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Wastewater Pretreatment Methods for Constructed Wetland: A Review

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ABSTRACT

The constructed wetland (CW) performance depends on constructed wetland, bed media, and vegetation variations. This study represents a descriptive review of wastewater methods for wetland construction. The wastewater generation includes dairy waste, textile waste, piggery waste, petrochemical waste, tannery waste, etc. This review summarizes constructed wetlands variations, including vegetation, efficiency removal, maintenance, and construction cost. The fundamental definition of CW is that it is an eco-friendly technique to remove the pollutants from the wastewater and is mostly used by petroleum refineries, municipalities, the drainage system of agriculture and so on. Earlier, multiple innovations in the microbiology field eventually correlated with wastewater contaminants removal techniques. This review provides a brief review of the CW key aspects, like the CW types, challenges, opportunities, applications, materials, the recent advances. It also covers the current-technical advancement evaluation report and frames the unsolved CW problems. The terminology on the performance metric demonstrates that the CW community is growing rapidly. This manuscript has also mentioned an outline of the future trends and research proposals.

Keywords- Constructed wetland, nutrients, wastewater, organics.

I. INTRODUCTION

Environmental consciousnesses have grown in the past decade, and the remediation of environmental contaminants is becoming a top priority for worried public bodies across the globe. Typically, an appropriate environmental cleanup approach for a specific waste material is chosen based on the efficiency of the degrading phase as well as the method's cost [1–3]. More significantly, the ecological impact of the chosen approach is of particular concern since the daughter product of the decomposition processes in some restoration procedures is more harmful than the initial contamination. Researchers and scientists think there is no one universal restoration strategy that is efficient for different types of pollutants and all causes; rather, a helpful solutions program may require the collaborative use of two or more technologies [1,2]. Wetlands are among the successful cleanup options that environmentalists are presently pursuing to remediation industrial effluents [2].

CW is designed frameworks that have been planned and developed to use the regular cycles, including vegetation, and the related microbial gatherings, to help with wastewater treatment. They are intended to exploit a considerable lot of the same cycles that happen in regular wetlands yet do as such inside a more controlled climate. The treatment of wastewater might be characterized by the existing type of the ruling macrophyte, into free-floating frameworks, new and lowered macrophytes [1]. A descriptive flow diagram has been shown below (fig 1) that represents the types of CW in a simple schematic form.

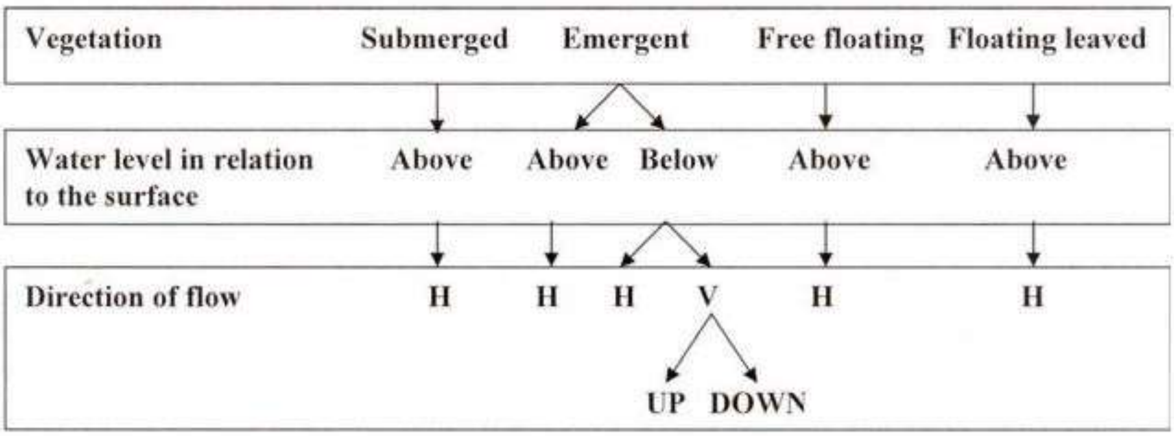

Figure 1: CW types for pretreatment of wastewater (H=Horizontal, V=Vertical)

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In the last few years, the awareness about the environment has recently increased, the government bodies have recently become more conscious of environmental pollution worldwide. Generally, an appropriate ecological remediation technique for a specific kind of waste is chosen in light of the viability of the corruption cycle and the expense of the strategy.

