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STUDY OF AERATION ON MICROBIAL FUEL CELL AND TREATMENT OF WASTE WATER IN CONSTRUCTED WETLAND

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Abstract

Waste water treatment is a problem that has plagued man ever since he discovered that discharging his wastes into surface waters can lead to many additional environmental problems. Strategies for control of water pollution have focused mainly on implementation of expensive and energy intensive conventional treatment technologies. The limited successes of such strategies can be attributed to the high capital investment requirement, continual replacement and high operation costs. In recent years, constructed wetlands systems have emerged as a low-cost higher forming waste water treatment technology compared to conventional treatment systems. There is a growing interest to develop and adopt this technology for water pollution control in India as well. This project gives some introductory information on the pollutant removal mechanisms, vegetation and applications of constructed wetlands, for waste water treatment and application of Microbial Fuel Cell (MFC) for the potential difference developed between the electrodes provided in the constructed wetland.

Keywords: *Constructed wetland (CW), Pollutant removal mechanisms, Microbial Fuel Cell (MFC) and Potential Difference (PD).*

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1. Introduction

The treatment of wastewater for reuse has been in a debate recently in large cities and small cities of India due to scarcity of water. The disposal of untreated wastewater directly in a river or lake has an adverse effect on the water bodies. The hurdle to treat municipal waste water comes from the unavailability of resources, skilled man power and not to forget the large power needed to run conventional treatment plants. In such a scenario the constructed wetland not only serve purpose of treating waste water and saving water bodies from adverse effect but also provide habitat for different amphibian and reptiles therefore increasing overall utility. By integrating the wetland into treatment infrastructure, we are trying to unleash its potential without affecting its basic utility as an ecosystem.

A wetland is a natural place where the land is covered by water, either salt, fresh or somewhere in between. Marshes and ponds, the edge of a lake or ocean, the delta at the mouth of a river, low-lying areas that frequently flood-all of these are wetlands.

A constructed wetland (CW) is an artificial wetland to treat municipal wastewater, greywater or storm water runoff. It may also be designed for land reclamation after mining or as a mitigation step for natural areas lost to land development.

A microbial fuel cell (MFC) is a device that generates electricity from the microbial degradation of organic and inorganic substrates. Constructed wetlands (CWs) are natural wastewater treatment systems that constitute a suitable technology for the sanitation of small communities. The synergy between MFCs and CWs is possible because of the presence of organic matter in CWs due to wastewater characteristics and the naturally generated redox gradient between the upper layer of CWs treatment bed (in aerobic conditions) and the deeper layers (completely anaerobic). As a result of (Microbial fuel cell (MFC) implementation in CWs (MFC-CW), it is possible not only to produce an energy surplus while wastewater is treated but also to improve and monitor the overall treatment process. Moreover, the implementation of MFCs may exert other beneficial effects on CWs, such as a decrease of surface treatment requirements, reduction of greenhouse gas emissions or clogging. Finally, MFCs implemented in CWs would be also a suitable bio-electrochemical tool for the assessment of treatment performance without any additional cost involved in the process. Overall, though considered to be at an infancy stage, MFC-CW represents a promising synergy between technologies that may reduce energy costs and enhance treatment performance and monitoring while wastewater is treated. The envisaged main challenges for maximizing the synergy between both technologies are linked to the optimization of both operational and design criteria in CW and MFC cell architecture and materials.

Role of plants is important, as it provides, in its root, the site for bio film to develop. The rhizome size, the growth rate of plant all play major role while selecting the wetland plant. Canna have high growth rate, have large rhizome and have

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found to be very adaptive in tropical places. The plant has been growing easily in everywhere. The research tries to find out the treatment efficiency of constructed wetland when the wetland is constructed with coal, aggregate, sand in the case the top layer is planted with Canna plant whose root system will extensively colonize layer.

