The EU funded SWIM-SM: developing capacity for Sustainable and Integrated Wastewater Treatment and Reuse

Online Course on Natural Treatment Systems: Types of Constructed Wetlands

Types of constructed treatment wetlands

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Overview

1. Introduction – classification
2. Surface flow systems
3. Subsurface flow systems
4. Combined and tertiary treatment systems
5. Intensified wetlands

Types of systems

Based on water flow characteristics

- **surface flow** (visible water surface)
- **subsurface flow** (water below soil surface)

Based on plant species characteristics

- **floating plants** (ex. duckweed)
- **submerged plants** (ex. waterpest)
- **emergent plants** (ex. reed)

Different groups of macrophytes

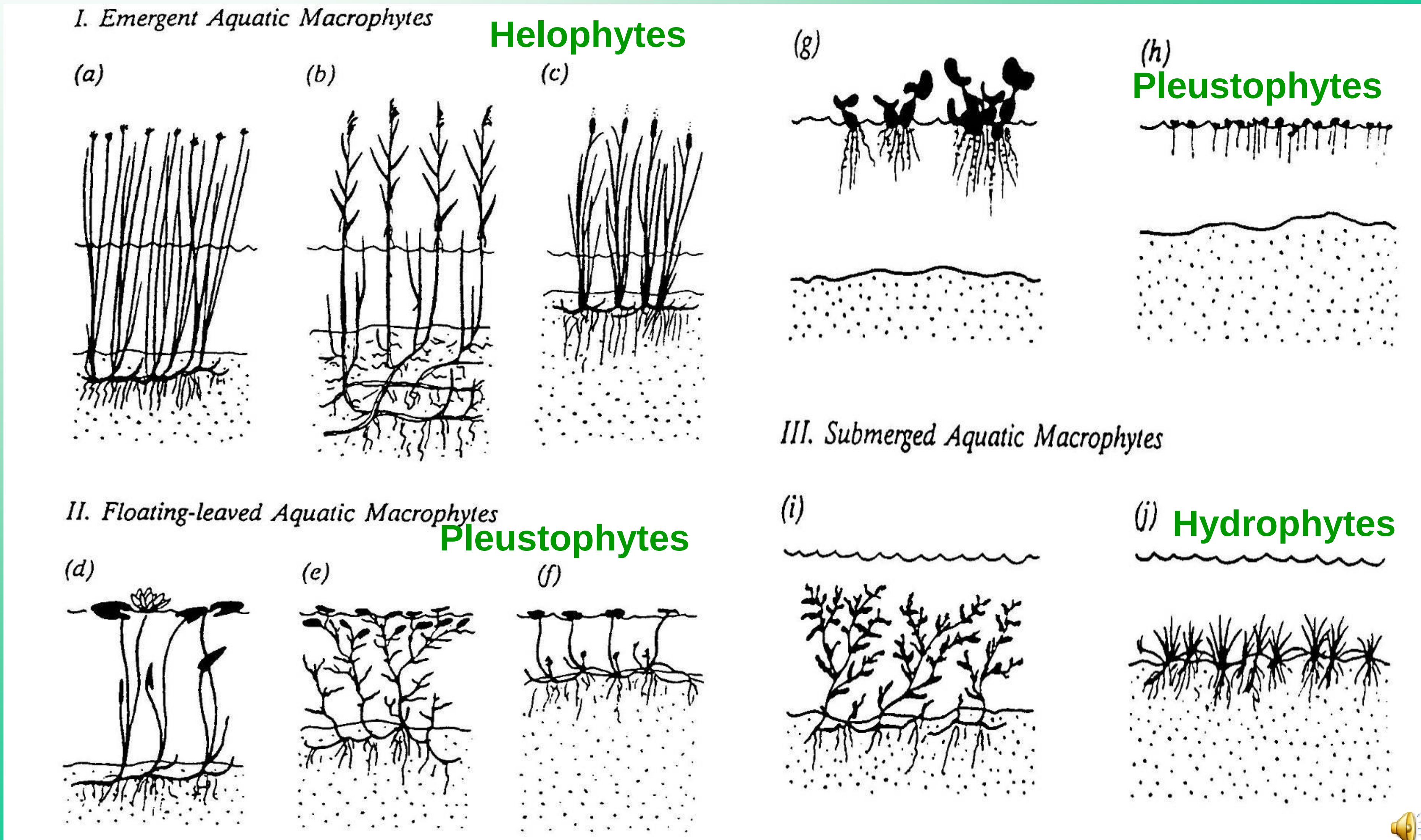
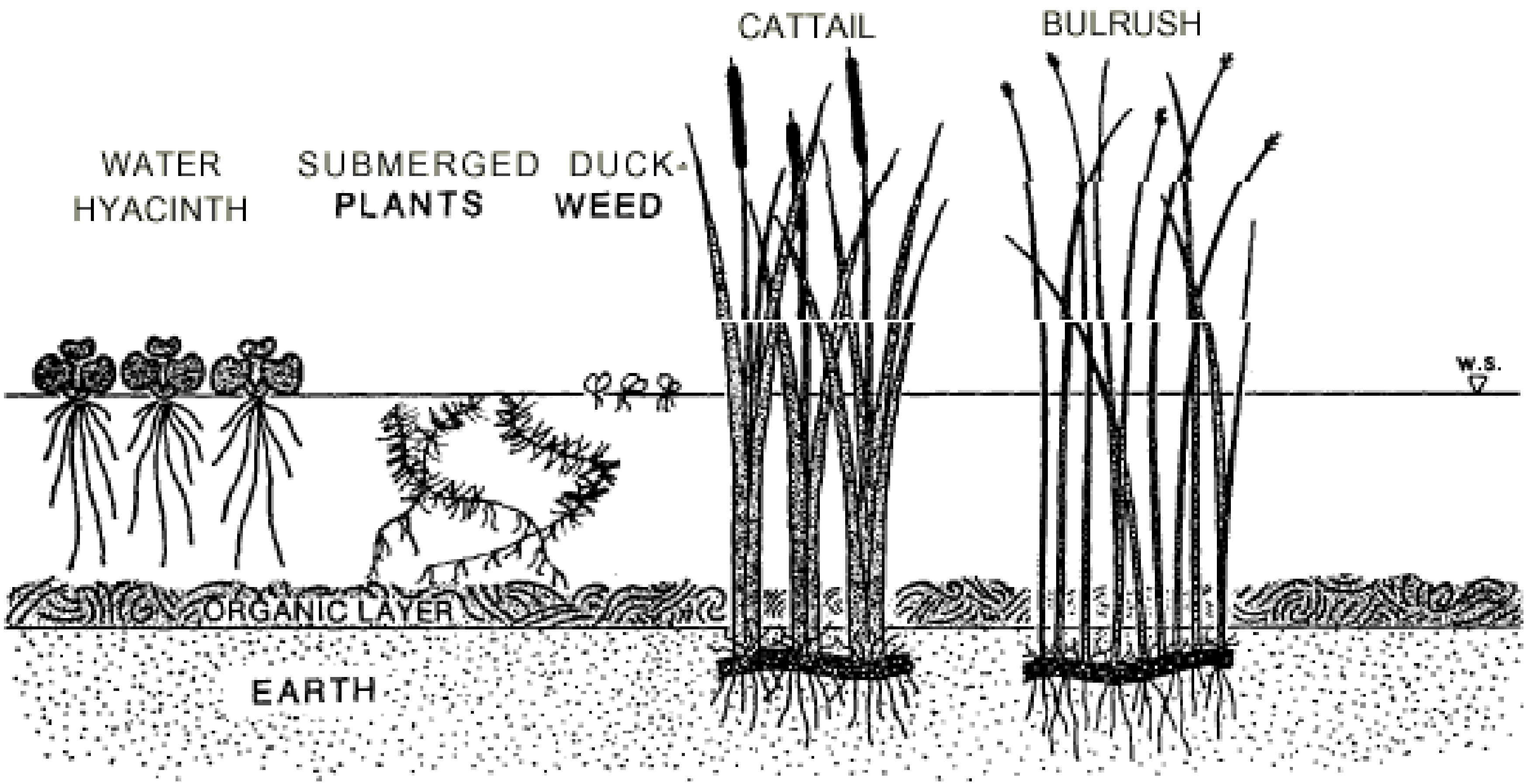


Figure I-l. Common aquatic plants.



