



iJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 Issue: III Month of publication: March 2018

DOI: <http://doi.org/10.22214/ijraset.2018.3281>

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Analysis and design of constructed wetland for waste water treatment

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Abstract: In recent years, the environmental effects of industrial activities have increased considerably, and current perspectives indicate that the trend for this problem is to be worsening. In this regard study is to treat the waste water generated from the restaurant by constructed wetland Physico-chemical and organic parameters of water samples of the restaurant were examined to determine the quality and extent of pollution. By which the pH, BOD, TSS, TDS, COD and the significant reduction in the parameters were observed and hence found more useful. In the study we found that initially the waste water sample was acidic but after the treatment the pH was observed around neutral also the BOD, COD & TSS removal efficiency 58.40%, 59.60% & 81.61% respectively was observed. The objective of this project to design and development of laboratory scale multispecies vertical flow constructed wetland system.

Keywords: CW-Constructed Wetland, SSFCW- subsurface flow constructed wetland, FWSCW- free water surface constructed wetland, HFSSCW- horizontal flow subsurface constructed wetland, VFSSCW- vertical flow subsurface constructed wetland.

I. INTRODUCTION

The term wetland encompasses the life interactions of various species of bacteria, the root of the wetland plants, soil, air, sun and of course, water. Wetland is one of the natural and attractive methods of treating domestic, industrial and agricultural wastes. It is an engineered method of purifying waste water as it passes through artificially constructed wetland area. It is considered as an effective and reliable secondary and tertiary treatment method. The wetland is a natural maintenance free system where the sewage waste water is purified by the roots of wetland plants. The wetland process functions according to the law of nature, to effectively purify domestic and industrial effluents. The process incorporates the self-regulating dynamics of an eco-system. Application of wetland is finding wider acceptability in developing and developed countries, as it appears to offer more economical and ecologically acceptable solution to water pollution management problems.

CW can be operated as subsurface flow constructed wetland (SSFCW) in which water level remains below the surface of wetland media and free water surface constructed wetland (FWSCW) in which water surface exposed to atmosphere. According to the flow direction, SSFCW further classified as horizontal flow subsurface constructed wetland (HFSSCW) and vertical flow subsurface constructed wetland (VFSSCW). The HFSSCW and VFSSCW have their own advantages and disadvantages. These systems can be operated in two stage or multistage with various combinations to counterbalance the disadvantages of one type with advantages of the other. Such systems with various combinations of HFSSCW and VFSSCW connected in series falls under the category of subsurface flow hybrid constructed wetlands (SSFHCW).

The present study focuses on treatment of restaurant wastewater by using the VFSSCW with different operational mode such as batch mode to assess the potential for organic matter removal efficiency from restaurant wastewater. The advantages of multispecies vegetation in CW are also incorporated by planting two different species in the developed VFSSCW system.

II. OBJECTIVES

- A. To analyze and characterize the waste water.
- B. To study the chemical and physical characteristics of the collected waste water.
- C. To design and development of laboratory scale multispecies vertical flow constructed wetland system.
- D. To carry out performance evaluation of developed system for restaurant wastewater treatment.

III. METHODOLOGY

A. Types of Constructed wetland

Constructed wetlands have been classified by the literature, based on the water flow regime, in two types of systems, which are distinguished by the location of the hydraulic grade line (USEPA, 2000)

