Constructed Wetlands- A Natural Solution for Waste Water Menace

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Abstract: India constitutes a large population and over the past few decades, due to rapid urbanization and industrialization, there has been a mass movement of people towards cities and towns from rural areas as a result of which these urbanized areas are growing in haphazard manner. There is also an increase in resource utilization due to growing concentration of population in these areas which has led to an excessive contamination of water bodies situated there. Many of these areas are not facilitated by central sewage treatment facilities like proper sewer networks due to the unplanned growth of these areas. Thus, the waste waters from these areas are either discharged directly or discharged after partial inadequate treatment into the surface water bodies. This is leading to increasing pollution of water bodies. In order to mitigate this problem, these areas should either be connected to central sewage treatment facility (CSTF), or should have some decentralized treatment facilities. Constructed wetland is one of the options which can be utilized at decentralized level. This paper lays emphasis on the use of constructed wetlands for the treatment of waste water from partially developed areas or from small communities. This natural wastewater treatment technique is a good alternative in the absence of any centralized treatment option as it is very cost effective, has high treatment efficiency, and this is a treatment option which is purely based on natural purification process as it does not constitute the use of chemicals and exhaustible energy resources. This paper discusses the waste water problems arising in the areas devoid of sewer network and the applicability of this natural technique in overcoming the same by taking into account some remarkable case studies in this field.

1. INTRODUCTION

The constructed wetlands (CWs) for wastewater treatment, also known as treatment wetlands, are engineered systems designed and constructed to utilize natural processes and remove pollutants from contaminated water within a more controlled environment [1, 2]. They are designed to take advantage of many of the same processes that occur in natural wetlands, but do so in a more regulated and organized manner. Constructed wetland systems are generally classified into two general types: the Surface Flow System (SFS) and the Sub-Surface Flow System (SSFS). SSFS has further two sub-types: Horizontal Sub-Surface Flow (HSSF) and Vertical Sub-surface Flow (VSSF) systems.

Along with the treatment of domestic wastewaters, the application of CWs has also been significantly expanded in purifying agricultural effluents [3, 4], tile drainage waters [5, 6], acid mine drainage [7], industrial effluents [8, 9], landfill leachates [10], aquaculture waters [11] and urban and highway runoff [12, 13]. They serve as a cost-effective and a more resourceful method than the natural wetland technique.

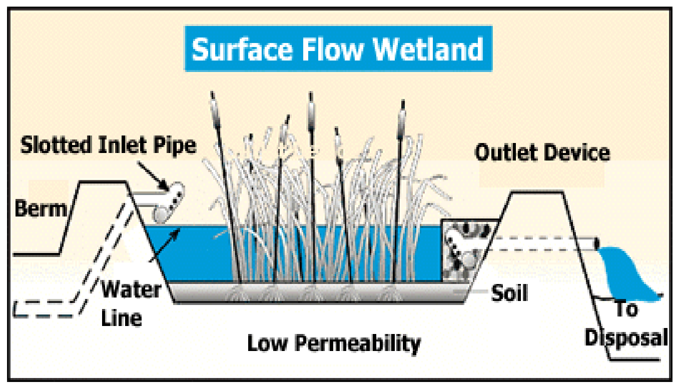

Fig. 1. Surface water flow constructed wetland

They can be designed for BOD, COD and nutrient removal processes and for maximum control over the hydraulic and vegetation management of the wetland. Not only their cleansing action, but they also add to the asthenic beauty of the area if maintained properly.

The main objective of this paper is to review and study the scope of this decentralized CW technique and its applicability and removal efficiency in treating the waste water from partially developed and small communities by considering examples of wetlands from some developed and developing nations.

Kadlec and Knight (1996) [14] gave a good historical account of the use of the natural and constructed wetlands for wastewater treatment and disposal. Research studies on the use of CW for the wastewater treatment began in Europe in the 1950s and in the US in the late 1960s. Research efforts in the US increased throughout the 1970s and 1980s with

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significant federal involvement by the Tennessee Valley Authority (TVA) and the US dept. of Agriculture in the late 1980s and early 1990s.