Selection of macrophyte species

- Most often used are emergent plants (reeds, rushes, sedges) and floating plants (water hyacinth, duckweed)
- Recommended to use local, indigenous species and not to import exotic, possibly invasive species
- Easy lab-scale growth tests can be performed to check whether or not the plants can survive and grow in the given wastewater
- Plants should have high biomass production, an extensive root system and should be able to withstand shock loads and short dry periods

Types of systems

Above-ground water: surface flow (SF) constructed wetlands

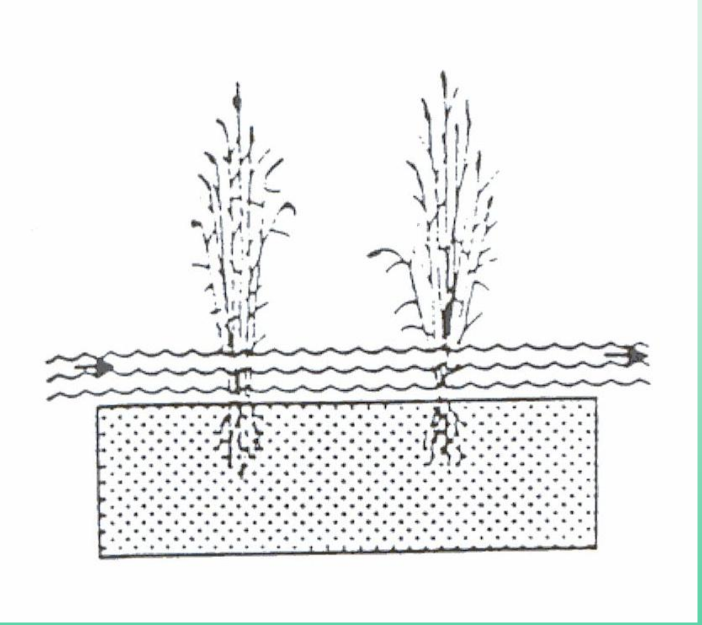
- with emergent macrophytes also called helophytes
- with floating-leaved, bottom-rooted macrophytes
- with free-floating macrophytes
- with submersed macrophytes
- with floating mats of emergent macrophytes

Below-ground water: subsurface-flow (SSF) constructed wetlands

- horizontal-flow systems (HSSF) or vegetated submerged beds (VSB), planted with emergent macrophytes or helophytes
- vertical-flow systems (VSSF) or infiltration wetlands, planted with emergent macrophytes or helophytes

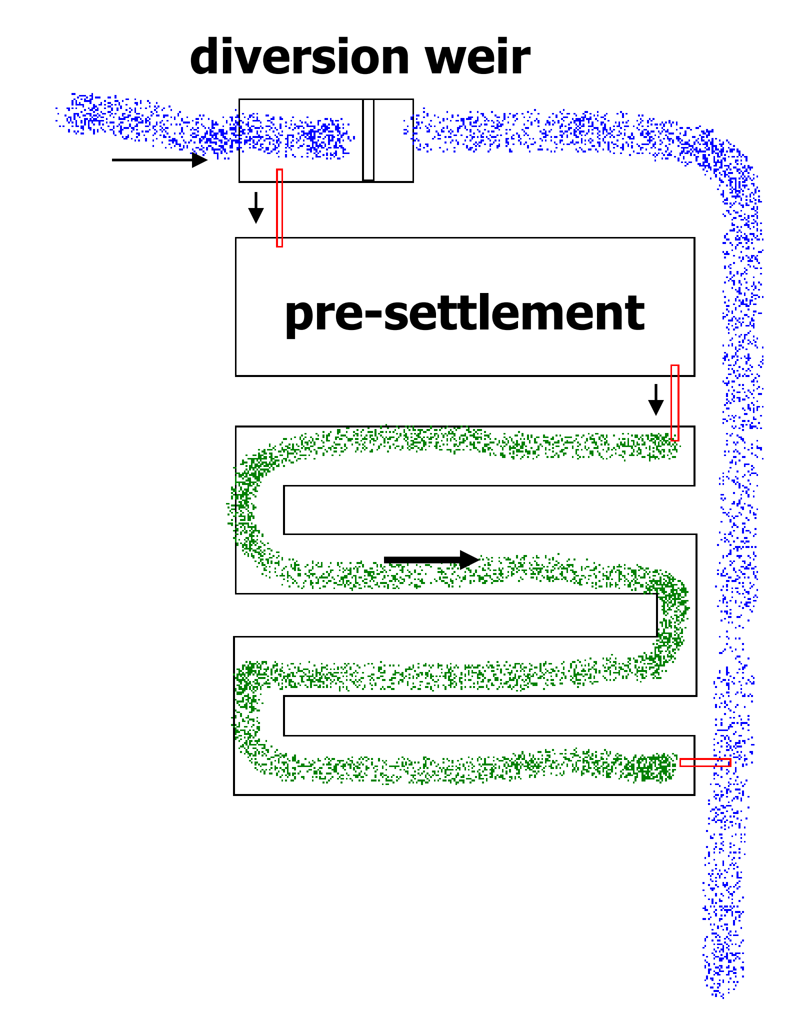
Part 2
Surface flow systems

Free-water-surface systems (FWS)



Water flows <u>over</u> soil media and < 50 cm deep.
Mostly planted with sedges, reeds, rushes.
This is a land intensive system (5-10 m^2 per PE).