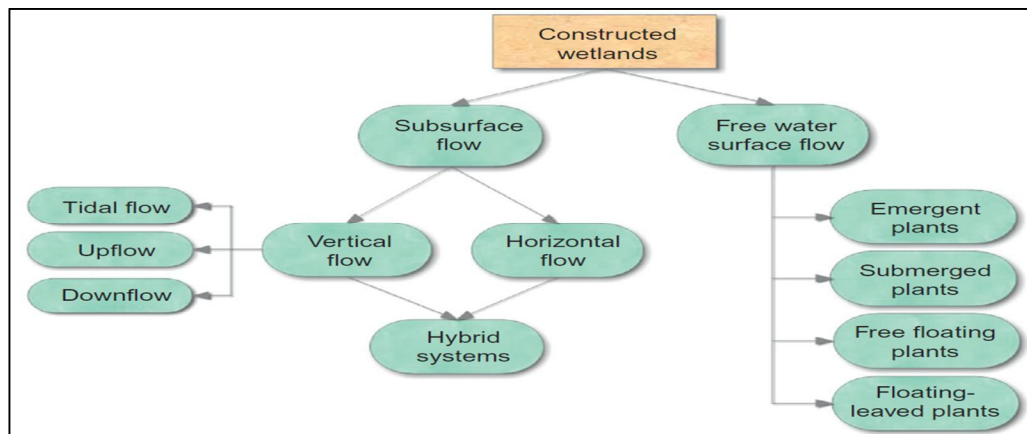


Fig.1.Classification of CWs for wastewater treatment

- 1) *Free water surface systems (FWS) (or surface flow wetlands)*: This type of system consists of a basin or channels with a barrier to prevent seepage, soil to support the roots of the vegetation, and water at a relatively shallow depth flowing through the system. The water surface is exposed to the atmosphere, and the flow path through the system is horizontal. FWS closely resemble natural wetland in appearance and functions because they contain aquatic plant that are rooted in a soil layer on the bottom of the wetland and water flow through the leaves and stems of plants, with a combination of open-water areas, emergent vegetation, varying water depths, and other typical wetland features. Shape, size, and complexity of design often are functions of site characteristics rather than preconceived design criteria.

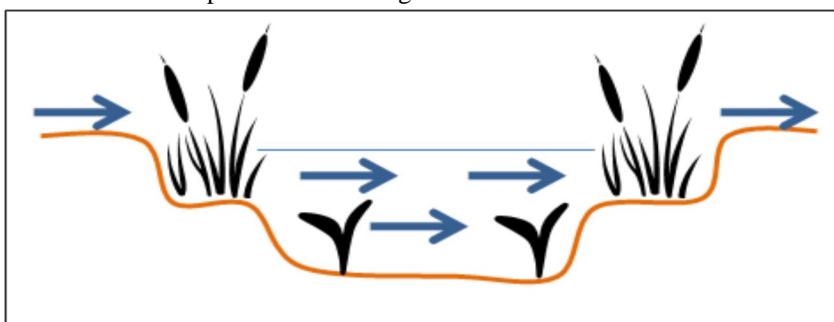


Fig.2.Schematic draw of Free Water Surface system (FWS)

- 2) *Vegetated submerged bed systems (VSB) (or subsurface flow wetlands)*: This system consists of gravel beds planted with wetland vegetation. In this case, the water level is below the surface of gravel or other media (such as crushed rock, small stones, gravel, sand or soil) placed in wetland bed. The subsurface flow wetland also consists of a basin or channel with a barrier to prevent seepage, but the bed contains a suitable depth of porous media. Wastewater can flow in two ways:
- 3) *Horizontal subsurface flow systems (HF or HSF)*

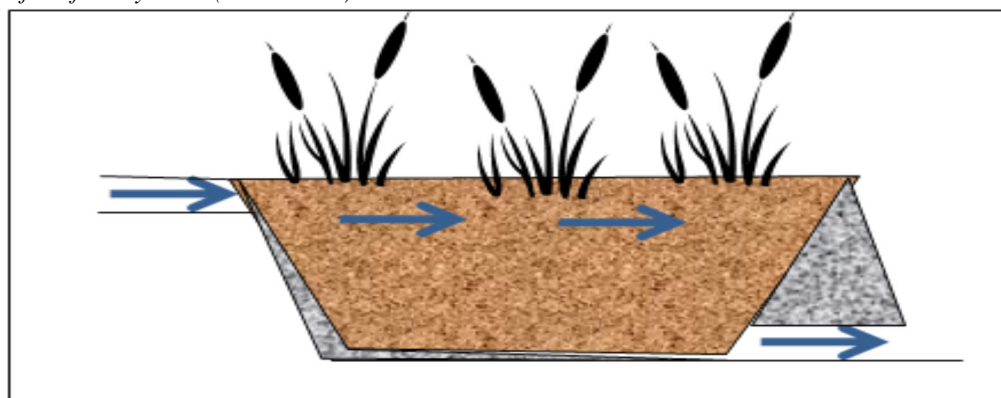


Fig.3.Schematic draw of Horizontal Subsurface Flow system (HF or HSF)

The wastewater comes from the inlet, flows slowly through the medium and flows out more or less in a horizontal way. In the passage through the system, the wastewater comes into contact with the soil-organism-plant complex resulting in a reduction of BOD, nitrogen, phosphorus and heavy metals of the treated water.

