Study on Constructed Wetlands for Water Resources Conservation

Dr. Nway Nway Khaing

C.C Member of MES

Member of WE Chapter

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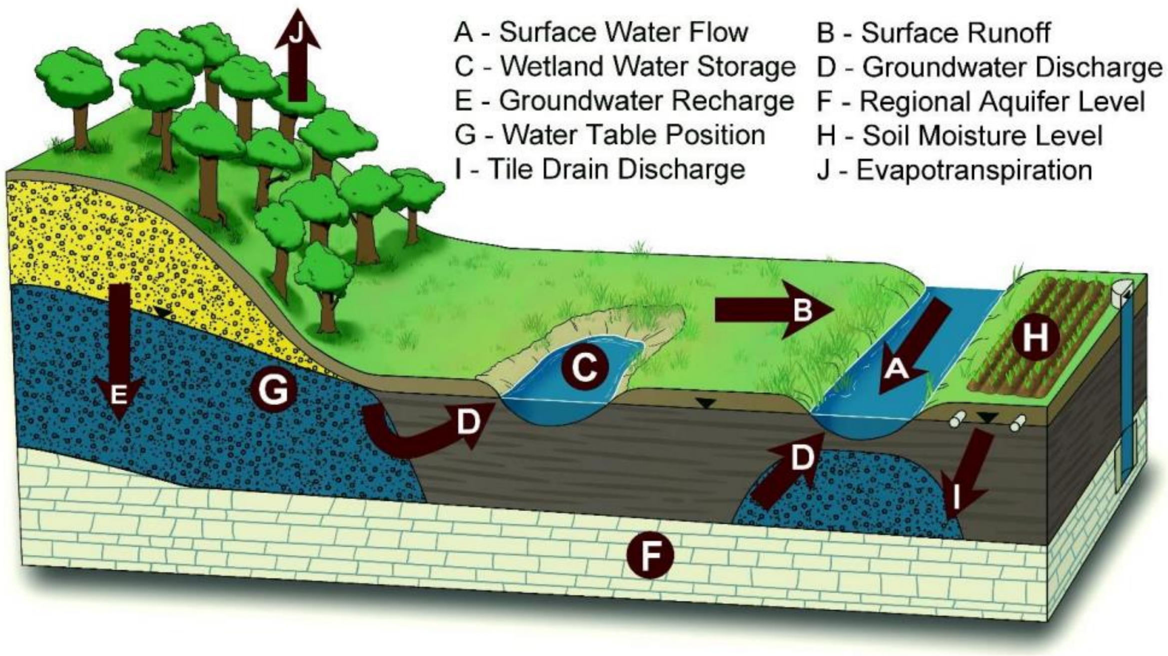
Contents

Introduction

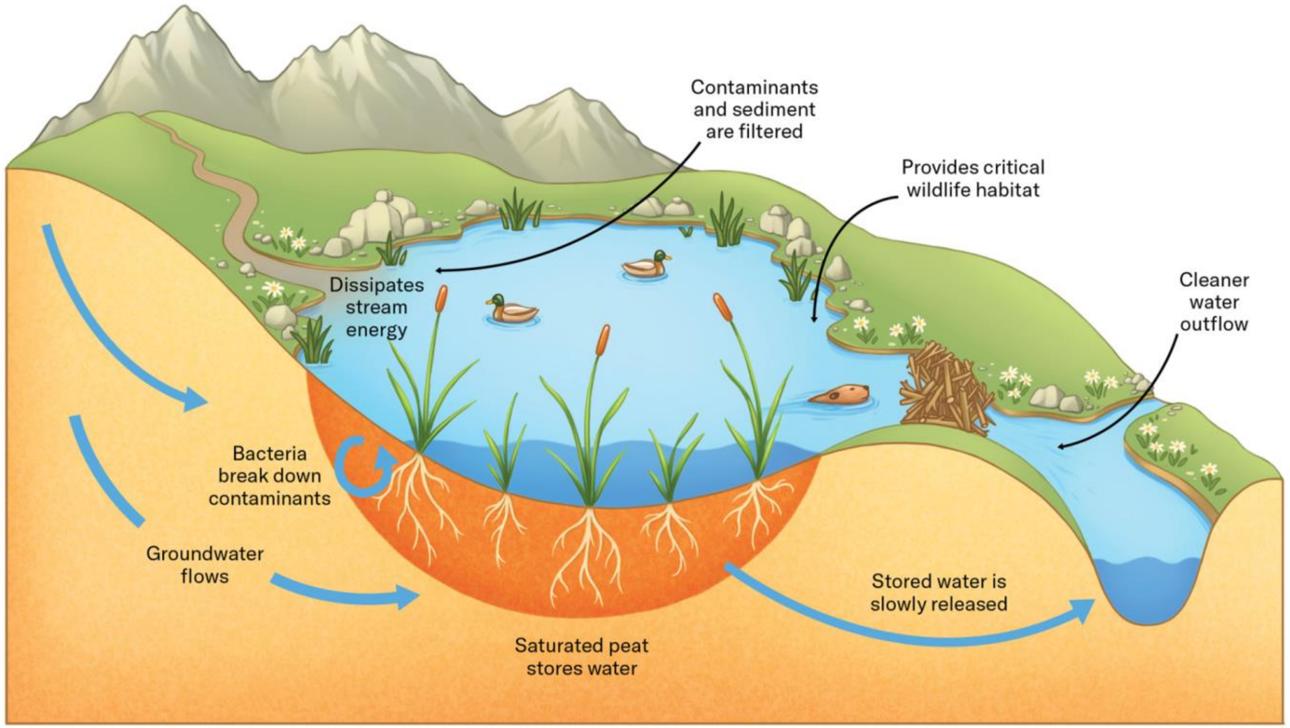
- Water Resource: Any of the entire range of natural water that occur on the earth and that are of potential use to humans.
- Freshwater Sources: Glacier and ice caps, Groundwater, Surface Water
    - Groundwater : Located in aquifers beneath the surface
    - Surface Water Sources: River, Streams, Lakes, Ponds, Wetland



(Tariq Aziz, 2025)

Introduction (continued)

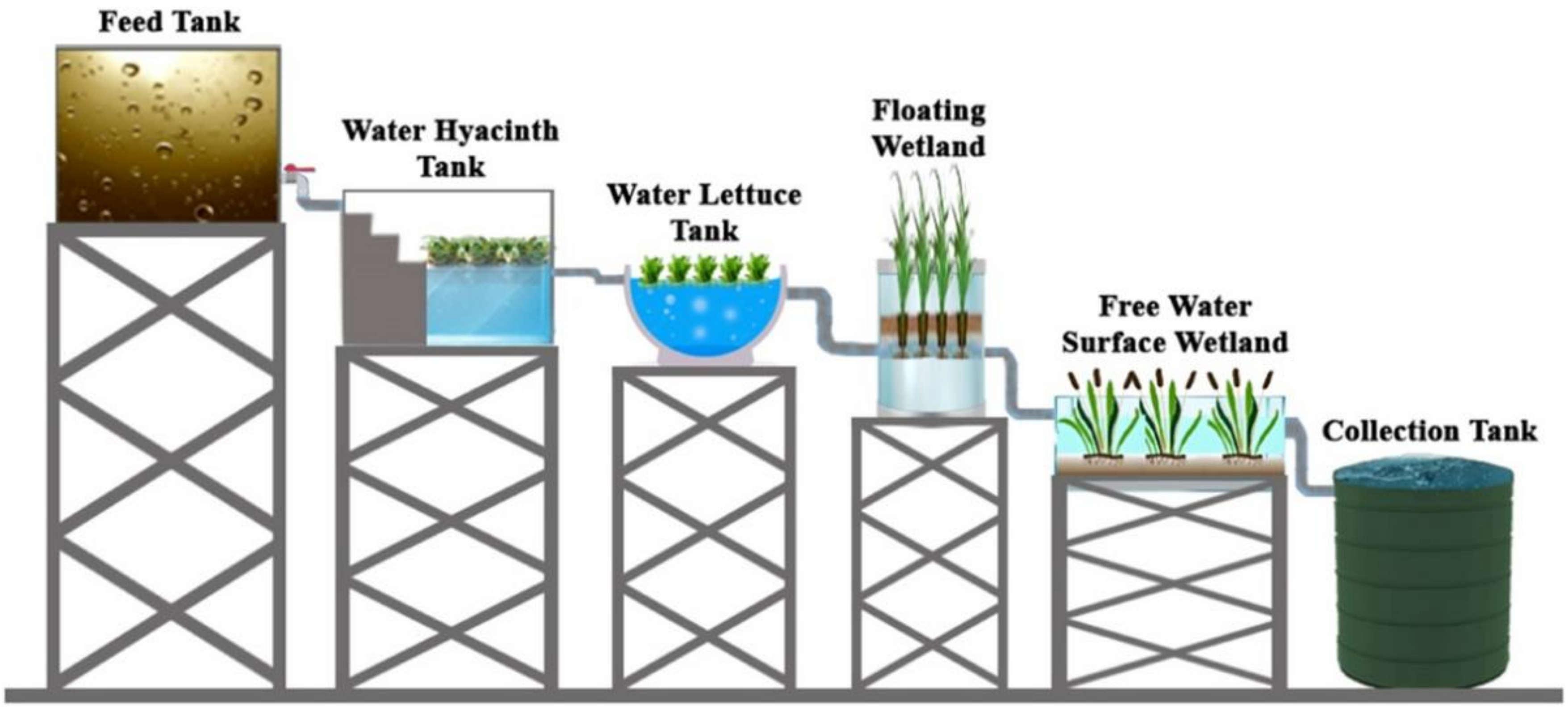
- Water Resources Conservation is a sustainable management to provide both the volume (quantity) and cleanliness (quality) of water to support human life and ecosystems
- Quantity: Constructed wetlands act as nature-based solutions that simultaneously filter stormwater, polish reclaimed water, and recharge local aquifers.



Natalia Mesa 2025

Introduction (continued)

- Quality: Constructed wetlands are treatment systems that use natural processes involving wetland vegetation, soils, and their associated microbial action to improve water quality.



(Atif Mustafa, 2024)

Objective of Presentation

- To share technical knowledge about the treatment of water and wastewater using constructed wetland systems
- To mention about the contribution of constructed wetland systems for conservation of water resources.

Constructed Wetland

- Constructed wetlands are artificial wastewater treatment systems consisting of shallow ponds or channels which have been planted with aquatic plants, and which rely upon natural microbial, biological, physical and chemical processes to treat wastewater
- Constructed wetlands are now used to improve the quality of point and nonpoint sources of water pollution, including stormwater runoff, domestic wastewater and agricultural wastewater

Source: Marginpar.com

Components of Constructed Wetlands

- A constructed wetland consists of a properly designed basin that contains water, a substrate, and vegetation. Other important components of wetlands, such as the communities of microbes and aquatic invertebrates, develop naturally.

❖ Water

- Wetlands are likely to form landforms direct surface water to shallow basins and where a relatively impermeable subsurface layer prevents the surface water from seeping into the ground.
- These conditions can be created to construct a wetland. A wetland can be built almost anywhere in the land scape by shaping the land surface to collect surface water and by sealing the basin to retain the water.