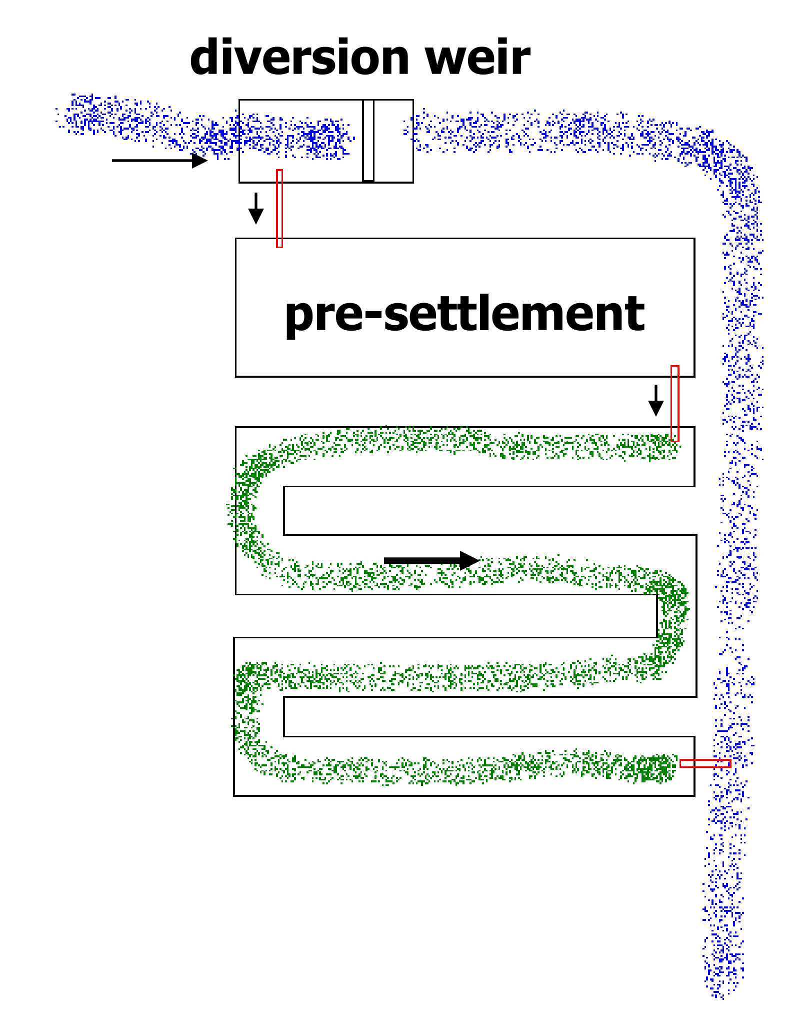
Example of typical lay-out



Diversion weir

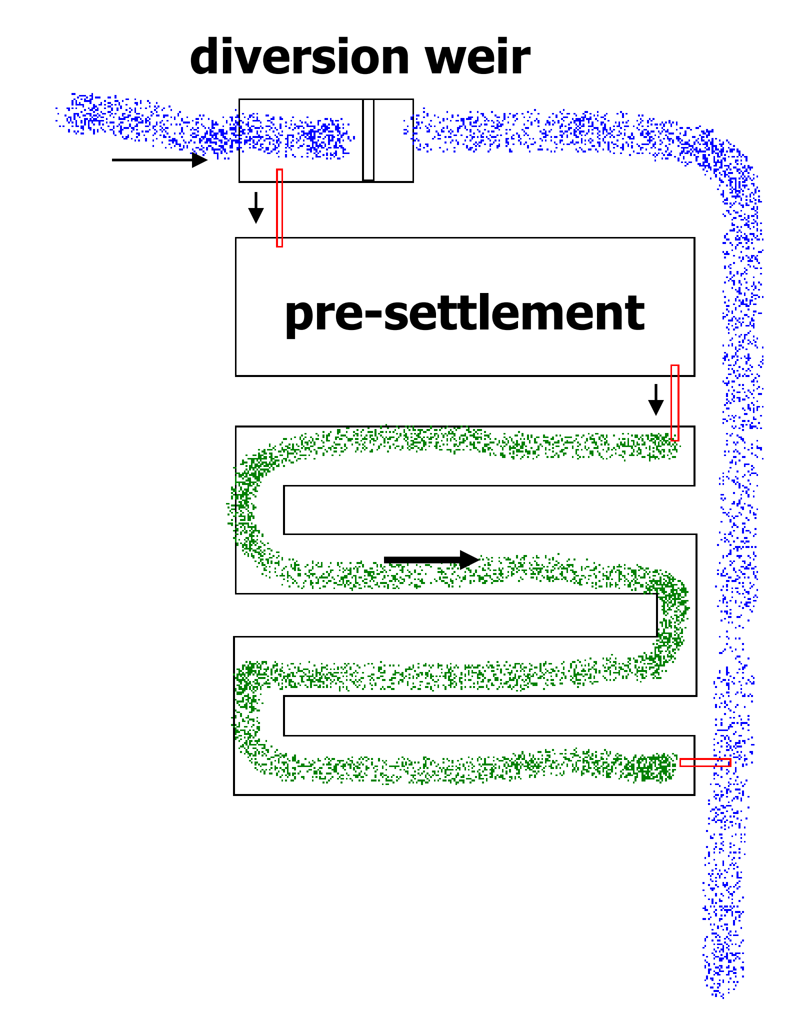
- normal flow to wetland
- storm flow bypassed

Example of typical lay-out



Presettlement pond, removes large part of suspended solids, enables easy access for desludging (no plants)

Example of typical lay-out



Reed ditches, serpentine shape (high length to width ratio) promotes plug flow and avoids dead zones, thus better treatment.

Marsh-pond-marsh system

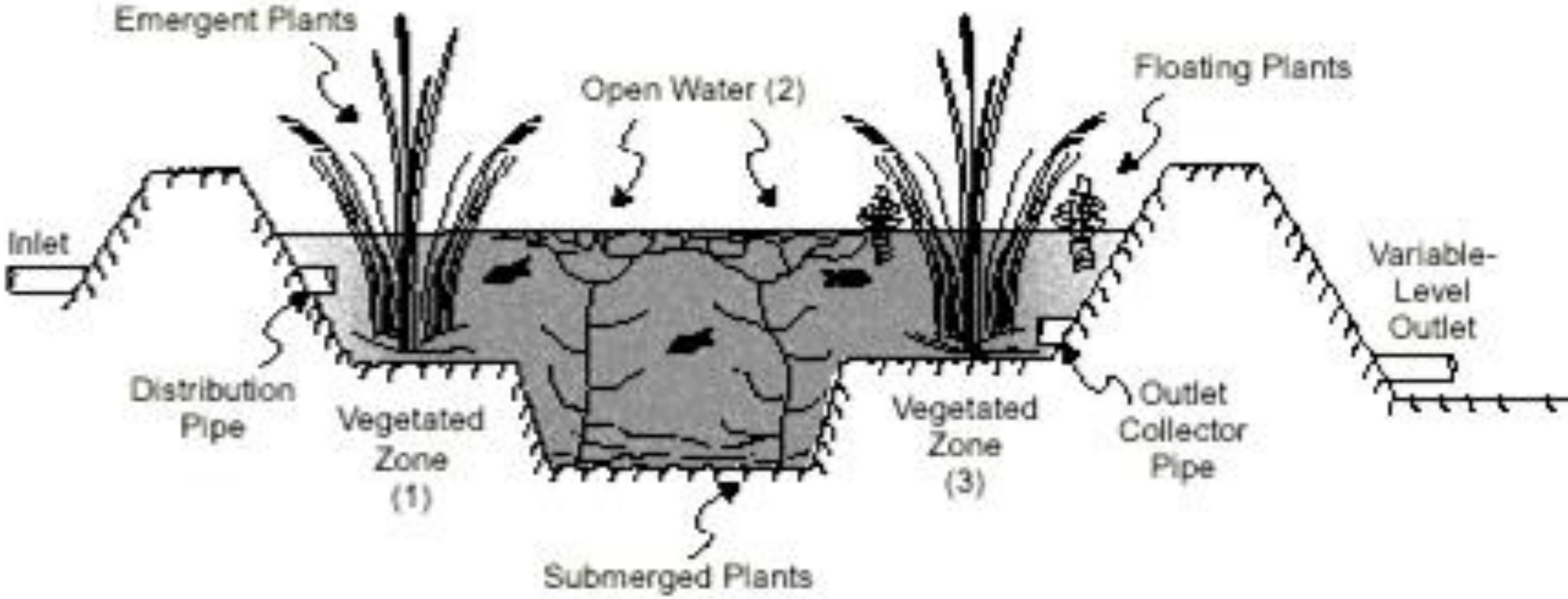


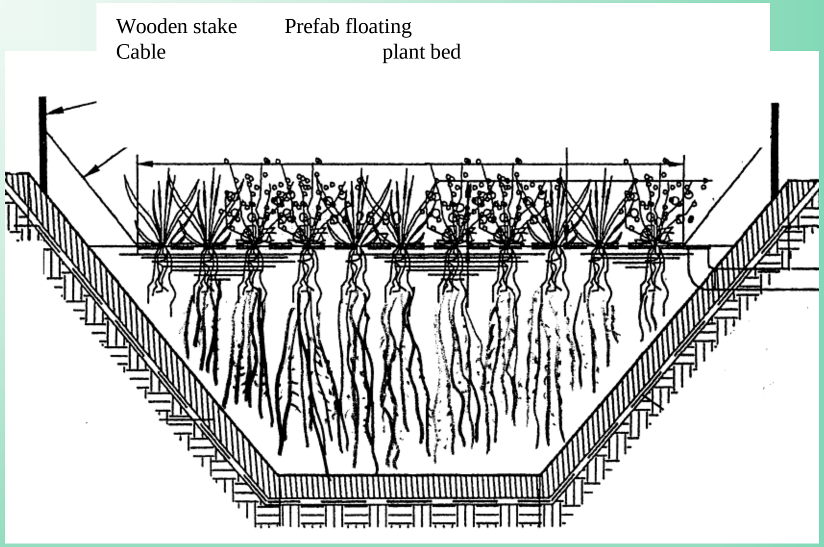
Figure 2-4. Profile of a three-zone FWS constructed wetland cell

Marsh-pond-marsh system

Marsh-pond-marsh system

- Different ecotypes have complementary pollutant removal capabilities
- Open water promotes disinfection and reaeration
- Open water zone redistributes flow
- Open water supports fish that predate on mosquito larvae
- Open water zone should not be too large in order to avoid algal blooms (2-3 days hydraulic residence time)
- Most easy way to maintain open water is to deepen the wetland to about 1.5m

Floating mats



Plants are growing on floating mats of coconut fiber; roots are suspended in the water. The main advantage is that plants move up and down with the water level, so there is no risk of drowning the plants in case the water level rises quickly.