4) *Vertical subsurface flow systems (VF or VSF)*

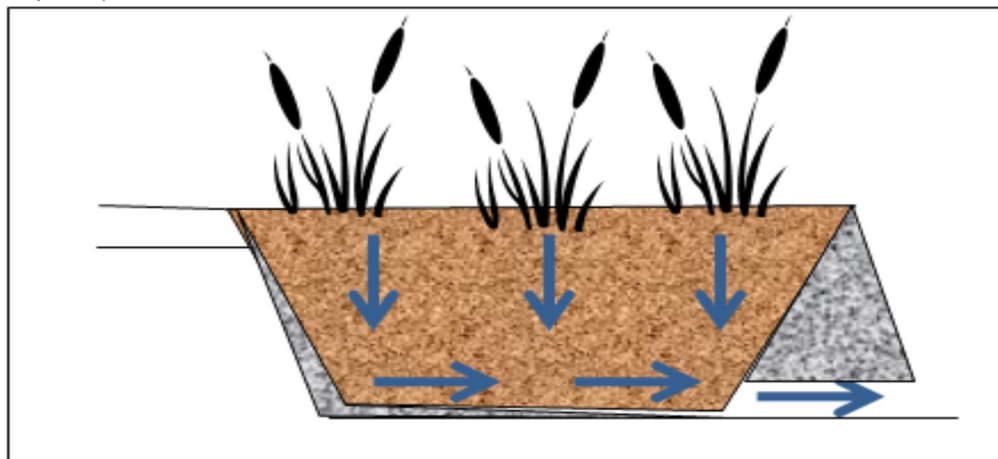


Fig.4.Schematic draw of Vertical Subsurface Flow system (VF or VSF)

The wastewater percolates through the gravel, giving better access to the plant roots and rhizomes and exposure to oxygenated conditions in the rhizosphere. The alternating oxidized-reduced conditions of the substrate stimulate nitrification/denitrification processes and phosphorus adsorption. When properly designed and operated, wastewater stays beneath the surface of the media, flows in contact with the roots and rhizomes of the plants, and is not visible or available to wildlife.

B. Vegetation in VFSSCW

Vegetation is among the most important components in VFCW systems. Wetland vegetation (mainly vascular plants, also known as macro-phytes) grows in semi saturated or fully saturated water conditions. In order to be suitable for use in CWs, the selected macro-phytes should meet the following criteria:

- 1) They should be well adapted to the local ecological conditions.
- 2) They should be tolerant against a variety of pollutants present in wastewater.
- 3) They should be easily available in the local area
- 4) They should transport efficient oxygen into the constructed wetland
- 5) They should have strong rhizomes with massive fibrous roots
- 6) They should have maximum absorption capacity of nutrients

The vegetation that are most often used in constructed wetlands are persistent emergent plants, such as bulrushes (*Scirpus*), spikerush (*Eleocharis*), and other sedges (*Cyperus*), rushes (*Juncus*), common reed (*Phragmites*), and cattails (*Typha*). All wetland species are not suitable for wastewater treatment. Plants for treatment wetlands must be able to tolerate the combination of continuous flooding and exposure to wastewater containing relatively high and often variable concentrations of pollutants (USDA-NRCS and US EPA). In VFSSCW or HFSSCW Common reeds (*Phragmites australis*) are more often used followed by cattails (*Typha latifolia*).

C. Role of vegetation in VFSSCW

CW vegetation provides series of benefits and contributes to the creation of the necessary conditions which directly or indirectly affect the system efficiency. Some of the major effects are discussed below:

- 1) *Physical Effects:* - The deep, complex, and extended root system within the substrate contributes to the water velocity deceleration, which increases the contact time between the wastewater and the substrate media and the roots, as it moves vertically through the VFCW bed.
- 2) *Hydraulic conductivity:* - The movement of the stems and the respective crack creation is also beneficial for the vertical permeability of the bed, which improves the hydraulic conductivity.