Source: USEPA, 2017

Components of Constructed Wetlands

❖ Substrate

- Substrates used to construct wetlands include soil, sand, gravel, rock, and organic materials such as compost.
- The substrates and sediments are important for several reasons because they support many of the living organisms in wetlands.
- Its permeability affects the movement of water through the wetland and many chemical and biological (especially microbial) transformations take place within the substrates

Source: USEPA, 2017

Papu Yadav, 2026

Components of Constructed Wetlands

❖ Vegetation for Free Surface Wetland System

Constructed wetlands (CWs) utilize four primary categories of wetland vegetation:

1. Emergent macrophytes: Plants rooted in the substrate with stems and leaves above the water.
2. Submerged macrophytes: Plants that remain completely underwater.
3. Free-floating plants: Plants drifting on the surface with roots hanging freely.
4. Floating-leaved plants: Rooted plants with large leaves resting on the water's surface.

Source: USEPA, 2017

❖ Vegetation for Free Surface Wetland System

- ❖ Water lettuce (Pistia stratiotes) is a highly effective, cost-efficient aquatic macrophyte used in free water surface constructed wetlands for wastewater phytoremediation. Its dense root systems absorb heavy metals and nutrients, achieving removal rates of up to 83.5% for BOD_5 and 97.53% for ammonia. (Majid Ali etal. 2024)

❖ Vegetation for Free Surface Wetland System

❖ Water hyacinth (Eichhornia crassipes) is a highly effective, green phytoremediation technology for constructed wetlands. Its rapid growth rate and dense root system filter out organic matter, absorb excess nutrients like nitrogen and phosphorus, and remove over 80% of heavy metals such as Lead and Cadmium from municipal and industrial wastewaters

(Siti Noor Hajjar Md Latip et al. 2022)

❖ Vegetation for Free Surface Wetland System

- ❖ Water lily wetlands are highly effective, low-maintenance constructed treatment systems (or phytoremediation ponds) used to purify municipal, agricultural, or greywater. They act as natural biological filters that break down complex pollutants, remove heavy metals, and absorb excess nutrients like nitrogen and phosphorus Ali Marefat, 2021

❖ Vegetation for Free Surface Wetland System

- ❖ Pontederia cordata (Pickerelweed) is an exceptional emergent aquatic plant for water treatment in constructed wetlands, ponds, and bio-filters.
- ❖ It highly efficiently absorbs heavy metals (like copper, lead, and cadmium), rapidly draws down excess nitrogen and phosphorus, and naturally inhibits harmful algal blooms

❖ Vegetation for Free Surface Wetland System

- Microsorum pteropus, commonly known as Java fern after the Indonesian island of Java, can be found in Malaysia, Thailand and some regions of China.
- Java Fern is a highly effective, low-maintenance freshwater aquarium plant used to naturally improve water quality. It absorbs harmful waste (like nitrates and ammonia) from the water column.

❖ Vegetation for Free Surface Wetland System

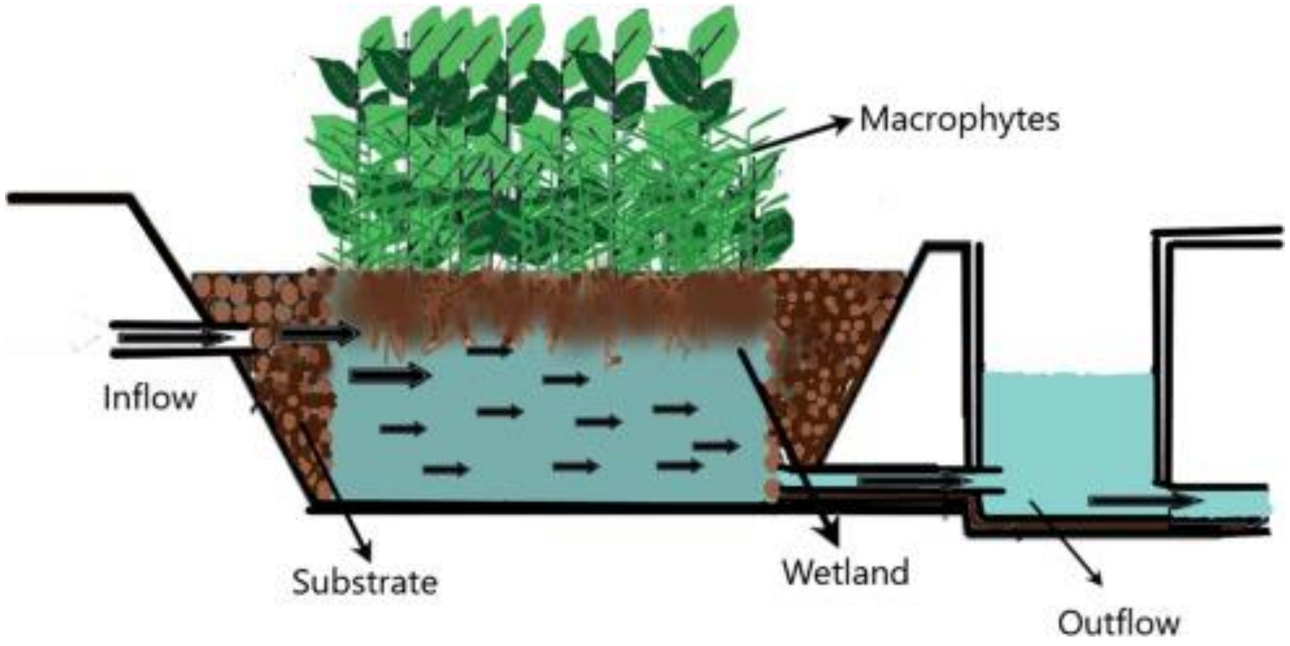
- Azolla (a fast-growing floating water fern) is a highly effective, nature-based agent for water treatment and phytoremediation.
- It acts as a natural biofilter, rapidly removing heavy metals, excess nitrogen, phosphorus, and other pollutants from wastewater, while generating valuable, nutrient-rich biomass that can be used for biofertilizer.

❖ Vegetation for Free Surface Wetland System

❖ Duckweed is a highly effective, low-cost phytoremediation tool used to purify municipal, industrial, and agricultural wastewater. These tiny floating aquatic plants rapidly absorb massive amounts of nitrogen and phosphorus while reducing overall biological oxygen demand, resulting in high-quality effluent

❖ Subsurface Wetland System

Subsurface wetland macrophytes are emergent aquatic plants rooted in a gravel, sand, or soil bed through which wastewater flows beneath the surface.
Horizontal subsurface flow constructed wetland (HSSFCW) is the most commonly used CW system.



Saloni Sachdeva, 2023

❖ Subsurface Wetland System

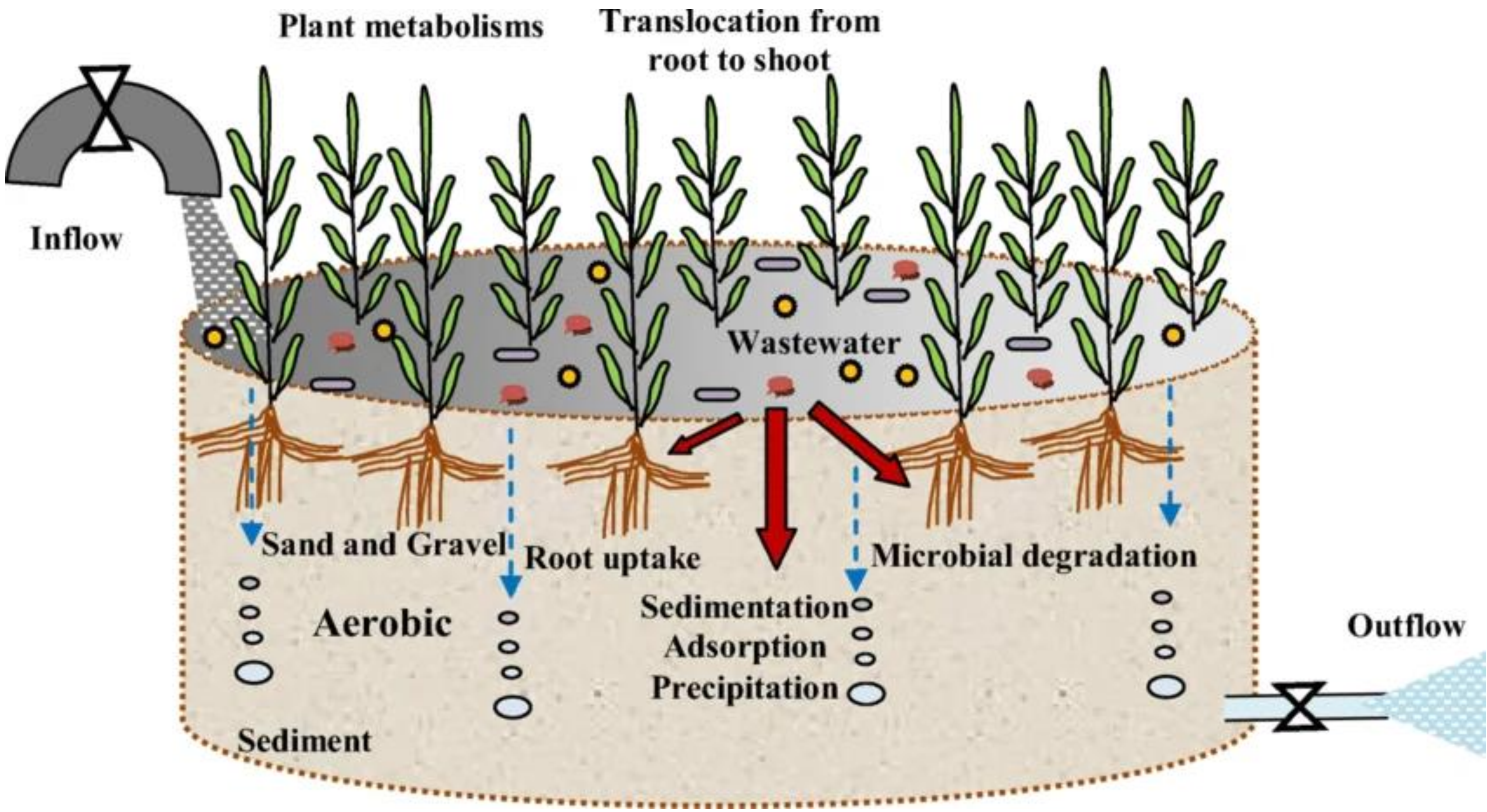
Table 1. Treatment efficiency of vegetated beds of HF CWs – worldwide experience

Parameter	*Inflow* ($mg l^{-1}$)	*Outflow* ($mg l^{-1}$)	*Efficiency* (%)
BOD_5	108	16.0	85
COD	284	72	75
TSS	107	18.1	83
TP	8.74	5.15	41
TN	46.6	26.9	42
NH_4^+-N	38.9	20.1	48

Saloni Sachdeva, 2023

❖ Subsurface Wetland System

- In a vertical flow subsurface wetland system, the influent percolates downward through a gravel and sand matrix to a drainage pipe. It is highly effective at aerating water and converting ammonia to nitrates.



Source: (Ilyas Huma, 2020)

❖ Vegetation for Subsurface Wetland System

- Typha latifolia (broadleaf cattail) is a powerful, low-cost wetland plant heavily utilized in constructed wetlands for phytoremediation.
- Its extensive root system absorbs heavy metals, stabilizes soil, and supports bacteria that break down organic waste, making it highly effective for treating domestic and industrial wastewater

❖ Vegetation for Subsurface Wetland System

- Tiger grass (Thysanolaena maxima) is utilized in water treatment as a natural, eco-friendly phytoremediation tool.
- Planted in constructed wetlands and vertical helophyte-filter systems, its deep, dense root systems absorb heavy metals, organic waste, and excess nutrients from wastewater while filtering out pollutants.

