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Wastewater Treatment through Constructed Wetland (CWL) System

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Abstract

Waste water treatment costs extra strain on every private and civic body. Previously waste used to be just dumped at refusal area without prior treatment. But it caused pollution and several environmental issues. Different treatment methods are implemented to treat this waste but are associated with certain limitations. Researchers have developed a wetland treatment method as a cost-effective technology dependent on nature for the treatment of waste. Vegetation and associated micro-organisms growing on wetland can break down the waste without charging extra operation cost. Constructed wetlands (CWL) are found to be capable enough to treat municipal, industrial sewage as well as stormwater runoffs. Pollutants present in wastewater are adsorbed by plants and microbes so their level is reduced down to make water reusable. In the present study, three case studies show evidence of the efficiency of CWL to treat different types of waste using locally available plant species. CWL also provides a natural habitat for living organisms and provides an aesthetic view for wetland landscape.

Keywords:- *CWL, wastewater, micro-organisms, pollution, plant species, aesthetics*

INTRODUCTION

Wetlands are the intermediate areas between land and water bodies. Natural wetland consists of marshy lands, bogs, swamps, tidal lands, flood plains, etc. Hydrology of wetland can be defined as gradual surface flow. It consists of plant habitat with the growth of microbes. The entire life cycle of plants is completed within the wetland and after the death of plants, their remains provide food for microbes to thrive and grow.

Wetlands are rich in carbon, nitrogen and phosphorous content, thus providing a favorable condition for microbial activity. Wetlands are also found to be the favorite location for the breeding of birds flying over continents to get a comfortable place for their newborn. Bird watching is a thriving recreational activity nearby wetlands. Water is an important component of wetlands. Wetlands are generally formed by the accumulation of surface water in shallow depression spread over a wide area. Sediments carried by flood water get accumulated in wetlands. They form a support system for plants and microorganisms to grow within soil pores. Wetlands are dependent on the metabolism of microorganisms. Aerobic, anaerobic, as well as facultative anaerobes, work together to break down the waste. They transform organic and inorganic waste into the soluble substrate. Resulting substances helps to reduce the overall volume of material adding to a wetland. Algae growing on the water surface are the main source of oxygen for organisms. Algae are also the main source of food for birds that are seen in wetlands. But this community is also prone to harmful effects on contact with pesticides and chemical fertilizers. Thus the entry of these chemicals within wetlands needs to be arrested. After fulfillment of primary objectives, both natural and constructed wetlands add aesthetics to the surrounding landscape.

LITERATURE REVIEW

In the past wetland area was considered as natural depression that can accumulate water through gravity flow. Further natural vegetation growing over wetland associated with micro-organisms was treating wastewater. During the last 50-years, researchers have worked on different aspects of wetland, its construction, operation, maintenance, and efficiency. Noticeable work amongst them was studied earlier and their conclusion on CWL was recorded as studied to develop own CWL system along with its practical implementation with the help of three case studies.

Alexander Mathew et. al. [1] investigated that plant species Cattail (TyphaLatifolia) can effectively treat landfill leachate. Maximum removal efficiencies of Turbidity, COD, Total Solids, Nitrates and Phosphates up to 84%, 82%, 91%, 65%, and 89% respectively was achieved with the retention time of 8 hours. ArushaiSheoran [2], Rajnikant Prasad et. al. [10] reviewed different types of wetlands adopted to treat municipal wastewater. The constructed wetland was found to be a cost-effective solution. It is a self-sustaining method and can operate unattended for many years.

It was also observed that wetlands are not effective in cold countries like Canada due to harsh climate, but is suitable for tropical countries like India due to favorable climatic conditions. Atif Mustafa [3] studied the pilot project of horizontal flow constructed wetland to treat domestic wastewater. Effectiveness of project was observed based upon the increase in values as BOD (50%), COD (44%), TSS (78%), NH4-N (49%), PO4-P (52%), TC (93%) and FC (98%). Treated water was used further for landscape irrigation. This system was found ineffective in removing Faceal coliforms which are responsible for causing diseases. BorkarR. P and Mahatme P.S [4] prepared laboratory set of vertical flow constructed wetland. Planted wetland system performed better than the unplanted system.

