A REVIEW ON WASTEWATER TREATMENT TECHNOLOGIES

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ABSTRACT

These days many water resources are polluted by sources including household and agricultural waste and industrial processes. Public concern over the environmental impact of wastewater pollution has increased. Several conventional wastewater treatment techniques, i.e. chemical coagulation, adsorption, activated sludge, have been applied to remove the pollution, however there are still some limitations, especially that of high operation costs. The use of aerobic waste water treatment as a reductive medium is receiving increased interest due to its low operation and maintenance costs. In addition, it is easy-to-obtain, with good effectiveness and ability for degrading contaminants. This paper reviews the use of waste water treatment technologies to remove contaminants from wastewater such as halogenated hydrocarbon compounds, heavy metals, dyes, pesticides, and herbicides, which represent the main pollutants in wastewater.

Key Words: Sewage, Aerobic, Treatment, Technologies

INTRODUCTION

A supply of clean water is an essential requirement for the establishment and maintenance of diverse human activities. Water resources provide valuable food through aquatic life and irrigation for agriculture production. However, liquid and solid wastes produced by human settlements and industrial activities pollute most of the water sources throughout the world. Due to massive worldwide increases in the human population, water will become one of the scarcest resources in the 21st century (Day D., 1996). In the year 2015 the majority of the global population (over 5 billion) will live in urban environments (UN, 1997). By the year 2015, there will be 23 megacities with a population of over 10 million each, 18 of which will exist in the developing world (Black, 1994). Central to the urbanization phenomena are the problems associated with providing municipal services and water sector infrastructure, including the provision of both fresh water resources and sanitation services. Currently, providing housing, health care, social services, and access to basic human needs infrastructure, such as clean water and the disposal of effluent, presents major challenges to engineers, planners and politicians (Black, 1994; Giles and Brown, 1997). As human numbers increase, greater strains will be placed on available resources and pose even greater threat to environmental sources. A report by the Secretary-General of the United Nations Commission on Sustainable Development (UNCSD, 1997) concluded that there is no sustainability in the current uses of fresh water by either developing or developed nations, and that worldwide, water usage has been growing at more than three times the world's population increase, consequently leading to widespread public health problems, limiting economic and agricultural development and adversely affecting a wide range of ecosystems.

Although India occupies only 3.29 million km2 geographical area, which forms 2.4% of the world's land area, it supports over 15% of world's population. The population of India as of March 1, 2001 was 1,027,015,247 persons (Census, 2001). India also has a livestock population of 500 million, which is about 20% of world's total livestock. However, total annual utilizable water resources of the country are 1086 km3 which is only 4% of world's water resources (Kumar et al., 2005).Total annual utilizable resources of surface water and ground water are 690 and 396 km3 , respectively (Ministry of Water Resources, 1999). Consequent to rapid growth in population and increasing water demand, stress on water resources in India is increasing and per capita water availability is reducing day by day. In India per capita surface water availability in the years 1991 and 2001 were 2300 m3 (6.3 m 3 /day) and 1980 m3 (5.7 m3 /day) respectively and these are projected to reduce to 1401 and 1191 m3 by the years 2025 and 2050, respectively (Kumar et al., 2005). Total water requirement of the country in 2050 is estimated to be 1450 km3 which is higher than the current availability of 1086 km3 . Much of the wastes of civilization enter water bodies through the discharge of waterborne waste from domestic, industrial and non-point sources carrying unwanted and unrecovered substances (Welch, 1992). Although the collection of wastewater dates back to ancient times, its treatment is a relatively recent development dating from the late 1800s and early 1900s (Chow et al., 1972). Modern knowledge of the need for sanitation and treatment of polluted waters however, started with the frequently cited case of John Snow in 1855, in which he proved that a cholera outbreak in London was due to sewage contaminated water obtained from the Thames River (Cooper, 2001). In developed nations, treatment and discharge systems can sharply differ between countries and between rural and urban users, with respect to urban high income and urban low-income users (Doorn et al., 2006). The most common wastewater treatment methods in developed countries are centralized aerobic wastewater treatment plants and lagoons for both domestic and industrial wastewater.

