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PERFORMANCE EVALUATION OF EXTRINSIC FACTORS AFFECTING GRANULATION IN SEWAGE

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Abstract - *The up-flow anaerobic sludge blanket reactor (UASBR) has been used to effectively treat the variety of wastewaters. Decades of investigations and explorations in the field of anaerobic wastewater treatment have resulted in the noteworthy indications about the significance function of the sludge granules in biodegradation anaerobic process. It is understood that the performance of reactor depends on the formation of granules. An outline on the theory of up-flow anaerobic sludge blanket UASB reactor process as well as the main parts of the reactor is briefly explained in this paper. The aim of this paper is to investigate and assess the mechanisms of granules initiation and development of granules inside the UASB reactor. The factors reviewed are pH and alkalinity, temperature, nutrients, organic loading rate, cations and heavy metals.*

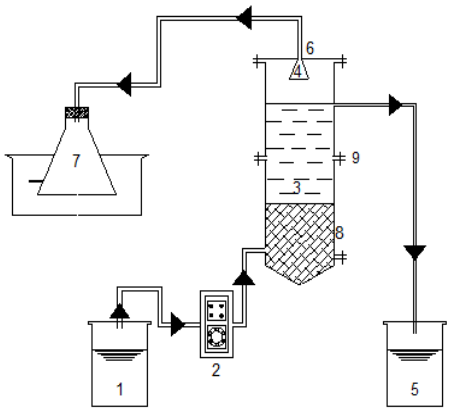
Key Words: Biogas, hydraulic retention time, nutrients, organic loading rate, reactor UASB.

1. INTRODUCTION

At present, Upflow Anaerobic Sludge Blanket Reactor (UASBR) is accepted as a most popular technique for the treatment of wastewater. The UASB process become the most attractive technique because of its low biomass production, high cost efficient, low area demand and high production methane gas. Nowadays, more than 1000 UASB units were being operated all over the world. The application of UASB reactors for the treatment of high strength industrial wastewater such as sugar industry wastes, distillery wastes and brewery wastes had been successful [1,2]. Due to the several advantages of UASBR can be considered as the most popular method of secondary treatment compared to other systems as conventional anaerobic digesters, considering that UASB reactor has the gas collection system as supplementary part on which it will reduce the effect of releasing gas emissions into atmosphere as it occurs in conventional ponds [2]. Anaerobic microbial granulation is considered to be a important parameter for the successful operation of a UASB reactor [3]. Sludge present in the reactor is collection of microorganisms that naturally form granules of diameter about 0.5-5 mm that shows high settling velocity and thus oppose wash out from the reactor even at higher loadings [4]. Hence, there is no support media is required for bacterial attachment to improve the retention time for sludge. Formation of high-quality granular sludge is the foremost characteristics of UASBR to achieve higher COD removal efficiency [5]. The granulation process is generally believed to be susceptible to the abrupt change in the environmental and operational conditions. Factors governing granulation have been widely studied on a variety of wastewaters. Some of these factors are operating conditions [6,7], pH and alkalinity [8], temperature [9], strength and composition of wastewater [10], reactor hydrodynamics [9,11], presence of metal ions and trace metals [12-14], presence of polymers [15,16], microbial ecology [17] and production of exocellular polymeric substances by anaerobic bacteria [18,19]. This paper presents an analysis of various factors such as pH and alkalinity, temperature, nutrients, OLR, and cations and heavy metals affecting granulation and granule size development in UASB reactor are discussed [3]. However, the mechanisms of granulation formation are still not satisfactorily clear [20].