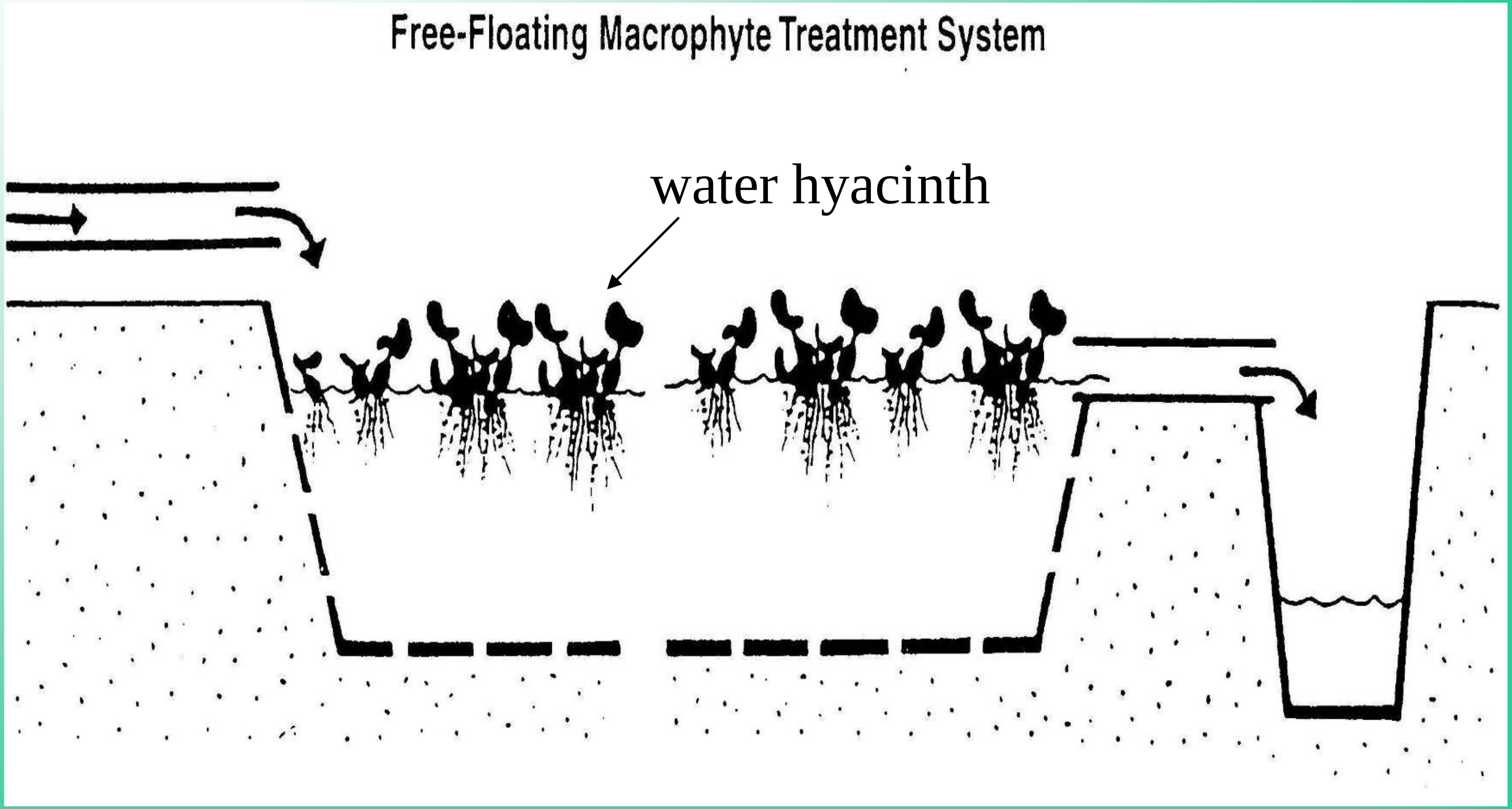
Floating mats

Combined sewer overflow water (mix of wastewater and stormwater) treated by floating mats of helophytes in Bornem, Belgium (Aquafin Ltd)

Aquatic plant systems

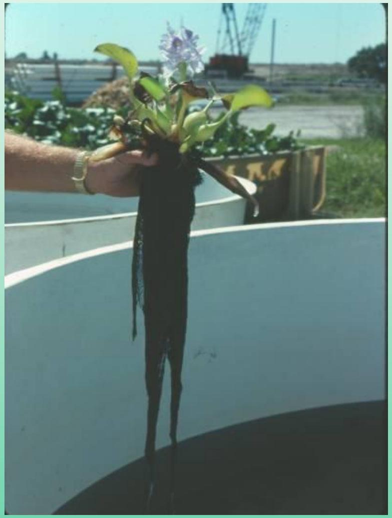
Similar to FWS except the water depth > 50 cm. Typical plants include water hyacinth, duckweed and pennywort. Fish can also be used in this system to aid in nutrient absorption.

Pleustophyte filter



Pleustophyte filter

Root system of water hyacinth *(Eichhornia)*



Domestic sewage treatment with water hyacinth ponds in Orlando, Florida.


Photo: George Tchobanoglous
Water hyacinth CW (Aqua III) in San Diego, California
3 25 '95

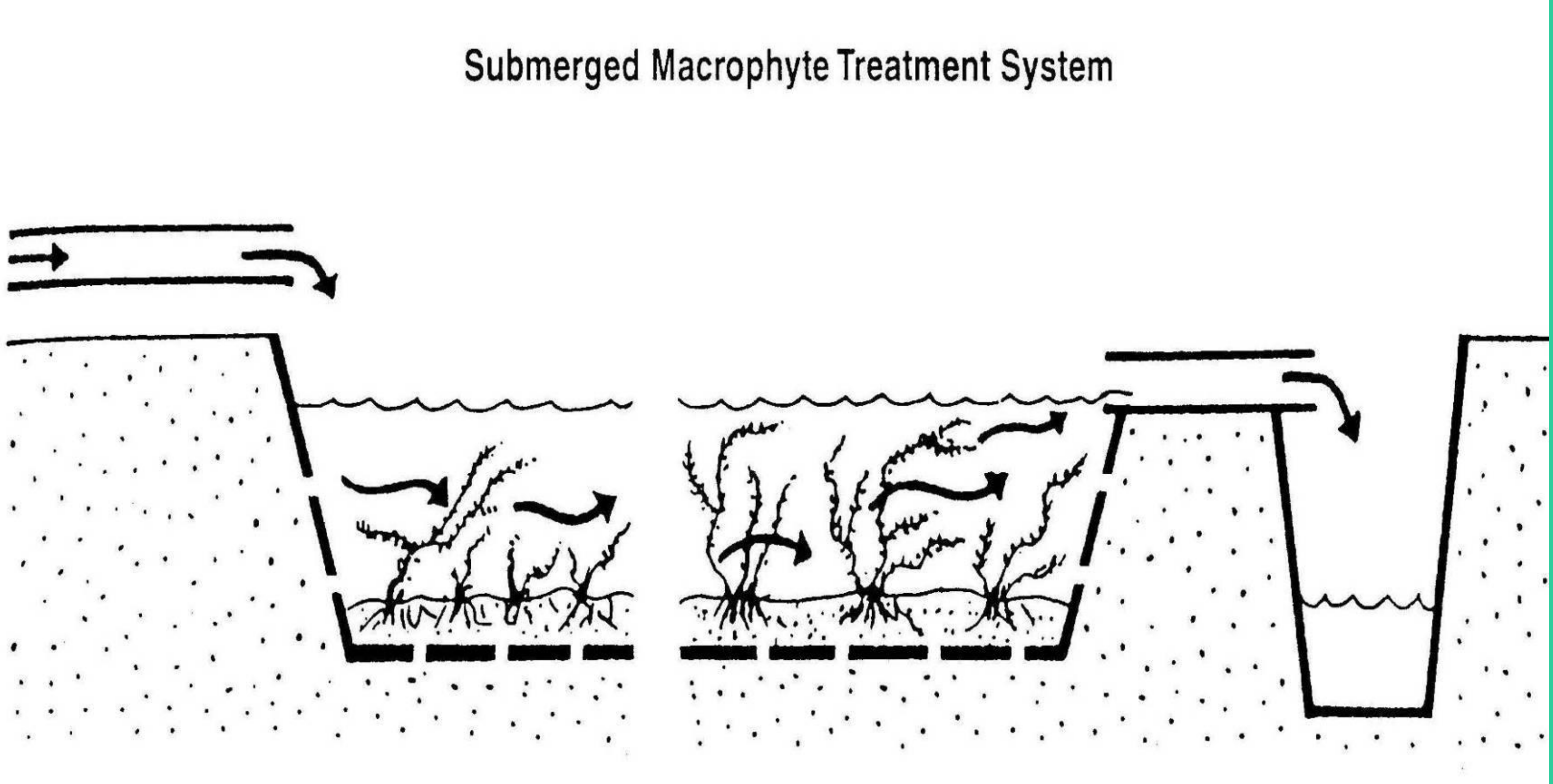
Aeration may be needed to reduce foul odors and to have more efficient aerobic processes.

Pleustophyte filter

Duckweed (*Lemna*) pond in Tielt-Winge, Belgium, Aquafin Ltd.

The black plastic squares avoid the piling up of plants in one corner due to wind action.