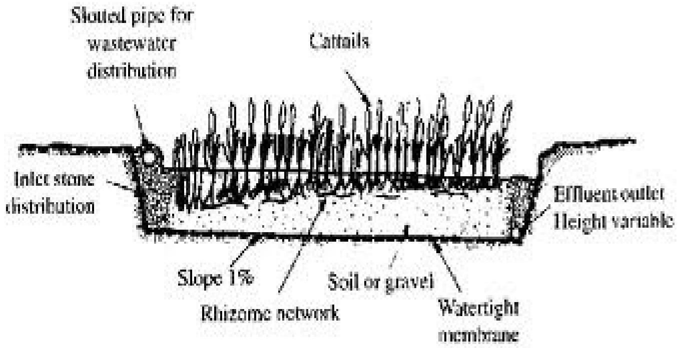

Fig. 2. A diagrammatic and actual field picture of a sub-surface constructed wetland

1.1 Components of Constructed Wetland

Constructed Wetlands comprises of the following components:

i. Basin
ii. Substrate
iii. Liner
iv. Vegetation
v. Inlet/Outlet system

The basin is filled with a permeable substrate (rock, gravel, sand and soil) and the substrate supports the roots system of the same types of emergent vegetation. A liner generally made up of materials like PVC is used to check the percolation of wastewater into the ground water. The collection of wastewater and its even distribution throughout the wetlands is done by inlet/outlet arrangement systems. The following are the major factors which should be considered for the selection of vegetation or plant species: *locally dominating macrophytes species, deep root penetration, strong rhizomes with massive fibrous roots, tolerance to high nutrient load, maximum surface area for microbes ad efficient oxygen transport into the root zone.* Some of the major plant species used in CWs are- Cattials (Typha latifolia), Bulrushes (Scirpus californicus), Iris (Iris spp.), Reeds (Juncus effuses), Umbrella Palms (Cyperus alternifolius). This plant uptake of nutrients is one of the predominant processes for the treatment of waste water.

2. CONFIGURATIONS OF CWS

There are various design configurations of the CWs and they can be classified according to the following-

i. Dominating Macrophytes (free-floating, emergent and submerged)
ii. Flow pattern in the wetland system (FWS flow, SSF: horizontal and vertical)
iii. Type of configuration of the wetland cells (hybrid system, one-stage, multi-stage systems)
iv. Type of wastewater to be treated
v. Treatment level of wastewater (primary, secondary or tertiary)
vi. Type of pre-treatment
vii. Type of influent and effluent structures
viii. Type of substrate (gravel, soil, sand etc.)
ix. Type of loading (intermittent or continuous loading)

3. OPERATION AND MAINTENANCE

Operation and Maintenance can be classified in terms of *start-up, routine* and *long-term.*

3.1. Start-Up

During the startup period, the operator is primarily responsible for adjusting the water level in the wetland corresponding to the plant growth and the length of this period depends on the type of design, season of year and characteristics of influent wastewater. This start-up period for wetlands is necessarily to establish the vegetation associated with the treatment process.

3.2. Routine Operation

This is mostly passive and requires little operator intervention. The most critical items in which the operator intervention is necessary are *adjustment of water levels, maintenance of flow uniformity (inlet and outlet structures), and management of vegetation, odor control* and *maintenance of berms.*

3.3. Long-term Operations

Long-term operations are essential in managing the wetlands. The performance of the wetlands should be assessed time to time and the samples should be collected, analyzed and checked for treatment efficiency. The main parameters which are needed to be analyzed are TSS, BOD_5, COD, Ammonia, Nitrates, Phosphorus and Fecal Coliform.