However, in some cases, the degradation process product is comparatively more toxic than the main contaminant; hereby, the major concern is to select the method very precisely. As per the researchers and their study report,no single method can remove all contaminant types. However, they suggest all methods together will be an effective solution [2,3]. The wetland is becoming a major sector for the top researchers nowadays to provide a highly technical advanced method for the contaminant treatment [3].

Wetlands are defined as soil saturation for a sufficiently long period to create the anaerobic circumstances. There are different wetlands, including salt-water and normal fresh wetlands and CW [3]. Wetlands built for remediation of impurities coordinate comprehensive cycles that include water, creatures, soil, microorganisms, plants, and the climate.

CW carried out different remediation techniques, including phytoremediation, biodegradation, and normal lessening [5]. The principle processes in wetlands consist of physical processes, for example, sedimentation and filtration, reactive chemical processes like precipitation and adsorption, and natural processes like plant digestion and biodegradation [6]. Most of the wetlands are described by vascular plants with high thickness. High-thickness vegetation brings about easing back the water stream, making microenvironments, and giving sorption locales to pollutants and microorganisms connections destinations [7]. The plant's termination creates extra sorption and trade locales.

Moreover, plant trash is an appropriate source of natural carbon furthermore supplements like phosphorous and nitrogen for the digestion of microorganisms. The oxygen fixation is exceptionally low in wetlands because of soil immersion conditions. In this manner, the wetlands vegetation is restricted to species that can develop at low oxygen fixations [7].

Figure 2: An example of free water surface constructed wetland [8]

Microorganisms assume a predominant part in the foreign substance corruption process in changing the defilement between the climate and the plant. Ordinarily, a microbial consortium is associated with changing processes and impurity degradation [8]. However, to degrade into a particular contaminant, every microorganism follows definite degradation pathways. The outcome of the course of foreign substance degradation depends on the presence of microorganisms expected for the degradation process [9,10]. Worldwide CW is used for wastewater treatment. For example, CWs have been utilized in Europe since the last century; the primary country to involve CWs was Germany [11]. Nations like Switzerland, the United Kingdom, Slovenia, Denmark, and Austria have CWs inactivity. A few nations in Africa have utilized CWs, like South Africa, Seychelles, Kenya, and Tanzania. A few insights show that the expense of subsurface CWs in Africa for

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wastewater treatment is around $4.5 per individual, contrasted with mechanical wastewater treatment, which costs about $52 per individual [10,11]. A review reported that the treatment of wastewater generally varies between €0.02-€0.85 per m^3 [12].

The primary CW functions are to remove the contaminants and treat the wastewater by applying degradation, creating a storage system, controlling floods, and recycling nutrients [13]. In any case, the value of the wetlands in corporate giving sporting facilities and giving appropriate information for study purposes. The benefits of CWs include (a) the low development cost contrasted with other remediation strategies, (b) a harmless to the ecosystem approach that is seen with favor by the general population, (c) somewhat low upkeep and activity costs, (d) high adaptability in the scene plan to give natural surroundings to untamed life and creatures, and (e) wetlands work with the reuse of treated water. In spite of the fact that they enjoy incredible benefits, there are a few restrictions of CWs that incorporate (a) requiring huge land regions contrasted with the other remediation techniques, (b) the irregularity of the treatment contrasted with the other wastewater treatment strategies, (c) not appropriate to treat assuming the release ought to satisfy explicit guidelines, (d) alkali and pesticides unfavorably affect the plants and microorganisms, and (e) low resilience of close total drying conditions.

II. HISTORICAL DEVELOPMENT

Natural wetlands have historically been used in suitable effluent and municipal wastewater facilities. As a result, many wetlands, such as marshland, were nutrient-saturated, resulting in significant environmental damage. Dr. Seidel, a German scientist, conducted the first studies on the possibilities of wastewater treatment with wetland plants at the Max Planck Institute in Germany in 1952. (Seidel, 1965). The application of CWs to treat diverse types of wastewater, such as industrial wastewater and stormwater, resulted in significant growth in the number of CWs in the 1990s [8]. In many regions of the globe, manmade wetlands for wastewater treatment are becoming increasingly common. Today subsurface flow CWs are quite common in many developed countries such as Germany, UK, France, Denmark, Austria, Poland, and Italy. Constructed wetlands are also appropriate for developing countries, but they stillhave to become better known [9-11].

