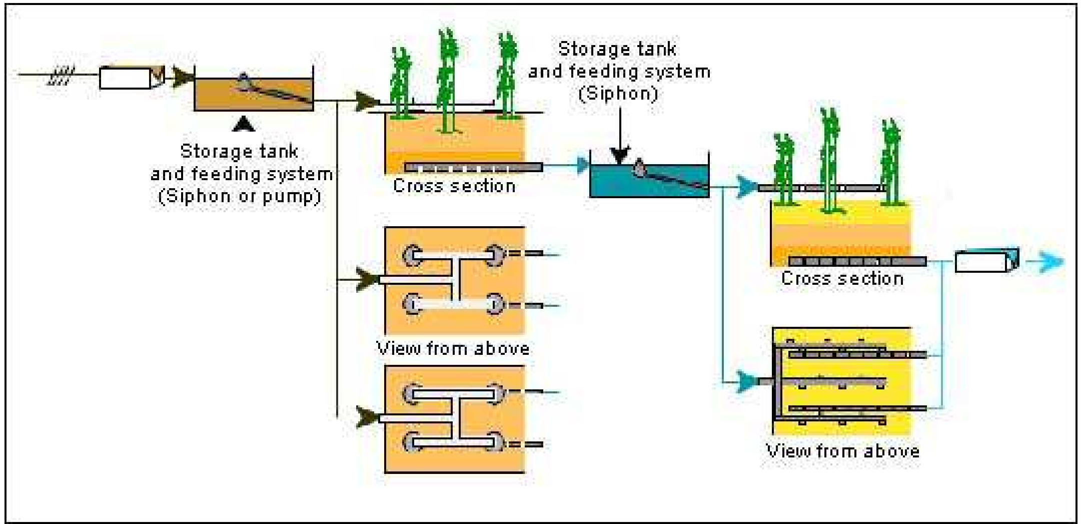


Treatment Stage	HLR ($m^3/m^2 \cdot d$)	COD ($g/m^2 \cdot d$)	BOD_5 ($g/m^2 \cdot d$)	TSS ($g/m^2 \cdot d$)	TKN ($g/m^2 \cdot d$)
First stage	0.37	350	150	150	< 30
Second stage	0.37	70	20	30	15

< 0.7 m/d when clear water intrusion is present in the sewer

Design

To avoid clogging : filters in parallel to implment feeding and resting periods → maintain aerobic conditions and control biomass



1st stage

- > 30 cm gravel (2-6 mm)
- Transition layer: 10 to 20 cm of gravel (5 –20 mm)
- Drainage layer : 10 to 20 cm of 20-40 mm gravel

2nd stage

- > 30 cm sand (0.25 mm< d_{10} <0.40 mm)
- Transition layer: 10 to 20 cm of gravel (3 –10 mm)
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Design

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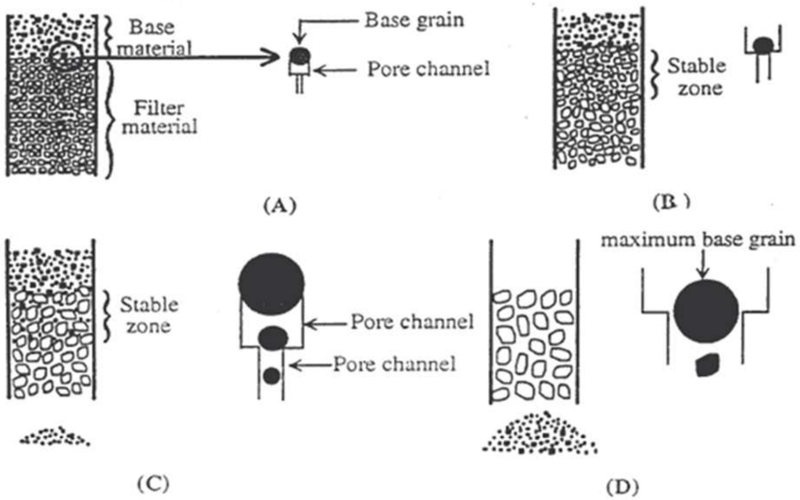

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Using gravel

$D_{15}/d_{85} < 4$

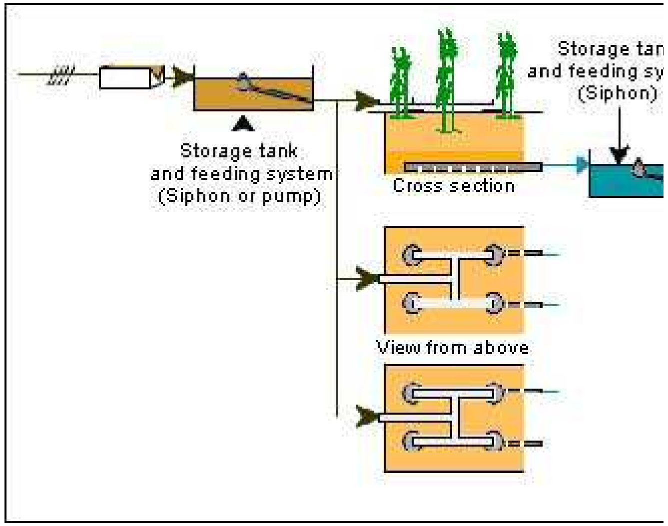
Using sand

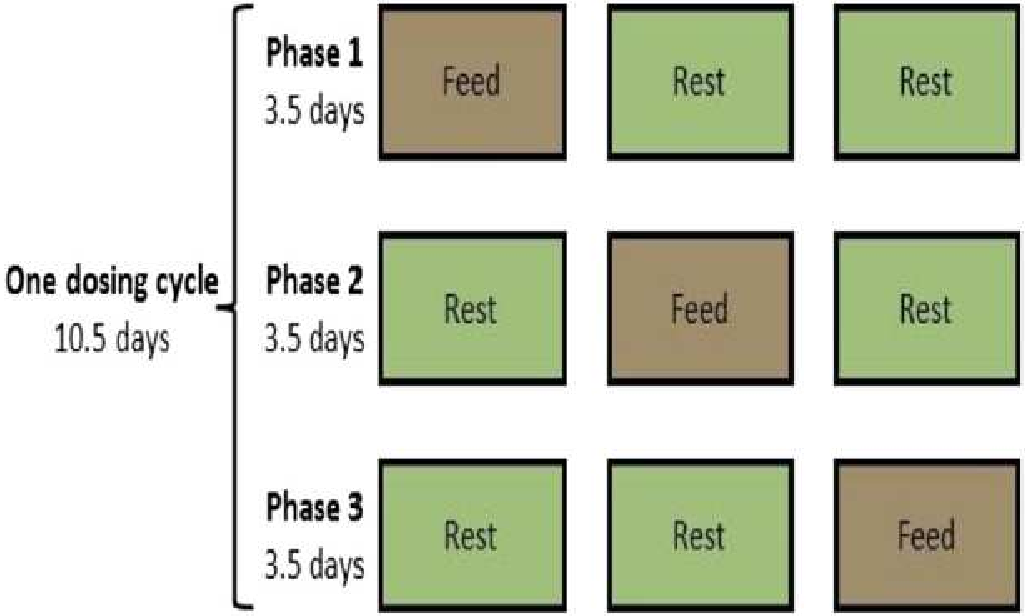
$D_{15}/d_{85} < 4$

$D_{15}/d_{15} \geq 4$

Design

To avoid clogging : filters in parallel to implment feeding and resting periods → maintain aerobic conditions and control biomass





1.2 m^2/PE at the first stage and 0.8 m^2/PE at the second stage

Feeding/resting periods 3.5/7 days at the first stage and 3.5/3.5 at the second stage

Distribution

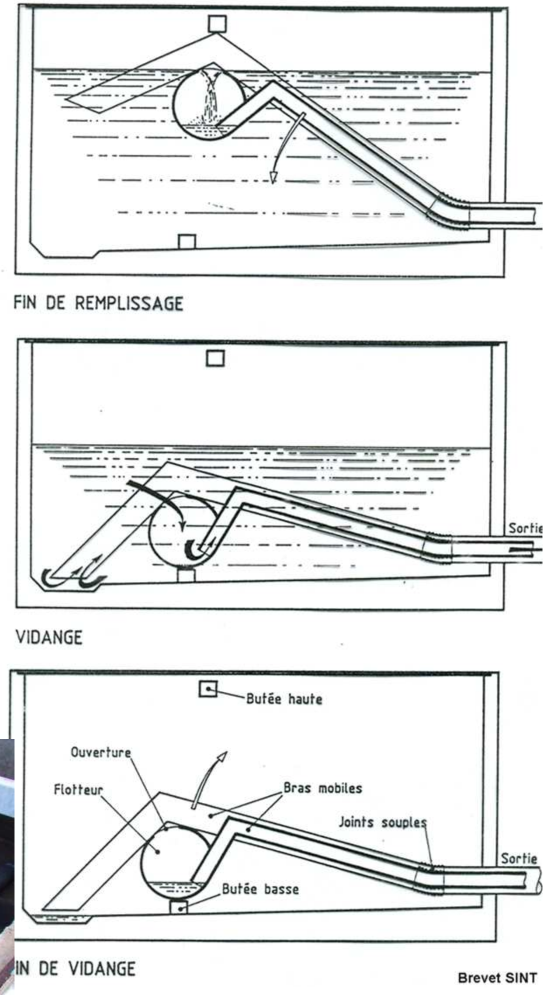
- The objective is to promote an homogenous water distribution on the whole surface of the filter in operation to:
  - Use the whole filter’s volume as a biological reator
  - Favour oxygen transfers

Feeding is done by batches

Distribution

Automatic siphon:

- High feeding flows
- Total emptying of the storage tank



Distribution

When there is not enough slope it is done by a pumping station

Distribution

Batch feeding flow:

Ensures an homogeneous water distribution at the surface

Allows a temporarly ponding of the filter

Ensures no deposit in the feeding pipes

Feeding flow > infiltration rates

> 0.5 $m^3/h/m^2$ of filter in operation

design value at **0.6 $m^3/h/m^2$**

Gravel : 3 cm of water per batches

Distribution

Water distribution pipes: 1st stage

- Big pipes to avoid pipe clogging
- No stagnant water in the pipes between batches

At least one feeding point for 50 m²

Not possible when fed by gravity

Distribution

Water distribution pipes: 2nd stage

- Less pipe clogging risk: finer distribution
- No stagnant water in the pipe between batches
- Pipes have to be in charge