4. POLLUTANT REMOVAL MECHANISM

Table 1. Mechanisms for pollutant removal

Wastewater Constituent	Removal Mechanism
Suspended Solids	Sedimentation, Filtration
Soluble Organics	Aerobic and Anaerobic Microbial Degradation
Phosphorous	Matrix Sorption and Plant Uptake
Nitrogen	Ammonification followed by microbial nitrification, Denitrification and Plant Uptake
Metals	Absorption and Cation Exchange, Matrix Adsorption, Complexation, Precipitation and Plant Uptake
Pathogens	Adsorption by Biomass, Microbial Oxidation and Reduction, Sedimentation, Filtration and Natural Die-off

5. SUCCESSFUL IMPLEMENTATION OF CWS AT VARIOUS LOCATIONS"

In order to get the idea of various know-hows of Constructed Wetlands Treatment Technique, there should be thorough study of the ongoing CW treatment projects which has been done here by considering examples from fields.

5.1. For Municipal Wastewater at NEERI, MUMBAI

A pilot scale study was conducted to examine the feasibility of CWs for treatment of sewage at NEERI, Mumbai [15].

Two experimental beds of size 2 x 1 x 0.3 m were prepared with the following components-

i. *Inlet Zone,* consists of crushed bricks

ii. *Treatment Zone,* consists of three layers viz., upper layer of crushed bricks, middle of sand and lower of stones

Fig. 3. Sewage beds at Neeri, Mumbai

iii. *Outlet zone*, consists of three apertures

iv. *Plant Species,* like Elephant grasses and Cattails for 1st bed and Canny Lily and Dwarf Palm for 2nd bed.

v. *Hydraulic Loading Rate*: 0.2614 m^3/m^2/day

vi. *Hydraulic Retention Time:* 1.14 day

vii. Efficiency of CW (Bed 1 and Bed 2) is tabulated as follows:

Table 2. Efficiency for Bed 1 and Bed 2

Parameters	Inlet conc.	Outlet conc.	Efficiency (%)
TSS[1]	144* 152**	25* 38**	83* 75**
BOD5[1]	152* 198**	23* 45**	85* 77**
Nitrogen[1]	24* 32**	9.4* 15**	60* 53**
Phosphorous[1]	2.8* 3.8**	1.5* 2.1*	46* 44**
Faecal Coliform[2]	$4.5x10^{7}$* $3.3x10^{6}$**	$1.7x10^{6}$* $5.9x10^{5}$**	96* 82**
** stands for 1st bed, **stands for 2nd bed, [1]stands for (mg/l), [2]stands for (colonies/100ml)*			

5.2. For Community-Based Wastewater Management

The location was Sunga wastewater treatment plant, Madhyapur Thimi Municipality [16].

A Horizontal Sub-Surface Flow type Constructed Wetland was built at the site followed by Vertical Flow reed beds. The total covered area of the CW was 375m^2 which was required to treat the total inlet water coming from almost 100 households of that locality. The wastewater to be treated comprised of high strength water with an average BOD of raw wastewater to be 1, 775mg/l. Because of such high strength, initially preliminary treatment was provided in a 42 m^3 of anaerobic baffle reactor (ABR). The average flow of waste water received by plant was 10$m^{3.}$

The *efficiency* of the CW observed is as follows;

1. *TSS* removal was observed to be around 98%
2. *BOD_5* removal was observed to be around 97%
3. *COD* removal was observed to be around 96%

5.3. Amba nala wastewater treatment, Amravati

The location was at Institute of Environmental Engineering Laboratory, Amravati [17].

A Vertical flow constructed wetland (VFCW) was built in an area of 100m^2 in order to treat the waste coming from the

Amba nala in a study conducted in the year 2008. The hydraulic loading rate was adjusted to be about $6m^3$ per day. The study was conducted with and without the use of vegetation for which the plant species *Typha Orientalis* was obtained from near a local stream and with different varieties of soil.

The *methodology* is that the raw waste water is sampled from Amba nala and is initially given a pre-treatment by constructing a sedimentation tank in order to reduce the strength of the inlet waste water. This partially treated waste water is then directly fed to the VFCW.