❖ Vegetation for Subsurface Wetland System

Juncus effusus
(commonly known as Soft Rush or Common Rush)

- Soft Rush is a highly effective, resilient emergent plant frequently used in constructed wetlands.
- It filters suspended solids, takes up excess nutrients, and transfers oxygen to its roots to cultivate purifying microorganisms.
- It typically achieves over 80% removal rates for biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in wastewater.

❖ Vegetation for Subsurface Wetland System

Miscanthus sinensis
(Chinese silvergrass)

- Using Miscanthus sinensis (Chinese silvergrass) in a constructed wetland system is an eco-friendly approach to wastewater treatment that combines phytoremediation with biomass production.
- The plants absorb heavy metals, reduce organic pollutants, and regulate oxygen transfer to promote biofilm growth, which naturally digests waste

❖ Vegetation for Subsurface Wetland System

Eleocharis dulcis
(Chinese water chestnut)

- Eleocharis dulcis (commonly known as purun tikus or Chinese water chestnut) is a highly effective, native emergent macrophyte used in Constructed Wetlands.
- Its robust root systems and high biomass production make it an excellent agent for phytoremediation, capable of reducing organic loads, nutrients, and heavy metals from industrial and domestic wastewater

❖ Vegetation for Subsurface Wetland System

Xanthosoma sagittifolium (commonly known as Tannia or Cocoyam)

- Xanthosoma sagittifolium (commonly known as Tannia or Cocoyam) is an effective plant for constructed wetlands.
- It is typically used in subsurface flow or Floating Treatment Wetlands where its dense root network filters pollutants, breaks down organic matter, and facilitates beneficial microbial growth to treat wastewater

❖ Vegetation for Subsurface Wetland System

Canna indica

- Canna indica is a highly resilient, fast-growing wetland macrophyte widely utilized in Constructed Wetlands (CWs) and Floating Treatment Wetlands (FTWs).
- Its long, fibrous root systems trap suspended solids while facilitating robust microbial activity in the rhizosphere, making it an excellent natural filter for removing heavy metals, nitrogen, and organic pollutants from wastewater

❖ Vegetation for Subsurface Wetland System

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❖ Vegetation for Subsurface Wetland System

Cyperus Haspan

- Cyperus haspan is a highly effective, fast-growing sedge widely used in Constructed Wetlands (CW) and Floating Treatment Wetlands (FTW) for bioremediation and wastewater treatment.
- It is highly efficient at reducing Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Suspended Solids (TSS), and heavy metals.

❖ Vegetation for Subsurface Wetland System

Cyperus Haspan

- Lepironia articulata (often called Grey Sedge or Purun danau) is a highly effective, native Southeast Asian wetland plant used in constructed wetland and phytoremediation systems.
- It naturally thrives in tropical climates and purifies wastewater through a combination of root filtration, oxygen release, and microbial breakdown.

❖ Vegetation for Subsurface Wetland System

- The Common Reed (Phragmites australis) is an incredibly resilient aquatic plant widely used in "reed bed" systems to naturally filter wastewater. It purifies water by transporting oxygen down into the gravel or soil, which cultivates beneficial microorganisms that actively digest organic pollutants and reduce harmful bacteria

❖ Vegetation for Subsurface Wetland System

- Constructed wetlands (CW) are being explored as an alternative treatment for boron removal.
- This study explored the capacity of this residue to treat boron-rich wastewaters as main wetland substrate in laboratory constructed wetland microcosms.
- Two plants, Typha angustifolia and Puccinellia frigida, were used to evaluate their capacity to increase boron removal.

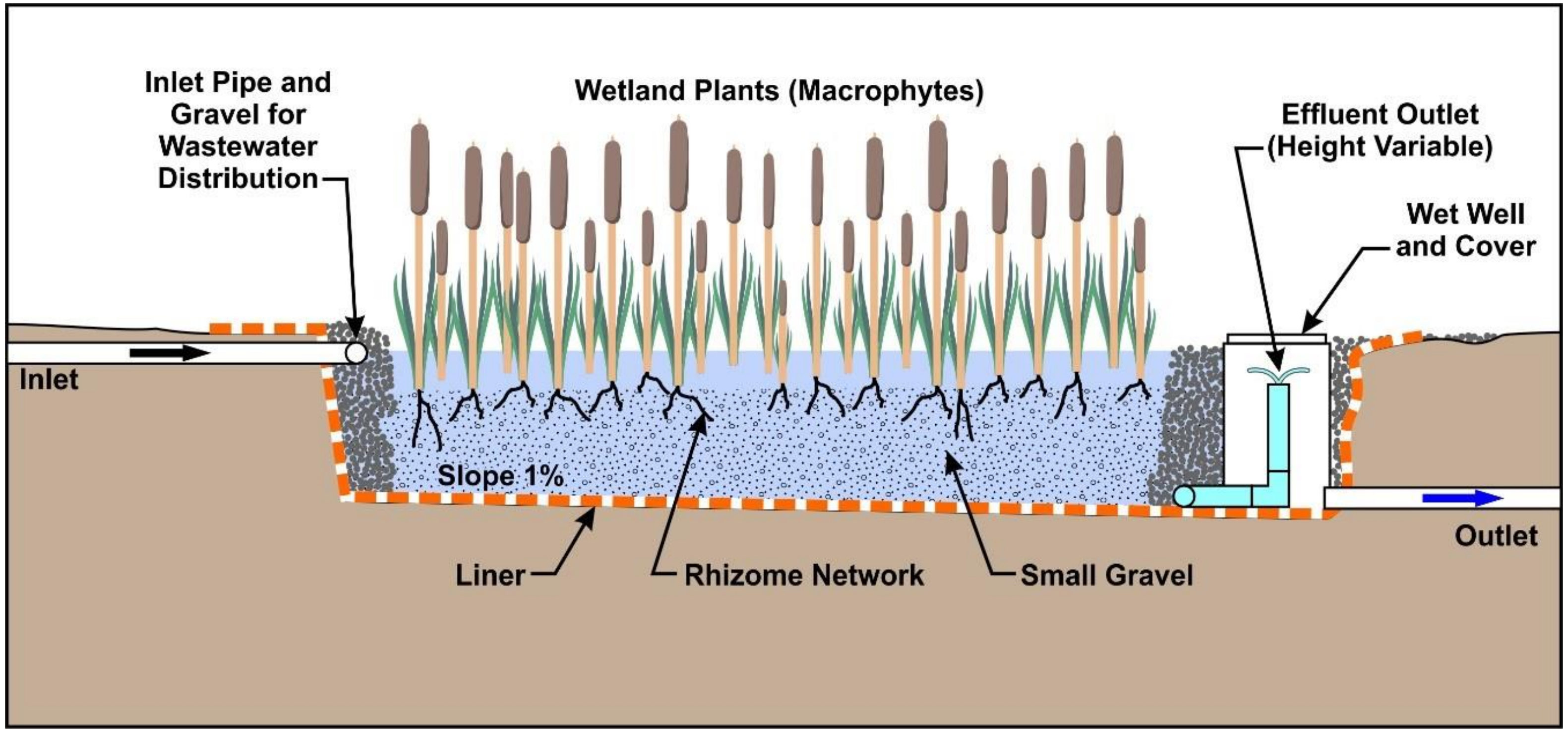
Utilization of Harvested Macrophytes

1. Composting these plants creates a natural, nutrient-rich fertilizer because plant tissues hold rich stores of nitrogen and phosphorus taken from the wastewater.
2. Heating the plant matter in a low-oxygen environment creates biochar. This is a charcoal-like substance used to filter polluted water or improve farm soil.
3. Some harvested plant species can serve as roughage or feed for certain farm animals.
4. Dried reeds and grasses work well as animal bedding, which later turns into manure-based fertilizer.

Mechanism of Constructed Wetlands

Physical Filtration

- The wetland is lined and filled with substrate (filter media) like sand, gravel and soil.
- The loose, porous material physically traps large suspended solids and particulate matter as water flow through.



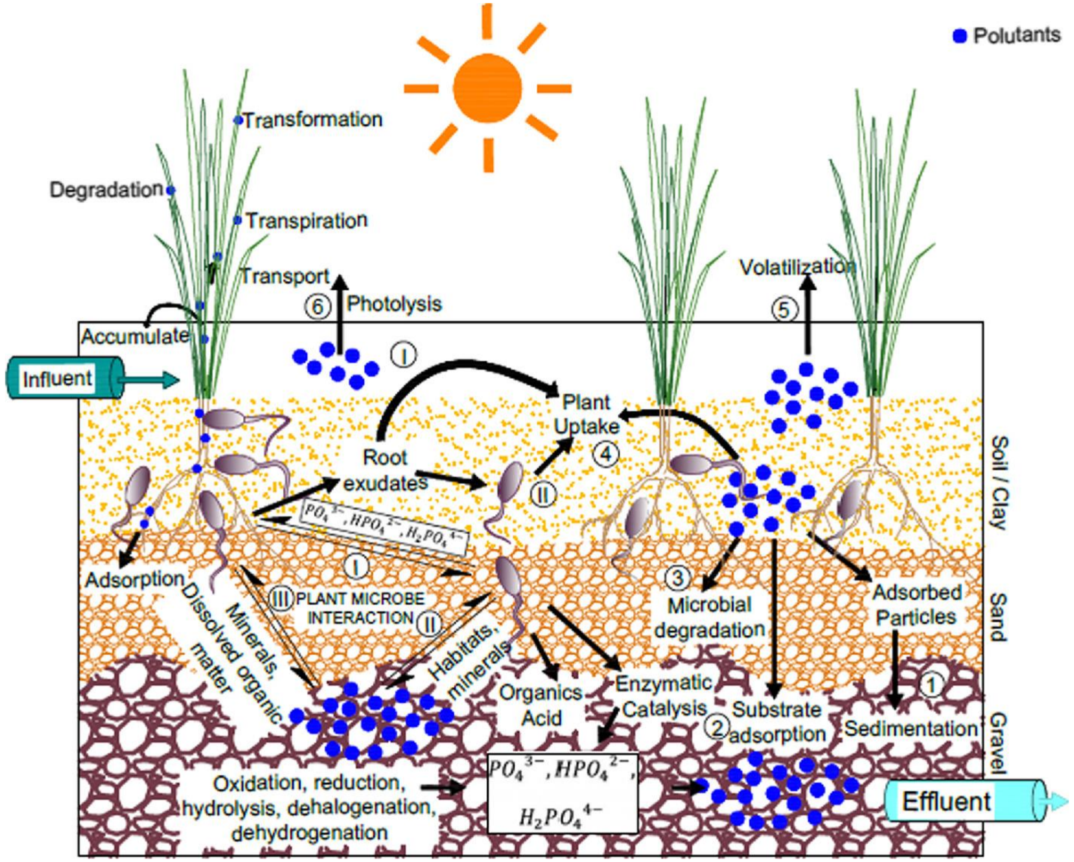
Tilley et al., 2014

Mechanism of Constructed Wetlands

Adsorption

- It is a primary for removing contaminants like heavy metals, phosphorus, and trace organics bind to the surfaces of substrate media (e.g., gravel, sand, zeolite, biochar).

- This process temporarily immobilizes the pollutants, allowing time for plant uptake and microbial degradation.

