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Wastewater Treatment Using Constructed Wetland

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Abstract - Municipal wastewater, wastewater from petroleum refineries, agricultural drainage, acid mine drainage, etc. have all benefited from the use of constructed wetlands (CW), an ecologically benign method for purging pollutants from wastewater. The science of microbiology has expanded at an astounding rate during the last decade. Focusing on developments in the previous three decades, this paper provides a comprehensive assessment of important facets of CW, including its many forms, the contaminants & their removal mechanisms, degradation routes, difficulties, possibilities, materials, applications, and theory. Key unresolved issues in CW have also been framed in an effort to both foresee and enable future progress in the area of CW. The rapidly expanding CW sector will benefit from these guidelines, which have been created via the standardization of essential design components. In an attempt to standardize the rapidly expanding CW community, this study summarizes the present state of the art of CW technology assessment and offers definitions & performance metric terminology.

Keywords - constructed wetland; wastewater; plants; microorganisms; remediation; degradation

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INTRODUCTION

Wetlands are separate ecosystems that are inundated by water, either continuously or periodically, and where oxygen-free processes rule, and their adaptable vegetation of aquatic species is the key differentiating trait from other landforms & water bodies. The phrase "constructed wetland" is used to describe the altered wetland. Complex, interconnected ecosystems of water, vegetation, fauna, microbes, and the surrounding environment are what make up artificial wetland treatment facilities. There are several benefits provided by wetlands, including as cleaning water, storing water, stabilizing shorelines, digesting carbon, and providing habitat for plants and animals. Understanding the structure and operation of natural wetlands considerably enhances the probability of successfully developing a wetland treatment system, despite the fact that wetlands are typically dependable, self-adjusting systems.[1]

Systems have been built in recent decades to take advantage of some of the natural processes that have always happened when water flows through rivers, lakes, streams, & wetlands to enhance water quality. Storm water runoff, municipal wastewater, agricultural wastewater, and coal mine drainage are just a few of the nonpoint sources of water pollution that wetland systems are now widely favored to treat. There has been an increase in the usage of artificial wetlands for the treatment of various wastes in an effort to improve the long-term viability of wastewater management. Wastes from oil refineries, sugar factories, landfills, composts, aquaculture systems, pulp and paper mills slaughterhouses, textile factories, and seafood processing facilities have all been successfully treated by man-made wetlands. Constructed wetlands may be used as the primary treatment for these pollutants, or they can be a component of a larger integrated system for wastewater treatment.[2]

The term "antimicrobial resistance" (AMR) refers to the phenomenon in which microorganisms develop resistance to treatment with drugs that were previously effective against them [9]. Antimicrobial resistance (AMR) includes antibiotic resistance (ABR), which refers specifically to bacteria developing resistance to antibiotics. AR phenotypes may emerge via mutation and lateral gene transfer within a microorganism. By transferring and acquiring new genetic material across bacteria from the same or different species or genera, chromosomal DNA mutations modify the existing bacterial proteins, resulting in the generation of mosaic proteins. Antibiotic resistance genes (ARGs) are a kind of emergent contaminant that has persisted in water bodies like wetlands that have been exposed to sewage contaminated with ARGs.[3]

While the use of manmade wetlands has been advocated for wastewater treatment, the effectiveness of such a system depends on a wide range of both natural and man-made elements, the most challenging of which are novel pollutants and contaminants like resistant genes. Furthermore, some research has found that man-made wetlands act as reservoirs for different types of resistant genes, capturing and releasing them before dispersing them in other aquatic systems. Many recommendations have been made to enhance the ecological management of wetlands and so increase their functional impact, efficiency, and predictability. This chapter discusses the role of artificial wetlands in wastewater treatment, as well as the difficulties posed by new pollutants such resistance genes, and makes suggestions for the safe management and disposal of these contaminants.[4]

The best way to remediate wastewater in a natural setting is with the help of a biological technology called constructed wetlands (CWs), which also happens to be very high maintenance. Renewable energy sources like biomass that have been gathered from CW may be utilized for power generation. Agricultural uses exist for wastewater that has been treated with CW. Dry mass per square meter (g/m2) ranges from roughly 1500 to 6000 for species often used in CW, and they found that 1 m2 of CW planted with A. donax may provide an average of 110 MJ of energy via direct combustion and 1660 L of methane through biogas. Thus, bioenergy generation from CW has the potential to balance energy and irrigation demands in many places while decreasing dependency on fossil fuels. [5]

