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Utilizing Constructed Wetlands as Wastewater Treatment Systems

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Introduction

Conventional wastewater treatment facilities can be expensive and complex to construct. This leads to more rural and underdeveloped areas having poorer wastewater treatment. Recently, research has been conducted to offer a new less expensive and more environmentally friendly type of wastewater treatment facility in the form of constructed wetlands using natural systems of influent reduction.

Although initially designed through modern engineering tools like Simuwork or Simapro, proper implementation has led to real world results.

Figure 1: Photo of constructed wetland for use in wastewater treatment. Source: Adapted from [1]

Process Description

A constructed wetlands treatment facility is one of the most common nature based technologies for wastewater treatment. The most common systems are designed either horizontally or vertically with filter material like gravel and sand combined with natural wetland vegetations. As wastewater flows through the filter materials, waste is removed and an effluent is produced that is suitable for applications like irrigation.
Vertical systems allow for influent to flow through multiple layers of sediment. This filters smaller waste particles as the process continues leaving a clean effluent as discharge [2, Fig. 1]. Conversely, horizontal systems utilize more vegetation as the main source of filtration and typically have longer runs to simulate a more natural cleansing of influent as sediments settle along the bottom of the wetland [3, Fig. 2].

More elaborate wetland systems utilize a three chamber septic system and a combination of vertical and horizontal flow constructed wetlands [4, Fig. 4]. These systems produce remarkably levels of removed solids around “90-93% for BOD5 and 96-97% for TSS” [5].

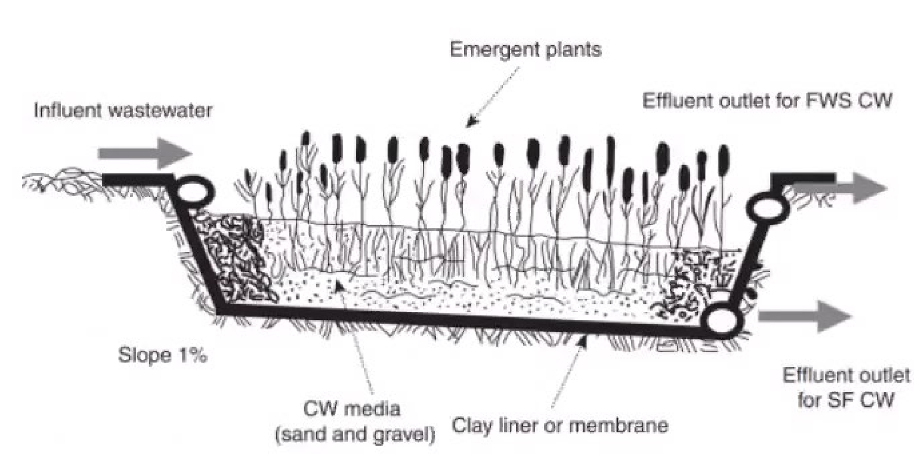


Fig. 2: Illustration of horizontal flow constructed wetland. Source: Adapted from [3].

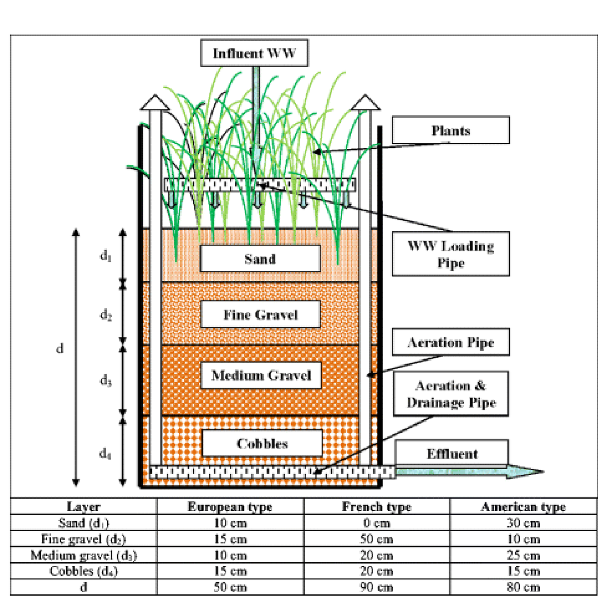


Fig. 3: Illustration of vertical flow constructed wetland. Source: Adapted from [2]

