Constructed Wetlands 101

technology know-how, purpose, performance and scale

Wasur National Park

West Papua, Indonesia

Been there?

Heard of it?

What is a Wetland?

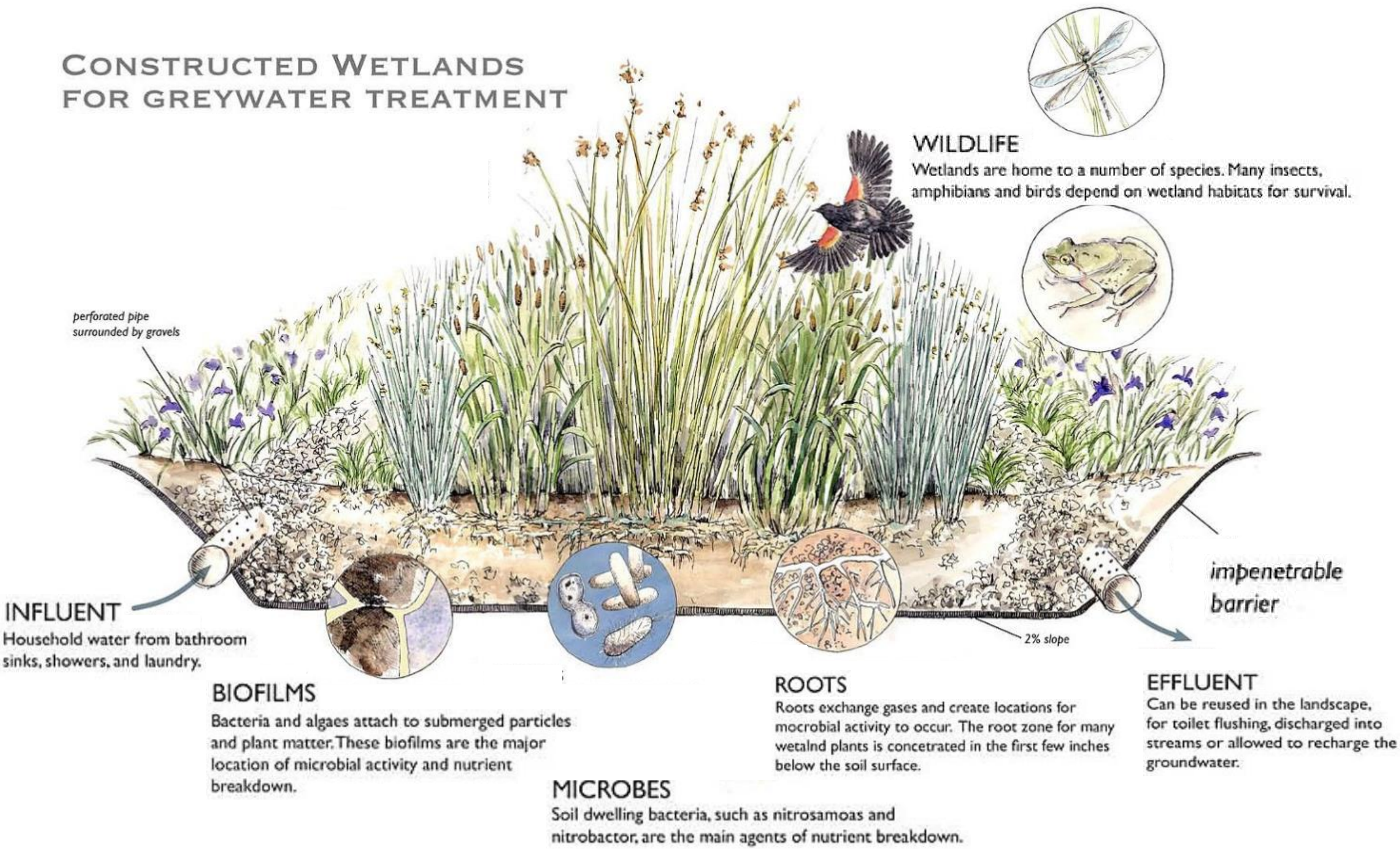
Land where an excess of water is the dominant factor determining the nature of soil development and the types of animals and plant communities living at the soil surface. It spans a continuum of environments where terrestrial and aquatic systems intergrade. *Cowardin et al. (1979)*

What is a Constructed Wetland?