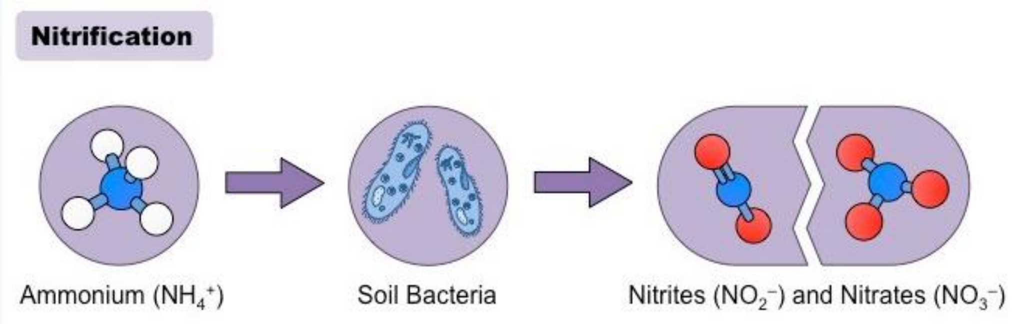


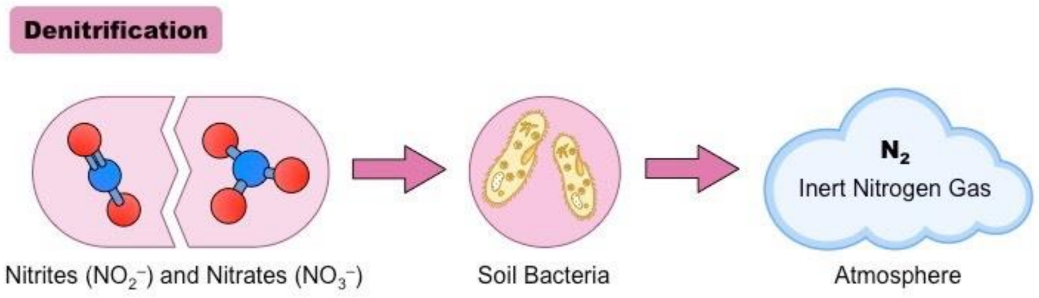
Suchhanda Mondal , 2026

Mechanism of Constructed Wetlands

<u>Microorganisms</u>

- Microorganisms aerobically or anaerobically decompose organic matter to reduce the concentration of biochemical oxygen demand (BOD) and chemical oxygen demand (COD).
- In nitrogen removal, nitrifying bacteria turns toxic ammonia into nitrates in oxygen rich zones.
- In anoxic/ anaerobic zones, denitrifying bacteria converts nitrates to nitrogen gas that escape to atmosphere.





Mechanism of Constructed Wetlands

Phytoremediation

- It is a technique that uses plants and associated microbes to remove toxify pollutants like heavy metals, pesticides and hydrocarbons from soil and water.
- Distinct Mechanisms
    - Phytoextraction
    - Phytostabilization
    - Phytodegradation
    - Phytofiltration

- Phytoextraction

Plants absorb contaminants through their roots and transport them to their stems and leaves, which are then harvested and safety disposed of.

- Phytostabilization

Plants trap contaminants in the soil, preventing them from spreading via wind, rain, or groundwater

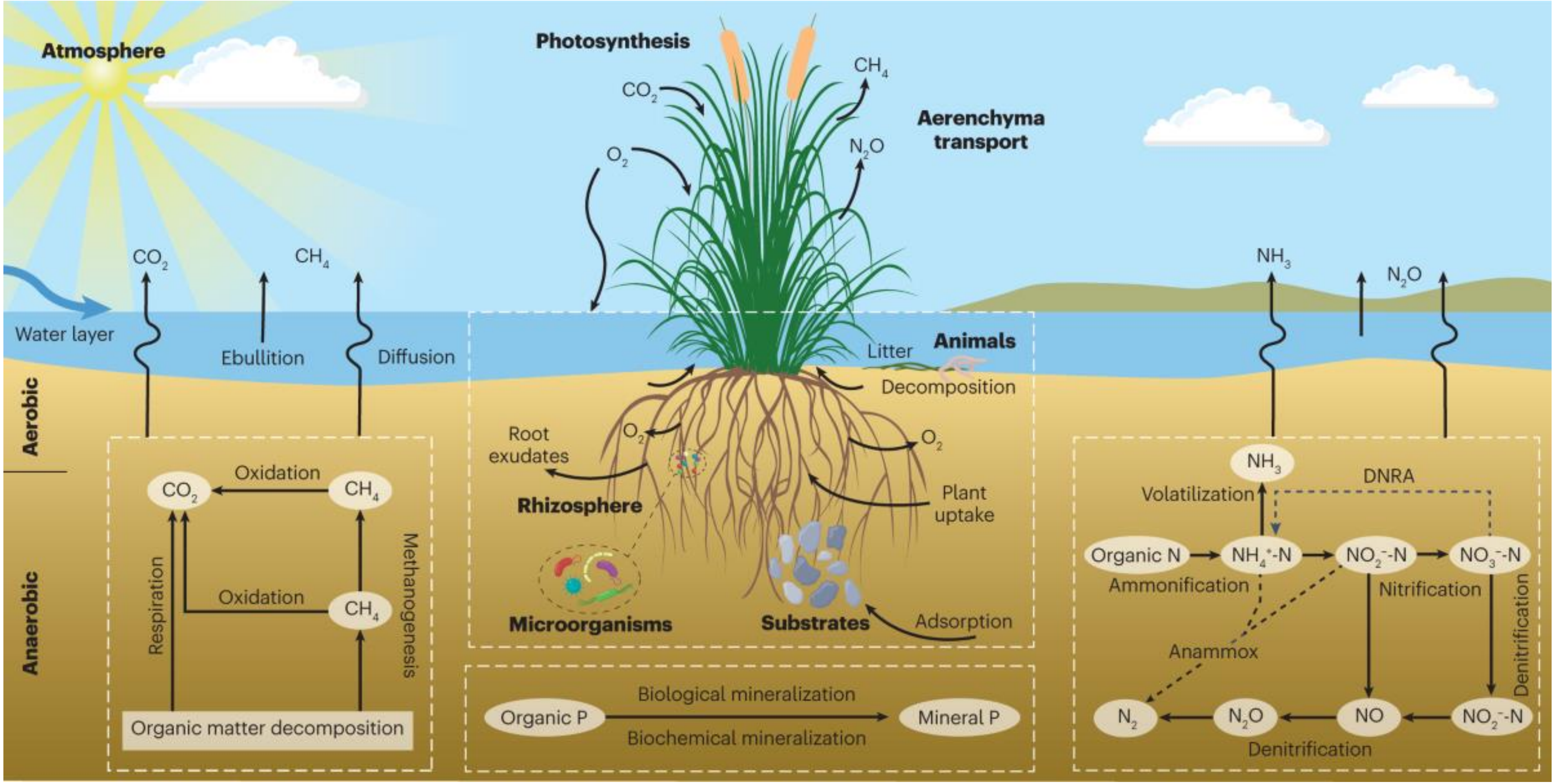
- Phytodegradation

Plants and their microbes use enzymes to break down organic contaminants into harmless by-products.

- Phytofiltration

Contaminants are filtered and absorbed from contaminated water or wastewater using plants grown hydroponically.

Mechanisms of Constructed Wetlands



(Haiming Wu, 2023)

Design Considerations of Constructed Wetland System

Hydrological Factors

- A hydrologic budget should be prepared to properly design a constructed wetland treatment system. Changes in the detention time or water volume can significantly affect the treatment performance.

For a constructed wetland, the water balance can be expressed as follows:

$$Q_i - Q_o + P - ET = [dV/dt] \qquad (3\text{-}1)$$

where,

Q_i = influent wastewater flow, volume/time,
Q_o = effluent wastewater flow, volume/time,
P = precipitation, volume/time
ET = evapotranspiration, volume/time
V = volume of water, and
t = time.

(USEPA, 1988)

BOD_5 removal in a wetland has been described by a first-order model as follows (1):

$$[C_e/C_o = \exp(-K_T t) \qquad (3-2)$$

where,

C_e = effluent BOD_5, mg/L
C_o = influent BOD_5, mg/L
K_T = temperature-dependent first-order reaction rateconstant, d^{-1}
t = hydraulic residence time, d

(USEPA, 1988)

Hydraulic residence time can be represented as:

$$t = LWd \div Q \qquad (3-3)$$

where,

L = length
W = width
d = depth
Q = average flow rate = $(flow_{in} + flow_{out}) \div 2$

Dimension Factors

- Surface Area can be estimated by using following equation.

$$A_s = [Q\ (\ln C_o - \ln C_e)] \div (K_T\ d\ n) \qquad (3\text{-}7)$$

where,

C_e = effluent BOD_5, mg/L
C_o = influent BOD_5, mg/L
K_T = temperature-dependent first-order reaction rate constant, d^{-1}
t = hydraulic residence time, d
Q = average flow rate through the system, m^3/d
d = depth of submergence, m
= porosity of the bed, as a fraction
A_s = surface area of the system, m^2

(USEPA, 1988)

Dimension Factors

- Width

There is no hard and fast rule on the optimum width of the wetland, however, it is recommended that if the width of the wetland is more than 15 m, the wetland cell should be partitioned inside the wetland.

It should also be kept in mind that it is better to use at least two parallel cells instead of a single wetland cell for the ease in operation and maintenance of the wetland.

- Slope

A slope of 0.5 to 1% is recommended for ease of construction and proper draining

(UNHABITATE, 2008)

Dimension Factors

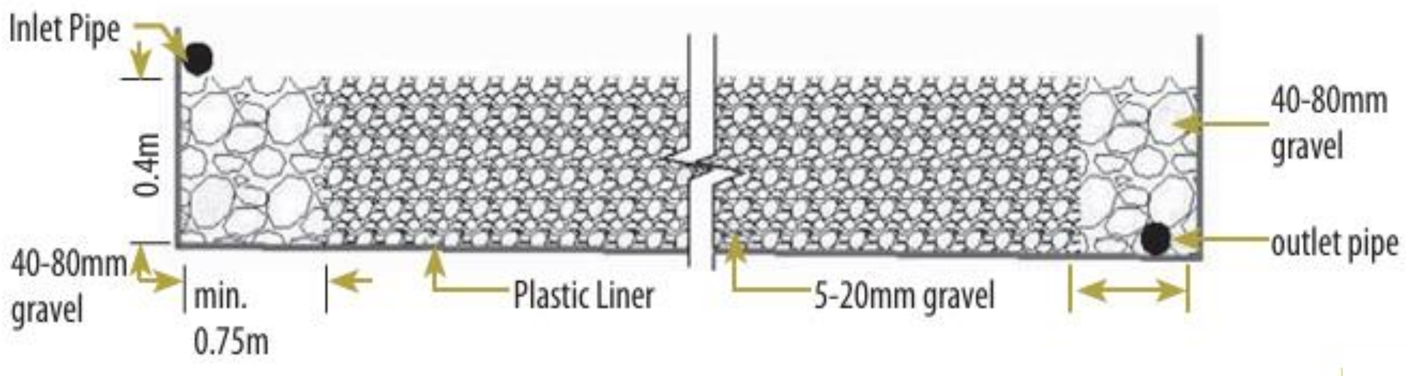
Water Depth

- The water level in the system and the duration of flooding can be important factors for the selection and maintenance of wetland vegetation
- Cattails grow well in submerged soils and may dominate where standing water depth is over 150 mm (6 in)
- Reeds occur along the shorelines of water bodies where the water table is below the surface but will also grow in water deeper than 1.5 m (5 ft).
- Bulrushes can tolerate long periods of soil submergence and occur at water depths of 7.5 250 mm (0.3-10 in)

(USEPA, 1988)

Media Selection

- The media perform several functions.
- They are (i) rooting material for vegetation, (ii) help to evenly distribute/collect flow at inlet/outlet, (iii) provide surface area for microbial growth, and (iv) filter and trap particles
- Figure shows the recommended substrate sizes, which uses 40 – 80 mm media at the inlet/outlet zones and 5 – 20 mm at the treatment zone.