An anaerobic environment near the anode and an aerobic environment close to the anode describe the microbial fuel cell (MFC), which is used to produce energy from wastewater. Conditions similar to this occur naturally in CW, with a high oxygen concentration on the water's top and low oxygen levels towards the bottom. As a result, MFC may be used with CW to spread the word about how effective it is at cleaning up wastewater and producing electricity. Biogas is produced in the MCF by anaerobic digestion of high-strength wastewater. Because of their low energy requirements for operation and low maintenance costs, and the inclusion of MFC, CWs may be the best alternative for authorities and policymakers. [6]

DEFINE CONSTRUCTED WETLANDS

"Built constructed wetlands are engineered systems, planned and constructed to use the natural processes of wetland plants, soils, and their microbial communities to treat pollutants in surface water, groundwater, or waste streams," according to the Environmental Protection Agency. Wetlands that are created by humans are sometimes known as treated wetlands, engineering wetlands, artificial wetlands, or simply man-made wetlands. Newcomers may also be confused by the variety of terminologies used to describe subsurface flow CWs. Unlike unplanted soil filters , planted soil filters have vegetation made up of macrophyte plants from natural wetlands. Due to the widespread usage of the common reed in these systems, the phrase "reed bed treatment system" is most often heard in the United Kingdom and Europe. Hydroponics systems that use gravel beds, gravel beds with vegetation, or submerged beds with vegetation as filters. The word "phytorestoration" describes the use of plants and related technology to repair damaged soils, ecosystems, and/or water supplies.[7-9]

It was attempted in the early 1960s to increase the efficacy of septic tank or pond performance by cultivating macrophytes in wastewater and sludge.[10]

In 1968, Hungary pioneered the use of FWS CW to treat municipal wastewater while still protecting Lake Balaton's water quality. Ecological engineering in North America has also been utilized to treat wastewater from natural wetlands using man-made wetlands built on free water surfaces. North America used this method to treat municipal wastewater as well as other forms of wastewater. Unlike FWS CW, subsurface flow technology took a little to catch on in North America, but there are now several such systems in use. Constructed wetlands were mostly used in the 1970s and 1980s for the sole purpose of cleaning up municipal and household wastewater.[11]

The Mandan Refinery of Amoco Oil Company in North Dakota installed CW in 1975 to purify process water & industrial storm water. FWS CW was first used in the early 1980s to treat urban wastewater in California. In Othfresen, Germany, the first large-scale artificial wetland was created to treat municipal sewage. Kickuth suggested using horizontally flowing, cohesive soils planted with Phragmites as a filter media. His tests were predicated on the theory that plants' root and rhizome development would improve soil conductivity, hence opening up up-flow channels in the unified soil. The removal of BOD5, TSS, N, P, and other organics was shown to be particularly effective as a result of the elevated conductivity.[12]

Roughly 500 of these "reed bed" or "root zone" systems had been set up by 1990 throughout the continent of Europe. Over the past two decades, man-made wetland systems have become increasingly popular for the treatment of various types of wastewater, including those from dairy farms, landfills, food processing facilities, industrial and agricultural operations, mine drainage systems, and sludge dewatering facilities. [13]

Sewage water may be cleaned in constructed wetlands by using eco-friendly and efficient design concepts such the utilization of plants, bacteria, sunshine, and gravity to create a garden and potable water from the wastewater. Physical filtration & sedimentation, biological absorption, the transformation of nutrients by anaerobic and aerobic bacteria, plant roots, and metabolism, and chemical reactions all play a role in the purification and treatment of wastewater. Water is recycled and purified by a number of natural processes; the system does not often rely on technology or chemicals, yet it is nonetheless quite efficient. When it comes to water treatment, WWG routinely goes above and above what is required by the local Health Authority. [14]

Increasing the amount of wetland area might be thought of as the equivalent of advanced water treatment when requirements greater than those of a typical municipality are needed for particular uses. Movement of Subsurface Horizontal Flow Since no wastewater is exposed just on surface, there are no odors, no insect breeding grounds, but no risk of colliding with sewage; additionally, because most people will only see a nice garden, they can be situated close entrances & gathering places, in addition to used as green belts all over communities. These systems are designed to be readily integrated into existing gardens on the Site, where space may be at a premium. They have shown to be more effective, cost-effective, & long-lasting than conventional sewage treatment systems.[15]

