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Review on Wastewater Treatment Technologies

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Abstract: Nowadays, water resources are becoming increasingly scarce and many of them are polluted by anthropogenic sources such as industrial purpose, agricultural waste and household. Treatment of wastewater therefore remains a vital requirement before it is returned to natural water sources. The main purpose of wastewater treatment is to eliminate the various pollutants in wastewater such as suspended solids, organic carbon, nutrients, inorganic salts, heavy metals, pathogens etc.The ultimate objective of wastewater treatment is to provide human health and environmental protection. In this article, the use of methods for treating wastewater such as biofilm processing, aerobic granulation, and microbial fuel cells are briefly discussed. Several water resources today are contaminated by anthropogenic sources like domestic, agricultural and industrial waste.The ultimate objective of wastewater treatment is to provide human health and environmental protection. In this article, the use of methods for treating wastewater such as biofilm processing, aerobic granulation, and microbial fuel cells are briefly discussed. Several water resources today are contaminated by anthropogenic sources like domestic, agricultural and industrial waste.

Keywords: Aerobic, AGS, BOD, Treatment, Technologies and Sewage.

INTRODUCTION

Due to the growing disparity between freshwater supply and use, water resources are becoming increasingly scarce around the world, while access to clean and healthy water has become one of the major challenges of our modern society. Demand for water is continuing to increase because of the following reasons:

- Increasing of population and migration to drought prone regions
- Rapid industrial development and increasing water use per capita
- Climate change leading to changing weather patterns in populated areas

On the other hand, the quality of water is compromised by the presence of a large number of contaminants and anthropogenic chemicals that penetrate the bodies of urban and rural water. Wastewater discharges from urban and industrial treatment plants have been identified as one of the most important factors of marine contamination worldwide. The majority of domestic and industrial wastewater is dumped directly into water streams in many developing countries without any treatment systems[1] or after primary treatment only.Even in a highly industrialized country such as China, approximately 55% of their sewage was discharged without any treatment. The discharge of untreated wastewater to the water bodies without any treatment processes will leads to several environmental problems such as:

- Untreated wastewater which contains a large amount of organic matter willconsume the dissolved oxygen for satisfying the biochemical oxygen demand (BOD) of wastewater[2] and thus, deplete the dissolved oxygen of the water stream required by the aquatic lives
- Untreated wastewater usually contains a large amount of pathogenic or diseasecausing microorganisms and toxic compounds, that can dwell in the human intestinal tract thus threatening the human health.
- Wastewater may also contain certain amount of nutrients, which can stimulate the growth of aquatic plants and algal blooms, thus, leading to eutrophication of the lakes and streams

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- The decomposition of the organic compounds present in wastewater can lead tothe production of large quantities of malodorous gases.

BIOFILM TECHNOLOGY

Definition of biofilm[3] itself is simply defined as communities or clusters of microorganisms that attached to a surface. Formation of biofilm could be achieved by a single or multispecies of microorganisms that have the ability to form at biotic and abiotic surfaces. As a general, there are few steps that important for development of biofilm, which starting with the initial attachment and establishment to the surface, followed by maturation and finally the detachment of cells from surface. Fig. 1 shows the process of biofilm development.

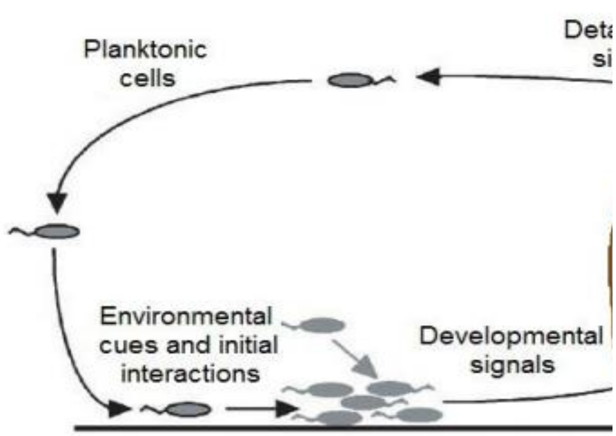

Figure 1: Process of Biofilm Development

First, before forming a transient attachment with the surface or other microorganisms that were formerly attached to the surface, the bacterium must approach close. This transitory attachment step allows the bacterium to search for a place before adapting it. It will form a secure association after the bacterium has finally settled down and join into a micro colony, which is the bacterium that has chosen the neighborhood to live in.Finally, biofilm construction is established and, irregularly, the biofilm-associated bacteria will detach themselves from the surface of the biofilm. Biological treatment process[4] uses have taken into place in terms of their efficiency and economy as compared to physical and chemical methods. Biofilm is one of the biological methods used to overcome the problems of bioremediation. Biofilm-mediated bioremediation, according to Decho, gives planktonic microorganisms a capability and a safer option to bioremediation them.The reason behind this is because the cells in a biofilm have a high potentially to survive and adapt towards the process as they are protected by the matrices. Moreover, microbial consortium in the form of biofilm has the ability to decolorize and metabolize dyes since there are intrinsic cellular mechanisms that will bring about the degradation or biosorption of dyestuffs.

