Geo Physicochemical Properties for Soil Base Subsurface Constructed Wetland System

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doi: https://doi.org/10.21467/proceedings.112.28

ABSTRACT

Wetland land system is the natural way for the treatment of wastewater. Constructed wetland system (CWs) is a traditional way for treatment. CWs are considered as secondary or tertiary treatment systems. CWs provide good landscape and better habitat quality for the community. Various types of media are used in Constructed Wetland Systems. Literature shows that various soils have the potential to filtration medium (in substratum) in Horizontal Flow Subsurface Constructed Wetland System (HFSCWs) for wastewater treatment. Soil should have few environmental and geo tech properties. Soil provides the root zone in rhizome network for the vegetation in CWs. Soil provides the absorbent media not only in the HFSCWs but Vertical Flow Constructed Wetland system (VFCWs) also. As per Environmental Protection Agency (EPA), various properties of filter media were described. This review base on types of commonly used wetland, filter media, plant use and geo physicochemical parameters of filter media.

Keywords: constructed wetland, geo physicochemical, wastewater, design

1 INTRODUCTION

The soil environmental treatment system is the most effective water and wastewater treatment system on earth. The constructed wetlands are low-cost, less power intensive, having less mechanized parts, and efficient alternative technology for wastewater treatment. Constructed Wetland system (CWs) are mimic of the natural wetland system with various important parameters engineered to get improved performance (WHO). Various types of wetlands conventional technology for the treatment of wastewater are challenged by high capital and operation & maintenance (O & M) cost. Additionally, the conventional wastewater treatment methodologies and philosophy are designed to satisfy/reduce various oxygen demands exerted by organics and chemical constituents present in the wastewater. Though, these methods are very efficient in removing such constituents, they largely overlook nutrients such as nitrogen and phosphorus. These nutrients are known to be the major cause of algal growth and eutrophication of aquatic sources. The traditional treatment methodologies are designed to process a large volume of wastewater hence they are designed with low residence time which limits the oxygen availability, resulting in poor nitrogen and phosphorus removal efficacy. In contrast, CWs are reported to be very effective in the removal of nitrogen and phosphorous from wastewater (Vohla et al., 2007). Soil place as a filter media (in substratum) in Horizontal Flow Subsurface Constructed Wetland System (HFSCWs) for wastewater treatment. Soil provides the root zone in rhizome network for the vegetation in CWs. Soil provides the absorbent in the horizontal subsurface constructed wetland system (HSCWs). Plants assume significant jobs in wetlands. Plants have been utilized for wastewater treatment, to eliminate substantial heavy metals and nutrients (Nitrogen and phosphorus) in development wetlands (Kruti et al., 2016). Figure 1 shows the constructed wetland. Major components of wetlands are a combination of soil, plants, and

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Proceedings DOI: 10.21467/proceedings.112; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-947843-3-3

microorganisms where macrophytes present in vegetation easily adapt to areas having similar hydrologic and hydric soil conditions (Haberl et al., 2003). All the three components, plants, soil, and microorganisms in the root zone in CWs participate in the removal mechanism and mainly responsible for the removal of harmful constituents from wastewater. The microorganisms are aerobic in nature and their efficacy depends upon oxygen availability which controls the type of metabolic activity occurring in root zones. Scirpus, Typha, Carex, Swamp Foxtail Grass P. australis, T. latifolia, P. hydropiper, A. sessilis, C. esculenta, and P. stratoites, common rush, common reed, Club-rush, Cattail, Common water plantain, Reed canary grass, Meadowsweet, Yellow flag, Compact rush and canna indica are used for wastewater treatment in soil base CWs (Jethwa et al.,2017)
The various laboratory examinations require for design and performance evaluations of CWs. In this paper, several laboratory examination and design parameters are discussed with aspects of soil and wastewater.