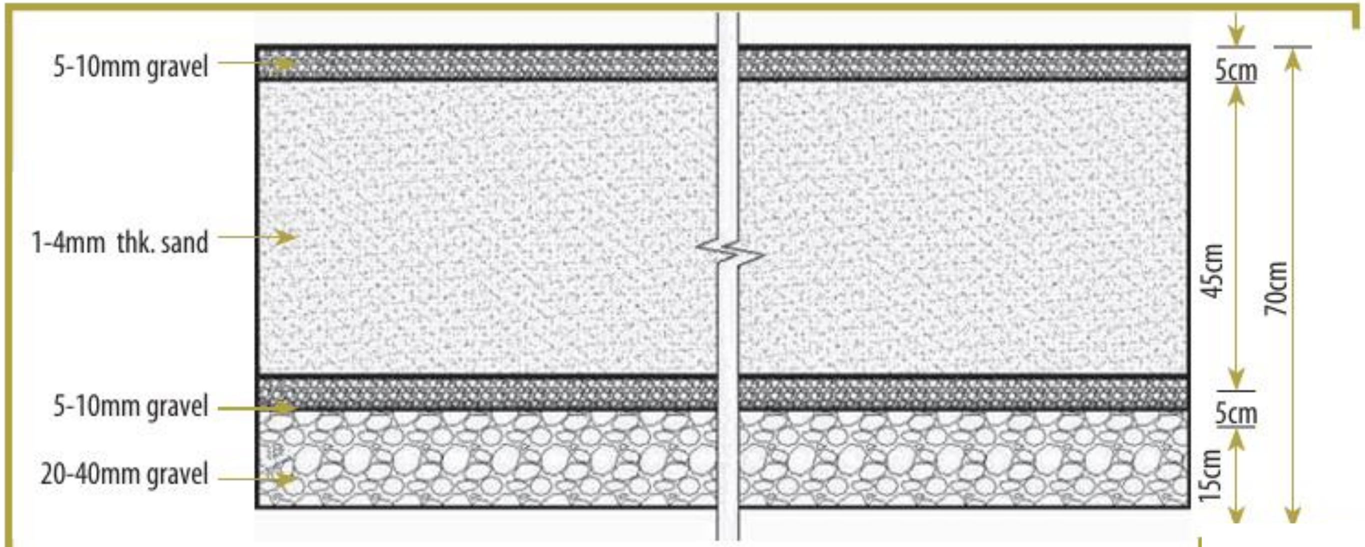


Substrate arrangement in a HF wetland

(UNHABITATE, 2008)

Media Selection

- There is not one uniform standard substrate design for the construction of VF wetland.
- Various literatures reports effective grain size should be $0.2 < d10 < 1.2$ mm, uniformity coefficient 3 to 6 and hydraulic conductivity Kf 10-3 to 10-4 m/s.
- The filter media used at Dhulikhel Hospital had d10 = 0.4 mm and d60/d10 = 1.5



Substrate arrangement in a VF wetland

(UNHABITATE, 2008)

Hydraulic Loading Rate

- Hydraulic loading rates of 150-500 m3/ha-d (16,000-54,000 gpd/ac), have been reported and, in general, the site-specific conditions of weather, soil conditions (permeability especially), and vegetation type must be considered in establishing the hydraulic loading rate.
- From the results obtained at Listowel, Ontario, it appears that hydraulic loading rates of 200 m3/ha-d (21,000 gpd/ac) will provide maximum treatment efficiencies.

(USEPA, 1988)

Hydraulic Detention Time

- A detention time of 6-7 days has been reported to be optimal for the treatment of wastewater.
- Shorter detention times do not provide adequate time for pollutant degradation to occur; longer detention times can lead to stagnant, anaerobic conditions.

Permissible Influent Concentration

❖ Constructed wetlands are generally designed for secondary or tertiary treatment, meaning influent concentrations shouldn't exceed typical municipal or agricultural wastewater loads. Exceeding these thresholds causes clogging and plant toxicity. Standard maximum recommended influent concentrations include,

- **BOD_5:** Up to 250 – 300 mg/L
- **COD:** Up to 500 – 800 mg/L
- **TSS:** Up to 200 – 300 mg/L
- **Total Nitrogen (TN):** Up to 50 – 80 mg/L
- **Ammonia ($NH_4^+ - N$):** Up to 20 – 50 mg/L
- **Total Phosphorus (TP):** Up to 15 – 20 mg/L

(G. Mancuso, 2023)

Lifetime of Macrophytes

- The lifetime of macrophytes (aquatic plants) is critically important for contaminant uptake in constructed wetlands. While plants directly absorb some pollutants, their life cycle heavily dictates the wetland's ability to filter and store contaminants.
- Their uptake changes at each growth stages.

1. Seedling stage: The plant is young and just starting to grow in the wetland and roots are small, so direct plant uptake is low.
2. Vegetative stage: The plant grows quickly, making leaves, stems, and long roots. This is the plant's fastest growing time. It absorbs large amounts of nutrients from the water to build new plant parts.
3. Mature stage: The plant is fully grown. It stops growing quickly and may make flowers or seeds. The total amount of nutrients stored in the plant is at its highest. However, the rate of new uptake slows down. Old plant parts die and sink. This traps pollutants in the mud. If they are not cleaned out, some trapped pollutants can leak back into the water as the old plants rot. If left in the water too long, the plant reaches its maximum capacity. Older plants start to decay. As they die, they release the stored pollutants back into the water.

Optimum Uptake Lifetime of Common Macrophytes

- The optimum uptake lifetime (from starting date of planting macrophytes in new environment of constructed wetland system) of common macrophytes are as follows,

No.	Macrophytes	Lifetime (days)	Type of constructed wetland
1.	water hyacinth	14 - 21	Free surface
2.	water lettuce	7 - 12	Free surface
3.	duckweed	3 - 7	Free surface
4.	water lilies	90 - 120	Free surface
5.	Common reeds	90 - 120	Subsurface
6.	Cattail	60 - 120	Subsurface
7.	Tiger Grass	60 - 120	Subsurface
8.	Canna Indica	45 - 90	Subsurface

Performance Expectation

- Wetland systems can significantly reduce biological oxygen demand (BOD5), suspended solids (SS), and nitrogen, as well as metals, trace organics, and pathogens.

Table 3-2. Performance of Pilot-Scale Constructed Wetland Systems (1)

	Effluent Concentration, mg/L					
Wetland Type	BOD_5	SS	NH_4	NO_3	T N	T P
Open water, channel	10	8	6	0.2	8.9	0.6
Open water, channel	<20	<8	<10	0.7	11.6	6.1
Gravel-filled channels	<30	<8	<5	<0.2	-	
Seepage basin wetland			2	1.2	6.2	2.1

(USEPA, 1988)

Constructed Wetlands for Lake Water Treatment (Case Study I)

(a) 0 Day (b) 5 Days

(c) 10 Days (d) 25 Days

Variation of Macrophyte's Surface Area throughout the Treatment Process

Hydraulic Detention Time	Surface Area (ft^2)	Vegetation Covered (%)
0 Day	1.7	60%
5 Days	2.3	80%
10 Days	2	70%
15 days	2.1	75%
20 days	2.4	85%
25 days	2.8	98%

(May Ingyine, 2024)

Constructed Wetlands for Water Treatment (Case Study I)

Parameters	Influent	Effluent (HDT - 25 days)	Removal Efficiency (%)
Color (TCU)	220	28.3	87
Turbidity (NTU)	4.05	0.52	87
TSS (mg/l)	955	100	90
TDS (mg/l)	340	35	90
Chloride (mg/l)	1175	100	91
Ammonia (mg/l)	2	0.15	93

(May Ingyine, 2024)

Constructed Wetlands for Water Treatment (Case Study II)

Figure A.15 Phragmites (common reeds)

Figure A.16 (5mm – 10mm) Gravel

Figure A.17 (0.05 mm – 0.2 mm) Sand

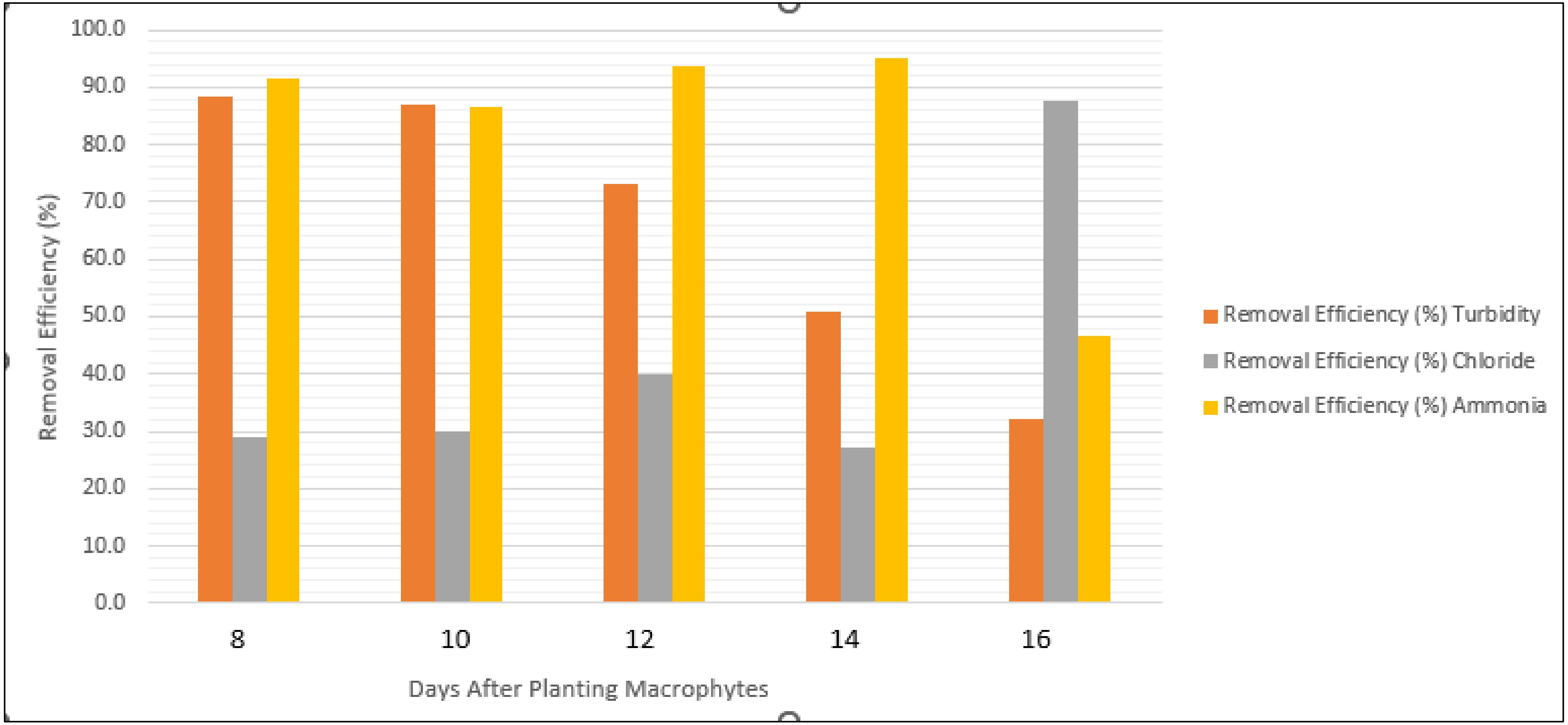
Figure A.18 Loam Soil

Figure A.19 Crushed Charcoal

Lab-scaled Vertical Flow Treatment Unit

(Me Me Khine, 2024)