Also, the increase in detention period showed an increase in removal rate. The removal rate in black cotton soil was more than sandy soil since Black cotton soil has good water holding capacity. Plant species TyphaOrientalis (macrophyte plant) removed 75% of total solids, 86% BOD and 63% COD from effluent. Garge M. M and Chaudhari P. S. [5] concluded that use of Data Information System (DIS) and GIS data enables the user a cost-effective, convenient and appropriate method of Detection of Wetland Site interpreted in terms of Raster Maps. Jan Vymazal [6] showed that wetlands can handle sewage, industrial and agricultural wastewaters, landfill leachate and stormwater runoff.

They are effective in removing organics and suspended solids, whereas removal of nitrogen and phosphorus requires modification is the system. Constructed wetlands also help in flood control, carbon sequestration or wildlife habitat. MahboobeGhasemi-Zaniani and et. al. [7] have investigated irrigation efficiency through water from constructed wetlands. In cold countries, wetlands can remove the appreciable amount of TSS from wastewater so that it can be reused to irrigate crops. Even BOD removal efficiency is high up to 58.8 to 99.84%. Constructed wetlands were not sufficient enough to bring down microbial content in the effluent to use it for agriculture. MihretDanantoUlsido [8] investigated sub-surface flow (SSF) constructed wetland as a post-treatment technique after the UASB reactor for wastewater treatment in arid and semi-arid areas. SSF wetland is effective in removing COD, TSS.

The surface flow wetland is an effective method for removal of nitrogen and Fecal Coliform. Parveen Kumar and Ashutosh Kumar Choudhary [9] investigated the performance of constructed wetland in treating landfill leachate. Waghmode R. B. et. al. [11] used a modified conventional root zone technology system to remove suspended solids from sewage waste. UmerMujtaba Khan and UmerMujtaba Khan [12] compared conventional and artificial methods for treatment of wastewater. The detailed study revealed constructed wetland as cost-effective and more reliable technology to treat water in the rural area of India. Treated water can be used easily for irrigation or recreational activities.

CONSTRUCTED WETLANDS

It is an artificial shallow water basin consisting of substrate usually soil or gravel. It forms a base for plants to grow to complete their life cycle, further die and decompose to form fertile compost for further plants. Composting of plants all other with other waste feed into wetland are consumed by micro-organisms to complete their mechanism and provide nutrients for plants for their growth.

Water containing impurities is feed into the system from one end. It is processed by natural agents to get the final product as treated water at the outlet end. Wetland includes the different process for waste reduction and treatment, they are settling of impurities, precipitation of floating impurities, adsorption on plant roots and sediments, breakdown of waste by microbes and insects, conversion of waste into nutrients and consumption of pathogens through insects. The primary objective of the wetland is to removes pollutants and contaminants present in wastewater as shown in table no.1.

Table No. 1. Pollutant removal process in wetland

Contaminant	Treatment
Organic impurities	› breakdown by soil bacteria › Adsorption on clay particles
Pathogens	› Consumption by bacteria › Filtration › Absorption › Sedimentation
Total Suspended Solids	› Sedimentation › Filtration
Nitrogen	› Nitrification and denitrification through nitrogen-fixing bacteria
Heavy metals	› Consumption through plants roots › Precipitation

Type of wetland includes surface flow, subsurface flow, and hybrid systems. Surface wetlands can be the marshy land formed due to storage of stormwater runoff in shallow depression basins. They consisting of aerobic as well as anaerobic systems for fixing waste. Surface wetlands are an ideal solution to treat mine drainage and irrigation runoff. Although, economical for construction and maintenance but are occupying a large area. Subsurface wetland consists of vegetation bed, plant rock filter system or a sealed basin requiring demanding measured inflow rate. Subsurface wetlands are typically used to reduce 5 days BOD of wastewater. The capacity of the subsurface system is quite as compared to the surface system designed to treat the same amount of wastewater. The disadvantage of the subsurface system is that they are costly in construction as well as operation. The hybrid system consists of a multistage process including features of both the above systems to achieve better results. Temperature change has a noticeable impact of aerobic decomposition of organic matter found within the waste. Rate of microbial activity is more in the warm season, but at the same time, evapotranspiration creates a shortage of water medium required for treatment of waste within wetlands. In cold climate, top layer reaches the freezing point, but aerobic decomposition activity is still active below the top ice layer in the wetland system. Transportation of toxic chemicals and heavy metals within wetlands causes accumulation of these wastes on wetland bed. These impurities will continue to remain for a longer duration of time and may cause hindrance to further waste treatment activity. Natural wetlands are subjected to change in the process over a period. This causes stress on the natural system. In the case of constructed wetland, periodical monitoring of all activities is necessary to predict the required change to be adopted in the system.