III. WETLAND TREATMENT SYSTEMS

The CW is classified according to the different criteria scope like macrophyte types, hydrology and flow path. The CW types include SSF (Subsurface flow wetlands), SF (Surface flow), and hybrid systems.Some wastewater treatment units are designed to promote the aerobic set of reactions, while the rest are for the anaerobic. An aerated CW is the air pump incorporated in the wetland connected through the air distribution networks [14]. The mechanism behind the air bubbles generated from the pump helps accelerate the rate of oxygen transfer in vertical and horizontal flow types of wetlands to create the aerobic condition.

Engineers and researchers utilize different terms to depict the term wetlands. however, for example, in FSF (free-surface flow), the wastewater's outer layer flows over the dirt [3,4,13]. On the other hand, a few researchers utilize the SF surface term flow to signify FSF. Moreover, SSF or sub-surface flow framework where the wastewater streams evenly or in an upward direction to such an extent that the water level is beneath the ground's surface. The HSSF is utilized for level subsurface stream or, on the other hand, SSHF subsurface even stream. The terms SSVF and VSSF are utilized individually for the upward subsurface stream or vertical subsurface stream (Fig 3).

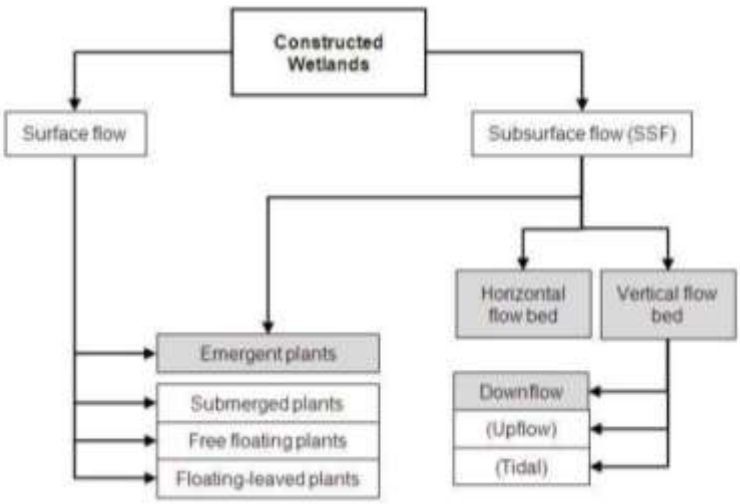

Figure 3. Classification of constructed wetlands

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IV. SURFACE FLOW

SF wetlands are where the outer layer of the wastewater stream is over the soil [15]. SF is composed of sandy soil and clay to help the underlying foundations of the plants and water control structures that keep a shallow profundity of water over the dirt [13,16] (Fig 3). The soil's lower part is fixed to keep up with water inside the framework. SF wetlands can be utilized to treat wastewater while supporting natural life living spaces. In SF the oxygen is directly proportional to depth [17].

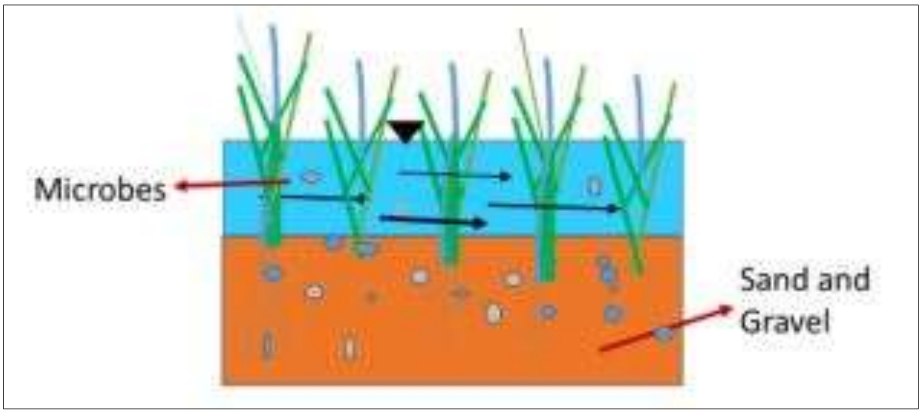

Figure 4: Surface flow schematic

As per the level of water threshold, the topmost layer, i.e., close to the water's surface, has a high level of oxygen, whereas the bottom has a low or 0 concentration of oxygen [3]. In this manner, the topmost layer supports the aerobic process taken as nitrification; the base layer represents the anaerobic that is taken as the denitrification process. The benefits of SF wetlands are the operational and construction cost is comparatively low than the SSF wetlands, and it has a simple technology.