The degrees of wastewater treatment vary in most developing countries. Domestic wastewater may be treated in centralized plants, pit latrines, septic systems or disposed of in unmanaged lagoons or waterways, via open or closed sewers (UNEP, 2002). In some cases industrial wastewater is discharged directly into water bodies, while major industrial facilities may have comprehensive inplant treatment (Carter et al., 1999; Doorn et al., 2006). In many developing countries the bulk of domestic and industrial wastewater is discharged without any treatment or after primary treatment only. In Latin America about 15% of collected wastewater passes through treatment plants (with varying levels of actual treatment). In Venezuela, 97% of the country's sewage is discharged raw into the environment (Caribbean Environment Programme, Technical Report, 1998). Even a highly industrialized country such as China discharges about 55 percent of all sewage without treatment (The People's Daily, Friday, November 30, 2001). In a relatively developed Middle Eastern country such as Iran, the majority of Tehran's population has totally untreated sewage injected into the city's groundwater (Tajrishy and Abrishamchi, 2005). In South Africa where some level of wastewater treatment is observed, Momba et al., (2006) reported the poor operational state and inadequate maintenance of most of the municipalities' sewage treatment works as leading to the pollution of various water bodies thereby posing very serious health and socio-economic threats to the dependants of such water bodies. Most of sub-Saharan Africa is without wastewater treatment (Sci-Tech. Encyclopaedia, 2007). Modern civilization, armed with rapidly advancing technology and fast growing economic system is under increasing threat from its own activities causing water pollution, (Singh et al. (1989). India is the seventh largest country in the world with a total landmass of 3.29 million sq. km, population over 1 billion, 29% of which live in urban areas spread over 5162 towns. With enormous natural resources and growing economy India is the second largest pool of technical and scientific personnel in the world. Pollution from small size industries (SSIs) puts the Indian regulators in front of a difficult arbitrage between economic development and environmental sustainability. The uncontrolled growth in urban areas has made planning and expansion of water and sewage systems very difficult and expensive (Looker, 1998).

Status of wastewater in India

The total wastewater generated by 299 class-1 cities is 16,652.5 MLD. Out of this, about 59% is generated by 23 metro cities. The state of Maharashtra alone contributes about 23%, while the Ganga river basin contributes about 31% of the total wastewater generated in class-1 cities. Only 72% of the total treated wastewater generated is collected. Out of 299 class-1 cities, 160 cities have sewerage system for more than 75 percent of population and 92 cities have more than 50 percent of population coverage. On the whole 70% of total population of class-1 cities is provided with sewerage facility, compared to 48% in 1988. The type of sewerage system is either open or closed or piped. The main objective of this study was to perform a review of the treatment of domestic sewage using the aerobic sludge to ensure effective discharge and/or re-use/recycling.

Wastewater treatment in India

Out of 16,662.5 MLD of wastewater generated, only 4037.2 mld (24 %) is treated before release, the rest (i.e. 12,626.30 MLD) is disposed of untreated. Twenty-seven cities have only primary treatment facilities and only forty-nine have primary and secondary treatment facilities.

Need of sewage treatment:

Wastewater treatment involves breakdown of complex organic compounds in the wastewater into simpler compounds that are stable and nuisance-free, either physico-chemically and/or by using micro-organisms (biological treatment). The adverse environmental impact of allowing untreated wastewater to be discharged in groundwater or surface water bodies and or lands are as follows:

1. The decomposition of the organic materials contained in wastewater can lead to the production of large quantities of malodorous gases.

2. Untreated wastewater (sewage) containing a large amount of organic matter, if discharged into a river / stream, will consume the dissolved oxygen for satisfying the Biochemical Oxygen Demand (BOD) of wastewater and thus deplete the dissolved oxygen of the stream, thereby causing fish kills and other undesirable effects.

3. Wastewater may also contain nutrients, which can stimulate the growth of aquatic plants and algal blooms, thus leading to eutrophication of the lakes and streams.

4. Untreated wastewater usually contains numerous pathogenic, or disease causing microorganisms and toxic compounds, that dwell in the human intestinal tract or may be present in certain industrial waste. These may contaminate the land or the water body, where such sewage is disposed.

For the above-mentioned reasons the treatment and disposal of wastewater, is not only desirable but also necessary.