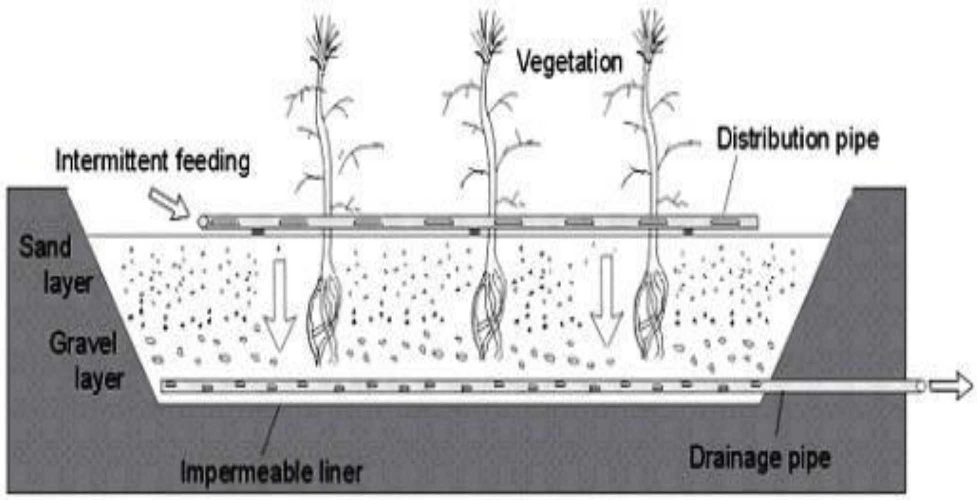

Fig.1.a. Vertical flow CWL

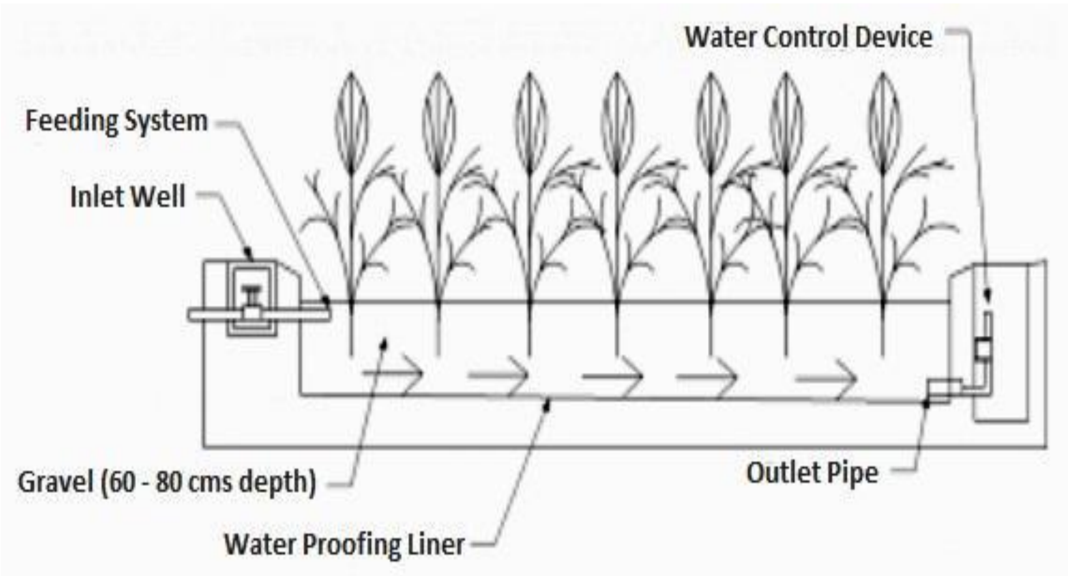

Fig.1.b. Horizontal flow CWL

Design of CWL

The design should be simple and maintenance-free. As far as possible adopt gravity flow in the system. The system must be workable in all weather conditions. It should suit to the topography of the site and should avoid costly construction methods. CWL takes time to become functional; this factor has to be taken into consideration while designing the system. Design of wetland involves consideration of the following factors:

a) Site selection: Site should be near to the source of wastewater and follow a sloping gradient so that water will flow under gravity. It must be above the groundwater level and must not lie on flood plains. The site should cause minimum disturbance to natural habitat. It should be well connected by road network but should be away from human settlements.