2. Types of Constructed Wetland

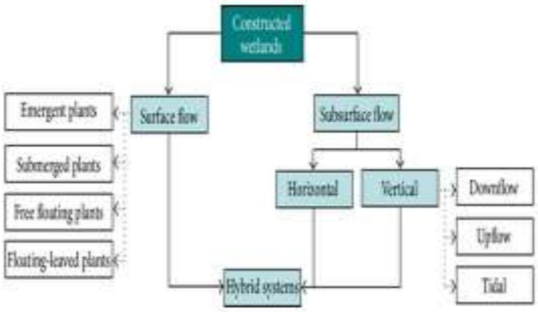

Fig. 1.4: Types of Wetlands

2.1 Surface flow constructed wetland

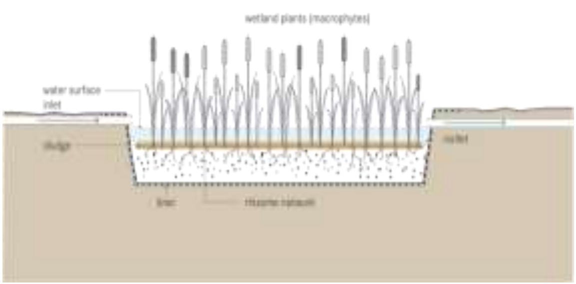

Fig. 2.1: Surface flow constructed wetland

Surface flow wetlands, also known as free water surface constructed wetlands, can be used for tertiary treatment or polishing of effluent from Aeration takes place as in surface flow constructed wetlands. The wastewater is however forced to pass thorough the matrix ensuring intensive contact between wastewater and the bacteria in the rhizosphere (root zone of the plants). In this manner all wastewater is treated as no short circuit flow is possible. Horizontal subsurface flow constructed wetlands, when accurately designed; provide an extremely reliable low cost aerobic post treatment solution which is applicable all over the world.

2.2 Subsurface flow constructed wetland

Subsurface flow wetlands can be further classified as horizontal flow and vertical flow constructed wetlands:

i) Horizontal subsurface flow constructed wetlands

This type of constructed wetland is most commonly used for aerobic post treatment of domestic waste water and can take a higher hydraulic load than a surface flow constructed wetland. In order to dissolve solid organic matter anaerobic pretreatment in a septic tank or bio digester is required. A thick layer of gravel above the aquifer holds a layer of stagnant air and prevents odor nuisance in the vicinity. They are also suitable to treat storm water drainage. Pathogens are destroyed by natural decay, predation from higher organisms, sedimentation and UV irradiation since the water is exposed to direct sunlight.

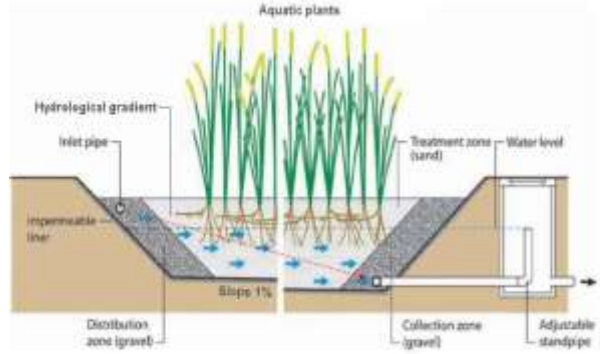

Fig.2.2 (a): Horizontal Subsurface Flow Constructed Wetland

ii) Vertical flow constructed wetlands

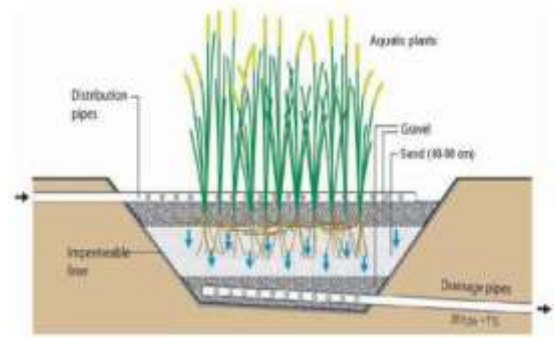

Fig.2.2 (b): Vertical Subsurface Flow Constructed Wetland

The desire to further reduce the size of constructed wetlands led to the development of vertical flow constructed wetlands. Anaerobic pre treated wastewater coming from a septic tank or bio digester is intermittently pumped on top of the constructed wetland. By trickling down the wastewater effectively sucks air in the constructed wetland whenever the pump stops, forcing aeration of the rhizosphere. This increases the aeration capacity up to approximately twenty times compare to horizontal subsurface flow constructed wetlands. Apart from that no short circuit flows are possible and due to lower levels of oxygen deeper in the matrix nitrate is removed under anoxic conditions. We can, for instance, adjust the level of the aquifer and the depth of the matrix as design parameters.

2.3 Hybrid Constructed Wetlands

Various types of constructed wetlands may be combined to achieve higher removal efficiency, especially for nitrogen. The design consists of two stages, several parallel VF beds followed by 2 or 3 HF beds in series (VSSF-HSSF system). The VSSF wetland is intended to remove organics and suspended solids and to promote nitrification, while in HSSF wetland denitrification and further removal of organics and suspended solids occur.

Another configuration is a HSSF-VSSF system. The large HSSF bed is placed first to remove organics and suspended solids and to promote denitrification. An intermittently loaded small VF bed is used for additional removal of organics and suspended solids and for nitrification of ammonia into nitrate. To maximize removal of total nitrogen, however, the nitrified effluent from the VF bed must be recycled to the sedimentation tank .The VSSF-HSSF and HSSF-VSSF constructed wetlands are the most common hybrid systems,

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but in general, any kind of constructed wetlands could be combined to achieve higher treatment effect.