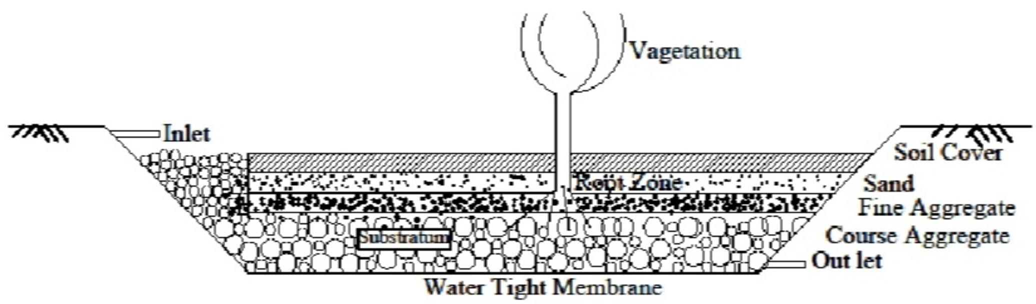

Figure 1. HSSF Constructed wetland (Kadlec & Wallace 2009).

2 SOIL CHARACTERISTICS (GEO ENVIRONMENTAL CHARACTERISTICS)

Soil provides the environment for the vegetation in the root zone or rhizome network or substratum for CWs. The soil environment gives an assortment of physical, chemical, and biological treatment processes for CWs. Among them are sedimentation, precipitation, filtration, adsorption, ion exchange, biodegradation, hydrolysis, nitrification, denitrification (Sims & Otis 2008). Various substrate materials are soil, gravel, sand, sediments, limestone, zeolite, plant waste, woodchip, flyash, slag, construction waste, activated carbon, synthetic fiber, cement cliker, recycled concrete, and modified clay used in CWs (Wang et al., 2020). For the design of CWs pH, Soil Organic Carbon (SOC), available nutrients or NPK (Nitrogen, Phosphorus and Potassium), electrical conductivity (EC), specfic gravity (G), permeability, grading of soil, hydrometer test, particle size distribution, and porosity of soil should be detected. The mineral properties such as SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, K_2O, Na_2O should also be detected. The heavy metals for example iron (Fe), manganese (Mn), copper (Cu), calcium (Ca), cadmium (Cd), nickel (Ni), total arsenic (As), lead (Pb) and chromium (Cr) and Zinc (Zn) can be removed through vegetation and substrate. The presence of heavy metal depends upon the local industries, type of soil and the fertilizer used.

3 PHYSICOCHEMICAL PARAMETERS FOR INFLUENTS AND EFFLUENTS

The water quality monitoring can be performed by evaluating the physicochemical parameters from influent and effluent samples. The sample should be collected regular interval. The temperature, pH, TDS, EC, DO, BOD, COD, Total Kjeldahl Nitrogen (TKN), total phosphorus, and heavy metals. The bacterial analysis should also be performed. The analysis of water and wastewater should be carried out as per the standard methods for examination described in American Public Health Association (APHA).
The pH of the soil can be classified as acidic, normal, and alkaline depending upon the pH value of the soil (Table 1).

Table 1: Classification of the soil depending on pH

S.No.	pH of soil	Classification
1	< 6.0	Acidic soil
2	6.0 - 8.5	Normal soil
3	> 6.0	Alkaline soil

The black cotton soils are reported to be normal soil (pH: 7.5-8.4) (Kumar 2011). Any crop production requires minimum pH value of 6.0 according to Shrivastav et al., 2015. To assess the change in the mineral nature of organic matter present in the soil, EC is used. The soils having EC < 1 (dS/cm) is considered as normal soil, whereas EC of 1-2(dS/cm) are marked as critical for germination of vegetation. The EC between 2-3(dS/cm) are found to be critical for the growth of salt-sensitive crops, with further increase in EC from 3(dS/cm) can drastically impact the growth of crops by injuring them (Brix and Arias 2005).

"COD of the soil is higher than BOD as COD oxidizes larger groups of compounds, and in wetland and environment, presence of humic substances result in much higher COD than BOD" (Kadlec and Wallace 2009). The microorganisms that are responsible for N and P transformative processes in wetlands use various mechanisms such as "enzymatic hydrolysis and metabolic activities to mineralize organic phosphorus, immobilize inorganic phosphorus. The biochemical process occurs by assimilation, which alter the physiochemical environment resulting in the release of phosphorus from insoluble phosphate complexes (Reddy and Delaune 2008).