Industrial, Municipal and Domestic Reuse of Wastewater

Municipal uses of treated wastewater include the irrigation of road plantings, parks, playgrounds, golf courses and toilet flushing etc. (Bouwer, 1993). Industrial reuses of wastewater include cooling systems, agricultural uses (irrigation and aquaculture), the food processing industry and other highrate water uses (Bouwer, 1993b; Khouri et al. 1994; Asano and Levine, 1996). In Middle Eastern countries, where water is scarce, dual istribution systems will, in the near future, provide high quality, treated effluents for toilet flushing to hotels, office buildings, etc. (Shelef and Azov, 1996).

In India, wastewater is currently being used for irrigation, gardening, flushing, cooling of air conditioning systems, as a feed for boilers, and as process water for industries (Chawathe and Kantawala, 1987). In China, national policy has been developed that promotes the development of water-efficient technologies, and encourages the reuse of reclaimed municipal wastewater in agriculture first, and then for industrial and municipal uses (Zhongxiang and Yi, 1991). In Japan, International Journal of Engineering Research & Technology (IJERT) Vol. 1 Issue 5, July - 2012 ISSN: 2278-0181 www.ijert.org 4 reclaimed wastewater is used for toilet flushing, industry, stream restoration and flow augmentation to create "urban amenities" such as green space (Asano, Maeda, Takaki, 1996)

METHODOLOGY

1. Biofilm technology

Definition of biofilm itself is simply defined as communities or clusters of microorganisms that attached to a surface [9-10]. Formation of biofilm could be achieved by a single or multispecies of microorganisms that have the ability to form at biotic and abiotic surfaces [9]. 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

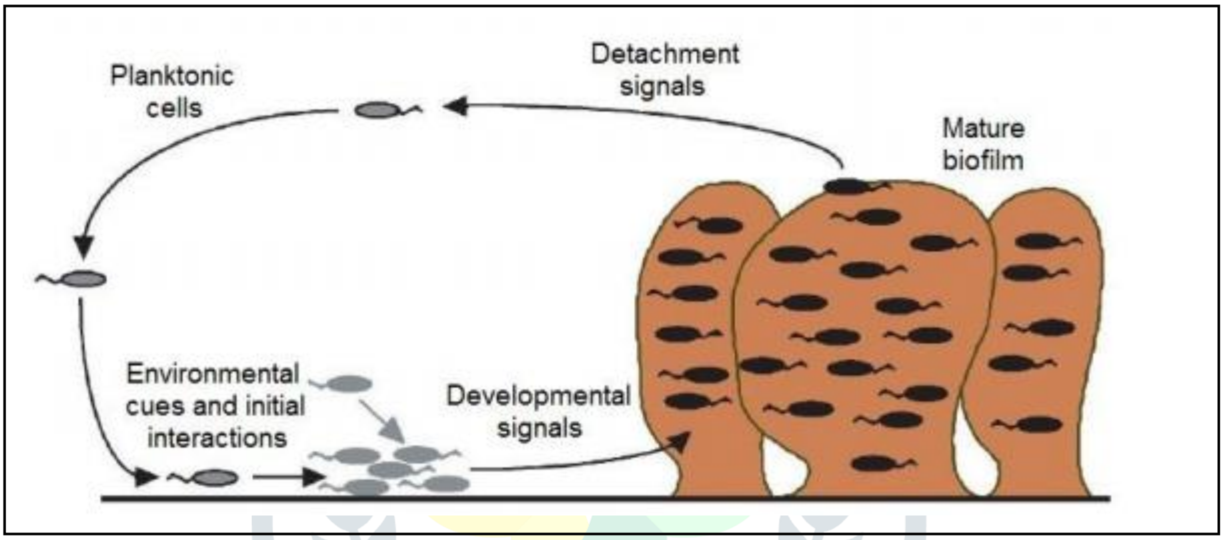

Figure 1: Process of biofilm development

According to Watnick and Kolter [11], the formation of a bacterial biofilm is a same with community that is built by human. First, the bacterium must approaches closely before form a transient attachment with the surface and/or other microorganisms that formerly attached to the surface. This step of transient attachment allows the bacterium to search a place before adapting it. After the bacterium has finally settled down, it will form a stable attachment and associate into a microcolony, which is the bacterium has chosen the neighbourhood to live. Finally, the building of biofilm is established and irregularly, the biofilm-associated bacteria will detach from biofilm surface. The uses of biological treatment process have taken into placed compared to physical and chemical method in terms of their efficiency and economy [12]. One of the biological methods that have been realised to overcome the bioremediation problems is biofilm. According to Decho [13], biofilm-mediated bioremediation hands a capability and safer option to bioremediation with planktonic microorganisms. 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 decolourise and metabolise dyes since there are intrinsic cellular mechanisms that will bring aboutthe degradation or biosorption of dyestuffs