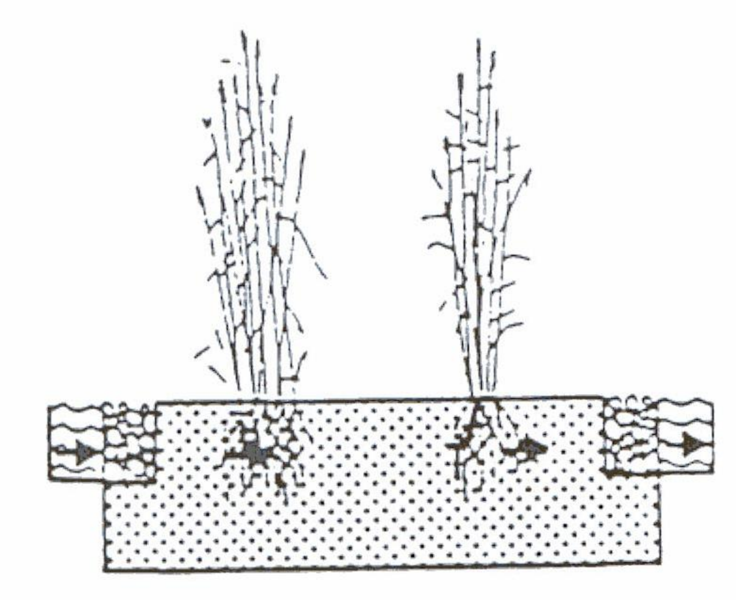
Hydrophyte filter



Schematic presentation of a hydrophyte filter for wastewater treatment with submerged plants like *Elodea canadensis* (from Brix, 1993).
Can only be used with non-turbid wastewater (pre-treated) otherwise plants do not receive enough light for photosynthesis.

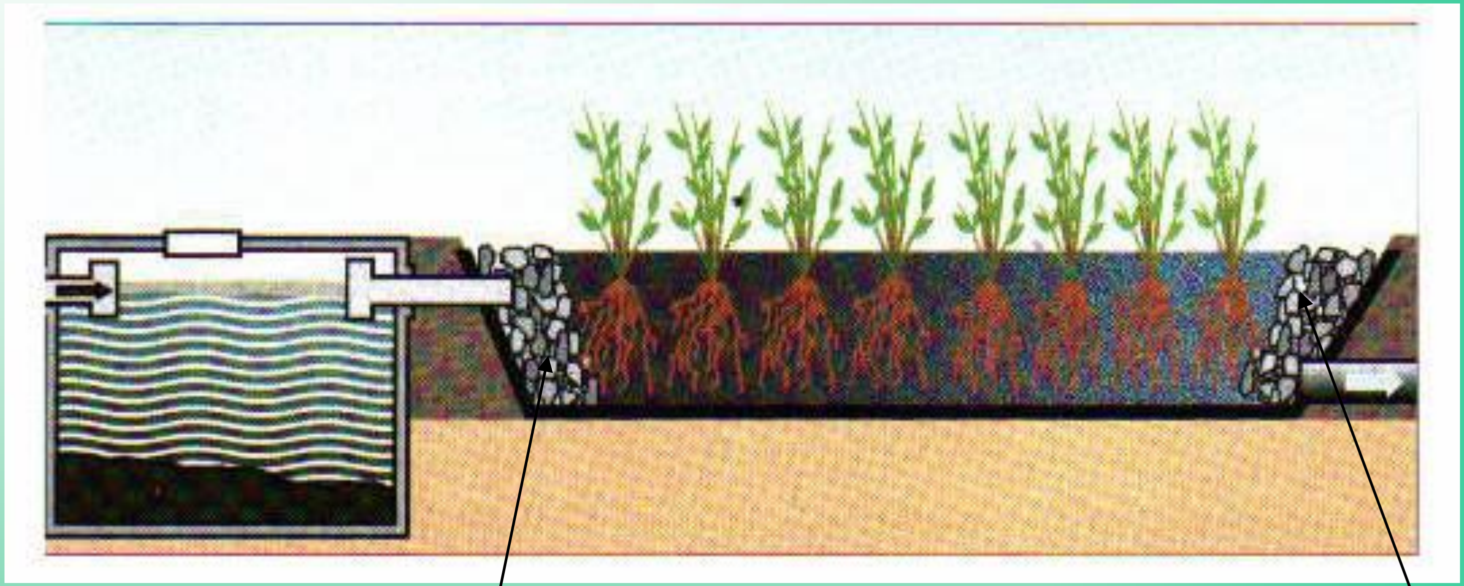
Part 3
Sub-surface flow systems

Horizontal sub-surface flow system or vegetated submerged beds



Water flows inside a medium of sand, gravel, soil and/or rock (layer of 60-80 cm). Most often planted with emergent macrophytes. Amount of land reduced (3-5 m^2 per PE) compared to FWS CW.