Calculate the head losses to have more than 25 cm of water column at the end of all pipes

Distribution

Water distribution pipes: 2nd stage

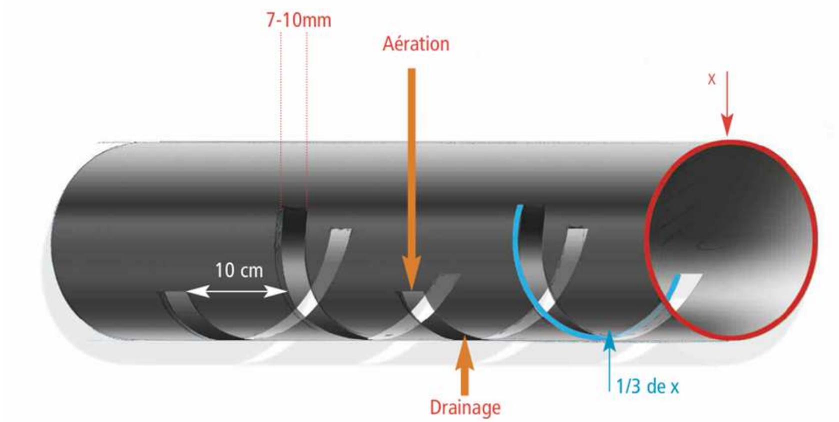
8 to 12 mm holes for water distribution

Some holes in the bottom part of the pipe to emptying it after batch load

Drainage/aeration

Drainage/aeration

- > 100 mm in diameter
- Central pipe has to be big enough to drain hydraulic peaks
- A 0.5 – 1 % slope to avoid water stagnation at the bottom of the filter



Freeboard

- Need to ensure a real sepration between filters
- For French system, it needs to allow organic matter deposit storage (maximum 20 cm)
- Need to store some ponding water in case of extreme events (difference between combine sewer and separate sewer)

- Primary treatment
  - 30 cm for separate sewers
  - > 50 cm for combine sewer (see storm water section)
- Secondary treatment
  - 20 cm for seperate sewer
  - 30 cm when used after a french system fed by a combine sewer