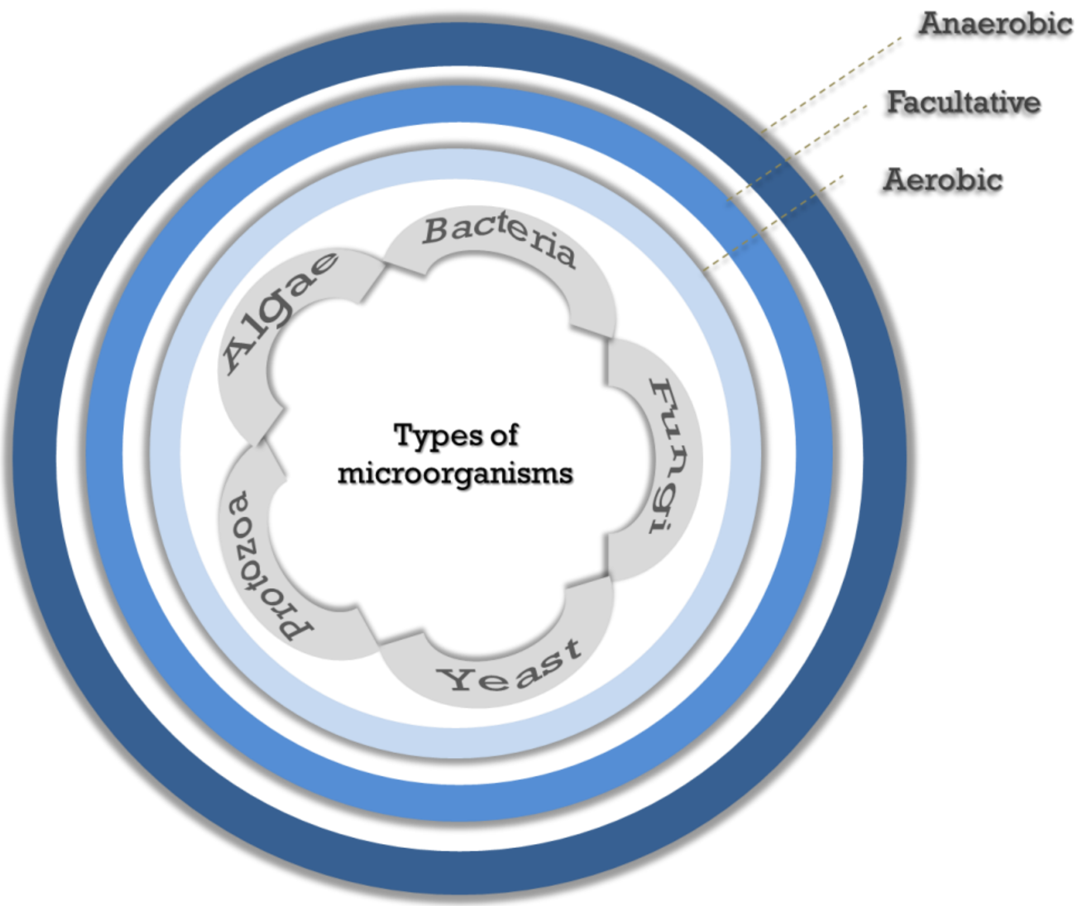
Imitation of natural functions of vegetation, soil, and organisms to treat different types of wastewater

Secondary and tertiary treatment unit

Major components of a wetland



Microorganisms



!! higher concentration of ***pesticides and heavy*** metals cause ***Toxic shock affecting microorganisms*** and functioning capacity of the wetlands

Plants

Common Reeds

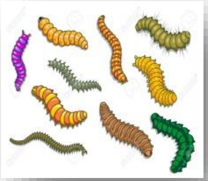
Cattails

Bulrush

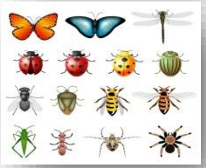
Canna lilies

Selection: Plant indigenous to the location

Animals



Invertebrates



Vertebrates

Consume organic matters

Breakdown the detritus

Home and visiting repository for

Amphibians, Turtles, Birds, Mammals

Substrate

Mainly surface flow constructed wetland

Soil

Sand

Gravel

Stones

Mainly sub-surface flow constructed wetland

Removal mechanism

Biological Process

- Microbiological degradation through catabolism and anabolism
- Protozoic predation and digestion
- Plant uptake and storage

