Aerobic wastewater treatment technologies: A mini review

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ABSTRACT

Treatment of sewage water from industries or domestic becomes very crucial in present days. For concentrated industrial wastewater aerobic treatment is a substitute to the slower anaerobic treatment processes. Due to its low operation and maintenance costs, use of aerobic waste water treatment as a reductive medium is getting increased attention. In addition, this is very easy-to-obtain, with well effectiveness and ability for degrading contaminants. In this article, the use of aerobic waste water treatment technologies to remove contaminants present in wastewater, which represent the main pollutants in wastewater, has been reviewed. The review concludes that suspended growth bioreactors are very efficient at low organic loading rates for treating wastewaters. Most of the biofilm reactors have a same level of COD removal.

1. Introduction

A supply of clean water is an essential requirement for the establishment and maintenance of different 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. Aerobic treatment is a biological process. Dissolved oxygen is used by microorganisms (aerobes) for the degradation of organic wastes.

Water is very important for human life, agriculture and to produce industrial products. Water resources are becoming increasingly scarce around the world due to the growing imbalance between freshwater availability and consumption. In our modern society the access to clean and safe water has become challenging. Due to the increase in population, the demand of water resources is also increasing to a modern consumer society. The amount of contaminated wastewater can be treated before being discharged into the natural ecosystems (Escapa et al. 2015). In dry climatic regions, wastewater treatment process, a practical alternative is recycling that can help to solve limited water resources problem (Almuktar et al. 2015). There are many infectious waterborne diseases transmitted by the biological waste water. The main pollutants in wastewater include nitrogen (N), particularly ammonia-N (NH₃-N), biochemical oxygen demand (BOD) and chemical oxygen demand (COD). To promote the aerobic biochemical reaction, the oxygen supply rate into microorganisms has to be fast because of oxygen feed limitation. A highly efficient oxygen supplier and more useful aerobic waste water treatment system are thus expected. There is many technology or reactor for the aerobic treatment of wastewater. Some of them are Sequencing Batch Reactor (SBR) system, contact stabilizer, trickling filter, microbubble aerator etc. Microbubbles have
useful characteristics, such as a large gas–liquid interfacial area, long residence time in the liquid phase and fast dissolution rate so that they have an advantage to dissolve the oxygen gas in air into water. To produce microbubbles, specific types of microbubble generators are necessary. Depending upon the design, SBR has some positive attributes: for instance short hydraulic retention time (HRT) that allows high organic loading rate (OLR) and lower sludge production (Dutta et al. 2014). SBRs containing aerobic granular sludge (AGS) that can be used to scale down the required reactor capacity leading to more compact designs and in treating high strength wastewater. AGS technology has been proposed as an innovative technique for the treatment of municipal and industrial wastewater (Henriet et al. 2016). The MBBR needs to be better understood. The characterization of the microbial community associated with the biological system is a critical step that needs to be done, since bacteria plays a major role in the bioreactor functioning (Muszyński et al. 2015).

2. Aerobic waste water treatment system

2.1. Aerobic granulation technology

The bio-granulation approaches are used to generate granular sludge. In the aerobic compartment 88% of ammonia can be oxidized (Zupancic et al. 2008). Short-time aerobic digestions (STAD) attain better flocculability of sludge. Effects of cocoamidopropyl betaine (CAPB) on the STAD evaluated. CAPB has a non-polar linear hydrocarbon group which can be used to scale down the required reactor capacity leading to more compact designs and in treating high strength wastewater. AGS technology has been proposed as an innovative technique for the treatment of municipal and industrial wastewater (Henriet et al. 2016). The MBBR needs to be better understood. The characterization of the microbial community associated with the biological system is a critical step that needs to be done, since bacteria plays a major role in the bioreactor functioning (Muszyński et al. 2015).

2.2. Biofilm reactor

Biofilm is communities or clusters of microorganisms that attached to a surface (‘O’Toole et al. 2000; Singh et al. 2006). It offers an adept and harmless option to bioremediation with planktonic microorganisms. In the biofilm the cells have a higher chance of adjustment and survival in unfavorable conditions. This situation is due to the matrix that acts as a barrier and protects the cells within it from environmental distress (Decho 2000). Extracellular polymeric substances (EPS) have significant towards the growth of biofilm which it appears that to be a part of the protective mechanism for biofilm community. It can minimize the impact of modification on pH, temperature, and concentration of toxic substances. There are various types of bioreactors which are as described below:
2.2.1. Integrated anaerobic-aerobic fluidized bed reactor

A cylindrical fluidized bed with pulverized pumice-stone has been used as the support material for microorganisms (Fdez-Polanco et al. 1994). It is performed by four cylindrical fine bubble membrane diffusers. It offers excellent stability in spite of variations in organic load and delivers short startup time for the operation. By this process, eliminates organic carbon and nitrogen from municipal and industrial wastewater.