Above the freeboard, it is a by-pass of the treatment plant

Freeboard

Not reliable and to small

Not water proof

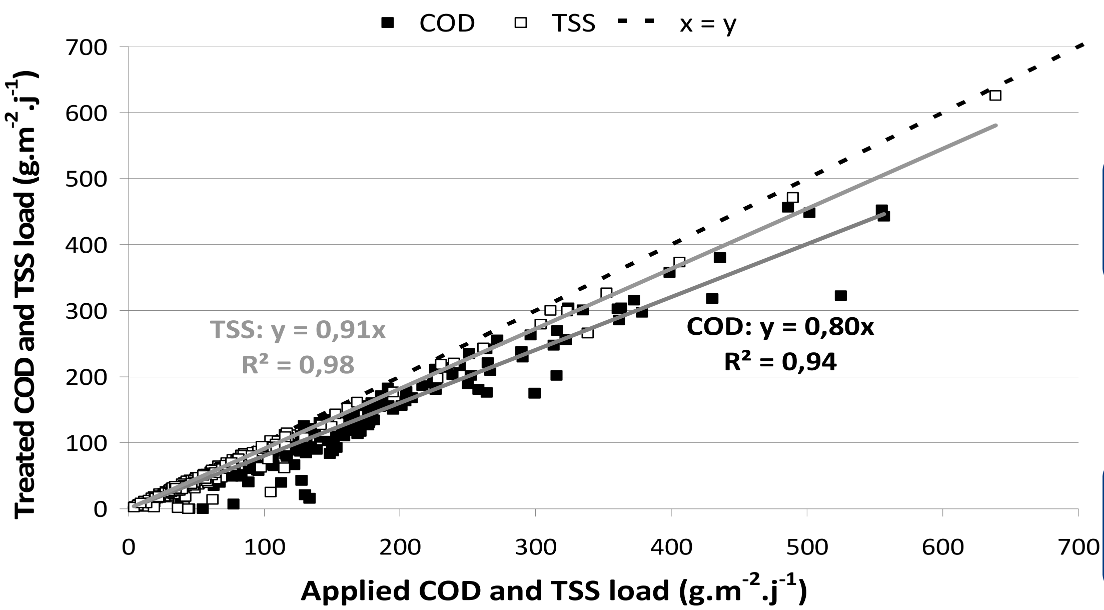
Freeboard

Need be sealed on the geomembrane

Need to go until at least 30 cm depth in the filtration layer

Possible to phase construction with time

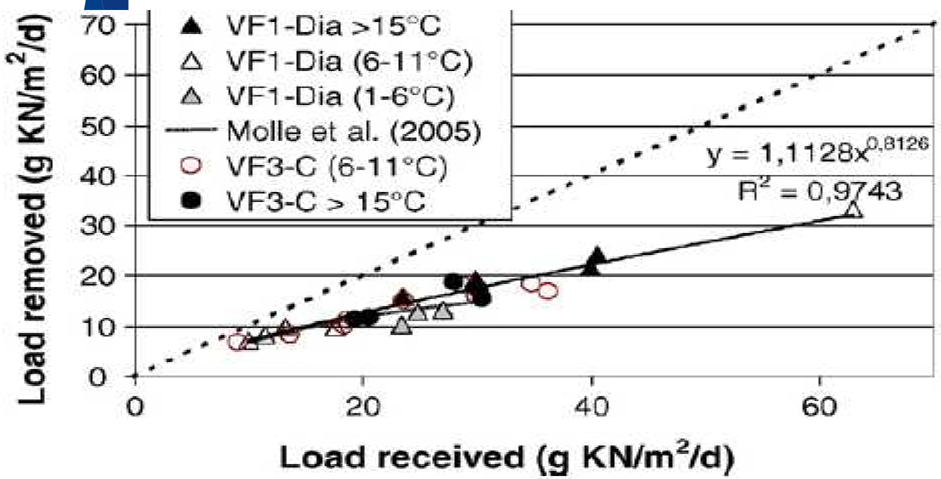
Performances : first stage

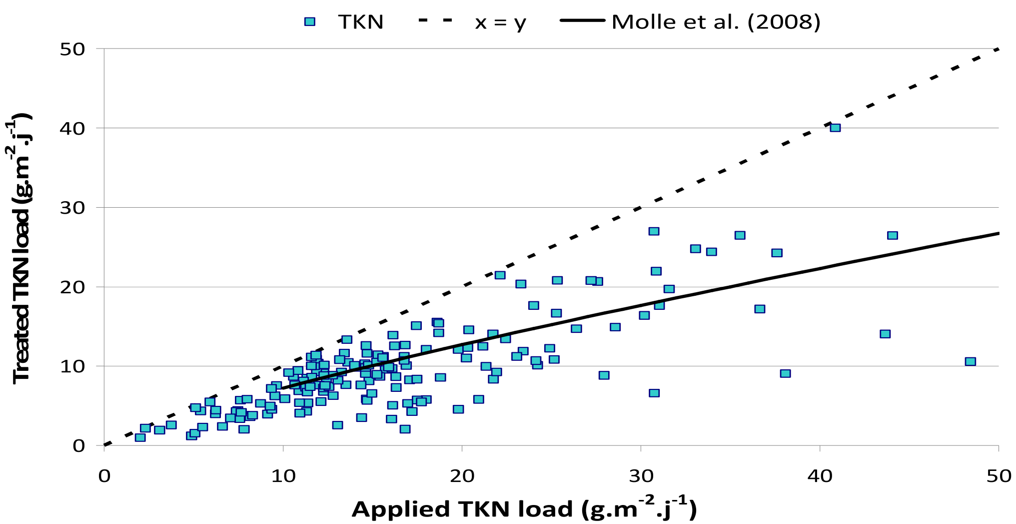


COD : 80 %

TSS, BOD : 90 %

Performances : first stage



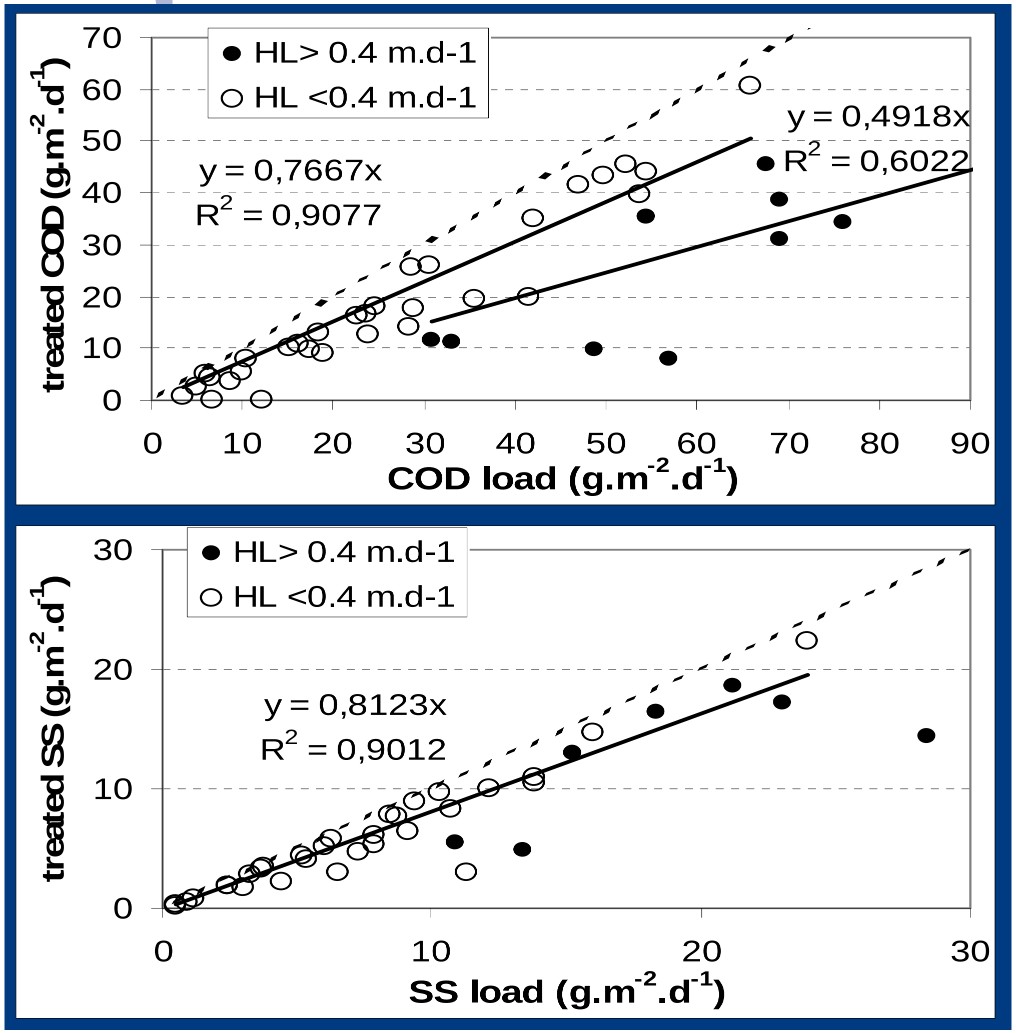


COD : 80 %

TSS, BOD : 90 %

KN : 50 - 60 %

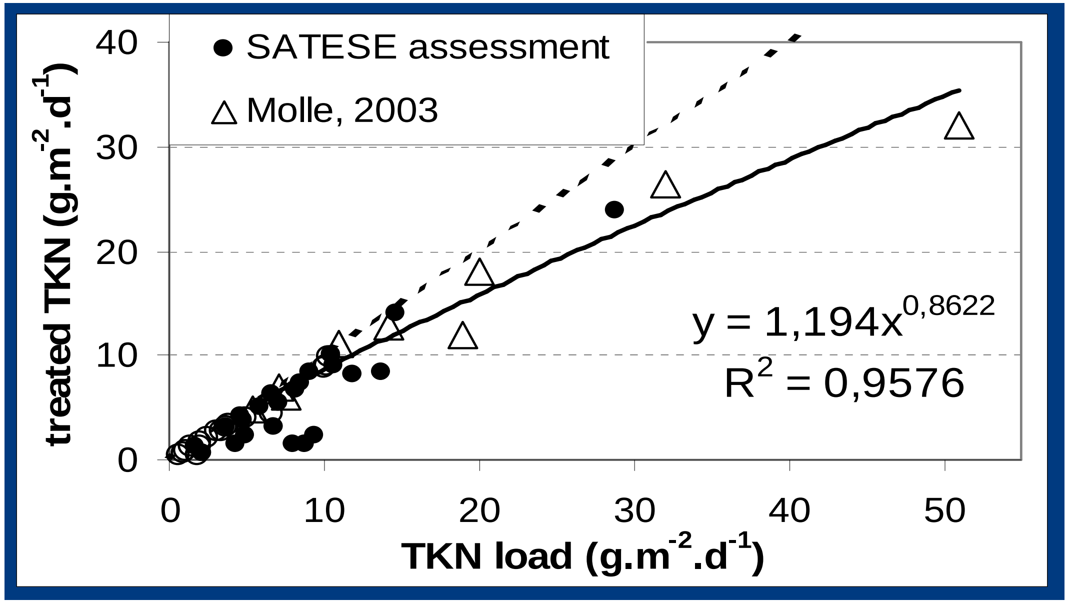
Performances : second stage



COD: 75 %

TSS: 80 %

Performances : second stage



COD: 75 %

TSS: 80 %

KN: 80 %

Performances

COD_{in} = 840 mg.l^{-1} (520-1400) HL < 0.75 m.d^{-1}	COD		TSS		TKN	
	R %	Outlet conc (mg.l^{-1})	R %	Outlet conc (mg.l^{-1})	R %	Outlet conc (mg.l^{-1})
stage 1	82	145	86	33	60	35
stage 2	60	55	72	11	78	6
Total	92	60	96	15	90	8
		↓ 90		↓ 15		↓ 12

First stage

Deposit layer accumulation

2 cm/y (Organic matter content of around 40 %)