V. SUBSURFACE FLOW

The SSF wetland is made out of permeable soil i.e, gravel and rock fixed from the base [8,18]. The soil level will be on top then the water level stays (Fig 4). The stream way in the SSF wetland is either a level or vertical stream way. SSF wetlands are appropriate for the treatment of wastewater, given that the strong fixation in the wastewater is low. For a high strong focus on the wastewater, sedimentation tanks or bowls are utilized to eliminate the solids from the wastewater. The primary benefits of SSF wetlands incorporate resistance to cold climate, fewer smell issues contrasted with SF wetlands, more prominent sorption and trade destinations contrasted with SF wetlands, and effective utilization of the land contrasted with SF wetlands. SSF wetlands can be built underneath recreational areas because the water level is beneath the ground surface. The restrictions of SSF wetlands incorporate their more significant expense contrasted with SF wetlands, utilized for little streams and pore obstruction [14, 19].

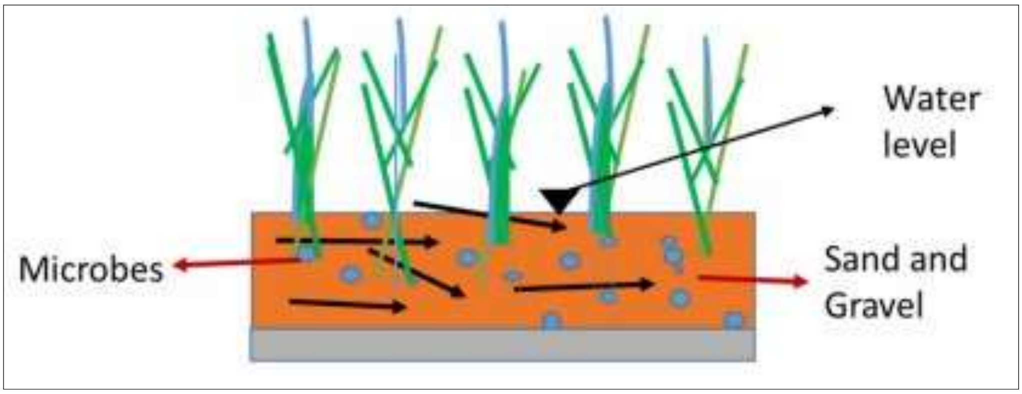

Figure 5: SubSurface flow schematic

The SSF with the CW is generally used to deal with the high oil-water production that contains gelatinoid, asphalt, polymers, wax, and surfactants. The CW in this has been highly successful to treat oil-water

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high output. The prior research shows that COD removal is significantly associated with DO concentration. The COD efficiency removal depends upon the organic rate of loading and conditions of anaerobic. Wetlands developed using vertical subsurface flow (SSVF) have an excess of oxygen. Soil holes were periodically supplied and emptied with water, resulting in an aerobic atmosphere conducive to specific bioactivities, including nitrogen removal or particle breakdown. Subsurface horizontal flow (SSHF) built wetlands have highly anaerobic, or anoxic, conditions inside the wetland bed medium. Under these circumstances, oxygen transmission at the soil-air interface is reduced, facilitating anaerobic biochemical activities such as nitrate denitrification to elemental nitrogen and sulfate reduction to hydrogen sulphide.

VI. HSSF (HORIZONTAL SUBSURFACE)

The HSSF is made out of a channel situated below the surface of the ground. The channel is loaded up with definite sizes and types of sand and gravel [8].The above channel is created with a reasonable plant. during the channel design, certain types of considerations need to be taken care of. For example, the flow of water in HSSF is planned to such an extent that the water level is beneath the surface of the ground. The wastewater needs to be cleaned from solid particles before channel entrance for clogging avoidance [18].