1.1 UASB Technology

The schematic diagram of a UASB reactor is shown in Fig. 1.The UASB reactor can be designed either in circular or rectangular way. The sludge granules present in the reactor acts themselves as a 'media' so it does not require any special medium [21]. In UASBR, the wastewater is fed through bottom of the reactor it contains sludge bed [20]. The suspended solids and bacterial activity and enlargement leads to the formation of sludge at the bottom [21]. Under suitable conditions, light and scattered Particles will be washed out whereas heavier particles will settled, thus reduce the increase of finely dispersed sludge while forming granules or flocs contains the inert organic, inorganic matters and small bacterial aggregates in the seed sludge [17]. The sludge blanket is the composition of microbial granules size ranges from 1 to 3 mm in diameter. The organic compounds in the wastewater are degraded by the microorganisms in the sludge. As a result, it produces methane rich gases [21].



1. Influent tank
2. Peristaltic pump
3. Granulated UASB reactor
4. Gas/liquid/solid separator
5. Effluent tank
6. Gas outlet
7. Gas collection system & measurement of the displaced gas
8. Granulation zone
9. Sampling port

Fig -1: Schematic Diagram for a Upflow Anaerobic Sludge Blanket Reactor

Gas-liquid-solid (GLS) separator is fitted at the top of the reactor to separate the solution contents i.e. the liquid as treated effluent, while the solids particle is trapped and returned back downward, and the gas is collected from the top of reactor in the form of biogas (methane and carbon-di-oxide) (20). The collected gas can be used for further purpose.

1.2 Granulation

The efficiency and stability of the UASB reactor depends sturdily on the initial start-up, which in turn is mostly affected by various physical, chemical and biological parameters [22], such as type of wastewaters, operational circumstances and the characteristics, accessibility and increase of active microbial populations in the seed sludge or inoculums. An acclimatization period is mandatory before the full design organic loading rates can be applied to inoculate the seed sludge. This period is usually 2-8 months [1] is quite time-consuming and has been the foremost drawback of the industrial applications of UASB reactors. The anaerobic sludge which provides anchorage to microflora is the principle element of a UASB reactor. The treatment of the UASB reactor can be achieved by the continuous interaction of wastewater with the microflora attached with the sludge particles [23]. Fig. 2 shows the anaerobic sludge granules from the UASB reactor.

Fig -2: Anaerobic granules from the UASB reactor

1.3 Granules Composition

Every granule has an assortment of structural compositions, which is diverse according to the discrepancy in the characteristics of wastewater as well as discrepancy in the operational condition. The compositions of Granules are inorganic compounds, microorganism cells, and extracellular polymer in assorted rates [20].

1.4 Inorganic Materials

The variation in granules composition is due to substrate description, supply of seed sludge, operational conditions of the reactor, occurrence chemical interactions, and extrinsic factors. Commonly, inorganic components contain minerals and ash [24]. Where, the granules contains inorganic components can range from 10 to 90% thus it depends on the contents of wastewater, and operational conditions [25]. In the same reactor, the inorganic content in the similar granules can change from place to place and this deviation may usually occur. In fact, under mesophilic condition, the granules in simple wastewater like acetate, propionate, or butyrate generate high amount of ash, while in complex wastewater, it generates low amount of ash [26]. Practically, there is a direct relationship between the ash and density, indicates that there is an increase in density is generally recognized by increase in ash [27]. It was found that, the ash contains calcium, potassium and iron. Besides that, the granules in black color contains FeS in the proportion of 30% of the ash content [28]. So far, it is observed that, the ash has no positive effects on the strength of granules structure [29].

1.5 Microorganism Cells

The granules are formed by the adhesion of microorganisms that forms the bacterial cells aggregations which was surrounded by extracellular polymer (ECP) and other components into spherical shapes. Whereby, most recently a variety of theories for the formation of granules have been recommended [17]. It is believed that, the species which is most important for the phenomenon of

granulation is Methanosaeta. Whereby, this functions as center of nucleation for the further aggregation [30]. Acetate is the firstly formed bacterial clusters. Afterwards, the primary bacteria will generate Methanosarcina species or Methanosaeta species [31].