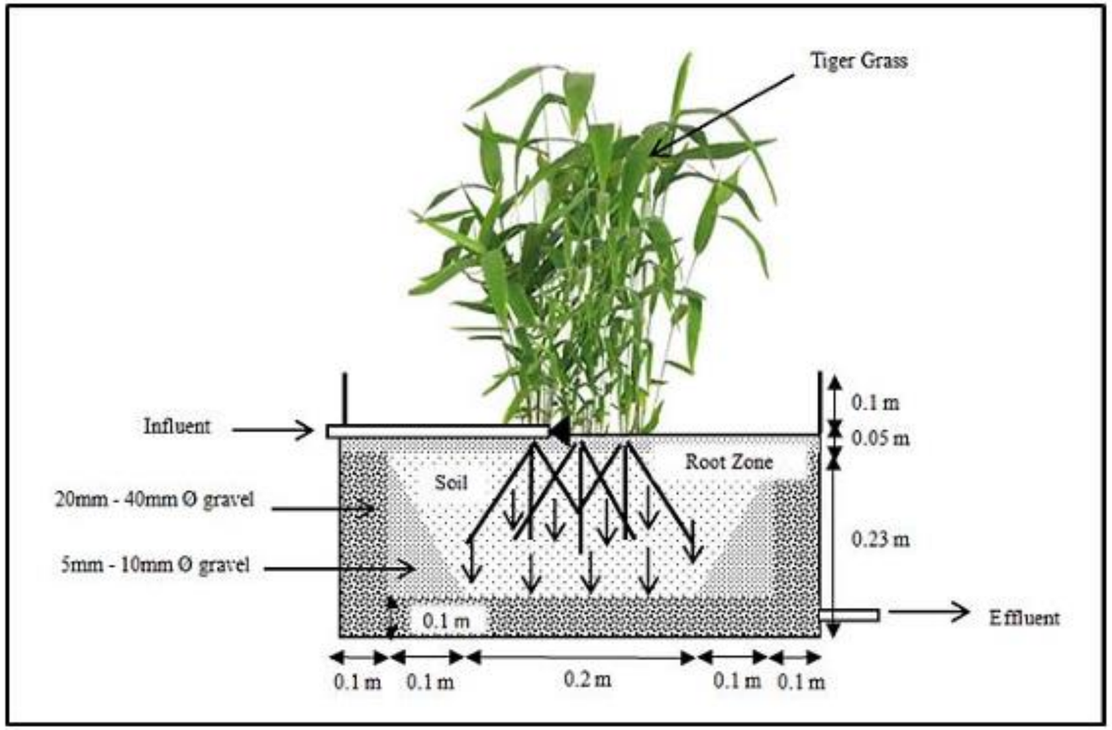
Constructed Wetlands for Water Treatment (Case Study II)



(Me Me Khine, 2024)

Constructed Wetlands for Water Treatment (Case Study III)

- Using tiger grass, the influent of fifth experiment (56 days of lifetime) had the highest phosphorous concentration compared with the concentration of the influent for other experiments.
- The lab-scaled VFSCW system can reduce the phosphorous concentration up to 20 mg/l with 88% of treatment efficiency.

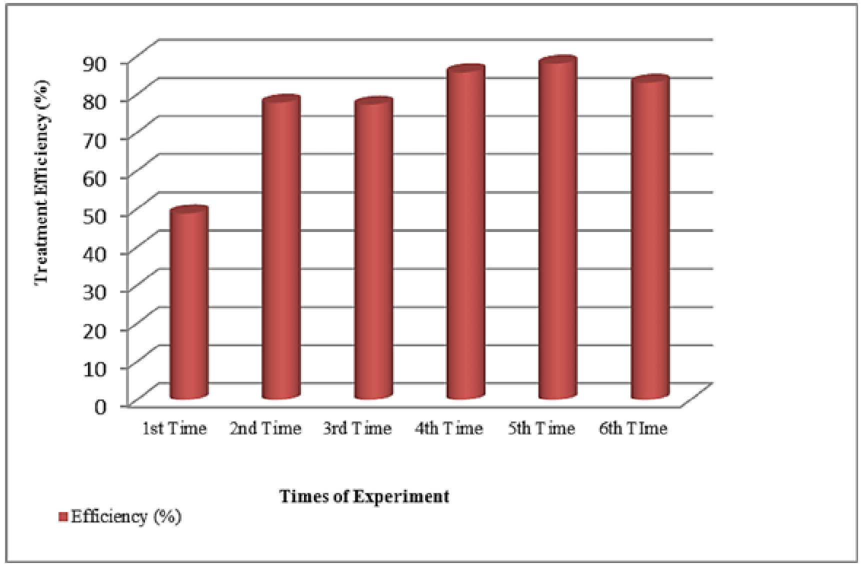


(Nway Nway Khaing, 2019)

Constructed Wetlands for Water Treatment (Case Study III)

Experimental Results of Phosphorous Removal Process

Days after planting macrophyte	P Concentration [mg/l]		PLR [g/m^2-d]	PRR [g/m^2-d]	RE [%]
	P_i	P_e			
20 days	27	14	5.20	2.53	49
29 days	27	6	5.18	4.03	78
36 days	22	5	4.22	3.26	77
40 days	9	1	1.77	1.52	86
56 days	165	20	31.68	27.88	88
65 days	59	10	11.40	9.50	83



4 Phosphorous Removal Efficiency of VFSCW System

(Nway Nway Khaing, 2019)

Constructed Wetlands for Wastewater Treatment (Review on International Research Papers)

Title: Water hyacinth (Eichhornia crassipes) – An efficient and economic adsorbent for textile effluent treatment – A review

- Floating aquatic macrophytes have a high level of proficiency in the removal of various contaminants, particularly nutrients, from wastewater.
- Water hyacinth (Eichhornia crassipes), a worst invasive aquatic weed has been utilised for various research activities over the last few decades. The biosorption capacity of the water hyacinth in minimising various contaminants present in the industrial wastewater is well studied. (E. Sanmcga Priya, 2013)
- In a lab scale study, Mahmood et al. (2005) observed that water hyacinth has the capability to reduce the pH of textile waste water from alkaline to neutral, COD and BOD reduction in the range of 40–70%, total solids with a maximum reduction of 50.64%.
- The author could achieve a reduction in volatile solids 72.6%, dissolved solids 60%, suspended solids 46.6%, 75% BOD and 81.4% COD. (Gamage and Yapa (2001))

Title: Constructed wetlands for pollution control

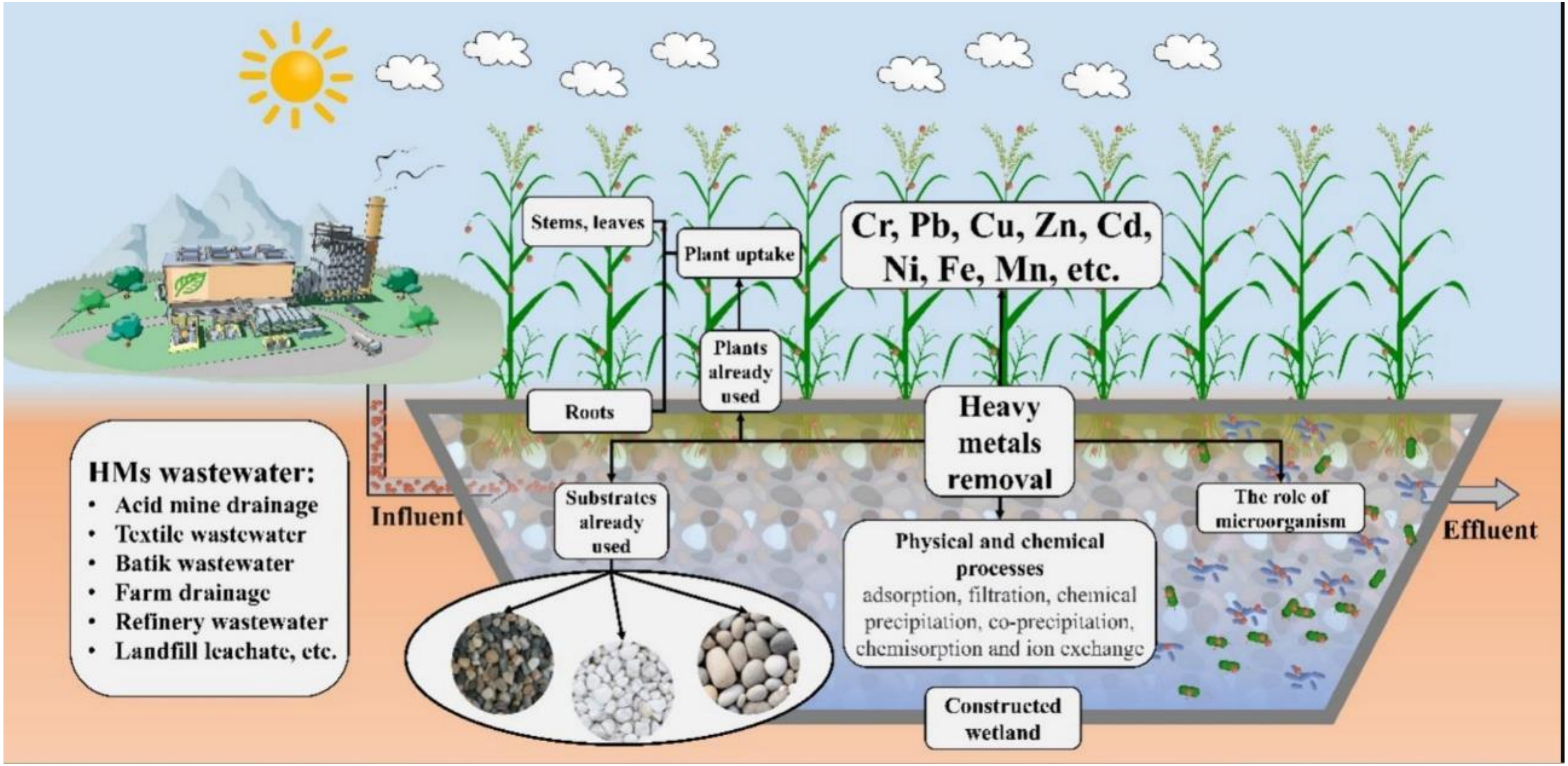
- Artificial wetlands are used in over 50 countries to sustainably treat wastewater. These constructed wetlands (CWs) make use of natural biogeochemical and physical processes to remove organic matter and nutrients, while providing co-benefits such as ecosystem services and recreation.
- Based on data from 335 field-scale CWs, hybrid CWs (which use two or more types of CW during water treatment) are the most effective for water-quality improvement removing 76%, 63% and 72% of organic matter, nitrogen and phosphorus, respectively (based on the median values).
- Field-scale CWs were used in over 50 countries globally during 2001–2021, mainly in Europe (38.8%), Asia (32.8%), North America (14.0%) and Africa (8.1%).