Sludge managment

Withdrawal the deposit layer once reaching 20 cm

Every 10 – 15 years

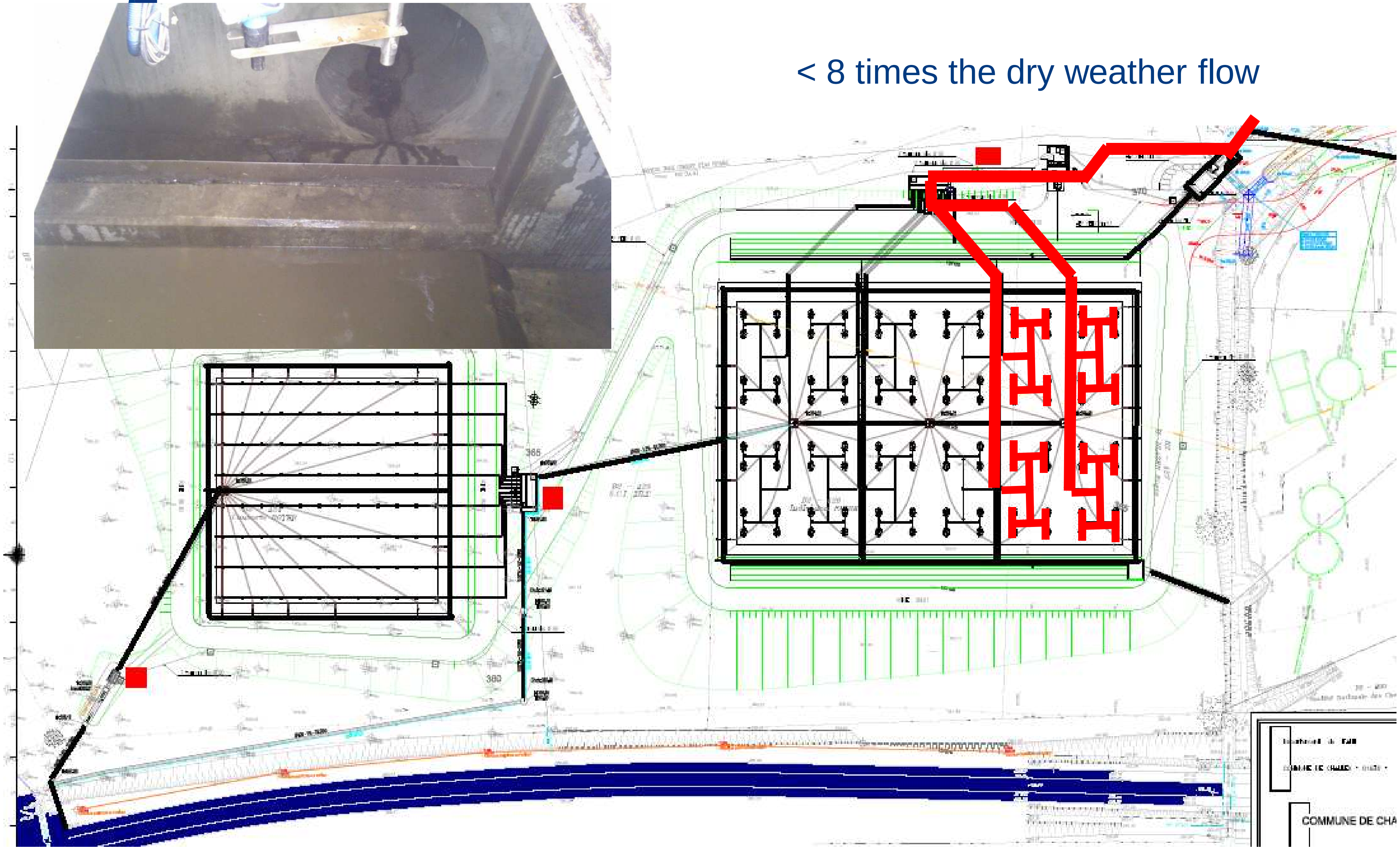
Sludge managment

No need to re-plant the reeds

Dynamic design

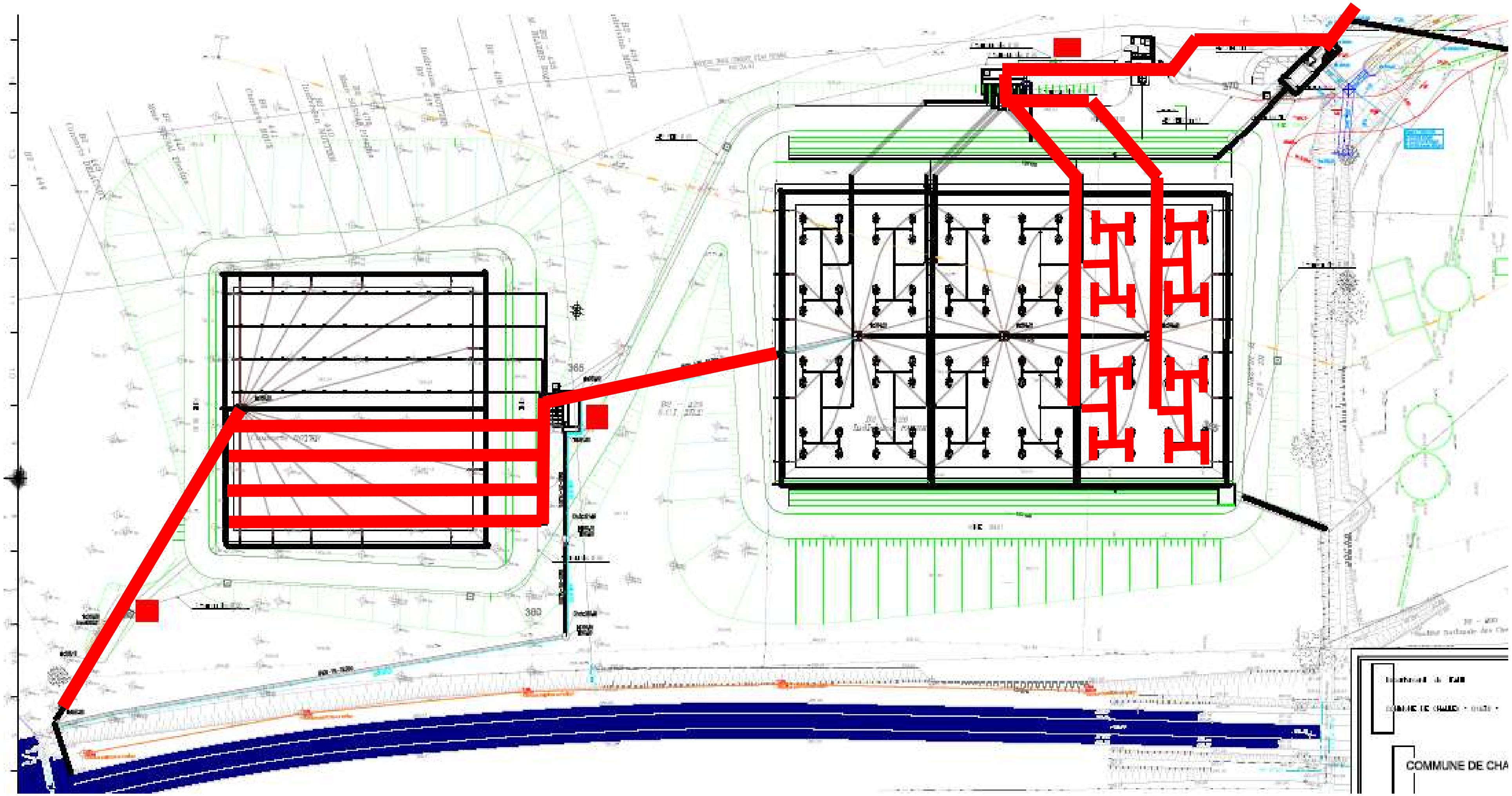
Storm events

< 8 times the dry weather flow



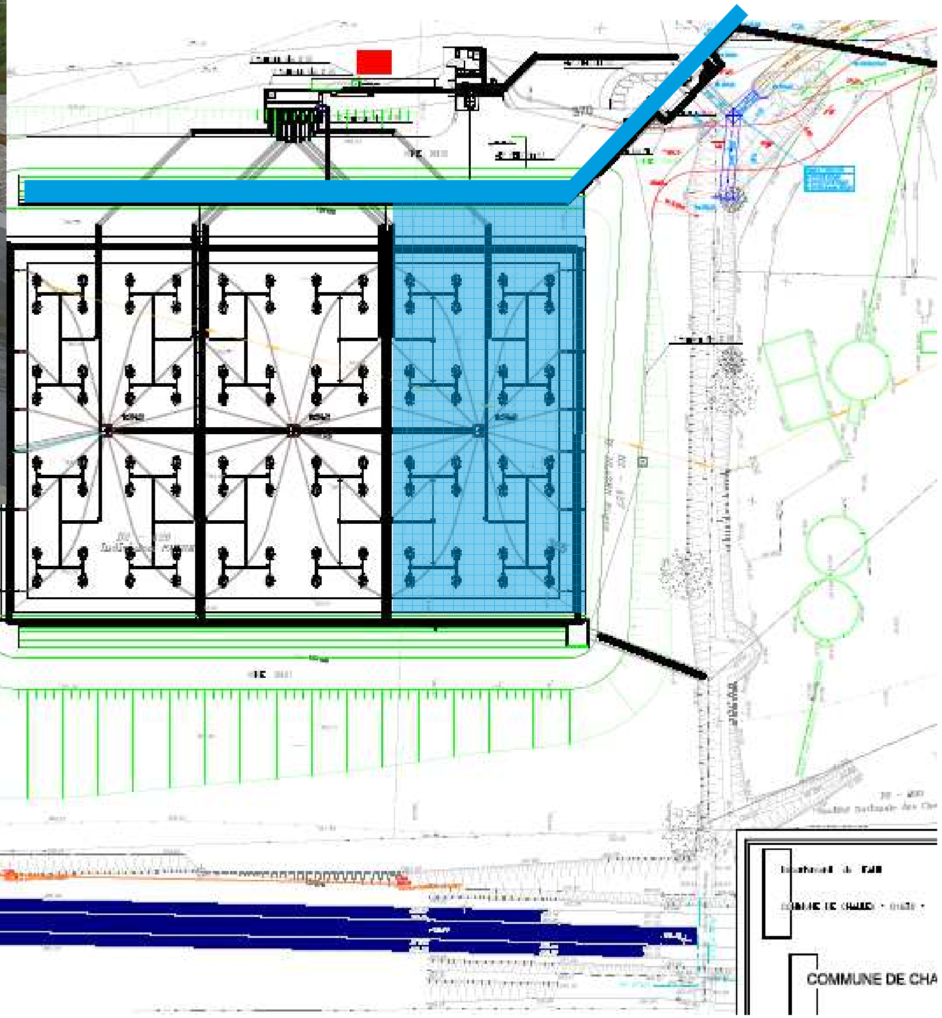
Dynamic design

< 8 times the dry weather flow



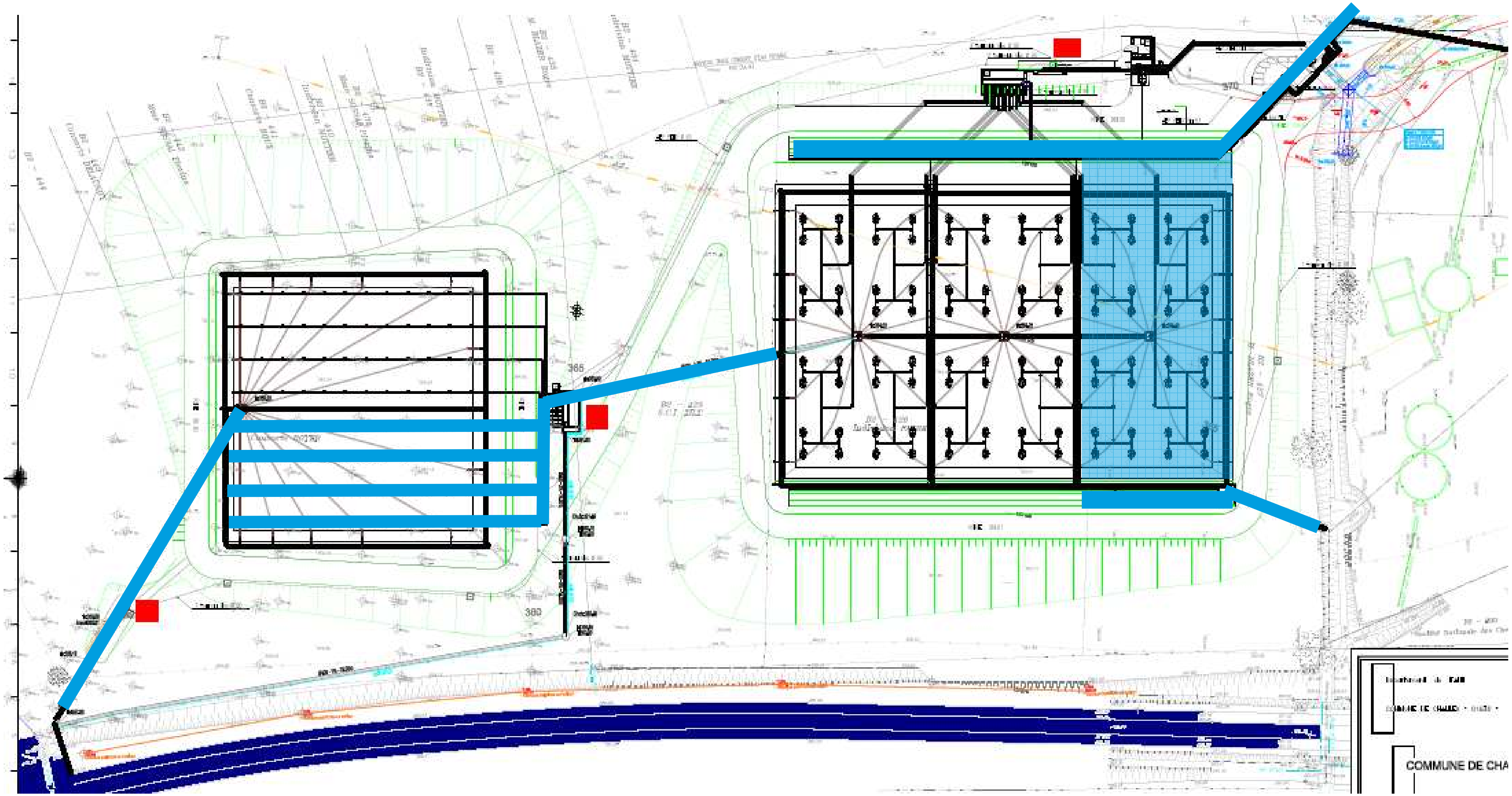
Dynamic design

> 8 times the dry weather flow



Dynamic design

> 8 times the dry hourly flow



Dynamic design

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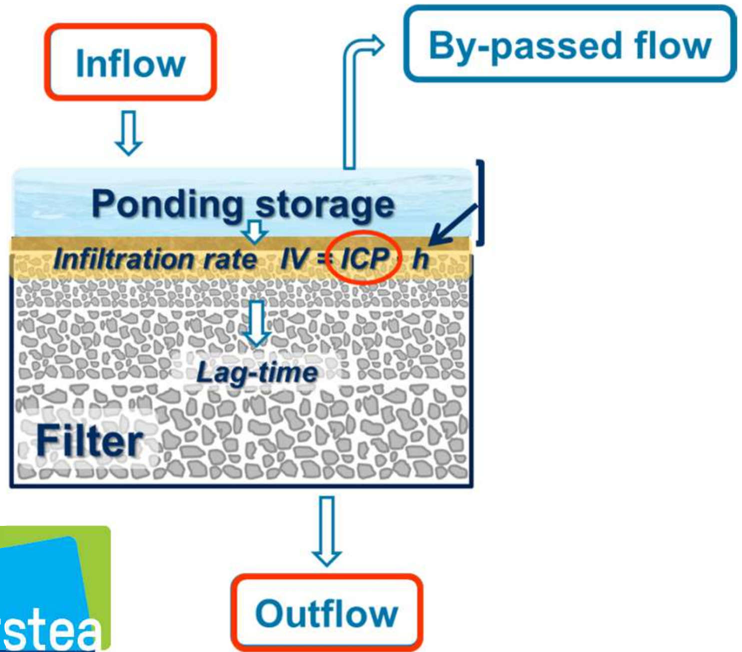
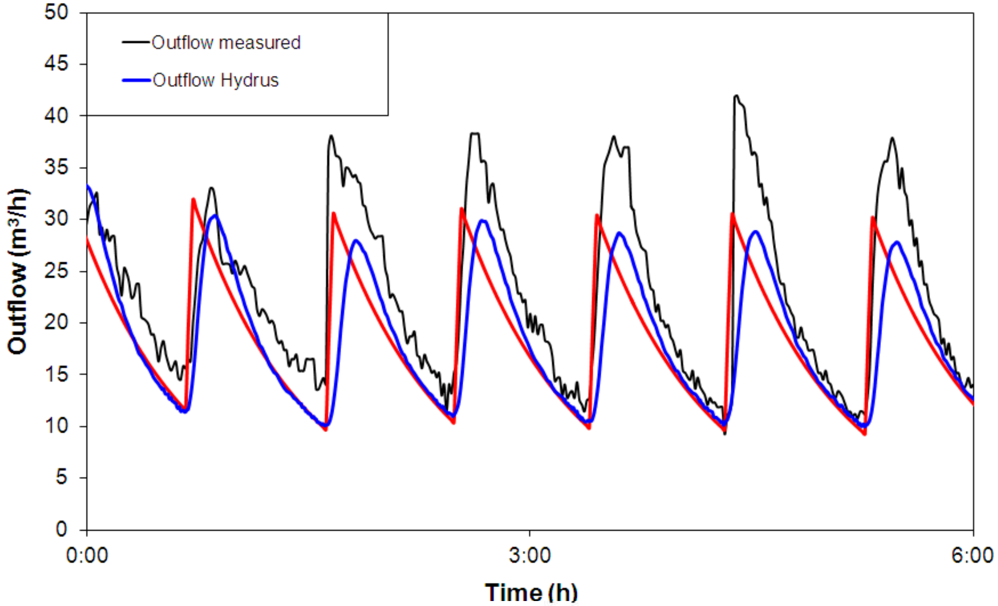
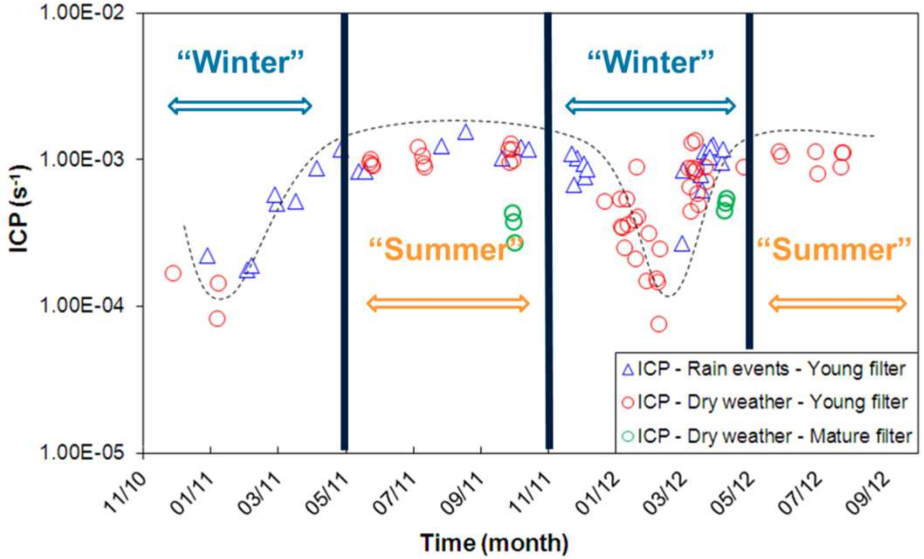
Simplified hydraulic model of French vertical-flow constructed wetlands

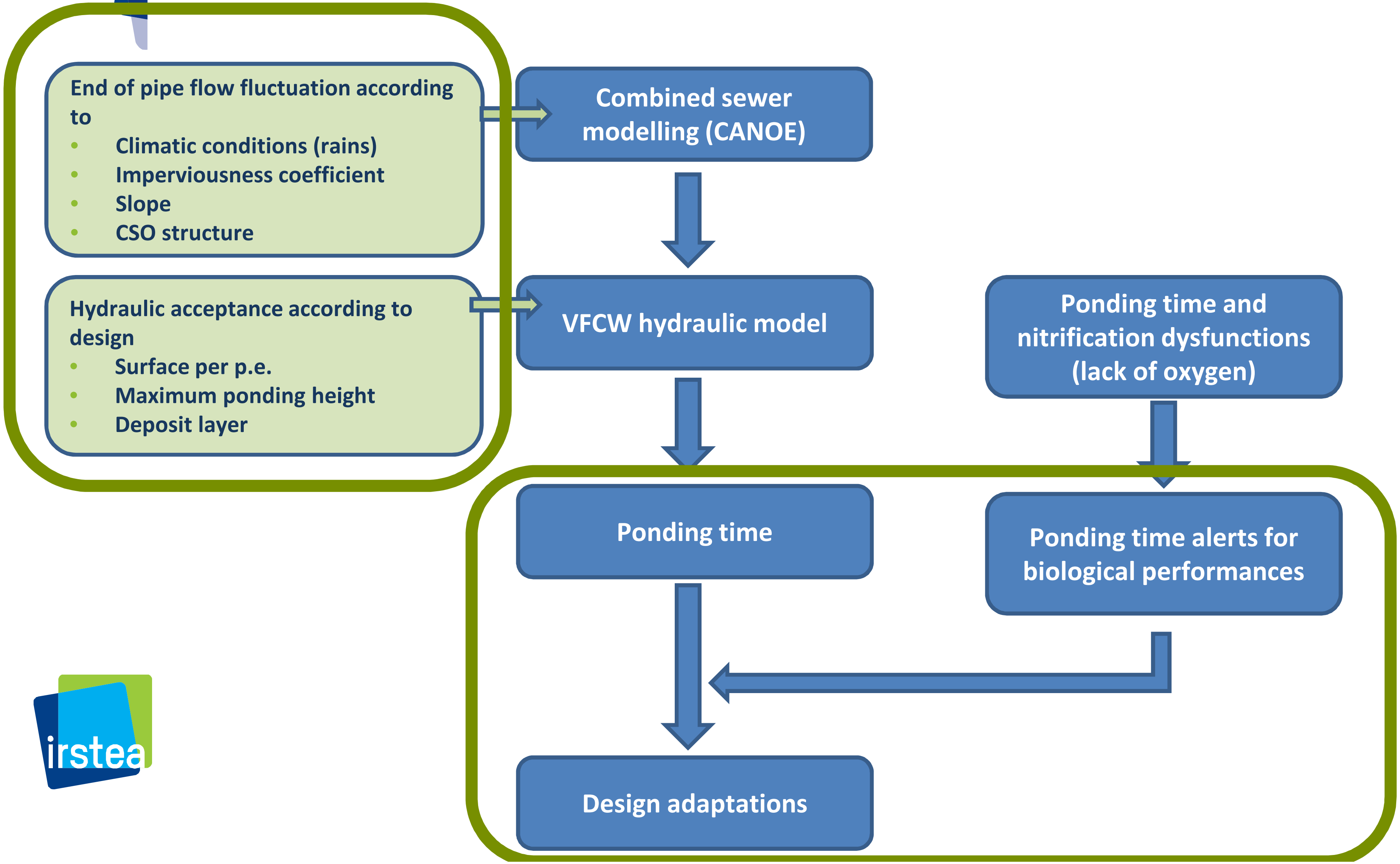
Luis Arias, Jean-Luc Bertrand-Krajewski and Pascal Molle







Dynamic design



Dynamic design

Paramètres		
Climate	Intense and occasional storms	Regular long rains
Filetr's surface (m²/PE)	1.2	1.5
First stage freeboard (m)	0.7	
Inlet by pass (m³/h per m² of filte rin operation	1.5	

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Operation

Operation

Compliance with the operating requirements of this treatment technique is indispensable to ensure the continued operation of the system and maintain its treatment performances.

The tasks of the site:

- are generally simply,
- take little time,
- do not require any particular skills.

<u>But</u> must be carried out frequently: at least twice per week.

PRE-TREATMENTS

SCREENING

Particular attention must be paid to the screening system : it can become obstructed very quickly.

If incorrectly managed, there are consequences:

- wastewaters may bypass and be sent directly to the environment,
- no input to the reed bed filters (disturbance for biomass and plants),
- malfunctions of the feeding system.

irstea

PRE-TREATMENTS

SCREENING

The **wastes** collected must be:

- **removed manually**,
- drained of any liquids (in a basket or garbage can with holes) that should be sent back to the wastewater treatment.

At each visit (twice per week).

Manual system with a slanted screen made of stainless steel.

PRE-TREATMENTS

GRIT REMOVAL (optional step)