- 3) *Bio-film development*: - The extensive and dense root system that gradually develops within the substrate layer functions as an attractive attachment area for the microbial population.
- 4) *Oxygen supply*: - The presence of plants ensures the enhanced aeration of the bed. Plants are capable of absorbing oxygen from the atmosphere through their leaves and transferring it to the deeper layers of the substrate via release from their roots. This oxygen provided by the roots is then consumed by the aerobic microorganisms in the bio-film and enables various aerobic processes (e.g., nitrification, aerobic degradation of OM).
- 5) *Direct constituent up-take*: - Vegetation planted in CW directly uptake various constituents present in wastewater, e.g. heavy metals.

D. Multispecies Constructed Wetland:-

The CW planted with two or more number of species can be termed as multispecies constructed wetland. The nutrient uptake capacity of any single species is different than another species. The nutrient uptake capacity also varies in single species over its lifespan; at initial phase of growth, plant has greater nutrient uptake capacities. The different types of species have capacity to uptake different kinds of metal present in the water; therefore there is need of multispecies CW for the removal different types of metals in a single stage.

E. Construction Of Constructed Wetland Pilot Unit

- 1) *Inlet Zone*: The primary criterion for design of inlet structure was discharge which was expected to be uniform along the entire width. A 25 liter container was used to provide a continuous flow of wastewater through the inlet.

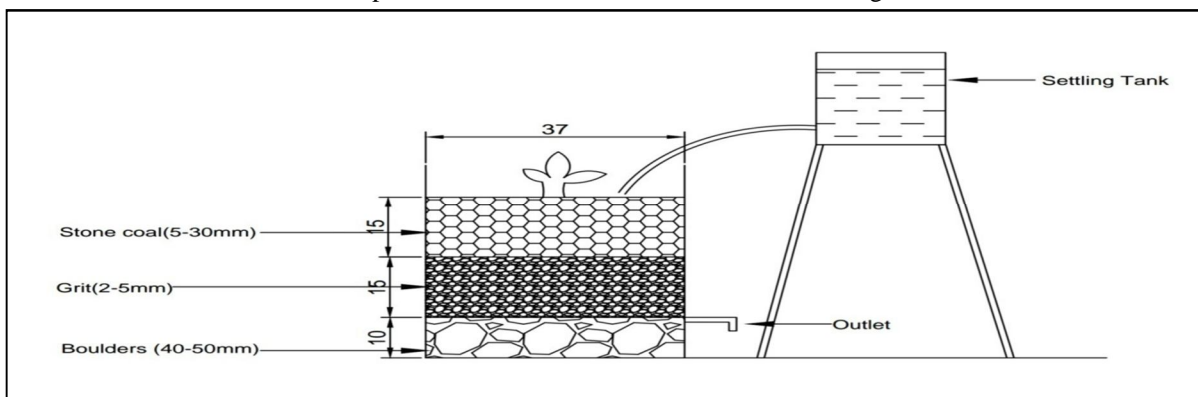


Fig.5.Schematic of Experimental Setup



Fig.6.The Constructed Wetland used for pilot model.

- 2) *Wetland Cell*: The pilot wetland unit consisted of a PVC container of diameter and depth of 37cm and 48 cm, respectively (Fig.5)
- 3) *Wetland Media*: The media consist of a bed underlain by an impermeable layer of filters. Bed was filled to height of 40 cm with Boulder of diameter 40-50 mm, Grit of diameter 2-5 mm and Stone Coal of diameter 5-30 mm to support vegetation. The media-characteristics are presented in Table.1

SR. NO.	TITLE	EFFECTIVE SIZE (CM)	DEPTH (CM)
1	STONE COAL	0.5-3	15
2	GRIT	0.2-0.5	15
3	BOULDER	4-5	10

Table.1.Media Characteristics

- 4) *Vegetation*: “*Canna indica & Typha*”, a local wetland species, was used in the study. The plants were collected from a nearby lake and planted in the wetland unit. They were used to increase the residence time of water by reducing velocity so as to increase sedimentation of the suspended particles as well as to add oxygen and provide a physical site for microbial bioremediation. The plants had been used to remove suspended solids, nutrients, heavy metals, toxic organic compounds and bacteria from acid mine drainage, agricultural landfill and urban storm water runoff as well as waste water.

