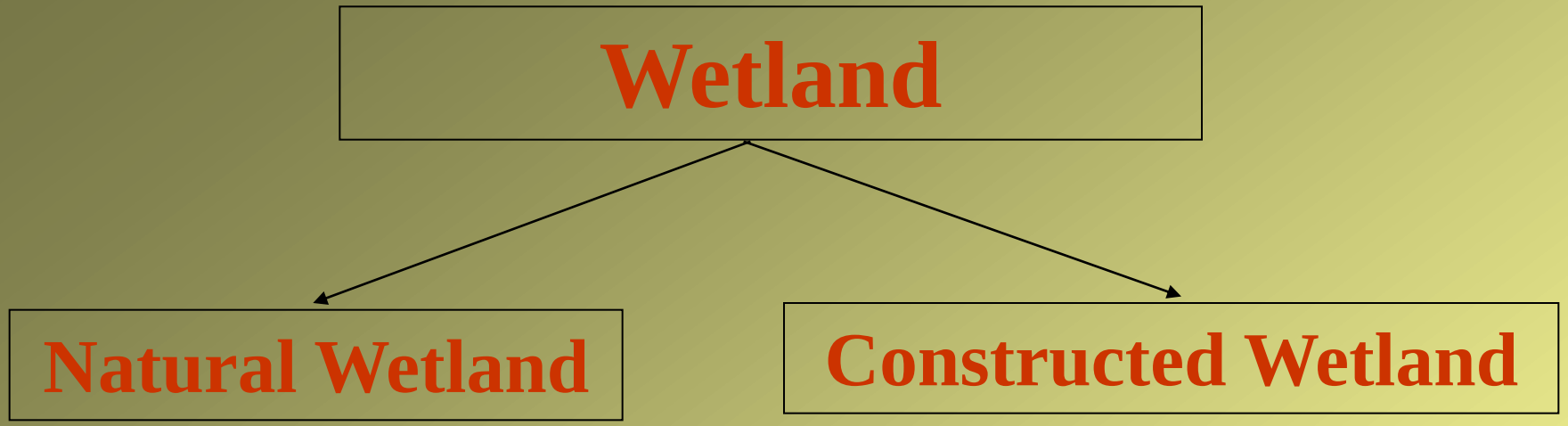
Constructed Wetland

by

Mohamed El-Khateeb

History

- **Natural wetlands have probably been used for wastewater disposal for as long as wastewater has been collected, with documented discharges dating back to 1912.**
- **Some early constructed wetlands researchers probably began their efforts based on observations of the apparent treatment capacity of natural wetlands.**
- **Research studies on the use of constructed wetlands for wastewater treatment began in Europe in the 1950's, and in the US in the late 1960’s.**
- **Research efforts increased throughout the 1970's till now.**



Natural Wetland

- Wetlands are land areas wet during part or all of the year because of their location in the landscape.

- Wetlands were called swamps, marshes, bogs, fen or sloughs, depending on existing plant and water conditions and on geographic setting.