The purpose is to extract from the treatment process the mineral elements (sand, gravel) transported by the raw wastewaters.

It is particularly useful in systems collecting rainwater.

Its functions are:

- **Avoid fermentation and odors** (accumulation of grit in the batch system),
- **Avoid filter clogging** (accumulation of particles in the first stage).

Static grit chamber

Once per year, remove the accumulated grit.

SEQUENTIAL SUPPLY SYSTEM (batch system)

Correct operation of the sequential supply system is an essential factor in the treatment process.

In the event of a malfunction, it is imperative to rapidly repair any faulty equipment and devices.

At each visit (twice per week):

- note the total number of batches since the last observation,
- check that no water flows between two batches (sign of a malfunction),
- remove any grease and floating objects (to avoid blocking the system),
- check the status of the flexible piping; spare flexible piping must always be on hand for immediate repairs.

Self-priming siphon for the first stage

Alternation of filters

During each visit (twice per week), change the filter in operation:

- proceed manually,
- note the number of the filter put into service in the register.

Pipes used as a bung to select the supplied filter

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EVEN DISTRIBUTION OF THE EFFLUENTS

At each visit (twice per week):

Visually check that the filters are correctly supplied:

- effluent evenly spread over the surface,
- no permanent ponding.

Feeding pipes for the first stage

Feeding point and anti-scouring plate

FILTERS

Several times a year:

- check the condition of the geomembranes and make repairs if holes have been made,
- check that the water drains well at the outlet and, if necessary, clean the drains,
- monitor the status of the constructions (leaks, cracks).

PLANTS

Good reed growth is an essential factor in the treatment process.

The site operator must ensure that this growth takes place during the vegetative phase of the plants (during spring and summer).

UNDESIRED PLANTS

Uprooted undesired plants

Each week (during the vegetative phase):

Uproot all undesired plants (bushes, tomatoes, nettles, etc.) **manually** and as early as possible to allow the reeds to develop, **particularly on new sites**.

