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Constructed Wetlands:Green Technology for Wastewater Treatment – A Review

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ABSTRACT

One of the most vital resources for living organisms is Water. Although water is considered a natural resource but inadequacy of water quality is a big issue. For multiple decades, ConstructedWetlands(CWs) have been used as an environmental technology for wastewater treatment. Constructed Wetland could be defined as an engineered system that consists of a properly constructed basin that contains wastewater, a substrate, and is mostlyplanted with macrophytes. This review paper describes types of constructed wetland, the substrate used, vegetation and various types of wastewaters treated such as industrial waste, washing water, seafood waste, pig industry waste, landfill leachate, stormwater,domestic and municipal wastewater, etc. Depending on the water flow CWs are classified as Free water surface flow and Sub-surface flow. Free water surface flow CWs can be further classified on the basis of the type of vegetation (Emergent plants, Submerged plants, and Free-floating plants). On the basis of the direction of the flow, Subsurface flow CWs further subdivided into Horizontal flow and Vertical flow. Recently, Hybrid CWs are also used in order to achieve highefficiency. Materials (gravel, soil, rice straw, zeolite, etc.) used as a substrate also play a key role in wastewater treatment. CWs remove contaminants such as Organic material, Suspended solids, Nitrogen, Phosphorous, Heavy metals, etc from water through adsorption, sedimentation, filtration, volatilization, and plant uptake. The macrophytes used are Eichhornia crassipes, Typhalatifolia, Iris spp., etc. In recent times, microbial fuel cells are incorporated with CWs to enhance the ability of wastewater treatment andbioenergy production.The findings of the study suggest that constructed wetlands are an environment-friendly, sustainable, profitable, and efficient method for treating wastewater of various types.

Keywords: *Constructed wetlands, Wastewater, Vegetation, Substrate, Sub-surface.*

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INTRODUCTION

Earth, our planet is known as a blue planet as it has more than 326 million trillion gallons of water, 97% of which is salt water and less than 3 % is fresh water. Water is one of the most crucial natural resources which is required for almost all activities. Water pollution, water scarcity, water conflicts, and climate change are the major threats to water resources. Water pollution is the primarycauseof water impurity. In developing countries like India,the key causesof water pollution are Urbanization, Industrial activities, Social and religious activities, agricultural runoff, etc.The conventional method of wastewater treatmentinvolves primary, secondary, and tertiary treatments [1]. The primary treatment removes the large particles by sedimentation and the secondary treatment helps in the removal of organic matterwith the help of bacteria. The tertiary treatment is used to remove the undesirable matter that is not removed by secondary treatment.

For multiple decades, Constructed Wetlands have been used as an environmental technology for wastewater treatment. Constructed Wetlands (CWs) are a manmade engineered system that consists of a properly constructed basin that contains wastewater, substrate with macrophytes.

Dr. Seidel organized the first trial on the practicabilityof the treatment of wastewater with wetlands plants at the Max Planck Institute in Germanyin 1952 [2].Later in 1965, she designed a lab-scale constructed wetland consistingof horizontal and vertical flow beds with *Phragmites australis* for sewage treatment.Since CWs have become a dependable technology for the treatment of different kind ofwastewaters.

TYPES OF CONSTRUCTED WETLANDs

Constructed wetlands are categorised into different types, on the basis oftheirprecise characteristics, e.g., the direction of flow of water and the type of vegetation. Depending on the water flow in the system, the two broad type's i.e. Surface flow (Free water surface) constructed wetlands (FWS CWs) and Sub-surface flow constructed wetlands (SF CWs) [3,4,5].

Surface flow constructed wetlands

Surface flow CWs are designed as shallow basins containing substrate (clay or mud), and water depth up to 20-40cm. The substrate act as rooting soil for emergent macrophytes. The flow of water is typically horizontally with low velocity. The bottom of the wetland system is lined by an impermeable barrier to avoid wastewater seepage and contamination of groundwater. In free water surface CWs, the flow of wateris above the substrate and thus createsa free water surface and a few cm deep water column.