1.6 Extra Cellular Polymer (ECP)

The generation of ECP is generally considered as natural property of microbial communities in suitable environment and constantly suggests within bacteria, yeast, algae and fungi [31]. Whereby ECP is usually formed from the result of microbial cells secretion and corruption and also organic materials fragments [33]. Gehr and Henry, 1983 reported that there are two types of ECP are obviously known: they are capsular and slime. Whereby, capsular is constantly bound with the microbial cell, as the slime does not bound with the microbial cell. Additionally, the role of capsular on the aggregation phenomenon has recognized as maximum [34].

1.7 Granules Size

The effective granules size can ranges from 0.5-5mm, therefore the effects on settling velocity (V_p) due to the size of the granules must be taken into consideration [4]. There is a strong evidence that indicates, the adding of crushed granular methanogenic sludge into digested sewage in an UASB reactor feed with acetate and propionate may increase diameter of methanogenic sludge granules into 1–4 mm [35]. The time interval for increasing the granule size of syntroph- seeded granules was 31 µm/day, for Methanothix-seeded granules it was 21 µm/day, for Methanosarcina-seeded granules it was 18 µm/day and for acidogenic flocs-seeded granules it was found that 7 µm/day only [14].

1.8 Factors affecting granulation

Temperature

The methanogens are somewhat more affected by temperature than acidogens [36]. Conversely, many kinds of microorganisms are more acclimatized in mesophilic temperature range. It is reported by (Henze, 1983; Zinder, 1990) that in mesophilic reactors, the most favourable range for microorganisms growth is between (30-40) °C. However, rising the temperature of reactor may result in opulence of some species of microorganisms and breakdown, of the other in versus. In fact, mesophilic granules have more warmth against temperature shocks than thermophilic granules, whereby any shock in temperature may breakdown the mesophilic granules [37]. On the other hand, it is reported that seed sludge are more vigorous and takes short period of time for the start-up operation in mesophilic condition than in thermophilic [38]. Although much gab in temperature effect of granulation process and development are alive and also strong scientific justifications for the respect of granules structure in each mesophilic and thermophilic are still indistinct.

pH and alkalinity

In general, neutral pH as well as eminent partial pressure of hydrogen is radically essential for high quality granules formation [39]. The pH value inside the granule particles have been usually found to be low-grade than the contiguous solutions [40]. According to the nature of microorganisms, methanogens have high pH fluctuation than the acidogenic microorganisms, which has typical pH value ranges from 6.3-7.8. Almost, execution of pH value less than 6.3 will result in customary acidic formation and its prohibits the formation of methanogens as well as methane gas production [41]. In contrast, alkalinity helps in neutralizing the fluctuations in the volatile fatty acids which is frequently arising from the organic loading rate variation [42]. Typically alkalinity value ranges from 250 to 950 mg/l [8].

Nutrient

The fundamental nutrients for the successful development of granules are Nitrogen, Phosphorus and Sulphur. Basically, the excess amount of nutrients in the influent can augment the process throughout the first phases and not affect the process. Although, nutrients deficient in the substrate can badly affects the formation of granules, whereby it has been reported that the growth of granules will declined when the Nitrogen concentration is less than 300 mg/l [**8**]. Additionally, over-elevated concentration of nutrients will inhibits the process [43]. However, the advantages of nutrients in the wastewater will prevents the flotation of granules as well as reduce the effect of shocks [44]. Ammonia is totally synthesized from nitrogen and hydrogen correlation to introduce electrons donor, it can be concluded that ammonia plays an important role on the correction of pH in medium [45]. Also it is important to reveal that methanogens are commonly utilizing the ammonia as a food source, which hastening the activity of granules in the methanogenic phase [20].