PLANTS

REED HARVESTING

Once per year:

- **in October or November**,
- cut the stalks at least 20 cm above the sludge,
- take care not to damage geomembranes, feeding pipes and vents.
- never use large mechanical devices in the filters (risk of compacting the filter and damaging the pipes),
- **remove the cut reeds** and handle them **similar to any other green waste**.

Harvesting the reeds in the late fall

SLUDGE MANAGEMENT

SLUDGE MANAGEMENT

The sludge should be removed as soon as it reaches a depth of 20 cm (after 10 to 15 years of operation). It will be used as a **fertilizer**.

Once per year:

measure the depth of the sludge accumulated on the first stage.

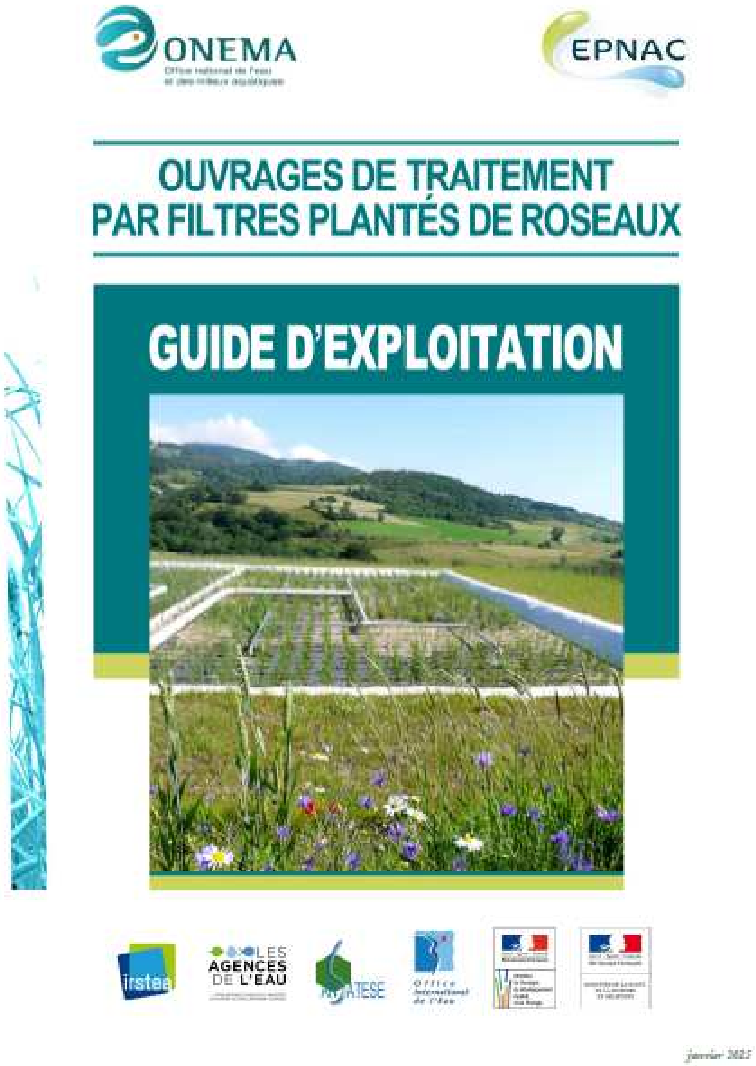
Measurement of the depth of the sludge accumulated in the first-stage

Sludge extraction

Operation is:

simple, take little time, and do not require any particular skills.

Two short visits to the site per week are necessary.



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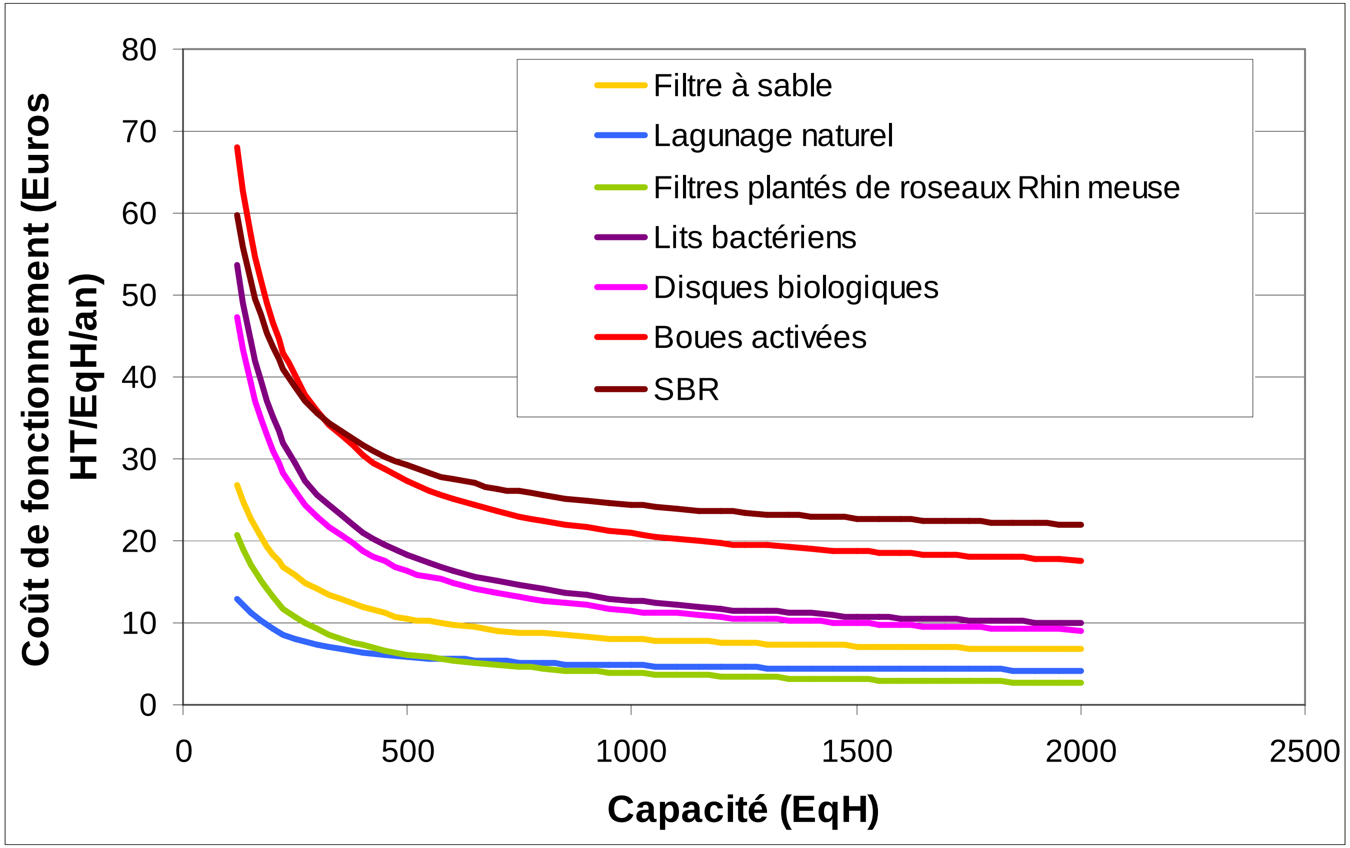
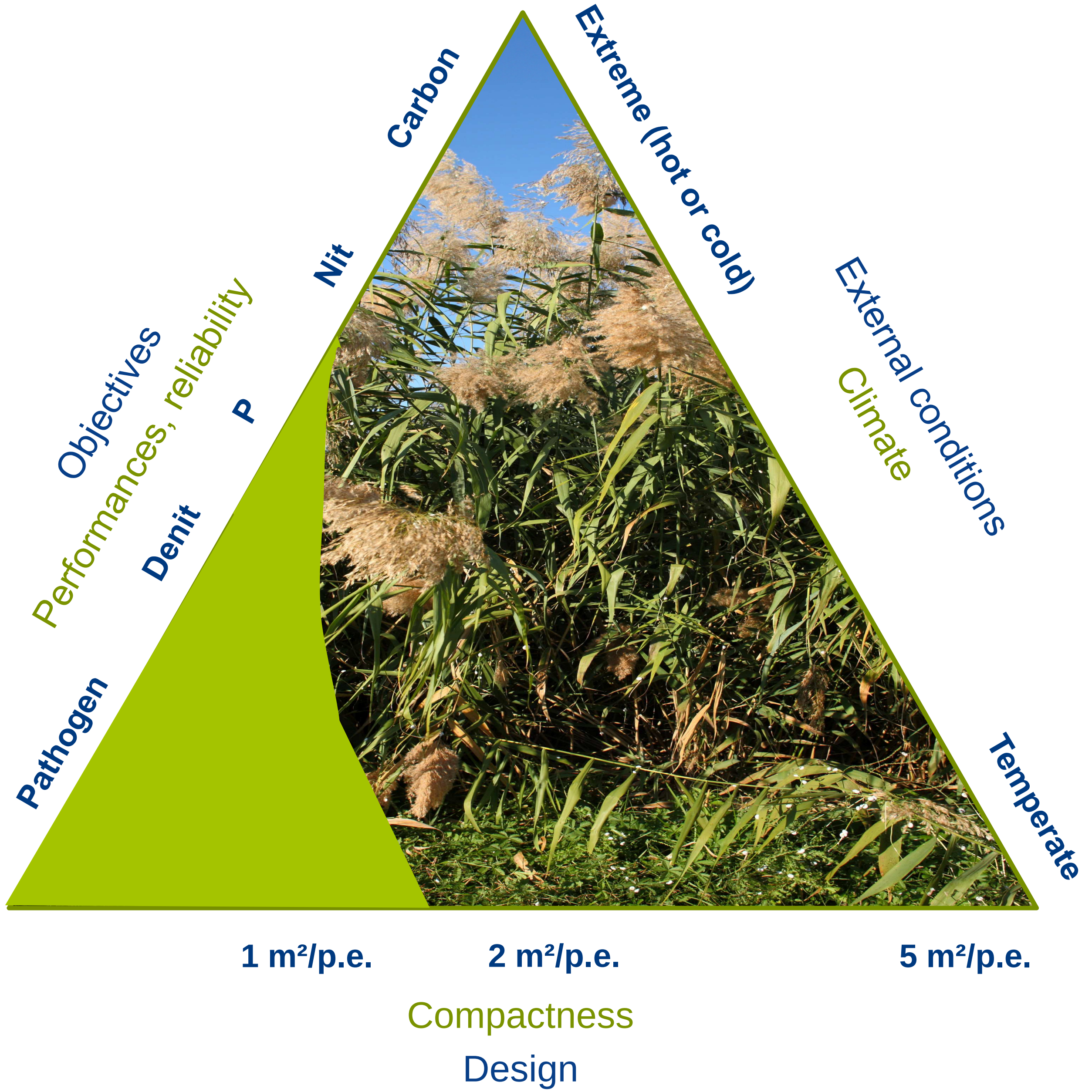
Operational costs