2.2.2. Anaerobic-aerobic fixed film bioreactor (FFB)

Two fixed-film bioreactors with arranged media connected in series with recirculation system has been used for aerobic treatment (Del Pozo et al. 2003). The system gives advantages of less sensitivity to environmental variations and higher growth rate due to the use of immobilized cells on the surface of the media. This bioreactor can remove the oil and grease from the wastewater.

2.2.3. Rotating biological contactor (RBC)

Rotating biological contactor (RBC) has been operated by attaching microorganisms to an inert support matrix to form a biofilm support matrix, and the following disc configuration is placed partially or entirely submerged in the reactor and it rotate around a horizontal axis slowly where the wastewater flows through it (Sperling et al. 2005). This type of reactor can treat highly effective synthetic wastewater with COD concentration up to 12000 mg/L.

2.2.4. Anaerobic–aerobic granular biofilm bioreactor

Granular biofilm bioreactor have an upflow anaerobic sludge bed (UASB) and an aeration column. It is placed in the middle of the reactor. Anaerobic and aerobic populations of the biofilm co-exist intimately in the similar reactor. This bioreactor offers a superior strategy to complete mineralization of highly substituted compounds (Tartakovsky et al. 2005). It can eliminate various chlorinated pollutants.

2.2.5. Aerobic membrane bioreactor (MBR)

Aerobic membrane bioreactor (MBR) functions has been applied as a dual mechanism in which membrane filtration occurs along with biodegradation processes water and small solution molecules pass through the membrane while solid materials, biomass, and macromolecules retained in the reactor (Dhaouadi et al. 2008). It can treat high-strength synthetic wastewater.

2.2.6. Moving-bed biofilm reactor

Advances in the wastewater treatment sector have culminated in the development of new processes showing high treatment performance and stability. Most of the new technologies based on the growth of bacteria adhered to a solid surface, which can be fixed or mobile. A growing technology is the moving-bed biofilm reactor, known as MBBR (Bassin et al. 2017). It has been decided to characterize the bacterial community of the biofilms cultivated in both anoxic and aerobic environments. The aerobic reactor exhibited a more equitable distribution of the bacterial groups, leading to higher values of diversity but the difference was less pronounced in the anoxic reactor. Synthetic media developed aerobic granules from conventional activated sludge under anaerobic-aerobic conditions. Their succeeding adaptation is used for the treatment of dyeing wastewater (Manavi et al. 2017). The development of aerobic granules depends on the exposure ness to the dyeing wastewater. As results it shows the changes of tightly-bound (TB-) and loosely-bound (LB-) extracellular polymeric substances (EPS), their carbohydrate, polysaccharides (PS) and protein (PN) fractions. The treatment of the aerobic granules was evaluated during the adaptation period. 68% COD and 73% color can remove for both phases (anaerobic and aerobic) at the time of operation in a single cycle.

2.3. Activated sludge process

2.3.1. Microbubble aerator

A microbubble is a small bubble with diameter of 10 to 60 mm. It has important characteristics (i) a large gas-liquid interfacial area, (ii) long residence time in the liquid phase and (iii) fast dissolution rate. Microbubbles have the capability to dissolve the oxygen into water. Particular types of microbubble generators are required for generating the microbubbles. A spiral liquid flow type microbubble is used for producing microbubbles (Ohnari et al. 1999). A microbubble generator was generated using cavitations in a heat pipe consists of two-phase nozzle (Takahashi et al. 1998). Microbubble has been analyzed with various applications for industrial purposes (Watanabe et al. 2004). Microbubble aeration system such as novel flotation system has been proposed to remove fine carbon particles suspended in wastewater. It need mechanical moving parts that have shear force acts on a liquid (Terasaka and Shinpo 2007). Prevent from damage to the activated sludge (Usui 2006) proposed to fix an aerobic filter which is made of polyethylene glycol. The sludge bed system has higher effectiveness in comparisons to others. When suspended flocs of activated sludge, flow into a pump then the flocs were broken. Therefore, the activities of the flocs decreased. After that the technology has been developed called microbubble flotation to remove the fine iron oxide particles suspended in wastewater (Terasaka et al. 2008). Microbubble behavior has investigated in an ultrasonic field (Kobayashi et al. 2008).