Typical lay-out for single household system



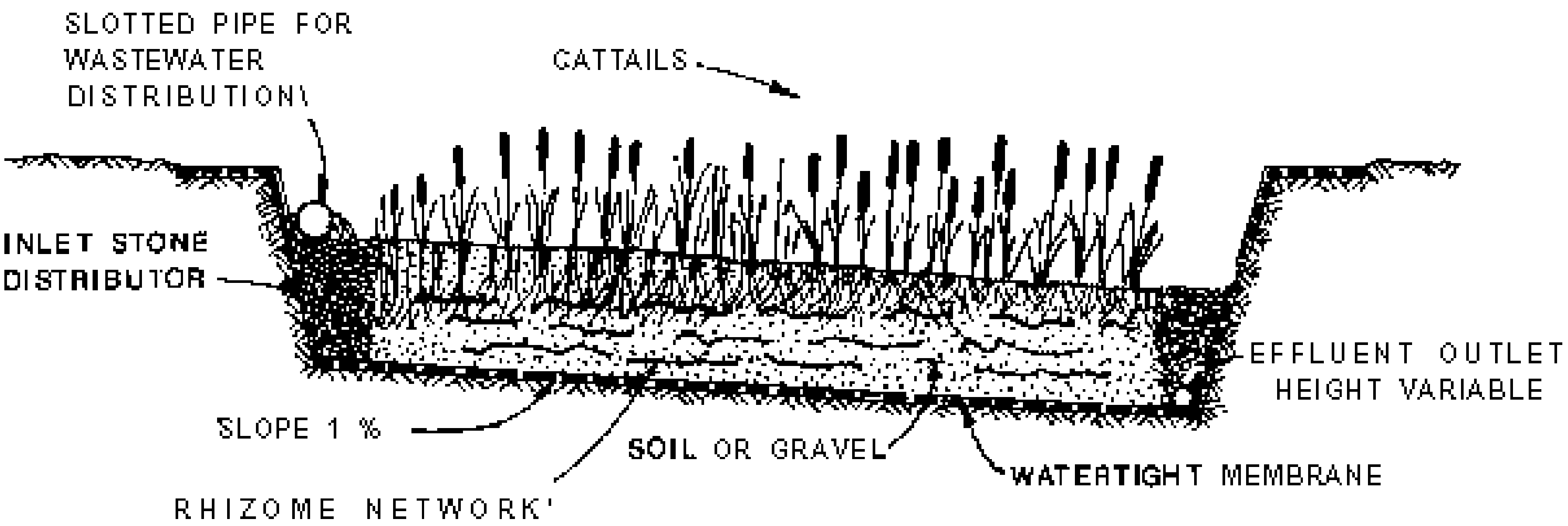
septic tank to reduce BOD and TSS

Gravel, sand or soil bed planted with emergent macrophytes

Inlet and outlet zone with coarse gravel or rocks for better water distribution

3. Subsurface flow systems

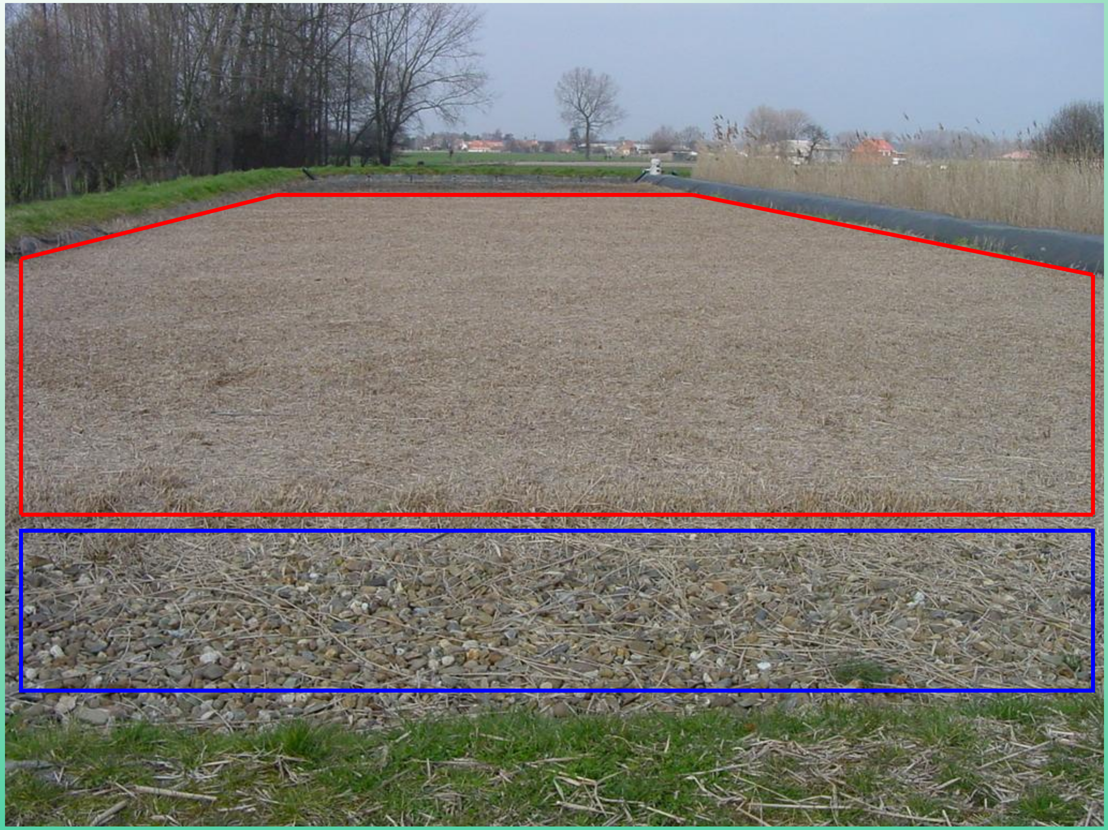
Figure 3-1. Typical cross section - SFS system.



Typical lay-out

Inlet zone with rocks and several vertical riser pipes to distribute wastewater over the entire width of the bed.

Typical lay-out



Gravel bed (fine gravel)

Outlet zone (cobbles)

Typical lay-out

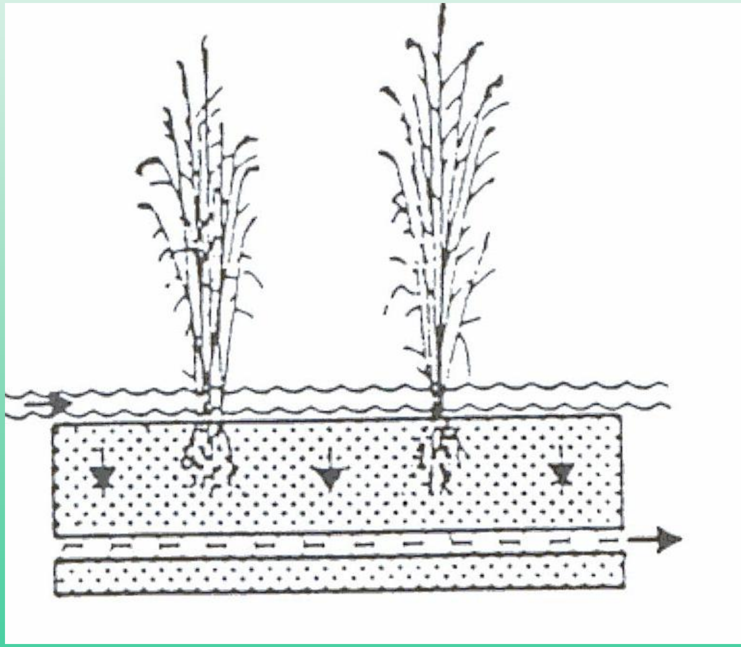
Outlet zones have a drainage tube at the bottom, connected to a flexible elbow which allows water level control.

Full-scale examples

Sub-surface flow reed bed in Saxby, England (Severn Trent Water), two beds in series.

Sub-surface flow reed bed in Zemst, Belgium (Aquafin) , two beds in parallel.

Vertical-infiltration systems



Water is pumped on the surface and then drains down through the filter layer.
Emergent macrophytes are commonly planted.
Amount of land minimal (2-3 m^2 per PE).

Filter material coarse sand or fine gravel.

Several vertical riser pipes ensure good distribution of water.

Example single-household system

Construction of impermeable basins.

With duplicate basins, one bed is loaded, the other one is resting (alternation between 4-7 days). During resting period, accumulated organic material can be composted and pores can fill again with air/oxygen.

Example single-household system

Influent distribution system (tubes with openings at regular distances).

Example single-household system

Planted with reed.
Top layer of gravel.

Full-scale example

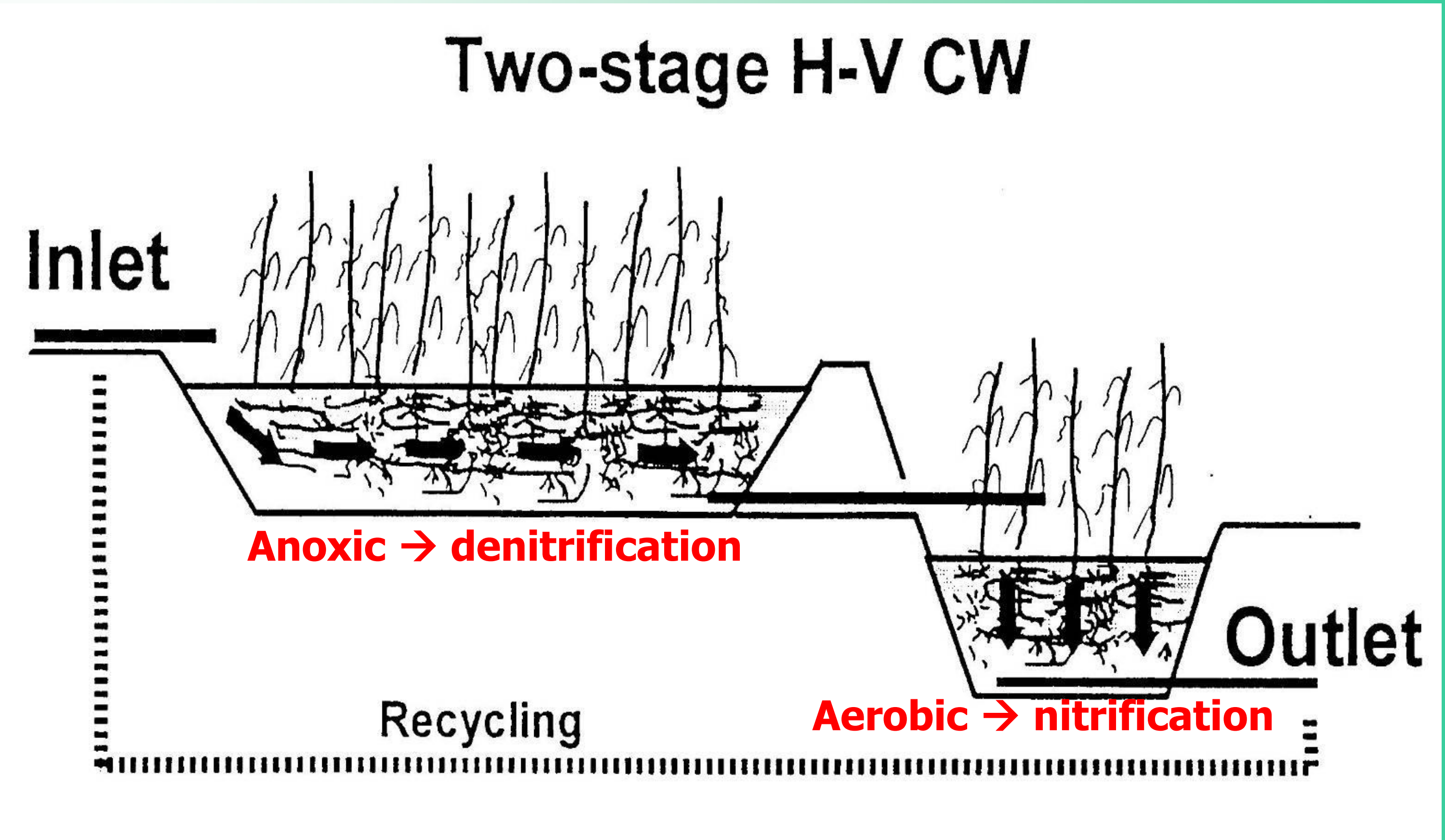
Sint-Niklaas (Belgium)
Aquafin Ltd.
Two VF beds.