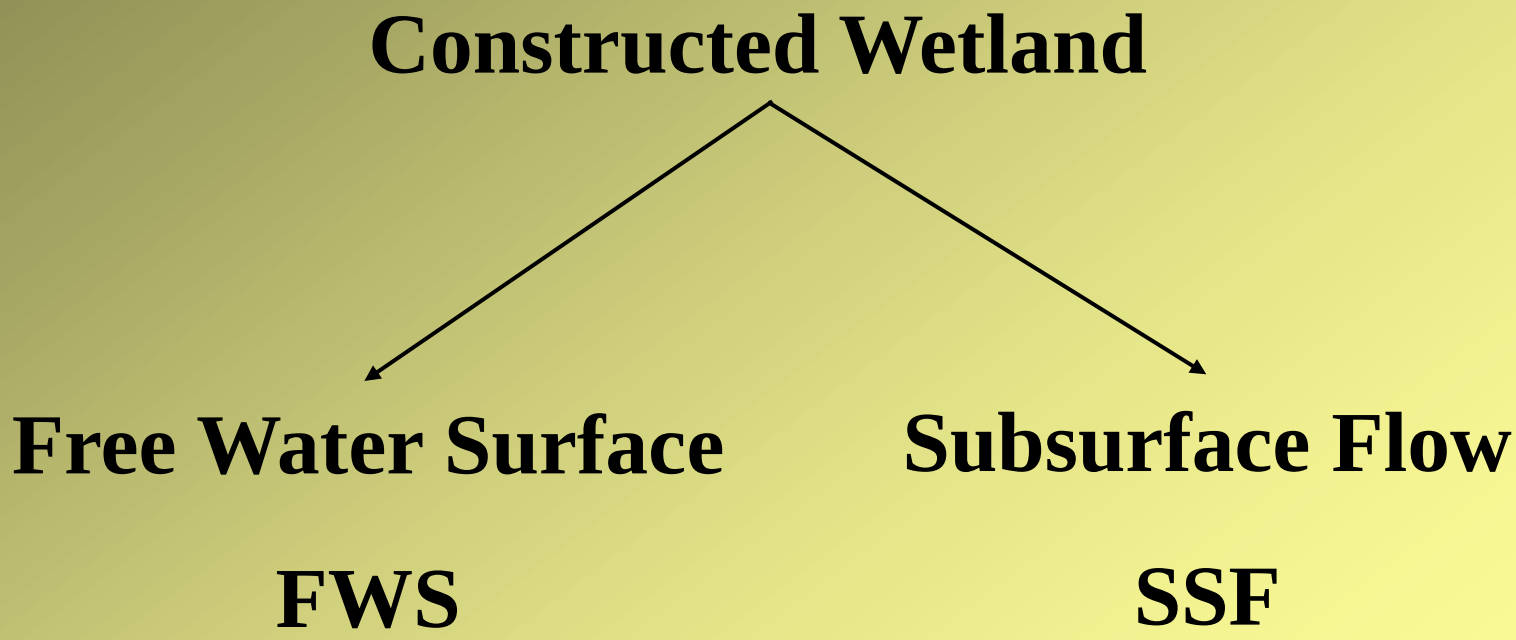
Natural Wetland

Constructed Wetland

- Constructed wetlands are defined as a designed and man-made complex of saturated substrates, emergent and submergent vegetation, and water that simulates natural wetlands for human use and benefits