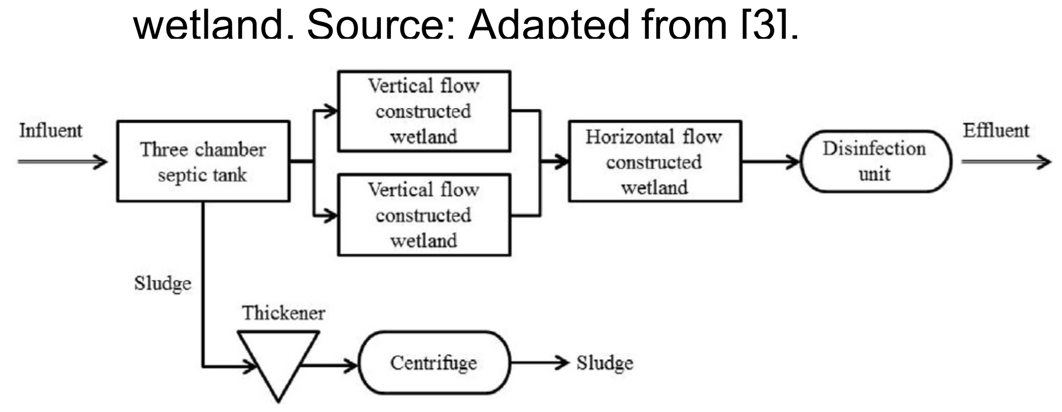


Fig. 4: Process map for constructed wetland system. Source: Adapted from [4].

Potential Ecosystem Impact

Utilizing wetlands to handle wastewater treatment initially seems like a biological disaster waiting to happen. However, research has shown that under certain conditions wetlands offer a surprisingly powerful source of wastewater treatment with minimal environmental impact and low monetary cost of construction.

On a basic level, constructed wetlands have shown to increase resistance to soil erosion by allowing for a variety of native vegetation to flourish. They also function as a functional habitat for many species.

[Source for info below 4.10]
Constructed wetlands lead to a notable reduction in BOD_5, Suspended Solids as well as...

- N removal
- P removal
- metal mobilization *
- cation exchange capacity (esp. by pH and salinity)*
- Heavy metal Removal through both Precipitation and Absorption

When compared to conventional treatment systems, constructed wetlands facilities...

- help to mitigate climate change
- consume less energy in operation
- lower GHG production by using less fossil fuels
- make a suitable habitat for emergent wetland plant species

Sensitive Unit

There are many important areas to consider when analyzing a water treatment technology. Some areas of consideration include inadequate expertise,temperature, limited space, and BOD5. Everyone of these areas possess a new challenge for implementation of a successful treatment facility. But overarchingly the most critical unit in constructed wetland wastewater facility is flow rate into the facility.

Because of the design of constructed wetlands, they are only able to properly treat certain levels of influent. Too high of levels and of course the plant could overflow and cause environmental damage. Too little flow, and the facility could be stressed for nutrients and moisture. It is critical that the wetland is able to accommodate varying levels of influent.

To counteract this problem facilities that are subject to high variabilities of flow rate often incorporate tiered vertical and horizontal systems as discussed in the process description. This allows for stored influent in the three chamber septic tank, which can be gradually used in times of low flow rate, or emptied completely during high flow rate times.

Of course if flow rate is too high than expansions to the facility will need to be made. Luckily, constructed wetlands also allow for ease of expansion due to their natural layout as long as enough land is available for development.[5]

Lifecycle of Constructed Wetlands

The system boundaries of a constructed wetland are the input and output flow as well as the energy resources required to operate and build the facility. Greenhouse gases are also taken into account because of their large impact on climate change.

Because it is difficult to retrieve LCA data constructed wetlands without access to simulation software, we have used a research article that takes these boundaries into consideration. [4]

Environmental impacts of conventional wastewater treatment facilities were “2 and 5 times higher than those of nature-based technologies” [4].