Wetlands are defined as "... a planned or man-made complex of saturated soils, emergent and submergent plant, animal life, and water that mimics natural wetlands for human usage advantages." Effective and eco-friendly, Constructed Wetlands may be used to process both liquid - vapor waste. The supply of biomass & aquaculture by CWs might deliver significant economic advantages to poor nations. Such wetland systems have the potential to generate substantial revenue for underprivileged areas and break the cycle of poverty. Loads of biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrogen, phosphorus, and suspended particles may be reduced using CWs by as much as 98%. Climate-wise, emerging nations are ideal, but wetland expansion has been "depressingly sluggish." [16]

A constructed wetland is a treatment system that relies on natural processes to stabilize, sequester, accumulate, degrade, metabolize, and mineralize pollutants. Previously, the usage of artificial wetlands was restricted to the treatment of storm water & municipal wastewater; but, these days, they are also utilized to treat other types of water pollution. The function of a wetland system as a water treatment facility has been an ancient one. Wetland systems have received considerable attention and use over the last several decades as a means of efficiently and sustainably treating wastewater and achieving other water quality goals in a managed setting. Preserving natural wetlands and, more recently, building wetlands systems for wastewater treatment, is warranted in large part due to the positive impact they have on water quality via their passive processes. Using rooted wetland plants or shallow, flooded and saturated soil, constructed wetland treatment processes may purify wastewater. The goal of wastewater treatment facilities using constructed wetlands is to mimic the natural wetlands' ability to filter out toxins via chemical and biological processes. As a result of extensive use, the technology is now reliable and stable. More and more research shows that wetland systems may efficiently enhance water quality while also offering various advantages, such as food and habitat for animals.[17]

WETLANDS, NATURAL AND CONSTRUCTED, FOR WASTEWATER TREATMENT

Natural wetland ecosystems are famously difficult to model because of the wide variation in their functional components. This makes it almost impossible to predict responses to wastewater application and to generalize results from one place to another. Natural wetlands often enhance wastewater quality greatly when flow is directed through them, but the amount of treatment capacity they possess is mostly unknown. Though most natural aquatic systems were not designed for wastewater treatment, studies have led to a greater understanding of the potential of native wetlands for pollutant absorption and the building of unique natural water treatment technologies. Recently, extensive study and planned, controlled deployment of wetland ecosystems for wastewater and water quality objectives have taken place. [18]

Due to their functional significance in improving water quality, wetlands have received a lot of support for preservation and the creation of wetland systems for wastewater treatment. Man-made wetlands, which allow for more control over the substrate, vegetation, or flow pattern, may be useful as experimental treatment facilities. Unlike natural wetlands, man-made ones provide for more flexibility in terms of location, size, and, most importantly, control over hydraulic courses and retention times. Sedimentation, precipitation, adhesion to sand grains, uptake by plant tissue, & microbial transformations are only some of the physical, chemical, & biological processes that help remove toxins from these systems.[19]

Traditional wetland ecosystems have been used for water purification for generations. The wetland was often used for this purpose since it was more handy than the closest river or other canal as a place to dispose of waste rather than remediate it. In many instances, irreparable deterioration of wetland habitats resulted from uncontrolled discharge of wastewater. However, the effect of various wastewaters on wetlands has not been well evaluated. For instance, Cooper & Boon (1987) said that the United Kingdom has been using natural wetlands for wastewater treatment for over a century. It was claimed in 1877 that 6 m3 of wastewater was being sprayed daily per m2 of land, leading to the creation of a swamp with a foul odor and highly contaminated effluent. Approximately 50 liters of sewage per m2 of land per day might be treated successfully without the soil getting blocked by installing sufficient under-drainage at a depth of about 1.8 m.[20]

Constructed wetlands have increased in popularity and effectiveness across the globe since the 1980s, however natural wetlands are still employed for wastewater treatment under regulated settings.

