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Biochar-Based Constructed Wetland for Wastewater Treatment

Raji Swaroop[1], Rekha V R Nair[1], Anjitha Das[2]

[1]Assistanat professor, [2]PG Scholar, Department of Soil Science and Agricultural Chemistry,
College of Agriculture, Vellayani, Thiruvananthapuram, Kerala

raji.swaroop@kau.in

Excessive discharge of polluted water can hamper the quality of water resources and the associated ecosystem, as it is a serious concern affecting public health globally. Hence, the need to control point and non-point sources of water pollution and wastewater treatment is a key necessity for saving the water environment. Constructed wetlands (CWs) are engineered ecosystems that are developed based on natural wetlands and can be used for wastewater purification by relying on a series of physical, chemical and, more importantly, biological processes that are driven by the synergy of substrates, aquatic plants and microorganisms in CWs (Vymazal, 2011). They are designed to take advantage of many of the processes that occur in natural wetlands but do so within a more controlled environment. It is an ecofriendly and sustainable wastewater treatment alternative to conventional wastewater treatment systems. Constructed wetlands are capable of purifying a wide range of wastewater like domestic sewage, secondary sewage effluent, agricultural runoff, polluted surface and underground waters, industrial effluent, wastewater generated from livestock rearing and acid mine drainage (Deng et al., 2021).

Mainly constructed wetlands are used to remove N and P nutrients along with other pollutants. The removal mechanisms include sedimentation, filtration, adsorption, plant and microbial uptake. The treated water can be effectively used for irrigation. Constructed wetlands typically consist of water bodies, aquatic plants, substrates or media, microorganisms, etc. Conventionally used substrates in CWs are sand, gravel, charcoal, zeolite etc. The properties of wetland substrates play an important role in the growth of aquatic macrophytes, the physical/chemical process, and the colonization of microbial communities which in turn influences the treatment performance of CWs.

Biochar (BC) is a highly aromatic carbon sequestration material produced by pyrolysis of biomass under anoxic or oxygen-limited conditions. Biochar is rich in nitrogen (N), phosphorus (P), and potassium (K), with high p^H, high porosity, huge specific surface area, high carbon content, high cation exchange capacity, and high thermal stability (Gul et al., 2015). Because of its properties biochar is gaining attention in wide range of environmental applications.

Biochar has been used as a substrate in CWs to intensify pollutant removal due to its highly porous structures, specific surface area, reactive functional groups and abundant micronutrients which enhance the adsorption of various pollutants and promote the growth of wetland plants, accelerate redox reactions and facilitate growth of microorganisms. Complex organics such as antibiotics, polyaromatic hydrocarbons, ibuprofen and diclofenac can be effectively removed in BC-based CWs. Besides, applying biochar in CWs helps regulate nitrous oxide (N_2O) emissions, reducing the greenhouse effect (Deng et al., 2021).

Mechanisms of biochar-based constructed wetlands in the treatment of wastewater

Biochar has high cation exchange capacity and abundant negatively charged functional groups for NH_4^+ adsorption and favourable porous structures for the growth of nitrifiers, and the high porosity of biochar substrates can facilitate atmospheric reaeration and oxygen filling within the CW matrix; thus, BC based CWS can accelerate nitrification and effectively enhance NH_4^+ and total nitrogen (TN) removal in CWs. Some biochar substrates were found to entrap more P from wastewaters, especially from those with a high P concentration (e.g., anaerobic digestion effluent), than can gravel (Kizito et al., 2017). Zhou et al. (2019) opined that incorporation of biochar into CWs plays an insignificant role in COD removal, despite organic matter can leach from the biochar. However, some studies revealed that biochar amendment significantly promoted COD removal in CW. Biochar based CWs can effectively remove the heavy metals in wastewater by abiotic substrate adsorption, precipitation, and microbial sulfate reduction for sulfide and hydroxide precipitation. Some properties of biochar, such as high porosity, organic leaching, and hydrophobicity, make BC-based CWs more ideal for microbial contaminant removal than sand or gravel (Deng et al., 2021).

Recycling of spent biochar

Biochar substrates in CWs enriched with nutrients can be used as a potential slow release organic fertilizer and remediator into the surrounding agroecosystems or degraded lands after grinding to ameliorate soil fertility and consequently improve crop yields and quality; However, the possible occurrence of secondary pollution from toxic micropollutants and pathogens from the used biochar should be considered (Deng et al., 2021).

Conclusion

Constructed wetlands are promising low-cost, green technology for sustainable wastewater treatment. Wastewater treatment efficiency of constructed wetlands can be enhanced by replacing the traditional substrates like sand or gravel by biochar. Biochar based constructed wetlands were found to improve macrophyte growth and the removal efficiencies of organic and inorganic contaminates in wastewater. Besides, biochar based constructed wetlands can mitigate the greenhouse effect.

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