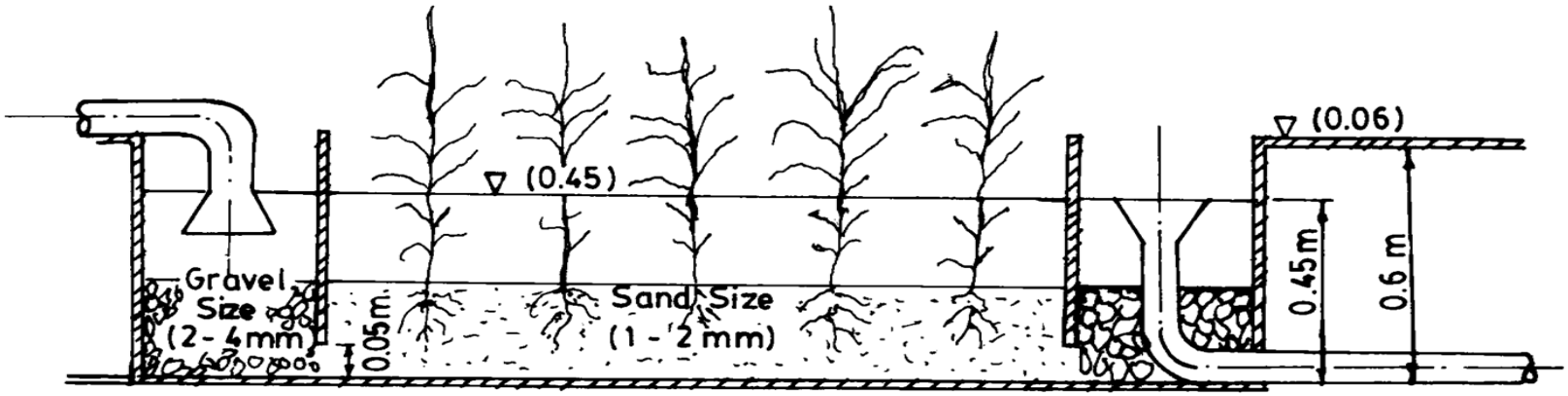
Types of constructed wetland

There are two major types of constructed wetlands in use

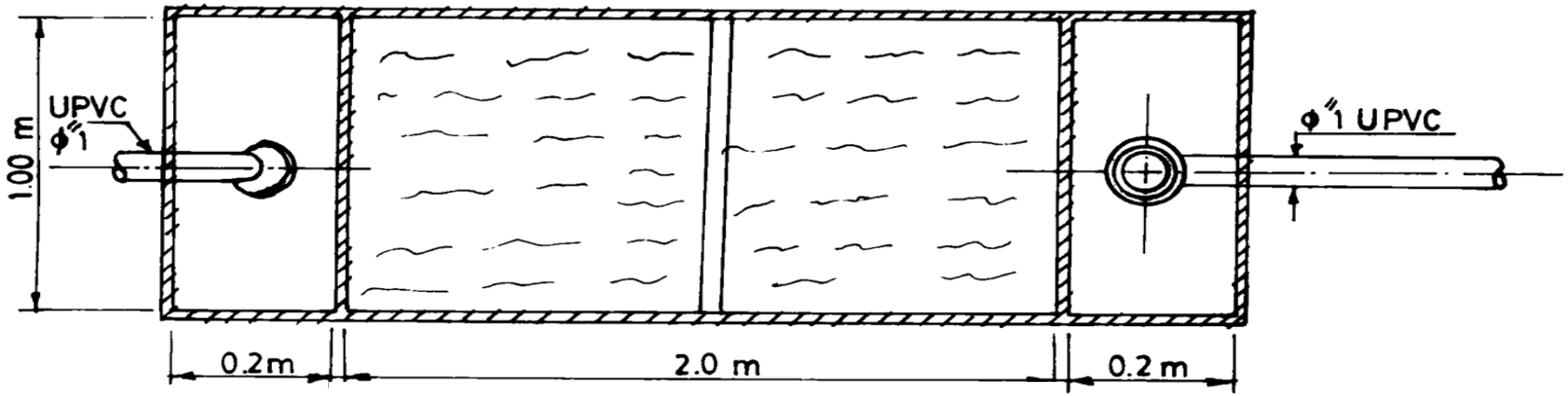


Free Water Surface (FWS)

In this type of wetlands the emergent vegetation is flooded to a depth ranges from 10.0 to 45.0 cm. A layer of suitable soil to serve as a rooting media. It consists of channel or constructed impermeable barrier to prevent seepage.



(a)