The application of Surface flow CWs includes secondary effluents treatment and storm-water runoff [5-7]. Suspended solids (SS) and biological oxygen demand (BOD) are removed effectively by the surface flow CWs system. Surface flow CWs highly effective in removing nitrogen (N), heavy metals (HM), and pathogens, while removal of phosphorous is minimal[4,5,8-10].

Sub-surface flow constructed wetlands

In Subsurface flow CWs (SSF CWs), the water flow occurs between the plant roots. The water flows inside the porous medium thus there is no water surfacing. Depending on the path of the flow of water, SSF CWs can be further categorized into Horizontal flow subsurface flow constructed wetlands (HSSF CWs) and Vertical flow subsurface flow constructed wetlands (VSSF CWs).

The Horizontal flow SSF is designed with soil or gravel bed sealed via an impermeable layer and planted with macrophytes. The flow of wastewater is usually horizontal through the substrate. The substrate is usually soil or gravel that provides support to the emergent plants. The porous substrate and plant rootssupport the improvement of the biofilm, which intensifies the removal of suspended solids (SS) and organic matter. The removal of nitrogen and phosphorous is usually at lower levels [5,11-13].

Compared to Surface flow systems, HSSF CWs are pricey, although the demand for area is small [5,14].

The vertical flow SSF CWs were formerlypopularized by Seidel to provide oxygen to anaerobic septic tank effluents. In vertical flow systems, the wastewater flows top to downward from planted layerthrough the porous substrate. Thecommon system includes substrates; sand or gravel layers with increasingdepth [11]. Thetreated water is collected at the bottom of the system which has a small slop and allows its drainage out of the system. The top of the bed is planted with the common reeds (*Phragmites australis*).

Many researchers have found the good efficiency of vertical flow SSF systems for the treatment of COD, BOD, and SS [15].

Vertical flow SSF are chiefly used for the treating domestic and municipal wastewater. They can be alsoused for the treatment of those wastewaterswhich has high amount of nitrogen ammonia such as dumpsite leachate, food processing wastewater, dairy wastewater,etc., byincreasing nitrification ability [5].

Hybrid Constructed Wetlands

Hybrid systems are a mixture of VF and HF systems in such a way that they complement one another, focusing onenhancing the overall efficiency of wastewater treatment[2,11]. Hybrid systems can be designed using many combinations of CWs of different flow types like HF-VF, SF-HF, SF-HF, VF, and so on.

At present, hybrid systems are used in different nations around the world.These systems are used especially for total nitrogen and ammonia-nitrogen removal[16]. Hybrid constructed wetlands are also used for the treatment ofshrimp and fish aquaculture [17,18], winerywastewater[19], landfill leachate [20], compost leachate[21],and slaughterhouse [22].

Various types of substrates:

The System of Constructed wetlands is mainly made up of substrate, which plays a major role in the wastewater treatment process [23].On the idea of features and origin of materials, the substrates are divided into different types such as conventional minerals, chemical products, biomass matter, industrial and municipal waste by-products, and new materials[24].

Conventional mineral materials like soil,gravel, sand, natural zeolite, limestone, etc. are the foremost extensively used substrates in constructed wetlands. The mostclassical materials chiefly used for the development of CWs are sand and soil for the development of macrophytes [25]. The most typicalsubstrate in CWs is gravel, and itisregularly usedin the pilot-scale study [26,27]. These conventional materials are found in nature;thus, they are ample, widely available, and cheap.

Chemical products are treatment substrates that are manufactured through naturally occurring substances or trash materials. These chemical products exhibit individual dominance in some aspects when compared with conventional mineral materials. Ceramics gives various advantagesto the raw materials, likehigh adsorption capacity, strong tensile strength, and steady crystal phases. By hyper-thermal decomposition, this process also removes organic pollutants and infectious materials [28].

Chemical products such as ceramic and synthetic zeolite, conventional materials such as medicinal stone and biomass materialsuch as oyster shells, whichremovesantibiotics and antibiotic resistance genes (ARGs) in constructed wetland systems.The most efficientperformance is shown by zeolite due to Si-OH structures and micropores [29].