Carbon
Nit
P
Denit
Pathogen
Objectives
Performances, reliability
Extreme (hot or cold)
External conditions
Climate
Temperate
1 m²/p.e.
2 m²/p.e.
5 m²/p.e.
Compactness
Design

Guideline for different climates

Including desert

Domestic WW treatment for workers house of petrol industry, Oman

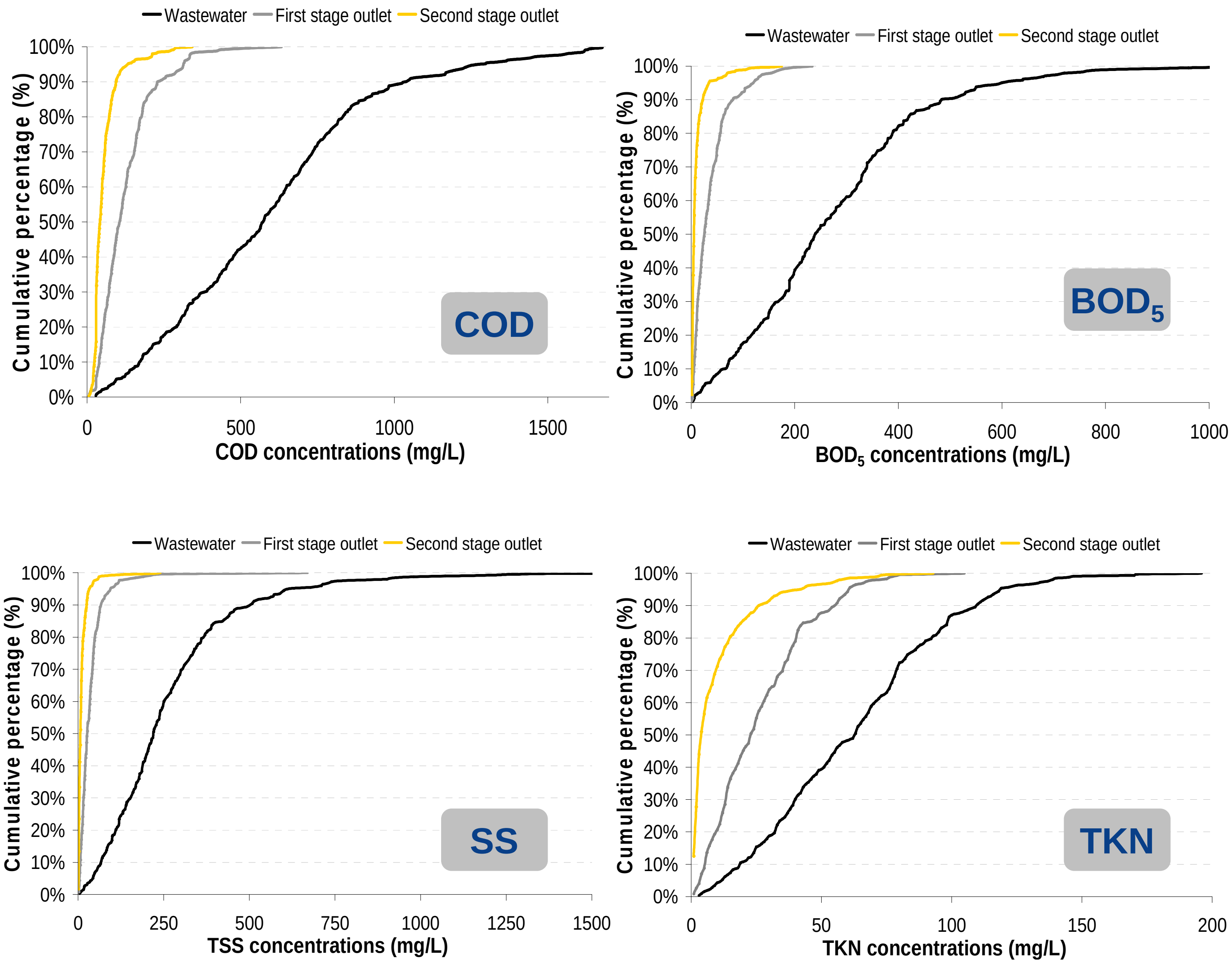
- **All by grravuty**
- **120m³/day**
- **REUSE for tree irrigation**
- **Started in January 2015**

Looking for a more compact solution

No strict outlet requirement

Similar or more stringent requirements

Looking for a more compact solution

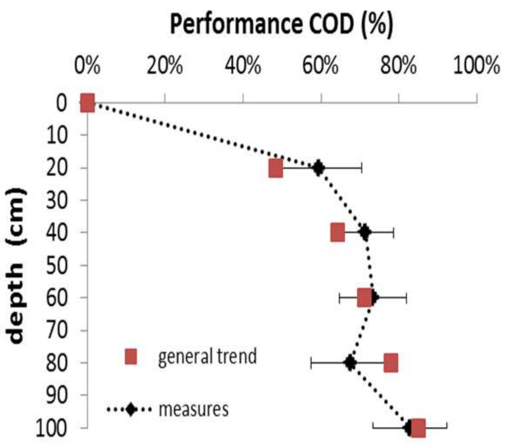


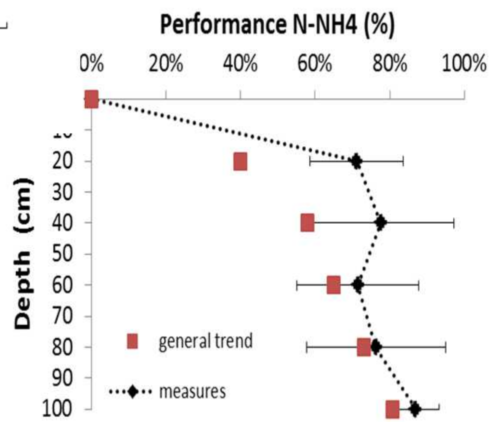
Looking for a more compact solution

No strict outlet requirement

Only the first stage

Increase the first layer





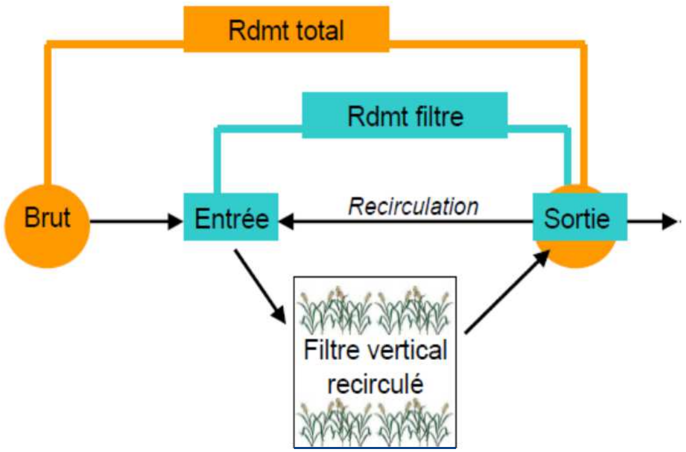
	Ensure removal rate of %
BOD	85
COD	80
TSS	85
TKN	70

Looking for a more compact solution

No strict outlet requirement

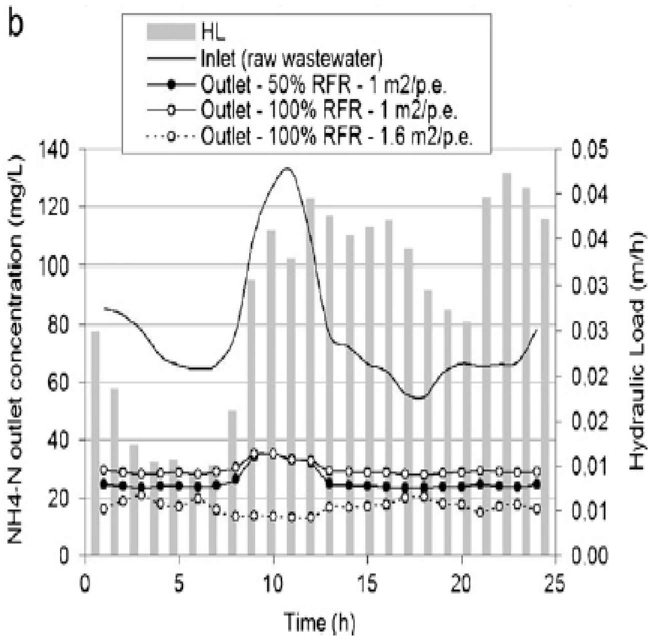
Only the first stage with recirculation

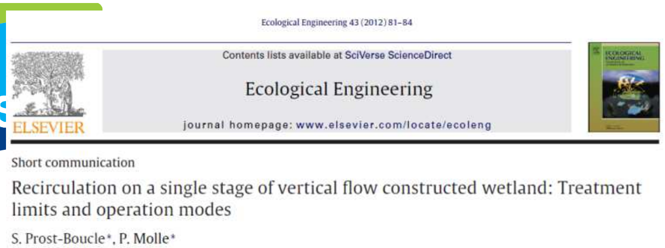
The filter has similar removal rate until HLR of 70 cm/d



Looking for a more compact solution

No strict outlet requirement





Ecological Engineering 43 (2012) 81–84

Contents lists available at SciVerse ScienceDirect

Ecological Engineering

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Short communication

Recirculation on a single stage of vertical flow constructed wetland: Treatment limits and operation modes