(Haiming Wu, 2023)

Title: Constructed wetlands for metallic wastewater treatment: An updated global profile

- Constructed wetlands (CWs) are increasingly used to treat heavy metals (HMs) wastewater.
- Bibliometric analysis on the research trends shows that there is increasing interest with more concentrated research on Cu, Zn, Cr, and Pb.
- The mechanisms of HMs removal by CWs include adsorption, filtration, precipitation, co-precipitation, and ion exchange, while the substrates adsorption plays a major role in the removal of HMs.
- Forty-five species of wetland plants were used for treating HMs in the last four years. More HMs are usually accumulated in the plants roots compared to the aboveground parts.
- As an important part of CWs, microorganisms play a considerable role in HMs removal, including adsorption of HMs by biofilm, promotion of plant growth, enhancement of plant resistance to HMs, and oxidation-reduction reaction to generate HMs precipitation.
- Typical Removal Rates Constructed wetlands have been widely documented to drastically reduce metal concentrations in various water sources: Lead (Pb): 74% to 98% removal Cadmium (Cd): 90% to 95% removal Copper (Cu): Up to 80% removal Zinc (Zn): 65% to 92% removal. (Zhongyan Zhang 2024)

Constructed wetlands for metallic wastewater treatment: An updated global profile (Continued)



Zhongyan Zhang 2024

Title: Nitrogen removal in constructed wetland systems

- Nitrogen is removed in constructed wetland systems through a combination of biological processes (nitrification and denitrification), plant uptake, and substrate filtration.
- Among various applications of these wetlands, a significant area is the removal of nitrogenous pollutants to protect the water environment and to enable effective reclamation and reuse of the wastewater.
- In a typical steel-and-concrete wastewater treatment system, the removal rate of pollutants is generally 80-95% for biological oxygen demand (BOD), 70-80% for suspended solids (SS), 20-30% for total nitrogen (TN), and less than 20% for total phosphorus (TP).
- In constructed wastewater wetlands, the denitrification process may remove 60-70% of the total removal nitrogen and 20-30% of that is derived from plant uptake.

Chang-gyun Lee. et al, 2009

Title: Nitrogen removal in constructed wetland systems (Continued)

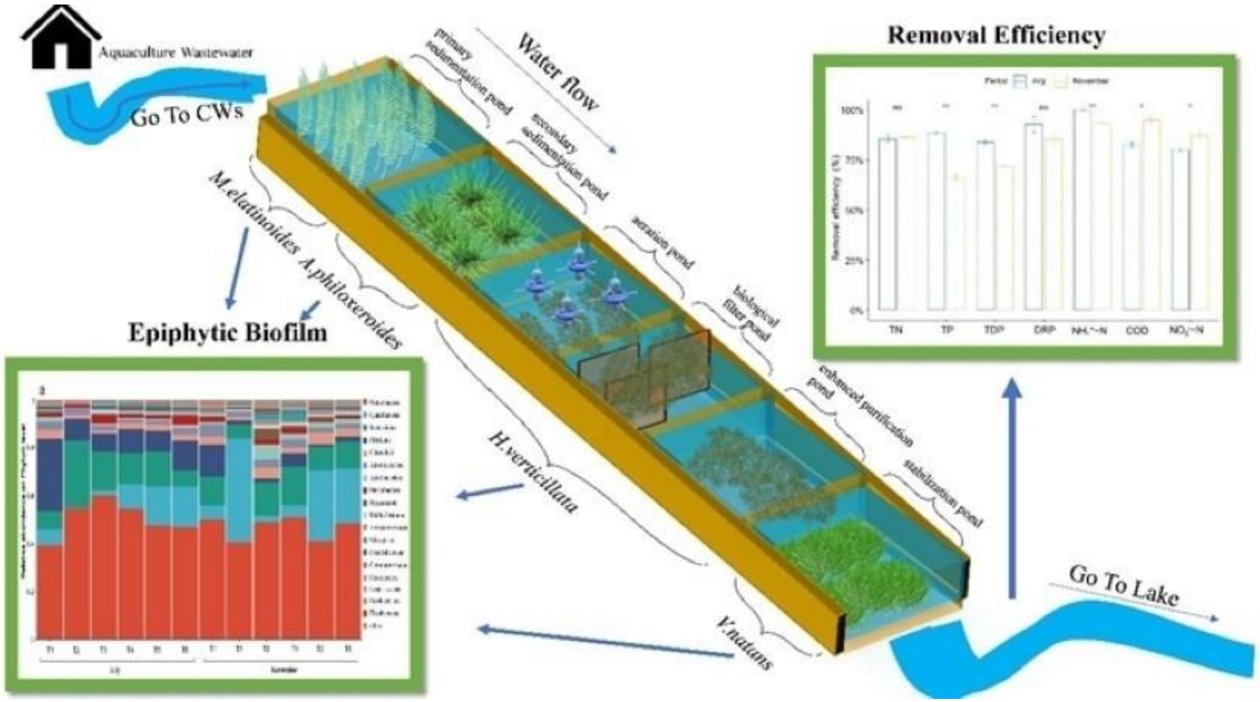
Table 1. Comparison of characteristics of constructed wetlands and conventional wastewater treatment plants.

		Economical considerations			Removal efficiency, %				
Type of treatment system	Treatment capacity	Construction cost, $	Management cost, $/year	Facility size, m^3	BOD	SS	TN	TP	Remarks
Constructed wetland	Sewage 100 m^3/day	220 000	300	800	80–90	80–90	40–50	50–60	Remove some heavy metals, *E. coli*
Conventional treatment plant		300 000	2000	450	80–99	70–80	20–30	<20	

Chang-gyun Lee. et al, 2009

Title: Innovative constructed wetland system enhances aquaculture wastewater treatment

- A demonstration site was established at a bullfrog aquaculture facility in the Datong Lake region of Yiyang City.
- Results showed that the constructed wetland system achieved a remarkable removal efficiency exceeding 60% for both total nitrogen and total phosphorus in bullfrog aquaculture wastewater, significantly reducing pollutant loads. However, treatment performance varied seasonally, with TN removal remaining stable, while TP removal fluctuated.



(CHAO Chuanxin, 2025)

Title: Phytoremediation of Heavy Metal Contaminated Groundwater Using Tropical Wetland Plants: Lepironia articulata and Typha angustifolia

- This study examines the efficacy of Lepironia articulata and Typha angustifolia in horizontal subsurface flow constructed wetlands (HSSF-CWs) for removing organic pollutants and heavy metals from contaminated water over a 10-week monitoring period.
- For Lepironia articulata, the average COD, BOD_5, Pb, Zn, Fe, and Cu concentrations were 38.2 mg/L, 13.09 mg/L, 0.0416 mg/L, 0.0368 mg/L, 1.1539 mg/L, and 0.0096 mg/L, with corresponding removal efficiencies of 31.02%, 22.89%, 11.18%, 19.87%, 23.18%, and 22.53%, respectively.
- For Typha angustifolia, they were 50.7 mg/L, 11.43 mg/L, 0.0289 mg/L, 0.0163 mg/L, 0.9795 mg/L, and 0.0095 mg/L, with removal efficiencies of 8.24%, 38.34%, 37.16%, 57.41%, 32.83%, and 34.08%, respectively.
- These findings highlight the complementary strengths of both macrophytes in mitigating organic and metal contaminants through wetland-based treatment.

(Baiyang Jiang. et al, 2025)

Title: Constructed Wetland of Lepironia Articulata for Household Greywater Treatment

- In this study, a pretreatment system and mini wetland were constructed at village dwelling for greywater treatment. The main purpose of this study was to investigate the greywater loading characteristics, provide appropriate onsite mini wetland and to measure the effectiveness of the wetland treatment system.
- The greywater samples were collected from the effluent of single house, at influent, pre-treatment model (particle material), mini wetland model (plant tube sedge Lepironia Articulata), and control model (without plant) at two sampling period.
- The mini wetland model shows high removal performance of 81.42% BOD, 84.57% COD, 39.83% AN, 54.70% SS, and 45.01% turbidity. Generally, the results show that the constructed mini wetland was effective to remove contaminants and suitable for treatment of greywater sources.

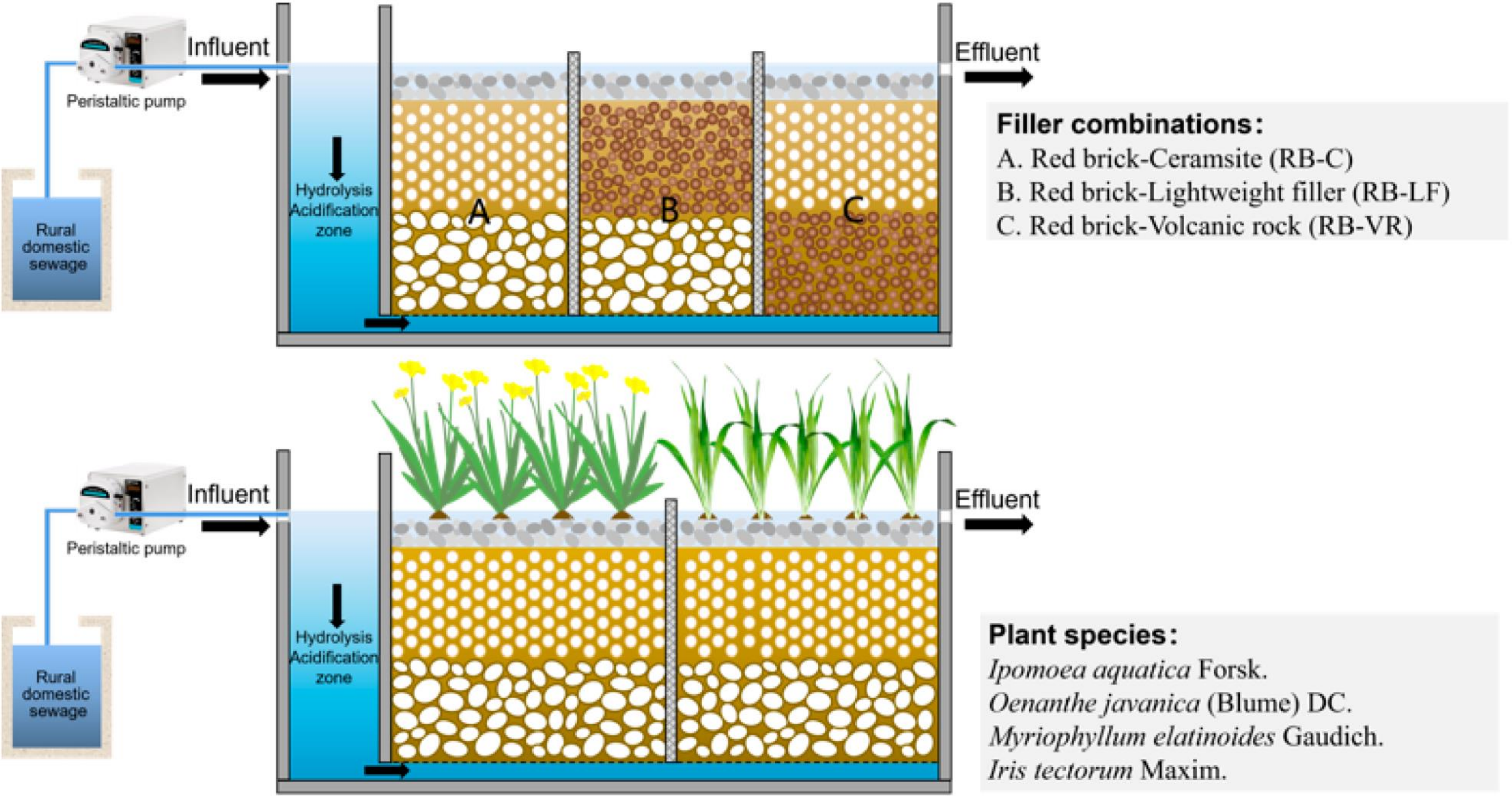
(A. A. Wurochekke, et al. 2014)

Title: Modular Constructed Wetlands for Treatment of Rural Domestic Wastewater: Laboratory Performance and Field Application

- In this paper, horizontal subsurface flow modular constructed wetlands (HSSF-MCWs) with different filler combinations and plant species were constructed to analyze the pollutant removal effect on rural domestic wastewater.
- The results indicated that the red brick–volcanic rock (RB-VR) combination showed the best comprehensive removal effect on rural domestic wastewater, with the highest average removal rate of ammonia nitrogen (NH4+-N 81.0 ± 2.5%) and total nitrogen (TN 64.5 ± 3.4%).
- The RB-VR systems with four rural plants in which Myriophyllum elatinoides Gaudich. showed the optimum long-term purification effect.