Novel crystallization system has been applied to show the behavior of shrinking microbubbles (Terasaka et al. 2009). Microbubble agglomeration has been used for the accurate ultrasonic irradiation (Hayashida et al. 2010). An application has found to generate micro water droplets using steam microbubbles (Watanabe et al. 2010). Many commercial microbubble generators were evaluated due to the oxygen dissolution device. This device depends on the oxygen transfer rate and power consumption rate. The most usable generator was attached to a novel aeration system. A novel wastewater treatment system was proposed with a spiral liquid flow type microbubble aerator, a draft tube, and a filtration chamber. The system showed a much more rapid oxygen dissolution rate into water. It was designed by the
acquainted design equation (Terasaka et al. 2011). The systems consume more energy than the others. It is used for the oxygen supply into an inactive region in anaerobic sludge tank. It is also used for more compact tank (Fig.1).

### 2.3.2. Contact stabilization

Contact stabilization activated sludge technology proved to be successful as an enhanced biological phosphorus removal (EBPR) (Rashed et al. 2014). The effect of contact stabilization activated sludge as an application of enhancing biological phosphorous removal (EBPR) by using contact tank as a phosphorus uptake zone and using thickening tank as a phosphorus release zone. The results showed the removal efficiencies of COD, BOD and TP for this pilot plant with the range of 94%, 85.44% and 80.54%, respectively. The results also showed that the reason of high ability of phosphorus removal for this pilot plant related to the high performance of microorganisms for phosphorus accumulating. Application of this system proved to be successful in activated sludge WWTP by some physical changes especially in the aeration tank and involves only one separate tank in these treatment plants. In contact stabilization, activated sludge technology proved to be successful as an EBPR using effective microorganisms (EM) with molasses. It is analyzed that activated EM has been used to the anaerobic zone for enhancement of fermentation (Rashed and Massoud 2015). Results showed the removal efficiencies of COD, BOD₅ and total phosphorus of this pilot plant were 93%, 93% and 90%, respectively. Eutrophication in water bodies is due to the presence of extremely high phosphorus. It needs to be reduced before being discharged into water bodies and rivers. For reducing phosphorus from wastewaters EBPR process proved to be an economical and environmentally compatible method. EBPR-available organic substrates such as short chain volatile fatty acids (VFAs) and an aerobic–anaerobic reactor configuration are provided. The performance of EBPR was investigated using modified contact stabilization activated sludge pilot plant (Ali et al. 2015). After that, the results indicated the removal efficiencies of COD, BOD₅ and TP are 91%, 92% and 85% respectively.

The contact-stabilization (CS) technology is as a not very costly method to develop the carbon harvesting from high-strength synthetic wastewater (Rahman et al. 2016). There are two types of reactors in the CS process: i) the contactor reactor receives influent feed and ii) stabilized biomass under anaerobic conditions. The remainder is sent to a stabilizer reactor. After that the sludge is left and the contactor is settled and harvested. It is aerated to oxidize the biosorbed and stored carbon. The carbon redirection and recovery could be achieved as a resultant at short solids retention time (SRT). The high-rate CS allowed 52 to 59% carbon removal, carbon redirection to sludge and carbon recovery than others. The biosorption capacity and bioflocculation affinity improved by the presence of RAS aeration in the CS configuration. The CS configuration has described a better potential for carbon capture and recovery than the other configuration. The high-rate CS system is also very useful for carbon and energy recovery from low-strength wastewaters. In light of maximizing energy recovery and carbon capture, high-rate CS technology has significant benefits and potential, as it maximizes biosorption capacity using RAS aeration scheme and promotes bioflocculation compared to conventional systems. This study focused on mechanistic understanding of EPS production in high-rate CS system and provides unique insights in the mechanistic differences of how bioflocculation is regulated when operated with high-
strength versus low-strength wastewater. There have some effect of extracellular polymeric substance (EPS) on bioflocculation improvement and carbon capture from municipal wastewater in pilot-scale and bench-scale CS systems (Rahman et al. 2017). The results showed that a rapid increase in EPS was established from the famine stabilizer to the aerobic feast contactor, and that mechanism was responsible for improved bioflocculation, carbon capture efficiency and effluent quality. The EPS production was driven by high organic loading rate for high-strength wastewater. It required minimum stabilization time to induce starvation condition for low-strength wastewater systems.

2.3.3. Trickling filter

Trickling filters proved to be very promising devices and it have the capacity of high removal rates of hexavalent chromium. For minimize the operating cost, it provides a support material for consistent biofilm structure development. The physical aeration is adequate for bacterial needs. Indigenous bacteria from industrial sludge were enriched. It has been used as an inoculum for the filter. There are three types of operating modes to investigate the optimal performance and efficiency of the filter: (a) batch, (b) continuous and (c) SBR with recirculation.