S. Prost-Boucle*, P. Molle*

Only the first stage with recirculation

The filter has similar removal rate until HL of 70 cm/d

1.5 m²/PE
100 % of recirculation

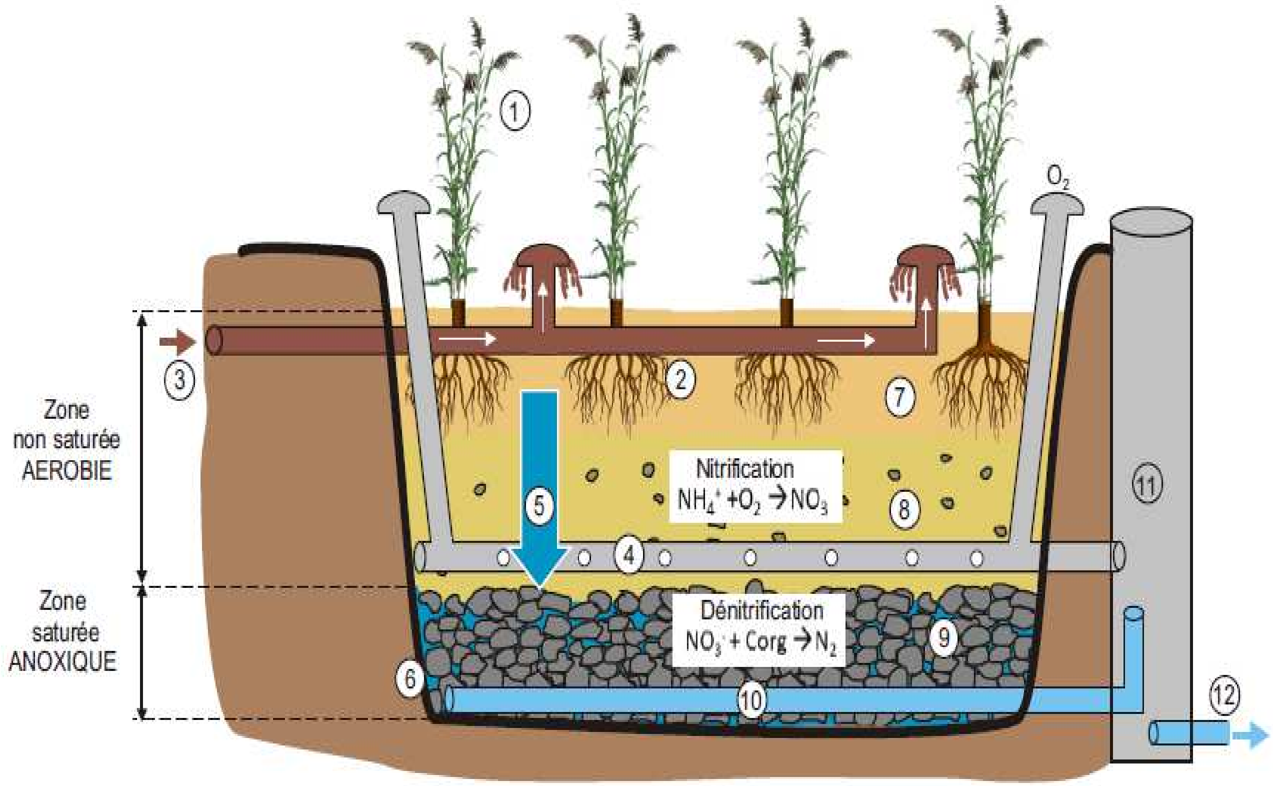
	Outlet concentration (mg/l)
BOD	25
COD	125
TSS	35
TKN	30

Similar or more stringent requirements

Unsaturated/saturated vertical filter

Objectives : increase HRT and decrease flow velocity (SS deposit)

Work with only one stage without using sand

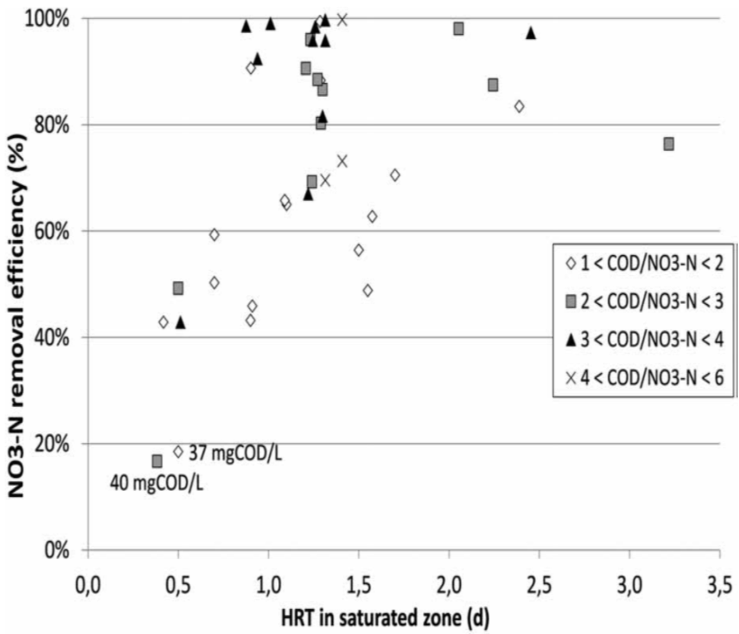


Similar or more stringent requirements

Unsaturated/saturated vertical filter

Performances

	Average removal rate %
BOD	96
COD	92
TSS	94
TKN	60- 90
NH4-N	50 - 90
TN	40-70



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Using one filter stage of unsaturated/saturated vertical flow filters for nitrogen removal and footprint reduction of constructed wetlands

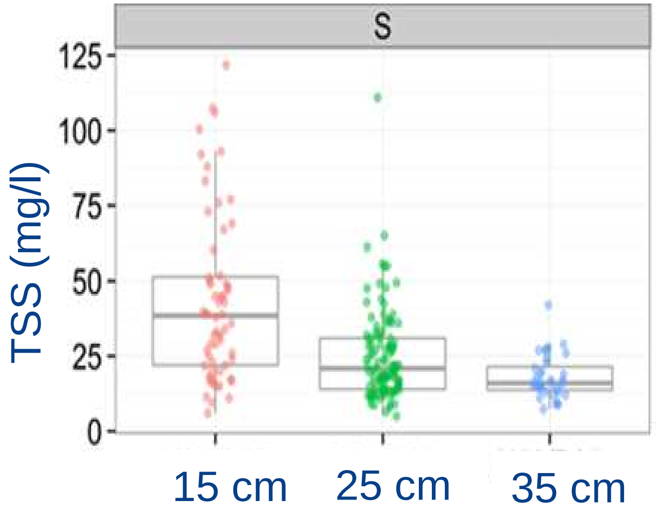
Ania Morvannou, Stéphane Troesch, Dirk Esser, Nicolas Forquet, Alain Petitjean and Pascal Molle

Similar or more stringent requirements

Unsaturated/saturated vertical filter

Nitrogen removal depend on designed used

- Recirculation rate (100 %)
- depth of unsaturated and saturated layer



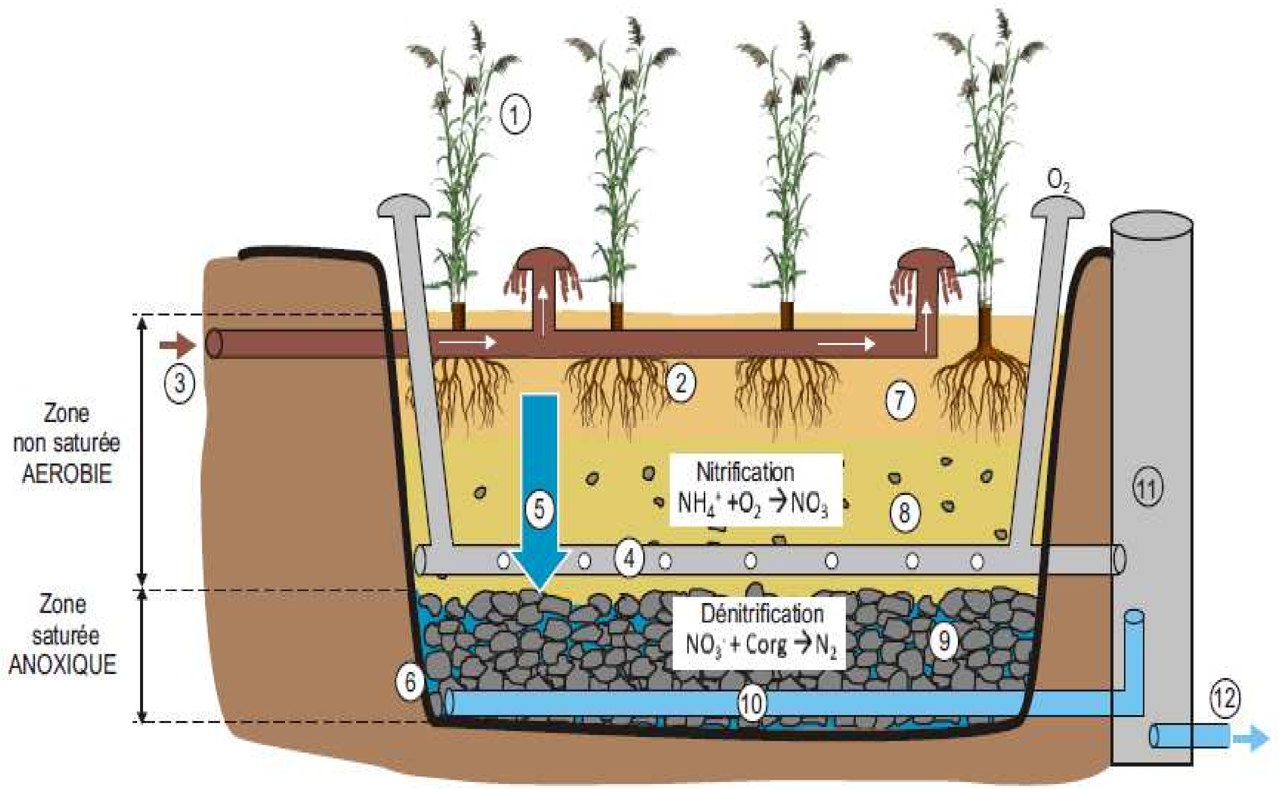
Depth of saturated layer has to be > 40 cm to ensure outlet SS below 35 mg/l

Similar or more stringent requirements

Unsaturated/saturated vertical filter

Accumulation of solids at the bottom of the filter

Drainage procedure once a year to bring back the solids at the treatment plant inlet



Construction

Before cosntruction

Looking for media
Permeability validation

Earthwork

Earthwork

Sealing system

Sealing system

Take care of run off waters

Drainage/aeration system




Filling the filters

Planting


Thank you for your attention