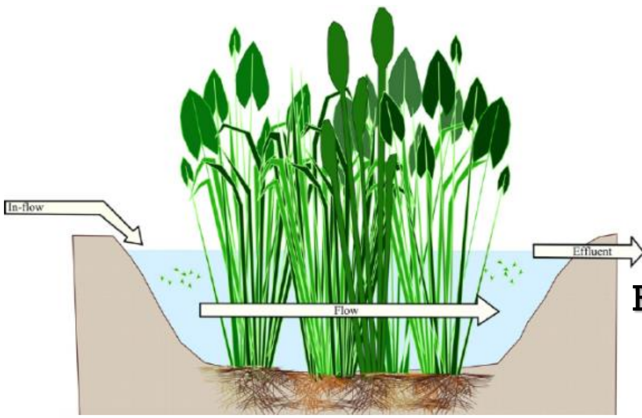
Physical Process

- Filtration
- Settlement

Chemical Process

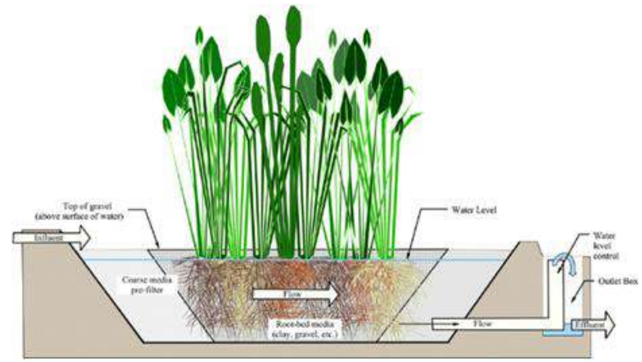
- Adsorption (ionic and covalent)
- Oxidation
- Reduction
- UV degradation

Types of constructed wetlands

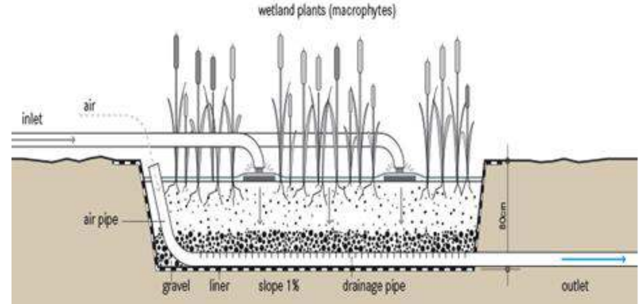


Horizontal flow

Surface flow



Horizontal Flow



Vertical Flow

Subsurface flow

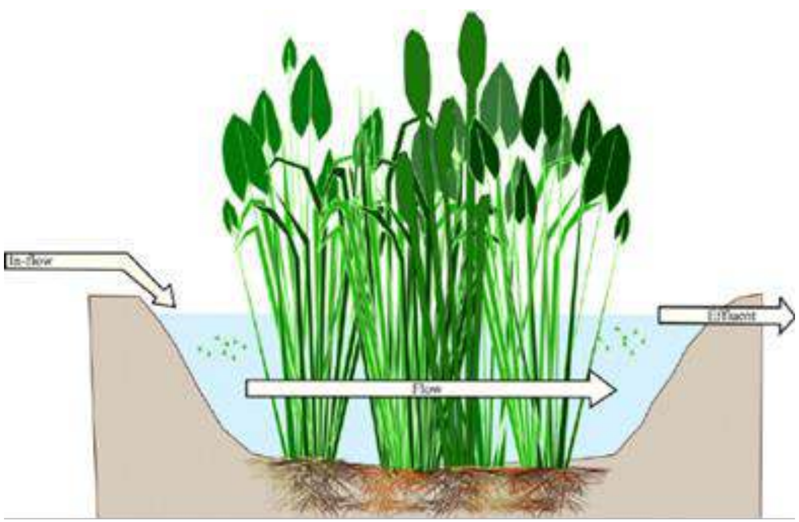
Source: https://www.sswm.info/water-nutrient-cycle/wastewater-treatment/hardwares/semi-centralised-wastewater-treatments/vertical-flow-constructed-wetland,3/23/2018