Advantages:

Biofilm offers a comprehensive and harmless option for bioremediation with planktonic microorganisms, as biofilm cells have a high chance of adaptation and survival, especially under unfavorable conditions. This condition is due to the matrix, which simply acts as a barrier and protects the cells within it against environmental disturbance. Extracellular polymeric substances or EPS are important for biofilm production which appears to be part of the biofilm community's protective mechanism.Wingender et al. stated that EPS can reduce the pH, temperature and toxic substance concentration impact of change. Biofilm can have very long residence periods for biomass when treatment requires slow growing species with poor biomass yield or when wastewater concentrations are too small to support the growth of activated sludge flocks.

Limitations:

There are several limitations of biofilm towards the implementation in wastewater treatment. The limitations are:

- Overgrowth of biofilms leads to elutriation of particles
- Control of biofilm thickness is difficult
- Liquid distributors for fluidized systems are costly for large-scale reactors
- Pose problems related to clogging and uniform fluidization

AEROBIC GRANULATION TECHNOLOGY

The improvement to certain biofilm drawbacks led to the discovery of the late 1990s of novel microbial self-immobilization processes called biogranulation. The granular sludge produced through biogranulation approaches has higher retention and reusability of biomass, broader range of bacterial strains for plausible bioaugmentation and higher microbial density with millions of cells per gram of biomass.Biogranulation can generate two types of granular sludge which were aerobic granular sludge (AGS)[5] and anaerobic granular sludge (AnGS), in which both of them can be developed in a fixed sequencing cycle of feeding, reacting, settlingand decanting under a single sequencing batch reactor (SBR) system.However, the AnGS exhibited several disadvantages such as long start-up period, required strictly anaerobic environment, relatively high operating temperature, unsuitable for low strength organic wastewater and low efficiency in the removal of nutrients (Nitrogen and Phosphate) from the wastewater.

Meanwhile the AGS was able to overcome all the drawbacks of the AnGS as mentioned, therefore increased the effectiveness of the AGS in treatment of raw industrial wastewater. The AGS was regarded by some researchers as suspended spherical biofilm that included microbial cells, inert particle, degradable particles and extra cellular polymeric substances (EPS). Aerobic granulation may be initiated by the microbial self-adhesion, since the bacteria cells were not likely to aggregate naturally due to the repulsive electrostatic forces and hydration interactions among them.Compared to conventional flock sludge, the granular sludge possessed an excellent settling property and thus enabled high biomass retention and dense microbial structures to withstand high resistance of organic wastewater and its shock loading. According to Beun et al., via a series of microscopic observations, a mechanism for the formation of aerobic granular sludge in an aerobic reactor without a carrier material is proposed. The proposed mechanism is illustrated in Figure 2.

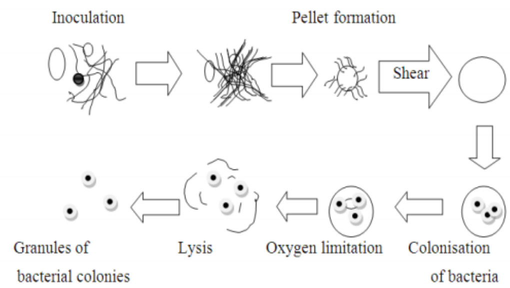

Figure 2: Proposed Mechanism of Granulation after the Start-Up of SBRwith A Short Settling Time

Fungi and filamentous bacteria easily form mycelial pellets at the beginning of the biogranulation stage which settle very well and can be retained in the reactor. Bacteria do not have this special property, and are almost completely washed out. So the biomass in the reactor will consist mainly of filamentous mycelial pellets during the start-up phase. As the granulation takes place inside the reactor due to the sheer force in the reactor, the filaments are removed on the pellet surface and the pellets become more compact.The pellets expand to 5±6 mm in diameter and then undergo a lysis process due to the lack of oxygen in the inner part of the pellet. The mycelial pellets appear to function as a matrix of immobilization in which the bacteria may grow into colonies. Because of the inner part of the pellets the mycelial pellets fall apart, the bacterial colonies can maintain themselves because they were now large enough to settle. Such micro-colonies continue to grow into denser granular sludge, eventually leading to a reactor-dominated bacterial population as granulation continues[6].