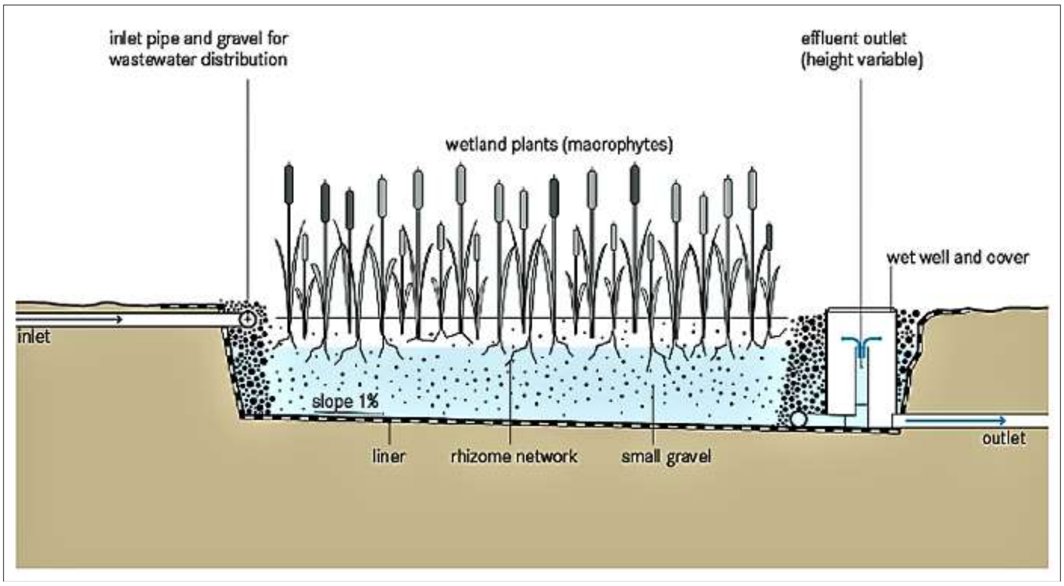

Figure 6: HSSF Schematic [20]

VII. VSSF (VERTICAL SUBSURFACE)

The VSSF stands for wetlands designed for the vertical flow of water, same as the HSSF in VSSF; the filtration has been done before the water enters the channels of CW [21]. However, in VSSF, the flow is done either by pumps or gravity. Primary considerations also need to be taken care of in the case of VSSF design (Fig 6). The percolate time requirement of wastewater in VSSF needs to be calculated precisely. VSSF flow is controlled by varying the intermittence loading and loading event intervals. The mechanism behind this is that the roots of the plant transfer oxygens and allow the diffusion of oxygen to the subsurface [22]. This is the reason for the high oxygen threshold in the VSSF, which encourages the aerobic growth of bacteria. In this way, the VSSF upgrades aerobics' degradation and nitrification are considered reasonable. Past investigations discovered that VSSF advances a broad scope of purifications and degradation processes, including adsorption, biodegradation, filtration, and precipitation. It has been concluded that organic matter and solid removal VSSF is highly successful. As the VSSF requires less space, it has less capital cost value than HSSF.

These might well be controlled in four modes: intermittent downflow, unsaturated downflow, saturated up- or downflow, and tidal flow. Irregular downflow is distinguished by washing the wetland's surface at irregular periods. Unsaturated downflow is distinguished by the distribution of water evenly across the surface of the wetland bed media, which then trickles through the medium and is frequently used in a recirculating fluid flow. Saturated up- or downflow employs continuous downward or upward flow to optimize soil saturation.

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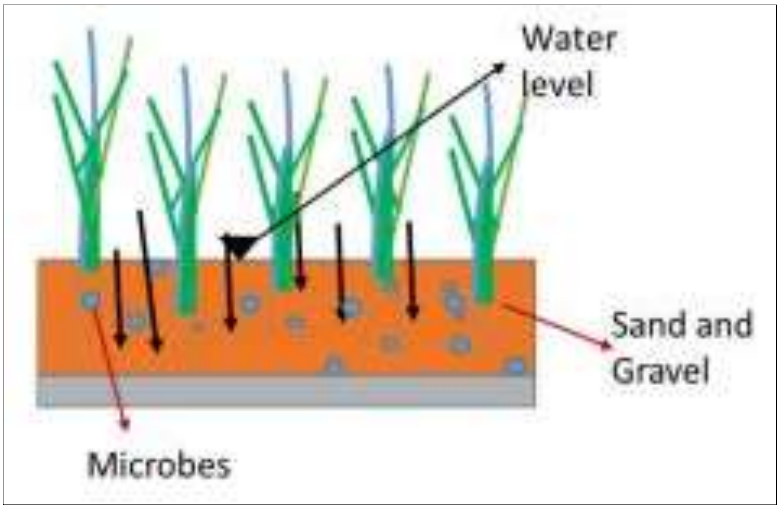