Hexavalent chromium is a strong poisonous and carcinogenic agent present in waste water. It is very necessary to remove the Cr (VI) before disposing to the nature. Pilot scale trickling filter was used for removing the biological chromium (VI) from wastewater. The bacterial populations provides an advantage and to ensure the durability under some operating conditions (Dermou et al. 2005). They were found that removal rates up to 530 g Cr (VI)/m² d. For biological hexavalent chromium removal from industrial wastewater effluents, it indicated a feasible, economical and efficient technique. The biological treatment process is not only continuously operated but also in an SBR mode (Kornaros and Lyberatos 2006). It is very promising filter technique for removing a great amount of the biodegradable compounds. COD removal efficiency was attained about 60 to 70%. In this filter technique, the microorganisms were efficient to remove COD up to 36,000 mg/L under aerobic conditions at pH 5.5 and 8.0. The rest of the COD was removed by biological action. Biological Cr (VI) reduction can be done by the use of pilot-scale bioreactors and bacterial population (Dermou and Vayenas 2007). A nonlinear dual enzyme kinetic model is introduced for operating those bioreactors under SBR mode. This model proved to be a tremendous tool in the reduction of Cr (VI) from industrial effluents and the treatment plants. By this respective operation, the reduction rates of Cr (VI)/d is near about 4.8 g. Various types of filter media is used to estimate Cr (VI) removal in biofilm reactors. The biofilm reactors operated in SBR operating mode. Two different materials has been applied in pilot-scale trickling filters: (a) plastic media and (b) calcitic gravel (Dermou et al. 2007). Gravel has high specific surface area. The void space becomes lesser due to the formation of sediments and pore clogging at the same time. The growth of a thicker biofilm layer has increased by the plastic media. Due to the thicker biofilm layer avoids the pore clogging. It is used for the industrial wastewater treatment because the filter void space is larger. Plastic media indicates the best performance compared to the gravel media at the different Cr (VI) concentrations. The rate of Cr (VI) removal in the plastic media is greater than gravel...
media. The plastic media has the capability to remove the Cr (VI) 4.23±0.18 for 5 mg/L, 3.62±0.1 for 30 mg/L and 3.3±0.08 g for 100 mg/L. In case of other media, the removal rates of Cr (VI) were4.11±0.09, 3.52±0.06 and 2.5±0.07 g for 5, 30 and 100 mg/L respectively. Natural ventilation trickling filters (NVTFs) with sponge, zeolite and ceramics were utilized in domestic wastewater to treat. NVTFs have the capability to remove COD and ammonia. Nitrification rates (NR), oxygen uptake rate (OUR) and dehydrogenase enzyme activity (DHA) of microorganism were tested by the parameters. Polymerase chain reaction-denaturing gradient gel electrophoresis (PCR-DGGE) analysis was conducted for the differences between microbial communities. The differences were showed between the biofilms on zeolite, sponge and ceramics (Zhang et al. 2016). The distribution of zeolite was similar with ceramics than sponge. Zeolite has no superior capability to remove pollutants or nitrifying bacteria growing. Biotrickling filter reactor (BTFR) treatment process is used to remove Formaldehyde (FA) from polluted air (Fulazzaky et al. 2016). It can be removed by two successive transfer mechanisms (1) the formation of formic acid and methanol in the aqueous phase. It is caused by the reaction of FA with water and hydrogen (2) microorganisms are able to metabolise the chemicals-derived FA from aqueous phase after passing through the biofilms. BTFR design and operations have the capability to reduce the contaminated air to improve quality of air (Fig. 2). Biogas produced by the landfills technique and also the anaerobic digestion systems to methanol using methanotrophs (aerobic CH₄-oxidizing bacteria). It is an emerging approach to convert the biogas (which is derived from waste) to liquid chemicals and fuels. A methanotrophic trickle-bed reactor improved mass transport of O₂ and enhanced CH₄ oxidation to methanol production. The highest CH₄ to methanol conversion rates were observed. Using optimal operating parameters, methanol productivity showed the highest (0.9 g/L/d) from the non-sterile TBR (Sheets et al. 2017).

3. Conclusion

Gradually, pollution regulation becomes stringent for the betterment of our future. Thus improvement of pollution abatement technology is gaining more impetus day by day. Proper management techniques for water treatment can prohibit the water crisis in near future. Aerobic water treatments gained prodigious importance over the past decades. Low energy consumption, easy process, less equipments’, potentiality of resource recovery etc. makes this process more attractive. Design of appropriate treatment technology, depends on the character of waste water. The main goal of treatment lies on the protection of environment as well as human health.

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