In The Name Of ALLAH, (swt)

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Effect of feed strategy on aerobic granulation process

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Abstract

Aerobic granular sludge, a novel environmental biotechnological process, was increasingly drawing interest of researchers in the area of biological wastewater treatment. So, in this research, laboratory experiments were conducted to investigate the effect of feeding regime on the granulation process including: a sequencing batch reactor (SBR) and continuous feed and intermittent discharge bioreactor (CFID). The soft drink wastewater was used as feed in both systems. In the experiments, two levels of the initial COD concentrations were examined in SBR, including 300 and 500 mg/l, whereas cycle time was set on 4 h. To have a proper comparison between SBR and CFID regimes, the same conditions were operated at the CFID bioreactor. Besides, at the CFID bioreactor, the idling time at three levels including: 30, 60, and 75 min was applied to provide a suitable feast phase. From the results, contrasting to SBR, CFID regime was not capable to form granular sludge at the applied conditions. In the SBR, on day 7 and 5 at initial COD concentrations of 300 and 500 mg/l, tiny granules and then after 20 days mature granules were achieved and SVI value in SBR was reached about 20 ml/g. With increasing the initial COD concentration from 300 to 900 mg/l, the stability and integrity of granules were reduced, so that SVI value was increased to 50 ml/g. To investigate the aerobic granulation process in the CFID bioreactor, HRT values of 8 and 12 h with idling times of 60 and 90 min were examined, respectively. In the CFID bioreactor, at HRT of 8h (COD_{in} of 500 mg/l), the aerobic granules appeared and with increasing HRT to 12 h (COD_{in} of 1000 mg/l) the aerobic granules were enlarged and more stable. So, the higher values of HRT favored the granulation process in the CFID bioreactor as a result of more famine phase in the bioreactor. Also, from the SEM images, the granules in SBR and CFID bioreactor showed different structure, so that aerobic granules in SBR were more integrated compared to CFID bioreactor.

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Chapter 1

Introduction

1-1- Introduction

Ever increasing industrialization and rapid urbanization have considerably increased the rate of water pollution. The dwindling supplies of natural resources of water have made this a serious constraint for industrial growth and for a reasonable standard of urban living. Sewage/wastewater are essentially generated from the water supply of the community after it has been fouled by a variety of uses (Seghezzo, Zeeman, van Lier, Hamelers, & Lettinga, 1998).

Fig. 1-1. Industrial wastewater effluent with neutralized pH from tailing runoff taken in Peru.

Wastewater is 99.9% water and 0.1% solids. It comprises liquid waste discharged by domestic residences, commercial properties, industry, and agriculture and can encompass a wide range of potential contaminants and concentrations.

The composition of wastewater varies widely. This is a partial list of what it may contain:

1) Water (more than 95 percent), which is often added during flushing to carry waste down a drain;
2) Pathogens such as bacteria, viruses, prions and parasitic worms;
3) Non-pathogenic bacteria;
4) Organic particles such as feces, hairs, food, vomit, paper fibers, plant material, humus, etc.;
5) Soluble organic material such as urea, fruit sugars, soluble proteins, drugs, pharmaceuticals, etc.;
6) Inorganic particles such as sand, grit, metal particles, ceramics, etc.;
7) Soluble inorganic material such as ammonia, road-salt, sea-salt, cyanide, hydrogen sulfide, thiocyanates, thiosulfates, etc.;
8) Animals such as protozoa, insects, arthropods, small fish, etc.;
9) Macro-solids such as sanitary napkins, nappies/diapers, condoms, needles, children's toys, dead animals or plants, etc.;
10) Gases such as hydrogen sulfide, carbon dioxide, methane, etc.;
11) Emulsions such as paints, adhesives, mayonnaise, hair colorants, emulsified oils, etc.;
12) Toxins such as pesticides, poisons, herbicides, etc.
13) Pharmaceuticals and hormones.

Discharging the pollutants into the environment cause the death of fish and other marine organisms and depletion of oxygen in the receiving waters (Chen, Jiang, Liang, & Tay, 2008; Z. Li, Yang, Yang, & Li, 2010). In order to avoid the advance impact on the environment; strict rules limiting the discharge of organic matter will not only allow but also for nutrients in aquatic ecosystems particularly sensitive to applied. Thus, wastewater with high pollution from industry has evolved rapidly in recent years have and methods of treatment are essential.

Physical parameters include color, odor, temperature, and turbidity. Insoluble contents such as solids, oil and grease, also fall into this category. Solids may be further subdivided into suspended and dissolved solids as well as organic (volatile) and inorganic (fixed) fractions.

Chemical parameters associated with the organic content of wastewater include biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), and total oxygen demand (TOD). Inorganic chemical parameters include salinity, hardness, pH, acidity and alkalinity, as well as concentrations of ionized metals such as iron and manganese, and anionic entities such as chlorides, sulfates, sulfides, nitrates and phosphates. Both constituents and concentrations vary with time and local conditions (Gogate & Pandit, 2004).