Biomass materials are organic andinorganic matter, obtained from animal and human waste, aquatic waste, agriculture waste,household, and industrial waste, wood waste, etc.[30]. Thesematerials may be used as sources of carbon and nucleophiles in biological processes. At cold temperature conditions, rice straw was used as a medium in floating CWs which removes the nitrogen containing compounds[31].The physicochemical attributes and adsorption capabilitiesof differentsubstrates are compared. Theresults indicate that phosphorous is efficiently absorbed by oyster shell and oyster shells, zeolite, and broken bricksare suitable for the growth and development of microbes and macrophytes[32].

Industrial activities and urbanization release by-productsof about 3.4–4.0 billion tons, every year globally [33]. In constructed wetlands,non-hazardous waste productsare used as substrates, which is a cheap and sustainable method for waste disposal. Broken bricks, residue from drinking wastewater treatment, furnace slag, saw-dust, polyethylene waste, etc. are used as substrate in CWs [34-36]. Lima et al., 2018 [37]comparedthe pollutant removal efficiency for different substratessuch as clay aggregates, broken bricks, and gravels and found that the broken brick substrate ismost effective for total nitrogen and total ammonia nitrogen removal.

With the expansion of CWs, several substrate materials are altered for increasing the treatment efficiency. In CWs, novel materials are used as substratemedium. Several materials are modified for increasing the function of substrates, like pore structure, adsorption capacity, acidity and basicity, water permeability and biocompatibility. Biological ceramsite, thermally-modified attapulgite,altered sustainable ceramsite and metal-altered zeolite have separate advantages in comparison to raw materials in CWs.[28, 38-40].

With the advancement of technology, some new materials are used as substrates in CWs. The newly developed materials mainly include porous geopolymer, light expanded clay aggregates, polysiloxane/micro-sized alumina, etc. [23, 41, 42]. These materials showed important advantages in treatment capability, high tensile strength, and long durability. These features deliver the utilization potential for novel materials.

The categories and arrangement of substrates are influenced by different factors like: pH, salinity, dissolved oxygen, hydroperiod, macrophyte growth, and microbes [43, 44].

Different types of substrates have different distillation abilities. Addition of organic matter to the substrate increases the temperature of the substrate and hence improves the efficiency of the organic matter and nitrogen removal [45]. When gravel and breakstone were used as substrate media, features like plant density, change in temperature, and wastewater influent concentration were found highly correlated with the efficiency of treatment [46].

Difference substrates have different adsorption capacities for pollutants, so the efficiency of pollutant removal is also different. By modifying the substrate, the removal efficiency of pollutants can be improved [29, 47].

Table 1: Classification and materials used as substrate in CWs.

Classification	Material used	References
Conventional mineral materials	Sand, Gravel, Soil, Natural zeolite	25, 26, 27
Chemical products	Ceramsite, Synthetic zeolite, Industrial zeolite, composite substrate	29, 48, 49
Biomass materials	Rice straw, Oyster shell, Biochar, Reed residue	32, 49, 50
Industrial and municipal waste products	Broken brick, residue of drinking wastewater treatment, saw-dust, polyethylene waste, Furnace slag	34, 35, 36
Modified functional materials	Biological ceramsite, Metal altered zeolite, Sustainable ceramsite.	28,38, 39, 40,
Novel material	Polysiloxane/micro-sized alumina, Porous geopolymer, clay aggregate,	23,41,42,

Macrophytes in Constructed Wetlands:

In Constructed wetlands, plants are the important components as theyplayseveralroles in wastewater treatment. The aquatic plants growing within the constructed wetlands are called macrophytes. Macrophytes are photoautotrophic in nature as they use solar energy to assimilate inorganic carbon into organic matter. Macrophytes include aquatic mosses, vascular plants (angiosperms and ferns), and a few larger alga.

According to the source of life forms, macrophytes growing in the CWs are divided into three major groups[51-53]:

Emergent aquatic macrophytes: These are the governing life form in wetland systems. They mainly grow below 50cm to the soil surface and 150cm depth in water. These plants have leaves,aerial stems,deeproots, and a rhizome system. Plants that growin the marshy or immersed substrate are morphologically adaptedto provide air spaces for oxygentransport to roots and rhizomes. These life formsinclude*Phragmites australis*,*Typhalatifolia*, *Iris* spp*., Juncus eftusus,* and S*cirpus validus*[55-57].

