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Challenges in Water Resources and Wastewater Treatment

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Human activities place significant demands on our water resources and have potentially significant and negative environmental impacts. Especially, water resources are also important components of energy infrastructure systems as well as sustainable development [1,2]. Pollutants from watersheds, including agriculture activities of energy biomass resources developments and treated domestic wastewater discharge, are major sources for water quality impairment. In recent years, US EPA has developed and implemented regulations to limit total maximum daily loading from watersheds to water bodies. A systems approach can be used to analyze the potential environmental impacts, including impacts on the ecosystem and human health, potential contamination of water, soil, and air, demands on water resources, and greenhouse gases, etc. Following are some current challenges and development in water resources and wastewater treatment.

Correlation of Water Quality Indicators for Coastal Marshes

Water quality is an important factor in nutrient and detrital distribution in coastal marshes, which is regulated by the Clean Water Act and US EPA. The adequacy of techniques for water quality monitoring of coastal marshes has received a great deal of attention in recent years because coastal marshes are suspected of being degraded by changes to their natural water sources, pollutants and sediment from runoff and encroachment by invasive species [3]. Effective coastal marsh management (including source water protection) requires detailed knowledge of the factors affecting water quality indicators. Nutrient levels currently are the most important considerations because they are related to eutrophication. Fertilizers, septic effluent leachate from coastal development, animal wastes, and atmospheric deposition are all sources of nitrate loading. Most of the water comes from seawater in the lower salt marsh, but the upper marsh is often heavily influenced either by abundant freshwater from the land drainage and flooding or the occasional catastrophic storms that floods the entire marsh with seawater.

In a recent research, water quality of coastal marshes at St. Marks National Wildlife Refuge, FL was evaluated in terms of coliform and chlorophyll a, along with dissolved oxygen, temperature, pH, conductivity, and total suspended solid [4]. Initial data analysis revealed an interesting disparity in the different water quality indicators. In coastal marshes, a spatial and temporal sequence in the composition, abundance and biomass of the microalgal communities is commonly observed, due to the occurrence of extreme abiotic gradients over the year [5]. Depending on the relative abundance of the major algal assemblages in wetlands (phytoplankton, epiphyton, epipelon and metaphyton), chlorophyll measurements may provide a useful estimate of algal biomass [6]. For this research, chlorophyll a, a type of chlorophyll that is most common and predominant in all oxygen-evolving photosynthetic organisms such as higher plants, red and green algae was also monitored. Coliform and chlorophyll a were further correlated to water physical and chemical parameters based on synthetically correlative principles.

Nutrient Removal and Energy Generation in Wastewater Treatment

Traditional biological nitrogen removal is nonreversible and is carried out in two stages: aerobic nitrification of ammonium via hydroxylamine and nitrite to nitrate, and subsequent anoxic denitrification of nitrate via intermediate stages to nitrogen gas. Both suspended processes and biofilm processes have been applied in full scale for nitrification and denitrification of wastewater with high nitrogen content as a means of nitrogen removal. A typical example is the four-stage Bardenpho process, which consists of a sequence of anoxic and aerobic zones with capacities of nitrification with pre- and postdenitrification [7]. Recently, a novel process called anaerobic ammonium oxidation (Anammox) has been introduced for the treatment of municipal wastewater with high concentrations of ammonium [8,9]. Anammox is a microbiological-mediated exergonic process during which ammonium is converted to nitrogen gas under anaerobic conditions with nitrite serving as the electron acceptor. Anammox process is strictly anaerobic and is inhibited by high concentrations of oxygen. Currently, microbial species that are responsible for the Anammox process have been identified. Anammox not only eliminates the need for complex compromises between organic carbon removal and nitrogen removal, but also saves oxygen supplies and reduces CO_2 emission as compared with the conventional nitrification/denitrification process.

Microbial fuel cell (MFC) technology has advantages in treating wastewater since MFCs allow microorganisms to break down the organic components in the wastewater while simultaneously generating power. Prior research has demonstrated the feasibility of using MFCs for simultaneous wastewater treatment and energy generation [10,11]. It was concluded that BOD_5 limited the process only at very small concentrations. Some open questions remain regarding the performance of MFCs in relation to the treatment of wastewater with high concentrations of nitrogen compounds [12,13]. To address this issue, MFCs have been reconfigured to wastewater with nitrate as an electron acceptor to achieve both carbon and nitrogen removal. Anammox has also been incorporated into MFCs to handle treat municipal wastewater with high nitrogen contents, which can enhance the power generation and nitrogen removal in a single treatment.

Pressurized Fiber Biofiltration

Biological treatment of wastewater with a biofilter is among the oldest and most well characterized technologies [14]. During biofiltration operations, the growth of microorganisms develops biofilms on the medium surfaces and the microorganisms in the biofilms absorb soluble and colloidal waste materials in the wastewater as it percolates over the medium surfaces. Recently, polypropylene fibers have been introduced as the biofilter media. Subsequently, pressurized suspended fiber biofilters have been practiced in drinking water and wastewater treatment as a space-saving technology [15]. The pressurized suspended filter pore space (and subsequent retention time) can be adjusted, which offers the flexibility to achieve different filtration functions. In addition, pressurized suspended fiber biofilters have other obvious advantages, the most important one of which is that the suspended fibers provide a tremendous amount of surface areas in a small volume. Therefore, microorganisms can grow on the fibers at a density greater than 1×10^8 cells per ml, the only means to culture cells at in vivo-like cell density [16]. Another advantage of the pressurized suspended fiber biofiltration is that the oxygen transfer barrier can be overcome and significantly increased dissolved oxygen level can be achieved. Prior studies have demonstrated that BOD and COD removal increases with the increase of pressure when the pressure is raised up to 6 bars in a laboratory scale rotating biological contactor [17]. As an innovative technology, the pressurized suspended fiber biofilters also makes biological contact oxidation possible, which can significantly improve organic removal and decrease the sludge yield. For iron removal, contact oxidation is achieved by microbial mediated iron oxidation and fixation during which ferrous iron is oxidized to ferric iron and fixed onto the filter media. There is minimal ferric iron suspending in the solution that can escape the filter.

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