Advantages:

Biofilm offers a proficient and harmless option to bioremediation with planktonic microorganisms since the cells in biofilm have a highly chance of adaptation and survival, particularly in unfavourable conditions. This situation is due to the matrix that actually acts as a barrier and protects the cells within it from environmental distress [13]. Extracellular polymeric substances or EPS have significant towards the growth of biofilm which it appears that to be a part of protective mechanism for biofilm community. Wingender et al. [14] reported that EPS can minimise the impact 114 Ta Wee Seow et al of modification in pH, temperature, and concentration of toxic substances. Biofilm can have very long biomass residence times when treatment requires slow growing organisms with poor biomass yield or when the concentration of wastewater is too low to sustain growth of activated sludge flocs [15].

Application in wastewater treatment:

Biofilm has becoming an interest subject to be explored, especially in the perspective of wastewater treatment, therefore, many studies has performed in order to achieve and gain understanding towards of the utilisation of biofilm to remediate the environment. Aerobic fluidised bed reactor, rotating biological contactors, aerobic membrane bioreactor are a few applications of biofilm reactors that have been invented to treat various condition of wastewater produced by the industrial.

Limitations:

There are several limitations of biofilm towards the implementation in wastewater treatment. The limitations are [21]: • Biofilm formation on carriers poses problems leading to long start-up times; • Overgrowth of biofilms leads to elutriation of particles; • Control of biofilm thickness is difficult; • Liquid distributors for fluidised systems are costly for large-scale reactors and pose problems with respect to clogging and uniform fluidisation.

2. Aerobic Granulation Technology:

The improvement to certain drawbacks of biofilm has led to the invention of a novel microbial self-immobilisation processes called biogranulation at the late 1990s [22]. The granular sludge generated via biogranulation approaches have higher biomass retention and reusability, broader selection of bacterial strains for plausible bioaugmentation and higher microbial density with millions of bacteria cells per gram of biomass [23]. Biogranulation can generated two types of granular sludge which were aerobic granular sludge (AGS) and anaerobic granular sludge (AnGS), in which both of them can be developed in a fixed sequencing cycle of feeding, reacting, settling, and decanting under a single sequencing batch reactor (SBR) system [24]. 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 [25]. Meanwhile the AGS 116 Ta Wee Seow et al was able to overcame 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)[26]. 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[27]. The granular sludge possessed an excellent settling property compared with the conventional floc sludge andtherefore enabling high biomass retention and dense microbial structures for withstanding high-strength organic wastewater and its shock loading[28]. According to Beun et al.[29], a mechanism for the formation of aerobic granular sludge in an aerobic reactor without the presence of a carrier material is proposed via a series of microscopic observation. The proposed mechanism is schematically illustrated in Figure 2.