Part 4
Combined systems and tertiary treatment systems

Combined or hybrid systems

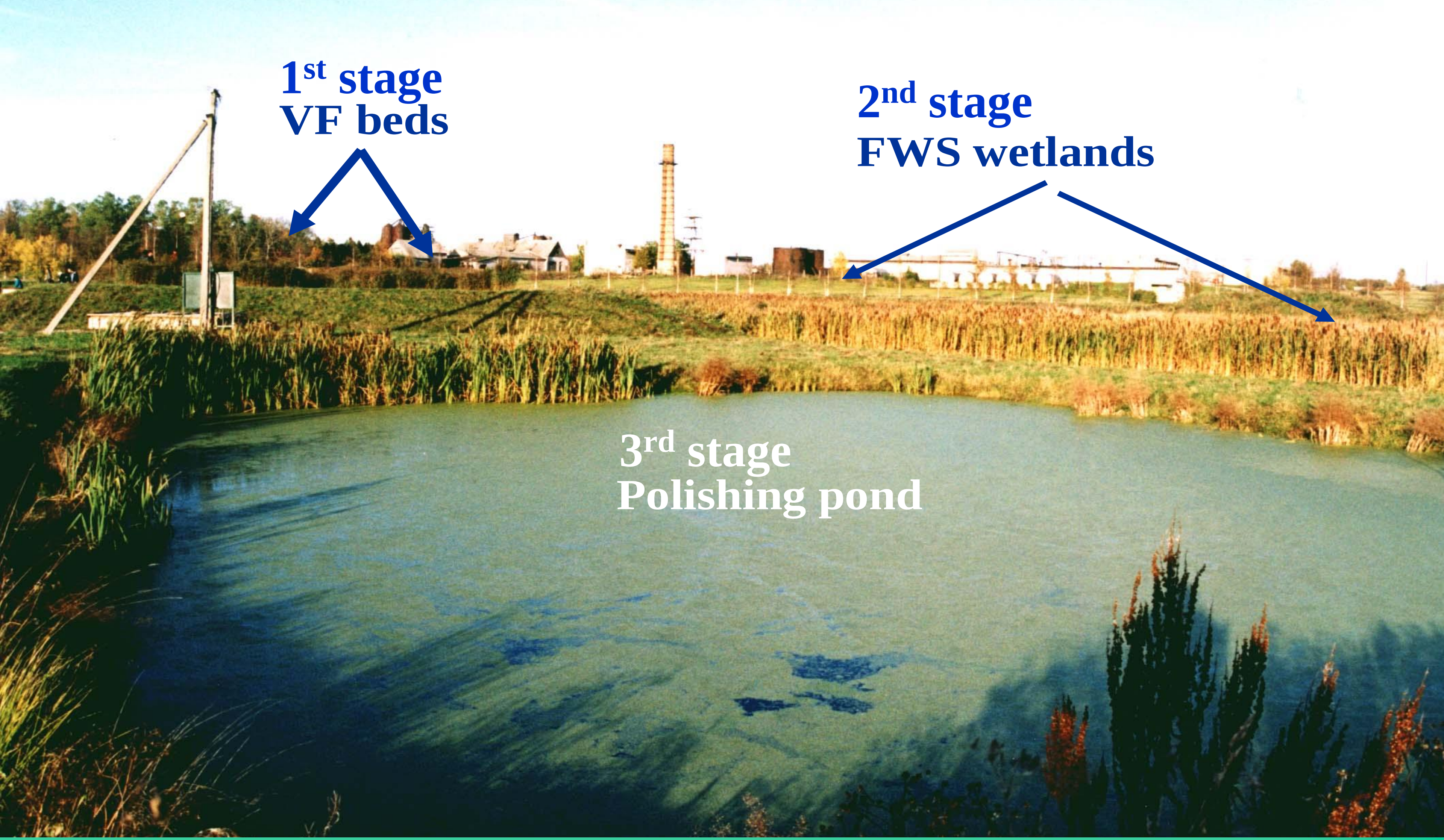
Various combinations of the previously described systems are called combined or hybrid systems.

Combined or hybrid systems



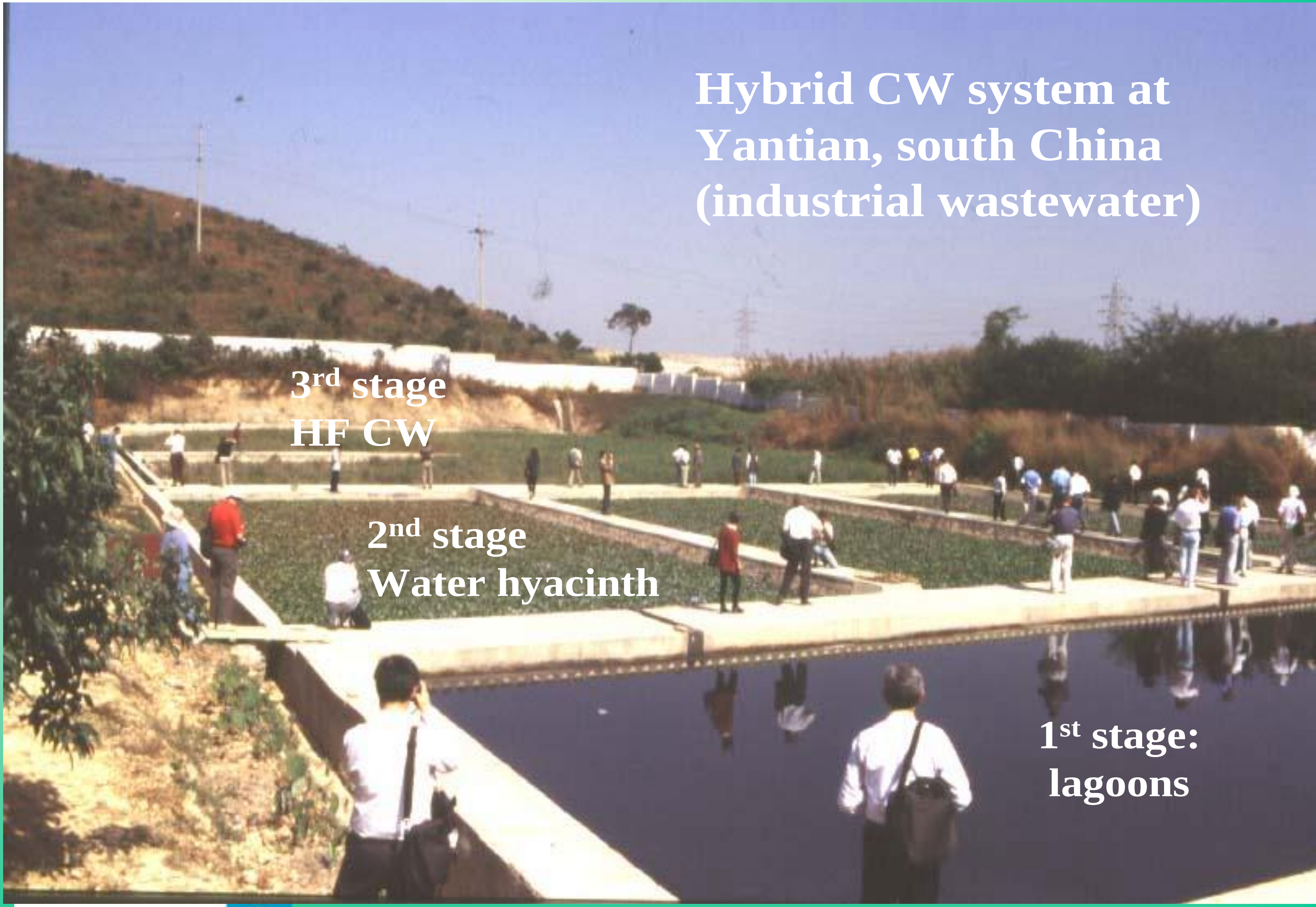
Two-step helophyte filter consisting of a horizontal subsurface and vertical flow (reed) bed. Different conditions in both wetlands trigger different removal pathways → hybrid systems are usually more efficient.

Kõo (Estonia) , overall view



Experimental CW in Aartselaar (Belgium), Aquafin Ltd.
Foreground: two parallel VF beds (first stage).
Background: two parallel HSSF beds (second stage).