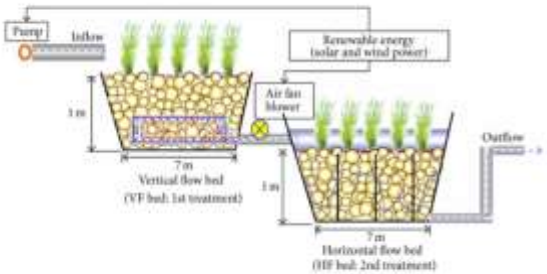

Fig.2.3: Hybrid Flow Constructed Wetland

3. Application of Constructed Wetlands for Wastewater Treatment

Constructed wetlands are used to improve the quality of water polluted from point and nonpoint sources of water pollution, including storm water runoff, domestic wastewater, agricultural wastewater, and mine drainage. Constructed wetlands are also being used to treat petroleum refinery wastes, compost and landfill leachates, aquaculture discharges, and pre-treated industrial wastewaters, such as those from pulp and paper mills, textile mills, and seafood processing. For some wastewaters, constructed wetlands are the sole treatment; for others, they are one component in a sequence of treatment processes. There are various types of constructed wetlands used for treatment of wastewater, and following paragraph highlights the main classification of constructed wetlands.

4. Literature Survey

4.1 General

(Tousignant et al., 1999) Constructed wetlands with free water surface (FWS cws) have been used for many purposes worldwide. Emergent macrophytes play important roles in FWS cws; they reduce wind speed and thus support sedimentation and prevent re-suspension, provide substrate for periphyton and bacteria, take up nutrients and in carbon-limited systems provide carbon for denitrification during biomass decomposition. It has been reported that treatment performance of planted FWS cws is superior to unvegetated lagoons. However, treatment performance of FWS cws could be affected by plant species used. The literature survey of 643 FWS cws from 43 countries recorded 150 plant species and revealed that the most commonly used was Typha, Scirpus (Schoenoplectus), Phragmites, Juncus and Eleocharis. In terms of species, most frequently used species were Typha latifolia, Phragmites australis, Typha angustangustifolai, Juncus effusus, Scirpuslacustris, Scirpus californicus and Phalaris arundinacea. In terms of continents, P. Australis is the most frequent species in Europe and Asia, T. Latifolia in North America, Cyperus papyrus in Africa, P. Australis and Typha domingensis in Central/South Americas and Scirpus validus in Oceania.

4.2 Removal of BOD by Constructed Wetlands

(Tousignant et al., 1999) The remaining soluble organic material, left over after sedimentation, is aerobically degraded by bacterial biofilm that is attached to the plants. In the wetland cells the aquatic plants supply oxygen to the wetland floor through their roots, thereby promoting the aerobic digestion of organic material. Some anaerobic degradation of organic material also occurs in the bottom sediments. Wetlands provide a diversified micro-environment which plays an important role in pollutant processing. Various processes occur within the water column, on the plants, in the wetland substrate and in concentrated areas of microbial activity known as biofilms. Biofilms are formed as bacteria and microorganisms attach themselves to the plant stems, the plant roots and the substrate matrix to form a biological filter from the water surface to the wetland floor. As water passes through the thick growth of plants, it is exposed to this living biofilm, which provides a treatment process similar to that found in conventional sewage treatment plants.

4.3 Removal of COD by Constructed Wetlands

(Xie et al., 2018) Removal of organics is high in all types of constructed wetlands. While in FWS and VF constructed wetlands, the microbial degradation processes are mostly aerobic, in HF constructed wetlands, anoxic and anaerobic processes prevail. The treatment efficiency is similar for FWS and HF CWs, while for VF CWs the percentage efficiency is higher due to higher inflow concentrations. VF constructed wetlands are nearly always used for primary or secondary treatment while FWS are often used for tertiary treatment and HF CWs are often used for treatment of wastewater diluted with storm water runoff. However, the outflow concentrations for secondary treatment systems are comparable for all types of constructed wetlands.

The COD value has been reduced to a greater extent by constructed wetland treatment method. Before the treatment, the value was 1320 mg/l in the grey water sample. After the treatment the value was 220mg/l. The treated sample attained the limits for irrigation, so it can be used for it. The COD is removed with help of rhizomes in the plant system. The maximum removal efficiency in terms of COD was 67% for an average inflow of 1966 MgO2 L (590 -1 kghad) -1, 55% for BOD5 for an average inflow of 875mgL-1 (263 kgha-1 d) , the -1 maximum removal efficiency in terms of COD was 73% for an average inflow of 2093mgO2 L-1 (1256 kghad) -1

The milk house wastewater discharge had a COD average effluent concentration of 1400 mg/L. Chemical oxygen demand concentrations measured during the study period for the wetland effluent are plotted in Graph. The reduction of COD is about 75% to 80%.