Floating-leafed aquatic macrophytes: Plant species that are rooted in the substrate and free-floating at the upper surface of the water. *Nymphaea* spp., *Nuphar* spp., *Potamogetonnatans,Hydrocotyle vulgaris*, etc. were macrophytes that are rooted in substrate. Free-floating includes*Pistia stratiotes, Eichhornia crassipes*, and *Lemna* spp. [58-60]. The free-floating plant species are diverse in nature and habitat, ranging from rosettes plants with aerial floating leaves and matured immersed roots such as *Eichhornia*, *Hydrocharis*, and *Trapa*, to surface-floating plants without roots such as *Azolla*, *Salvinia*, and Lemnaceae family.

Submerged aquatic macrophytes: The photosynthetic material of the plantis fullyimmersed in water and the floral part isfreeto the air.Elodeid and Isoteid are two major kinds of submerged macrophytes. Elodeidtype mainly includes *Ceratophyllum, Elodea, Myriophyllum*, etc., and isoetid type includes *Lobelia, Isoetes, Littorella*, etc.

Major roles of macrophytes:

In CWs, the macrophytes grown havemany assetsrelevantto the processof wastewater treatment. Physical effects, root release, plant uptake, and surface area for growth of microbes are the foremost important effects of the macrophytes in treatment process.

Physical Effects: Macrophytes diminish and distribute the velocity of the water current. These help to createhealthierenvironments for suspended solids sedimentation, reduce the risk of soil erosion and re-suspension. Macrophytes also amplify the period of contact between the roots of plants and water [61, 62]. Due to the presence of dense and deep root systems, wetland plantssupportstabilizing thesurface soilofCWs as the root system helps the reduction of soil erosions.As a consequence of wind, the movement of plant keep the open surface, and the roots within the substratehelp in the degradation of organic matter and also prevents clogging.

Surface area for attached microbial growth: The stems and leaves of plants that are submerged within the water provide a large expanse for biofilms. The rhizomes androots which are deep act as a substrate for thegrowth ofmicroorganisms [63]. Biofilm formation takes placeat the above and below-ground tissue of the macrophytes. These biofilms are answerable for the majority of the microbial activities that occur in wetlands.

Nutrient Uptake: The rooted macrophytes through their root systems take up nutrients for growth and reproduction. Sometimes the nutrient uptake also occurs through submerged stems and leaves from the nearby water. The uptake capacity and removal efficiency of emergent macrophytes after biomass harvesting, is roughly in the range of 30 to 150 kg P ha-1 year-1 and 200 to 2500 kg N ha-1 year-1 reported by many researchers[52, 64-66].Majority of the nutrients which are not utilised by plant tissue will return to the water by decomposition processes if the wetlands are not harvested.

Root Release: The aquatic macrophytes roots release oxygen into the rhizosphere and through the effects on the redox status of the sediments this released oxygen enhances the biogeochemical cycles[67, 68]. The rate of Oxygen release from roots mainly depends on inner oxygen concentration, demand of oxygen by the surrounding medium, and the root wall permeability [69]. Many other substances other than oxygen are also released by root systems. Dr. Seidel also reported release of antibiotics from the roots of bulrush *Schoenoplectus* in her study at Max-Planck Institute in Germany.

Other Roles: The macrophytes in constructedwetlands also played several functions that are not much associatedwith the treatment processes. In large wetland systems, theplantsalsosupport diverse fauna [70-72]. As natural wetlands andthe habitat of wildlife has been destroyed at a high rate in many places it could be of great importance. Another important functionis the aesthetic value of the macrophytes insmall systems serving single houses, hotels, etc. If selected plants arebeautifulsuch as*Iris pseudacorus* (Yellow Flag) or *Canna* spp. (Canna Lilies), this will give treatment system an aesthetic appearance.