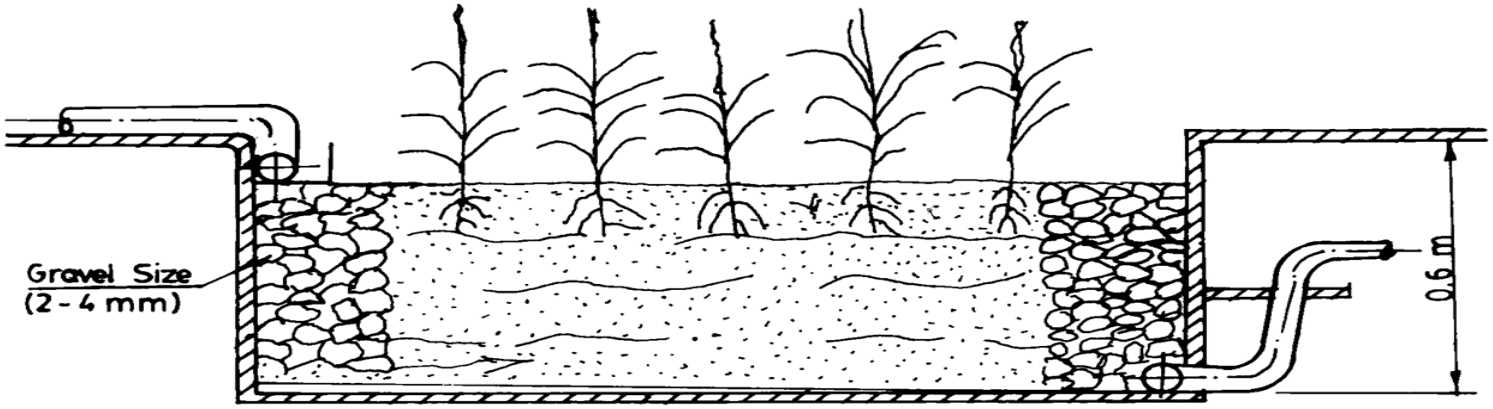


(b)

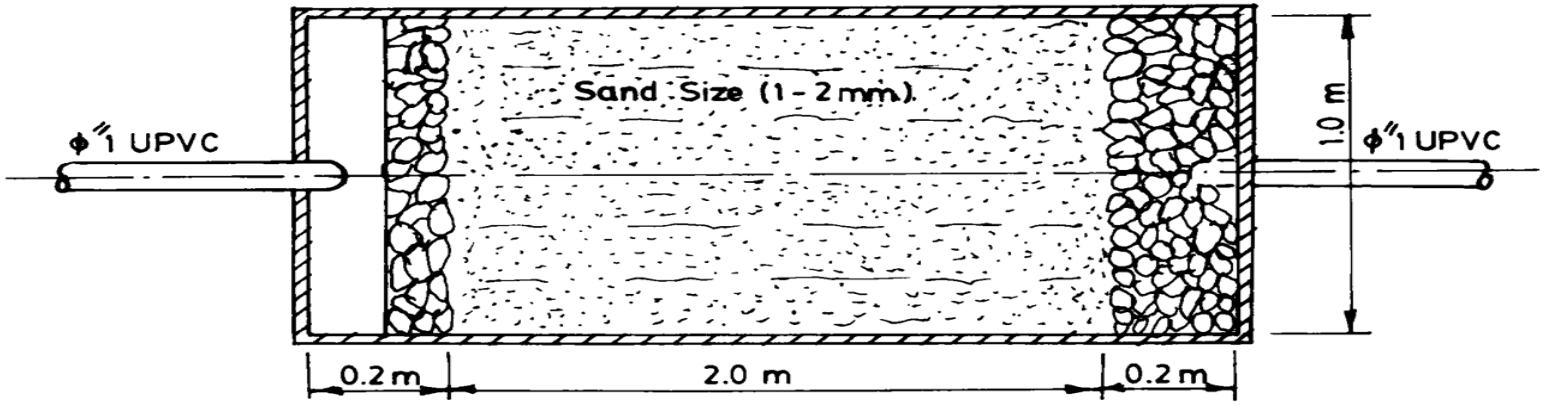
Schematic diagram of the FWS wetland

Subsurface Flow (SSF)

In a subsurface flow constructed wetland (also called Root Zone, Rock Bed Filter or Vegetated submerged bed), the wastewater is treated as it flows through the porous medium. Emergent vegetation is planted in the medium, which ranges from coarse gravel to sand. The depth of the bed ranges from 45 to 100 cm (according to the used plant).