Xiaolin Zhao, 2025

Title: Modular Constructed Wetlands for Treatment of Rural Domestic Wastewater: Laboratory Performance and Field Application



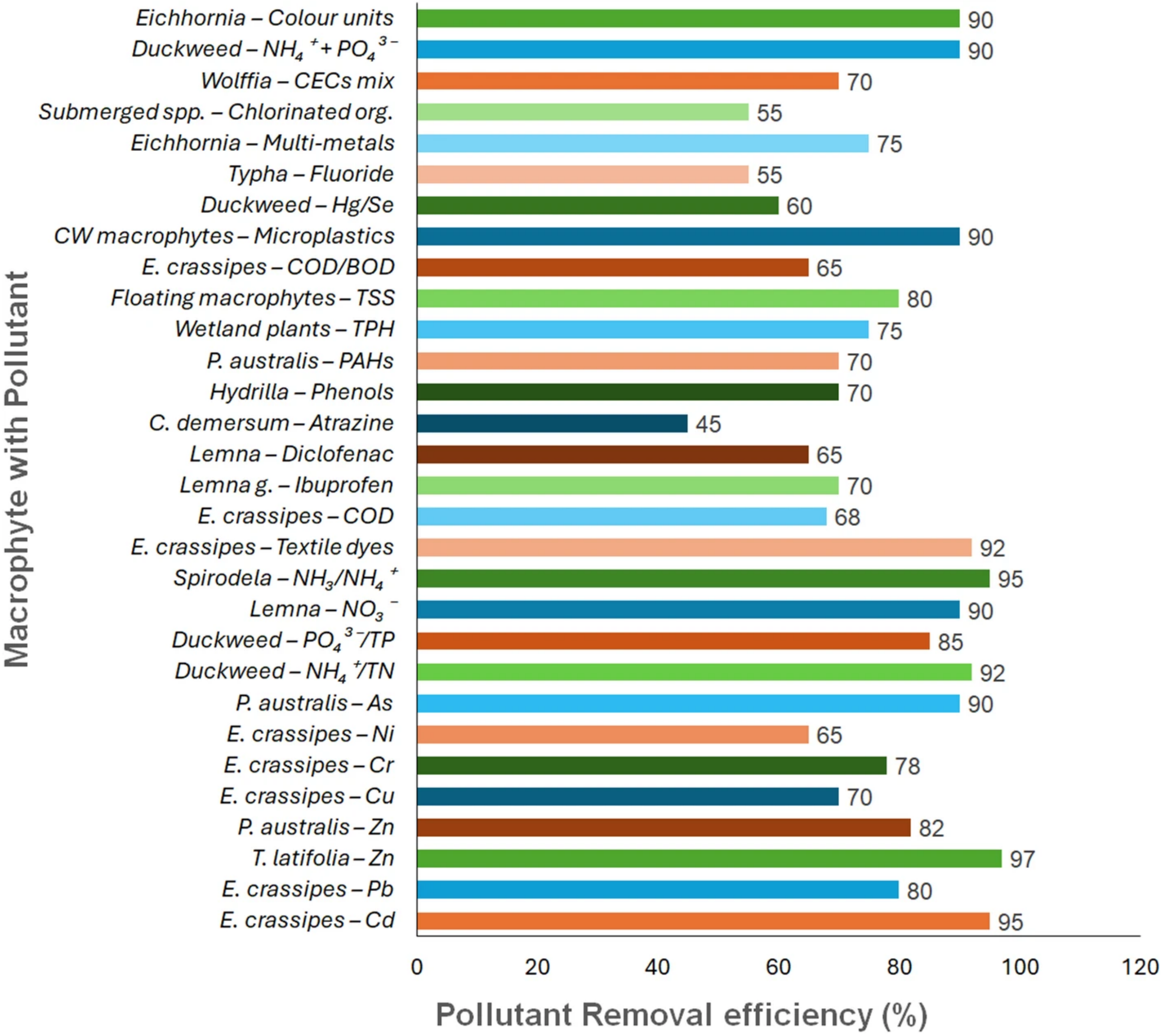
Xiaolin Zhao, 2025

Title: Harnessing aquatic macrophytes for water pollution remediation through constructed wetlands and future perspectives

- Aquatic macrophyte-based bioremediation has emerged as a sustainable and cost-effective strategy for the treatment of contaminated water systems.
- This review systematically evaluates the functional classification of macrophytes and their roles in pollutant removal through mechanisms such as phytoextraction, rhizofiltration, and microbially mediated degradation.
- Analysis of reported studies indicates that macrophyte-based systems can achieve high removal efficiencies for conventional pollutants, often exceeding 70–90% for nutrients, organic matter, and selected heavy metals under optimized conditions.

(Archana Sahu et al, 2026)

Title: Harnessing aquatic macrophytes for water pollution remediation through constructed wetlands and future perspectives



(Archana Sahu et al, 2026)

Constructed Wetland Systems for Water Resources Conservation

- As mentioned above, constructed wetland systems can remove nutrients, heavy metals, and pathogens from agricultural runoff and urban and industrial wastewater before it reaches natural bodies of water.
- Thus, the treated wastewater can be reclaimed for non-potable uses such as agricultural irrigation, and municipal landscaping resulting directly lessens the extraction volume from rivers and lakes.
- Since constructed wetlands use the natural purification processes of vegetation, soils and microbes to remove contaminants from discharge, they provide a cost-effective, low maintenance and ecofriendly alternative to conventional treatment.
- This system can polish wastewater effluent for groundwater recharge. It naturally reduces contaminants like nutrients, pathogens, and micropollutants while replenishing local aquifers and preventing saltwater intrusion.

Conclusion

- Depending on the findings of harnessing aquatic macrophytes, the removal efficiency of heavy metal such as Pb, Cd, Cu, and Zn are upto 98%, 95%, 80% and 92%, respectively.
- For the reduction of organic matter concentration, the treatment efficiency of BOD, COD, turbidity and suspended solids are upto 95%, 81%, 87% and 80%, respectively.
- From this study, it can be seen that the properly designed constructed wetland systems can provide the treated effluent that can be acceptable to safely discharge to the related water sources.
- Moreover, the implementation of this treatment system is simple, eco-friendly, nature-based system to reduce contaminants from water by means of phytoremediation of aquatic plants.
- Thus, they provide a highly sustainable, low-cost alternative to conventional treatment plants, serving as an excellent solution for both water purification and resource conservation.

Conclusion (Continued)

- However, a constructed wetland is **secondary or tertiary treatment**. If untreated water directly enters a wetland, the suspended solids and organic matter will quickly **clog the gravel beds** and cause flooding.
- It is needed to perform that the harvesting of matured macrophytes and cleaning of substrate in CWs should be carried out systematically.
- If the water and wastewater treatment can be carried out with properly designed constructed wetland system, it can reduce effectively the pollutants concentration of water sources.

References

1. A.A. Wurochekke, et al. 2014, Constructed Wetland of Lepironia Articulata for Household Greywater Treatment. < https://www.sciencedirect.com/science/article/pii/S2212670814001754>.

2. Ali Marefat 2021 Application of Artificial Wetlands in Agricultural Wastewater Treatment https://biomedres.us/fulltexts/BJSTR.MS.ID.005508.php

3. Archana Sahu et al, 2026, Harnessing aquatic macrophytes for water pollution remediation through constructed wetlands and future perspectives. https://www.researchgate.net/figure/Layout-of-a-macrophyte-based-constructed-wetland-system_fig6_407312263

4. Arifin Sandhi, et al. 2025. Assessment of Heavy Metals in Water, Sediment and Macrophytes in Old Glasswork Sites: Implications for Phytoremediation Management < https://www.researchgate.net/publication/398609808_Assessment_of_Heavy_Metals_in_Water_Sediment_and_Macrophytes_in_Old_Glasswork_Sites_Implications_for_Phytoremediation_Management>

5. Atif Mustafa, 2024. Hybrid constructed wetlands and filamentous fungi for treatment of mixed sewage and industrial effluents. https://link.springer.com/article/10.1007/s11356-024-34037-8

6. Baiyang Jiang. et al, 2025. Phytoremediation of Heavy Metal Contaminated Groundwater Using Tropical Wetland Plants: Lepironia articulata and Typha angustifolia. < https://journal.ump.edu.my/construction/article/view/12168>

References

7. CHAO Chuanxin, 2025. Innovative constructed wetland system enhances aquaculture wastewater treatment. < https://smartwatermagazine.com/news/chinese-academy-sciences/innovative-constructed-wetland-system-enhances-aquaculture-wastewater>

8. Gamage N.S., Yapa P.A.J., . Use of water hyacinth [Eichhornia crassipes (Mart.) solms] in treatment systems for textile mill effluents - A case study. J. Natn. Sci. Foundation Sri Lanka. 2001;29(1&2):15-28.
9. Haiming Wu, 2023. Constructed wetlands for pollution control. https://www.nature.com/articles/s43017-023-00395-zG.

10. G. Mancuso. 2023. Performance of lagoon and constructed wetland systems for tertiary wastewater treatment and potential of reclaimed water in agricultural irrigation. https://www.sciencedirect.com/science/article/pii/S0301479723020662

11. Mahmood Q., Zheng P., Islam E., Hayat Y., Hassan M.J., Jilani G., Jin R.C., . Lab scale studies on water hyacinth (Eichhornia crassipes Marts. Solms) for biotreatment of textile wastewater. Caspian J. Environ. Sci.. 2005;3(2):83-88.
12. Majid Ali etal. 2024. Domestic wastewater treatment by Pistia stratiotes in constructed wetland. < https://www.nature.com/articles/s41598-024-57329-y>

13. Natalia Mesa 2025**. Western states step up to save their wetlands**
14. **https://www.hcn.org/issues/57-7/western-states-step-up-to-save-their-wetlands/**

15. Papu Yadav, 2026, Constructed Wetland Filtration System for Sustainable Water Treatment.< https://www.linkedin.com/posts/pappu-yadav-688665239_constructedwetland-wastewatertreatment-activity-

References

16. Saloni Sachdeva, 2023. Chapter 9 - Efficacy of biotic components in constructed wetlands for mitigating pesticides https://www.sciencedirect.com/science/chapter/edited-volume/abs/pii/B9780323960021000031

17. Siti Noor Hajjar Md Latip et al. 2022. Utilization of water hyacinth in constructed wetlands for wastewater treatment.< https://iopscience.iop.org/article/10.1088/1755-1315/1105/1/012032/pdf>

18. Tariq Aziz, 2025. Economic valuation of subsurface water contributions to watershed ecosystem services using a fully integrated groundwater–surface-water mode. https://hess.copernicus.org/articles/29/1549/2025/

19. USEPA, 2017. A Handbook of Constructed Wetlands. < https://www.epa.gov/sites/default/files/2015-10/documents/constructed-wetlands-handbook.pdf>

20. Xiaolin Zhao, 2025. Modular Constructed Wetlands for Treatment of Rural Domestic Wastewater: Laboratory Performance and Field Application. https://www.mdpi.com/2071-1050/17/10/4427

21. Zhongyan Zhang 2024, onstructed wetlands for metallic wastewater treatment: An updated global profile. < https://www.sciencedirect.com/science/article/abs/pii/S2214714424010845>

Thank You For Your Time!