Macrophytes planted in the constructed wetlands systems have many properties associated with the wastewater treatment process.Macrophytes are the main source of oxygen in the root zones through a process called radial oxygen loss (ROL) [73]. Due to the anaerobic nature of the main environment of the constructed wetland, there is less pollutant removal. The ROL helpsin the acceleration of pollutants removalas it favors an oxygen rich micro-environment. Hernandez et al.[74] compared the high plant density of 32 plants m^{-2} and low plant density 16 plants m^{-2} sizeconstructed wetlands and observed that the removal efficiency of nitrogen compounds in high plant density CWs was twicethat low plant density CWs, which is robust evidence of the importance of plants in such systems. In asimilar study of 35 different plant species, total nitrogen (TN) and total phosphorous (TP) removal rate was also positively correlated with the ROL of wetland plants [75].

Some studies have given evidence that there is a positive effect of vegetation in natural wetlands on removal of organic matter, nitrogen compounds and phosphorus compound in constructed wetlands when compared to systems without vegetation [76,77]. Removal efficiency of total nitrogen (97%) and total phosphorous (91%) in planted while, in systems without plants, the removal efficiency for total nitrogen (53%) and total phosphorous(61%)in constructed wetlands planted with *Phragmites australis* [78]. Removal of fluoride ions in constructed wetlands, was found to be 20% lower than in systems with vegetation [79].

Type of wastewater treated in Constructed Wetlands:

Javeed et al. [80] reported the use of Constructed wetlands system to treat tannery and mixed industry effluent. For the treatment process, three horizontal surface flow wetlands were constructed and planted with *Hemarthria compressa*. After sixty days of water treatment, there was a percentage decline in heavy metal concentrations of zinc(35.83-95.59), chromium(30.63-95.49), copper(24.3-97.05),and nickel (20.3-93.2). The drop-in chemical oxygen demand, total dissolved salts, pH,and electrical conductivity were 72.14%, 98.75%, 11.72%, and 92.92%, respectively. Heavy metal tolerance index for the *H. compressa* was 0.25-3.25 and 0.25-2.2, respectively for tannery and mixed industry effluent. The final treated water was proved safe for the cultivation of *Abelmoschus esculentus*. The results revealed that constructed wetlands planted with *H. compressa* effectivelyhelps in reduction of pollutant concentration in the industrial effluents and also act as a sink for different heavy metals.

United Nations International Children's Emergency Fund first proposed the modernization of Toilets. Central government of China in 2017, proposed toilet modernization to enable thousands of villages to separate their faces and urines from the washing wastewater. Li et al. [56]selected a village to treat the washing wastewater in four different subsurface constructed wetlands and reuse it. Five typical households include kitchen rinsing, wash basin, bath, laundry and miscellaneous wastewater collected and mixed. The four constructed wetlands were designed, including gravel without plants(CW1), wetlands with plants and gravel(CW2), plants with an improved substrate (CW3), and plants with an improved substrate modular (CW4), with a plant density of 30 plants/m^2 size with reeds and irises.The experiment was carried out for approx. 6 months. The results showed that the average washing wastewater production was 121 L/(cap .d) with the highest quantity production of 46.19% by bathing wastewater. Chemical Oxygen Demand(COD) is analysed as a crucial pollutant with an average concentration of 337 mg/L. After being treated with constructed wetlands, the removal rates of Chemical Oxygen Demand(COD) was 61.5%, Total Nitrogen(TN), and Total Phosphorous(TP) were68.8%, and 70.5%, respectively. Constructed wetlands with modular design had positive effects on the removal of nitrogen and phosphorous but little removal of COD. The treated water is used for irrigation in paddy fields. Constructed wetlands with combined substrateswere considered an appropriate technology for washing water in China.

Glass industry generates wastewater rich in organic matter and suspended solids. Gholipour et al. [81] in his study designed a horizontal sub-surface flow constructed wetlands to treat glass industrywastewater.The constructed wetlandsfor pilot scale and full scale was planted with pampas grass (*Cortaderia selloana*) using natural gravel as substrate. The average concentrations of COD, BOD, TN, TP, and TSS in inflow were 3690mg l^{-1}, 127 mg l^{-1}, 4.0 mg l^{-1}, 0.66 mg l^{-1}, and 9624 mg l^{-1}, respectively. The removal efficiency of COD, BOD, TN, TP, and TSS were 90%, 90%, 92.5%, 86.4%, and 99.8% respectively. The results revealed very high removal efficiency of said pollutants which allows the reuse of treated water.