(a)



(b)

Schematic diagram of the SSF wetland

Most constructed wetlands have four principal components

- substrates with various rates of hydraulic conductivity,
- plants adapted to water-saturated anaerobic substrates,
- a water column (water flowing in or above the surface of the substrate),
- an aerobic and anaerobic microbial population

Substrate

Substrates, various soils, sand or gravel, provide physical support for plants; reactive area for complexing ions, anions, and other compounds; and attachment surfaces for microbial populations (Hammer and Bastian, 1989)

Media Characteristics for Wetland System

Type	n^a Porosity %	k^b Hydraulic Conductivity ($m^3/ m^2/ d$)
Coarse Sand	32	1,000
Gravelly Sand	35	5,000
Fine Gravel	38	7,500
Medium Gravel	40	10,000
Coarse Rock	45	100,000

a: The porosity is used to determine the actual flow velocity in the void spaces. Porosity is equal to Void Volume/Total Volume, and is expressed as a percent.

b: Assuming non-turbulent, near laminar flow conditions, with clean. water.

Plants

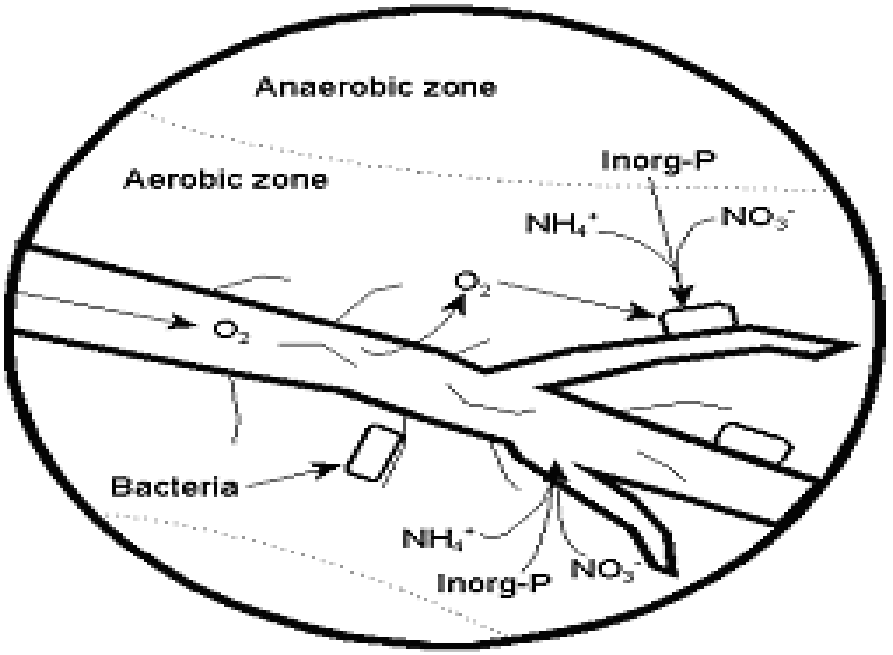
The plants in wetland system are an essential component in the process, but contrary to popular belief they do not serve a significant role via plant uptake of the pollutants. The physical presence of the plants is essential since they provide host surfaces for the attached growth organisms and in the FWS case the canopy of leaves shades the surface and prevents detrimental algae growth. The plant roots are also thought to be a partial source of oxygen in the SSF case (Reed et al., 1996 & Brix 2001).