F. *Design Of Pilot Model Of Constructed Wetland*

1) *Surface Area*:

$$A_h = \frac{Q_d (\ln C_i - \ln C_e)}{K_{BOD}}$$

$$0.1075 = \frac{Q_d \times (\ln 512 - \ln 200)}{0.123}$$

$$Q_d = 0.014 \text{ m}^3/\text{d}$$

Where,

- A_h = Surface area of bed (m^2) = 0.1075 m^2
- Q_d = average daily flow rate of sewage (m^3/d)
- C_i = influent BOD5 concentration (mg/l) = 512 mg/l
- C_e = effluent BOD5 concentration (mg/l) = 200 mg/l
- K_{BOD} = rate constant (m/d) = 0.123 m/d

K_{BOD} is determined from the expression $K_T d_n$, where,

- $K_T = K_{20} (1.054)^{(T-20)}$
- K_{20} = rate constant at 20 °C (d^{-1})
- T = operational temperature of system (°C)
- d = depth of water column (m)
- n = porosity of the substrate medium

2) *Porosity*

$$\begin{aligned}
 n &= (\text{volume of void's}/\text{total volume}) \times 100 \\
 &= [\text{volume occupied by water}/(0.1075 \times 0.4)] \times 100 \\
 &= (0.014/0.043) \times 100 \\
 &= 32.55\%
 \end{aligned}$$

3) *Hydraulic Retention Time*

$$t = nLWd/Q$$

Where,

t = Hydraulic retention time (HRT)

n = Porosity of Media in % = 32.55%

A = LW = Area of bed in m² = 0.1075m²

d = Average depth of liquid in bed in m = 0.4m

Q = Average flow through the bed in cub.m/day = 0.014cub.m/day

$$t = (0.3255 \times 0.1075 \times 0.4) / 0.014$$

$$= 0.999 \text{ day}$$

$$t = 24 \text{ hr}$$

G. Results

Sr.No.	Retention Time		pH (No Unit)	BOD (Mg/lit.)	COD (Mg/lit.)	TSS (Mg/lit.)	TDS (Mg/lit.)
1	-	Inlet	4.91	512	896	223	984
2	24 hr.	Outlet	4.93	476	819	180	790
3	3 day	Outlet	4.97	427	751	139	688
4	5 day	Outlet	5.02	369	653	87	513
5	7 day	Outlet	5.06	299	521	63	428
6	9 day	Outlet	5.12	213	362	41	354

Table.2.Results of Waste Water Treated By Pilot Model Of Constructed Wetland.

H. Colour Analysis Result

The colour of waste water at the inlet of pilot wetland model is not clear or it is not observable clearly, when it is taken in transferring glass. And After the treatment of waste water at outlet of pilot model of wetland it is clearly visible or observed clearly. The color test result is shown is below given fig.