THE TYPES OF CONSTRUCTED WETLANDS FOR THE TREATMENT OF WASTE WATER

The term "constructed wetland treatment system" refers to an engineered system that has been planned, built, and used to treat wastewater via the natural processes involving wetland plants, soils, or their associated microbial assemblages. Many of the activities that occur in natural wetlands may be harnessed in these artificial ones, but in a safer and more manageable setting. Man-made, engineered, and artificial wetland systems are all synonyms for created. More precise control over substrate, vegetation, and flow may be exercised in the construction of man-made wetland systems, allowing for the creation of experimental rehab centers with well specified parameters. In addition to the benefits already mentioned , manmade wetlands provide even more benefits as compared to natural wetlands.[21]

Unfortunately, It was pointed out that some of the wetland traits have been used interchangeably, and that these ambiguities need to be made clear. Wetlands that have been restored are those that were formerly home to natural wetlands but have been altered or transformed to serve other uses, resulting in the loss of native flora and fauna. Poorly drained soils , wetland plant and animal life have been restored to these places, which were originally modified for various purposes such as flood control, human habitation, tourism, or education. Formerly supporting land based flora and fauna, created wetlands have had their hydrological conditions altered to foster the growth of poorly drained soils & wetland flora and fauna to serve a variety of new purposes, including but not limited to: flood control, recreation, education, and human sustenance.[22]

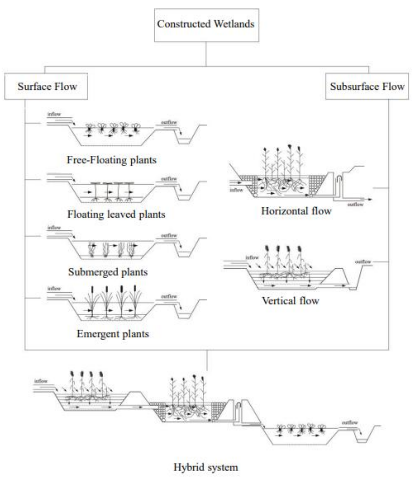

Figure 1. Categorization of Wastewater Treatment Wetlands.

Several factors may be used to categorize man-made wetlands, but the water flow regime (both above and below ground) and the kind of macrophytic development are the most crucial. Hybrid or mixed systems, which include the use of more than one form of artificial wetland, may be used to maximize the benefits of each type. The more the facility's complexity, the better the systems' end effluent.[23]

ADVANTAGES OF CONSTRUCTED WETLANDS

Because of their low cost and high technical feasibility, constructed wetlands are increasingly being used to treat wastewater and runoff.[24]

- The cost of constructing wetlands is often lower than that of competing treatment methods.
- costs for utilities and materials to keep it running are minimal.
- There is no need for constant onsite labor, since operation and maintenance may be done with just occasional visits.
- Wetlands are able to adapt to changing water levels.
- They make it simpler to recycle and reuse water.

In addition:

- There are a wide variety of wetland creatures because of the environment they give.
- They may be designed to blend in with their surroundings.
- Besides helping the water supply, they also assist animals and the landscape in other ways.
- as a method, they are well-liked because of the positive impact they have on the environment.

CONCLUSION

CWs stand out from the crowd since they are not only a straightforward and eco-friendly treatment option, but also a dynamic and ever-developing resource for the planet's ecology. CWs serve as a compromise between the demands of land acquisition and the preservation of green space, providing shelter for both resident and transient fauna. Fertilizers (phosphate) are used in agricultural schemes, and a surplus of these fertilizers is often flashed with storm runoff or contaminates the neighboring water bodies. Algae thrive in environments with high levels of phosphorus. Plant absorption, adsorption to bottom sediments or substrate of the beds , and adsorption to suspended particles, followed by sedimentation, are the ways by which pollutants are removed.

While it's true that POPs may be eliminated in CW, there are still certain restrictions that must be dealt with, such as the impact of seasonal temperature shifts and the necessity to explore uptake routes to ascertain the relative importance of each absorption mechanism.