b) Planning & designing stage: Sanctioned wetland must fulfill all requirements. Every CWL is unique in its design and number of units in the system depends on the amount of wastewater to be treated. CWL should fit in surroundings and not harm the natural ecosystem.

c) Government regulations and Permits: All necessary sanctions and permits must be taken from local as well as weather/ irrigation. Agricultural departments while dealing with stormwater runoff and agricultural wastewaters. In past Government of India has passed different laws for the construction of wetlands and protection of wildlife adjoining wetlands. As per wildlife protection act-1976, bird sanctuaries are reserved spaces for migrating birds to live and breed under the protection of the forest department. As per regulations, wetlands, marshy lands, swamps, etc are places that are conserved for wildlife.

d) Structural cells/ units: Entire basin is divided into cells by slopes or dikes. Dikes are made up of fine-grained material. The ratio of dike slope is 2H: 1V. Slopes are protected by liners to avoid erosion. Natural liners made of soil, clay (15%) or bentonite are used. Synthetic liners made from asphalt, plastic sheets (o.5 to 10 mm HDPE) can also be used. Bed slope of 1 to 3 % upstream is maintained to avoid rapid flow. Along the sloping ground, terrace cells are constructed on slopes.

e) Flow control structures: Provide inlet with control valves to maintain uniform flow to the system. A rocky layer is kept at the entry for rapid filtration. Adopt fixed inlet and flexible outlet to increase the efficiency of the system. If the required water flow path is increased by providing cross-work to reduce flow velocity for promoting sedimentation and treatment of wastewater. At the outlet, weirs are installed. Sub-surface manifolds are located at the bottom of the bed to control water level as well as drainage from an outlet. Required depth must always be maintained in the system to keep vegetation as well as micro-organisms alive. Water will avoid unwanted weed growth that may occur on the exposed bed.

f) Design life: Theoretically design life of CWL is predicted as infinite life. It means once wetland is constructed by excavating basin, growing vegetation and feeding wastewater. Then such a system will continue to work lifelong if maintained properly. But in practice life of wetland depends on wetland spread area, amount of sediments deposition and the interval between tow maintenance schedules.

g) Wetland parameters: Efficient working of CWL depends on careful monitoring of the following parameters:

i. Meteorological parameters: Rainfall, snowfall can cause heavy flow towards wetland and cause flooding. Increase in runoff will reduce the residence time and decrease the efficiency of the system. Generally, excess flow is observed due to snowmelt in summer and temperature drop occurring in winter affects the efficiency of wetland.

ii. Hydrology: Precipitation, runoff, hydraulic residence time, rainfall loading rate, infiltration and losses due to evapotranspiration are the parameter that can affect the wetland. Check water balance equation of CWL system.

iii. Hydro-period: It is seasonal fluctuations of water level and depends on duration, frequency and depth of wetland, it follows the water budget equation. Seasonal differences may also affect the design of the wetland system

iv. Hydraulic retention time: It the ratio of the volume of the tank (wetland basin) to influent flow ratio. HRT of 5 days will increase BOD removal rate. HRT of 3 to 4 days can treat polluted river water efficiently. Longer HRT will not be able to remove Total suspended solids and ammonia.

v. Hydraulic residence time: It the average time for which water remains in the wetland basin. It is calculated as the ratio of the volume of the basin to mean outflow rate.

vi. Hydraulic loading rate: It is the amount of wastewater feed per unit area of the system. it defines the amount of water entering CWL.

h) Evapotranspiration (ET) losses from CWL: Evapotranspiration is the loss of water due to evaporation from water surface and transpiration of plants. It causes heavy loss of water without any treatment. Wetland can soon become dry, all living organisms are dead. It will stop the treatment procedure of wetland. In the subsequent working cycle again vegetation has to grow new plant and requires a waiting period of their growth and micro-organisms to form colonies in plant roots region. Proper provision is required to control the ET rate.