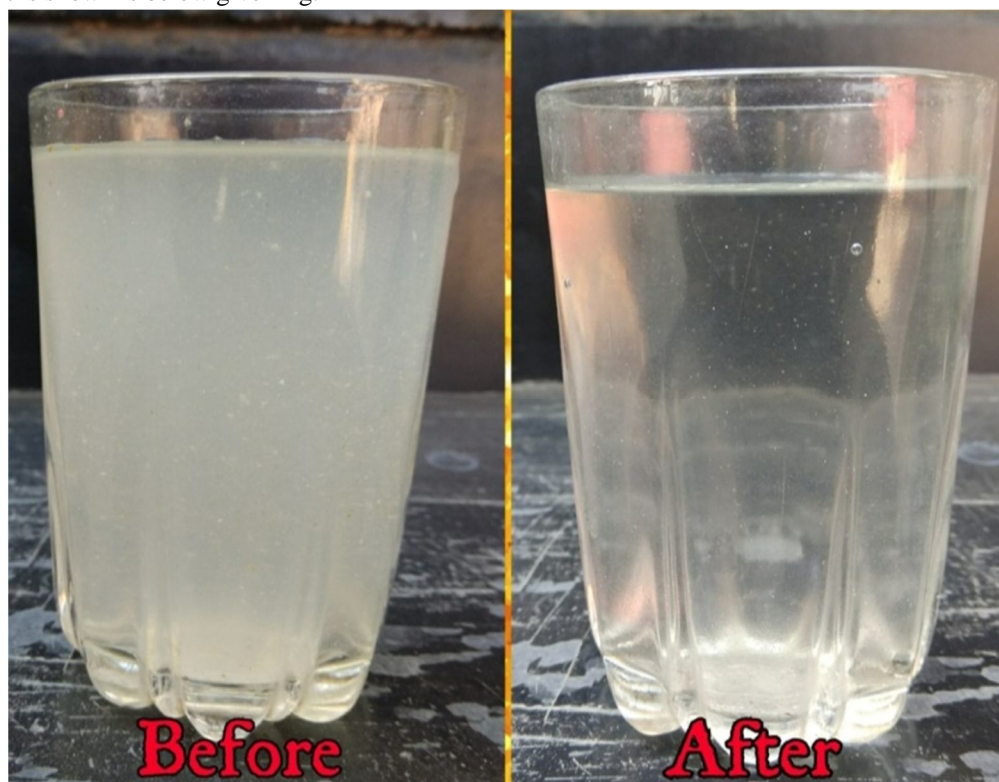
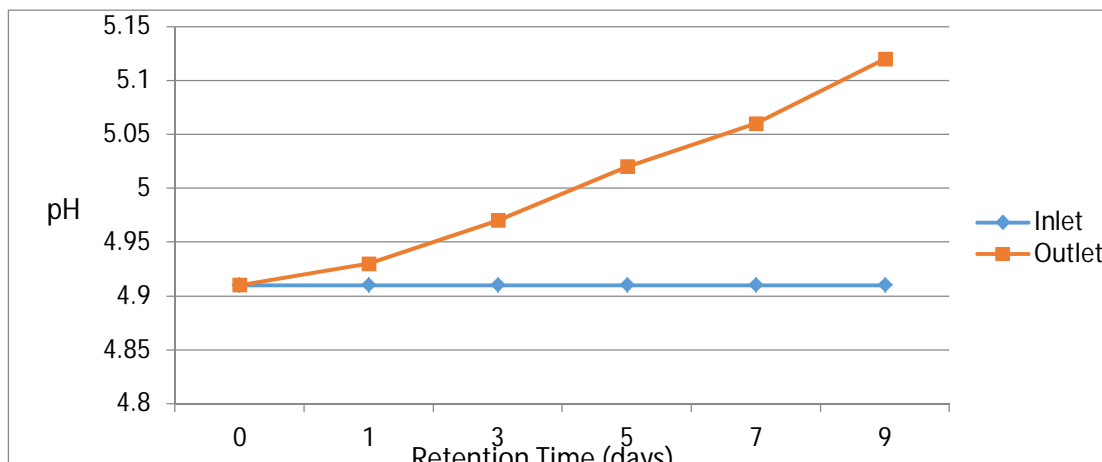