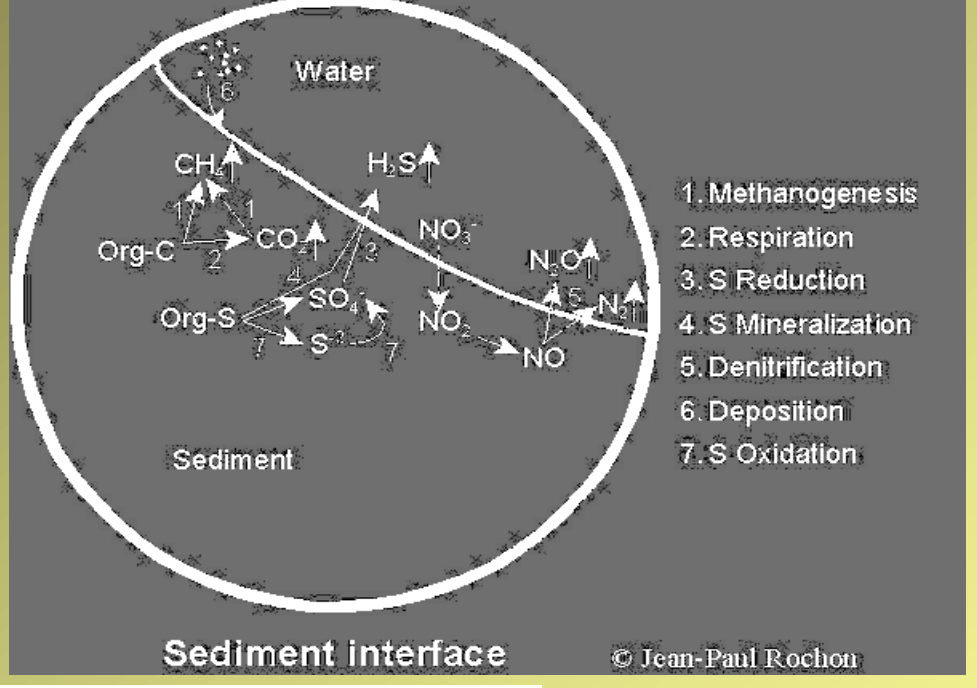
Consequently, wetland plants appear to have two indirect important functions:

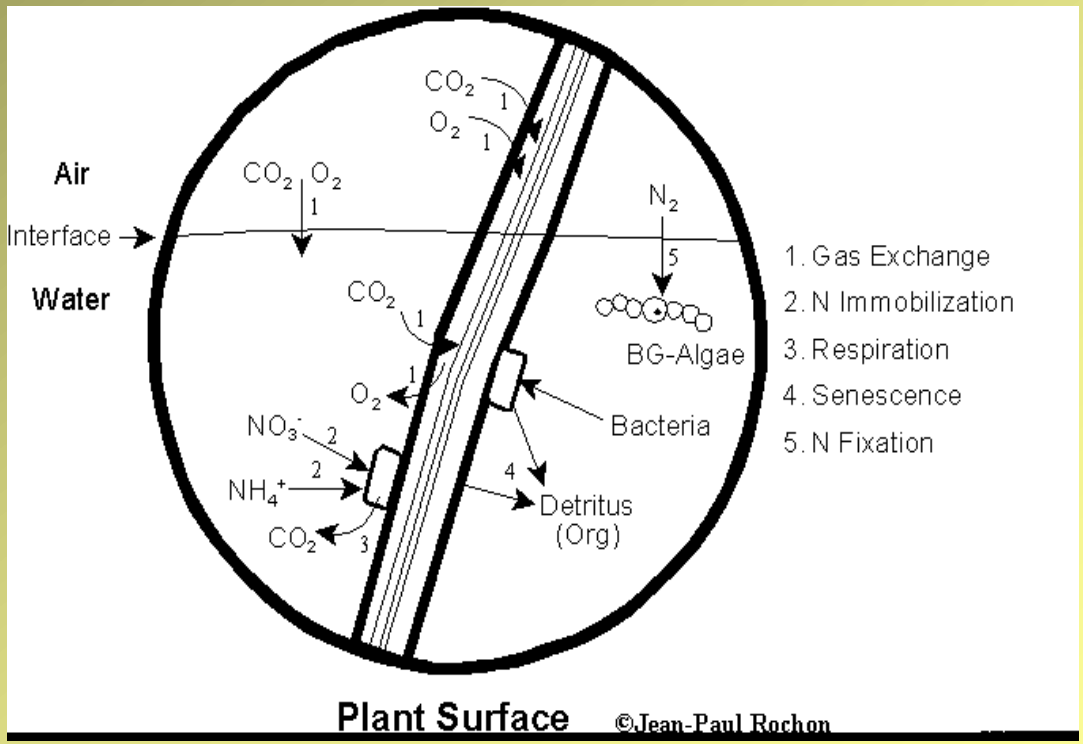
1. **Within the water column, stems and leaves increase surface area for attachment of microbial populations**

2. **Wetland plants have the ability to transport atmospheric gases (including oxygen) down into the roots to enable their roots to survive in an anaerobic environment**

A thin film surrounding each root hair (in the aerobic region) called rhizosphere. Some chemical oxidation occurs around the rhizosphere, but more important, it supports large microbial populations. Consequently, the aerobic region surrounded by anaerobic regions. So that nitrification-denitrification and other numerous desirable pollutant transformations takes place (Gersberg et al., 1986, USEPA, 2000).


