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Tidal Flow Constructed Wetland: An Overview

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Abstract: *Constructed wetlands for wastewater treatment have evolved substantially over the last 40 years. Engineered wetlands have become an effective means of advanced water treatment, including nitrogen removal. Integration of hydraulic or aeration machinery into constructed wetlands is responsible for these increased treatment capabilities. Together with improved scientific understanding of wetlands, these developments represent the emergence of a tidal flow of engineered wetlands that not only improve treatment performance, but also can successfully compete with many conventional technologies.*

Keywords: *Tidal Wetland, Heavy Metals*

I. INTRODUCTION

There is a critical need in the confined livestock industry for development, validation and deployment of alternative waste management technologies that reduce environmental impacts of manure-derived pollutants including nutrients, heavy metals, odors, pathogens, antibiotics, growth hormones, fine particulates, and emissions of greenhouse gases. Wetlands are a generic term covering a variety of water bodies supporting aquatic vegetation and providing a biofiltration capability. They include not only natural marsh and swamp environments but also artificially constructed storage basins or ponds. Wetlands are essentially transitional between terrestrial and aquatic systems, where the water table is normally at or near the soil surface or where there is a permanent shallow water cover. However, the presence of water by ponding, flooding or soil saturation is not always a good indicator of wetlands as they can often appear to be dry.

Constructed wetlands (CWs) are engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils, and the associated microbial assemblages to assist in treating wastewaters. They are designed to take advantage of many of the same processes that occur in natural wetlands, but do so within a more controlled environment. CWs for wastewater treatment may be classified according to the life form of the dominating macrophyte, into systems with free-floating, floating leaved, rooted emergent and submerged macrophytes. Further division could be made according to the wetland hydrology (free water surface and subsurface systems) and subsurface flow CWs could be classified according to the flow direction (horizontal and vertical).

II. TYPES AND CLASSIFICATION OF CONSTRUCTED WETLANDS

Most diverse methods and variants exist in the field of wastewater treatment with constructed wetlands that make it difficult to clearly specify the separate types. They can be classified according to their loading pattern (continuous or intermittent flow),life-form category of the dominating vegetation (rooted emergent, floating or submerged macrophyte-based system), wastewater characteristic (municipal, agricultural or industrial) or soil hydraulics and materials.

Surface flow treatment wetlands

Surface flow or free-water-surface wetland systems show, as the name suggests, a water flow primarily conducted aboveground and exposed to the atmosphere (free water body).

Subsurface flow treatment wetlands

Subsurface flow treatment wetlands can be divided into soil- and gravel-based wetlands on the one hand, and into horizontal and vertical flow systems on the other hand.

Horizontal flow systems

Main feature of horizontal flow systems is that the water level remains underneath the ground surface. The wastewater flows horizontally through a porous soil medium where the emergent plant vegetation is rooted, and is purified during the contact with the surface areas of the soil particles and the roots of the plants.

Vertical flow systems

Vertical flow systems are characterized by an intermittent charging including filling and resting periods where wastewater percolates vertically through a soil layer that consists of sand, gravel or soil. The plant species primarily used in vertical flow wetlands is common reed (Phragmites australis) due to its deeply penetrating, dense root and rhizome system.

III. RECENT DEVELOPMENTS IN ENGINEERED WETLANDS

Different types of wetlands form a continuum from completely passive designs, which require large land areas to highly engineered wetlands that are very compact. Pond wetlands and free water surface wetlands are typically used in situations where ancillary benefits, such as wildlife habitat, are an important part of the design process. Subsurface flow (SSF) wetlands have received the most attention from technology developers because of their treatment efficiency. SSF wetland influent is typically raw or primary wastewater. They “work harder” than free water surface or pond wetlands because they have larger surface areas of bacteria biofilms in contact with wastewater. Passive SSF wetlands are proven technology for removal of biochemical oxygen demand (BOD) and total suspended solids. Due to the limited availability of oxygen, the root zone of these SSF wetlands is anaerobic, and processes that require oxygen, such as oxidation of ammonia to nitrite and nitrate (nitrification) occurs very slowly, if at fall. Aeration and tidal flow are the two methods developed to provide oxygen for nitrification to wetland systems.

Aerated wetlands

Aerated wetlands use tubing distributed across the bed of the wetland to create multiple coarse bubble curtains through which wastewater must pass. They are effective at nitrification even in cold climates. Aerated wetlands use less energy than conventional treatment processes, such as activated sludge. Passive processes remove BOD near the inlet zone, leaving much of the aerated wetland free for nitrification. Recycle of nitrified effluent to the anoxic inlet zone can be implemented to promote denitrification.

Tidal flow wetlands

The Tidal Flow Wetland Living Machine incorporates a series of wetland cells, or basins, filled with special gravel that promotes the development of micro-ecosystems. Tidal flow systems employ two or more flood and drain cycles per day within the wetland bed (David Austin). These highly flexible cells may be integrated into exterior landscaping or built into a building or greenhouse. As water moves through the system, the cells are alternately flooded and drained to create multiple tidal cycles each day, much like natural wetlands, resulting in high quality reusable water. The micro-ecosystems within the cells efficiently remove nutrients and solids from the wastewater, resulting in high quality effluent. The final polishing stage, which involves filtration and disinfection, leaves water crystal clear and ready for reuse.