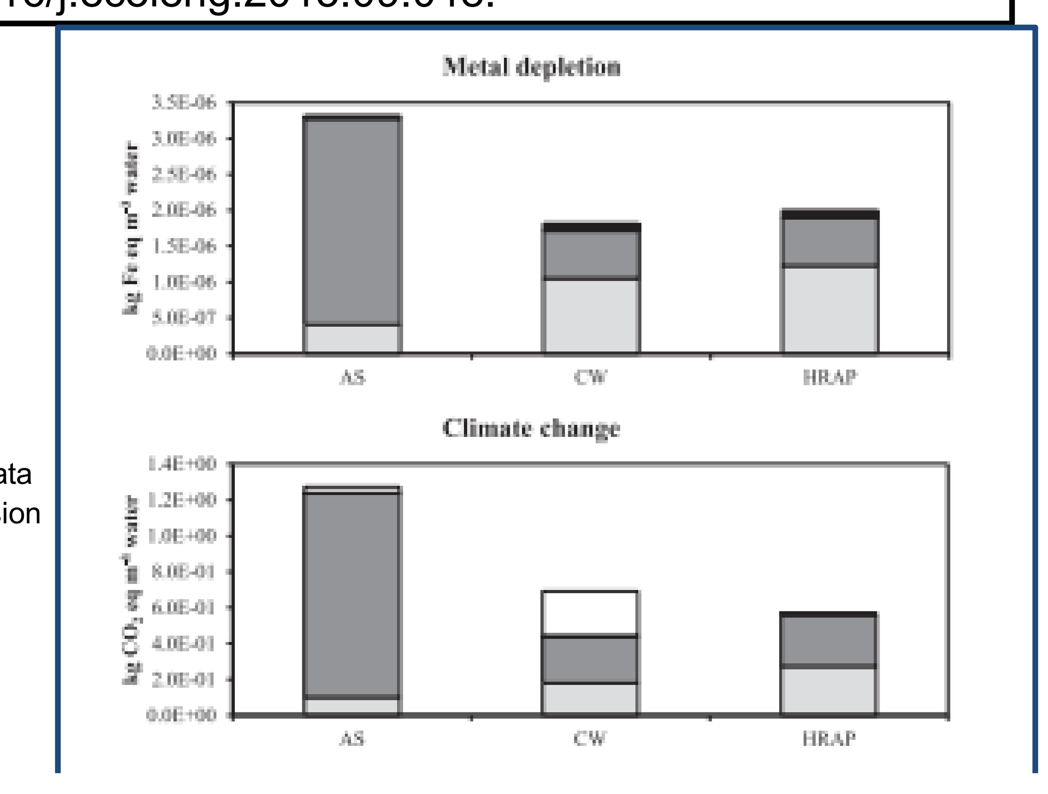
For constructed wetlands construction and operation stages of the LCA “accounted for 25-35% and 35-65% of the total impact respectively” [4.]

Because of the high demand of land for construction of nature based systems, the metal depletion rate is affected at higher rates initially then conventional systems

CO_2 emissions saving due to the implementation of CW and HRAP vs. AS.

	Unit	AS	CW	HRAP
CO_2 emissions	$kg_{CO2\ eq}\ m^{-3}$	1.27	0.69	0.57
	$kg_{CO2\ eq}$ p.e.$^{-1}$ d^{-1}	0.25	0.13	0.11
CO_2 emissions reduction	$kg_{CO2\ eq}$ p.e.$^{-1}$ d^{-1}	–	0.11	0.14
	$kg_{CO2\ eq}$ p.e.$^{-1}$ year^{-1}	–	41.36	50.22

(Right) Fig. 6: LCA Data
(Left) Fig 5.CO2 emission
Source: [4]



Research

Objectives:

- Determining the capability of the sensitive component
- Treat wastewater to an acceptable level of quality
- Maximize energy resource efficiency of the system
- Reduce the system HRT to less than 1 week
- Maintain these conditions even with high variability in flow rate[5]

Tasks:

- initial site assessment
- determine combination of various constructed wetland units a for working system
- Design a constructed wetland system with the capability of treating various wastewater conditions to acceptable levels of quality.[5]

Data analysis techniques / Methods

- Record key water quality indicators such as BOD_5, and pH, at each stage of the system.
- Determine system Hydraulic Retention Time

References

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[2]V. A. Tsihrintzis, “The use of Vertical Flow Constructed Wetlands in Wastewater Treatment,” *Water Resources Management*, vol. 31, no. 10, pp. 3245–3270, May 2017, doi: 10.1007/s11269-017-1710-x.

[3]C. Polprasert and S. Kittipongvises, “Constructed Wetlands and Waste Stabilization Ponds,” *Treatise on Water Science*, vol. 4, pp. 277–299, 2011, doi: 10.1016/B978-0-444-53199-5.00090-7.

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[5]C. Ávila, M. Garfí, and J. García, “Three-stage hybrid constructed wetland system for wastewater treatment and reuse in warm climate regions,” *Ecological Engineering*, vol. 61, pp. 43–49, Dec. 2013, doi: 10.1016/j.ecoleng.2013.09.048.