Construction of wetlands

Construction of wetland involves providing following facilities. Construction of approach roads, site clearance and excavation for the basin. Construction of sides and installation of inlet and outlet structures consisting of valves to regulate the flow. Spreading seeds or planting saplings, spreading wastewater over the prepared basin and finally preparing the site to operate smoothly. Follow bed slope as per the design to avoid channeling. Take care to provide lining to avoid leakage to the underlying groundwater basin. Use of geotextiles is recommended these days. Before operating the wetland, a trial run must be performed. The initial stage of the wetland is quite crucial. Plants and micro-organisms are trying to adjust to a new habitat. Proper care and corrective measures must be taken whenever needed. After initial settlement occurs, the wetland is made functional gradually by feeding with wastewater until it reaches an optimum level. Agricultural wastewater must be supplied gradually as compared to stormwater or municipal wastewater since it consists of traces of chemical found in pesticides

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Selection of plant species is important. Role of plants to grow by consuming nutrients from wastewater, complete their life cycle and die. Death remains of plants are decomposed by micro-organisms. Plant roots also provide a dwelling for micro-organisms. Plants also add an aesthetic view to wetland areas. Use local plant species that can survive in flood water of storm runoff. Plants like Scirpus, Spike crush, sedges, rushes, common reed, cattails, etc are preferred. Table No.2 shows the importance of plants species in wastewater treatment.

Wetland Health:

Generally, plant seeds or plant samplings are used to plant new species at wetland site. Birds and animals especially rodents are causing trouble for planting new vegetation. Different measures are taken to avoid hindrance this factor. It is also observed that dissolved solid concentration, heavy metals, high nutrients and toxic chemicals present in wastewater feed to a wetland can also affect the growth of vegetation in wetland site. Avoid growth of unwanted vegetation like weed growth and remove it occasionally. Avoid spraying of insecticides, pesticides or herbicides on wetland vegetation, since they add a toxic element to treated water.

Table No. 2 Plant species and their characteristics

Plant species	**Role in wastewater treatment**
Bulrush Scripus	Tolerant to high nutrient value organic waste. Preferred for subsurface flow wetlands
Arrowhead & pickerelweed	Treats agricultural wastewater
Sweet flag	Treats heavy metals and toxic waste in water
Blue flag iris	Suitable for the edge of CWL
Cattails & common reed	Tolerant to all types of wastewater
Reed canary	Ground cover for berms
Lizards tail	Grows at a faster rate to treat waste
spike rush	Tolerant to difficult site conditions

Periodically check that water is being spread evenly over the entire wetland bed area. Although the gradual but continuous flow of wastewater must be maintained in and out of the system. Flowing water avoids breeding of mosquito larvae. Mosquitoes are the main cause of diseases like malaria. Mosquito fish (Gambusia) or green sunfish (Teporniscyanellus) are also released in wetland water to get rid of mosquito larvae. Avoid erosion of bed and banks or wetland that may occur during surface or subsurface flow of wastewater over the wetland. Monitoring of wetland includes identifying problems and suggesting cost-effective solutions. Periodical measurement of BOD, COD, nitrogen, phosphorus, total suspended solids, heavy metals, bacteria is necessary to access the quality of treated wastewater before it leaves the CWL for further reuse of post-treatment.

Avoid dumping of garbage in wetlands and maintain time to time cleanliness of wetland and surrounding area. For efficient working of the system carefully monitor agricultural or mining wastewater that is feed to CWL. If possible supply pre-treated wastewater to reduce time and overall stress on CWL.

Case study No.1: Treatment of produced water from oil rig site.