Anaerobic zone
Aerobic zone
Inorg-P
NH_4^+
NO_3^-
O_2
O_2
Bacteria
NH_4^+
Inorg-P
NO_3^-


Water
CH_4
H_2S
Org-C
CO_2
NO_3^-
N_2O
Org-S
SO_4^{--}
S^0
NO_2^-
NO
N_2
Sediment
1. Methanogenesis
2. Respiration
3. S Reduction
4. S Mineralization
5. Denitrification
6. Deposition
7. S Oxidation
Sediment interface
© Jean-Paul Rochon


CO_2
O_2
Air
Interface
Water
CO_2 O_2
N_2
BG-Algae
Bacteria
NO_3^-
NH_4^+
CO_2
Detritus
(Org)
1. Gas Exchange
2. N Immobilization
3. Respiration
4. Senescence
5. N Fixation
Plant Surface
©Jean-Paul Rochon

Macrophytes selected for growth in artificial wetlands should be

1. Robust in habit
2. Have a high biomass throughout the year, and
3. Readily available in the local area

Plant Species Tested for Use in Constructed Wetlands for Wastewater Treatment (cited from Guntenspergen et al., 1990)

Emergent	Submerged	Floating
Scirpus robustus	*Egeria densa*	*Lagorosiphon major*
Scirpus lacustris	*Ceratophyllum demersum*	*Salvinia rotundifolia*
Schoenoplectus lacustris	*Elodea nuttallii*	*Spirodela polyrhiza*
Phragmites australis	*Myriophyllum aquaticum*	*Pistia stratiotes*
Phalaris arundinacea		*Lemna minor*
Typha domingensis		*Eichhornia crassipes*
Typha latifolia		*Wolffia arrhiza*
Canna flaccida		*Azolla caroliniana*
Iris pseudacorus		*Hydrocotyle umbellata*
Scirpus validus		*Lemna gibba*
Scirpus pungens		*Lemna* spp.
Glyceria maxima		
Eleochairs dulcis		
Eleochairs sphacelata		
Typha orientalis		
Zantedeschia aethiopica		
Colocasia esculenta		

Advantages of using wetland systems:

- **low capital costs**
- **simple construction involving no mechanical or electrical equipment**
- **low maintenance costs**
- **robust process able to withstand a wide range of operating conditions**
- **consistent effluent quality and**
- **environmentally acceptable with potential for wildlife conservation.**

Advantages of SSF over FWS Wetland

In the SSF type, the vegetation is planted in the upper part of the gravel. The biological reactions occurring in both types of wetlands are believed due to attached growth organisms. Since the gravel media has more surface area than the FWS wetlands, the gravel bed will have a higher reaction rate and therefore can be smaller in size. Since the water surface is not exposed there are no public exposure risks, and mosquitoes are not a problem with the SSF type. The SSF type also provides greater thermal protection in colder climates.

These advantages make the artificial wetlands very attractive for use by small to medium sized communities for meeting discharge limitations.

Disadvantages

- Area required from 5 – 10 m^2/person
- Many sites do not have the soil or geologic properties to effectively serve as a wetland.
- Slope, topography, depth of soil, depth to bedrock, permeability and the size of area to be devoted to the constructed wetland could be limiting factors.
- Vegetation may accumulate and at some point need to be cleaned out and disposed of in an environmentally sound manner.
- Increased mosquito populations and potential for odors.