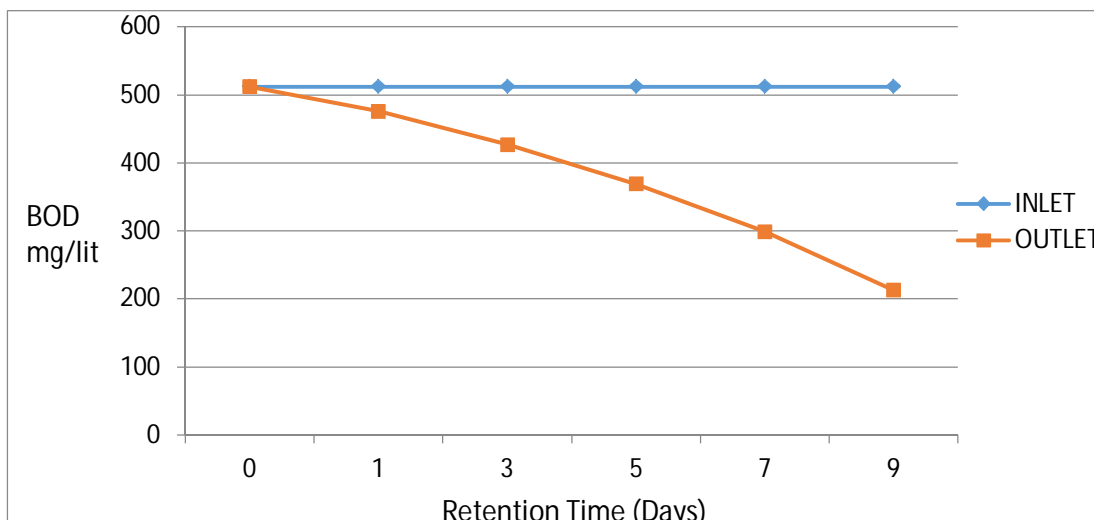
Fig.5.Color testing and analysis

I. Graphs

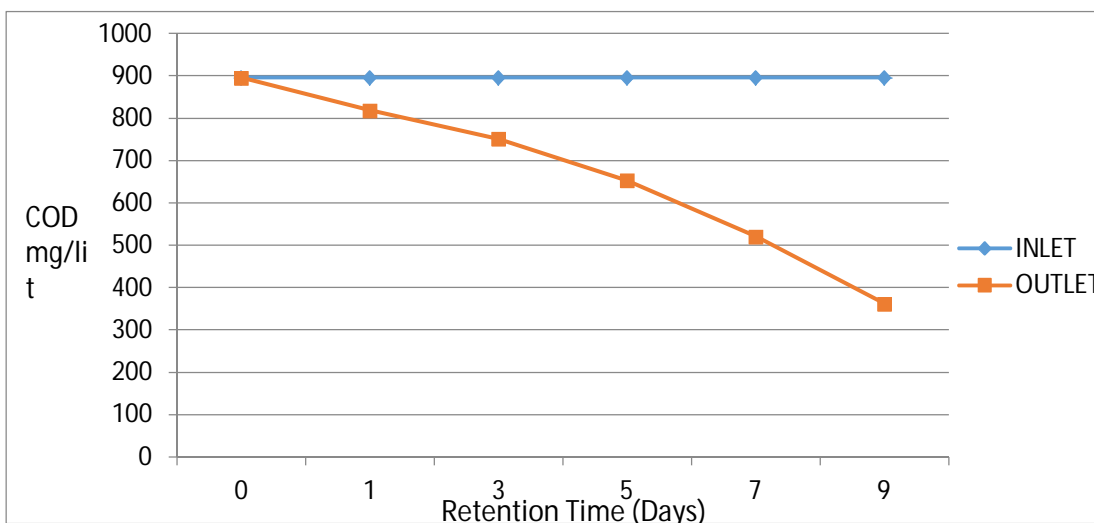
1) Change in pH



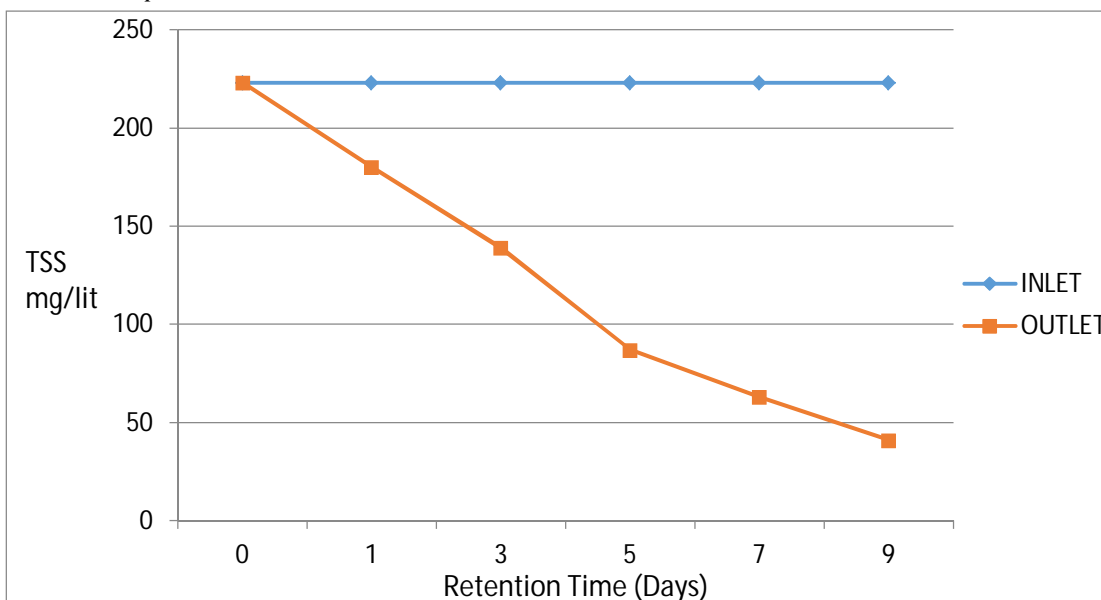
2) Change in BOD



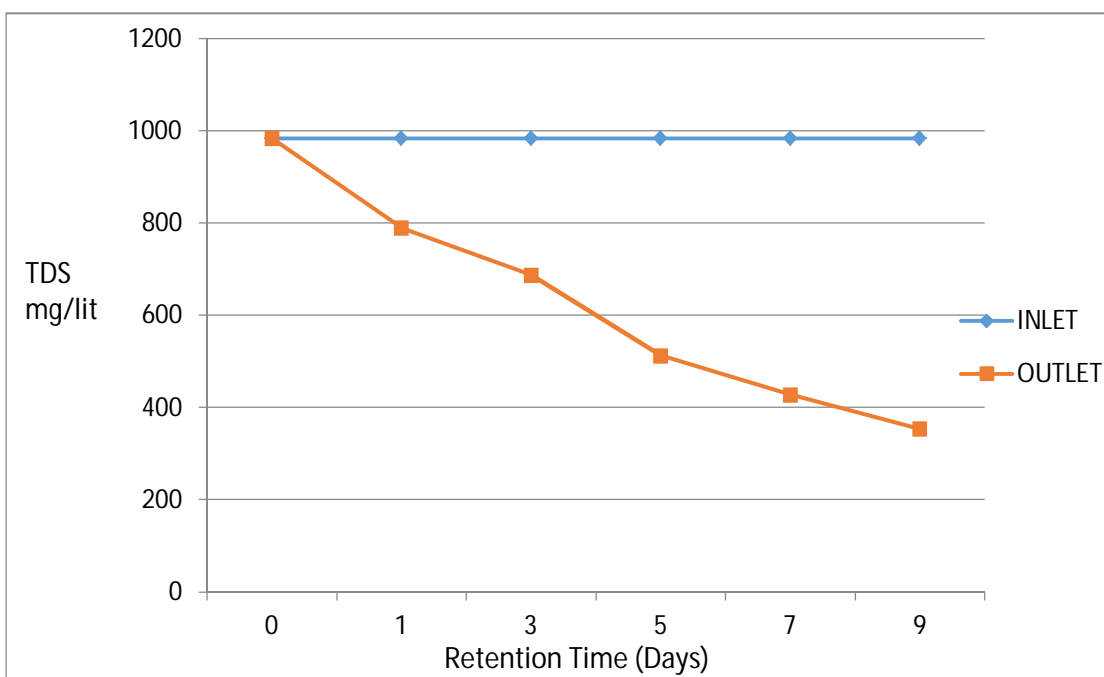
3) Change in COD



4) Change in Total Suspended Solids



5) Change in Total Dissolved Solids



J. Efficiency

- 1) BOD Removal Efficiency =58.40%
- 2) COD Removal Efficiency =59.60%
- 3) TSS Removal Efficiency=81.61%
- 4) TDS Removal Efficiency=64.02%
- 5) No Significant Variation in pH

IV. CONCLUSION

- A. In the study we found that BOD, COD, TSS & TDS removal efficiency 58.40%, 59.60%, 81.61% & 64.02% respectively was observed.
- B. It is very economical process as canna indica & thypha is naturally available in abundance in our area & Low cost material is used.
- C. Cost Of Construction, Operation, maintenance is less & no skilled labour is required.
- D. The treated water can be used gardening, washing, firefighting, Construction, toilet flushing etc.
- E. Method is suitable for rural, undeveloped areas, industry (Sugar, Pulp& Paper).
- F. The cost of construction and maintenance is low as compare to other type of waste water treatment plant.
- G. Constructed wetland can be effectively used for isolated households or apartments as it is compact in size.

V. ACKNOWLEDGMENT

This research was supported by, Prof. A. A. Mahajan, Prof. S. S. Pujari and V. G. Awasare, VTC Patgaon, Miraj. We are thankful to our colleagues from Civil Department, who provided expertise that greatly assisted the research.

We have to express out-appreciation to the Prof. A. A. Mahajan for shearing their pearls of wisdom with us during the course of research.

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