1-1-1- Use of untreated wastewater by agriculture

Treated wastewater can be reused as drinking water, in industry (cooling towers), in artificial recharge of aquifers, in agriculture and in the rehabilitation of natural ecosystems. Around 90% of wastewater produced globally remains untreated, causing widespread water pollution, especially in low-income countries. Increasingly, agriculture is using untreated wastewater for irrigation. There can be significant health hazards related to using the water in this way. Wastewater from cities can contain a mixture of chemical and biological pollutants. The World Health Organization, in collaboration with the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Environmental Program (UNEP), has developed guidelines for safe use of wastewater.

1-1-2- Environmental regulation of effluent discharge

The highly pollution loading on the water resources from various sources (municipal, industrial and agricultural) has been led to the increasingly stringent environmental regulations. The permitting variable effluent standards are applied based on the demands of prevailing environmental circumstances. The effluent discharge standards ordinarily applicable to effluent wastewater are presented in Table 1-2.

Table 1-2. Effluent discharge standards for treated wastewater (Iran)

Parameter	Discharge to surface water(mg/l)	Discharge to well (mg/l)	Agriculture Uses (mg/l)
COD	60	60	200
BOD_5	30	30	100
TSS	40	-	100
TDS	10	10	-
NH_4	2.5	1	-
NO_2	10	10	-
NO_3	50	10	-
TP	6	6	-
pH	6.5-8.5	5-9	6-8.5
Turbidity(NTU)	50	-	50

1-2- Biological treatment systems and granular bioreactor

Nowadays wastewater treatment has been a challenging problem throughout the world with increasing consciousness about water pollution. Different techniques for treating wide range of wastewaters have been investigated by researcher for instance biological treatment, membrane technology, advanced oxidation, coagulation and etc. Being more cost effective and effortless to operate, Biological treatment is identified as desired method to develop to industry. Activated sludge systems are the first generation bioreactors to treat wastewaters which are still the most commonly used systems for biologial wastewater treatment. In these systems, a mixed culture of suspended biomass is growing and removing organic carbon and nutrients from the influent in an aeration tank. Discharged wastewater from the aeration tank enters into a settling tank, in which the treated effluent is separated from the biomass by gravity.

The settling rate is a limiting factor for the overall size of wastewater treatment plants since long settling time dictates large volume requirements of settling tanks. If biomass forms loose, filamentous flocs, separation of biomass from the effluent is inhibited, and effluent can be discharged together with the activated sludge, causing treatment failure. Therefore, the efficiency of biological wastewater treatment depends upon the selection and growth of microorganisms metabolically capable of converting the polluting agents and growth under given circumstances, and upon the efficient separation of these organisms from the treated effluent in the settling tank.

Increasing population and city development require compact treatment systems which could avoid large footprints. So, high rate bioreactors with low required volume are being enlarged. Moreover, the main trouble with industrial wastewaters is high concentration of nitrogen and phosphorus compounds.

Single bioreactors classified into high rate bioreactors have been modified to provide the required situations to nutrients removal consisting of anaerobic, aerobic and anoxic zones. One of the modified methods is adjusting aeration time. Physical separation is another way to amend bioreactors which has attracted extensive attention in the few last years. Some of the continues bioreactors were employed to treat various wastewaters i.e. jet loop membrane bioreactor (JLMBR) for treating cheese whey wastewater, (Farizoglu, Keskinler, Yildiz, & Nuhoglu, 2007). Bubble column with a draught tube to treat synthetic wastewater (Hano, Matsumoto, Kuribayashi, & Hatate, 1992), radial anaerobic aerobic immobilized biomass bioreactor (RAAIB) to treat sewage wastewater (Garbossa, Lapa, Zaiat, & Foresti, 2005), simultaneous aerobic anaerobic bioreactor (SAA) for treating diluted land filled leachate (Z. Yang & Zhou, 2008).

Another strategy to develop biological treatment is using granular sludge. Granules are described as a collection of self-immobilized cells into a somewhat spherical form, and they are considered to be a special case of biofilm (Beun et al., 1999; Grotenhuis, Smit, Van Lammeren, Stams, & Zehnder, 1991): microorganisms aggregate into circular form without any supporting material under selective conditions. Granular size is much larger than suspended flocs, up to 5 mm in diameter. Granular sludge with a high settleability and high biomass retention is advantageous, which makes compact reactors with integrated sludge separation feasible.

Although the upflow anaerobic sludge blanket (UASB) bioreactor using anaerobic granules is one of the best-known processes and has been extensively applied to anaerobic wastewater treatment, aerobic granulation is a relatively new field investigated in the past decade. Aerobic granules have great potential in the wastewater treatment due to the advantages of strong structure, excellent settleability of biomass, high biomass retention, and the ability to withstand a high organic loading rate (Adav, Lee, Show, & Tay, 2008; Beun, Van Loosdrecht, & Heijnen, 2002; de Bruin, de Kreuk, van der Roest, Uijterlinde, & van Loosdrecht, 2004; Jiang, Tay, Maszenan, & Tay, 2004). So far, aerobic granulation of suspended growth was mainly reported in sequencing batch reactors (SBR). The main feature of sequencing batch reactor is its cyclic operation, which consists of filling, aeration, settling and discharging. Equalization, aeration, and clarification can all be achieved using a single batch reactor. The SBR is no more than an activated sludge system and its operation is resolved in time rather than space.