Sudarsan et al. [54] designed a subsurface flow constructed wetland at SRM University, Tamil Nadu, India to treat domestic wastewater. Constructed wetland was designed as per EPA 1986 manual with the dimension of 0.7*0.4*0.3m.Gravel and sand were used as substrates, planted with *Typha latifolia* and *Phragmites australis*for the reduction in pollutant levels. Different physio-chemical properties of wastewater were analysed for both the vegetation*T. latifolia*and *P. australis*, the removal percentage for BOD was 75% and 65% and for COD was 70%. The results revealed that *T. latifolia* was slightly more efficient than *P. australis*. For removal of pollutants. From the study, it can be concluded that for treating small community domestic wastewater this technique is efficient with minimal installation, operating and maintenance cost.

Wastewater from Seafood processing produced suspended solids, organics, and nutrients types of highly concentrated pollutants. Discharging of these type of pollutants may deteriorate the quality of the aquatic environments [82]. To evaluate the feasibility of constructed wetlands to remove the pollutants from seawater processing wastewater Sohsalam et al. [83] conducted an investigation. He observed the pollutants removal efficiency of six emergent macrophytes (*Cyperus involucratus*, *Canna siamensis, Heliconia spp*., *Hymenocallislittoralis*, *Typha augustifolia* and *Thaliadeabata* J. Fraser) with one control and Hydraulic Retention Times (HRTs) period of 90 days by three levels; 5 days, 3 days, and 1 day ina surface flow constructed wetland of dimensions 0.6*2.0*0.5m filled with gravels. The influent seafood wastewater was50% diluted with treated seafood wastewater. The highest treatment efficiency was found for 5 days HRT with all emergent macrophytes. The mean percentage removal efficiency of BOD, SS, TN, and TP were 91-99%, 52-90%, 72-92%, and 72-77% respectively.The study revealed that surface flow constructed wetland could be used for seafood wastewater treatment with a high removal efficiency.

Dias et al.[55] conducted a study for the removal of metals from pig industry effluentsusing constructed wetlands by maintaining the organic matter and nutrient level for later use as fertilizers. He designed six vertical sub-surface flow constructed wetlands with first layer of gravel. Out of Six three systems were filled with a second layer of lava rock and the other three with clay aggregates. Finally, the third layer was filled withsand in all six systems. *P. australis* was first used for experiment and the next with transplanting *T. latifolia*.The results showed that the percentage removal of metals(Cd, Cr, Cu, Fe, Mn, and Zn) wasmore than 80% in constructed wetlands planted with *T. latifolia* while more than 60% in constructed wetlands planted with *P. australis*. The removal rate of organic matter was more than 77% with no significant change between substrate or plants. The percentage removal of ammonium and phosphate ions in constructed wetlands planted with *P. australis* ranged between 59-84% and 32-92% respectively, while in constructed wetlands planted with *T. latifolia* ranged between 62-75% and 7-68% respectively, with no significant change betweensubstrates. The results revealed that constructed wetlands had the efficient potential for removing toxic metals. The reclaimed water had a moderate amount of nutrients that can be used as fertilizers in agriculture.

Akinbile et al. [84]conducted a study for treatment of landfill leachate in constructed wetlands. He designed sub-surface flow CWswith *Cyperus haspan*with sand and gravel as substrate medium. The experiment was conducted for three weeks of retention time. Samples were taken from both the influent and effluent water and were tested for pH, turbidity, color, TSS, COD,BOD, NH_3-N, TP, TN, and also for heavy metals such as Fe,Mg,Mn, and Zn. The results showed that the percentage removal efficiency of pH, turbidity, color, TSS, COD, BOD, NH_3-N, TP, and TN were 7.2–12.4%, 39.3–86.6%, 63.5–86.6%, 59.7–98.8%, 39.2–91.8%, 60.8–78.7%, 29.8–53.8%, 59.8–99.7%, and 33.8–67.0%, respectively. The percentage removal of heavy metals was 34.9–59.0% of Fe, 29.0–75.0% of Mg, 51.2–70.5% of Mn, and 75.9–89.4% of Zn. Study proved that leachate may be treated effectively using subsurface constructed wetlands with *C. haspan* high removal efficiencies.