REFERENCES

1. Allen, G.H. and R.H. Gearheart (eds). 2021. Proceedings of a Conference on Wetlands for Wastewater Treatment and Resource Enhancement. Humbolt Sate Univ., Arcata, CA
2. Brinson, M.M. and F.R. Westall. 2018. Application of Wastewater to Wetlands. Rept. #5, Water Research Inst., Univ. of North Carolina, Raleigh, NC
3. Brix, H. 2019. Treatment of Wastewater in the Rhizosphere of Wetland PlantsùThe Root Zone Method. Water Sci Technol., 19:107-118
4. Brown, M.T. 2020. Evaluating Constructed Wetlands Through Comparisons with Natural Wetlands. EPA/600\3-91-058. EPA Environmental Research Lab., Corvallis.
5. Chan, E., T.A. Bunsztynsky, N. Hantzsche, and Y.J. Litwin. 1981. The Use of Wetlands for Water Pollution Control. EPA-600/S2-82-086. EPA Municipal Environmental Research Lab., Cincinnati.
6. Confer, S.R. and W.A. Niering. 2021. Comparison of Created and Natural Freshwater Emergent Wetlands in Connecticut (USA). Wetlands Ecology & Management. 2(3):143-156
7. Cooper, P.F. and B.C. Findlater. 2020. Constructed Wetlands in Water Pollution Control. IAWPRC. Pergamon Press, Inc., Maxwell House.
8. Etnier, C. and B. Guterstam. 2019. Ecological Engineering for Wastewater Treatment. Bokskogen, Gothenburg, Sweden
9. Gamroth, M.J. and J.A. Moore. April 2018. Design and Construction of Demonstration/Research Wetlands for Treatment of Dairy Farm Wastewater. EPA/600/R-93/105. EPA Environmental Research Laboratory, Corvallis.
10. Gersberg, R.M., S.R. Lyon, B.Y. Elkins, and C.R. Goldman. 2016. The Removal of Heavy Metals by Artificial Wetlands. EPA-600/D-84-258. Robt. S. Kerr Env. Research Lab., Ada, OK
11. Gersberg, R.M., B.V. Elkins, S.R. Lyon and C.R. Goldman. 2014. Role of Aquatic Plants in Wastewater Treatment by Artificial Wetlands. Water Res. 20:363-368
12. Good, R.E., D.F. Whigham, and R.L. Simpson (eds). 2019. Freshwater Wetlands: Ecological Processes and Management Potential. Academic Press, New York, NY
13. Greeson, P.E., J.R. Clark & J.E. Clark (eds). 2014. Wetland Functions and Values: The State of Our Understanding. Amer. Water Resources Assoc., Minneapolis, MN
14. Hammer, D.A. (ed). 2019. Constructed Wetlands for Wastewater Treatment - Municipal, Industrial & Agricultural. Lewis Publ., Chelsea, MI
15. Hammer, D.E. and R.H. Kadlec. 2020. Design Principles for Wetland Treatment Systems. EPA600/S2-83-026. EPA Municipal Environmental Research Lab, Cincinnati, OH
16. Hook, D.D. et. al. 2017. The Ecology and Management of Wetlands (2 vols.). Croom Held, Ltd., London/Timber Press, Portland, OR
17. Hyde, H.C. R.S. Ross and F.C. Demgen. 2017. Technology Assessment of Wetlands for Municipal Wastewater Treatment. EPA 600/2-84-154. EPA Municipal Environmental Research Lab., Cincinnati, OH
18. Kusler, J.A. and M.E. Kentula (eds). 2021. Wetland Creation and Restoration: The Status of the Science. Island Press, Washington, DC
19. Nixon, S.W. and V. Lee. 2018. Wetlands and Water Quality: A Regional Review of Recent Research in the U.S. on the Role of Freshwater and Saltwater Wetlands as Sources, Sinks, and Transformers of Nitrogen, Phosphorus, and Heavy Metals. Technical Rept. Y-86-2, U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS
20. Reed, S.C., R. Bastian, S. Black, and R. Khettry. 2016. Wetlands for Wastewater Treatment in Cold Climates. IN: Future of Water Reuse, Proceedings of the Water Reuse Symposium III. Vol. 2:962-972. AWWA Research Foundation, Denver, CO
21. Richardson, C.J. 2018. Mechanisms Controlling Phosphorous Retention Capacity in Freshwater Wetlands. Science 228:1424-1427
22. Stockdale, E.C. 2017. Freshwater Wetlands, Urban Stormwater, and Nonpoint Pollution Control: A Literature Review and Annotated Bibliography. 2nd Ed. WA Dept. of Ecology, Olympia, WA
23. Strecker, E.W., J.M. Kersnar, E.D. Driscoll & R.R. Horner. April 2014. The Use of Wetlands for Controlling Stormwater Pollution. The Terrene Inst., Washington, DC
24. Tourbier, J. and R.W. Pierson (eds). 2019. Biological Control of Water Pollution. Univ. of Pennsylvania Press, Philadelphia, PA

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