Source: Wetland Technologies for Nursery and Greenhouse Compliance with Nutrient Regulations, Sarah A. White, 2013

Surface flow Constructed Wetland

Also known as free water surface CW

Continuous flow



Surface flow

Substrate: Soil
Floating, submerged, and emergent plants

Tertiary treatment of municipal wastewater treatment

Storm water runoff

Mine drainage

Agricultural runoff (Kadlec and Wallace 2008)

Low capital and operating costs

Low skill requirement for O&M

!! Require larger land area

Sub-surface flow Constructed Wetland

Also known as Reed Bed Treatment System

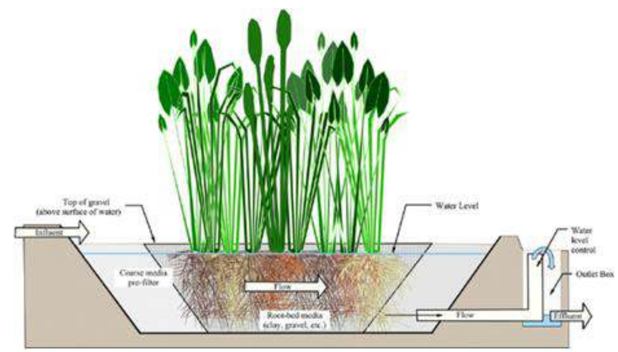
Intermittent Flow

effective for ammonia removal

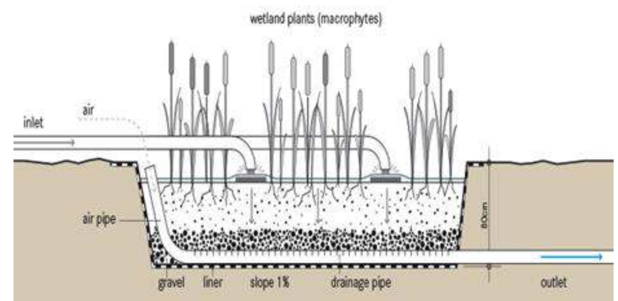
reduce (BOD_5) from domestic wastewaters

best for wastewaters with relatively low solids concentrations

require relatively uniform flow conditions



Horizontal Flow



Vertical Flow

Subsurface flow

Substrate: Sand, Gravel, Rocks

Macrophytes

Sub-surface flow Constructed Wetland

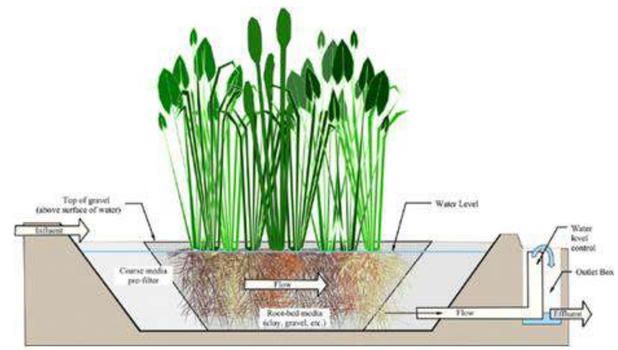
Low capital and operating costs
Low skill requirement for O&M

!!