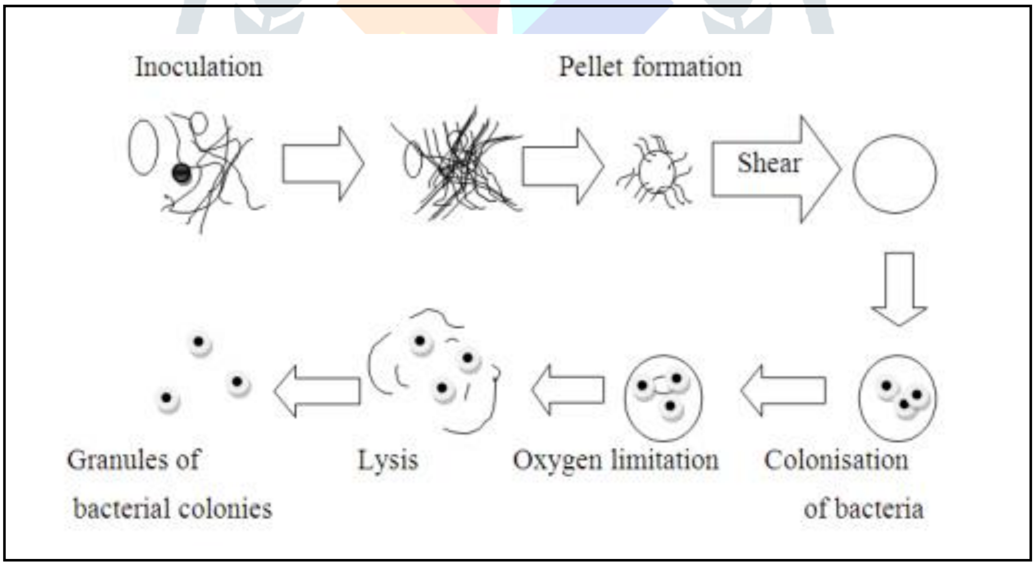

Figure 2: Proposed mechanism of granulation after the start-up of SBR with a short settling time

At the beginning stage of the biogranulation, fungi and filamentous bacteria easily form mycelial pellets which settle very well and can be retained in the reactor. Bacteria do not possess this special property and will be washed out almost completely. Therefore, during the start-up period, the biomass in the reactor will consist mainly of filamentous mycelial pellets. As the granulation proceed within the reactor, due to the shear force in the reactor, detachment of the filaments on the surface of the pellets takes place and the pellets become more compact. The pellets grow out to a diameter of 5±6 mm and then undergo a lysis process due to the oxygen limitation in the inner part of the pellet. The mycelial pellets seem to function as an immobilization matrix in which the bacteria can grow out tocolonies. When the mycelial pellets fall apart due tolysis of the inner part of the pellets, the bacterialcolonies can maintain themselves because now they were large enough to Review On Wastewater Treatment Technologies 117 settle. These microcolonies further grow out to become denser granular sludge, leading eventually to a bacterial dominated population in the reactor as the granulation proceed [29-30].

Advantages:

The aerobic granules were known to exhibit attributes of compact, regular, smooth and nearly round in shape; excellent settle ability; dense and strong microbial structure; high biomass retention; ability to withstand high organic loading rate or shock loadings; endurance to starvation; tolerance to toxicity and simultaneous COD, nitrogen and phosphate removal [25, 31-32]. Bio-augmentation of specific bacteria strains which were able to degrade a target recalcitrant compound was also possible as these bacteria can be introduced as inoculum during the granulation period. For example, the AGS was successfully cultivated in a SBR treating high strength pyridine wastewater, using a single bacterial strain Rhizobium sp. NJUST18as the inoculum [33]. The degradation of 2-fluorophenol with the AGS in a SBR also achievable with inoculation of Rhodococcus

Application in wastewater treatment:

Due to their unique attributes, the aerobic granulation technology was recently developed for treating a variety of high strength raw wastewater. Table 2 summarised the application of the AGS technology in treating either synthetic or raw wastewater and their overall treatment efficiencies.

Limitations:

Although the aerobic granulation technolgy has been successfully applied for the treatment of lots of different types of wastewater, however most of the research achievements of AGS were from bench-scale SBR, while the volume of the reactors was usually small (0.5-4 L) with limited processing capacity and their operational conditions were strictly controlled [42].Apparently, the results of those researches had only theoretical guiding implication for practical engineering applications, and therefore AGS technology need to be testified by vast pilot projects treating different types of raw wasterwater.

CONCLUSION

This paper is a review of the application of biofilm technology, aerobic granulation and microbial fuel cell for the treatment of wastewater. The treatment performances in terms of their advantages, applications and limitations have been discussed thoroughly. The ultimate goal of the wastewater treatment is the protection of the environment in a manner commensurate with public health and socio-economic concerns. Understanding the nature of wastewater is fundamental to design an appropriate treatment technology in order to ensure the safety, efficacy and the quality of the treated wastewater. Further, improved public education to ensure awareness of the technology and its benefits, both environmental and economic, is recommended.

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