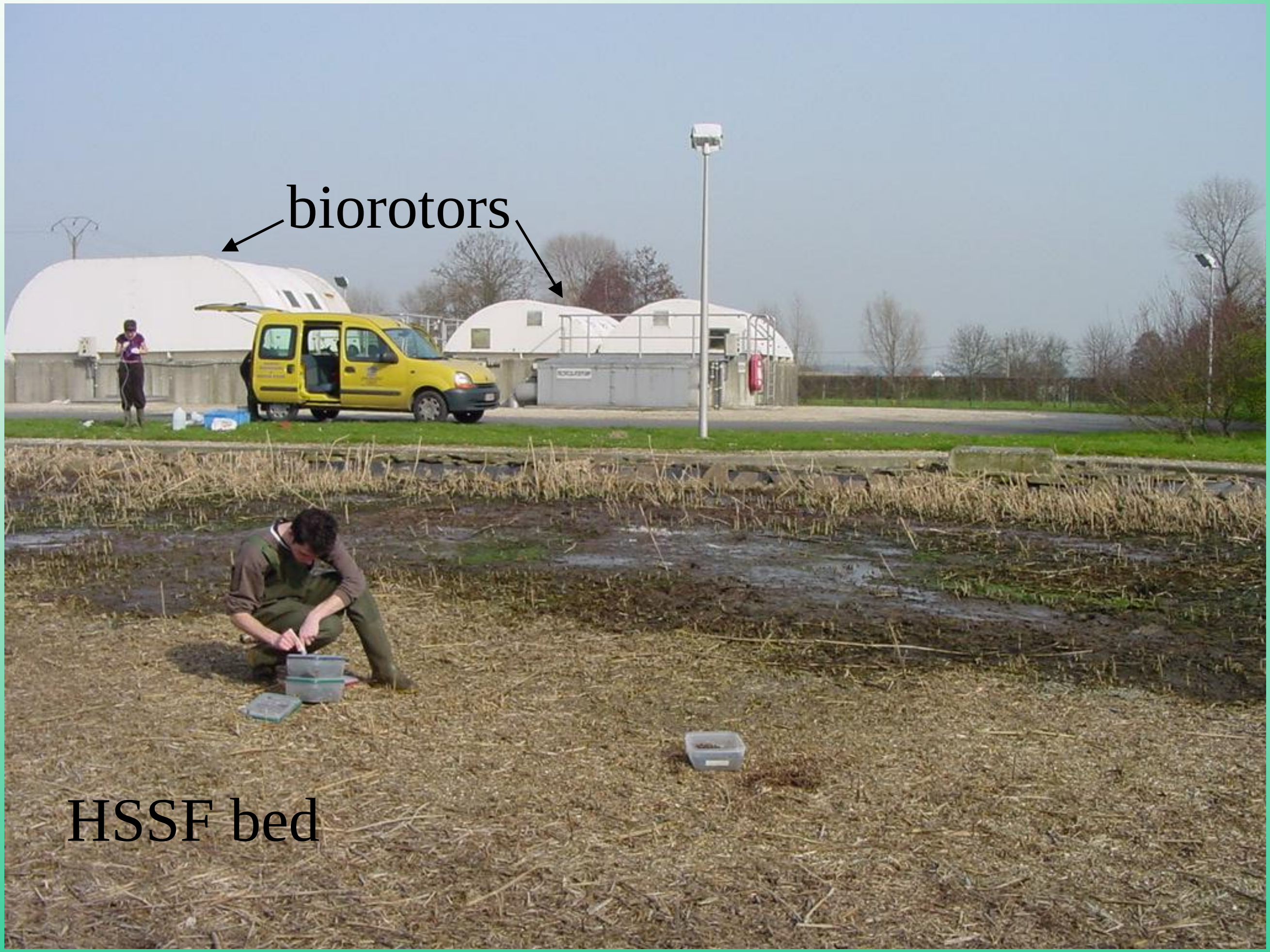
Experimental MHEA ® system in Viville (Belgium). “Mosaïque Hiérarchisée d’Ecosystèmes Aquatiques”. Various aquatic ecosystems found along a land-water gradient.


Hybrid CW system at Yantian, south China (industrial wastewater)
3rd stage HF CW
2nd stage Water hyacinth
1st stage: lagoons

Tertiary treatment wetlands

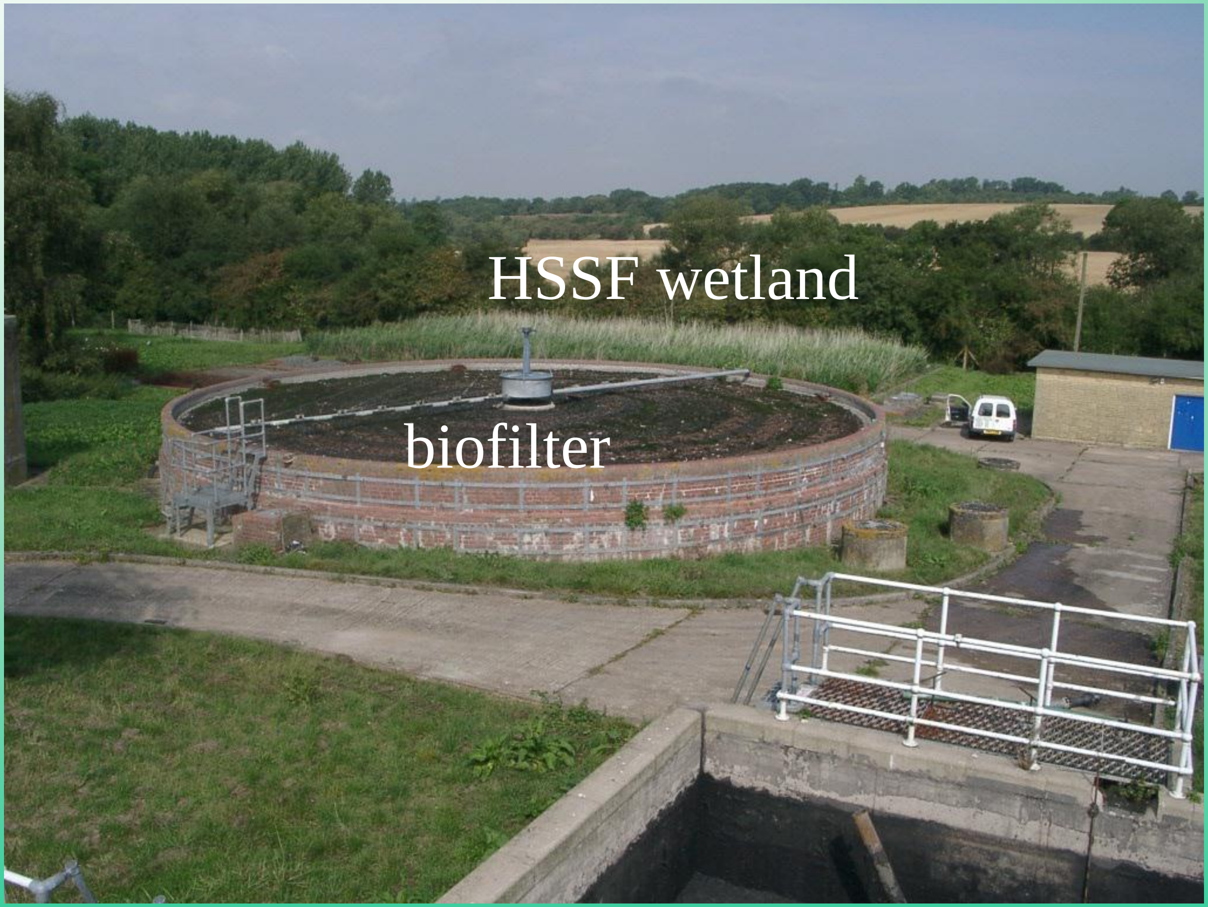
Constructed wetlands preceded by another treatment technology like a rotating biological contactor, activated sludge, UASB etc.

Tertiary treatment wetlands



Aalbeke (Belgium).
Aquafin Ltd.

Tertiary treatment wetlands



Butlers Marston (UK)
Severn Trent Water Ltd

Part 5
Intensified systems

Definition of Intensified treatment wetlands

Constructed wetlands with some form of energy and/or chemicals input aimed at improving treatment performance and/or reduce area requirement.

Note: not completely “natural” anymore but energy inputs are normally very small compared to conventional wastewater treatment systems

Principle: increased O_2 supply

1. **Normal CW**
   - **Physical transfer**
   - **Plant root oxygen release**

HSSF-CW: 1 – 6 g $O_2/(m^2.day)$

≅ 10 - 60% of daily cBOD

2. **Intensified CW**
   - **Intermittent feeding**
   - **Passive aeration**
   - **Tidal flow**
   - **Active aeration**

up to 100 g $O_2/(m^2.day)$

SSF-CW: <0.1 kW.h/m^3
Intens-CW: 0.17 kW.h/m^3
Act. Sludge: 0.76 kW.h/m^3

UNESCO-IHE Institute for Water Education

Forced Bed Aeration™ (picture Scott Wallace)

Tidal flow CW