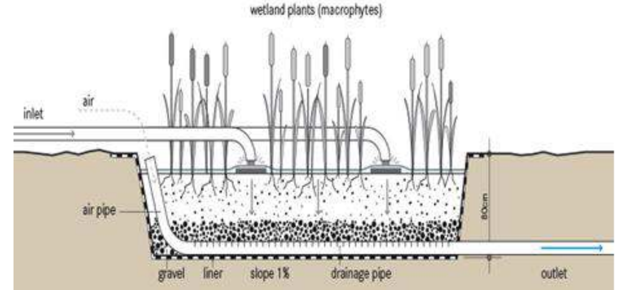
expensive to construct
difficult to regulate

higher maintenance and repair costs

Clogging problems



Horizontal Flow



Vertical Flow

Subsurface flow

Substrate: Sand, Gravel, Rocks
Macrophytes

Wetland design

Pollutant loading rate method

2 ways

First Order Kinetic Rate Equations Method

Pollutant Loading Rate Method

- mass loading rate (daily inflow (m^3) * concentration of pollutant (mg/l)
- acceptable range 3-7 kg/ha/day

Source: A. ECONOMOPOULOU, M. (2004). Design Methodology of Free Water Surface Constructed Wetlands. Water Resources Management, pp.2,3.

Wetland design

First Order Kinetic Rate Equations Method

$$\frac{Ce}{Ci} = e^{-KTt}$$

Hydraulic retention time

$$t = \boxed{\frac{V}{Q}} = \frac{Ay\Phi}{Q} = \frac{y\Phi}{hydraulic\ loading\ rate}$$

plug flow reactor

Ce: pollutant effluent concentration [mg /L], Ci: pollutant influent concentration [mg /L], K_T: reaction rate parameter [d−1] is temperature dependent and pollutant specific, t: hydraulic retention time in the system [d], V: volume of the system [m^3], Q: design flow rate [m^3/d], A: mean surface area of the system [m^2], y: flow depth [m], Φ: fractional porosity

Source: A. ECONOMOPOULOU, M. (2004). Design Methodology of Free Water Surface Constructed Wetlands. Water Resources Management, pp.2,3.

Wetland design

Water Balance

$$S = Q + R + I - O - ET$$

S: net change in storage, *Q*: surface flow, including wastewater or stormwater inflow, R: : contribution from rainfall, *I*: net infiltration, *O*: surface outflow, *E T :* loss due to evapotranspiration

Wetland design consideration

Keep it simple

Minimal maintenance requirement

Imitate natural process like gravity flow

Use of local resources and flora and fauna for better results

Adopt to the landscape

Wetland performance

$$Removal\ efficiency = (1 - \frac{Ce}{Ci}) * 100\%$$

Other influencing factors

Location,
Type of wastewater or runoff,
Wetland design,
Climate, weather,
Disturbance,
Daily or seasonal variability

Ce: pollutant effluent concentration [mg /L], Ci: pollutant influent concentration [mg /L]

Source: Zhang. Y. (2012). Design of a Constructed Wetland for Wastewater Treatment and Reuse in Mount Pleasant, Utah, pp.52

Scale of the treatment plants

world's biggest industrial constructed wetland in Oman

Constructed by Bauer Nimr

115,000 m3/day, 2014

175,000 m3/day with the expansion

reduce heavy hydrocarbon loads from the industrial wastewater down to below 0.5 parts per million

Source: http://www.waterworld.com/articles/wwi/2017/11/world-s-largest-constructed-wetland-treatment-plant-to-be-expanded-in-oman.html


CONSTRUCTED WETLANDS
FOR GREYWATER TREATMENT
perforated pipe
surrounded by gravels
2% slope

Thank you

Table I. Pollutant removal equations and rate constants for FWS constructed wetlands

Pollutant	Equation used	Rate constant		Rate constant units
BOD	(1)*	$K_T = 0.678(1.06)^{T-20}$		[d^{-1}]
Fecal coliforms	(2)**	$K_1 = 0.3$		[m d^{-1}]
Nitrogen				
Nitrification	(1)*	$K_T = 0.0389T$	$0 < T < 1°C$	[d^{-1}]
		$K_T = 0.1367(1.15)^{T-10}$	$1 < T < 10° C$	[d^{-1}]
		$K_T = 0.2187(1.048)^{T-20}$	$T > 10 °C$	[d^{-1}]
Denitrification	(1)*	$K_T = 0.023T$	$0 < T < 1°C$	[d^{-1}]
		$K_T = 1.15^{(T-20)}$	$T > 1 °C$	[d^{-1}]
Phosphorus	(2)**	$K_1 = 0.0273$		[m d^{-1}]

*by Reed *et al.* (1995), **by Kadlec and Knight (1996).