Advantages:

Aerobic granules were known to exhibit attributes of lightweight, normal, smooth and almost circular shape; excellent ability to settle; dense and solid microbial structure; high retention of biomass; ability to withstand high organic loading or shock loads; durability of starvation; toxicity tolerance and simultaneous removal of COD, nitrogen and phosphates. Bio-augmentation of specific strains of bacteria that were able to degrade a target recalcitrant compound was also possible since these bacteria can be introduced as inoculum during the granulation period.For example, the AGS[7] was successfully cultivated in a SBR treating high strength pyridine wastewater, using a single bacterial strain Rhizobium as the inoculum.

Limitations:

Although the aerobic granulation technology was successfully applied to treat lots of different types of wastewater, however most of AGS research achievements were from bench-scale SBR, while reactor volumes were usually small with limited processing capacity, and their operating conditions were strictly controlled. Obviously, the findings of these work had only theoretical guidance for practical engineering applications and therefore AGS technology must be tested by comprehensive pilot projects dealing with different types of wastewater. However, the researches in this field were scarce, neither at local or abroad. Furthermore, according to previous researches, AGS was easily unstable, slow growing and disintegrated in long-term operational reactors, which were the biggest bottleneck of AGS for engineering.

MICROBIAL FUEL CELL (MFC) TECHNOLOGY

Recently the application of MFC technology[8] has been widely reported for the treatment of wastewater with electricity generation. MFC is a biochemical system that transforms chemical energy found in organic matter such as glucose into electricity using bacteria as a biocatalyst. MFC basically consists of an anaerobic anode chamber, a cathode chamber, and a proton exchange membrane (PEM) or salt bridge that divides both chambers and only allows the movement of proton H+ from the anode chamber to the cathode chamber.

Bacteria gain energy by transferring electrons from their central metabolic system to the anode which acts as MFC's final acceptor of electrons. The electron is then conducted to the cathode via an external circuit, where they combine to form water with oxygen and H+. At present, both mixed and pure bacterial cultures have been used to generate electricity in MFC.The transfer of electron from bacteria to the anode, known as the extracellular electron transfer mechanism in MFC can be achieved in three different pathway:

(1) Direct outer membrane c-type cytochrome transfer
(2) Exploitation of electron mediators that are either externally added or produced by the microorganisms themselves
(3) Through electrically conductive pili.

Advantages:

MFC[9] provides some advantages over other organic-material producing energy technology. According to Rabaey and Verstraete, these advantages include high energy conversion efficiency due to direct conversion of chemical energy into electricity within substrates, efficient operation at normal and low temperatures, and lack of gas treatment because released gasses are rich in CO2 that have no useful energy content. Moreover, aeration is not required since the cathode is aerated passively, thus reducing the cost of operation.

Limitations:

The system is still not fully developed and ready for real application, taking into account the power output and treatment capacity of MFC technology[10]. The main drawback of using MFC is the low power density in MFC which hinders device scaling. Thus, research into advancing economically feasible materials and architectures and producing high power densities has become a focal point in MFC research. Membrane fouling is a common problem in the MFC setup with membrane that often occurs particularly in the treatment of wastewater containing high amounts of suspended solid. These membranes may require continues replacement, subsequently increasing the cost of operation. This has limited the commercial application of MFC for wastewater treatment.

CONCLUSION

This paper is an analysis of the application of biofilm processing, aerobic granulation and microbial fuel cell for wastewater treatment. The efficiency of the treatment in terms of its benefits, implementations and drawbacks was discussed in depth. The ultimate objective of wastewater treatment is environmental protection in a manner that is commensurate with public health and socio-economic concerns. Understanding the nature of wastewater is important for developing a suitable treatment system to ensure the safety, effectiveness and consistency of the wastewater treated.Additionally, improved public education is recommended to ensure understanding of the technology and its environmental and economic benefits. It is clear that a number of solutions in the developing world are feasible for use and even more obvious that many low-technology alternatives can be mixed and matched for very high efficiencies. Environmental management techniques draw much attention from environmental managers. Natural treatment technologies are considered viable because of their low capital costs, their ease of maintenance, their potentially longer life-cycles and their ability to recover a variety of resources including: treated effluent for irrigation, organic humus for soil amendment and energy in the form of biogas.

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