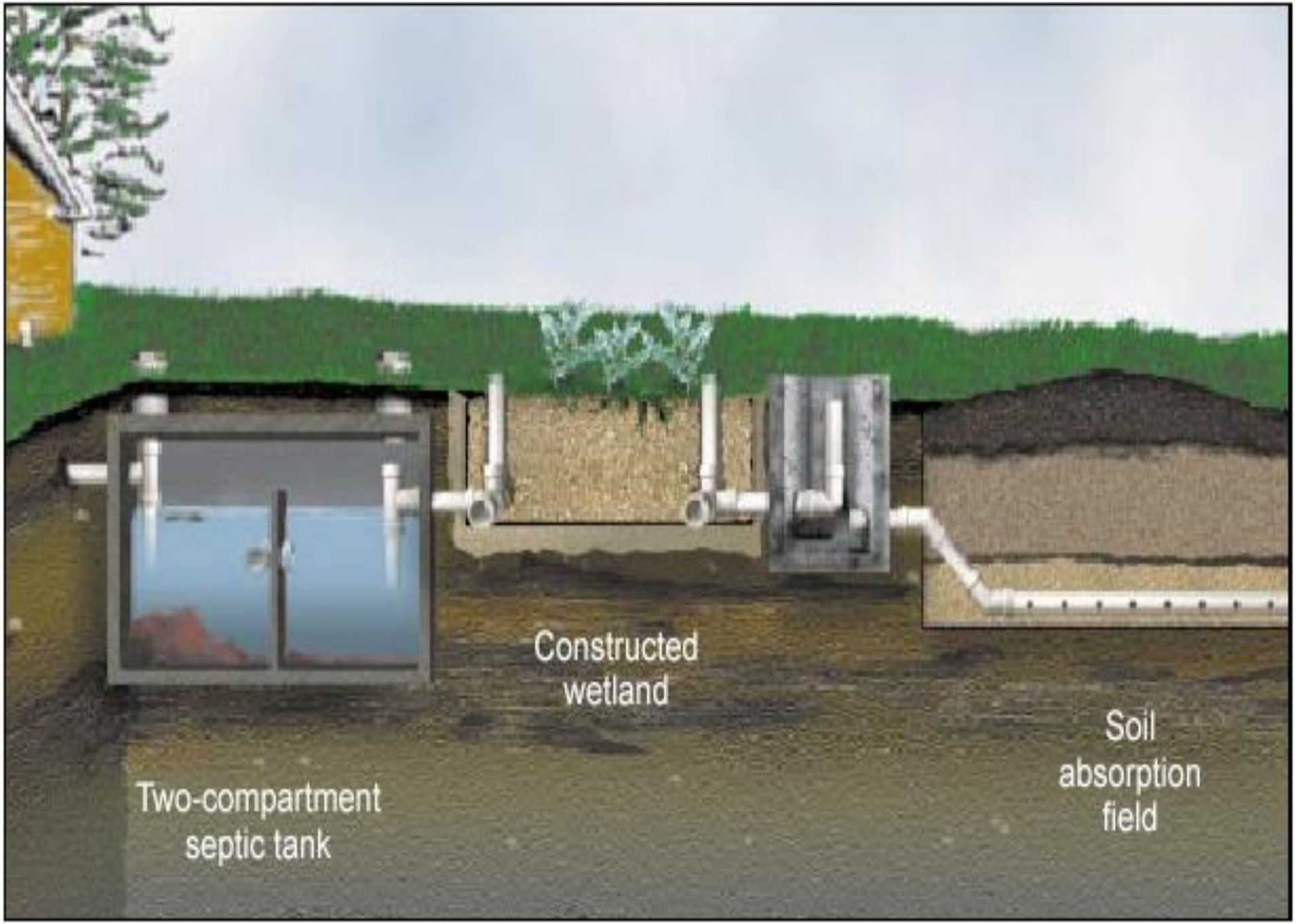
- ***It is important to mention that constructed wetlands are not recommended for treatment of raw wastewater.***

Constructed Wetland

Constructed Wetland

Constructed Wetlands

for On-Site Septic Treatment


Constructed
wetland
Two-compartment
septic tank
Soil
absorption
field