The maximum *efficiency* was observed in the case of the constructed wetland with black cotton soil along with Typha orientalis as vegetation and is as follows.

i. *Total solids* removal: 75%
ii. *BOD* removal: 88%
iii. *COD* removal: 65%

5.4. Grey water recycling at household level using constructed wetland

The house under study is located in Dallu, ward 15 of Kathmandu metropolitan city [16]. It is the first house in Nepal that treats and recycles its waste water and it belongs to Dr. Roshan Raj Shreshtha who first pioneered the use of constructed wetlands in Nepal. It is a simple house which is built on about $135m^2$ of land.
Year of operation-1998
Type of wastewater feed- grey water
Type of CW- Vertical Flow CW

The methodology followed is simple and convenient. A settling tank of $0.5m^3$ capacity is provided, which in series if followed by a feeding tank. At last a small vertical flow reed bed with an area of only $6m^2$ is built.

The efficiency observed is listed below;
i. *TSS* removal – 97%
ii. *BOD_5* removal- 98%
iii. *Ammonia nitrogen* removal- 98%
iv. *Total coliform* removal- 99.9%

This system is efficient and capable enough to treat all the grey water generated in the house of seven members. Thus, everyday almost 400 liters of water is saved by the family. The treated water is used for non-potable uses such as flushing, gardening and washing which is a very judicious use of water.

5.5. Wastewater Treatment at Farmhouse, Indonesia

The wastewater from farmhouse including the agricultural waste is treated using the CW technique with aquatic microphyte at Jatinanagar, Indonesia [18].

A vertical sub surface CW of size 6x6x1.2 m is built and planted with *Phragmites Karka* at a density of 16 plants per m^2. The wastewater is mechanically pre-treated in a sedimentation tank and passed through a multi layered sand filter media. The water samples are collected at every two weeks interval.

The efficiency of the Constructed Wetland finally obtained is as follows-

Table 3. Efficiency of Treatment

Parameter	Average %age removal
NH_4-N	86
Total Nitrogen	75
PO_4-P	90
BOD_5	75
COD	75
Total coliform bacteria	99

Along with a great efficiency, it has also been observed in this case that the Constructed Wetland Technique is efficient for the purification of agricultural waste.

6. CONCLUSION

There are certain standards specified by the Central Pollution Control Board (CPCB) for disposal of treated waste water into the surface water and it is very important to check the quality of wastewater as per these standards before finally disposing off the treated wastewater.

The standards for the disposal are as follows:

Table 4. Standards for disposal

Parameter	Unit	Permissible limit for disposal to surface water
pH	------	5.5-9.0
TSS	mg/l	100
TDS	mg/l	2100
COD	mg/l	250
BOD	mg/l	30

After a comprehensive study of the literature and the case studies on *constructed wetlands,* it has been observed that the characteristics of the outflow from constructed wetlands comply with the CPCB standards.

Also, this is the most *efficient* options for decentralized waste water treatment. They are *cost effective* as only a little amount of investment is needed for its installation compared to which the results provided by it are quite excellent and profitable.

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Operation and maintenance costs are negligible too. It has also that if any preliminary treatment option such as septic tank or even simply a sedimentation tank is provided before a constructed wetland; the efficiency of treatment tends to increase.

Moreover, this decentralized technique facilitates recycle and reuse options of treated effluent in various activities such as gardening, washing cars, or floors, for flushing and in fountains.

Constructed wetlands are “natural systems”, thus they requires minimum or no external energy such as electricity for its operation and also use materials that are locally available. They are very tolerant systems as they are able to bear the fluctuation in wastewater flow or in its pH. Apart from purification, they offer good asthenic beauty to the surroundings.

Wastewater treatment by using aquatic plants in CWs is in wide use throughout the globe such as Germany [19], USA [20], Australia [21], U.K. [22], China [23], Sweden [24] etc. [25].

Hence, we can say that Constructed Wetlands are the best in-situ technology for treatment of waste water especially in developing nations like India where economic aspects and a wide diversity are to be taken care of.

This study can further be extended to the application of this technology in treatment of Industrial Wastewater effluents.

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