Figure 7: VSSF Schematic

VIII. CONSTRUCTED WETLAND: MEDIA AND VEGETATION

The medium in built wetland technology plays a crucial role in removing phosphorus sulfates and arsenate and providing a platform for bacterial activity; apart from sand, broken bricks, stones, and aggregates, some of the sorbent media that may be used in engineered wetland technologies to improve pollution removal effectiveness. Zero-valent iron is a medium that may be utilized for arsenate sorption. It may also improve the sorption process [23]. Phosphorus elimination can also benefit from zero-valent iron and bimetallic iron/copper [24]. Sawdust is a low-cost carbon-rich substance that improves biological sulfate reduction from wastewater and beneficial to bacterial activity. Phosphorus elimination can be enhanced by using marble dust as a medium [25]. Waste composting may also be utilized as a part of a waste management strategy. Waste compost keeps the alkaline character of the medium, which is beneficial to plant development. As a filter medium, biochar may also remove contaminants such as suspended particles, nutrients, and heavy metals [26-27]. Compared to the medium of gravel and river stones planted with sugarcane and reeds, a constructed wetland with volcanic tufa as a medium and planted with sugarcane, phragmites, and reeds displays variances in removal effectiveness. There was a facultative pond and a seasonal reservoir existent before treatment sedimentation. The results demonstrate that TSS is almost identical for everybody [28].

IX. CONSTRUCTED WETLAND TREATMENTS

In the last few years, the CW bioremediation method has shown an efficient normal process for wastewater treatment. The CW treatment has proved efficient in municipal, domestic, industrial, and agricultural wastewater [17]. The CW is considered a green technology that is very effective in the organic-rich sewage treatment [34], toxic contaminated metals in water [30], and pharmaceuticals [31]. In the following section, a short discussion on removing the above contaminants has been provided.

X. MUNICIPAL AND DOMESTIC CONTAMINANTS

The population expansion of metropolitan cities leads to an expansion in domestic and sewerage water supply, resulting in the acceleration of wastewater quantities. Appropriately overseeing metropolitan wastewater treatment would bring about fewer contamination issues of surface water tainting [35]. The contaminants include phosphorous, nitrogens, and many harmful impurities. The CW treatment is inexpensive and can be done quickly. The treatment follows BOD removal, COD removal, and the removal of the phosphorous and nitrogen pollutants.

XI. TOXIC METAL CONTAMINANTS

In recent years, industrial water treatment that contains toxic metals has received significant attention. High natural matter substances characterize the Wetland soils, and the diminished conditions could include some amount of heavy metals. Soil with the overlying water and vegetation on the top also assume a significant part in eliminating the metals inside wetlands. As prior studies reported heavy metals like Ni and Cu were removed mostly from the CW have been discussed very frequently nowadays. The lab-scale system of the wetland does the metal removals by following the storm runoff treatment [31].

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XII. PHARMACEUTICALS PRODUCTS

In recent years, a wide range of pharmaceutical products has been noticed around the globe. With the advancement of these products, the application of various unwanted chemicals has increased [35]. Biotechnology considered the eco-sounded and cost-effective approach gained a high interest that mostly uses microalgae and aquatic macrophytes for the treatment of wastewater. The CW with Phytoremediation is the most efficient decontamination method of pharmaceuticals and personal care products. Researchers have also found that the application of aquatic macrophytes is also highly useful in removing contaminants from industrial and municipal wastewater.

XIII. CONCLUSION

The CW contains a unique feature as it is not only an eco-friendly or simple treatment method, but it is also gradually evolving and highly contributes to the worldwide ecosystem. It maintains a balance between the green cover requirement and the land development [36]. The future scope of CW is of a wide range; it will be highly contributive to sustaining the food source, highly impactful in the change of climates, the consideration of wetland wildlife, and so on. This paper briefly discusses the CW key aspects, like the CW types, challenges, opportunities, applications, materials, and recent advances. It also covers the current-technical advancement evaluation report and frames the unsolved CW problems.

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