Organic loading rate

Organic loading rate (OLR) can be considered as the most decisive factor that should be cautiously adjusted, and it can be easily adjusted by means of adjusting the influent COD or by adjusting the inflow rate [46]. Boosting the organic loading rate up to rational limit is entirely resulted in accumulation of volatile fatty acids where the newest will decrease the pH value of the reactor [47]. Alternatively, the disadvantages of OLR dwindle are mainly represented by its negative role of breaking down the large granules as a result of deficient in food, where an organic loading rate of ≤1.5 kg COD/m3.d is not suggested and resulted in granules deterioration [48]. However, Tiwari (2005) conducted an experiment with a low

organic loading rate of 1.5 kg COD/m3.d has indicated the victorious granulation process with no breakdown in granules structure and also in size [13]. Although, organic loading rates of (2-4.5) kg COD/m3.d have been suggested for the high-quality growth of granules [49]. It can be considered that during the start-up process and the formation of granules, the execution OLR values should be cautiously studied to attain good growth [20].

Cations and heavy metals

Numerous concepts which variously explains the formation of Granules. However, it is believed that, the granules are formed by the bacterial adsorption and adhesion. The Granules formation can be accelerated, have been accurately observed in case of subsistence cations or adding up through correlation between assorted charge cells such relating their surfaces with extra cellular polymer (ECP) structure to fabricate bigger as well as stronger granules [17]. On the other hand, the amino and carboxyl fractions in the proteins are the most important required fractions for metals on the bacterial surface [50]. The toxicities of some metals are entirely sovereign on various factors such as category and structure of metal ion, pH, HRT, VFA concentration, and the strength of required fractions on the bacterial surfaces [51]. The literature has broadly exposed the task of some definite multivalent cations on the formation of granules such as Aluminium, Calcium and Iron. Calcium is one of the essential nutrient that enhance the formation of primary granules. Particularly, calcium enhances the adhesion process between the cells and the ECP, where it used as connecting material [52]. Thus, the existence of calcium is indispensable for the successful growth of granules. A variety of opinions have been proposed for the optimum concentration of calcium in solution. For the formation of granules in the first phases, the optimum concentration for calcium was proposed as ranges from (80-150) mg/l [53]. Nonetheless, other opinion for the optimum concentration of calcium should be ranges from (150-300) mg/l [54]. Further opinions by researchers have been roughly conducted to provide diverse cases in the optimization of calcium. Even though, if the concentration of calcium excess the limits may inhibits the growth of granules. In relation to the iron, COD and iron alteration to biomass is actually existed [55]. The excess of iron concentration upto 300 mg/l which is more significant to obtain large size granules within shorter interval [56]. In addition, the Aluminum has radical role on the speeding up the formation of granules [54]. On the other hand, the surplus minerals existing in UASB reactor have completely inhibits the process and also cause formation of ashes instead of activated granules [20].

1.9 Bacterial activity towards biogas

UASB reactor employs treating wastewater includes organic materials under anaerobic conditions which produces methane gas in the form of biogas. This process generally requires some kinds of bacterial activity. The bacterial alteration can be achieved through the following phases: hydrolysis, acidogenesis, acetogenesis and methanogenesis and also depends on the solutions pH and temperature [57]. No gas can be produced under low pH while considering that at low pH the methanogens are inactive. However, temperature in the reactor plays an optimistic important role on the quantity of gas produced, whereby under psychrophilic condition the temperature range can be implemented less than 20°C, the amount of biogas will be produced but partial. More biogas can be produced under thermophilic condition (42-55) °C. Nonetheless, in mesophilic condition (28-41) °C biogas generation will be more. It is understood that methanogens microorganisms are absolutely responsible of organics biodegradation which is results in the production of biogas [20].

2. CONCLUSION

Granulation development is the key factor for the successful operation of UASB reactor. These days, granules can be used to treat a variety of industrial effluents which provides more safety as well as protection to our environment. High removal efficiency can be achieved in UASB reactor by preparing big granules with active microorganisms which can easily digest complex wastewater. According to extra cellular polymer (ECP), it is found that ECP is an essential factor used to aggregates the microorganisms. Whereas, inorganic materials are not involved in the activities towards granules formation. Also, it is important to mention that biogas production is generally interrelated with the granular activities. It is recommended that adjustment of temperature and pH is more significant to achieve successful as well as comprehensive work in this field.

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