Tidal flow systems employ two or more flood and drain cycles per day within the wetland bed. The cation exchange capacity of wetland media is important to design. When the wetland floods, ammonium ions (NH_4^+) adsorb to negatively charged surfaces within the aggregate/root matrix. When the wetland drains, the adsorbed ammonium ions remain in thin biofilms exposed to atmospheric oxygen. Rapid oxygen saturation of biofilms induces nitrification. In the next flood cycle, nitrate ions (NO_3^-) desorb into bulk water. Nitrate is then denitrified by bacteria. Significantly, there is no BOD inhibition of nitrification in the drained phased, but there can be a high BOD *and* nitrate environment in the flooded phase, creating ideal conditions for denitrification.

IV. EFFICIENCY OF TIDAL WETLAND FOR HEAVY METAL REMOVAL

Tidal wetlands have been proven to remove both organic and inorganic contaminants in municipal waste water. The remediation of wastewater containing heavy metals has assumed great relevance in the last decades. Unlike organic pollutants, metals do not undergo degradation and generally need to be removed through highly expensive cleanup methods. As an alternative,phytoremediation is a biological, low-cost and environmental friendly clean-up technology, which can be exploited for heavy metal removal.

Lead Removal

The toxic effects of lead have been known for centuries. Its many useful properties gave rise to a dramatic escalation of lead use around the time of the industrial revolution, when lead poisoning was common amongst workers in the smelting, painting, plumbing, printing and other industries. With the advent of motor vehicles early in the 20th century, and the use of lead in petrol, environmental lead contamination increased substantially (Landrigan, P. J. (1999)). Researchers work on the lead removal concentration for the 3 types of macrophytes and some conclusion has been made. After 8 days retention, *Polygonum, Typha and Papyrus* reeds had the maximum removal 89.8 % of the lead in the original raw sewage. The actual concentration was 0.201 mg/l. This combination of plants is therefore the most efficient in wetlands where the raw influent has high concentrations of lead metal to be removed.

Cadmium Removal
Cadmium concentration in the raw water is generally lower than other metals. After 8 days retention, maximum removal at 88.5 % and therefore was the most efficient for use in wetlands in treating water high in Cadmium concentration. The final concentration was 0.0045 mg/l.

Zinc Removal
This trend of absorbance conforms to the selectivity series for metal uptake by plants in the order: Cr >Pb > Cu > Cd > Zn > Ni. After 8 days retention period, the maximum % removal was 80.4.

V.ADVANTAGES OF PROCESS IN TIDAL WETLANDS TREATMENT

Simpson et al. (1983) and Odum et al. (1984) had suggested that freshwater tidal wetlands would have higher levels of productivity than non-tidal riverine wetlands because of the daily tidal subsidies. Higher rates of production would also be suggestive of higher rates of nutrient cycling if the vegetation was obtaining nutrients primarily from the soils. The tidal treatment wetlands embrace the pragmatic integration of machinery into wetland treatment processes. The need to nitrify has been the principle driving force behind this development. The benefits, however, go beyond nitrification. Aerated and tidal flow wetlands are hydraulically efficient because they resist formation of preferential flow paths that commonly short-circuit passive SSF wetlands. Aerated wetlands do so by mixing perpendicular to the flow, tidal systems by complete flooding and draining of the wetland. As a result, aerated and tidal flow wetlands can be twice as deep (about 1.2 m) as passive horizontal SSF wetlands without losing hydraulic efficiency. Deeper systems occupy less area, thereby broadening the number of potential wetland treatment sites. The higher oxidation reduction potential of aerated or tidal flow wetland systems (> -200 mV) suppresses hydrogen sulfide (H_2S) formation. Hydrogen sulfide is toxic to plants, and high concentrations of H_2S in the root zone forces plants to grow “on tiptoe” in highly reduced wetland environments. When H_2S formation is eliminated through aeration or tidal flow, plant roots have no problem growing deep into the wetland bed. The energy efficiency of aerated and tidal flow systems is higher than equivalent activated sludge nitrogen removal systems. Passive BOD removal mechanisms, low yield with *in situ* degradation of biosolids, and the absence of mixing requirements require substantially less energy than conventional activated sludge systems; however, wetland systems have larger area requirements than conventional treatment processes. Tidal flow systems may use up to 70% less energy for nitrogen removal because of the use of efficient pumps and the occurrence of nitrification during the drained phase. Similarly, aerated wetlands use much less energy than activated sludge systems. More operational experience is needed to rigorously assess the energy efficiency of these technologies.

VI. CONCLUSIONS

Constructed Wetlands have shown that there is capability of treating different kinds of wastewater. New generation of treatment wetland is emerging to build upon the successes of earlier wetland technologies. These new generation wetlands can address current market needs or open new market niches, while addressing the limitations of earlier wetland systems. The judicious integration of machinery into heretofore passive wetland processes is a distinguishing characteristic of these emerging technologies. Moreover, increasing scientific sophistication of treatment wetland designers is likely only the beginning of a more profound understanding in the near future of how these complex bioreactors function at a molecular level. Better knowledge is already leading to new applications for engineered wetlands. This trend shows every sign of continuing into the foreseeable future.

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