Kao et al. [85] conducted a study on constructed wetlands to remove non-point source (NPS) pollutants from stormwater. A field-scale constructed wetland was constructed which received 85m^3 per day of untreatedwater from the storm drain. CWs planted with *Pistia stratiotes* and *Phragmites communis.* Samples were analyzed for TSS,NO3 –,TP, pH, NO2 –,NO4 +, COD, and DO.Results indicated that the constructed wetland showed a significant amount of NPS pollutant. The percentage removal was more than 88% forTN, 81% for COD, 85% for heavy metals, and 60% for TSS.

Recent advancements in CWs

In recent times, researchers' interest in microbial fuel cells is increasing day by day[86].India's energy (power) sector is attempting to address the issue of producing sufficient power to feed the country's developing economy. This expansion of the power sector, however, must adhere to the principles of sustainable development. Maximizing efficiency across the entire electricity chain is also given priority, which has the dual benefit of saving precious resources while also reducing environmental impact. In order to fulfil the energy demand on sustainable basis Microbial Fuel Cell is a new innovative technology that can be used.

Microbial Fuel Cell (MFC) technology is a new approach to wastewater treatment that captures energy in the form of organic matter and converts it to electricity or hydrogen gas. Potter initially reported the creation of electrical current by bacteria in 1911, but even 55 years later, little progress has been made in this subject. MFC development accelerated in the early 1990s. [87]. Microorganisms break down (oxidise) organic matter in an MFC, producing electrons that are transferred exogenously (outside the cell) to a

Terminal Electron Acceptor like iron oxide. Exoelectrogens are bacteria that can transfer electrons exogenously, the process is called electrogenesis, and the reactor is a microbial fuel cell (MFC).

The bacteria grow on the surface of the anode, oxidizing organic matter and releasing electrons to the anode and protons to the solution. The protons are transferred to the cathode via proton exchange membrane and the electrons move through wire via external load. The cathode was sparged with air to provide dissolved oxygen for the reactions of electrons, protons and oxygen at the cathode, with a wire (and load) completing the circuit and producing power. The voltage across the load is measured using a multimeter attached to a data acquisition system and from the measured voltage current and power are determined.

MFC is a self-sustaining system because the bacteria in it are self-replicating and self-sustaining, exploiting the organic materials in the waste for bioenergy generation. In any wastewater treatment system, MFC can replace the anaerobic digester and the trickling filter system. It can remove BOD in the same way that the standard AS (Activated Sludge) aeration tank or the TF can because it is a biological treatment method (Trickling Filter).Some important benefits of MFC’s are;

By incorporating MFCs into CWs the potential of the wetlands to treat wastewater without oxygen is improved. In cold climates it ac as protective layer to prevent the wetland from freezing [88] thus reduce the oxygen diffusion into the wetland [89]. For treating high-strength wastewater [90] or desirable for energy input can be reclaimed by the inclusion of MFCs [91, 92]. CW-MFCs have high removal efficiency of different types of pollutants in comparison to CWs. However, less CEs indicate that this can be not an on-the-spot response to the current generation. For increasing the electrical output new operational strategies must be explored to reduce the electrode spacing while maintaining the desired redox conditions within the system. This remains an area which required more emphasis and required deep research.

CONCLUSION

This review illustrates that constructed wetlands are an environment-friendly, sustainable, cost-effective, and efficient method fortreatment of various kind of wastewatersuch as municipal, industrial, washing, stormwater, and landfill leachate. Constructed wetlands are manmade systems that contains wastewater, media, and macrophytes. Constructed wetlands are broadly of two types, Surface flow and Subsurface flow CWs. Recently,Hybrid CWs are used to increase the overall efficiency of treatment. Substrates alsoplay a central role in the pollutant removal. Different types of substrates such as soil, gravel, zeolite, rice straw, biochar, etc. Macrophytes are an importantcomponent that plays severalsuch as physical effects (sedimentation, re-suspension, erosion control, filtration), Nutrient uptake, Root release, etc. In large wetlands, the vegetation also supports diverse wildlife, including birds, etc. The macrophytes also provide an aesthetic value. In recent times, MCFs are incorporated into CWs which improves the efficiency to treat wastewater and also acts as a source of bioenergy.

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