In another study it was observed that when the influent COD concentration was controlled between 100 mg/ L–500 mg/L, which giving a COD loading rate between 0.05 and 0.5 kg COD/(m3 d), the effluent COD concentration of the three groups was in the range of 20 mg/L–120 mg/L (HRT = 24, 48 h). The COD removal rate was between 67.92% and 78.30%, and the MFC-CW was the most efficient treatment for COD degradation. The COD removal rate of CK, MFC and MFC-CW was 70.46%, 74.13% and 78.3%, respectively (HRT = 24 h), indicating that microbial electricity production and plant absorption may simultaneously contribute to the removal of COD. When HRT increased from 24 h to 48 h, the COD removal rate of CK increased slightly while the removal rate of MFC and MFC-CW showed an inverse variation, which implies that the extension of HRT did not help with the removal of COD in MFC and MFC-CW.

4.4 Removal of Nitrogen by Constructed Wetlands

(Johnson and Brooke, 1989) Wetlands promote the process of nitrification/denitrification which removes nitrogen from the water. In wetlands, the percentage of nitrogen removed is relatively small (about 30 percent) because of the low oxygen availability in the filter media. The largely oxygen-free conditions -in the substrate of the bed limit nitrification, the first step in (biological) nitrogen removal. Some nitrogen is taken up by the plants growing on the wetland, but the amount is usually small compared with the amount of nitrogen loaded into the wetland by the wastewater.During 4the process, bacteria in the water (Nitrosomonas) oxidizes ammonia to Nitrite in anaerobic reaction. The nitrite is then oxidized aerobically by another bacteria (Nitrobacter) forming nitrate. Denitrification occurs as nitrate is reduced to gaseous forms under anaerobic conditions in the litter layer of the wetland substrate. This reaction is catalyzed by the denitrifying bacteria Pseudomonas spp. and other bacteria. Wetland plants play an important role in nitrogen removal by providing bio film attachment points and by supplying oxygen for nitrification in the root zone.

4.5 Plant Functions

(Campbell et al., 2018) The vegetation used in CW's performs a variety of functions. These include cleansing, facilitating in the sorption of nutrients, filtering out suspended solids, and through the use of appropriate emergent vegetation odours and pathogens can be controlled. The choice of vegetation used is therefore of tremendous importance if the ICW system is to be effective. Through research carried out by Burton et al (2007) it was found that the plants within a constructed wetland should differ and be sub-divided into regions, they claim that "The first region should be planted with a combination of Carex (common sedge) and Zantedeschia aethiopica (Arum Lily). The second region should be planted with Zantedeschia aethiopica (Arum Lily) and Typha capensis (Bullrush). Region three should be planted with Arum lilies and Region 4 should be planted with Persicaria decipiens (willow-weed)." However making no mention of sub-divisions is whose opinion regarding the most appropriate choice of plant species also differs. It is believed that the common reed (Phragmites australis) should be used due to its ability to thrive in nutrient rich situations, combined with its high level of tolerance to pollutants.

Generally researchers' opinions do differ in this area; however it has become clear that it is recommended to choose a species that is indigenous to the area, hereby providing a high level of ecological value. As the common reed (Phragmites australis) is native to the British Isles it would seem to be an appropriate choice given its innate ability to survive in areas with vast levels of nutrients and pollutants.

4.6 Microbial fuel cell-Constructed wetlands (MFC-CW) System Configuration

(Xie et al., 2018) The main structure was made of organic glass with internal diameter 30 cm and height 55 cm. Gravels with diameter of 5–12 mm were used as a packing layer. The graphite was used as cathode and anode after being polished and drilled. Graphite is competitive with low-surface catalyzed cathodes in terms of cost and power production. The gravel and the alum sludge both provided alternative surfaces for the attachment and growth of bacteria. The anode was embedded into the packing layer while the cathode was placed at the air-water interface. This placement made the anode zone relatively anaerobic and the cathode zone more aerobic. A closed circuit was formed by connecting the electrodes to the external resistance with a copper wire. The water hyacinth was planted above the cathode in the MFC-CW system to ensure the cathode to get oxygen from both the atmosphere and the rhizosphere of the water hyacinth. The arrangement of MFC was same as the MFC-CW except that no water hyacinth was planted. A control group (CK) with no electrodes or plant was also constructed to investigate the direct degradation of microorganisms.

5. CONCLUSION

From this study it can be conclude that

1. The constructed wetland systems showed considerable potential for removing BOD, COD, TS respectively of waste water without use of any external source of electricity and chemicals.
2. CWs with vertical subsurface flow seem to be a viable alternative for reducing the organic matter content from wastewater, being able to tolerate inflow fluctuations, including interruptions in the feed.
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