1-2-1- Aerobic granulation

Aerobic granules were considered to be a special case of biofilm composing of self-immobilized cells (Adav et al., 2008). Aerobic granular sludge technology has been widely reported in sequencing batch reactors (SBRs).

On one hand, it is evolved from flocculating sludge and is resulting in the formation of suspended microbial aggregates without any support media; On the other hand, it is similar to biofilm in mass transferring, with aerobic zone, anoxic zone and anaerobic zone along the direction of mass transfer, which will provide favorable environment for growth of facultative and aerobic bacteria, such as ammonia oxidizing bacteria, denitrifying phosphate accumulating bacteria (DPB), denitrifying glycogen-accumulating bacteria, and phosphate-accumulating organisms (PAOs) (FenWang, 2009). To date, the application of aerobic granular sludge was regarded as one of the promising biotechnologies in wastewater treatment (Adav et al., 2008).

The aerobic granules are densely packed microbial aggregates and their densities are much higher than that of conventional activated sludge.

In addition, the aerobic granules were known to exhibit attributes of:

1) Regular, smooth and nearly round in shape

2) Excellent settle ability

3) Dense and strong microbial structure

4) High biomass retention

5) Ability to withstand at high organic loading

6) Tolerance to toxicity (Adav et al., 2008)

Some of the main disadvantages in activated sludge wastewater treatment relate to the floccular nature of the sludge, as large areas for reactors and especially settlers are required. Granules are large suspended biofilms having regular and dense structure with advantageous qualities in comparison to floccular sludge, these include: superior settling properties, high biomass retention, better able to withstand high-strength wastewater and shock loadings, and improved dewatering capabilities.

The performance of aerobic granular sludge systems has been assessed in laboratory-scale reactors while treating synthetic wastewater, or more recently to treat industrial wastewater, such as dairy or livestock (M. Coma 2012). Successful COD and nitrogen removal from domestic wastewater by aerobic granules is reported when applying high loads. The majority of studies of aerobic granulation focus on organic matter removal while applying complete aerobic conditions. In order to perform both nitrogen and phosphorus removal, anaerobic and anoxic phases are also required.

Nitrogen is removed in a two-stage process: oxidation of ammonium to nitrite or nitrate under aerobic conditions (nitrification) and reduction of these compounds to nitrogen gas in the presence of organic matter under anoxic conditions (de nitrification).

Enhanced biological phosphorus removal (EBPR) also occurs under alternating conditions; in anaerobic conditions organic matter is taken up by polyphosphate accumulating organisms (PAOs) using the glycolysis of intracellular glycogen and cleavage of polyphosphate to conserve energy and build up intracellular stores of polyhydroxyalkanoates (PHA). It is likely that the conditions within granules are favorable for good nutrient removal. Biological nitrogen and phosphorus removal require the combination of different conditions and different microbial populations within a system (M. Coma 2012).

1-3- Problem statement

Biological process has been widely used as the main process for treatment any type of wastewater (municipal or industrial). Biological treatment systems are effective and efficient for treating biodegradable wastewaters, if good process control is ensured (Metcalf & Eddy, 2003). For the biological removal of nutrients (N and P) and carbonaceous matters, anaerobic, anoxic and aerobic conditions are required. Combinations of different high rate anaerobic and aerobic bioreactors have been applied with continuous regime to treat a wide range of industrial wastewater removing carbon, nitrogen and phosphorus. From reactor design point of view, the compact high-rate bioreactors have been more investigated for wastewater treatment due to small space required and less production of odor and sludge (Tartakovsky, Manuel, & Guiot, 2005). Sequencing batch reactor (SBR) is considered as suitable example of integrated bioreactors are cost effective, efficient and have smaller footsteps as clarifiers and flow equalization tanks are needless in the SBR, and thus, costs of services and operation running are lower than those of continuous regime systems. A methodology to promote the performance of SBR is to use granular sludge. Granular sludge has some advantages such as high MLSS concentrations, providing aerobic and anoxic conditions in a single bioreactor without adjusting time. In recent decades, granular sludge has been used in SBR to treat different wastewater (Ji, Zhai, Wang, & Ni, 2010; A.-J. Li & Li, 2009; F. Wang, Lu, Wei, & Ji, 2009; Zhao, Liu, Zhang, & Liu, 2011). One category of SBR systems discriminates those that operate with continuous feed and intermittent discharge (CFID). The CFID bioreactors collect wastewater in all stages of the treatment cycle [13]. Based on the recent researches, the performance of CFID is more compared to SBR. Therefore, providing aerobic granular sludge could be an effective approach to make CFID more favorite. So far, the aerobic granulation process in CFID bioreactor has not been investigated. Possibility of producing granular sludge in CFID bioreactor was assessed in is this study. Also, the optimum conditions to produce granular sludge in SBR and CFID bioreactors were reported.