The organic loading rate (OLR) is defined as the mass of organic matter (BOD) applied per day over a unit surface area, for example, kg/ha/day. An uneven distribution of OLR results in the death of the vegetation (USEPA 2000). The hydraulic loading rate is represented as volume of influent per day applied over a unit surface area. It does not indicate the uniform distribution of water over the wetland surface (Kadlec 2009). The Hydraulic Retention Time (HRT) is determine by the average length of time that a soluble constitute remains in a constructed bioreactor. Large dead spaces may be created in the wetlands due to differences in topography, plant growth pattern, and solids sedimentation rate and short-circuiting creates uncertainty in the estimation of HRT (USEPA 2000). Only a fraction of the surface area, in wetlands, may be available for wastewater flow (EPA 1988).

Testing of physicochemical parameters for influents and effluents depends on (i) Local temperature condition (ii) Types of wastewater to treat (iii) Design criteria (iv) Feeding mode (v) Types of wetland reactors and types of waterbody.

4 DESIGN PARAMETERS FOR CWs

The first order BOD removal rate coefficient is depending on batch loading or continuous loading and its hydraulic retention time (HRT).

HLR = Q/A

where: A = Area of CWs in m^2

Q = flow rate in m^3/day (USEPA 2000)

Kadlec and Knight (1996) suggested the k–C* model as an alternative to the Metcalf & Eddy (Metcalf and Eddy 2003). This model is based on an aerial loading equation:

Surface area –

(-K/Q) = In [(Co−C∗)/ (Ci− C∗)]

Where-

k = area-based first-order removal rate constant (md^{-1}),

q = HRL (md^{-1}),

Ci=Inflow concentration (mg/L);

Co=Outflow concentration (mg/L);

C*= Background concentration (mg/L).

According to Kadlec and Knight 1996, background concentration can be calculated by the Equation

$C*=3.5+0.053Ci$

The typical value for C∗ being commonly used is 10 mg/L (USEPA 2000). The above equation is also based on first-order kinetics, and k are temperature-dependent (Metcalf and Eddy 2003). The temperature effect on rate constant k is calculated by Arrhenius Equation

$K= K_{20} * \theta^{(T-20)}$

Where: k_{20}=Rate constant at 20°C (0.23 d^{-1}).

ϴ = thermal coefficient (dimensionless), with a suggested value of 1.03

T= Water temperature (°C).

Above Equation is used for determining the HLR

$K=HLR*\ln(C_{in}-C_{out})$

Value of 'K' shall be substituted from the equation considering the effect of temperature.

The minimum required surface area to provide the required hydraulic residence time is estimated by the following Equation (Metcalfe and Eddy 2003)

Surface area needed = t / [d * (p/q)]

Where-, t = HRT in days

d = avg. depth in m

p = porosity for the soil

hydraulic retention time (HRT) can also calculate by geotechnical approach.

HRT =(L*W*D*η)/Q

Where,

L = Length in m

W = Width in m

D = Depth in m

η = Porosity of soil

Q = Avg. Flow (m^3/d)

For Porosity (Punmia 2001)

$\eta = e/(1+e)$

$Y_d = (GY_w)/(1+e)$

Y_d= Bulk Density of soil

Y_w= Density of water

G= Specific gravity for soil

e =Void Ratio for soil

All above values should be determine by geotechnical parameters of soil media and physicochemical parameters of wastewater.

5 TREATMENT EFFICIENCIES FOR CWs

The reduction of pollutants is the main parameter for efficiency check-in CWs. The physicochemical parameters for the influents and effluents should be identified for the regular interval. BOD_5, COD, TSS, TP, and TN are the main physicochemical parameters for wastewater quality monitoring. The subdivision of TN and TP depends on the type of wastewater (domestic or industrial). Various researchers are reported 1, 2,3,4,5, and a maximum of 8 days HRT for checking of treatment efficiency of CWs.

6 CONCLUSION

Recently researchers are focused on the removal of various wastewaters from domestic, mines, and industrial influents. The expulsion of SOM, TN, TP, heavy metals, pesticides, microplastics, coliform bacteria depends on materials used in substrates and vegetation's used in CWs. All the design considerations depend on geo physicochemical parameters. The ability of absorption and precipitation for wastewater highly depends on the soil used. Therefore, geo physicochemical properties for soil and wastewater are necessary for a design of a constructed wetland and monitoring its efficiency during its running time.

How to Cite this Article:

Swarnakar, A. K., Bajpai, S., & Ahmad, I. (2021). Geo Physicochemical Properties for Soil Base Subsurface Constructed Wetland System. *AIJR Proceedings*, 228-233.

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