Water is produced during extracting oil from crude oil wells as a byproduct. This produced water is required to be treated to remove dissolved contents before it is released on natural streams. Produced water contains dissolved, suspended solids and heavy metals like zinc, iron, magnesium, manganese, selenium, arsenic, etc. Currently, available treatment methods include ion exchange, reverse electrodialysis, reverse osmosis, evaporation, etc which are quite costly. It is difficult to remove heavy metals and organic contents from produced water obtained from oil or gas rigs. CWL is a low-cost method. Water treated was used further used for agriculture, municipal and domestic use. Water quality is regularly checked to make necessary modifications. CWL was effectively used to remove metals, salts, microbes, etc from produced water. It is best-recommended method in the oil industry for the treatment of produced water.

Case study No. 2: CWL for treatment of wastewater treatment released from Hostel in New Science Commerce College Campus, Pune.

Local plant species were selected depending on their ability to treat toxins from wastewater. CWL was divided into four components:

1. Pretreatment: Providing net at the inlet to avoid entry of floating debris in further compartments

2. Floating vegetation: water is released in wide basin consisting vegetation at a gradual rate for treatment due to plant and microbial activity

3. Shallow depth emergent vegetation: Vegetation in intermediate compartment breaks down waste and adsorbs nutrients form waste. Removes dissolved solids.

4. Submerged vegetation: Removal of suspended solids from waste that might have escaped in previous compartments.

During construction, the lining was provided at sides to avoid percolation and leakage problem. Bed bottom is natural bedrock or compacted soil make the suitable condition of plants to grow fast. Plant species like Echhorniacrassipes, Pistia, Azzola, etc were recommended for plantation. BOD and COD values at inlet and outlet of the system were monitored to check the efficiency of the system. These values were reduced by feeding wastewater to CWL. The present system has an increased amount of dissolved oxygen (DO) level within the wastewater. This is evident by observing algae growth in the second stage of CWL. Nitrogen in sewage from hostel building was extracted by plants and reduction in odour was found in treated water. This foul odor was initially due to ammonia present in sewage. By studying the CWL of this hostel building, it is concluded that CWL of this size and capacity is suitable for small communities to treat domestic and sewage wastewater.

Case study No.3: CWL to treat waste from industrial wastewater of Pune MIDC.

MIDC officials have always encouraged adopting ecological and environmentally friendly wastewater treatment methods. In present, the investigation CWL was used to treat wastewater from the auto industry in Pune MIDC area.

Bioremediation technique was used in CWL. Biological agents were used to treat waste using micro-organisms. CWL system consisted of the following components:

1. Iron nets were used before inlet pipe to remove floating debris that may enter

wetland and settle down on wetland basin.

2. Settling of suspended matter takes place in the first cell by reducing flow velocity.

3. Filtration and precipitation of fine impurities by passing wastewater through a filter bed at a gradual rate.

4. Chemical breakdown, ion exchange and adsorption on plant root surface in vegetation bed.

5. Treatment or organic contents by micro-organism and further consumed by plants during its growth. Microbes convert waste into nutrients that are easily taken by plants.

6. Removal of pathogens also takes place in the treatment process

Different plants species like Eichorniacrassipes, Pistia, salvainamolesta, Azzola were used as vegetation for removal of metals, toxic elements and organic matter present in wastewater flowing out of industries.

CONCLUSION

Based upon a literature review of conventional and constructed wetlands it is found that CWL requires large spread area, operates seasonally and its operation is still based on trial and error basis until it functions to the full extent. Although limitations are associated with wetlands it also has following efficiencies, making it a cost-effective and reliable method for treatment of wastewater.

- CWL can be used to treat municipal, agricultural and industrial waste and sewage water. Also capable to treat a huge load of landfill leachate and stormwater runoff.

- It is capable enough to remove pathogens and suspended solids.

- Ammonia present in sewage water can cause a foul smell. Nitrogen present in waste is extracted by vegetation present in wetland and thus reduced the odor of treated water.

- Dissolved oxygen level in wastewater is found to increase will passing water through CWL. It can be observed as the growth of algae in cells of CWL.

- Reduction in BOD and COD level is observed by comparing results of influent and effluent water.

- It can tolerate fluctuations in inflow feed to the system. The system required occasional inspection, not continuous. This makes the system cost-efficient and affordable for industrial corporations.

- CWL is cost-effective for treating wastewater released from small localities. Its initial construction cost, as well as its O& M cost, is also less.

- Owing to problems in operating to different seasons, and flow fluctuations, further research is required to make the CWL system functional in all situations and capacity.

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